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A New Template for the Integrated Grid

How a Revised National Standard for Distributed Energy Resources Could Change the Power System

By Cassandra Sweet

Facilitating an Industry Paradigm Shift on Grid Integration

EPRI played an instrumental role in the collaborative effort to craft the new IEEE 1547 standard, which outlines technical specifications for the interconnection and interoperability between distributed energy resources and the electric power grid. Now, EPRI is working with more than 20 utilities on applying the standard. "EPRI has been helpful in facilitating this high-stakes conversation between transmission and distribution grid operators," said Andrew Levitt, senior market strategist at PJM. "These are not easy topics to discuss."

The widespread deployment of rooftop solar and other distributed energy resources (DER) is a game-changer for the electric power industry. The U.S. Energy Information Administration reports that small-scale solar systems generated 60% more power in 2018 relative to 2016. Utilities and regulators now seek new tools to help integrate these resources with grid planning and operations.

An important initial step is to define the requirements and capabilities at the interface between distributed resources and the power grid. This is the objective of the revised national standard IEEE Standard 1547™. (*IEEE*, which stands for the *Institute of Electrical and Electronics Engineers*, is an international technology standards organization.) A year after IEEE published a fully revised version of the standard in April 2018, utilities and regulators have started adopting its technical specifications for the interconnection and interoperability between DER and electric power systems. Originally published in 2003, IEEE 1547 is the only national standard of its kind, establishing uniform DER requirements for

performance, operation, testing, safety, and maintenance.

A key contribution of the revised standard is its technical specifications for smart inverters. In 2020, IEEE is expected to publish related compliance test procedures to establish interoperability for inverters and other equipment used to connect DER with the power grid (IEEE Standard 1547.1). By 2021, manufacturers are expected to commercialize components that comply with the revised standards and respond to dynamic grid conditions. This can help increase the distribution grid's hosting capacity and make DER integral with grid operations.

Drawing on its technical expertise and relationships with utilities and other stakeholders, EPRI played an instrumental role in the collaborative effort to craft the new standards. The four-year undertaking convened more than 100 technical experts from all corners of the power industry. EPRI personnel led three key expert groups that crafted the technical specifications at the heart of the standard's revision. These groups focused on voltage control, ride-through, and communication interfaces and protocols. EPRI staff provided independent technical input, facilitated discussions, helped resolve more than 1,500 comments during the standard's balloting stage, and helped review and edit the final draft.

"Because the new standard represented a paradigm shift in how to integrate DER with the grid, there was a lot of feedback from distribution and transmission system planners and operators," said EPRI Principal Technical Leader Jens Boemer. "EPRI collaborates with them on a regular basis, and this helped facilitate the standard's revision. However, as EPRI is an independent research institute, we do not endorse a particular entity's actions or lobby for a certain viewpoint. We facilitate the transfer of research and the consideration of all stakeholders' perspectives, including the public and other non-utilities."

As part of a two-year project, EPRI is working collaboratively with more than 20 utilities on applying the standard. This includes training utility staff and developing general and company-specific recommendations for DER interconnection and interoperability requirements and functional settings. EPRI is also helping to inform industry stakeholders on the standard's application through EPRI-U courses (see list at end of article), webinars, and other outreach. In addition, EPRI continues to facilitate discussions among distribution and transmission system planners and operators on mutually acceptable ways to implement the standard. Drawing on years of laboratory testing, EPRI is also informing the test procedures in IEEE 1547.1.

AN IMPORTANT TOOL FOR UTILITIES

Some utilities view the standard as an important tool for managing and optimizing energy resources and to enhance grid operations.

Xcel Energy, one of the participants in EPRI's project, is evaluating the new standard and working with state regulators in Minnesota and potentially Colorado to weigh in on interconnection standards. In addition to Minnesota and Colorado, Xcel Energy serves customers in Michigan, New Mexico, North Dakota, South Dakota, Texas, and Wisconsin.

"The percentage of DER is relatively low across our entire service territory, but we're starting to see DER clusters, such as 5-megawatt solar gardens in Minnesota and entire communities in Colorado that installed rooftop solar," said Patrick Dalton, distributed energy resources engineer at Xcel Energy. "It's likely that the future power system will have a higher penetration of DER, and we want the right capabilities and tools to operate that system."

The standard provides utilities with technical specifications to integrate more DER capabilities without adversely impacting the reliability of the transmission or bulk electricity system, Dalton added.

"A SENSE OF URGENCY" FOR STATE REGULATORS

IEEE 1547 is being scrutinized by regulators in states that are prioritizing grid modernization. Because the standard is not plug-and-play, regulators need to base decisions on local challenges, conditions, and needs. They can work with regional power industry stakeholders to specify DER capabilities and communication protocols for DER interfaces.

