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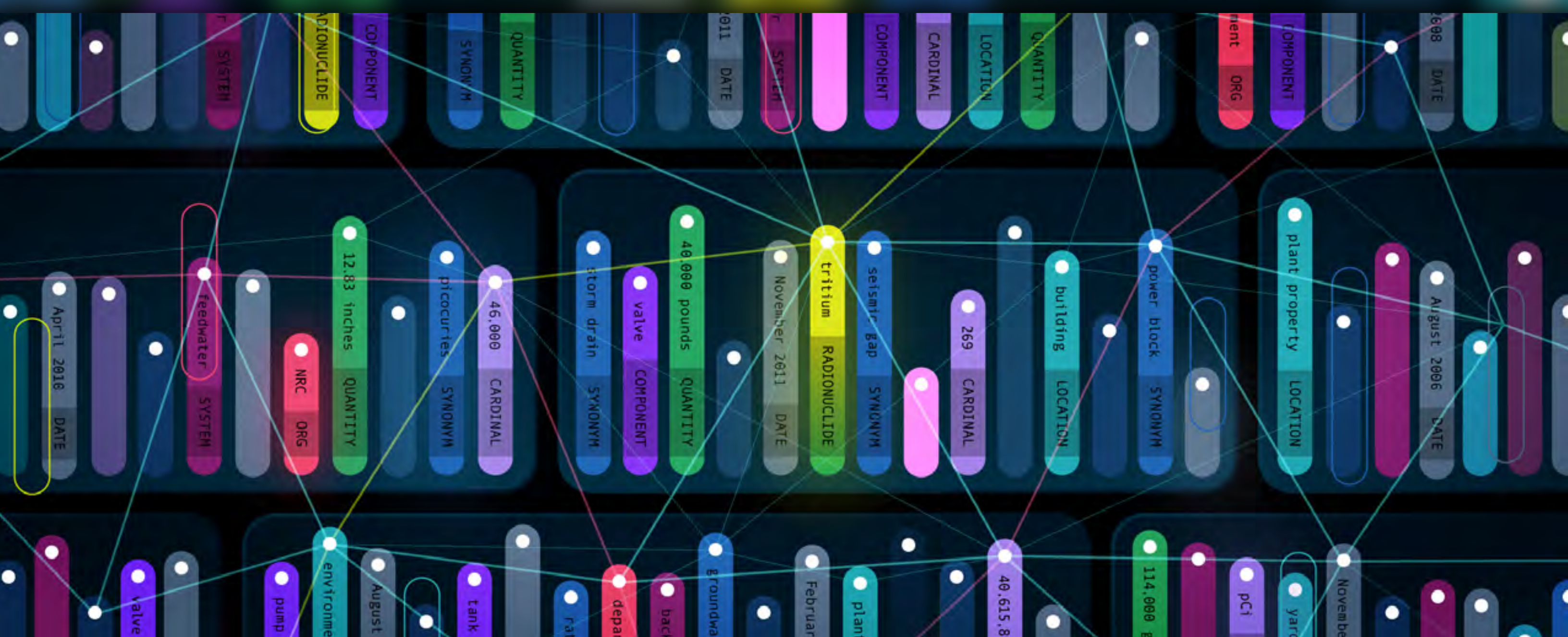
# EPRI JOURNAL

## A 'Dictionary' to Help AI Tools Understand the Language of the Electric Power Industry

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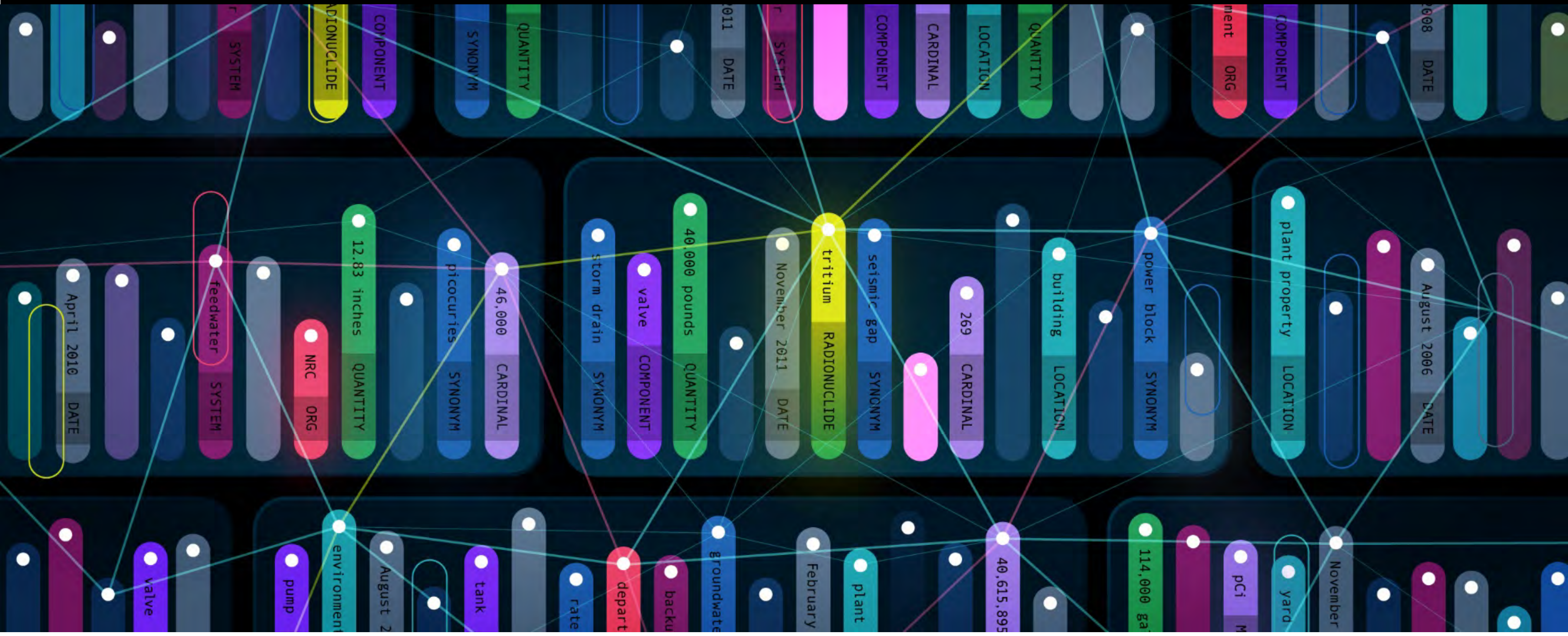



# A 'Dictionary' to Help AI Tools Understand the Language of the Electric Power industry

***By Michael Matz***

EPRI has embarked on a four-year effort to build a comprehensive dictionary of electric power industry terms aimed at advancing the industry's adoption of artificial intelligence (AI) technologies.

As part of planning, operation, and training activities, electric utility staff often need to review many long documents, find data in the documents for subsequent analyses, and synthesize the information into actionable results. These activities are time-intensive and often tedious. In nuclear plants, for instance, workers spend a considerable amount of time combing through plant maintenance logs, regulatory reports, inspection reports, and operating experience reports.

"Many tasks in nuclear plant operations require analysts to search for information in numerous technical documents that can be hundreds of pages long," said Carola Gregorich, an EPRI researcher investigating the use of AI in the nuclear power industry. "These tasks can take hours or days, and the analysts may not even find what they are looking for."

Natural language processing (NLP)—a type of AI that reads, understands, and analyzes human language—offers the potential to automate these activities and complete them much more quickly. While NLP has been researched for decades, only recently has it advanced sufficiently for commercial applications, such as smart speakers, word suggestions for texts on smartphones, Web searches, and chatbots that can answer questions from customers.

Because language is inherently ambiguous and word meanings vary by context, NLP algorithms need a reference or dictionary to understand and analyze text. Dictionaries for NLP applications typically do not contain definitions; rather, they include words and phrases, their variations, and their associations with other words.

Open-source NLP dictionaries such as Wordnet have been successfully used for analysis of commonly used language, but they don't understand the power industry's unique technical terms, phrases, acronyms, and abbreviations. For example, the nuclear industry term "drain cooler relief valve" is a compound noun that refers to a specific type of relief valve found in nuclear plants. Generic NLP dictionaries would divide the phrase into separate words—drain, cooler, relief, and valve—and therefore not understand its intended meaning.

