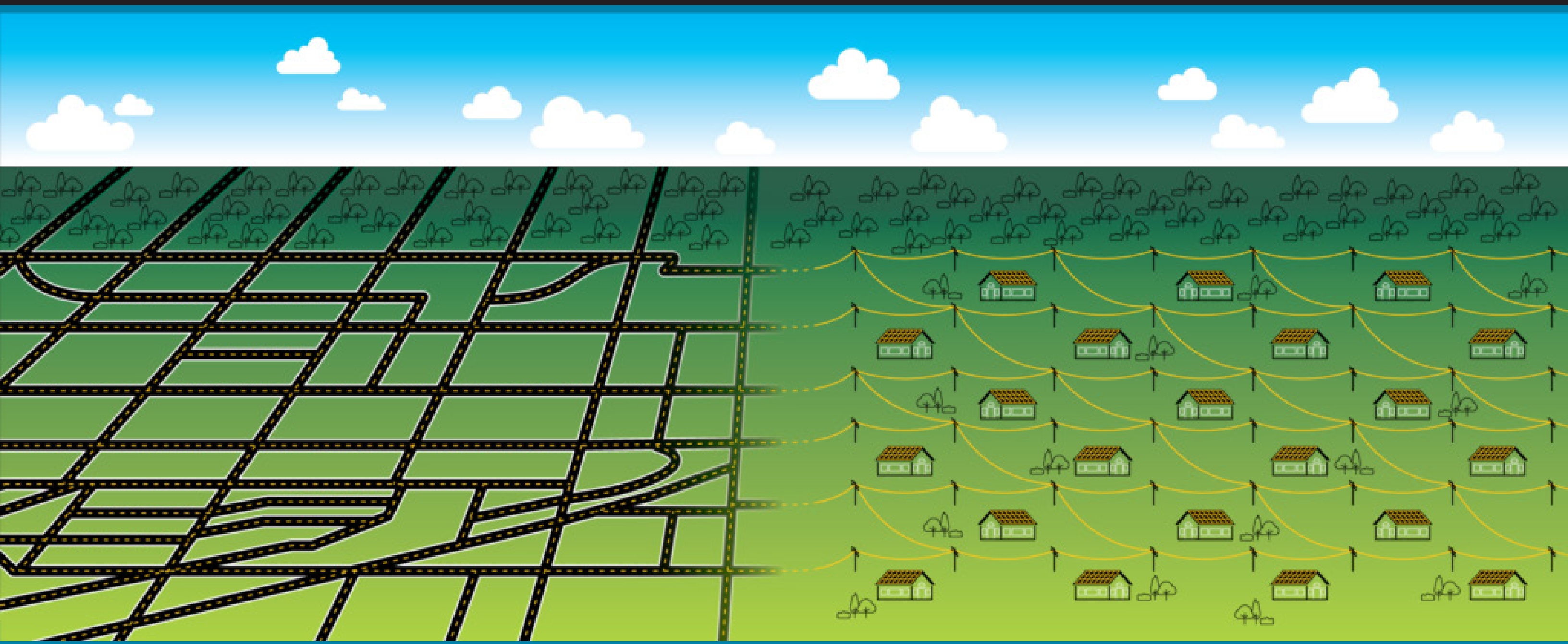
2017 No. 3, July/August

EPRI JOURNAL

ELECTRIC POWER RESEARCH INSTITUTE

UPGRADING THE GRID'S "LOCAL ROADS"



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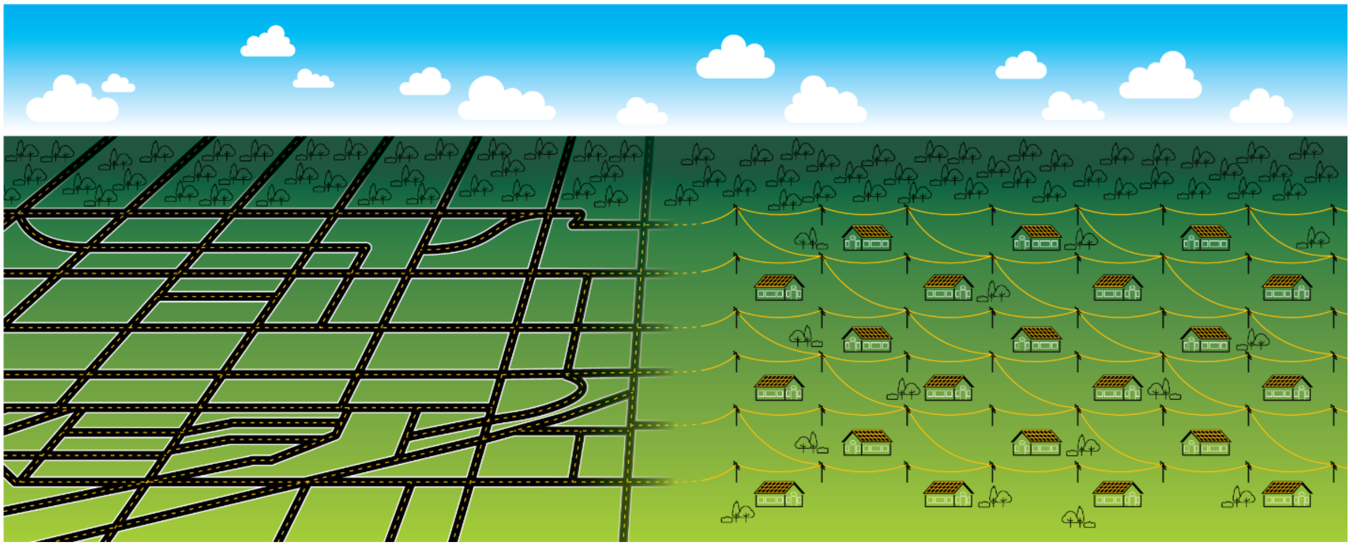


New Program to Help Utilities Spare Their Customers the Effects of Bad Traffic

By Sarah Stankorb

Heather Adams has a complicated job, and it's getting more so. As Director of Electric Distribution and Standards at Central Hudson Gas & Electric Corporation, she is responsible for planning the utility's distribution system. Over the past five years, customers in Central Hudson's service territory increased the system's solar power capacity from 7.3 megawatts to 60 megawatts. The queue for proposed capacity could raise the total to 725 megawatts.

The influx of distributed solar has resulted in voltage fluctuations and two-way energy flows on a system designed for one-way flow, and Central Hudson has installed automation technology equipping the system to respond. It's likely that other technologies will need to be deployed soon to make the system more flexible, resilient, and reliable.

"Deploying technology is the easy part—the challenge is in modifying processes to integrate it into operations," said Adams. "To manage the rapidly evolving system, our processes and methods must adapt so that system models are quickly updated with new information."

Meanwhile, new regulations under New York's Reforming the Energy Vision initiative require Central Hudson and other utilities in the state to step up efforts to integrate distributed energy resources (DER).

Adams' monumental undertaking—coordinating updates in many technologies, processes, and procedures while maintaining grid safety, reliability, and affordability—is shared by distribution utilities across the United States. To help them, EPRI has launched the Distribution Operations and Planning Program to equip today's grids for effectively integrating DER. The focus includes developing advanced automation and other technologies for distribution operations, along with new planning processes, models, and analytics.

Managing More "Traffic" on the Distribution Grid

The grid's high-voltage transmission system is often compared to the U.S. interstate highway system. "Both are highly interconnected and have multiple routes between destinations in case one experiences a traffic jam," explained EPRI Program Manager Jeff Smith. "The distribution system is similar to local roads that lead to individual homes. Both provide a limited number of routes to destinations, and many of these routes have limited throughput or capacity."

