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EPRI JOURNAL

More Clarity on DERMS

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More Clarity on DERMS

EPRI Helps PG&E Define Requirements for New Systems to Manage Distributed Energy Resources

By Steve Kerekes

Utility Innovation: Managing Distributed Energy Resources

EPRI developed reference requirements that enable utilities to define various features for DERMS, which are new types of software control systems that manage distributed energy resources. These requirements equipped PG&E to transition from a DERMS demonstration project to deployment of specific DERMS functions in its power system. “EPRI has been able to look across many utilities and see what the standard requirements could be,” said PG&E Grid Innovation Manager Alex Portilla. “Now that EPRI’s reference requirements are available, every utility doesn’t have to experiment on its own.”

Pacific Gas & Electric (PG&E) is no stranger to distributed energy resources (DER). The California utility connects about 5,000 private rooftop solar systems to its grid every month and has a total of more than 420,000 grid-connected solar customers. These resources can result in two-way power flow on the grid, and PG&E faces the question of how to monitor, control, and harness their energy production while continuing to operate its power grid safely, efficiently, and reliably. The utility is considering the deployment of Distributed Energy Resources Management Systems, or DERMS, which are new types of software control systems that manage DER. During events on the grid, DERMS can address potential reliability and power quality problems by instructing DER to increase or reduce output. However, PG&E has found that identifying the right software systems is no easy task.

“This is a nascent area,” said PG&E Grid Innovation Manager Alex Portilla. “The technology is still rapidly evolving, and we as the buyers of the technology are still in the process of defining the functionalities and how they might fit into the overall operational technology portfolio. PG&E has been conducting demonstration projects to explore DERMS and related technologies to inform our future roadmap.”

"With more DER connected to the grid, utilities need new control systems to manage them," said EPRI Technical Leader Ajit Renjit. "Many utilities do not have DERMS technology and have not defined the features and specifications they would want in such systems. This makes it difficult for commercial DERMS vendors to develop products that utilities can integrate seamlessly into their systems and processes."

To take the guesswork out of the process, EPRI has developed a set of reference DERMS requirements. When planning, procuring, integrating, and operating DERMS, utilities can use these requirements to help define features such as architectures, functionality, scalability, reliability, speed and performance, points of connection with DER and other grid assets, user interfaces, integration with distribution management systems and advanced metering infrastructure, alarms, presentation of data and information, and security.

"EPRI has been able to look across many utilities and see what the standard requirements could be," said Portilla. "Now that EPRI's reference requirements are available, every utility doesn't have to experiment on its own."

"EPRI is taking a collaborative approach to develop these requirements," said Renjit. "Utilities approach us with research questions that provide the basis for our technical studies. We also facilitate utility interest groups and vendor working groups and provide technical input on standards relevant to DERMS and DER integration. All these activities contribute to the development of requirements that can be supported by commercial products."

After PG&E considered and applied aspects of the EPRI reference requirements, it was much better positioned to properly define the features for its Advanced Distribution Management System (ADMS). While grid operators use an ADMS for traditional distribution grid functions such as fault isolation and management, outage management, and automated voltage control, they use DERMS to predict and mitigate grid impacts of DER.

"We had initially viewed DERMS as the same system as the ADMS," said Portilla. "But in EPRI's framework, DERMS has one set of functions, and ADMS has a different set of functions. This helped us to define our needs more clearly. We were able to parse those out and specify the required interactions between the two systems. The immediate practical benefit was that we were able to develop a request-for-proposals that outlined the most appropriate ADMS functions for prospective vendors. We were also able to transition from a proof-of-concept DERMS demonstration project to deployment of specific DERMS functions at certain locations in our system."

According to Portilla, the "biggest plus" of PG&E's interaction with EPRI was the regular, in-person meetings with Renjit and his colleagues over a five-month period.

"What was helpful for me was the face-to-face interaction," Portilla said. "A lot of the value came from talking through our plans, the questions EPRI asked, and the back and forth. It wasn't, 'EPRI, go write a report for us.' It was collaboration every four to five weeks."

According to Portilla, the move towards more standardization of cyber security-related DERMS requirements is particularly important because DERMS will communicate with third party-owned DER to enable key grid support functions.

"When utility systems are talking to hundreds of thousands of devices owned by external parties, you need standards to guide the actions and responses of all these devices," said Portilla. "You can't do commissioning tests with every single device. DERMS needs to be plug-and-play."