Recognizing these limitations, EPRI researchers have started to develop a power industry–specific dictionary for NLP applications. When completed, it would be available for use by utility staff.

"The vision is to create a large, comprehensive power industry dictionary comprised of numerous, separate sub-dictionaries, each focused on specific technical areas," said Gregorich. "The terms in the sub-dictionaries would be transferrable to other sub-dictionaries. As more sub-dictionaries are created, they would be merged with the overall dictionary—similar to building with LEGO bricks. It would be a living dictionary, continually expanded and refined."

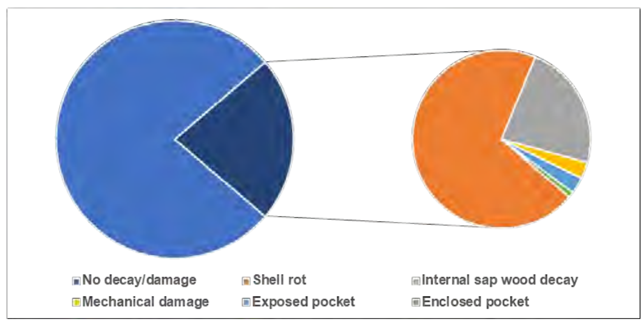
EPRI has started the first sub-dictionary, which is focused on groundwater protection at nuclear plants.

"Protecting groundwater from spills and leaks is a high priority for nuclear plant operators," said Gregorich. "We want this dictionary to support NLP algorithms that can analyze industry operating experience to yield new insights on how to reduce the risk of leaks and spills—or prevent them altogether."

To build the dictionary, a collaborative team of groundwater experts and data scientists used various NLP algorithms to process a broad set of groundwater-related documents from EPRI, the Institute of Nuclear Power Operations, and the U.S. Nuclear Regulatory Commission. The algorithms identified key terms and phrases, their relationships with other words, and their variations (for example, “groundwater,” “g water,” “gnd water,” and “GW” all have the same meaning).

The current dictionary, which contains about 900 words and phrases, can be used by NLP tools to understand the language in similar documents and process them for answers to groundwater research questions much more comprehensively and much faster than any human. The effort demonstrated a repeatable process for building dictionaries specific to a technical area. Over the next four years, the team plans to apply the process to create dictionaries for several other technical areas, including:

- **Nuclear plant maintenance**: NLP algorithms can evaluate large amounts of maintenance-related documents (such as maintenance logs and work orders) for insights on the root causes of component failures, enabling plants to improve maintenance strategies.
- **Corrective Action Program**: Each year, a nuclear plant generates an average of 10,000 Corrective Action Reports, which evaluate the safety and reliability implications of problems, observations, near-misses, and other plant incidents. Activities associated with these reports are time-intensive: Each day, several managers may each spend hours reviewing the reports, assessing the severity of the incidents, and setting priorities for addressing them. With NLP, this process can potentially be streamlined, reducing staff time and effort by 80%.
- **Performance of grid assets**: NLP techniques have shown early promise in analysis of transmission and distribution asset performance. In particular, EPRI has found them useful in analyzing descriptive maintenance and outage records to yield actionable insights, such as the cause of equipment outages and the most common maintenance actions for different equipment families, makes, and models. The next step is to make the techniques more powerful by applying them to larger datasets compiled by pooling equipment maintenance records from across the industry.
- **Automated component tagging:** Utilities’ monitoring and diagnostics centers gather data on power plant operations across their fleets and analyze that data for insights on the performance of components and systems—and for early signs of failures. These analyses are challenged by the fact that different plants and manufacturers use different conventions and standards to name or “tag” components. EPRI is developing an NLP tool that can search through all the tags in incoming data to create standard names for each component, supporting more efficient, robust analyses of fleet performance.

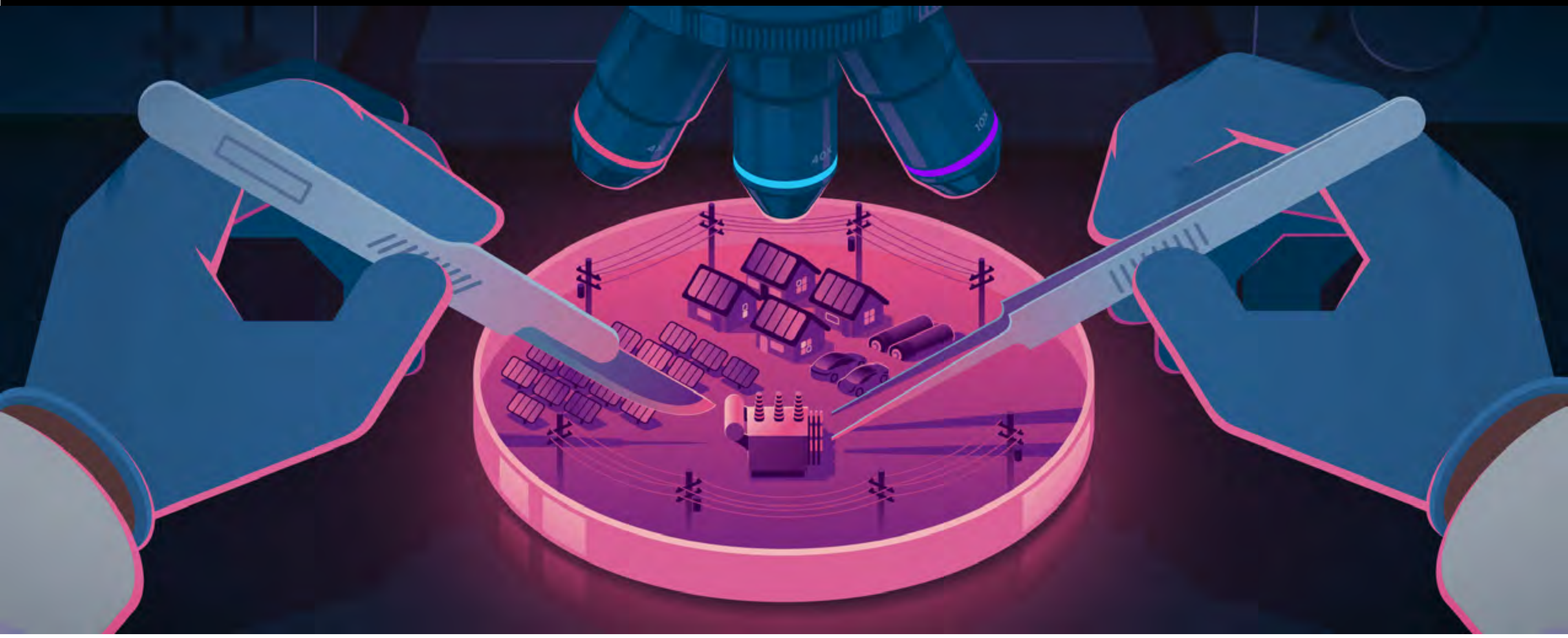



EPRI used an NLP algorithm to extract the type of decay and damage from 485,000 wood pole inspection records.

“EPRI is in a unique position to create dictionaries and use NLP methods for different applications in the power industry,” said Jeremy Renshaw, manager of EPRI’s AI Initiative. “We have access to more than 25 million industry-related reports, and each one represents a dataset that we can use to refine the dictionaries and train NLP algorithms. Our ongoing collaboration with utilities enables us to get even more data.”

## KEY EPRI TECHNICAL EXPERTS

Carola Gregorich, Chris Wiegand, Jeremy Renshaw, Bhavin Desai, Lea Boche, Yashwant Jankay



# A Bridge to Grid Modernization

## *EPRI and Utilities Use New Laboratory to Investigate Emerging Technologies Before Grid Deployment*

***By Chris Warren***

At a new EPRI lab designed to evaluate emerging grid technologies, researchers recently spent several months prototyping, testing, and validating a low-cost device designed to prevent distributed energy resources (DER) from islanding. The team made several important adjustments intended to avoid technical problems that could compromise grid safety and reliability.