As more rooftop solar and other local DER are installed on distribution grids, "traffic" is increasing in many regions.

"Customers are installing significant local generation, but the grid is limited in its capacity to accommodate it," said Smith. "This can stress the grid and potentially impacts the utility's ability to serve customers reliably. It's like trying to squeeze high-speed traffic from a four-lane highway down to a two-lane residential road. The roads can't handle the traffic, making it more difficult for local residents to travel to and from their homes."

With more generation from DER, the distribution grid is becoming a dynamic system in which power flows in both directions.

"Most distribution systems were not designed for this," said Smith. "Similar to how roundabouts can be used to mitigate unnecessary backups at four-way stop-sign intersections, modernizing grid design and operations for two-way power flow can help systems accommodate high levels of DER for reliable, cost-effective service."

In systems such as those in Hawaii with extensive DER, excess energy often flows upstream into the transmission system, with adverse impacts on both distribution and transmission systems. System operators require new techniques and tools to coordinate planning and operations between distribution and transmission.

New grid infrastructure can mitigate such problems and enable more dynamic flows. In some cases, utilities deploy additional feeder ties and reconfigure the grid to increase options for power flow. Smith says this is comparable to "connecting dead-end streets in your neighborhood to provide more options for traffic flow from point A to point B."

Central Hudson is updating its distribution system by reconductoring and deploying bidirectional regulators and switched capacitors. While driven by other system needs, these projects also improve hosting capacity for DER.

Another emerging approach relies on new communications and automation technology to respond to congestion by rerouting energy flows. This could potentially enable power flow from multiple sources, help to serve demand locally, reduce power line losses, and increase the grid's hosting capacity for DER.

"Much like adjustable red lights that change traffic patterns based upon the time of day, distribution grids can be reconfigured with automation to route power flow based on changing local needs," said Smith. "This requires new technology along with advanced distribution planning tools and models to optimize its use."

State regulators are recognizing the need for new technologies, processes, and programs. Besides New York's Reforming the Energy Vision, California requires its investor-owned utilities to submit "distribution resource plans" that describe how they will integrate DER into distribution grid planning, operations, and investment. Utilities in other states may not yet face such mandates but nevertheless must address the growing need to integrate DER for continued reliability.

Technologies, Analytics, and Guidelines to Modernize the Distribution Grid

Funded by more than 30 utilities in 2017, EPRI's Distribution Planning and Operations Program comprises many efforts to integrate DER and modernize the distribution grid.

To support reliability in a dynamic grid, EPRI is developing and testing communication, protection, and control devices; distribution automation; automated restoration; monitoring equipment; advanced distribution management systems; and other technologies. Given the considerable influx of new technology, the program's research results help utilities reduce costs and increase reliability by showing how to use new capabilities effectively.

"We want to inform utilities on infrastructure investment decisions and provide information enabling them to determine how best to deploy these new technologies," said Smith.

EPRI is working on analytical tools that can help grid operators and planners extract insights from the large amounts of data produced by new technologies. For example, advanced metering infrastructure deployed in many distribution systems produces vast data sets that are used for little else than billing. Advanced tools can help utilities translate these data into actionable information to enhance distribution planning models and operators' awareness of system conditions.

"We want to advance the analytics for distribution planners and operators so that they can take full advantage of what's being deployed in the field," said Smith.

Researchers are examining how to integrate volt/VAR optimization and fault location, isolation, and service restoration into the simulation software that grid planners use to model and analyze their distribution systems. EPRI has developed methods and tools to analyze the distribution feeders' hosting capacity and is working with utilities to incorporate these into their planning software.

Generally, utility distribution management systems for modeling and controlling operations are not capable of tracking and controlling the grid impacts of DER, and EPRI has identified the key research needs to advance these systems. "EPRI is prototyping, modeling, and testing enhanced distribution management systems to provide system operators with the tools necessary to overcome the challenges of dynamic distribution systems," said EPRI Senior Technical Executive Brian Deaver.

EPRI moderates a Distribution Operations Interest Group, which provides a forum for distribution control center professionals to meet bi-annually, collaborate, and discuss current and future challenges.

"These challenges impact technologies, processes, and operator training," said Deaver, the group's moderator. "For example, distribution system operators must account for generation from DER in their manual and automated restoration procedures. If a utility restores power from an outage without factoring a region's DER, the unanticipated power demand could damage equipment. This is just one of many operating scenarios that must be defined, understood, and accounted for."

What works on electricity's superhighways—the transmission grid—may prove helpful for meeting these distribution challenges. "Many of the methods and techniques used at the transmission level can be adapted and applied for distribution," said Daniel Brooks, who manages EPRI research on transmission grid operations and planning.

As distribution-connected DER feeds more power into these systems, the challenge of integrating them becomes more relevant to transmission system operators. EPRI is investigating new ways for operators to track distribution-connected DER and developing methods for accurately valuing DER capacity and energy at the bulk transmission level.

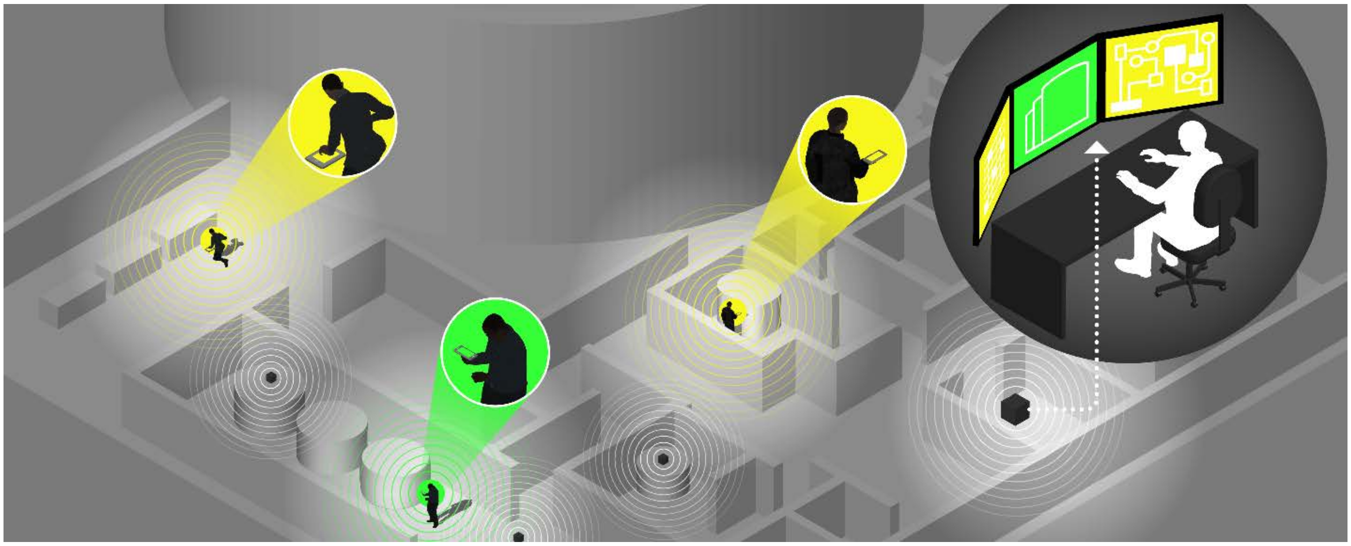
Notwithstanding all the changes and challenges, distribution planners and operators seek to integrate DER while increasing systems' reliability, efficiency, and cost-effectiveness. This requires an integrated suite of solutions. EPRI will develop guidelines to help them incorporate technologies, analytics, and processes into the design of their future distribution systems.