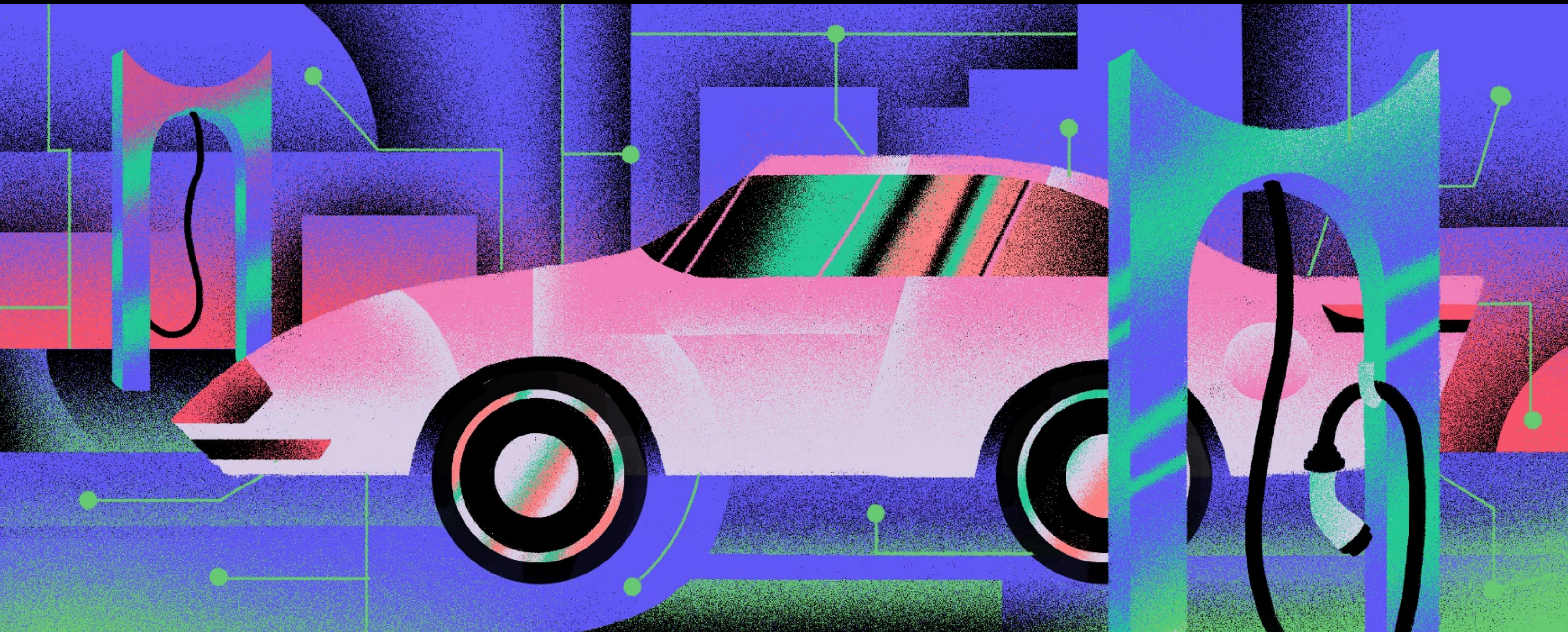
According to Renjit, the challenge that PG&E faced with respect to clarifying functions and requirements in vendor solicitations is increasingly common in the electric utility industry.

"As utility customers deploy more DER, it is essential that utilities have the means to effectively manage the energy exported to the grid, which was originally designed for one-way power flow," said Renjit. "This can result in greater use of clean energy such as distributed solar resources while supporting reliable, safe, and efficient operation of the electric grid."

KEY EPRI TECHNICAL EXPERTS

Ajit Renjit

EPRI JOURNAL



Electric Vehicles: A Day in the Life

Arizona Electric Vehicle Research Informs Grid Planning and Operations

By Mary Beckman

Utility Innovation: Analysis of Electric Vehicle Data

EPRI and Salt River Project (SRP) deployed data loggers on electric vehicles owned by SRP customers to track various data including where, when, and how much they charged. The results can inform SRP's load forecasting. "The more information we have on when people charge their cars and how much energy they're using, the more we can refine the energy forecast, which reduces cost for our customers," said SRP Principal Environmental Scientist Kathy Knoop.

With more electric vehicles (EVs) on the road every year, power companies need to plan for the power capacity needed to charge all the batteries.

"Our gas stations are moving to our houses," said EPRI Data Scientist Jamie Dunckley. "Utilities need to provide energy whenever drivers want it."

But power companies have limited data on how their customers use EVs. How many miles do they drive, how many kilowatt-hours do they consume, and when do they charge? Would they be willing to charge at off-peak times? Utilities need such information for planning.