"The lab enabled us to refine the device and develop associated control software so that it would operate reliably in the field," said EPRI's Lindsey Rogers, project manager in EPRI's Distribution Operations and Planning Program.

This example points to EPRI's rationale for launching its Knoxville-based Operations, Protection, and Systems (OPS) Lab in 2019: to thoroughly vet the performance of new technologies and support their successful deployment in distribution grids.

"The lab is equipped with grid hardware," said Rogers. "We can replicate a utility's grid by using simulation software and configuring the hardware to act just as it would on that grid. This provides an ideal setting for utilities to investigate new technologies and understand how they may perform in the field. It's an important, interim step before grid deployment."

With an unprecedented level of change occurring in distribution grids, this interim step is essential. Utilities seek to integrate new technologies, such as sensors, advanced metering infrastructure (AMI), distribution automation, distribution management systems (DMS), distributed energy resource management systems (DERMS), and much more. According to a 2018 U.S. Department of Energy report, investor-owned utilities spent $27 billion on distribution grid upgrades in 2016, and annual smart grid investments are projected increase from $4.8 billion in 2016 to $13.8 billion by 2024.

"When utilities conduct pilot studies on new devices and software in the field, it can take months to fully test the technology under a range of grid conditions," said EPRI's Van Holsomback, who manages EPRI's OPS lab. "It would be extremely time-intensive for utilities to go through this process for the dozens of new technologies they seek to deploy as they modernize their grids."

For example, a comprehensive evaluation of a new device installed on a distribution grid might include its response to a voltage increase, extreme weather conditions, and load fluctuations. These conditions can have a negative impact on a distribution system, so it's preferable to examine them in a lab.

"Because our lab can replicate the behavior of much of the distribution system, we can evaluate numerous system conditions in a matter of weeks," said Holsomback.

The lab contains various grid hardware and software, including a supervisory control and data acquisition system (SCADA), DMS applications, DERMS, and distribution automation devices. Researchers configure devices so that they behave in the same manner as the devices used in a particular utility's grid. This enables the utility to study the implications of the hardware and software combinations and configurations that it is considering as part of its grid modernization activities. With EPRI's OpenDSS tool, users can test relays, regulators, and other grid hardware under various simulated grid scenarios.

In one project, EPRI is working with a utility to test different fault location, isolation, and service restoration (FLISR) schemes. "The lab lets the utility simulate faults in different parts of the grid and then examine how switches and other devices would react in these scenarios," said Rogers. "Before we launched the lab, utilities would need to implement expensive, labor-intensive tests to evaluate these applications and devices on their systems."

EPRI and New York State Energy Research and Development Authority also are using the lab to test new DMS applications, including volt-var optimization. "We're developing algorithms for volt-var optimization to help integrate large numbers of DER with other grid assets," said Rogers.

### KEY EPRI TECHNICAL EXPERTS

Lindsey Rogers, Van Holsomback

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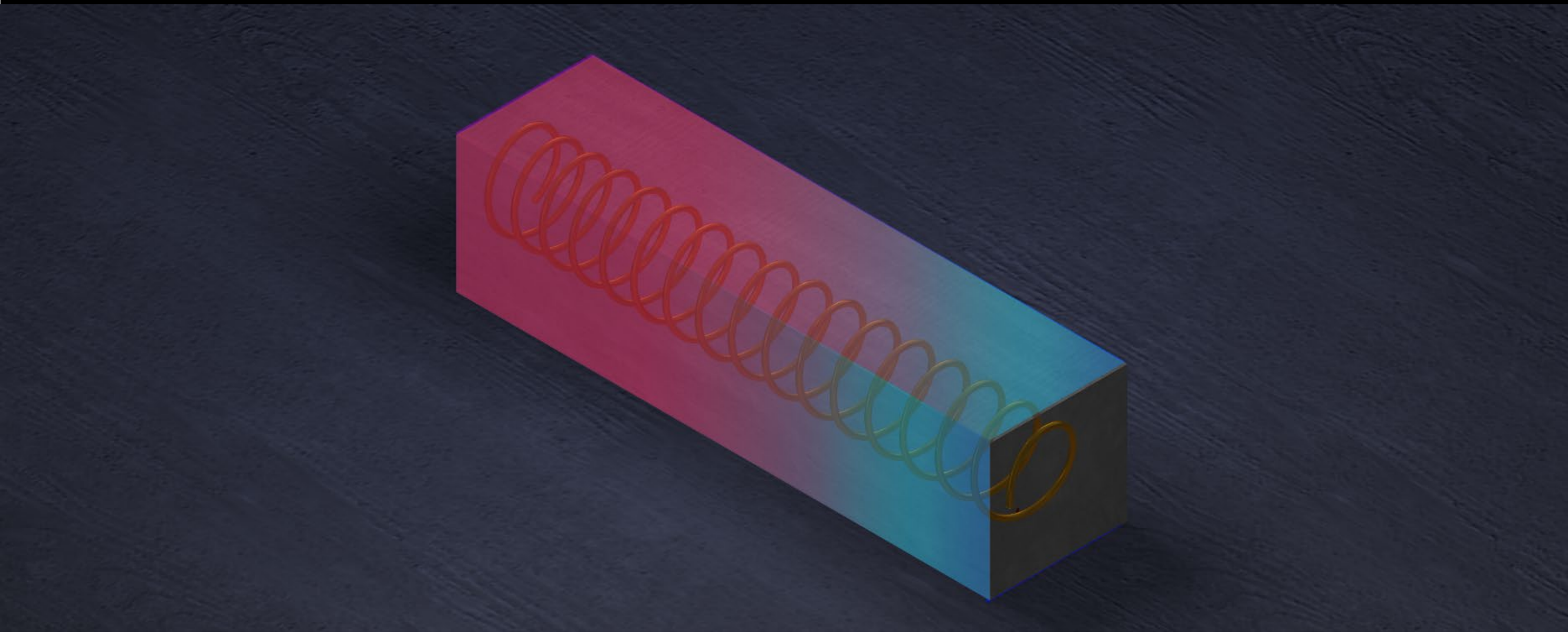


# A New Use for a 3,000-Year-Old Technology: Concrete Thermal Energy Storage

***By Michael Matz***

Concrete has been used widely since Roman times, with a track record of providing cheap, durable material for structures ranging from the Colosseum to the Hoover Dam. Now it is being developed for a new purpose: cost-effective, large-scale energy storage.

