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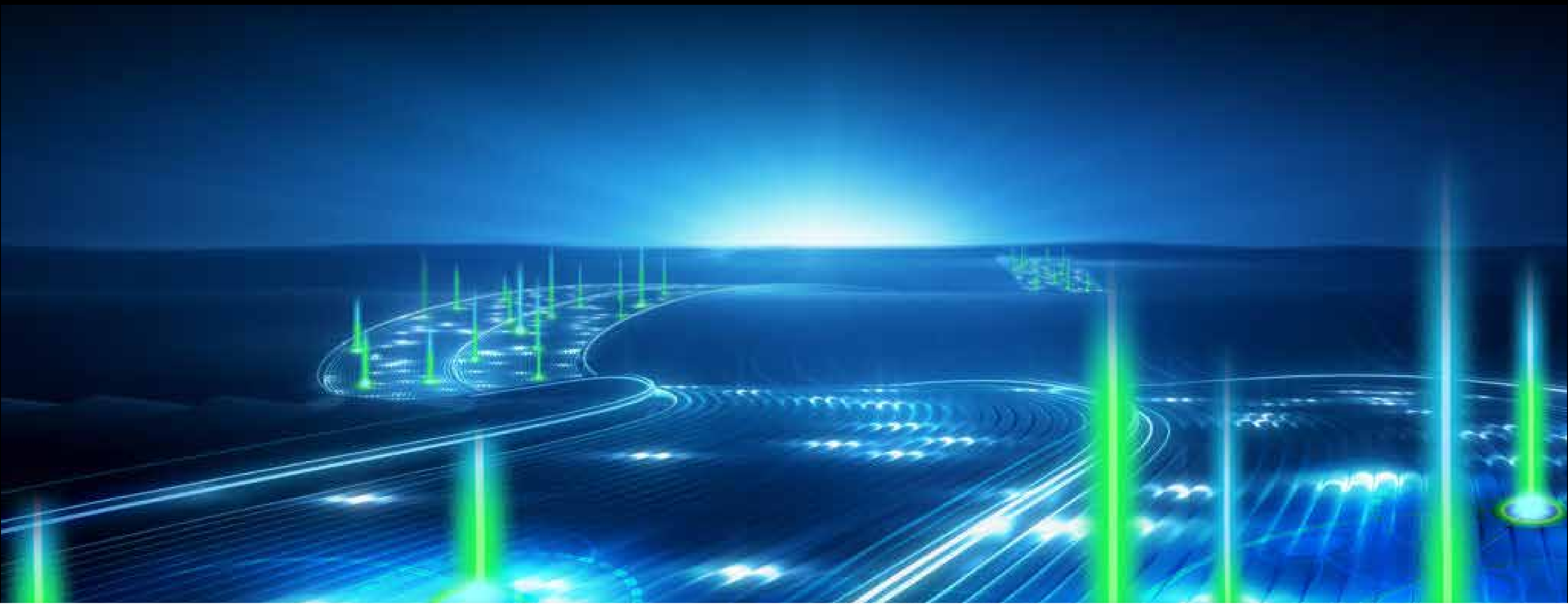
THE INTEGRATED ENERGY NETWORK



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Viewpoint—The Integrated Energy Network: The Times Demand It

In February, EPRI issued a paper introducing what we call the Integrated Energy Network. Essentially, it encourages a wide circle of stakeholders to chart a common pathway to a future in which customers have the flexibility to use, produce, and manage energy as they choose, while improving access to reliable, safe, affordable, and cleaner energy. We are at the beginning of an unprecedented and fundamental transformation in the ways we live, work, and relate to each other. In contrast to previous periods, we see accelerated innovation and the promise for systems to change exponentially rather than at a linear, sequential pace.

Our progress along this path in the next few years will be defined by how stakeholders can refine the thinking presented in this paper, while developing broader approaches to both regulation and science and technology innovation.

What do we need to accomplish as we move forward on the path? Here's how the paper sums this up:

- Manage energy and natural resources as an integrated system.
- Guide an efficient transition to much more digital, dynamic, and networked energy systems.
- Accelerate the development of cleaner energy technologies—supply, demand, delivery, and storage technologies—that can operate more flexibly.
- Unleash the opportunities for efficient electrification.
- Create new business and regulatory models that build on the strengths of today's energy infrastructure while taking advantage of new innovations.

Because these sound familiar, we may not realize how much challenge and opportunity they present us. To appreciate this, let's consider the world in 1804—about the halfway mark in the Industrial Revolution, and when the human population reached 1 billion.

Mike Howard, President and Chief Executive Officer, EPRI

The Industrial Revolution created major social changes and opportunities, freeing us from unproductive manual tasks. It owed its development initially to the power of flowing water to turn machinery. With windmills also supplying energy to early industry, this revolution was to a significant extent launched by renewable energy and turning wheels.

By 1804, the coal-fired steam engine was poised to take industrial production to an entirely new level—and not just to power factories but to power the machines and tools that would make possible today's electric grid, and to make entire populations mobile. And while steam engines freed industry from limited flowing water or blowing winds, the resulting growth placed greater demands and stresses on fresh water and clean air.

In the 200 years following humanity's 1 billion benchmark, global energy consumption has grown more than 20 times as our population has increased to 7.5 billion on a trajectory that can at times seem destined to continue indefinitely. Some forecasts project the 2050 population at 9 billion. That will certainly create new challenges for all energy resources, including water—which is profoundly more limited in the urban world of 7.5 billion people than in the largely rural world of 1 billion. We are putting a great deal of scientific focus on precisely what our growing energy appetite means for the continued supply of safe, reliable, affordable, and environmentally responsible energy.

We must focus equally on our utility infrastructure—how to provide and use energy more cleanly and efficiently, and extend to everyone the benefits of our modern energy systems.

EPRI's purpose in publishing this first paper on the Integrated Energy Network—with more to follow—is this: In considering and addressing fundamental energy and resource issues, we must take a more concerted and integrated path.

In 1804 we had room to grow, even as we lacked a comprehensive view of resource and ecosystem limits. Today we are crowded, and our planet's resources are showing the strain, yet we have a much clearer reckoning of the limits of natural resources. We have much broader research and development. We have a worldwide industrial base to drive innovation, and in our "global village" we can share and learn from innovation in weeks or months instead of years or decades—all because of the growing integration of so many different disciplines and discoveries. But we have no time to spare, and the stakes are high. We continue to add billions of people, and we are adding most of them in cities.

Even with their optimism and their inventiveness, the scientists, inventors, and innovators of 1804 could not imagine today's systems of producing, delivering, and using energy worldwide. Today we don't have the luxury to focus just on the "next thing." We must focus on the world of "next things" and knit them together in new systems of systems. When considered as a whole, these systems must be so clean, efficient, reliable, and accessible that they can sustain human health and prosperity indefinitely.

To learn more about the Integrated Energy Network, check out this *EPRI Journal* article. To get an appreciation of the breadth and diversity of work that may apply, I invite you also to read the articles about solar technology, a potential battery renaissance, and innovation scouting, where we're looking at technologies such as Ethernet-powered lighting, solar panel coatings, and even "self-healing concrete."

Mike Howard

President and Chief Executive Officer, EPRI

Charting a Common Pathway

EPRI Charts Path to an 'Integrated Energy Network'

By Chris Warren

David Owens has seen it all in the electricity industry. For 36 years at the Edison Electric Institute, he has helped guide the utility trade group's efforts in rates, regulation, energy supply, advancement of new technologies, climate change, and more.

As an industry veteran, Owens has observed dramatic changes as utility customers embrace new technologies in the Internet of Things. "The industry is in a transformation driven by technology and changing customer needs and expectations," he said. "Surrounding that is a desire for cleaner energy." As customers install solar panels, battery storage, electric vehicle charging, and digital energy management systems, the grid's power flows and system operations are becoming more dynamic and complex.

According to Owens, the boundaries that have long divided various parts of the energy sector are beginning to blur, which has major implications for business, consumers, and natural resources. "Cities are trying to improve their street lighting, and they're supporting investment to make buildings smarter," he said. "They're trying to accelerate the development of electric charging stations to make the transportation sector cleaner. They're looking at rebuilding the aging water infrastructure. They're saying, 'Let's make all of this infrastructure and these systems smarter and more integrated.'"