EPRI's Dunckley worked with Salt River Project (SRP) and their EV-driving customers to answer these and other questions. Researchers developed a comprehensive picture of EV use by deploying data loggers on 100 vehicles owned by SRP customers. Over 18 months, the data loggers tracked where, when, and how much customers charged, how much energy they consumed while driving, where and how far they drove, vehicle speed, and other data.

Each EV consumed 2,700–3,300 kilowatt-hours per year at a cost of $324–$396 (based on a national average electricity price of 12 cents per kilowatt-hour). For non-Tesla owners, more than 80% of their charging sessions were at home compared with 63% for Tesla owners—who could charge for free in 30 minutes at public "Supercharger" stations.

SRP offers three rate options: a flat rate plan, a time-of-use plan with higher rates in the afternoon and evening, and a time-of-use plan with much cheaper rates between 11 p.m. and 5 a.m. More than half selected time-of-use plans and consumed six times more electricity for overnight charging relative to daytime charging, indicating that cheaper off-peak rates can shift load.

“Even Tesla drivers with $100,000 vehicles were incentivized by saving a few dollars,” said Dunckley.

Most charging occurred at Level 2 (74%), followed by Level 1 (23%) and DC fast charging (3%). Charging level proportions varied widely by EV model. For example, DC fast chargers provided LEAF owners with approximately 2% of their energy while they provided Tesla owners with about 11%.

“I was surprised to see how the different EV models used electricity differently,” said SRP Principal Environmental Scientist Kathy Knoop.

Teslas used energy less efficiently than other models. “We chalked that up to Tesla drivers showcasing the vehicle’s performance with the ‘Ludicrous’ acceleration mode,” said Knoop.

Knoop expects the logger data to be valuable for utility load forecasting. “The more information we have on when people charge their cars and how much energy they’re using, the more we can refine the energy forecast, which reduces cost for our customers,” she said.

“The study opened our eyes to new uses for the data loggers,” said Knoop. “We found an innovative approach to demand response.”

Drawing on information from the data loggers, utilities can offer a rewards program, similar to those offered by grocery stores, gas stations, and credit cards. For example, if there is excess solar generation on a sunny afternoon, a rewards program could use a logger’s GPS data to determine a car’s location and send a text or e-mail to the driver offering a gift card for charging at a nearby station.

“It gives customers different options outside of a pricing plan,” said Knoop.

Some utilities have started to make such offers. ConEdison’s SmartCharge New York program rewards customers for charging at certain times of the day.

While it’s true that our gas stations are moving to our houses, EV drivers may increasingly have ways to get out and follow the sun.

KEY EPRI TECHNICAL EXPERTS

Jamie Dunckley

EPRI JOURNAL

Sustainability at Portland General Electric 'Matures' with Help from EPRI Model

EPRI Trains Nuclear Power Industry on How to Identify and Assess Risks That May Affect Plant Operations

By Steve Kerekes

Utility Innovation: Greenhouse Gas Emissions Strategy

During EPRI-facilitated workshops, Portland General Electric (PGE) identified key opportunities to make progress on sustainability goals, leading the utility to set a scientifically backed greenhouse gas reduction goal. "Now that we've set the goal, we're figuring out how to implement it not just for the power we supply our customers, but also for other areas of our business," said PGE Sustainability Manager Caitlin Horsley. "This work is pushing us to get our ducks in a row so we can look at our full greenhouse gas picture as a company and as an Oregon economy."

Informed by work with an EPRI sustainability model, Portland General Electric (PGE) solidified its greenhouse gas emissions strategy and set one of the electricity sector's most ambitious emissions goals: an 80% reduction by 2050.

First developed in 2011, EPRI's Electric Power Sustainability Maturity Model is designed to help power companies assess *sustainability maturity*—progress toward sustainability goals—and use insights from the analysis to facilitate strategic planning and investment decisions. Users can analyze energy affordability, air emissions (such as nitrogen oxides, sulfur oxides, mercury, and particulates), greenhouse gas emissions, energy reliability, and water availability—with respect to strategy, implementation, measurement of results, and shared value. The model's dashboards summarize current and aspirational maturity scores for these five "domains."

During two EPRI-facilitated workshops in 2017, 15 PGE executives and managers from various disciplines applied the model to assess the greenhouse gas emissions and energy affordability domains. Inputs from the discussion were plugged into the model to yield maturity scores. The final report outlined opportunities to enhance maturity over the next 3–5 years.

According to EPRI Senior Project Manager Morgan Scott, the model is more qualitative than quantitative.