"There is no single 'silver bullet' technology that addresses all of the growing needs of distribution," said Smith. "Our goal with this new program is to help utilities implement a coordinated set of technologies, analytics, tools, and more. This will help realize the full potential of the distribution grid."

Key EPRI Technical Experts

Jeff Smith, Brian Deaver

A Wireless Eye in Nuclear Plants



EPRI Investigates Automated, Real-Time Monitoring with Wireless Sensors

By Brent Barker

Nuclear power plants have achieved high levels of performance, safety, and reliability. With a new EPRI initiative, they now have opportunities to improve their operational efficiency using advanced technologies to automate monitoring, inspection, and other tasks. Many of these technologies have already been deployed in other industries and in coal- and natural-gas-fired power generation.

EPRI's initiative aims to advance these technologies for nuclear plants *without* sacrificing the plants' historic high safety and reliability.

"By identifying opportunities to improve plant instrumentation and monitoring technologies, equipment maintenance strategies can be optimized, making nuclear power competitive in this changing energy environment," said Howard Nudi, manager for nuclear engineering and equipment reliability at Duke Energy.

Distributed Antenna Systems

Historically, nuclear plants have relied on conventional handheld radios for communications and on wired sensors for data. Now, some plants are considering the installation of Wi-Fi networks. However, the plant infrastructure is so complex and the walls so thick that signals don't transmit readily. Even with multiple access points, signal strength degrades rapidly. Plants typically have little to no cellular coverage.

EPRI Senior Technical Leader Nick Camilli is investigating the use of cellular long-term evolution (LTE) networks and distributed antenna systems to amplify and distribute radio frequencies. Such systems can be a cost-effective wireless solution, as demonstrated by their successful application in large hotels, subways, and tunnels.

"Distributed antenna technology brings a flexible wireless platform to support voice communications, equipment monitoring, and other new technologies that the industry is adopting," said Camilli. "It can enable a faster, more efficient work execution process and increase the mobility of maintenance workers using handheld tablets and other digital devices."

Radiating cables can augment distributed antenna systems. These slotted coaxial cables extend up to several hundred feet and operate as a single antenna, enabling signals to propagate along their length. They can be snaked around equipment and into voids and “shadow areas” where traditional wireless signals cannot reach.

“Power plants will likely use a combination of point-source antennas and radiating cables, depending on the coverage requirements and building structures,” said Camilli.

Relative to conventional Wi-Fi, distributed antenna systems can operate at lower frequencies, which propagate more widely and penetrate more extensively. This is key in nuclear power plants, with walls 2–3 feet thick and filled with rebar. “We’re looking at frequencies in the 700–800 megahertz range, well below the 2,400 megahertz of conventional Wi-Fi,” said Camilli. “Our testing has proven that these systems can produce coverage 2–3 times stronger than Wi-Fi.”

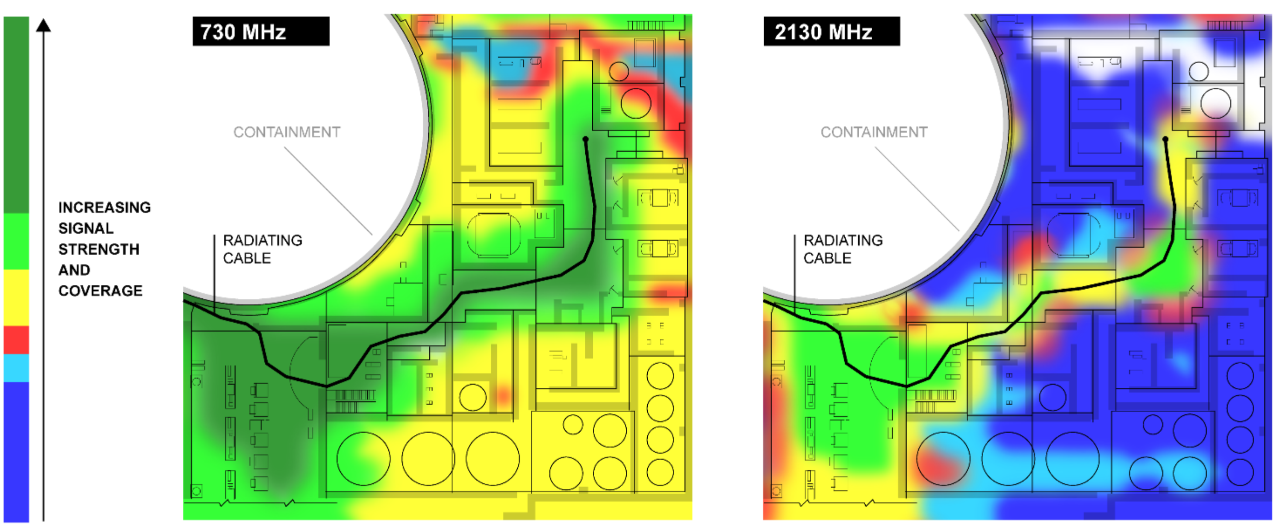
Camilli and his team examined the feasibility of a distributed antenna system at two nuclear plants that are being decommissioned.

“We focused our testing in the auxiliary building and containment,” said Camilli. “Because we were using lower frequencies, we were able to generate more coverage with fewer components. Both pilot demonstrations have proven that distributed antenna systems have the flexibility and reliability to address the needs of nuclear facilities with different plant designs and configurations.”

DISTRIBUTED ANTENNA SYSTEMS:

BETTER WIRELESS COVERAGE WITH LOWER FREQUENCY

EPRI’s evaluation of a distributed antenna system at the Crystal River nuclear plant revealed that lower frequency wireless signals penetrate power plant structures significantly better than higher frequency signals. This graphic compares signal coverage at 730 megahertz (left) with coverage at 2130 megahertz (right). The radiating cable propagates the signal. Yellow and green areas have higher signal strength while red and blue areas have weaker strength. Distributed antenna systems have the potential to support automated equipment monitoring, voice communications, and other advanced digital technologies that the nuclear industry is adopting.



Monitoring and Automation

Using a communications backbone of distributed antenna systems, many formerly manual and periodic inspections could now be done continuously with wireless sensors feeding data to an automated monitoring system. The software is programmed to detect abnormalities and performance deviations and signal the need for intervention and maintenance.

"You could still get the high reliability that nuclear plant operators have come to expect, but do so with less labor in the field," said EPRI Senior Program Manager Rob Austin.

For example, each month technicians measure vibration in turbines and other rotating equipment and schedule maintenance if readings are too high.

"Alternatively, you could install a wireless vibration sensor on the equipment and measure it 24/7, giving you an early warning of an imminent problem," said Austin. "You may not save on the maintenance itself, but you would on the personnel time required to take the measurement. Multiply that by the number of components being manually inspected, and you can save significant time and labor."

In 2016, Austin and utility technical advisors developed a five-part plan to help accelerate the adoption of automated, wireless performance monitoring:

1. Develop a strong, quantifiable business case.
2. Create a step-by-step implementation guide for utilities.
3. Assess commercially available wireless sensors, and provide guidance on the most effective locations.
4. Assess commercially available statistical analysis tools for integrating equipment performance data from wireless sensors and guiding maintenance priorities.
5. Maintain cyber security.