The vision of an integrated "system of systems" for electricity, water, natural gas, and transportation is at the core of EPRI's Integrated Energy Network, unveiled at the February meeting of the National Association of Regulatory Utility Commissioners (NARUC).

"It was exciting to have EPRI present its findings on this topic at NARUC. In this era of changing technology and unprecedented interconnectedness, the days of utilities operating in silos are long gone," said NARUC President Robert Powelson. "Communication across utility sectors is an essential component to integrating new technology and protecting reliability."

The result of research and collaboration with energy industry leaders, the Integrated Energy Network describes both a future and a path to get there.

"There is a cacophony of voices out there with future perspectives," said Anda Ray, EPRI's senior vice president, External Relations and Technical Resources, and chief sustainability officer. "What makes this different is that EPRI is not prescribing specific results, but we are pointing to a broad outcome. We've identified a common pathway and actions to move forward through collaborative consultation and R&D, creating the opportunity for discussion."

The Three Pillars

The Integrated Energy Network is an invitation to contribute new ideas and approaches to plan from three perspectives:

- **Using affordable, cleaner energy—through efficiency and electrification**. The world's rapidly growing and dramatically more urban populations share common needs for cleaner, affordable energy. This can be provided through electrification and the more efficient use of electricity. There are clearer, more reliable options for cleaning electricity than there are for cleaning direct use of fossil fuels. Examples of electrification include advanced manufacturing processes, high-efficiency heat pumps, and electric transportation. EPRI's report points out that in many regions today, electrifying vehicles can cut carbon dioxide emissions by 75% and reduce fuel costs by 70%.
- **Producing cleaner energy—through more efficient, environmentally sustainable, flexible generation**. Whether it's wind, solar, nuclear, or fossil-fueled generation with carbon capture, the potential for affordable, clean electricity has been clearly established, but it requires substantial investment and progress in the power production portfolio. The electricity sector must develop and deploy "next-gen" versions of both workhorse technologies (such as nuclear plants) and the newer contributors (such as photovoltaics). Intermittent renewables must be deployed in portfolios that make effective use of geographic diversity and storage technologies in both utility-scale and distributed applications. New technologies, regulations, and business models are needed to support the deployment of utility power portfolios and extensive distributed energy sources. Capital will be needed also to link larger, more diverse power production assets through interregional high-voltage transmission networks.
- **Integrating energy resources—through new control technologies, communications, standards, and markets**. Natural gas exemplifies the interdependence of energy systems. During winters in the United States, Midwest natural gas supplies are constrained, which could result in simultaneous, downstream constraints on power if those supplies are not integrated to serve both heat and power generation. The Integrated Energy Network points our thinking far beyond a given winter's supply and demand scenario. Better integration of planning, dispatch, and markets presents an important opportunity to improve flexibility and efficiency for customers and system operators. Other interconnections among electricity, natural gas, transportation, and water systems point to additional opportunity (or need) for integration through smart technologies, communications systems, and secure cyber networks. Near term, the electricity sector's progress in integrating utility systems with diverse, distributed resources makes the "Integrated Grid" an instrumental milestone in the Integrated Energy Network.

Integration Is Not Inevitable

Given the electricity sector's progress in achieving the Integrated Grid, will the Integrated Energy Network follow, as night follows day? Even assuming that integration can enhance efficiency, affordability, security, flexibility, and customer choice, it cannot happen on its own.

Today's business models, markets, policies, and regulations are configured for a world in which energy and natural resource sectors connect their respective resources and consumers through separately managed and operated systems. "These siloed systems were created as these industries and technologies developed independently," said Ray. "Without taking deliberate steps to achieve integration, we will delay that time at which we make optimal use of these resources. We have to start this conversation today."

Edison Electric Institute's Owens highlights the need for regulatory reform. "Our regulatory structure has to keep pace," he said. "We need to look at regulatory models that make sure that customers get the right price signals and that encourage the efficient use of energy."

The Integrated Energy Network is a call for broader innovation and collaboration—and sooner—and EPRI is supporting that by:

- **Refocusing research** to look beyond electricity to the interconnections among gas, water, transport, other energy systems, and natural resources. As part of that effort, EPRI will examine new customer expectations and opportunities presented by interconnected industries.
- **Expanding membership** to enable more diverse institutions to participate in EPRI's collaborative research.
- **Increasing communication and outreach** to bolster collaboration with stakeholders across various sectors.
- **Engaging more international stakeholders** to widen the diversity of ideas and perspectives and to support collaborative research.

While new ways of thinking and operating are needed to move forward, EPRI's mission remains the same. "Our charter is to help shape the future of the electricity industry," said Ray. "When we look ahead, we see that the electric power industry's limitations, challenges, opportunities, and potential will be profoundly intertwined with other systems and resources. If we believe this to be true, then we owe it to energy providers, consumers, and society to say, 'the sooner the better' for thinking and acting more collaboratively. And specifically, EPRI has an obligation to examine and accelerate innovations to help advance efficient, cost-effective use of energy."

Integrated Energy Network—What Do We Need to Accomplish?

- Manage energy and natural resources as an integrated system.
- Guide an efficient transition to much more digital, dynamic, and networked energy systems.
- Accelerate the development of cleaner energy technologies—supply, demand, delivery, and storage technologies—that can operate more flexibly.
- Unleash and promote opportunities for efficient electrification.
- Create new business models that build on the strengths of today's energy infrastructure while taking advantage of new technological possibilities.

Protect, Detect, Respond, Recover

EPRI Project to Develop Comprehensive Cyber Security Guidelines for Power Plants

By Scott Sowers

Two days before Christmas in 2015, a coordinated series of cyber attacks knocked parts of Ukraine's electric grid offline, and nearly a quarter of a million residences lost their lights and heat for several hours.

The attacks, directed at three regional electric distribution companies, demonstrated prowess in several complex hacking techniques. These included spear phishing to obtain faked credentials, exploiting vulnerabilities in Microsoft® Office® documents, and deploying Black Energy 3 malware to infiltrate the utilities' networks and connected infrastructure such as uninterruptible power supplies.

The perpetrators were able to obtain login credentials to the utilities' virtual private networks, allowing access via the Internet to manipulate supervisory control and data acquisition (SCADA) servers. With this, they moved to cut off power to substations and change passwords. Locked out of their computers, utility staff watched the substations go offline one by one. The attackers then bombarded the distribution companies' call centers with thousands of calls, denying access to customers reporting outages.

Investigations revealed that the attacks were enabled by months of reconnaissance to learn the various systems, find weaknesses, and devise strategies to impact components.

"Once again, this past December there was another cyber attack on the Ukrainian grid, making it two attacks in a year. The repeated nature of these incidents reflects how electric power infrastructure is a potential target," said EPRI Senior Technical Leader Justin Thibault. "Generation control systems are moving into a new digital era with more automation. They are becoming more connected—potentially decreasing the cost of ownership, but increasing vulnerability to attacks."

EPRI has launched comprehensive R&D to develop cyber security guidelines and technologies for bulk power generation. This builds on four years of collaborative research in EPRI's Generation Sector on electric system security.

"In 2012, EPRI and a small group of utility members started a project looking at cyber security for instrumentation and controls in bulk power generation facilities," said Thibault. "In subsequent years, it grew to more than 20 members and produced six reports on topics such as security status monitoring."

A key insight from this work: Cyber security for generation can draw on lessons learned from security efforts in utility information technology (IT) departments. Power plants employ operational technology (OT), which uses computer hardware and software to control switches, valves, pumps, and other devices.

"The IT world has been dealing with cyber security for decades," said EPRI Principal Technical Executive Annabelle Lee. "We need to take the techniques that have worked for IT and apply them to the OT side."

The North American Electric Reliability Corporation's (NERC) Critical Infrastructure Protection Standards now require more sophisticated security strategies for a growing number of components and systems. While the proliferation of digital components makes the electric power system more interconnected and potentially vulnerable, the upside is that many new devices have built-in cyber security.

Power plants have several attributes that can support cyber security. Plant systems are usually contained within discrete security perimeters, with assets close to control room personnel who can physically disconnect devices from networks. Plants have significant instrumentation for monitoring and controlling various systems, making it easier to detect unusual network behavior.