"It's a capability model. Rather than determining a company's maturity based on a quantitative performance, it evaluates how a company is set up to enhance performance," she said. "For example, with greenhouse gas emissions, it's not 'What were your emissions last year?' It's: 'Are you measuring your performance on greenhouse gas emissions? Is the metric publicly disclosed? Have you set a goal?'"

According to PGE Sustainability Manager Caitlin Horsley, EPRI served a vital role as a trusted third party to inform PGE about the steps needed to make progress on greenhouse gas emissions issues.

"One of the things that came out of our workshop was a specific greenhouse gas emissions strategy distinct from our integrated resource plan," said Horsley. "The maturity model recommended that we develop a greenhouse gas cost curve identifying our short-term opportunities and associated financial costs. We decided to conduct a more comprehensive 'Deep Decarbonization Study' that included separate cost curves for PGE and the Oregon economy in our service territory. Based on that study, we set a scientifically backed greenhouse gas reduction goal."

In early 2018, the company announced this goal as part of its clean energy vision.

"Now that we've set the goal, we're figuring out how to implement it not just for the power we supply our customers, but also for other areas of our business," said Horsley. "This work is pushing us to get our ducks in a row so we can look at our full greenhouse gas picture as a company and as an Oregon economy. I would definitely call our experience with the model a success. It gave us the right framework and roadmap to put our resources where we could have the most impact."

In 2018, Horsley and five PGE colleagues received an EPRI Technology Transfer Award for their leadership in applying the model and using the recommendations.

According to Scott and Horsley, a comprehensive application of the model requires a substantial time commitment, but one that is well worth the effort.

"The biggest challenge is the time," Scott said. "It takes a full day to go through the process for just one domain. For a lot of companies, it's a huge commitment to ask 15–20 employees to take time out from their jobs to dive into this work. But as PGE has demonstrated, the reward can be substantial."

"Successful sustainability initiatives require long-term effort," said Horsley, adding that PGE's emissions reduction strategy has progressed more quickly than its plans to improve energy affordability. "That's a lesson learned—don't expect all aspects of your sustainability program to progress at the same speed."

"When you get started with this work, you're not always going to see what the end of road looks like exactly," Horsley said, "The work might lead to something bigger and better than what you originally planned, as it did with our greenhouse gas emissions reduction goal. We were able to build momentum toward the goal."

Four other power companies have participated in similar EPRI-facilitated workshops to apply the model.

The model's ongoing development is informed by participants in EPRI's Strategic Sustainability Science program.

"The significant growth of the research reflects the growing expectations for power company sustainability from customers, employees, investors, nongovernmental organizations, and other stakeholders," said Scott. "It also reflects the value that companies can realize through a commitment to sustainability. This includes more customer satisfaction, enhanced performance, increased efficiency, access to new capital, opportunities to explore new markets, and the ability to attract a new generation of employees."

KEY EPRI TECHNICAL EXPERTS

Morgan Scott

Viewing the Power Grid Over Time

How Open-Source EPRI Software Sparked Innovation in Distribution System Planning

By Chris Warren

Utility Innovation: Time and Distribution Planning

EPRI's OpenDSS tool equips distribution planners to compute power flows over time and assess when and how distributed energy resources benefit or adversely impact the power system. "A big value [of OpenDSS] is that it has made multi-state iterative analysis possible, where conditions are always changing," said Justin Price, FirstEnergy's supervisor of distribution planning and protection. "Some commercially available tools have the ability to generate thousands of simulations, and OpenDSS was a driver in making that happen."

When created in 1997, EPRI's comprehensive distribution system simulation tool, OpenDSS, was ahead of its time. Although the number and impact of grid-connected distributed energy resources (DER) were limited then, some distribution planners already needed a tool that was more robust than the simple load projection spreadsheets then in use.

"Distribution planners project peak load a certain number of years in the future and design the system to deliver the needed power," said EPRI Senior Technical Executive Roger Dugan. "With more distributed resources on the grid, we realized that you needed to examine the system over time rather than use a static peak load value."

The OpenDSS tool introduced *time-series power flow simulations* to distribution system planning as an efficient way to capture the time-dependent impacts and benefits of DER. "A time-series power flow simulation involves computing a series of power flows that correspond to varying load and generation over time," said Dugan. "Unlike historical planning based on a single snapshot of power flow on the distribution grid, time-series simulations equip planners to assess how and when new energy resources will benefit or adversely impact the power system."

For example, planners need to know about weather-related changes in solar output to determine the regulation equipment necessary for distribution feeders to safely handle resulting voltage changes.