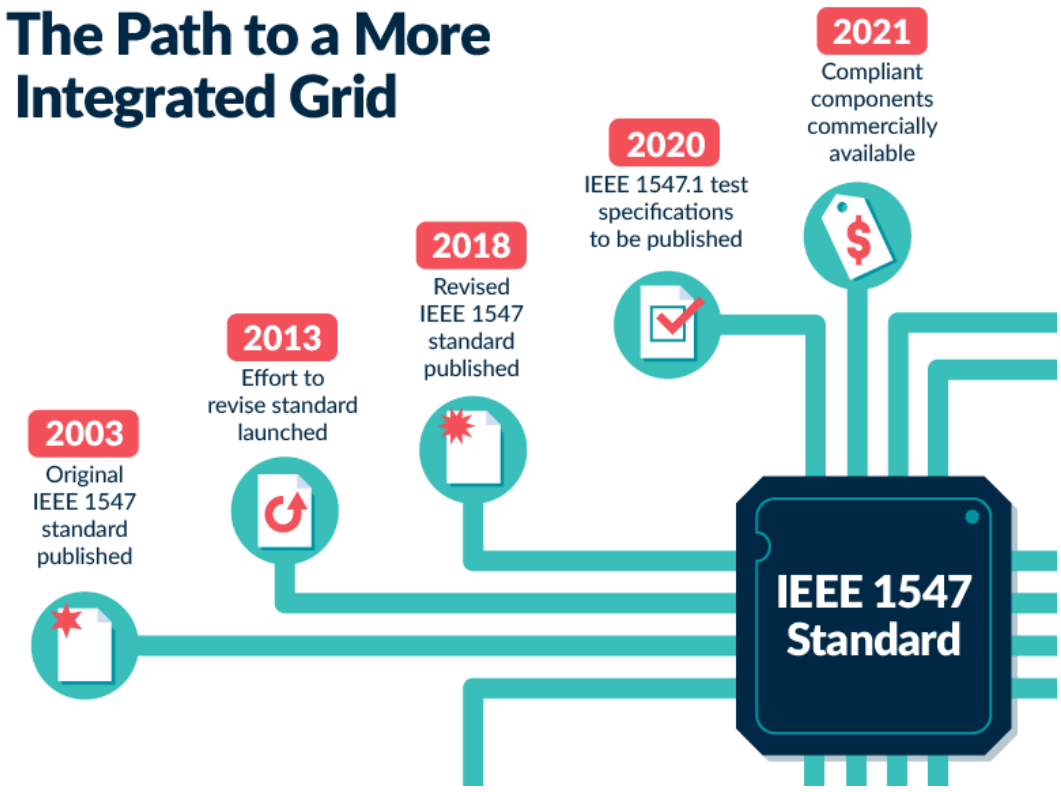
"These stakeholder discussions can take one to two years," said Boemer. "This creates a sense of urgency to start the process now, particularly if the regulator wants to implement the new standard when compliant smart inverters become commercially available in 2021."

The Minnesota Public Utilities Commission is incorporating the revised standard into its statewide technical requirements for utilities and DER, according to Michelle Rosier, the Commission's distributed energy resources specialist.

"In Minnesota, we don't yet have a high level of penetration of DER, but we want to get this standard in place so that we're prepared," Rosier said.

IEEE 1547 requires many smart inverter capabilities, including:

- Monitoring and communicating grid status, receiving off-site operation instructions, and making autonomous decisions to maintain grid stability and reliability.
- Directing rooftop solar arrays or other energy resources to "ride through" or stay online during brief frequency or voltage disturbances. (Historically in the United States and other countries, DER have been required to trip [turn off] automatically during disturbances. If large numbers of DER stop feeding power into the grid simultaneously, outages and other grid disturbances may result.)
- Changing the amount of power exchanged with the grid.
- Directing DER to reconnect to the grid in stages after an outage to avoid power spikes.
- Responding to deviations in local grid voltage by adjusting reactive power (a function known as volt-VAR).



Many regulators are considering these and other inverter requirements. They will have to decide whether grid operators can use customers' smart inverter functions to bolster the grid. While such an arrangement is technically possible, there are questions to consider: How often would a utility use its customers' voltage or frequency support capabilities? Would customers be paid a fee for each use? If so, how much?

"IEEE 1547 is a foundational building block that encourages a new discussion about how utilities use these capabilities—for example, as a substitute for existing equipment and methods or as a backup for worst-case scenarios," said Rosier. "Regulators will have to decide which of these new capabilities and functions are the safest, the most reliable, and in the public's interest." This is where EPRI's independent, fact-based research can serve crucial and specific needs.

California and Hawaii, which have high penetrations of rooftop solar, have established their own DER interconnection standards. These are similar to—though not as aggressive as—IEEE 1547, which requires greater reliability and interoperability of DER with the grid.

States not expected to have significant DER penetration in the next several years can prepare for unexpected DER deployment by revising their DER interconnection requirements now.

"States that use IEEE 1547 as a blueprint to adopt new DER interconnection rules can future-proof their grids for expected and unexpected DER deployment," said Boemer. "They can build DER capabilities now and use them when DER penetration reaches a significant value."

