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BUILDING ALLIANCES FOR SPECIES PROTECTION

ALSO IN THIS ISSUE:

The Architecture for an Integrated Grid

From "Moonbeam Gas" to Shale Revolution to What's Next

Table of Contents

Building Alliances for Species Protection

New EPRI Program Facilitates Collaborative, Cost-Effective Efforts to Safeguard Plants and Animals

By Chris Warren

Shortly after Stephen Cain became manager of environmental compliance for the Arkansas Electric Cooperative Corporation in 2012, he had to take an unexpected crash course. He learned that the U.S. Fish and Wildlife Service had proposed designating several hundred miles of streams and rivers in Arkansas as critical habitat to support the conservation of two freshwater mussel species—the Neosho mucket and the rabbitsfoot. The federal agency, along with the National Marine Fisheries Service, is responsible for formulating regulations to protect threatened and endangered species. In September 2013, the Neosho mucket was listed as endangered and the rabbitsfoot was declared threatened under the federal Endangered Species Act.

Cain was concerned that the electric cooperative's staff and member companies would turn to him with questions about the potential impacts and scientific rigor of the proposed critical habitat designation. For example, could the designation limit the siting of distribution, transmission, and generation facilities?

"This was my first major experience with endangered species policy, and I needed a great deal of knowledge fast," he said. For help, he turned to EPRI, which had initiated a research project focused on endangered and protected species. EPRI provided a fact sheet that explained the listing process, factors considered in listing determinations, and stakeholder input. Cain shared the materials with a local stakeholder group—which included an association of county judges and the Arkansas Farm Bureau—formed to respond to potential regulations.

With the help of a biologist and economist hired to investigate potential impacts of the critical habitat designations, the group formulated public comments making the case that a less expansive critical habitat would still provide important protections to the mussels. The information informed agency decisions to reduce the extent of habitat designated as critical.

"Our comments supported protections for the species backed by hard science," said Cain. "This helped us to reduce the extent of critical habitat and the possible impact it would have on siting transmission and generation facilities."

New EPRI Program to Examine Key Issues, Pool Resources

For years, EPRI researchers have investigated science and research to inform stakeholders about policies and practices to protect endangered species. In the 1990s, EPRI Senior Technical Executive Robert Goldstein spearheaded the development of the "RAMAS" software that enables scientists and utility managers to predict how the construction of transmission and generation facilities may impact species populations. EPRI Senior Program Manager Jessica Fox has contributed to books about the Endangered Species Act and species protection strategies.

Prompted by the recent need to better inform power companies and other stakeholders about the science regarding regulatory developments, EPRI took a more in-depth, focused approach to research on threatened and endangered species protection. "When it comes to critical habitat designations, endangered species listings, and the best methods for protecting species, it's best to not be in reactive mode," said EPRI Project Manager Becca Madsen.

In 2016 EPRI launched its Endangered and Protected Species program to examine issues related to listing and delisting of species, critical habitat, and conservation planning—and to pool resources, data, and research findings. The objective is to inform the regulatory process by providing timely tools and analysis to determine the most effective, cost-efficient actions to protect species while limiting impacts to power company operations.

For decades, the electric power industry has taken steps to limit its impacts on species by complying with various state and federal laws, including the Bald and Golden Eagle Protection Act, the Marine Mammal Protection Act, the Migratory Bird Treaty Act, and the Endangered Species Act. For example, power plant operators have installed better water intake screens to prevent fish from being sucked into cooling systems.

Two trends have elevated the importance of endangered species protection. First, when the Fish and Wildlife Service accumulated a backlog of investigations to determine whether hundreds of species should be listed as endangered or threatened, environmental organizations sued the agency in the mid-2000s. A 2011 legal settlement required the agency to clear the backlog of candidate species and make final listing decisions on approximately 250 species by 2017. In addition, the Fish and Wildlife Service is now considering more than 500 species petitions that had previously been on the back burner. This could result in the designation of many more species as threatened or endangered, with significant impact particularly in the U.S. Southeast.

"Traditionally, most of the species listed have been in the U.S. Southwest and Northwest," said Nalini Rao, an EPRI project manager and technical leader. "In the Southeast, all of a sudden the number of endangered species could quadruple."

The stronger attention to endangered species in the West is due largely to California and other states' strictly enforced species protection regulations. The West also has a much greater proportion of publicly held lands. In contrast, the Southeast is primarily privately-held land, making it more difficult for the federal government to monitor species and enforce the Endangered Species Act.

The second trend is the deployment of large-scale renewable power plants, with potential impacts at plant sites and along the hundreds of miles of new transmission lines needed to connect them to the grid. "Any time there is construction, there is going to be some ground disturbance, and there's a chance you're going to need an endangered species permit," said Madsen. "Solar and wind facilities and transmission lines all fit in this category because they can impact various species."