If load shapes change little from year to year, simple load projections can drive planning. Today, such projections are inadequate because the influx of solar generation and electric vehicles alters traditional load shapes.

“Using OpenDSS, we have been able to demonstrate how the power industry can move from time-consuming manual processes to more automated methods for planning, saving valuable engineering time,” said EPRI Senior Program Manager Jeff Smith. “The tool enables planners to quickly run thousands of feeder scenarios. As new DER are deployed, they can simulate the system repeatedly to determine the range of impacts and better assess the potential value of DER as an alternative to building new grid infrastructure. This can inform investment decisions.”

Con Edison finds high value in OpenDSS software,” said Simon Odie, a senior engineer at Con Edison, the utility that serves New York City and Westchester County, New York. “As DER penetration increases in our service territory, alternative methods to study system impacts are critical for understanding and processing new customer DER installation requests. The capabilities in OpenDSS to conduct time-series analyses and modify inverter functionality provide great insight for us as we endeavor to identify optimal smart inverter settings that comply with IEEE 1547-2018.

As open source software for more than a decade, OpenDSS provides many features that have found their way into commercial planning software used by utilities, consultants, universities, and national research laboratories. It has been downloaded by nearly 80,000 users in countries such as the United States, Brazil, China, India, Germany, Italy, and South Korea.

Justin Price, FirstEnergy’s supervisor of distribution planning and protection, cites OpenDSS’s positive effects on features offered in commercial tools. “A big value is that it has made multi-state iterative analysis possible, where conditions are always changing,” he said. “Some commercially available tools have the ability to generate thousands of simulations, and OpenDSS was a driver in making that happen.”

For FirstEnergy’s interconnection training in 2017, 169 engineers used OpenDSS to study DER impacts on the distribution system. OpenDSS made the course possible because FirstEnergy didn’t have enough licenses for its commercial planning tool for all the students to perform the study simultaneously.

Universities around the globe use OpenDSS as a teaching tool to give new distribution engineering students an opportunity to practice their craft in a simulated environment. IEEE (Institute of Electrical and Electronics Engineers) used the tool to develop distribution feeder models for testing the capabilities of distribution planning tools.

Over the past two decades, EPRI has added new capabilities to OpenDSS, such as:

- **Simulation of advanced inverter controls**: This enables planners to characterize voltage changes as a result of variable generation—and can inform adjustments to the control equipment used to support system reliability.
- **Simulation of energy storage controls**: This can equip planners to determine optimal storage control settings as load and generation vary.
- **Analysis of a feeder’s hosting capacity for solar**: This enables planners to determine whether new solar capacity may cause grid problems.

In 2018, EPRI introduced an interface that makes OpenDSS easier to use. “The interface makes the tool more accessible with features such as click, point, and drag,” said Dr. Davis Montenegro, an EPRI engineer scientist. “It enables engineers to go straight to the problem they want to examine.”

The tool drives research within EPRI. “OpenDSS is a critical tool in a dozen EPRI programs related to the distribution system—from DER integration and energy storage to power quality and transportation,” said Smith.

KEY EPRI TECHNICAL EXPERTS

Roger Dugan, Jeff Smith, Davis Montenegro, Lindsey Rogers

In Development

Toward Global Monitoring of Neutron Absorbers

Years of EPRI Research Equip Nuclear Plant Operators to Safely Store Used Fuel

By Tom Shiel

Utility Innovation: Safer Used Fuel Storage

EPRI conducted a series of lab and field studies to investigate the efficacy of the neutron absorbers used in spent fuel pools at nuclear power plants. EPRI is also developing a program to coordinate monitoring of the absorbers across the global nuclear industry. "EPRI's research has helped Exelon to more accurately assess the condition of neutron absorber panels at our plants," said David Phegley, senior staff engineer at Exelon. "I expect EPRI's program to be superior to anything an individual utility could create."

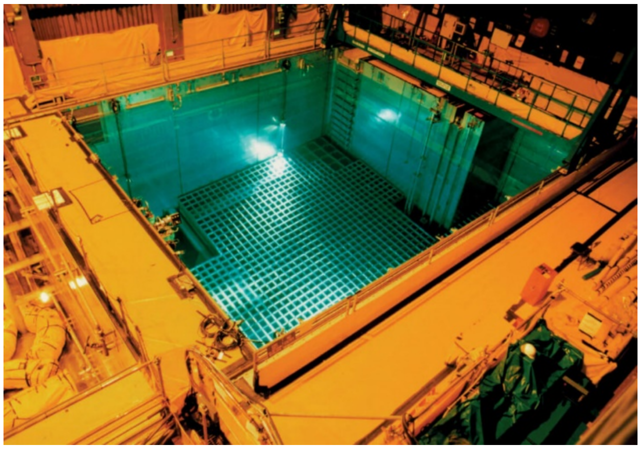
EPRI lab and field research and a new industrywide program are equipping nuclear power plants to get ahead of safety concerns regarding used nuclear fuel stored on-site.