What constitutes a "significant" DER penetration depends on regional grid characteristics. EPRI has developed a model and other tools that can help regulators and transmission planners with this assessment.

COORDINATION AMONG TRANSMISSION AND DISTRIBUTION SYSTEMS

Like many power companies and regulators, transmission system planners and operators view IEEE 1547 as one way to enhance how DER interact with the grid. Successful adoption of the standard will require coordination among distribution and transmission planners and operators, who often have competing needs. For example, during grid disturbances, distribution operators may want DER to temporarily suspend feeding power into the grid to help keep line workers safe. In contrast, transmission operators may want DER to feed into the grid without interruption to help with voltage control and to support system reliability.

"The standard provides a framework to facilitate conversations among transmission and distribution system planners and operators to specify DER capabilities and settings," said Boemer. "It even introduces a new DER ride-through mode called momentary cessation, which can ease the tension between transmission and distribution."

DER connected to the distribution system can have an aggregate impact on the upstream transmission system. For example, if 500,000 rooftop solar arrays in a regional distribution system trip offline simultaneously as a result of a transmission fault, Boemer cautions that the transmission system could experience a significant power imbalance. To address this risk, the updated 1547 standard requires DER to remain connected to the grid during frequency and voltage deviations.

"Otherwise the transmission system operator may need to increase operating reserves or lean on other regions for grid support, which may not be technically feasible or cost-effective," said Boemer. "Transmission faults occur so regularly that tripping of DER should be minimized as much as possible."

PJM Interconnection, the regional transmission organization that coordinates power across 13 states (plus Washington, D.C.) in the U.S. Mid-Atlantic and Midwest, is closely watching the new standard.

PJM is concerned about existing grid settings that require DER to trip offline in response to a grid disturbance, especially in New Jersey and North Carolina, where distributed solar is growing.

"If we continue business-as-usual, the concern is that a disturbance on the transmission system could cause DER across a portion of New Jersey to trip offline at the same time," said Andrew Levitt, senior

market strategist at PJM. "By 2021, you could see as much as 1,000 megawatts tripping offline at the same time."

Some power industry stakeholders contend that a DER ride-through requirement is unnecessary because widespread tripping of distributed generators has never occurred in the United States. They point to ride-through's potential adverse impacts such as unintentional islanding.

While these concerns are to be taken seriously, there have been instances of large transmission-connected renewable power generators tripping offline and destabilizing U.S. and Australian transmission grids. In August 2016, while the Blue Cut wildfire raged in southern California, a series of faults on a 500-kilovolt transmission line prompted several large solar farms to trip offline, resulting in the loss of 1,200 megawatts of power, according to a report by the North American Electric Reliability Corporation. During a strong storm in September 2016 in South Australia, the sudden loss of electricity from several wind farms triggered a widespread blackout, according to a report by the Australian Energy Market Operator. A recent analysis suggests that large numbers of distribution-connected solar systems may have tripped or ceased power output in California in 2018.

To be sure, PJM has procedures and equipment to maintain power flow if substantial generation suddenly trips offline. But with more widespread DER, a ride-through requirement for DER can help avoid power losses.

"Large power plants are required to stay online under certain conditions," Levitt said. "It would be good if DER have the same requirements—for example, they're not allowed to trip offline under certain circumstances for a short period."

While PJM does not have authority to regulate DER, it has been educating state regulators about the standard's potential benefits and recently hosted a workshop and formed a task force for regulators and distribution and transmission engineers to discuss DER ride-through settings associated with the new standard.

EPRI also is facilitating discussion of these issues among power industry stakeholders through numerous webinars and workshops. It is working with its utility members and smart inverter vendors to investigate ways to minimize the likelihood of unintentional islanding. It also hosts a series of workshops where utilities share experiences regarding smart inverter integration, lessons from demonstration projects, and best practices.

"EPRI has been helpful in facilitating this high-stakes conversation between transmission and distribution grid operators," said PJM's Levitt. "These are not easy topics to discuss."

Five Ways EPRI Is Helping the Power Industry Standardize the Use of Smart Inverters

1. Development of first-of-its-kind test procedures for smart inverter interoperability and communications with the grid (IEEE Standard 1547.1).
2. Development of tools and open source software to help manufacturers meet new requirements for communications between solar and energy storage systems and the grid (SunSpec Modbus, IEEE Standard 2030.5 and IEEE Standard 1815—DNP3).
3. Development of a model that can aggregate distributed energy resources for transmission planning studies.
4. Laboratory and field evaluation of smart inverters' advanced grid support functions and interoperability in accordance with IEEE 1547.
5. Development of an open test bed to assess functional capabilities, interoperability, performance, grid impacts, and benefits of commercial Distributed Energy Resources Management Systems (DERMS).

KEY EPRI TECHNICAL EXPERTS

Jens C. Boemer