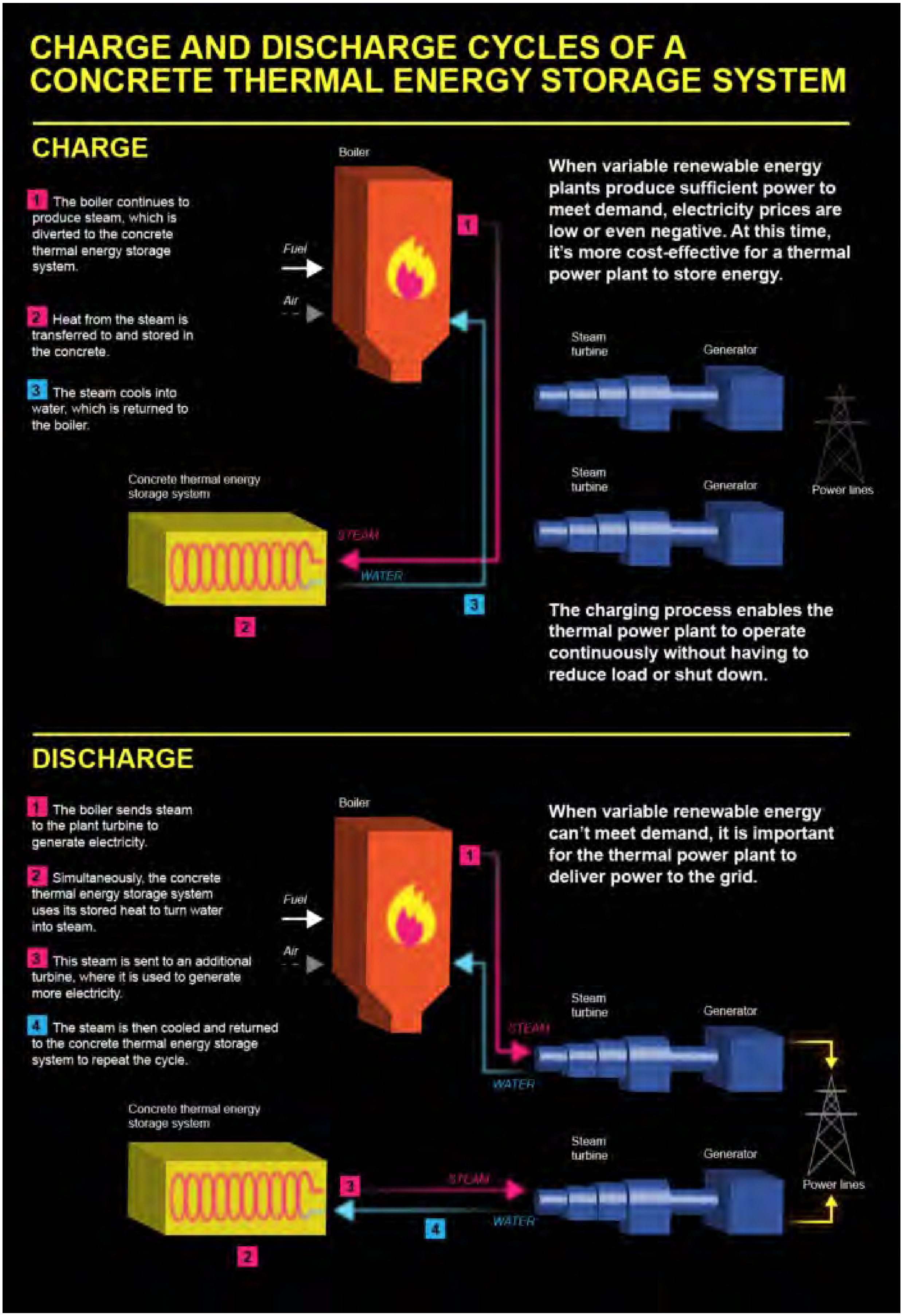
EPRI and storage developer Bright Energy are examining a technology that uses concrete to store energy generated by thermal power plants (fossil, nuclear, and concentrating solar). Recent laboratory tests validated a Bright Energy design, setting the stage for a pilot-scale demonstration at an operating coal-fired power plant.

## THE POTENTIAL OF CONCRETE

As variable renewable energy gains share in the electricity system, the result is excess power and low power prices during certain periods. In response, thermal power plants may cycle up and down in output or shut down temporarily. Most conventional generating units were not designed for such cycles, which can diminish plant performance and damage components. Large-scale energy storage is emerging as a more viable option for handling load fluctuations. BloombergNEF forecasts that global energy storage deployment will grow from 9 gigawatts (GW) to 1,095 GW between 2018 and 2040—a 122-fold increase.

Today, more than 160 GW of pumped hydro storage account for about 94% of grid storage worldwide, though deployment has slowed in some regions due in part to restrictions on land and water use. Batteries represent the largest share of recent bulk storage deployment.

It's likely that a mix of technologies is necessary to provide the enormous storage capacity in the future. In particular, there is growing need for sustained storage over longer periods when renewable energy generation is not available. Relative to lithium ion batteries, concrete can provide thermal energy storage for longer durations and at lower cost.


CHARGE AND DISCHARGE CYCLES OF A CONCRETE THERMAL ENERGY STORAGE SYSTEM
CHARGE
1 The boiler continues to produce steam, which is diverted to the concrete thermal energy storage system.
2 Heat from the steam is transferred to and stored in the concrete.
3 The steam cools into water, which is returned to the boiler.
Boiler
Fuel
Air
Concrete thermal energy storage system
STEAM
WATER
When variable renewable energy plants produce sufficient power to meet demand, electricity prices are low or even negative. At this time, it's more cost-effective for a thermal power plant to store energy.
Steam turbine
Generator
Steam turbine
Generator
Power lines
The charging process enables the thermal power plant to operate continuously without having to reduce load or shut down.
DISCHARGE
1 The boiler sends steam to the plant turbine to generate electricity.
2 Simultaneously, the concrete thermal energy storage system uses its stored heat to turn water into steam.
3 This steam is sent to an additional turbine, where it is used to generate more electricity.
4 The steam is then cooled and returned to the concrete thermal energy storage system to repeat the cycle.
Boiler
Fuel
Air
Concrete thermal energy storage system
When variable renewable energy can't meet demand, it is important for the thermal power plant to deliver power to the grid.
STEAM
WATER
Steam turbine
Generator
Steam turbine
Generator
Power lines
STEAM
WATER

"In the same way that different generation technologies help balance the grid today, a range of storage technologies can serve various applications," said EPRI Principal Technical Leader Scott Hume. "Grid operators can dispatch the lowest cost storage technology on a case-by-case basis, and grid planners can select the optimal mix of technologies for reliability."

## HOW IT WORKS

With concrete thermal energy storage, large concrete blocks are stacked in a location adjacent to a thermal power plant. When the plant's power output is not needed by the grid, its steam is redirected from the plant's turbines to tubes embedded in the blocks, storing the steam's heat in the concrete. When plant power production needs to be increased again, heated feedwater from the plant is pumped into the tubes and converted to superheated steam for power generation at a separate steam turbine. At the same time, steam generated by the power plant is diverted back to the plant's main turbine to generate additional output (see diagram). This approach can extend the time for the plant to run at full load, boosting efficiency and reducing damage that can result from cycling up and down and other dynamic modes.

Using readily available, cheap concrete can potentially enable energy storage at capital costs of less than $100 per kilowatt-hour—well below the capital costs of lithium ion batteries. Because concrete is a strong material, systems can be assembled in stacks, resulting in significantly smaller footprints per unit of energy relative to battery systems.

"At about $65 per ton, concrete is less than 10 percent of the cost of the molten salts currently used for thermal storage," said Hume. "With heat losses of about 1 percent per day, concrete systems can potentially provide several days of storage, which is what's needed in wind- and solar-dominated energy markets. That's well above the four hours of storage possible with today's grid-scale battery storage systems. In the future, several days of storage will be needed to shift solar and wind energy from periods of excess production to periods of limited production."

When thermal plants are retired, thermal storage systems can then be retrofitted to store renewable energy and use the plant's power cycle to generate emissions-free power.

## PUTTING CONCRETE TO THE TEST

To simulate plant operating conditions in the laboratory, researchers cycled samples of 3 different concrete mixes from 400°C to 600°C more than 1,500 times and continuously exposed other samples to 600°C for 5,000 hours, periodically assessing material properties. One mix outperformed the other two, meeting or exceeding targets established by modeling a full-scale system. It had no damage at the tube-concrete interface.

"1,500 thermal cycles are equivalent to more than three years of operation, so these tests give us a reasonably good indication of how the system will perform long-term," said Hume.

One concern with concrete thermal storage is that corrosion or defects in the tubes could result in steam leaks that create cavities in the concrete. If steam pressure were to build in these cavities, the concrete blocks could potentially rupture. To examine this possibility, the team drilled pinholes in the tubes and examined the impacts of the resulting steam leaks. They found that the concrete formed small cracks that enabled the steam to escape without significant damage to the blocks.

## DEMONSTRATION IN ALABAMA

In collaboration with Southern Company, Bright Energy, and engineering company AECOM, EPRI plans to demonstrate the optimized design at Alabama Power's Plant Gaston. The project is supported by a $4 million award from the U.S. Department of Energy. The system will consist of 60 blocks, each weighing 18 tons with approximately 200 kilowatt-hours of storage capability. In total, the system will measure 50 feet long, 25 feet wide, and 30 feet tall, and provide 10 megawatt-hours of thermal storage. The blocks are designed to be transportable to the site. While the system is pilot-scale, larger, commercial-scale systems could be deployed by simply adding blocks.

Researchers will use the demonstration to examine the system's ability to accept steam from the plant and to generate steam of appropriate temperature, pressure, and flow to enable rapid ramping. Over 11 months of testing, it will be cycled more than a thousand times to verify the concrete blocks' ability to withstand thermal cycling. To reflect the grid's flexibility needs, it will be charged and discharged at various rates.