Nuclear plants in the United States were constructed with spent fuel pools for temporary storage of used nuclear fuel. The federal government originally planned to take the fuel for disposal in an underground repository. With the cancellation of the Yucca Mountain repository in 2009, the U.S. Nuclear Regulatory Commission (NRC) instructed utilities to continue managing used fuel on-site until other solutions are developed. Used fuel typically is cooled in pools for several years, then moved into interim dry storage systems.

As pools filled, operators have retrofitted them with storage racks equipped with neutron-absorbing materials, enabling more fuel assemblies to be stored without achieving criticality. To track the condition of these materials, most plants place samples (known as coupons) in the pools and periodically evaluate them for degradation. Plants that have exhausted their coupon supply directly measure the areal density of the neutron absorbers in the pools (a technique known as *in situ* measurement). Replacing coupons is not an option because they must be placed in pools at the same time as the neutron absorbers to accurately represent degradation over time.

Plant operators have observed pitting, blistering, and other degradation in some neutron absorber materials. In a 2016 Generic Letter, the NRC requested that operators evaluate the efficacy of their absorbers and absorber monitoring.

EPRI investigated these issues in a series of projects. Its 2017–2018 modeling study found that blistering and pitting observed in neutron-absorber materials to date did not measurably impact their performance. In a five-year laboratory study completed this year, EPRI placed BORAL® coupons in test baths and subjected them to heat and water chemistry designed to accelerate corrosion. Researchers found no significant degradation.



Spent fuel pool at the San Onofre Nuclear Generating Station. Photo courtesy of U.S. Nuclear Regulatory Commission.

Researchers remove coupons from the spent fuel pool at the decommissioned Zion Nuclear Power Plant.

As part of a four-year project at the decommissioned Zion Nuclear Power Plant in Illinois, EPRI collected *in situ* panel measurements from the spent fuel pool and removed panels and coupons from the pools to evaluate them in the laboratory. Even after 22 years in the pools, the panels and coupons were in very good condition. The results demonstrated that the condition of coupons is representative of the condition of the panels, suggesting that coupons are an effective monitoring tool. *In situ* measurements contained large errors and yielded false positives for panel degradation.

"Nuclear utilities and other stakeholders around the world can use these research results to expand efforts to monitor neutron absorber materials, improving public health and safety," said Dr. Hatice Akkurt, EPRI Technical Executive. "Our research benefits stakeholders in the United States by providing data and other information to support their response to the NRC's inquiries."

For spent fuel pools lacking coupon monitoring programs or with limited remaining coupons, EPRI is developing a global Industrywide Learning Aging Management Program (i-LAMP) for neutron absorber monitoring. It is based on the idea that neutron absorbers of the same materials and exposed to similar water chemistries and irradiation should age in the same ways. If a pool without coupons can demonstrate that it has characteristics (such as materials and age) similar to those in pools with coupons, it can use their coupon degradation data to inform neutron absorber monitoring.

i-LAMP has these components:

- Collect and analyze water chemistry data from pools across the world and use the results to assess whether changes are needed in water chemistry guidelines.
- Collect global data from coupon monitoring programs and analyze them for indicators of degradation, trends in coupon conditions, and potential relationships between degradation and water chemistry.
- Collect data from pool operators without coupon monitoring programs, such as areal density and thickness of neutron absorbers, and the year in which these materials were manufactured and deployed.
- Evaluate water chemistry, panel, and coupon data to determine the ways in which pools are similar. Develop criteria that potentially enable pools without coupon monitoring programs to rely on pools with monitoring programs for insights on the condition of neutron absorber panels.
- Develop guidelines for use by all pool operators (with and without coupon monitoring programs) to track neutron absorbers, mitigate degradation, and maintain safe, reliable pool operations.

Initially, guidelines will focus on pools that use BORAL but will later broaden to include other neutron absorber materials. EPRI is also considering the possibility of coordinating coupon monitoring and sharing operating experience across the industry. This can improve management of neutron absorber materials by preserving remaining coupons, reducing costs, and enhancing safety and efficiency.