At Catawba Nuclear Station, Duke Energy is installing this wireless sensor technology and is consolidating the data in Charlotte, North Carolina. The utility will use the technology to closely monitor equipment performance and health, while reducing the frequency of maintenance and inspection tasks. Based on these tests, it will assess plant reliability and apply lessons across its 11-unit nuclear fleet.

"As we gain confidence with non-safety-related components, we will be able to extend automated monitoring to more critical components," said Austin. "The U.S. Nuclear Regulatory Commission recommends that plants use risk-informed in-service inspection as much as possible to prioritize maintenance activities, and real-time monitoring can help with that."

Advanced Tools for Maintenance Workers

In addition to deploying wireless sensors and automated monitoring, nuclear plants can reduce labor costs and optimize maintenance with effective digital tools and resources for workers.

With 3-D graphics technology, EPRI is developing interactive applications that can be loaded on a laptop as well as interactive PDFs with embedded videos and animations. These can help workers complete maintenance and inspection tasks more efficiently and effectively, improving plant safety and reliability.

"If I can see a picture of all the parts of a component, understand how they are put together, and listen to a seasoned expert explaining how the component works, I can learn much faster and more thoroughly than I can by reading a five-part description in a report," said EPRI Senior Program Manager Jim Heishman.

An EPRI app for the Terry Turbine enables the user to view the component from every angle, along with its internal and external features. With EPRI's app for the medium-voltage K-Line circuit breaker, users can disassemble and reassemble the component in the proper sequence. "This circuit breaker is a marvel of mechanical engineering, with 1,500 parts," said Heishman. "For training purposes, a virtual reality model helps workers to understand the operation and maintenance tasks more clearly."

A third example is the air-operated valve. "We selected this valve for app development because a few years ago the industry faced a significant problem with an air-operated regulating valve in plant feedwater systems that was causing plants to reduce power or trip offline," said Heishman. "The app explains how the valve works and how to maintain it, and it provides troubleshooting and diagnostics to identify causes of degradation."

Key EPRI Technical Experts

Rob Austin, Nick Camilli, Jim Heishman

Wired In—Working with the Press to Get the Story Right

By Eric Freedman, Director, Knight Center for Environmental Journalism, Michigan State University


Eric Freedman

It can be challenging to clearly communicate electric power industry issues to the public because many media professionals are unfamiliar with industry concepts, regulations, and technology. Yet, clear communication by utilities and regulators is essential for informing customers who may have concerns about reliability, safety, and cost. It can also inform public agencies and elected officials, who are engaged in critical decision-making and policymaking that directly affect the economy, the environment, national security, and stock prices.

Journalists also have a professional responsibility to understand the technical aspects of the issues and to provide the public with fair, accurate reporting, even under the pressure of deadlines and shrunken newsrooms.

While there are experienced energy reporters, especially those at trade publications, most journalists cover utility stories only occasionally and may lack the time to cultivate industry expertise and respectful relationships with industry communications professionals. Nevertheless, journalists should ask utilities and regulators as many questions as needed to understand the concepts, technical terms, and issues in their stories.

Before the shale gas boom, Consumers Energy proposed to regulators a plan to build a new $1 billion-plus coal-fired unit at an existing power plant, and the proposal came under heavy fire from anti-coal activists who demanded solar, wind, and energy conservation. A local reporter assigned to cover the controversy spoke frequently with the utility's communications officer and became familiar with all aspects of the proposal, including projections for customer demand and jobs creation. That process produced what the utility felt was balanced coverage on an issue important to the community.

As Jeffrey Holyfield, former executive director of communications at Consumers Energy, told me, “If you don’t translate the technical and economic data and make them simple for the reporters, they have to do it themselves or go to someone on the other side—and you may not like it.”

Rather than simply providing journalists with press releases and dense documents, utility communicators can put industry jargon into plain English and explain in easy-to-understand terms how customers may be impacted by rate requests, regulatory changes, power plant construction and decommissioning proposals, new legislation, and court orders. Avoid acronyms and terms that make sense to everyone in the business but not to the general public.

What’s a State Reliability Mechanism (SRM)? Or financial securitization? Or a power purchase agreement (PPA)? Or avoided cost? Will the confused, on-deadline journalist parrot the jargon, explain it incorrectly, or even omit an important point from the story? Instead of assuming that a reporter understands the concept of “stranded costs,” a utility media professional might explain it as a utility’s infrastructure investments that may become unnecessary if market or regulatory conditions change substantially.

The press frequently reports on regulatory decisions about rate increases. Rather than announcing only gross figures—a $122 million rate hike, for example—utilities and regulators should explain how those changes affect the average residential ratepayer’s bills. Will they go up or down, and by how much each month? The reasons for the rate changes should be clear and explicit as well.

Utility and regulatory communicators also need to pay closer attention to journalists’ well-intentioned efforts to ensure balanced coverage. These include interviewing sources on opposing sides along with experts unaffiliated with either side—and providing all perspectives with approximately equal space or air time. In some cases, reporters may give too much credence to positions that are unsubstantiated by data, reports, and other evidence. Utilities should provide the media with well-documented evidence to support their positions and buttress their credibility. This could take the form of reports with highlighted key passages, jargon-free executive summaries, or bullet points.

Utility communicators can point reporters to a lack of evidence supporting the other side’s arguments—and even suggest that reporters ask the other side for evidence.

Reporters can enhance the credibility of their stories by interviewing independent experts, such as those at research organizations and university professors who study the industry, energy economics, environmental policy, and related topics. Their views and analysis can add perspective to the news coverage.

In an era of 24/7 news, utilities should be prepared to respond to press inquiries as quickly as possible. In other words, make it easy for journalists to get the story right.

Getting the story right not only provides the public with a clear picture of utility operations, rates, and regulatory processes. It can also help build public confidence in the electric power industry.

The City of Tomorrow: Smart, Electric

Mike Howard, President and Chief Executive Officer, EPRI

Across the globe, electric utilities are rapidly becoming "digital utilities." They are deploying advanced communciations networks along with millions of smart meters at homes and businesses and sensors at power plants, transmission, and distribution grids. Supported by advanced data analytics techniques, these investments are enabling sophisticated monitoring and control of energy networks and distributed energy resources, improving service for customers.

The New York Power Authority (NYPA) is rethinking the use of data in the energy industry, deploying sensors, software, and data analytics to monitor and optimize real-time performance of its *entire* network of power plants and grids. Similar efforts are underway at other utilities.

Digital utilities are uniquely positioned to support smart city initiatives, which rely on digital technologies to optimize urban services such as gas, water, electricity, transportation, lighting, and heating. Cities and communities can leverage electric utility investments in meters and secure communications networks to operate these other services. Rather than reinvent the wheel for each service, the infrastructure can be set up once and used by many, with significant potential cost savings.

I'll return to NYPA as an example. At thousands of buildings in New York, the utility has deployed its "New York Energy Manager," a digital dashboard that collects energy data from various metered systems, analyzes it, and shows building managers how to reduce consumption. This infrastructure also examines the buildings' water and natural gas systems.

We are headed for a global urban population of 10 billion at the end of this century. According to the United Nations, 66% of the world's population will be urban by 2050—up from 30% in 1950. Our cities must get unimaginably efficient, even as they grow unimaginably large. Integration of urban systems can only be realized with growing engagement and coordination among utilities, cities, regulators, and other stakeholders. We need vigorous discussion of the big picture.