EPRI's initiative aims to develop a spectrum of security strategies that protect plant computer networks with multiple mechanisms, so that if one fails, another is ready to stop an attack. Research focuses in three areas: Protect, Detect, and Respond and Recover.

Protect

To secure critical components, most power generation plants use *network segregation*. This involves separating external connections to control systems with unidirectional gateways or limiting physical connections to outside networks (also known as *air-gapping*). However, recent control systems intrusions demonstrate that disconnection from the outside is not sufficient protection against a cyber attack.

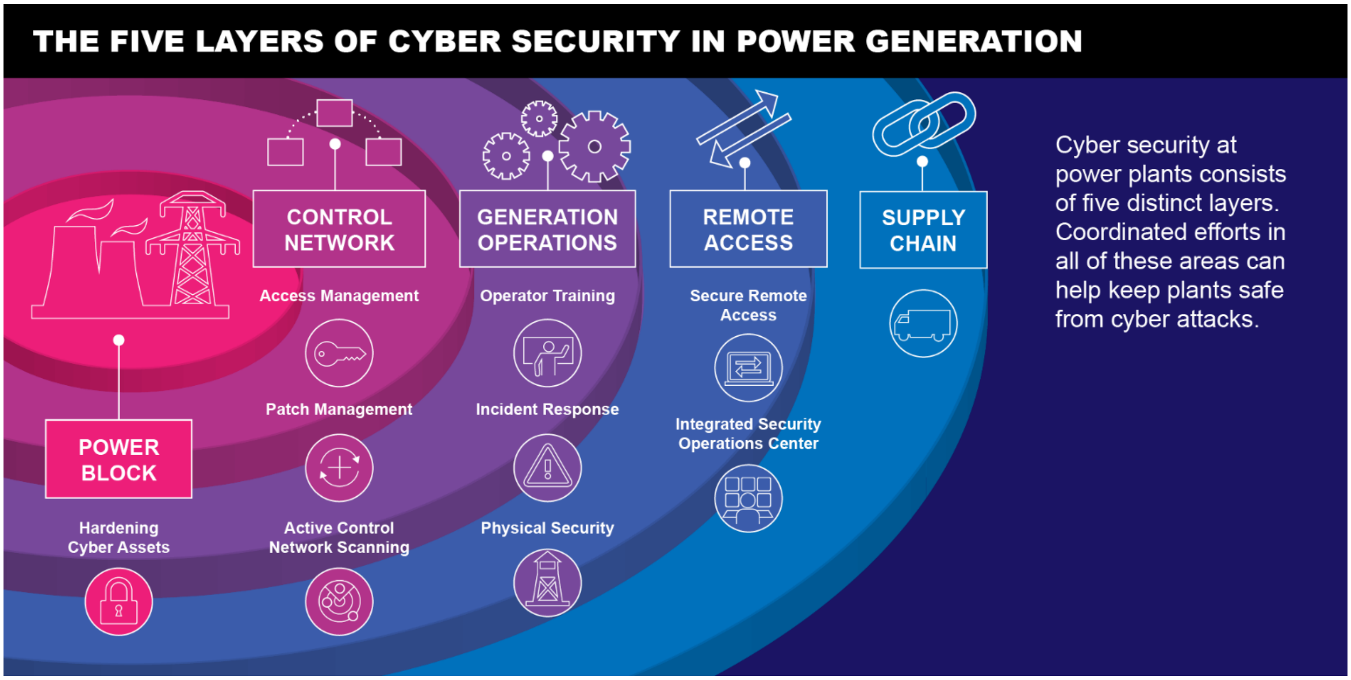
"Depending on network segregation alone to secure a control network would be like a bank with only one form of protection—doors that lock," said Thibault. "Most air-gapped systems can be compromised by personnel using thumb drives or other external media (as with Stuxnet) and by temporary network connections granted to external parties."

The computer "worm" Stuxnet was spread through thumb drives and targeted specific control components. It is believed to have damaged centrifuges at Iranian uranium enrichment facilities in 2009 and 2010.

EPRI is looking at technologies to secure "interactive remote access," which requires anyone attempting to access control systems from outside a utility to go through an intermediate server that authenticates identity. The server filters out suspicious actors.

Regularly installing cyber security patches (multiple code changes) in key computer systems is important for addressing vulnerabilities, and EPRI is examining their application in power generation. As the volume of malware has increased, so has the importance of performing the right system updates at the right time. Applying patches can be challenging because it often requires systems to be taken out of operation, potentially affecting power availability.

Devices can be "hardened" to reduce their "attack surface." A valve actuator presents a relatively small attack surface, while a digital control system's more complex attack surface likely requires additional layers of security. An example of hardening: Unnecessary software is removed and default passwords are changed to reduce the attack surface.



Detect

A big challenge with cyber security is that the victims rarely know that they are under attack until damage is already done. The staff at the Ukrainian distribution companies didn't realize what was happening until they were locked out of their own accounts, watching outsiders control their systems. EPRI researchers are examining emerging detection technologies that can alert utility personnel to potential threats and attacks.

"Most cyber security breaches go undetected for months and sometimes years," said Thibault. "Breaches are most often discovered when law enforcement contacts the victims or when the consequences of the breach have become apparent."

Detecting an attack requires an ability to identify anomalies in networks and systems. This involves training personnel to recognize attack signs and deploying technologies such as intrusion detection systems, intrusion prevention systems, and security information and event management systems.

"We are seeing more cyber security companies develop intrusion detection systems for industrial control systems and networks," said EPRI Senior Program Manager Galen Rasche. "Rather than relying solely on the traditional signature-based approach, these products also establish baseline system readings for a network's behavior and look for unusual behavior."

Detection must be accurate to be effective, and threat management can help. These techniques are used to collect and interpret information about security threats from reliable sources and characterize intent, capability, and targets.

Rasche points out that security companies are improving the exchange of threat information among computers and systems to facilitate detection and a speedy response. “The goal is to quickly share key indicators of compromise for specific cyber threats, enabling security staff to proactively detect and thwart a threat before it turns into a larger incident,” said Rasche.

Respond and Recover

Ukraine’s 2015 outage was corrected within hours, but repairing system damage took months. A speedy recovery is critically important because the primary objective of power generation is availability.

“After securing a system that has been breached, a utility must be able to restore the system fully and quickly,” said Thibault. “This is achieved with good planning—systems are backed up in advance, the configurations of various components and systems are well known, and processes are in place to restore them. Properly classifying cyber security incidents helps to determine the best course of recovery actions.”

After recovery, *forensic analysis* is used to identify, preserve, recover, analyze, and present facts about the attack, helping operators understand how their systems were breached and how they can be improved.

“Forensic analysis also adds to the lessons learned and industry operating experience,” said Thibault.

“Doing Common Things Uncommonly Well”

There’s more to cyber security than simply deploying advanced technologies for protection, detection, and recovery. “A lot of doing security work is doing common things uncommonly well,” said Thibault.

Two “common” areas—configuration management and procurement—are fundamental to protecting power generation assets. In 2014, EPRI published guidance on implementing configuration management for digital control systems. Many cyber attacks exploit factory default settings, and effective configuration management can help protect against such intrusions. Carefully managing the installation of new components and keeping patches up-to-date eliminates many vulnerabilities.

Even with configuration management, the digital components themselves could be a security threat, given their design and manufacture. A 2013 EPRI report provides strategies for addressing security concerns in procuring digital assets.

EPRI plans to publish guidelines on other aspects of generation cyber security, along with “reference architectures” or templates for securing control systems and integrating future technologies. Also in the works is an online exchange for EPRI utility members to share research insights and operational experience.

“Cyber security for power plants is a multi-layered challenge, but it is not insurmountable,” said Thibault. “Developing best practices and more robust security will make it more difficult to infiltrate generation assets. When a power company chooses to avoid the challenge of implementing effective cyber security, it is choosing to live in the dark.”

EPRI R&D on Transmission and Distribution Cyber Security

Safeguarding generation plants is a big part of cyber security in the utility industry. Equally important is securing transmission and distribution systems. As grid devices become more interconnected through telecommunications networks, cyber security measures must be implemented to support reliable power delivery.