"EPRI's research has helped Exelon to more accurately assess the condition of neutron absorber panels at our plants," said David Phegley, senior staff engineer at Exelon, which operates a 22-unit nuclear fleet. "Because all spent fuel pools are similar, EPRI's data on coupon degradation is relevant to our plants without coupons. This can significantly reduce costs and occupational dose for Exelon if *in situ* testing is not used."

As part of an EPRI laboratory study, researchers placed coupons in test baths designed to accelerate corrosion.

A neutron absorber module being removed from the spent fuel pool at Zion Nuclear Power Plant.

"Over the last several years, regulators around the world have expressed concern about the effects of aging in pools and increasing pool capacities," said Akkurt. "We are not seeing any problems with degradation today, but we have to keep monitoring long-term."

The NRC has accepted a draft version of the i-LAMP program. When program development is completed in 2020, EPRI will submit it for formal NRC review and endorsement as an alternative monitoring approach.

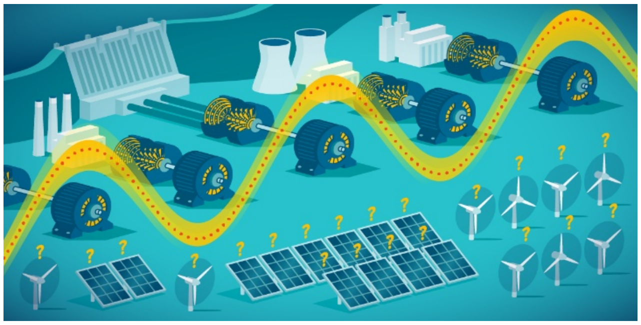
"I expect EPRI's program to be superior to anything an individual utility could create," Phegley said.

KEY EPRI TECHNICAL EXPERTS

Hatice Akkurt

R&D Quick Hits

Inertia Is a Growing Challenge for the Grid, But There Are Solutions



An EPRI study looks at the potential impacts of reduced inertia on frequency stability in the world's electric power grids and reviews emerging solutions.

Turbines, generators, and motors in fossil, nuclear, and hydro power plants spin at speeds proportional to grid frequency. The rotational energy of these massive devices provides significant inertia that can counteract changes in grid frequency due to disturbances. For example, if one power plant in a region goes offline, grid frequency will decrease. Other spinning generators can respond by speeding up slightly to resist the frequency shift and stabilize the grid.

Because solar energy plants don't have any moving parts (and thus inertia), the power system's inertia declines as solar penetration grows—potentially leading to rapid frequency changes. If left unchecked, such changes can cause electricity service interruptions. Wind generation likewise does not contribute inertia because most modern wind turbines transmit energy through power electronics and are not connected directly to the grid. According to the EPRI study, smaller, islanded grids already face inertia-related challenges. Grid operators in Ireland and Nordic countries regularly adjust power plants' output based on predictions that low inertia will cause service interruptions.

"These operators are monitoring inertia on a second-to-second basis and re-dispatching power plants to maintain frequency stability," said EPRI Principal Project Manager Aidan Tuohy.

The study identifies numerous potential technological, operational, and market-based solutions for grid operators, such as:

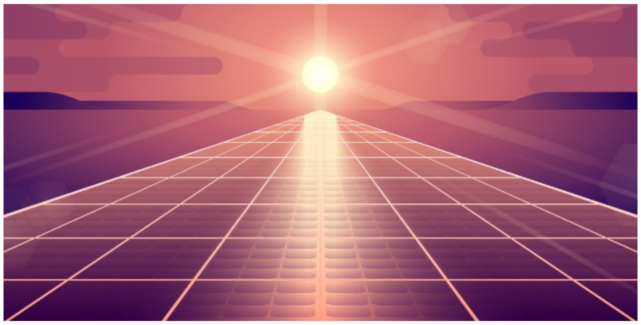
- Controlling the inverters of solar and wind power plants and battery energy storage systems to provide frequency support during disruptions
- Requiring an inertia "floor" or minimum that results in the operation of additional spinning generators
- Compensating generators for providing inertia to encourage them to stay online

According to the study's authors, these and other solutions need to be evaluated for their effectiveness in maintaining grid stability. In addition, operators need more real-time data on the impacts of reduced inertia along with analytical tools to evaluate those impacts.

KEY EPRI TECHNICAL EXPERTS

Aidan Tuohy, Adrian Kelly

Solar Beyond 2020



Utility-scale solar photovoltaic plants in 2030 are likely to look different and have more capabilities than they do today, according to an EPRI study. Over the next decade, plant operators and developers are expected to use various design strategies and technologies to continue deployment and mitigate declining solar value.