Earlier in 2017 EPRI introduced the Integrated Energy Network concept to direct thinking about integrating today's fragmented electric, natural gas, and water systems and their diverse business models, markets, and regulations. The Integrated Energy Network provides a pathway to the unprecedented reliability, efficiency, and service urban populations will need. If we are to survive and thrive, humanity will have to make every aspect of energy use sustainable.

Electricity is key to this vision. Closely linked to the Integrated Energy Network, EPRI's new Efficient Electrification initiative includes a national electrification assessment for the United States, followed by regional assessments, accelerated R&D and other R&D projects.

We already know the environmental advantages of converting natural gas to electrons in power plants, then delivering the electric "fuel" to vehicles. Relative to internal combustion engines, this approach can be more than twice as energy efficient, save 70% in fuel costs, and reduce CO_2 emissions by 75%. Advanced heat pumps can *move* heat more efficiently than traditional electric and fossil heating technologies can *produce* it. And here's a twist on the city of tomorrow: It may well include farms. EPRI is evaluating "indoor agriculture" that harnesses electric power to produce fresh food locally, significantly reducing pesticide application and water consumption.

We see similar thinking elsewhere. Europe's newly formed Electrification Alliance is calling for electricity to be recognized as the key energy carrier for an efficient and decarbonized Europe. It issued a declaration calling for policies to remove barriers to electrification, to roll-out the much needed widespread electric vehicle charging infrastructure, and to enable the deployment of smart and efficient heating and cooling technologies.

A final thought on smart cities: Much innovation and attention are directed to smart technologies—everything from servers, sensors, and apps to global communication networks and appliances. I can tell you firsthand that this is certainly true also for electricity sector R&D. Advances in information and communication technologies are not only unleashing huge gains in performance and reliability for the sector. They are also establishing a foundation of infrastructure for smart cities to evolve more quickly, safely, and effectively. Smart cities and smart utilities go hand-in-hand.

Mike Howard

President and Chief Executive Officer, EPRI

Shaping the Future

Powering a Cleaner Energy Future—For Customers and Society

Efficient Electrification Empowers Customers to Reduce Emissions, Lower Costs, and Improve Performance

By Chris Warren

Customers are at the heart of EPRI's Integrated Energy Network, demanding affordable, clean energy, and choice. With global population expected to increase by more than 50% by 2100—mostly in urban centers—new technologies, policies, and business models are essential to meeting customers' energy and environmental needs. Efficient electrification is poised to play an important role, facilitated by rapid advances in electric vehicles and other electric technologies, clear technical pathways to cleaner electricity generation, plummeting costs of renewables, and ubiquitous digitalization.

"Electric technologies can provide a wide array of benefits," said Rob Chapman, vice president of EPRI's Energy and Environment Sector. "They can improve end-to-end energy efficiency, providing more value for less fuel. For residential and commercial customers, they can lower costs and increase comfort and control. For industry, they can often improve productivity and create a safer, more appealing workplace. And for society and the environment, they can enable significant reductions in CO_2 and other air emissions and reduce water use."

Broad adoption of efficient electrification technologies faces significant challenges, including legislative and regulatory disincentives and consumers' lack of familiarity with electric technologies. A broader, more concerted research effort is needed to help make the next generation of electric technologies cost-effective in the near term.

As a first step, EPRI is conducting an Efficient Electrification National Assessment in 2017 to improve understanding of the costs, benefits, drivers, and impediments to electrification in the United States, with a report expected in early 2018.

"In addition to this national perspective, we are planning local and regional studies with utility companies and other stakeholders to gain a more detailed understanding of regional nuances and associated electric technologies that can provide near-term economic value," said Chapman.

EPRI recommends that research and development immediately focus and accelerate work in the following areas to support efficient electrification and the use of cleaner energy:

- **Explore policies and technical options to achieve cost-effective efficiency gains**. Traditional energy efficiency efforts, which focus on improving the efficiency of equipment such as heat pumps or lighting, remain essential and should accelerate. Expand efficiency R&D to include options that can reduce energy use by switching fuels or improving processes. For example, airlines improved efficiency in recent decades by flying more fuel-efficient planes. They made more dramatic efficiency improvements by creating pricing structures to fill seats.
- **Evaluate energy and environmental policies to encourage electrification**. Many existing rules penalize utilities for increasing carbon emissions by electrifying vehicle fleets, even though there is a net decrease in emissions overall as a result of reduced gasoline consumption. Policymakers and regulators can seek new cross-sector approaches to achieve their goals and create incentives necessary to spur investment in infrastructure such as electric vehicle charging.

- **Develop and demonstrate advanced, clean energy end-use technologies**. Sustained R&D is vital to develop more technologies that are powered by clean energy and that reduce emissions, water use, and other adverse environmental impacts. These include electric technologies and other advanced clean technologies such as hydrogen fuel cells.

The Three Pillars of the Integrated Energy Network

The Integrated Energy Network provides EPRI's perspective on the future of energy. Research needs are identified for each of three supporting pillars:

- **Using affordable, cleaner energy through efficiency and electrification**: focuses on the opportunities and challenges—both technical and institutional—involved with scaling the use of cleaner energy sources.
- **Producing cleaner energy**: details the potential of cleaner electric generation technologies—renewable energy, nuclear power, and fossil-fueled generation with carbon capture—along with promising non-electric technologies.
- **Integrating energy resources**: examines how new technologies and markets must be tapped to better integrate the electricity, gas, water, and transportation systems.

EPRI invites you to share your ideas and approaches for addressing each of the three pillars.

Technology At Work

EPRI Helps Utilities Track Down Elusive Legacy of PCBs in Transformers

By Brent Barker

Sitting atop poles or mounted on pads, distribution transformers play a critical role in the electric distribution system. They reduce electricity voltage for customer use, relying on internal fluid to help protect the equipment. These sturdy workhorses of the power distribution network can remain in service for well over half a century.

The protective fluid in most distribution transformers for homes and businesses is mineral oil. However, between the 1930s and 1970s, transformers were sometimes manufactured with Askarel (a group of synthetic fire-resistant chemicals used in electrical insulating fluids), which may contain 45–100% polychlorinated biphenyls (PCBs). This Askarel equipment was of particular value where fire was a significant concern, though many utilities did not purchase these units.

PCBs were found to have potential adverse health and environmental risks, and in 1976 Congress passed the Toxic Substances Control Act, which banned the manufacture, use, processing, and commercial distribution of PCBs in any manner other than a "totally enclosed" application—unless authorized by the U.S. Environmental Protection Agency (EPA). Though production of PCBs ceased in the United States nearly 40 years ago, the use of PCBs is still authorized in transformers and other electrical equipment as long as it does not present unreasonable health or environmental risks.

As a result, PCBs are still found at permitted levels in a small and decreasing number of in-service transformers. In addition, some mineral oil–filled distribution transformers contain lower levels of PCBs as the result of servicing with PCB-containing fluids.

Building a Database

Though the use of these transformers is authorized under EPA's PCB regulations, many utilities have developed voluntary programs to identify and remove PCB-containing transformers from service before the end of their useful life. While these programs can be labor- and resource-intensive, these utilities are pushing forward. Identifying PCB-containing transformers can be challenging because the process of sampling fluids sometimes damages units or involves service outages.

EPRI addressed this challenge by compiling and analyzing historical data related to PCB-containing transformers. Since 2012, EPRI has gathered data on 345,000 transformers—including type of unit, manufacturer name, manufacturing location and date, and PCB concentration. The goal is to use this information to help identify the production facilities and dates associated with the greatest likelihood of PCB contamination.