EPRI's Cyber Security and Privacy Program develops security requirements and metrics, guidelines for risk assessment and monitoring, and tools and technologies to assess security and manage grid devices and threats. For example, researchers are:

- Incorporating security into various grid components and developing approaches for utilities to meet regulatory requirements
- Examining ways to gather near real-time knowledge on the system and security status of substations, field devices, and other parts of the grid
- Establishing plans and technologies to detect and respond to cyber attacks while maintaining power delivery
- Identifying threat hunting approaches, tools, and methodologies for operational technology

Key EPRI Technical Experts

Justin Thibault, Annabelle Lee, Galen Rasche, Matt Gibson, Mike Thow

Tracking Sustainability with Data, Not Anecdotes

EPRI Initiative Helps More Than 30 Utilities Accurately Measure Sustainability Performance

By Chris Warren

In 2015, Los Angeles Mayor Eric Garcetti unveiled the Sustainable City pLAn, a roadmap of short- and long-term sustainability goals in areas such as water conservation, air quality, transit, energy efficiency, greenhouse gas emissions, and minimum wages. In his opening letter to the pLAn, the Mayor points to the potential multifaceted benefits: "This pLAn sets the course for a cleaner environment and a stronger economy, with a commitment to equity as its foundation."

One city organization in particular has a significant role in the roadmap. "We are involved in or responsible for more than half the goals," said Nancy Sutley, chief sustainability and economic development officer at the Los Angeles Department of Water and Power (LADWP), the city's municipal utility. "We're a critical part of this effort because the city owns so much infrastructure, including power and water."

Sutley also has a strong mandate to report on the utility's progress toward the city's sustainability goals. "There is a big emphasis on transparency in Los Angeles," she said. "The mayor's office maintains an open data website so that anybody can see our progress." For example, it requires just a few mouse clicks to learn that Los Angeles reduced water use by 19% between summer 2015 and summer 2016, just shy of its 20% goal for 2017. It also has surpassed its 2017 target of installing 1,000 public charging stations for electric vehicles.

Sutley says that her work has been aided by LADWP's participation in EPRI's Energy Sustainability Program and access to an online EPRI tool that enables electric utilities to measure and benchmark their sustainability performance relative to industry peers.

A Product of Collaborative Research

EPRI's Sustainability Benchmarking Tool builds on years of collaborative research by EPRI and the Tennessee Valley Authority (TVA). A 2013 EPRI study identified the 15 most relevant sustainability issues in the North American electric power industry, based on input from hundreds of utilities, government agencies, environmental organizations, and academic institutions. The issues are grouped under the three "pillars" of sustainability: environmental, economic, and social.

In 2015, EPRI assumed management of the environmental benchmarking initiative that TVA maintained since 2010. Utility participants in EPRI's initiative narrowed down a list of nearly 450 sustainability metrics to the 77 considered most useful for benchmarking. Examples include CO_2 emissions, employee volunteer rates, and skilled worker availability. EPRI used those 77 metrics to create the tool.

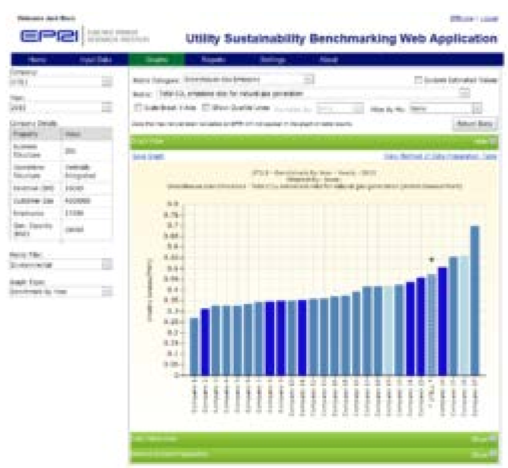
Over the past two years, more than 30 companies have submitted sustainability performance data and generated tailored benchmarking reports that examine issues such as water availability and employee safety. Utilities compare their performance with other companies through filters that narrow results based on revenues, generation capacity, and company type (investor-owned or "other" including municipal and cooperative).

For LADWP, the online platform provides an accurate measure of performance, supporting its transparency obligations for Los Angeles. "It is good to get a sense of where you stand by relying on data rather than anecdotes," said Sutley.

An Effective, User-Friendly Tool

"With two years of data in the platform, a company can now create charts that track performance year-to-year and compare that to an average industry trend for the reporting companies," said EPRI Technical Leader Morgan Scott. "For example, a company can demonstrate visually how its greenhouse gas emissions have changed over the past two years and identify activities contributing to the change, such as the retirement of coal plants or investment in renewables. With each new year of data and enhanced database structure and capabilities, companies will deepen their understanding of performance on these sustainability issues."

Another 2016 enhancement: The tool asks users to specify how they prepared their data. As an example, when submitting CO_2 emissions data from coal-fired power plants, companies must indicate whether the data was third-party verified, compiled internally, or is a company's best estimate (meaning that it is within 25% of actual performance). Each method is flagged using a different color in the tool's graphing interface (see chart).



EPRI's Sustainability Benchmarking Tool uses different colors to indicate different data preparation methods.

Such features provide deeper insights and help companies better understand how their peers approach third-party verification, potentially informing decisions about whether to undertake this more expensive approach to data collection.

"As we continue to benchmark, we may be able to quantify third-party verification trends," said Scott.

Companies can use such features to make more direct comparisons with their peers. "Companies can filter out data from 'best estimates' and benchmark only data prepared internally or verified by third parties," said Scott.

More Robust Analyses

At some companies, sustainability managers provide executives with customized reports and graphics, which can inform decisions about recruiting new workers, community involvement, investments in greenhouse gas management strategies, and more.

"The benchmarking allows us to show that our programs and focus on environmental discipline are resulting in progress," said Harry Sideris, Duke Energy's state president for Florida. "The tool gave us a directional sense and validated that Duke was moving the needle compared to its peers. It has also directly led to the development of additional internal tools, stirred the brain, and provided a springboard to drive dialogue and internal innovation."

Other participants report that involvement with the benchmarking initiative has improved employees' understanding of sustainability. "Sustainability managers have sparked internal dialogue by reaching out to utility subject matter experts and requesting data for benchmarking," said Scott. "Many employees don't consider their jobs as sustainability-related. This work has helped to engage more employees and raise awareness that everybody's work supports sustainability."

American Electric Power (AEP) has used the tool to enhance sustainability analyses. "After collecting data from subject matter experts, we always circle back to share the results and confirm that we've accurately extracted the key takeaways," said Sandra Nessing, AEP's managing director for corporate sustainability. "This helps us to assess whether we are measuring the right things and how relevant they are to AEP."

AEP will use data collected over the past two years through the EPRI benchmarking initiative to help set new sustainability goals in 2017. "Benchmarking provides historical trends to support the storyline of transformation and will be very helpful as we set new goals to clearly show our path forward and our progress," said Nessing.

A commitment to continuous improvement is embedded in EPRI's approach to sustainability. There's a "reflection period" each year when member companies provide input to bolster the relevance and technical rigor of the metrics, applying lessons learned from the previous year's data collection. EPRI and the participating utilities are reassessing the 15 priority issues. If they identify new issues, the next step would be to identify metrics for those issues and incorporate them into the benchmarking tool. They also are considering possible new features for the tool.

Award-Winning Work

For their work developing the online sustainability platform, the members of EPRI's Energy Sustainability research steering committee received a 2017 EPRI Technology Transfer Award: Sandy Nessing (AEP), Anand Yegnan (Dominion), Patty Ireland (DTE Energy), Michelle Abbott (Duke Energy), Rick Johnson (Entergy), and Lee Matthews (TVA).

Committee members provided guidance essential to identifying the right metrics and defining the three methods of data preparation. "They offered important insights that helped us to create an easy-to-use tool that is relevant and delivering value to a wide range of companies," said Scott.

By providing quantitative data on sustainability, the tool illuminates what is often only a qualitative discussion, driving better decisions by company leaders. "It helps to translate sustainability for an industry that is very metric-driven," said Scott. "When an executive understands how a company's performance compares to industry peers, new opportunities can be identified to do better as a business and as a corporate citizen. To become an industry leader, sustainability commitments should be an integral part of the future success of a business."