Solar energy is becoming a victim of its own success. As with other electricity generating assets, the more capacity deployed in a region, the less each additional unit is worth. The U.S. Energy Information Agency projects that solar will account for more than half of electricity capacity added between now and 2050. In some regions, high solar penetration is likely to provide nearly 100% of mid-day power demand. Increasingly, grid operators may need to curtail solar plant output, reducing its value. Solar's value also may decline as peak demand shifts to after sunset.

Through analysis of commercially available and emerging technologies, researchers projected that future plants will enhance plant value and flexibility through approaches that include:

- **Advanced controllers** through which remote operators instruct solar plants to provide ancillary services such as frequency regulation and fast ramping.
- **Lithium ion batteries** to store energy for feeding into the grid when demand is greater and the power more valuable.
- **Single-axis tracking systems** that produce roughly 20–30% more energy than fixed-tilt systems. While capital costs are higher, their increased production can result in a lower levelized cost of electricity in certain locations. As tracking costs decline, it's anticipated that such systems will become more cost-effective in more regions relative to fixed-tilt, leading to increased deployment.
- **String inverters** are becoming more popular, particularly for plants under 100 megawatts, driven by declining capital costs, lower installation and maintenance costs, fewer types of equipment needed, and increased energy output in certain scenarios (such as when a plant is partially shaded). In the past, plant developers have primarily used large central inverters.
- **Bifacial modules** to increase energy yield.

KEY EPRI TECHNICAL EXPERTS

Joe Stekli, Nicholas Pilot, Michael Bolen, Robin

R&D Quick Hits

On the Cusp of a Hydrogen Revolution?

According to an EPRI study, electrolyzer technologies are moving closer to the efficiency and equipment life necessary for large-scale hydrogen production. Continued technological development is needed for hydrogen to serve mass markets for fuel cell electric vehicles and cost-effective, long-duration energy storage.

For fuel cells in the transportation sector, hydrogen production costs need to be at or below $2 per kilogram. The U.S. Department of Energy reports that to achieve this target, electricity prices for hydrogen production need to be less than 3¢ per kilowatt-hour, and electrolyzers need a system efficiency of at least 75%, an operating life of at least 10 years, and capital costs at or below $300 per kilowatt. In interviews with the researchers, electrolyzer developers and manufacturers indicated that today's technologies already can operate for 10 years at 50–60% efficiency. However, at about $1,000 per kilowatt, the capital costs are projected not to reach competitive levels for about 10 years. Reaching these targets requires low-cost, mass manufacturing of systems and components. The feasibility of procuring electricity under 3¢ per kilowatt-hour is uncertain.

Today, most U.S. hydrogen production reacts steam with natural gas, with electrolysis accounting for only 3–4% of production. For the industrial, transportation, and energy sectors, electrolyzers powered by cheap renewable energy present a promising pathway to carbon reduction. As an example, the study's authors describe a scenario in which challenges associated with fuel cell vehicle production have been addressed: If 50 million vehicles—or about 20% of vehicles on U.S. roads today—were powered by fuel cells and hydrogen, an additional 60 gigawatts of electric generation capacity would be needed to provide the hydrogen. If this capacity were renewable generation, annual CO_2 emissions in the transportation sector would decrease by about 125 million tons, or about 8% of the sector's emissions.

Several manufacturers are planning megawatt-scale electrolyzer demonstration projects that are expected to provide valuable insights on the performance, costs, and value of hydrogen.

"The cost of hydrogen produced with electrolyzers and renewable energy is a decisive factor that is likely to enable or impede new business models and infrastructure investment in the power, natural gas, transportation, and manufacturing sectors," said EPRI Technical Leader Brittany Westlake. "Our findings suggest that hydrogen could be a potential solution at the utility scale after 2030 and should be considered among other technologies to provide flexibility for a low-carbon grid."

KEY EPRI TECHNICAL EXPERTS

Brittany Westlake

ELECTRIC POWER RESEARCH INSTITUTE

The Electric Power Research Institute, Inc. (EPRI, www.epri.com) conducts research and development relating to the generation, delivery and use of electricity for the benefit of the public. An independent, nonprofit organization, EPRI brings together its scientists and engineers as well as experts from academia and industry to help address challenges in electricity, including reliability, efficiency, affordability, health, safety and the environment. EPRI also provides technology, policy and economic analyses to drive long-range research and development planning, and supports research in emerging technologies. EPRI members represent 90% of the electricity generated and delivered in the United States with international participation extending to 40 countries. EPRI's principal offices and laboratories are located in Palo Alto, Calif.; Charlotte, N.C.; Knoxville, Tenn.; Dallas, Texas; Lenox, Mass., and Washington, District of Columbia.

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