With engineering underway, participants expect construction to be complete in September 2021, with the demonstration completed by the end of 2022.

"A technology portfolio that includes new forms of energy storage will be essential as our generating fleet adapts to the operational demands of intermittent renewable resources," said Josh Barron, Southern Company senior research and development engineer. "Southern Company expects to gain important knowledge on concrete thermal energy storage from this new collaborative research with EPRI, the Department of Energy, and our industry partners."

## KEY EPRI TECHNICAL EXPERTS

Scott Hume


# Can Drones Be Used to Eliminate Worker Radiation Exposure For Certain Tasks in Nuclear Plants?

## *At Peach Bottom Nuclear Plant, EPRI and Exelon Demonstrate Drone that Surveys for Radiation and Inspects Components Autonomously*

***By Michael Matz***

EPRI and Exelon successfully demonstrated the use of an autonomous drone to map radiation levels and inspect equipment in a nuclear plant—one of the first such demonstrations in the U.S. nuclear power industry. The tests took place at Peach Bottom Atomic Power Station's Unit 1, which has been inoperable since 1974, as well as a Peach Bottom facility used to store low-level radioactive waste. Unit 1 has equipment and tight spaces similar to those in operating nuclear plants, making the demonstration an important first step to deploying autonomous drones in the nuclear power industry. RADeCO Inc. provided the radiation detection instruments for the demonstration, and Exyn Technologies provided the autonomous drone navigation system.

Radiation surveys, equipment inspections, and other tasks can expose nuclear plant workers to elevated radiation. Drones offer the potential to complete these tasks autonomously, reducing exposure to radiation and other industrial hazards. Prior use of drones in nuclear plants has relied on manual operation, which can be difficult in tight spaces and requires line of sight between the operator and drone—often resulting in radiation exposure. For safe navigation during this early-stage demonstration, the Exyn drone automatically maintained a 3-foot buffer around it. For future demonstrations and deployments, this buffer can be adjusted based on operating experience and location of sensitive equipment.

The team made software and hardware changes to connect the radiation detectors with the drone and navigation system. Using laser-based light imaging detection and radar (LIDAR) technology, the drone created high-resolution 3D maps of several areas inside Unit 1 and the low-level waste facility. Using a base station tablet, participants programmed the drone's flight plans onto these maps. As it flew to various locations, the radiation detectors collected readings every three seconds, displaying the results on the 3D maps.


Watch video on YouTube

A video camera simulated the inspection of various components. Electric heated blankets were wrapped around pipes, and the drone's infrared camera detected the elevated temperatures. To test the drone's ability to avoid obstacles, a worker walked in its path. The drone immediately detected the worker, safely flew around him, and returned to its programmed route.

"I'm very impressed with this technology," said Peach Bottom's Senior Instrument Physicist Richard Bolding. "It's so user-friendly. It took me three minutes to set a destination and return path for the drone. This can greatly reduce the learning curve compared to the manual drone technology we presently use."

Researchers also deployed the 3D mapping system, radiation detectors, and cameras on a manually operated ground vehicle, which completed a similar set of tasks in Peach Bottom's operating units (2 and 3).

"This project showed that drones can potentially replace people for certain tasks in nuclear plants, eliminating worker radiation exposure for those tasks," said Phung Tran, an EPRI expert on radiation safety in nuclear plants.

The Peach Bottom demonstration is part of EPRI's Next Generation Radiation Protection (NextGen RP) initiative, which is examining various ways to streamline radiation protection and reduce worker radiation exposure. This drone is one of a suite of technologies under investigation as part of broader plant modernization in the nuclear power industry.

While the drone successfully completed all tasks at Peach Bottom, the demonstration pointed to areas for improvement. For instance, the team used a large drone to accommodate a heavy payload, restricting access in tight spaces. The drone's powerful propellers stirred up dust in some areas, raising the concern that it could potentially spread contaminated materials in certain applications. Future deployments may consider the use of smaller, less powerful drones.

### KEY EPRI TECHNICAL EXPERTS

Richard McGrath, Phung Tran

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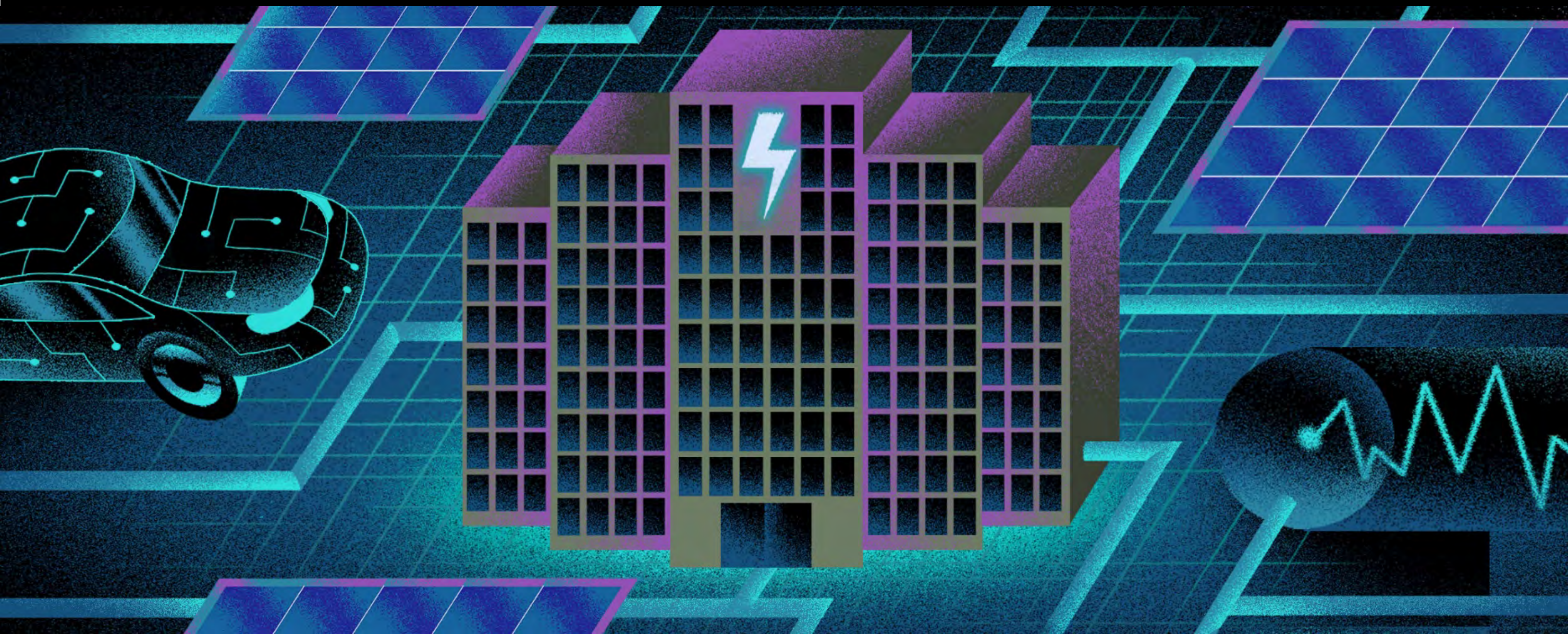

# EPRI Guidelines Aim to Secure Communication Networks Between Utilities and the Grid's Edge

***By Michael Matz***

EPRI published the first comprehensive cybersecurity guidelines for the networks that connect distributed energy resources (DER) with utility grid systems. The guidelines are intended to inform utilities, installers, integrators, aggregators, and manufacturers on securing solar power systems, wind turbines, energy storage, microgrids, and other DER.

Utilities are increasingly deploying systems (such as Distributed Energy Resources Management Systems and Advanced Distribution Management Systems) that remotely manage and control grid-connected DER via public or private communication networks. These systems send commands to smart inverters, sensors, and other devices, which may reply with information on their operational status or other data. The growing prevalence of new, interconnected devices across the energy system requires continued diligence to mitigate cybersecurity risks.

"A cyberattack on a smart inverter could compromise a utility server that controls hundreds or even thousands of devices connected the distribution grid—and that could lead to an outage," said Candace Suh-Lee, an EPRI cyber security expert who developed the guidelines with input from dozens of utilities and other industry stakeholders. "It is also important to secure the cloud-based systems that DER aggregators use to communicate with devices."