Key EPRI Technical Experts

Morgan Scott

Technology At Work

A Standard Industry Approach to Evaluating Workers

EPRI Guidelines for Supplemental Workforce Testing Gain Acceptance in the Nuclear Industry

By Matthew Hirsch

When nuclear power plant operators use supplemental workers during scheduled outages, they want them to be prepared for tasks such as rigging and lifting. When these workers require additional training upon arrival, higher labor costs result.

Beginning in the 1980s, EPRI investigated how to reduce these costs by assessing the knowledge, skills, and experience of the nuclear industry's temporary, mobile workforce. EPRI's Standardized Task Evaluation (STE) Program helps utilities identify and qualify workers by developing evaluations for industry-wide maintenance tasks. It supports a registry of more than 17,000 workers who have completed written and performance tests for specialized tasks.

More than 9,000 people in the registry have completed the written and performance tests for industrial rigging—more than any other task. More than 2,000 have completed tests for general valve maintenance.

Collaboration and Peer Review

For member utilities and workforce providers, the program provides a library of tests for evaluating supplemental workers' skills and knowledge.

EPRI convenes working groups of utilities and workforce providers to systematically develop evaluations. They analyze each task and create test banks that can be used to generate written exams and performance evaluations. These tools are peer reviewed by utility and workforce experts prior to their release.

"The collaboration among our utility members is a strength of this program, enabling us to create evaluations that are useful across the industry," said EPRI STE Program Coordinator Patty Wade.

To give utilities confidence that supplemental workers have been evaluated according to established standards such as training documents from the Institute of Nuclear Power Operations, EPRI developed the Administrative Protocol for Portable Practicals (AP3), a set of guidelines for workforce providers to follow for administering performance evaluations. AP3 compliance includes an EPRI-led team review of the workforce provider's program and a site visit to evaluate performance test administration. In some cases, compliance with AP3 can take six months to one year.

Savings for Utilities

Utilities can use EPRI's STE program to save significant time and money. Entergy's Fleet Maintenance and Technical Training Manager Jim Caery said that in an 18-month operating cycle, a two-unit nuclear power plant may spend $150,000 to $200,000 to train supplemental workers.

"We used to ask vendors to provide trained and qualified workers without specifying what 'trained and qualified' means," said Caery. "We were giving away free training."

To reduce these costs, Entergy has started to require workforce providers to comply with the AP3 guidelines to help confirm that supplemental workers bring to the job the necessary knowledge and skills.

According to Caery, the STE program could yield additional savings by expanding beyond maintenance and orientation training. "If we add training for health physics technicians, we cover the bulk of the supplemental workforce needed during refueling outages," he said. EPRI is evaluating the program's expansion into health physics and other areas.

The EPRI STE program continues to expand in the North American nuclear industry, with 19 utilities and 14 workforce vendors participating.

Key EPRI Technical Experts

Patty Wade, Heather Feldman

In Development

EPRI Connects Utilities and Clean Energy Innovators

By Garrett Hering

Clean energy entrepreneurs often must overcome the so-called "Valley of Death," where public funding for early-stage technology development runs dry before private funding emerges for production and commercial release.

To support technology scouting and accelerate adoption, EPRI is leading the Incubatenergy Network in partnership with the U.S. Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL). The Network is connecting clean energy entrepreneurs worldwide with stakeholders including incubators, accelerators, investors, and electric utilities in search of novel technologies for the future grid.

"Through our technology scouting efforts, we are very much focused on new technology offerings and helping young companies through introductions to utilities and others," said Elizabeth Hartman, EPRI project manager for the Incubatenergy Network.

Launched in 2015, the network includes 15 incubator groups, such as Austin Technology Incubator, Oregon BEST, and the LA Cleantech Incubator. These groups collectively support nearly 500 startups that have raised more than $1.6 billion, generate more than $440 million in revenue, and employ more than 3,300 people.

The startups have access to hundreds of technology experts and business development mentors across the incubators, DOE, NREL, and EPRI's utility members.

Connecting Utilities and Startups

For participants in an energy incubator, networking and demonstration of technical prowess emerge as key functions, facilitated by frequent competitions, conferences, and other events that can connect clean energy innovators with strategic partners. Massachusetts-based incubator Greentown Labs holds monthly "EnergyBar" networking events and an annual DemoDay for prototype demonstrations. NREL's Lab Impact Summit in Golden, Colorado invites participants to pitch market applications for their products. EPRI hosts an annual summer meeting for members of the Incubatenergy Network, enabling potential connections with utilities and building awareness about the public benefits of innovative technologies.

Such opportunities lead to many collaborative research studies, pilot projects, and field demonstrations with EPRI and utilities. Since the start of the Incubatenergy Network, at least a dozen companies have collaborated with EPRI and utilities on research and pilots, with dozens of additional ongoing conversations.

For example, utilities are interested in technologies to integrate solar, batteries, and other distributed energy resources (DER) into the grid. One network company, ConnectDER, has developed an attachment for a residential electric meter that can reduce wiring and DER installation costs and provide utilities with DER management capabilities. It is being tested in pilot programs with Con Edison, Austin Energy, Hawaiian Electric, and Potomac Electric Power Company.

"We pitched at an Incubatenergy event in Los Angeles, and the benefit was threefold," explained Whit Fulton, ConnectDER's founder and chief executive. "We were introduced to new utility contacts, we deepened relationships with existing utility accounts, and we networked with the entire Incubatenergy community of companies, utilities, and investors."

Also attracting utilities' interest is AutoGrid Systems, which in 2016 garnered a $20 million investment led by Energy Impact Partners, a venture capital firm founded by several utilities. The investment will advance the commercialization of AutoGrid's software that enables real-time utility management of extensive deployment of DER.

"Utilities are engaged as development and demonstration partners and increasingly as investors," said Hartman, adding, "The incubator network has become a critical component of EPRI's technology scouting effort."

While EPRI, DOE, and NREL initially funded the Incubatenergy Network as a three-year initiative ending in 2017, it may continue into the future, pending additional funding.

"The connections we have forged between the utility industry, the regional incubator groups, and hundreds of clean energy companies form a strong foundation for future collaboration," Hartman said.

Key EPRI Technical Experts

Elizabeth Hartman

In The Field

Storming Back When the Poles Are Down

EPRI and Exelon Investigate Sensors to Speed Up Storm Restoration

By Chris Warren

Electric utility customers who have experienced a power outage during a storm are familiar with the scene that unfolds when the winds, rain, and snow subside. Fleets of bucket trucks and crews of linemen fan out to repair damaged poles and power lines to get the lights back on as quickly as possible.

While utilities typically have detailed storm response plans, a lack of knowledge about grid conditions can slow restoration.

"We first send out damage assessment crews, and they drive around to find and record damage," said Alexandra Ryder, an engineer with PECO, a division of Exelon that serves more than 1.5 million electric customers in southeastern Pennsylvania. "It's time consuming, but after a bad storm, it's one of the few ways to find out where we have downed poles."

To reduce such delays, EPRI is developing and testing pole-top sensors that can quickly alert utilities to downed or damaged equipment in distribution systems.

"We want to develop a sensor that could be attached to distribution poles, crossarms, and power lines that can report back damage information immediately," said EPRI Engineer Jason Anderson. "This can enable quick damage assessments and guide where to stage crews and locate spare parts for repairs."

Adapting Technology Used in Smartphones

In recent years, utilities have increasingly deployed sensors on distribution systems to monitor various parameters. In 2015, EPRI's Distribution Research Program began to modify sensors developed by EPRI's Transmission and Substations Programs to monitor pole movement.

EPRI researchers adapted accelerometer technology used in mobile phones to detect changes in orientation and rotate the screen as necessary. "In our sensor, the accelerometer can detect a change in the orientation of a pole, crossarm, or conductor," said Anderson.

EPRI is designing the device to integrate with a utility's communications system and alert operators when a pole, crossarm, or conductor falls. The sensor is designed for easy installation and a 15- to 20-year lifetime. Laboratory tests have demonstrated that the sensors can reliably detect downed poles and conductors.

Field Testing at 3 Exelon Utilities

In 2016, Exelon installed 80 sensors at sites at PECO, ComEd, and Baltimore Gas and Electric. They are being monitored continuously for 15 months to get a better idea of how the sensors can be used in the field.

Ryder wants to learn more about optimizing the sensors' configurations, which may vary depending on their location.