"If the database is big enough, you can look for patterns—for example, in a given transformer production year at a given manufacturing site—to see if there was a higher incidence of PCB contamination in sampled, out-of-service units," said EPRI Principal Technical Leader John Acklen. "This can help you assess the likelihood of PCB contamination in a given in-service unit. The data can inform utilities' efforts as they prioritize and focus their removal efforts on those pieces of equipment most likely to contain PCBs, particularly those located in areas such as schools or public facilities."

EPRI first published the database in a collection of tables that sorted transformers by manufacturer, production date, plant location, and PCB levels based on sampling of out-of-service units. To facilitate data analysis, EPRI built and beta-tested software in 2015, and a final version was completed in December 2016. While the database cannot definitively predict PCB content, it can help inform utilities as they define and implement their voluntary phase-out programs.

"It's already proving useful as a decision-making tool, helping a few utilities zero in on units in service with a higher likelihood of PCB contamination," said Acklen. "But the database is not comprehensive and should not be considered a panacea. We look forward to expanding the data set as new information becomes available to us."

Technology Transfer Awards

Individuals at PECO and ComEd received a 2015 EPRI Technology Transfer Award for applying EPRI's database methodology to identify transformers with the potential for PCB contamination. They used their own databases along with EPRI data on transformer contamination levels to screen in-service transformers.

"We are using the results of the analysis to inspect, dispose of, and replace PCB-containing equipment. We hope to use the database and methodology continuously as part of our voluntary, proactive phase-out effort," said Lorinda Alms, senior compliance specialist at ComEd and one of the awardees. The other awardees were Keith Kowalski, PECO's manager of environmental programs and services, and David Mobraaten, PECO's senior environmental compliance specialist.

Key EPRI Technical Experts

John Acklen, Jim Lingle, Naomi Goodman

In Development

Conserve, Recover, Replace

EPRI Investigates How to Address a Vulnerable Lithium-7 Supply

By Sarah Stankorb

In 2014, a mechanical malfunction at a Chinese production plant led to a global shortage of lithium-7, the non-radioactive isotope used in western pressurized water nuclear reactors (PWRs) to control the pH of coolant water and minimize corrosion of fuel and materials. During the shortage, some nuclear plants with long-term contracts obtained lithium-7, while others received only partial orders.

"Eventually, many operators around the world were told that there was no more supply," said EPRI Senior Program Manager Lisa Edwards. "While no plants ran out of lithium-7, some were close."

Lithium-7 is produced only in China and Russia, making it vulnerable to shortages. Indeed, before the 2014 shortage, the U.S. Government Accountability Office pointed to the risks of the U.S. nuclear industry relying on just two suppliers.

The potential implications of a shortage are significant. Coolant water with a pH that's too high or too low can lead to cracking of the reactor pressure vessel, nuclear fuel cladding failures, and higher radiation dose rates for workers. If a plant were to run out of lithium-7, it would have to use an alternative chemical. This would not happen because no alternatives have been qualified for use in western PWRs. In a technical investigation, EPRI found that the other naturally abundant isotope (lithium-6) cannot be used because it would generate unacceptable levels of tritium, a radioactive isotope of hydrogen.

"Lithium-7 is currently the only chemical qualified to control pH in the United States and many other countries," said Edwards. "Qualifying any other chemical would require significant technical information for a safety evaluation to demonstrate that the change is low-risk. I don't think that any plant would operate without pH control."

Prompted by these supply challenges, EPRI has prioritized a three-pronged approach to mitigate potential lithium-7 shortages:

1. Use the existing lithium-7 supply more efficiently, while maintaining adequate inventories.
2. Recover and reuse lithium-7 from plant operations.
3. Find and qualify a replacement chemical.

The U.S. Department of Energy's Office of Nuclear Energy is a key partner, providing $500,000 to support these efforts.

It could potentially take many years to demonstrate and qualify a different chemical. "A replacement might be the best long-term solution, but if a shortage occurs in the near term, plant operators will need a more immediate solution," said Edwards. "That's why we're also looking at conservation and recovery options."

Conservation

EPRI researchers analyzed the lithium-7 practices among EPRI-member utilities and found that the amount used in PWR fuel cycles varies widely. Drawing from industry experiences and best practices, EPRI published a report to help plants minimize the amount used. This analysis confirmed that the savings are likely small, and another solution is required.

Recovery

Lithium-7 is generated in PWRs through a nuclear reaction in the reactor core. EPRI is evaluating processes to recover this lithium-7 from waste resin, which also contains radioactive metals such as nickel, iron, and cobalt, and is typically disposed of as low-level radioactive waste.

EPRI lab-tested two chemicals that can potentially be used to separate lithium-7 from the resin—sulfuric acid and ammonium bicarbonate—and both recovered more than 90% of the lithium-7. EPRI is evaluating which process is more effective, with published results expected later in 2017.

“It is currently cheaper to buy new lithium-7 than to recover it,” said EPRI Principal Technical Leader Dennis Hussey. “But if supplies again become limited, recovery could become cost-effective.”

Replacement

While lithium-7 is the only chemical qualified for adjusting pH in western PWRs, VVER reactors typically use potassium hydroxide, and EPRI is investigating the feasibility of switching western PWRs to this chemical. In 2015, researchers evaluated the use of these chemicals in VVERs and PWRs and identified technical gaps that need to be addressed to enable such a switch.

Relative to VVERs, PWRs have different plant materials and a higher fuel duty, resulting in more deposits of corrosion products on fuel surfaces. The composition of these deposits and their impacts on fuel cladding need to be evaluated. Another area of investigation is the extent to which potassium hydroxide will impact the release of nickel from steam generator tubes in PWRs and form an isotope that causes radiation fields. Steam generator tubes in VVERs and western PWRs are made of different materials.

Adding an alternative chemical would necessitate that plant operators manage more chemicals. “Even though plant chemists will add potassium hydroxide for pH control, lithium-7 generated during the fuel cycle will also be present,” said EPRI Senior Technical Executive Keith Fruzzetti. “To maintain pH in the proper range, chemists will have to control both the potassium and lithium concentrations.”

If operators were to switch to potassium hydroxide, they could use the same injection systems currently used with lithium-7. Potassium hydroxide is abundant and less costly than lithium-7. EPRI estimates that the switch could save each reactor approximately $100,000 per year.

Use of potassium hydroxide may provide other benefits beyond cost savings and independence from a vulnerable lithium-7 supply. Preliminary analysis indicates that potassium hydroxide can reduce the susceptibility of fuel to crud-induced power shifts, which can potentially lead a plant to reduce its power rating and incur a significant financial loss. EPRI will also evaluate whether potassium hydroxide could help to reduce irradiation-assisted stress corrosion cracking in plant components.

For the next phase of qualification, EPRI in 2020 will begin a demonstration of potassium hydroxide in a western PWR. It has formed an advisory committee of U.S. utilities and international VVER operators to gather technical input for the tests and analyses during qualification.

Fortunately, no plants in the United States have run out of lithium-7 for pH control. “But contemplating how a plant would respond to a shortage makes people uncomfortable enough to know that this is a vulnerability we need to address,” said Edwards.

Key EPRI Technical Experts

Lisa Edwards, Keith Fruzzetti, Daniel Wells, Dennis Hussey, Joel McElrath

Innovation

Accident-Tolerant Fuels: A Global Collaboration

EPRI, DOE, Vendors, Utilities, and Other Stakeholders Advance Several Concepts

By Brent Barker

"Imagine Fukushima without zirconium." That was the thought experiment EPRI Nuclear Sector Vice President Neil Wilmshurst handed his staff and the nuclear industry in 2012. Zirconium-alloy cladding for fuel rods has been the industry standard for nearly 50 years. With proven performance, it has been the ideal material under normal operating conditions but does not hold up under severe accident conditions. At temperatures approaching 700°C, the cladding loses its physical integrity, begins to buckle, and rapidly oxidizes in the presence of water or steam, generating heat and releasing flammable hydrogen.