The guidelines focus on network communications between utility systems and DER connected to the distribution grid. They categorize DER as high-risk, medium-risk, or low-risk, recommending the strictest security measures for high-risk systems. For example, a 100-megawatt solar power plant might be considered high-risk because a security breach could lead to a significant loss of grid power. On the other hand, a kilowatt-scale, residential rooftop solar installation would likely be low-risk. The risk-based approach enables utility cybersecurity teams to allocate resources effectively. The guidelines provide a 60-point implementation checklist along with examples of technologies that can be deployed to secure networks.

To develop the guidelines, EPRI's Suh-Lee identified techniques and approaches applicable to DER in 10 power industry cyber security standards published by organizations including the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), National Institute of Standards and Technology (NIST), and North American Electric Reliability Corporation (NERC). Suh-Lee gathered input from more than 100 staff at the 31 utilities participating in EPRI's Cyber Security Task Force for DER and Grid-Edge Systems. The SunSpec Alliance, an industry group of solar component manufacturers, integrators, and aggregators, also provided feedback on the guidelines.

Suh-Lee offers an example of how these guidelines might improve security. If a high school installs a large solar panel canopy on its parking lot, and the installer connects the system's smart inverter to the school's Wi-Fi network, any student on the school's network could connect into the inverter and manipulate data or settings.

"It's a common practice for solar installers to manage inverters via public Internet. To provide the Internet connectivity to the inverter, they may resort to using an insecure network such as a home or school Wi-Fi network. Today, there are no standards to prevent them from doing so," said Suh-Lee. "In the high school example, the EPRI guidelines would categorize the school's solar system as high-risk or medium-risk and recommend configuring the inverter on a network that is appropriately segregated from the school's network."

Suh-Lee expects the guidelines to inform cyber security standards such as IEEE 1547, which defines the requirements and capabilities at the interface between DER and the power grid. Following a discussion about the guideline's recommendations, an IEEE 1547 working group has started to draft a section of the standard (IEEE 1547.3) that provides cyber security guidelines for DER.

Utilities are considering how to apply the EPRI guidelines to their DER integration activities. "All utilities can implement EPRI's simple, practical guidelines for DER network integration," said Mark Johnson-Barbier, senior principal analyst at Salt River Project. "The guidelines should be considered as myriad devices, systems, and microgrids are connected to the distribution power grid in the near future."

"It's important to get ahead of DER security risks now—when DER are not yet widespread," said Suh-Lee. "I expect it to be much cheaper to design and build secure DER networks today than to retrofit utility systems and DER with network security five years from now."

EPRI's guidelines address only one facet of DER cyber security risks: communication networks. According to Suh-Lee, the power industry needs a comprehensive cybersecurity standard that covers many other areas, including device-level security (such as anti-virus software), monitoring, incident response, physical security, and management of cryptographic keys.

### KEY EPRI TECHNICAL EXPERTS

Candace Suh-Lee, Xavier Francia

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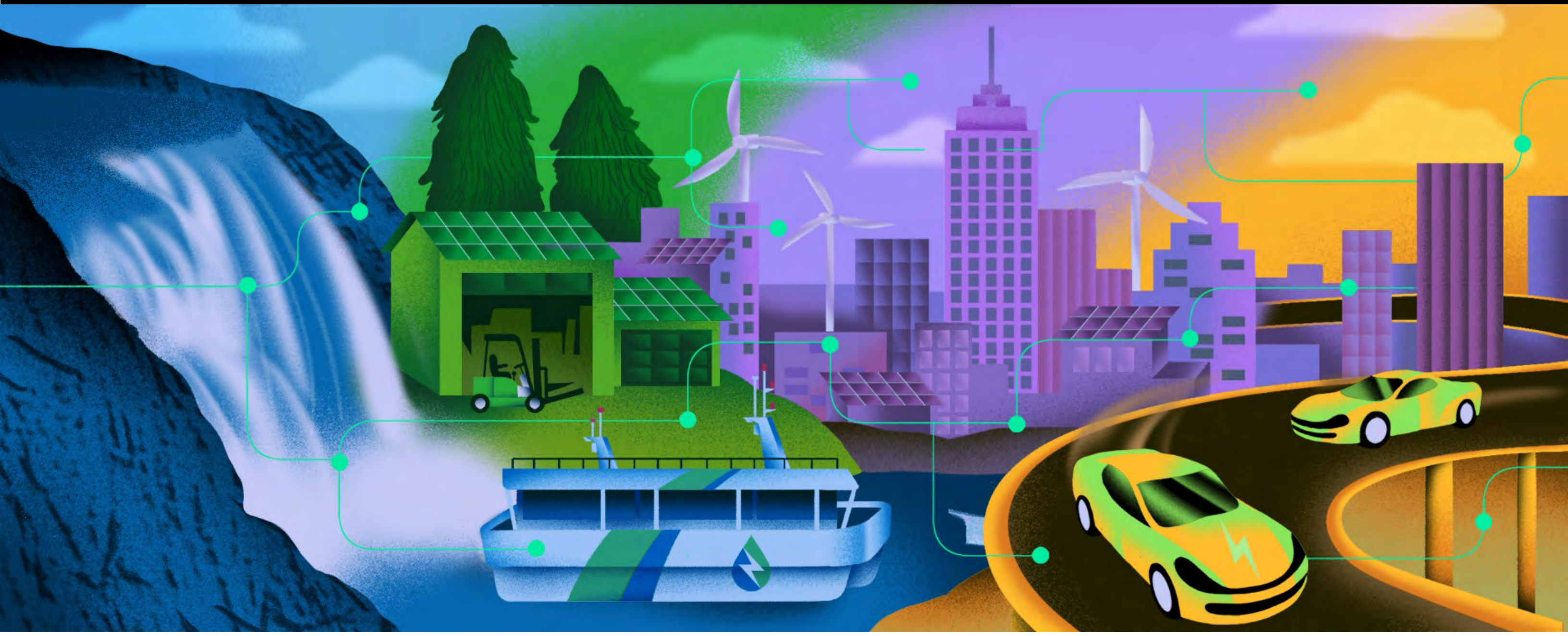

# EPRI Study: Electricity Can Drive New York's Low-Carbon Future

***By Michael Matz***

An EPRI study shows that electricity could power up to 70% of the New York economy by 2050. The study, *Electrification Scenarios for New York's Energy Future*, examines electrification opportunities in New York over the next three decades, along with key implications for energy efficiency, the environment, and the grid. EPRI conducted the study in collaboration with Con Edison, the New York Power Authority, and the New York Independent System Operator. It is one of more than a dozen state-focused projects that build on EPRI's 2018 U.S. National Electrification Assessment.

As a first step in the study, EPRI integrated extensive in-state and county data into its U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model to capture characteristics unique to New York's energy system, households, and economy. For more than a decade, EPRI has used US-REGEN for various energy system analyses, including its U.S. National Electrification Assessment.

EPRI researchers modeled the impacts of adoption of electric technologies across several scenarios with varying policy, economic, and technology factors.

"What is the extent and timing of electrification? What are the infrastructure and investment needs? What are the resulting economy-wide emissions reductions?" said EPRI Principal Technical Leader Delavane Diaz, one of the study's authors. "These were some of the impacts we examined through our scenario approach." She noted that the study was not designed to identify a single pathway to achieving the state's greenhouse gas reduction targets, though it offers insights on the system-level implications of deep decarbonization through electrification.

Key findings:

- There is significant potential for electrification and associated reductions in $CO_2$ emissions. Across the study's four principal scenarios, electricity's share of final energy use ranges from 28% to 70% in 2050, up from about 20% today. Energy efficiency and electric transportation offer the greatest potential for cost-effective emissions reduction. Under the most transformational scenario, in which electricity powers 70% of the economy, $CO_2$ emissions drop to 86% percent below 1990 levels.