"The threshold for when the pole sensor sends an alert will be different from the threshold for the conductor sensor, because the conductor sensor may have times during a windy day when it moves but is not damaged or downed," she said. "The pole will not move much on a windy day unless it has been downed."

Ryder also wants to assess how often the sensors send false alerts.

After 15 months, Exelon and EPRI will examine the data and evaluate the sensor's benefits and capabilities. EPRI will continue to refine the sensor's design to reduce its cost—which remains a big hurdle to widespread deployment.

Ryder believes that the sensor could make a big difference in how quickly PECO can get the power back on. "For a large-scale storm, we think that this could help shave significant time off of restoration," she said.

Field tests of similar sensors are beginning at Ameren's Technology Applications Center and Pepco Holdings, Inc.

Key EPRI Technical Experts

Jason Anderson

Innovation

Improved Safety Through Data

Analysis of EPRI's Occupational Health and Safety Database Aims to Improve Employee Well-Being

By Chris Warren

The best way to prevent accidents and injuries is to understand their causes and take appropriate actions. That was a key insight that led EPRI in 1999 to establish the Occupational Health and Safety Database (OHSD), which tracks annual injury and illness trends among 390,000 employees in the U.S. electric power industry. Today the voluntary reporting system contains 2 million records—such as injury reports and claims—submitted by 18 utilities and dating back to 1995.

EPRI designed the unique database to help utilities evaluate and act on the information to improve employee health and safety. "EPRI developed coding systems for occupations, types of injuries, severity, and causes to support industry-wide analyses," said Ximena Vergara, an EPRI project manager focused on health and safety. With the database, EPRI develops injury rates, and companies can compare their rates with those of other companies.

Examining Injury Severity

Using the database, EPRI's Occupational Health and Safety research program publishes annual health and safety reports and in-depth analyses on specific topics.

A recent study examined relationships among various occupations, types of injuries, and injury severity. The authors found a relatively stable average rate of 0.52 severe injuries per 100 employee-years between 1995 and 2013, with 77% of injuries considered minor (less than one workday missed). Line workers, meter readers, and mechanics had among the highest rates for severe injuries (five or more missed workdays). For example, line workers:

- Had a severe injury rate of 1.99 per 100 employee-years
- Experienced the most flash burns (31%), electric shocks (29%), hernias and ruptures (27%), fractures and dislocations (20%), and concussions (15%)
- Had the highest fatality rate, with about 18 deaths per 100,000 employee-years—most often a result of vehicle accidents, contact with electric current, and being struck by an object

At Risk of Falls

Another recent EPRI study examined two types of falls—from an elevation and on the same level—and the resulting injuries. It found that line workers had an increased risk of fall from elevation relative to other utility occupations, such as office workers. Prior EPRI research demonstrated risk factors for line workers, including strenuous work and handling heavy equipment.

The report found that security officers also were at an increased risk of falling from elevation. The authors hypothesize that this results from patrolling at facilities with grades, obstacles, and changes in elevation—often in areas without handrails and under adverse weather conditions. They also may work at night in areas with inadequate lighting.

Applying the Results

Utilities can use EPRI's database and these analyses as a guide for internal health and safety assessments, leading to actions that address the specific risks to their employees. "Companies can look at our analyses and assess whether our observations apply to their own workforce," said Vergara. "Do they see the same risks and injuries, and are there ways to prevent the majority of those injuries? For instance, they can examine work practices in high-risk groups such as line workers or security guards by conducting fall assessments."

Findings about causes of injuries can guide prevention efforts and industry-wide interventions for specific occupations, such as improved lighting and slip mats in areas that security officers inspect.

"As our workplace incorporates new technologies and innovations, we must be aware of potential new hazards to protect the welfare of our employees," said Ben Colgrove, senior manager of EPRI Safety and Labs. "A culture of continuous improvement is a must since there is no status quo in the quest to improve worker safety."

Key EPRI Technical Experts

Ximena Vergara

Innovation

Twitter, Mobile Apps, and Environmental Data

Study Examines Citizen Science on Social Media and Its Implications for the Electric Power Industry and a Cleaner Environment

By Chris Warren

The Twitter feed of the organization "I See Change" has the feel of an environmental diary. One post features a close-up photo of a flower in a Pennsylvania yard, with the caption, "One bloom on what I thought was a casualty of this summer's drought." Another displays a Connecticut mulberry tree's thick canopy of leaves near its top and bare branches at the bottom, with the post speculating whether odd leaf-dying patterns are becoming more prevalent. I See Change, which describes itself as a community-driven almanac for recording local environmental changes, recently released a mobile app that links citizens' photos and observations with satellite data to support NASA climate research.

I See Change is part of an emerging trend in which citizen scientists use social media to share environmental data with scientists, policymakers, advocacy groups, and other stakeholders—from photos of endangered species sightings to sensor readings for air and water quality.

A new EPRI study assesses this trend, potential public and environmental benefits, and implications for the electric power industry. "We are examining how social media is being used for environmental data, for what purposes, what information is out there, and what areas utilities might be interested in," said Nalini Rao, EPRI technical leader and a co-author of the report (to be published in Spring 2017).

Governments Encourage Novel Data Collection and Analysis Tools

Governments worldwide are encouraging citizens to collect environmental data, including measurements or information about air, water, species, oceans, landscapes, and coastal areas. For example, the European Union enlisted citizen scientists to collect biodiversity data that have been used to track the continent's progress toward 2020 habitat and species preservation goals.

The U.S. Environmental Protection Agency (EPA) initiative Apps for the Environment has led to the development of hundreds of apps for tracking carbon footprint and measuring water quality, ozone, air quality, and more. Data from many apps are shared via social media. The EPA also is soliciting citizen science data through community projects and other avenues, many of which use apps.

Why Social Media Matters to Utilities

Sharing of environmental data on social media has many potential benefits. "Agencies and scientists can use it to supplement traditional data collection efforts and mine it for their research," said Rao. "It can help educate and elevate public awareness about environmental issues, concerns, and successes."

Typically, utilities use social media to broadcast information about storms and power outages. EPRI's research on social media's evolution points to several implications for the electric power industry.

Data collected and shared by citizens on social media could be directly related to the environmental impacts of power plants and other utility-owned facilities. It is important for utilities to determine the data's accuracy and quality, and in certain cases they may need to work with citizens to do so. This can support utilities' efforts to make their facilities cleaner, benefiting the public and the environment. It can also help with emissions and discharge permitting and reporting to regulatory agencies.

"It's a good time to pay closer attention to social media and the increasing amount of shared environmental data because citizen science is involving more public stakeholders, and federal agency support is increasing," said Rao.

"Citizen scientist research projects are becoming more rigorous. If this trend continues, then there are going to be a lot more data sets out there," said Stephanie Shaw, principal technical leader in EPRI's Environment Sector. "This could mean more opportunities for collaboration with the public, and more opportunities to deepen our understanding of the environment and the environmental impacts of utility operations."

"To get ahead of this trend, utilities can obtain and evaluate environmental data sets from citizen scientists," said Shaw. "They can also identify specific research areas that would benefit from a detailed scouting of social media and app activities."

The field of citizen science will continue to grow, incorporating new technology and social media platforms. While there are still questions regarding the benefits of this new data collection approach, it is likely that environmental monitoring will be taking on a new, important dimension.

Key EPRI Technical Experts

Stephanie Shaw, Nalini Rao

Shaping the Future

Innovation Scouts: Looking for the Next Big Thing

By Scott Sowers

If your job were "innovation scout," how would you spend your days? Hanging out in a Silicon Valley Starbucks? Eavesdropping at the major technology trade shows?

Perhaps, but the job consists of much more. Scouting is about matching innovation with opportunity. Stephen Stella is a self-described "emerging energy technology champion" and manager of EPRI's Innovation Scouting Program. He describes the role of scouting as critically important. "Scouts are always on the lookout for new information on emerging technologies that can potentially be applied in the electric power industry," said Stella.

In addition to digging through articles and reports, scouts need to seek out diverse people and opportunities. "They may reach out to and communicate with technology developers—including university research labs, national labs, and startup companies—to better understand the technologies and market approaches," said Stella. "They also interact with electric utilities, oil and gas companies, nonprofit organizations, venture capitalists and other investment entities, manufacturers, regulators, test facilities, and many others stakeholders. Dialogue can range from an informal chat in the break room to a formal visit half a world away."