Shortly after the Fukushima accident, the U.S. Department of Energy (DOE) and materials research institutions around the world turned their attention to accident-tolerant nuclear fuels. Some concepts can potentially maintain structural integrity at 1200–1500°C for up to several hours, while also eliminating or reducing hydrogen generation from cladding oxidation. This increases the safety margin and "coping time" for operators to restore cooling. Other potential benefits include enhanced performance under normal operating conditions, increased power levels (power uprates), and extended plant life.

To pursue alternatives for accident-tolerant fuels, DOE is funding separate teams headed by three major vendors—GE, Westinghouse, and AREVA.

"Congressional authorization for funding came with a hard deadline," said EPRI Principal Technical Leader Andrew Sowder. "At least one concept has to be loaded into a commercial reactor by 2022 as a lead test rod or assembly."

One concept being pursued in the United States and internationally involves applying coatings to protect the zirconium-alloy cladding from oxidation. Because of their similarity to existing rods, such fuels could potentially be loaded into reactors in the near future. Ceramic claddings made of silicon carbide represent a significant departure from metallic claddings but offer potentially substantial improvements in high-temperature performance with minimal neutron absorption penalties. In contrast, cladding with advanced steels such as iron-chromium-aluminum alloys offers resistance to oxidation and modest improvements in temperature ranges—but with significant neutron absorption penalties. EPRI has developed and is testing a thin-walled coated molybdenum cladding, which maintains its strength at very high temperatures.

It will take time to move these fuel concepts from testing to commercial availability. "Developing accident-tolerant fuels is a complicated, expensive, high-risk proposition. It requires years of testing alternative materials and designs," said Sowder. "No company or country can do it alone. It demands collaboration on a global scale. We are trying to bring together all the global stakeholders: DOE, developers, vendors, utilities, and regulators."

The Organisation for Economic Co-operation and Development's Nuclear Energy Agency in Paris, a global center for nuclear collaboration, has established the Expert Group on Accident-Tolerant Fuels to provide information and coordinate research. The International Atomic Energy Agency has also set up a program to coordinate research.

"Interest among U.S. utilities has increased markedly in the last year as they begin to see the long-term value and benefit," said Sowder.

The Nuclear Energy Institute, a U.S.-based industry group, has recently set up a working group, with EPRI serving as the technical collaboration hub. "We have global reach, and collaboration is part of our mission," said Sowder.

Key EPRI Technical Experts

Andrew Sowder

Innovation

Securing the Grid's Edge

EPRI to Develop Secure 'Architectures' for Distributed Energy Resources

By Scott Sowers

If a private firm installs an Internet-enabled solar array on a homeowner's roof and it gets hacked, who would be responsible for addressing the breach? Could the hackers impact grid operations?

"Today, various companies install large numbers of solar arrays, lease them back to the property owners, and manage them through Internet-based communications," said Galen Rasche, EPRI senior program manager for cyber security. "If any of these companies have security problems, they can impact distribution grid operations."

For an integrated grid, this emerging cyber security concern emphasizes the importance of securing distributed energy resources (DER) and consumer equipment, including rooftop solar.

"Security is important throughout the grid, but with DER, it can be easily overlooked because there are many parties involved—utilities, customers, makers of home energy management devices, solar installers, and companies that use cloud-based software to monitor grid-edge devices, such as rooftop solar arrays," said EPRI Senior Technical Leader Candace Suh-Lee. "This introduces more risk."

Developing Secure Architectures, Informing Stakeholders

EPRI is launching a project in 2017 to examine cyber security for grid integration of DER and to develop more secure communications architectures for protecting the grid and customer privacy.

EPRI will identify DER-related security objectives, risks, and possible roles and responsibilities of the various parties involved. Preliminary findings reveal uncertainty both in determining responsibility and in the lack of common architecture guidelines and roadmaps.

"The results of this research will help regulators, the public, and other stakeholders better understand the challenges and determine the appropriate mix of standards, technology, and policy to address them."

"Today we have a multi-party grid," said Rasche. "Utilities can't be the only parties responsible for security because they're not able to monitor and control everything. All the parties have to do their part."

In EPRI's Knoxville laboratory, researchers will bench-test DER system components with security assessment tools, such as vulnerability scanners, protocol analyzers, and penetration testing software.

They will evaluate how devices react to common attacks, such as "replay attacks," in which a hacker captures a legitimate message and sends it to a device in different time and context. Another common hacking technique is called "fuzzing."

"Hackers try to 'fuzz' a device when they send malformed messages to it to see how it reacts," said Rasche.

Researchers will assess utilities' DER architectures, devices, and components and evaluate their security solutions.

"We'll check systems and devices in the field for vulnerabilities and assess DER communications to see if they are properly protected, or assess the extent to which someone could compromise the security of the data," said Suh-Lee.

EPRI is researching ways to help utilities monitor the cyber security status of grid-edge devices and networks.

"Utilities will want to monitor data traffic on the grid's communications infrastructure to determine whether systems are behaving as expected," said Rasche. "They may find that some data was supposed to be protected, but was not. Or they may find that some traffic patterns are not normal—a sign that something might be configured incorrectly or that a cyber attack may have occurred."

"If security gaps can be addressed with existing technologies, we will include those in the architectures we are developing," said Suh-Lee. "If not, identifying the gaps will help us to direct future research or to make recommendations to standards bodies."

"The results of this research will help regulators, the public, and other stakeholders better understand the challenges and determine the appropriate mix of standards, technology, and policy to address them," said Suh-Lee.

Key EPRI Technical Experts

Candace Suh-Lee, Galen Rasche

In The Field

A Heating and Cooling Game Changer?

EPRI Tests 'Next-Gen' Heat Pump with a Potential Application in up to 90% of American Homes

By Sarah Stankorb

Insights from EPRI lab and field tests on advanced heat pumps are helping to speed adoption of this promising technology, with potential for significant energy savings for consumers and grid flexibility for utilities.

Using electricity to move heat from one area to another, heat pumps can heat cold rooms or cool hot rooms. They are far more efficient than heating systems that burn fossil fuels. Yet they have historically had limited heating ability and lower efficiency in regions with very cold winters, and the majority are deployed in the Southeast. According to the U.S. Energy Information Administration, in 2015 they were used in just 10% of American homes.

To help encourage mass adoption, EPRI has outlined technically achievable performance attributes for a next-generation heat pump that include better efficiency, higher heating capacity in cold climates, variable operation for demand response, remote control, and grid connectivity. A key component is the variable-speed compressor, which operates more efficiently and can provide up to 50% more heating capacity than a similarly sized traditional system with a single-speed compressor. This makes the "next-gen" version potentially applicable to 90% of the U.S. population.

"That's the fundamental change," said EPRI Program Manager Ron Domitrovic. "Systems now are able to provide enough heat for heating in cold climates."

"In northern geographies and especially in rural communities, variable-speed heat pump technology is becoming very much a part of the conversation," said Jeff Tyminski, portfolio leader for heat pumps at Ingersoll Rand (which owns Trane, a company that manufactures heating, ventilation, and air conditioning systems).