- The baseline scenario projects that 950,000 passenger electric vehicle (EVs) will be on New York roads in 2025 and 2.3 million in 2030. EVs are expected to account for 50% of new light-duty vehicle sales by 2030. An extensive charging network will be needed to enable this widespread adoption.
- Relative to other regions of the United States, New York's winter climate and building stock require advanced technologies to achieve widespread heating electrification. In New York, today's electric heat pumps are less cost-effective than natural gas furnaces due to higher upfront capital and installation costs, though lifetime economics could improve with significant advances in next-generation heat pumps designed for cold climates.
- In all scenarios, statewide peak demand shifts from summer afternoons to winter mornings and increases as a result of heat pump adoption and greater EV charging in low temperatures. Summer demand drops as a result of air conditioning efficiency improvements. In those scenarios in which utility customers electrify nearly all space heating and transportation, peak winter demand in 2050 could be more than twice as high as today's system peak. Opportunities to reduce peak demand include load-shifting strategies (such as smart EV charging, time-of-use pricing, and behind-the-meter storage) and load reduction strategies (such as building envelope efficiency improvements and advanced, cold-climate heating technologies including ground-source or dual-fuel systems).
- A full portfolio of advanced technologies will be critical to decarbonizing electricity generation and balancing system operations. As more renewables are added to the grid, dispatchable energy resources will be needed to maintain reliability. The need for additional transmission is projected for integrating large off-shore wind deployments and to move renewable generation from upstate New York to downstate population centers. Broadening the state's portfolio of low-carbon, flexible generation assets can reduce reliance on fossil fuels.

"This study illustrates how an expanded portfolio of electric technologies could play a significant role in reaching New York's energy and decarbonization goals," said Diaz. "Our initial findings identify additional research opportunities in key areas—like peak management, market design, grid modernization, and system planning—where stakeholders can work together to guide the transition to New York's clean energy future."

### KEY EPRI TECHNICAL EXPERTS

Delavane Diaz

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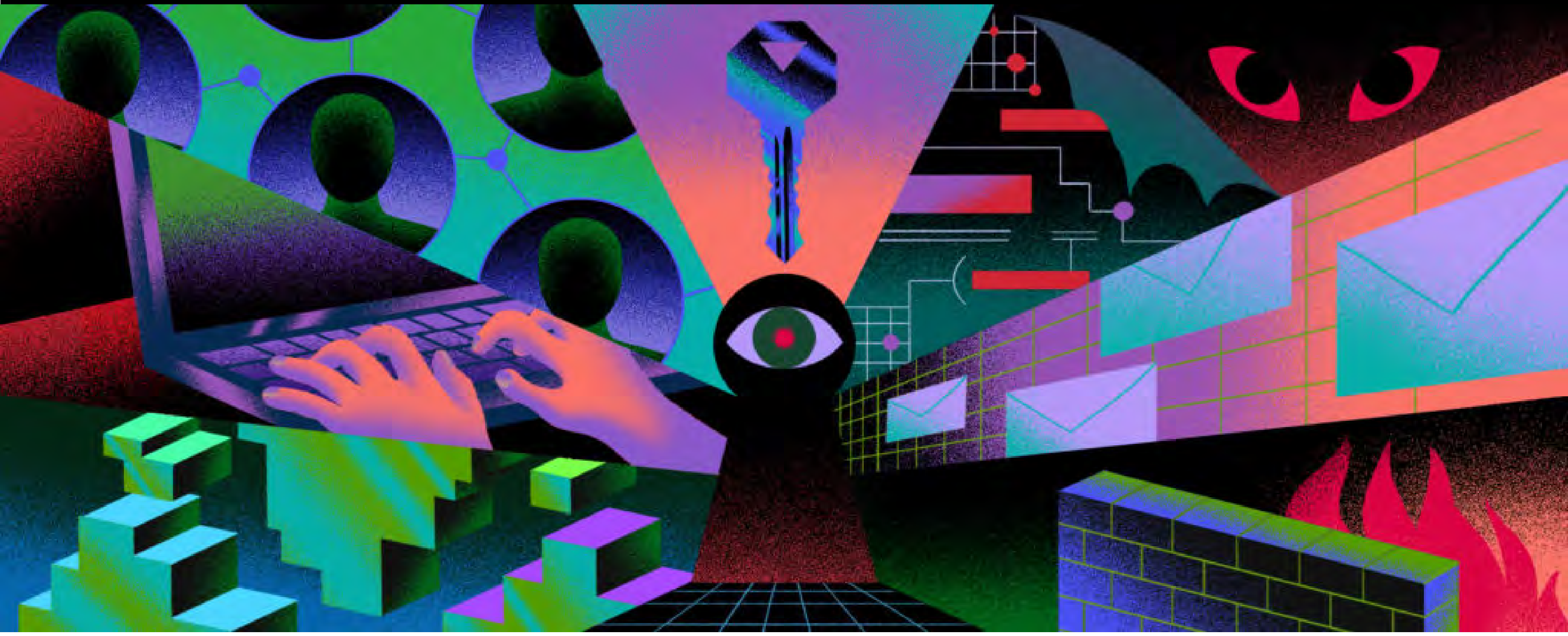

# A New Security Center in a Flash

## *EPRI Guide Enables Alliant Energy to Integrate Its Cyber Security Activities in Less Than a Year*

***By Lucinda Trew***

In football, defensive coordinators manage various defensive players and strategies in response to the actions of opposing offensive teams. Some utilities today are taking a similar approach to cyber security. They are establishing Integrated Security Operations Centers (ISOC), which integrate and coordinate cyber security for information technology (IT) and operational technology (OT) along with physical security for equipment and assets.

Alliant Energy recently established its ISOC in less than a year—much faster than the typical timeline. Alliant used the EPRI ISOC Guidebook, which draws on five years of research and the experience of five utilities that have successfully implemented ISOCs. The guidebook covers various aspects of creating and operating ISOCs, including mission, organizational structure, personnel, and technologies. It is designed to benefit utilities with a range of experience, from those with limited security capabilities to those with robust security monitoring and responses in place.

Power companies typically call on different departments that independently monitor and analyze security status and threats in their IT systems and OT systems for generation, transmission and distribution equipment. A more coordinated approach is needed as electric power systems become more connected and automated—and as threats grow more frequent and sophisticated. Since 2013, EPRI research has considered how to design, implement, and operate ISOCs. Such centers simultaneously monitor and detect threats across various utility departments, enabling a unified response to and recovery from security events.

"We had in-house expertise within separate teams," said Alliant's Manager of Cybersecurity Operations John Kotolski. "EPRI's guidebook provided a detailed roadmap for integrating these teams in a single center. We also benefited from the guidance on defining an ISOC's mission, the recommendations on personnel and technologies, and the comprehensive focus on OT."

Alliant's ISOC operates in two rooms. In one, walls of monitors display status of various assets, weather and news updates, alerts, metrics for security events, and live camera feeds from various locations such as substations. This is where Alliant staff monitor the security of IT and OT systems and physical assets and detect potential problems. The second room is where staff convene to manage and respond to emergencies.

"Bringing the security functions together in one space has significantly improved the frequency, timeliness, and quality of communications and information sharing," said Kotolski.

In the summer of 2019, Alliant's ISOC conducted a drill using the scenario of a compromised company badge system, practicing communications and procedures and identifying areas for improvement.

"We plan to continue building synergies through joint drills and exercises," Kotolski said. "As we execute our ISOC roadmap, we are bringing more OT into the center through partnerships with our generation and energy delivery colleagues."

EPRI expects to update the guide annually, combining up-to-date research and technology development with utilities' feedback and their experience with drills, attacks, and other security events.

"We're tracking and researching emerging technologies that can potentially be used to protect critical systems, such as artificial intelligence, machine learning, security orchestration, automation, and response, and cyber security forensics," said EPRI Program Manager Ralph King.

EPRI's Cyber Security Research Lab in Knoxville, Tennessee includes a functioning ISOC. Technical staff use this to demonstrate ISOC capabilities and best practices to utility security professionals. Additionally, EPRI conducts ISOC workshops internationally. With EPRI technical support, Tokyo Electric Power Corporation launched its ISOC in 2018.

### KEY EPRI TECHNICAL EXPERTS

Ralph King

# The Grid is Moving to the Cloud

***By Michael Matz***

As utilities seek to decarbonize and digitize their grids while managing accelerating numbers of grid-connected devices, they need more powerful tools to process and analyze large amounts of data for grid planning and operations. Many utilities view cloud computing as an important enabler of these efforts.