While glamorous at first glance, innovation scouting requires digging and diligence. "One challenge with scouting is that technologies and opportunities do not always appear in a clear, concise, and compelling box that enables quick understanding," said Stella.

Scouts need to be nimble thinkers and skeptical of hype. "They must be able to cut through the clutter and glitzy marketing," said Stella, "A strong technical background is essential, as is the ability to deal with a wide variety of people, places, and situations. Scouts should also be savvy in evaluating costs and benefits as well as policies and regulations."

With EPRI's approach to innovation scouting, creating and engaging networks enables the crowdsourcing of ideas and greater collaboration.

Here are just a few of the areas that scouts are examining:

- **Solar modules**. Increasing the efficiency of solar photovoltaic (PV) cells by tinkering with their chemical makeup continues to offer promise. Another area under investigation is anti-reflective and anti-soiling coatings for solar modules. A recent study from an EPRI scout focused on two aspects: "First, anti-reflection coatings increase a PV module's power output by increasing the amount of absorbed light. Second, anti-soiling coatings mitigate the soiling of PV modules, which increases overall energy output and offers flexibility in PV plant operations and maintenance." While questions remain regarding their durability, coatings have the potential to reduce the price of solar electricity.
- **Ethernet-powered lighting**. Innovation scouts are working with an Iowa-based company developing LED lighting systems that can be powered and controlled by an Ethernet cable and smartphone app, and installed without an electrician. EPRI is assessing the technology's performance and potential market impact through laboratory testing.
- **Infrared cameras**. EPRI research reveals that these devices are suitable for diverse power industry applications. They can detect cold spots in concrete dams, indicating water penetration. They can "see" warm areas on an electrical relay that's about to fail and identify cold or hot spots on a solar panel that's

not operating properly or is partially shaded. Prices have plunged from thousands of dollars to hundreds, making them affordable for utilities to deploy throughout their systems.

- **Self-sensing concrete**. Concrete is used in nuclear and fossil power plants, hydroelectric dams, wind turbine bases, and many other power industry settings. Scouts are looking at concrete containing nanotubes—tube-shaped carbon molecules that can carry an electrical charge—potentially turning concrete into a sensor that transmits failure data. So far, the phenomenon has been demonstrated only in laboratories, but early results are promising.
- **Self-healing concrete**. "Autogenous healing" is a natural crack repair process in concrete that occurs as a result of chemical reactions among compounds exposed at the surface. Self-healing concrete extends this process. Researchers are experimenting with blending chopped fibers into concrete to make it more flexible, resulting in fewer and smaller cracks and more complete healing.

EPRI's scouts are active in many areas, including energy use, energy storage, wind power, advanced nuclear technologies, advanced fossil fuel power cycles, carbon capture, and water conservation in power plants.

Innovation scouts are not unique to the electric power industry. A listing of scouts on LinkedIn reveals researchers and a venture capitalist in biotechnology, telecommunications, management consulting, and transportation. "There's no formal training program for scouts," said Stella. "Some companies may have dedicated scouts, whose sole purpose is to seek out new technologies and innovations, or the scouting role may just be one of many responsibilities an employee has."

Key EPRI Technical Experts

Stephen Stella

Shaping the Future

Renaissance in Batteries for Utility-Scale Storage

By Brent Barker

For more than 200 years, battery technology has advanced in waves. In 1800, Alessandro Volta invented the first battery providing continuous current. In 1859, Gaston Planté invented the lead acid battery, establishing a chemistry that dominated the commercial and industrial battery market for 150 years. In the 1960s and 1970s, NASA-funded research unleashed a new wave of electrochemical innovation. In 1991, Sony introduced the first commercial lithium ion battery, and the technology's costs and performance have improved over the past 25 years as commercial giants LG, Samsung, Sony, Panasonic, and Tesla scaled up manufacturing.

Lithium ion dominates consumer electronics and electric vehicles, and Navigant Research reports that these batteries remain the leading form of energy storage for new projects worldwide—accounting for 83% of newly announced systems through the third quarter of 2016.

The growing need for grid storage to support solar and wind is providing energy to create a new wave of battery innovation.

"With more technologies such as sodium ion and flow batteries entering the picture, the big question for researchers and the electricity industry is, will the next generation include technologies other than lithium ion?" said Brittany Westlake, energy scientist in EPRI's Energy Storage and Distributed Generation program. "The answer will vary depending on the application."

In mobile battery applications such as electric vehicles, high energy density is critical. For stationary applications such as substations, cost, cycle life, and duration are paramount.

Sodium Ion Technologies

Sodium ion batteries are similar to their lithium ion counterparts, but sodium ions replace the transport charge. In the battery's discharge mode, electrons stripped from sodium atoms move through an external circuit to produce energy, while positive sodium ions are shuttled from the anode to the cathode, where they are intercalated (lodged) in the lattice structure.

"Think of intercalation as stuffing ping pong balls into spaced layers of chicken wire," said Westlake.

The key advantages of sodium ion: Sodium is more naturally abundant, and the aqueous electrolyte (such as salt water) is safer. Because lithium is highly reactive with water, organic electrolytes must be used, and the batteries must be carefully packaged to prevent electrolyte evaporation and possible short circuit.

The disadvantage: Sodium ion batteries are 25% larger and much heavier, which can result in longer charge and discharge times, as well as a lower energy and power density. "Sodium ion batteries may not be the best choice to replace lithium ion in electric vehicles," said Westlake. "But it could be competitive in stationary applications such as substations and remote grid-scale storage where weight and battery footprint are less important."

Several sodium ion start-up companies have entered the race for stationary battery markets. One of them, Alveo, emerged from Stanford University a few years ago. "There are a number of competitive cell chemistries in the stationary battery market," said Alveo Chief Executive Officer Colin Wessells. "Lead-acid, the current workhorse, is the cheapest but has a relatively short cycle life. Lithium ion has a good cycle life and costs are falling, but total costs for installed systems are still about $600 per kilowatt-hour."

Alveo and others are targeting markets in which they have a performance or economic advantage. They focus technology development on creating a battery with high power and long cycle life at a lower cost. Alveo is about a year away from sending out demonstration packages to interested parties.

Aquion, a sodium-ion startup out of Carnegie Mellon University, is focusing its products on long-duration storage for solar applications, providing cycles of 4 to more than 20 hours.

Flow Batteries

Flow batteries operate much like fuel cells: Two different electrolytes are pumped from separate tanks through a stack of electrochemical reaction cells to generate electricity. Enlarging the tanks prolongs the duration of the battery's *energy* output (kilowatt-hours) while enlarging the reaction cells increases the *power* output (kilowatts).

"One of the strengths of flow batteries is that they enable independent adjustments to energy and power, so that you can tailor the system design to your needs," said Westlake.

A 2015 EPRI survey of 20 commercial flow battery companies provides a snapshot of the market, including information on chemistry and products. According to the study, all-vanadium and zinc bromide chemistries account for the most commercially available products, with system power averaging 763 kilowatts and 1507 kilowatts, respectively. The most economic application of flow batteries is for daily discharging of 4 or more hours.

Pacific Northwest National Laboratories (PNNL) has pioneered flow battery technology, and three companies have licensed its vanadium battery design, which increased storage capacity by 70%. PNNL is developing an organic-aqueous flow battery with the potential to produce energy at $180 per kilowatt-hour, 60% less than the cost for vanadium flow batteries.

"We're in a battery chemistry renaissance," said Wessells. "There are many more new technologies being commercialized than you would have imagined 10 years ago. Most are not going to work out, but it is good for the industry that so many things are being attempted."

Key EPRI Technical Experts

Brittany Westlake

R&D Quick Hits

Synchronizing the Grid

Time for a "Time Guru"? Study Says Grid Reliance on "Precision Time" Offers Benefits and Cyber Security Vulnerabilities

Utilities increasingly rely on precision time as they deploy more automation and time-dependent applications on the grid, according to an EPRI survey of 24 companies. Such systems can synchronize all grid data to support reliability, safety, and flexibility.

Today, utilities typically require accuracy within 1 millisecond for such applications as digital fault recording, synchrophasor measurements, substation metering, and monitoring grid disturbances. They are planning significant deployment of network-based precision time protocol for synchronizing devices with sub-microsecond precision.