Based on insights from prototype development and testing, EPRI has offered guidance to heat pump manufacturers such as Trane, Carrier, Daikin, and Mitsubishi. "We've built prototypes to show manufacturers what's possible with a next-gen heat pump," said Domitrovic.

Insights from Lab and Field Tests

In recent years, some manufacturers have commercialized systems that meet EPRI's next-gen attributes and that include other new features. Many are equipped with internal diagnostics, which can be used for system maintenance. Trane's next-gen heat pump is integrated into a home automation system with zoned heating and air conditioning.

Because these systems are relatively new, EPRI is evaluating their operations and performance to better inform consumers, manufacturers, and installers about the potential benefits of heat pumps. One area of investigation is their ability to enhance efficiency by eliminating the use of backup electric resistance heat. On cold days when single-speed heat pumps cannot meet building heating demand, they engage these backup systems, which can increase a utility's peak load. EPRI field tests in Ocala, Florida demonstrated that next-gen heat pumps can eliminate this peak by providing sufficient heat capacity without engaging backup systems.

In the laboratory, researchers compared the performance of several next-gen and single-speed heat pumps during demand response events. The single-speed devices turn off for part of the events, while the next-gen devices throttle power draw primarily by reducing the compressor's speed. EPRI found that this throttling strategy was 10–30% more efficient than the on-off cycling, potentially making the next-gen version more cost-effective for consumers and utilities. In 2017, EPRI plans to conduct similar tests in the field. Strong performance could inform utilities and other stakeholders in their decisions to encourage deployment of next-gen units through energy efficiency programs.

Over the next few years, EPRI will continue to test next-gen heat pump technology from multiple manufacturers, examining topics such as:

- Ability to provide comfort to consumers across geographical regions
- Carbon emissions reductions enabled by displacing fossil-fuel-powered heating systems
- Remote feedback on system status to support maintenance

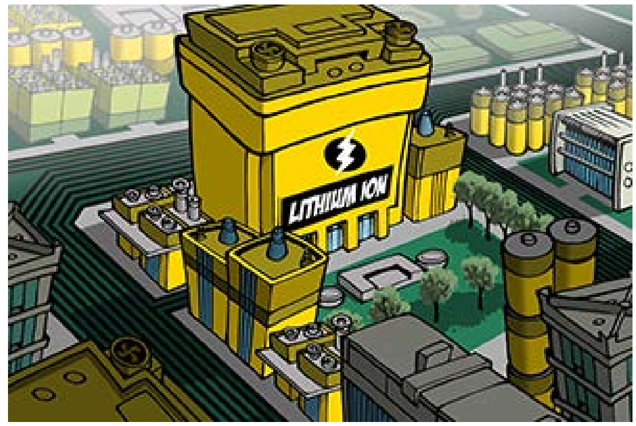
Key EPRI Technical Experts

Ron Domitrovic

R&D Quick Hits

A Battery Tipping Point?

Momentum Builds Behind Lithium Ion Battery Technology



Propelled by rapidly falling costs, lithium ion battery technology is likely to dominate the grid-scale energy storage market for at least the next five years, concludes an EPRI report.

Although conventional wisdom holds that lithium ion technology is not ideal for many large-scale grid applications, it has a significant head start over competing technologies with respect to grid deployment. Lithium ion costs have fallen dramatically in recent years, driven by investments in the consumer electronics and electric vehicle industries. Manufacturers of lithium ion batteries tend to be large companies with strong balance sheets and credibility for warranties and post-deployment support. Other technologies are more expensive, less mature, and are often developed and produced by startup companies that may have more constrained access to capital.

These factors "will mean that even those technologies and products with theoretically superior performance to lithium ion may lose out in the near term," the report says. Indeed, several large-scale, lithium ion grid projects are being deployed in Hawaii, Southern California, and the United Kingdom.

In the long term, other technologies may be able to outcompete lithium ion in certain grid applications such as long-duration storage greater than 6–8 hours.

The authors add that many challenges still need to be addressed before widespread grid deployment of lithium ion systems. These include making components more reliable, developing an industry-wide recycling program, and resolving fire suppression requirements.

R&D Quick Hits

A New Earthquake Preparedness Kit

Advanced Tools to Help Design Nuclear Plants for High-Frequency Earthquakes

EPRI has demonstrated robust advanced computer models for considering the effects of high-frequency earthquakes in the design of new nuclear power plants.

The design of most existing nuclear plants incorporates potential effects of low-frequency earthquakes. Until recently, there has been little research examining how high-frequency earthquakes can impact the structural integrity and operation of nuclear plant components. As more data on this became available, plant designers and operators added new design considerations.

To test the new models, EPRI used them to evaluate the effects of high-frequency earthquakes on standard-design nuclear plants. Compared to existing tools, the models provided a more detailed picture of high-frequency motions through soil and rock below buildings, the buildings themselves, and components in various locations inside buildings. Researchers found that these motions:

- Have minimal impacts on nuclear plant buildings
- Have minimal impacts on components in plants built on soil sites
- Can potentially have more significant impacts on components in plants built on rock sites
- Are dampened by soil used to fill below and along the sides of plant structures
- Can be amplified as they move through buildings, especially in the vertical direction

Based on the analysis, EPRI recommended methods for modeling the effects of high-frequency motions on structural members and equipment and for designing appropriate mitigations. Designers can consider these tools for new plants in regions with high-frequency seismic motion, such as the Central and Eastern United States, northern United Kingdom, parts of Canada, the Korean peninsula, and many parts of China.

R&D Quick Hits

Aligning Bird Eyes and Power Lines

Study Aims to Address Knowledge Gap on Bird Vision

An EPRI study recommends ways to use colored markers to prevent bird collisions with power lines, while emphasizing that more research is needed to understand how birds perceive the markers.

Many birds are killed each year as a result of collisions with power lines, and utilities deploy markers on lines to improve visibility. Some markers spin or rock in the wind, and some include lights, luminescent bases, and coatings to enhance visibility. Studies indicate that their effectiveness varies widely, and no research has confirmed or quantified how birds perceive them.

Through a literature review on bird vision, researchers gathered insights on how various spectra of reflected light may affect visibility to birds. They measured light as a function of wavelength reflected and scattered from the surface of 12 commercially available markers, concluding that:

- Contrast between parts of a marker increases its reflectivity.
- Markers with reflective and non-reflective parts may enhance visibility during the day.
- Because motion is an important visual cue to birds, markers that move are recommended.
- Because bird collisions often occur in low light, markers visible in the dark are recommended.

The authors state that these findings are preliminary. More research is needed to quantify basic characteristics of bird visual systems by species and to develop models for predicting how various light spectra affect bird perception. These can potentially help utilities determine which markers are more visible to specific species and select the most appropriate ones.

R&D Quick Hits

Bright Lights, Big City

With Urbanization, an Opportunity for Utilities and Cities to Collaborate

By 2050, two-thirds of the world's people will be urban dwellers, presenting utilities and cities with the opportunity (if not the urgent need) to optimize systems for the delivery and use of gas, water, electricity, transportation, and heat. An EPRI paper points to ways for electric utilities and cities to work together to address the influx of people and the potential for strained city services and power systems—particularly in light of urban load growth and the drive to electrify transportation and heating.

Utilities can deploy smart grid infrastructure and integrate distributed energy resources, dovetailing with emerging "smart city" initiatives that use digital technologies to integrate urban systems. Long term, more integrated planning and operations will be needed among these systems.

While smart grid technologies can help enable communications and coordination across city services, the authors note that innovative business models, regulation, and commercial mechanisms also will be needed for effective integration.

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