"The cloud represents a paradigm shift in how utilities manage their data and computing abilities," said Xavier Francia, an EPRI expert in grid cybersecurity. "By working with cloud service providers, utilities can potentially avoid the large expense of operating their own data centers and other computing infrastructure, enabling them to focus more resources on their primary mission—operating the grid safely, reliably, and affordably. Innovation in cloud computing capabilities can drive innovation in how utilities manage their grids."

A key potential benefit of the cloud is *elastic computing* — the ability to rapidly expand or decrease computer processing and data storage resources according to real-time need. For example, the need for these resources may increase significantly during a major storm when a utility is addressing outages and informing customers about restoration. In this way, utilities can avoid paying for computing infrastructure that is not used all the time.

According to a 2019 Zpryme survey, 71% of utilities indicated that they are using cloud applications—up from 45% in 2016. In an EPRI poll of 22 utilities in 2020, half said that they expected to use cloud-based transmission and distribution planning applications within the next five years, and 30% expected to use cloud-based tools to manage and control distributed energy resources, such as electric vehicle charging infrastructure, energy storage, and distributed rooftop solar.

Despite the rapid move toward cloud computing in the electric power industry, cybersecurity is a major concern. By migrating grid applications to the cloud, utilities are relinquishing some security responsibilities to a third party. Indeed, 79% of respondents in the Zpryme survey said that security is barrier to expanding cloud applications. The EPRI poll revealed that a main challenge was compliance with the North American Electric Reliability Corporation's (NERC) Critical Infrastructure

Protection Standards, which are regulations that address the cybersecurity of assets essential to grid reliability. In addition, recent cyber events—such as the SolarWinds software hack that impacted government and corporate computer networks—point to a need for closer coordination among organizations and their vendors to broaden cybersecurity assurances across supply chains.

Recognizing these concerns, EPRI has launched research to advance the security state-of-the-art for utility applications hosted in the cloud. In April 2020, EPRI started a working group for utilities, cloud service providers, and vendors to discuss how they can work together to protect these applications and enhance supply-chain security and how NERC security standards may apply to cloud-based platforms. Participants include 22 power companies as well as major cloud service providers such as IBM, Microsoft, and Amazon Web Services. They collaborated on a white paper that identifies clarifications needed in the NERC standards, determines necessary updates to utility security plans, and examines how cloud service providers' tools can support security.

"The cloud service providers understand the importance of cybersecurity in utility grid applications and are engaged with the working group to find solutions," said Francia. "There's agreement among the group members that responsibility for security needs to be shared among utilities, cloud service providers, and vendors. It's essential that all parties involved understand the exact delineation of responsibilities and that utilities are equipped with the tools and knowledge to carry out cybersecurity requirements in the cloud."

As part of a new project, EPRI plans to create cloud security *reference architectures*, which include security guidance and diagrams that describe how a utility and a cloud service provider can work together, using processes and technologies to secure particular grid applications. The architectures will recommend security controls, the entity responsible for those controls, approaches to implement them, NERC compliance considerations, and existing cloud service provider tools that could help.

If a utility wants to pursue a particular application in the cloud, it can use the results of this research to identify the risks and determine the security measures that it needs to implement to meet its business objectives, operational requirements, and compliance obligations. The idea is to inform utilities in selecting the most appropriate cloud services for their applications.

"For a successful cloud journey, it is important for a utility to carefully select cloud services and understand their implications for security and compliance," said Francia. "The security considerations we identify in this project can reveal what security investments must be made to migrate a particular application to the cloud."

### KEY EPRI TECHNICAL EXPERTS

Xavier Francia

EPRI JOURNAL

# Reactors Built Like Cars in a Factory

## *Innovative Technologies Could Reduce Nuclear Reactor Production Costs by 40%; Commercialization Possible in the Next Decade*

***By Chris Warren***

When David Gandy envisions the future of nuclear power, he sees reactors being made in a similar way as automobiles. “Our goal is to get to a point where reactors can be produced on an assembly line in a factory,” said Gandy, who is an EPRI senior technical executive. “Steel or other raw materials come in one end and out comes a reactor on the other end.”

Since 2016, Gandy has been working toward this vision. With the support and sponsorship of the U.S. Department of Energy (DOE), EPRI is investigating advanced manufacturing and fabrication technologies with potential to dramatically reduce the time and costs required to build a nuclear plant’s reactor pressure vessel. Gandy expects that welding time can be reduced by up to 90%—and that overall costs can be cut by 40%.

Researchers are testing the technologies for constructing small modular reactors (SMRs). Collaborators include the United Kingdom–based Nuclear Advanced Manufacturing Research Center (Nuclear AMRC) and Oregon-based reactor manufacturer NuScale Power. The work focuses on producing the upper and lower assemblies of the reactor pressure vessel of NuScale’s 60-megawatt SMR.

One technology under investigation is powder metallurgy/hot isostatic pressing, which involves atomizing metal alloys into a powder, placing the powder into a metal mold, and using high temperatures and pressures to consolidate the powder into solid components.

Relative to traditional forging, this process produces near net shape parts with much less material wasted during machining. Production of components can be accomplished in as little as four to six months—just a fraction of the two to five years often required with forging.

The team has successfully produced a 3,650-pound reactor head at 44% scale with good strength and dimensional quality, which means that the size of the components doesn’t change during production.

The team has produced components as heavy as 7,000 pounds.

Fabrication has required addressing challenges associated with oxygen absorption. “When fine powder absorbs oxygen, the oxygen can react with silicon and manganese to form oxides, which reduces the toughness of the components,” said Gandy. “Working together with DOE and our collaborators, we have developed new processing methods to create components with excellent toughness and tensile strength.”

Researchers also are investigating electron beam welding, which fuses two sections of metal by focusing a high-intensity energy beam on the junction. The process occurs in a vacuum chamber. Unlike traditional welding, it does not require the use of filler material and can be completed in one pass.

Nuclear AMRC has demonstrated for two-thirds-scale SMR components that electron beam welding can be completed much faster than traditional welding.

“These welds are about 4-3/8 inches thick, and we demonstrated that you can complete a weld in one pass of the beam in 47 minutes,” said Matthew Cusworth, who manages welding and materials engineering at Nuclear AMRC. “By comparison, traditional welding can take days, weeks, or months for one weld.”

The goal is to complete a 10-foot diameter weld in about 90 minutes, which Gandy believes can be achieved. That would reduce total welding time for an SMR by up to 90%. If electron beam welding—coupled with an appropriate heat treatment—can produce components with uniform microstructures and material properties, it might eliminate the need for in-service inspections, which could save millions of dollars over the life of a nuclear power plant.

## NEXT STEPS: BUILDING AND WELDING LARGER COMPONENTS

Over the next two years, researchers will use electron beam welding to join two-thirds-scale reactor components, some fabricated using conventional forging and others with powder metallurgy and hot isostatic pressing.

If successful, EPRI plans to transfer the technologies to other reactor manufacturers. Gandy believes that manufacturers could be able to use powder metallurgy and electron beam welding in about seven years, though the timeline depends on approvals from the U.S. Nuclear Regulatory Commission and ASME.

In a new project, also supported by DOE, researchers plan to use electron beam welding to assemble a full-size reactor pressure vessel. A primary challenge is to overcome the need to construct a 40-foot-plus long vacuum chamber necessary to accommodate the 35-foot-long vessel. This would be cost-prohibitive.

In previous research, a much smaller vacuum chamber has been sufficient to fit the relatively small reactor assemblies. “The chamber is large enough to easily assemble 6-foot-diameter components inside,” said Gandy. “But it’s not large enough for full-scale reactor vessel components, which are about 10 feet in diameter.”

As an alternative to the large vacuum chamber, researchers are testing a new modular approach: As the vessel’s components are stacked and welded together, modular vacuum chamber sections are moved or added to enclose each weld, making the process significantly faster and cheaper.

“Applied together, these new manufacturing and fabrication technologies could be game changers for manufacturing nuclear plant components,” said Gandy.

## KEY EPRI TECHNICAL EXPERTS

Arindam Maitra

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 nearly 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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