Along with the grid benefits, such systems bring cyber security vulnerability. EPRI has launched research to assess such risks and develop mitigations. Early results reveal that some applications supporting reliable power delivery, such as line differential protections, are susceptible to changes in global positioning systems. The research has also demonstrated that actors with malicious intent can effect changes in GPS operations.

"Military technology specialists and industry participants are now keenly aware that even a temporary loss of a portion of this infrastructure can cause significant disruption in critical applications," the study reports.

The authors state that many utilities would benefit from a "Time Guru"—a company leader who cultivates greater focus on precision time as critical infrastructure.

R&D Quick Hits

Augmented Reality: Breakthroughs Just Around the Corner

By 2018, utilities should see significant improvement in smart glasses, helmets, and other augmented reality devices, concludes an EPRI study.

“In the meantime, it is critical for companies to monitor technology developments, assess potential applications, and consider policy changes to accommodate new ways of working,” said EPRI Technical Executive John Simmins.

While technological barriers remain, innovation is rapid. Near term, the EPRI study predicts improved computational power, reduced size and power consumption, and breakthroughs in devices’ optics, lenses, and sensors. Vendors will introduce new options for connectivity, charging, and security, and ease of use will improve with new software.

Utilities are testing devices for applications such as inventory management, conduits and cables, ergonomics, safety, and weld inspections. EPRI has been involved in several vendors’ efforts to develop augmented reality prototypes that could provide technicians with work information as they perform tasks on substations, power lines, circuit breakers, and other assets. The technician interacts with the data using familiar gestures and voice commands.

Utilities may need to review and update policies and practices that conflict with augmented reality applications. For instance, many companies prohibit employees from using smart phones while driving, operating industrial equipment, and working in environments with sensitive information.

EPRI is also assessing additional worker safety measures to address ergonomics, eye strain, and awareness of the surrounding environment when using augmented reality devices.

R&D Quick Hits

Going Offline—At the Right Time

Uncertainties in a Changing Energy Grid Call for New Methods to Schedule Maintenance Outages

If your job were to repair potholes in a road where "rush hour" can happen at any time of day, you would need to be ready at a moment's notice and watch oncoming traffic carefully. Power plant and transmission system owners face a similar challenge today: With more renewables impacting the use of the grid and other generation resources, it's becoming much more difficult to schedule maintenance-related outages. EPRI has documented these challenges in a recent report and is examining the need for more sophisticated tools to make scheduling easier.

Owners typically submit outage requests to grid operators days, weeks, or even years in advance. Historically, it has been straightforward to schedule outages at times—such as off-peak demand—when the grid can continue to operate safely and reliably.

However, as more renewable and distributed energy resources come online, the grid will operate closer to its limits with respect to generation capacity and flexibility, transmission capacity, voltage, and stability. This makes scheduling potentially more difficult.

"While outages for fossil and nuclear power plants can be scheduled as far as five years in advance, solar power plants can be constructed and brought online in just weeks," EPRI Engineer Eamonn Lannoye said. "This mismatch of time scales is one factor that creates uncertainty for grid operators and asset owners."

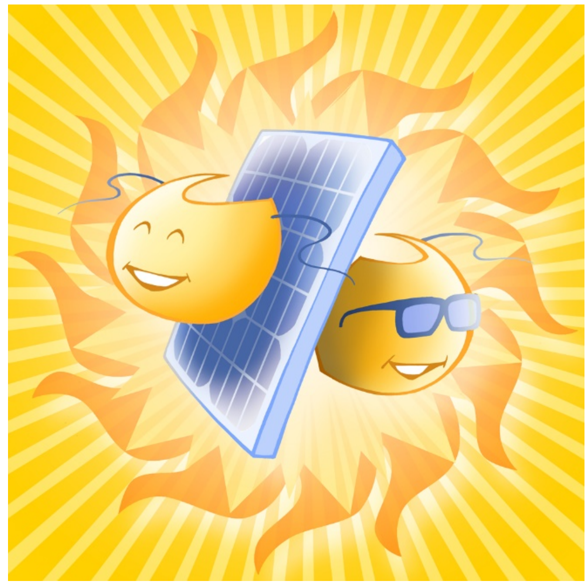
Today schedulers use a *deterministic* approach, which assumes that most data is known with certainty: When evaluating outage requests for a given month, grid operators use peak demand forecasts for that month. A *probabilistic* approach could help address forecast uncertainties by factoring in predictions of unknown parameters. This could involve, for instance, analyzing historical peak demand and wind and solar output—along with forecasts for several periods—to determine the likelihood of maintaining grid reliability during an outage.

EPRI is helping the electric power industry develop grid simulation tools that use probabilistic methods.

R&D Quick Hits

Soaking in the Sun from Two Sides

Field Tests Indicate Up to 30% Energy Boost for Bifacial Solar Modules



"Bifacial" solar modules offer the promise for greater electricity output, but they face significant challenges to widespread adoption, according to an EPRI technology assessment.

A key R&D focus in solar is increasing electricity generation over the lifetime of a solar power plant, and bifacial solar modules represent a potential step forward. Under controlled experimental conditions, these modules can boost power generation by as much as 50% relative to traditional modules, but field tests suggest an increase of 5–30%. The wide range is a result of factors such as plant design, the ground surface's albedo, and shading.

Bifacial modules cost more than conventional solar products (in dollars per square meter) because they require modifications to manufacturing equipment, processes, and materials. Increased market adoption may drive cost reductions through economies of scale.

A current barrier to broader use is the lack of an accurate model of power and energy generation to provide system owners with more certainty about product performance and financial benefits. Sandia National Laboratories, National Renewable Energy Laboratory, EPRI, and others are conducting field demonstrations to assess the technology's performance, and its use is being piloted in commercial power plants.

Also needed is a method to rate a bifacial module's nameplate power. Through the International Electrotechnical Commission, industry stakeholders are developing a technical specification to provide guidance on this rating. This can assist in developing a common approach for calculating the cost of bifacial modules (in dollars per watt).

R&D Quick Hits

Time, Location, and the Grid

EPRI Demonstrates Comprehensive Method to Model Benefits and Costs of Distributed Energy Resources

Can solar and other distributed energy resources (DER) help utilities serve load growth and avoid infrastructure investment?

The answer from an EPRI study: It depends on complex local factors, including load-growth rates, load variation over time, location and other characteristics of grid-connected DER, grid design, location and timing of grid upgrades, and environmental conditions. DER may benefit the grid in some cases, but not others.

Following the approach described in EPRI's Integrated Grid Benefit-Cost Framework, researchers modeled feeders in distinctly different distribution grids—Con Edison's mesh network in New York and Southern California Edison's radial system—and then analyzed grid impacts and societal costs of locating DER to meet load growth over 10 years. In some scenarios, DER costs were roughly the same as for traditional grid upgrades. In others, the costs were more than four times those of traditional upgrades.

Researchers determined that DER location is particularly important. For instance, to address load growth in a mesh network, DER must be tightly situated near a capacity-constrained asset to relieve it cost-effectively. In a radial grid, DER can address capacity constraints when located downstream of the substation. Reconfiguring radial grids, however, could redirect DER generation such that it could have little benefit with respect to avoiding traditional grid upgrades.

The results point to the need for comprehensive, consistent engineering methods for assessing DER's value in serving the grid as demand grows.

R&D Quick Hits

An Evaluation of Radio Frequency Fields Produced by School WiFi Systems

Emitted by radio and television broadcast stations, mobile telephone base stations, handheld mobile units, and other sources, radio frequency fields exist almost everywhere today. Although public exposure to these fields is generally minimal, growing use of WiFi in schools has raised questions about potential exposure to students.

This study examined the magnitude of radio frequency fields produced by WiFi systems in two northern California schools.

Understanding Clean Power Plan Choices in Kansas: Options and Uncertainties

The U.S. Environmental Protection Agency's Clean Power Plan requires states to create plans explaining how they would comply with mandates for power plants to reduce carbon dioxide emissions. This report examines compliance options in Kansas' state plan, using results of EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy model.

EPRI JOURNAL

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3002009252

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 | PO Box 10412, Palo Alto, California 94303-0813 | USA
800.313.3774 | 650.855.2121 | askepri@epri.com | www.epri.com