Commitment to Collaboration

EPRI and its member companies viewed the Fish and Wildlife Service settlement as an opportunity to work collaboratively with other utilities, government agencies, and environmental organizations to gather the scientific information needed to support listing decisions—and potentially implement conservation actions that could make such listings unnecessary.

"All these groups have limited resources, and often little is known about the species," said Goldstein, who leads the Endangered and Protected Species Program. "The federal agencies have to make decisions about listings based on what they know, so it is in the interest of all parties to collaborate and share resources, data, and knowledge."

Indeed, one focus of the new EPRI program is sharing knowledge and facilitating collaboration through an online clearinghouse of endangered species research, government agency announcements, and lessons from utility conservation efforts. EPRI also helps to arrange networking and information sharing events for utilities, environmental organizations, and government regulators.

"We want government agencies and environmental organizations to use the results of our research," said Goldstein. "That means working directly with them and making them aware of our research."

Utilities can use these for siting grid infrastructure or evaluating whether to develop in their service territories. The tools developed can help stakeholders as they consider their own contributions to public discussions.

Opportunities with Conservation Planning

Recent EPRI research has laid the groundwork for the new program. In an analysis of the 250 species in the Fish and Wildlife Service's listing backlog, researchers identified species with habitat in multiple utility service territories, creating opportunities for collaboration among companies and government agencies.

"This research enables utilities with large service territories to work with federal, state, and local agencies and citizen groups on conservation planning to protect species," said Rao.

Last year, Rao investigated the option for utilities to develop habitat conservation plans—legally binding documents that outline specific steps a company will take to protect a species and minimize impacts from its operations. Such voluntary conservation efforts typically involve agreements with government agencies and other stakeholders. Plans can serve as positive actions toward species protection that might preclude the need to list a species as endangered or threatened.

"With habitat conservation plans, a utility would look at the local population of a species—its size, geographical extent, and current and historic changes—to determine the most effective conservation tools and actions," said Rao. "For example, the plan might specify a population size the utility wants to preserve and indicate that its operations will stay a certain distance from habitats such as nesting grounds and wetlands."

Effective habitat conservation plans can benefit all stakeholders. Government agencies can achieve beneficial results at lower costs relative to some alternatives, utilities can reduce uncertainty related to the regulatory process, and species can benefit from plans and actions that prevent habitat loss. In this way, the research aligns with the Fish and Wildlife Service's objective to make implementation of the Endangered Species Act and other species protection statutes more efficient and effective for all stakeholders.

While there are not yet data to confirm it, anecdotal evidence points to conservation plans as significantly cost-effective relative to more traditional compliance in some cases. For example, Southern Company invested $2.5 million to implement a habitat conservation plan known as a candidate conservation agreement to protect the

robust redhorse, a fish species near one of its hydro plants. By contrast, the utility has spent $20 million to comply with species hydro license obligations for the robust redhorse at a different hydro facility of similar size and capacity.

From Long Leaf Pines to Decision Trees

This year, researchers are investigating the possibility of developing habitat conservation plans that protect multiple species, rather than the typical single-species plans. According to Goldstein, one way to do this is to preserve a habitat vital to a number of species. “If you protect the long leaf pine ecosystem, you can also protect the red cockaded woodpecker and a host of other birds that build nests in it,” he said. Another project is examining whether general conservation principles—such as limiting tree cutting during bird breeding season and prohibiting mussel farming near stream banks—can be applied effectively across similar species.

“It’s possible, for example, that you could pool data for many butterfly species in different ecosystems and develop principles that can protect all of them,” said Goldstein. “You might have to fine-tune what you’re doing for individual species, but you could more efficiently implement conservation strategies by looking at the whole batch rather than just doing species one by one.”

Also underway:

- A review of field case studies to identify effective conservation tools, such as prescribed fires that remove nonnative species and enhance habitat for threatened and endangered species
- The creation of a practical primer to guide utilities through their options when species in their service territories are candidates for or are listed as endangered or threatened

“We are developing a decision tree that suggests different ways to approach conservation, including safe harbor agreements, habitat conservation plans, and other conservation planning,” said Madsen.

“As we decide on new research projects, we will keep our eyes on our main objective—to increase the efficiency and efficacy of species protection and get the biggest bang for the buck,” said Goldstein.

“In the rapidly transforming energy industry, right-of-ways for electric transmission and distribution lines, gas lines, large solar and wind plants, and other developments will lead to growing needs for endangered species conservation,” said Anda Ray, EPRI senior vice president for energy, environment, and external relations. “That makes this EPRI research good for the environment and good for business.”

Key EPRI Technical Experts

Becca Madsen, Robert Goldstein, Nalini Rao

The Architecture for an Integrated Grid

New Architecture of Software, Tools, and Test Beds to Integrate Millions of Grid Devices

By Garrett Hering

A century-and-a-half following the opening of Thomas Edison's laboratory and Alexander Graham Bell's invention of the telephone, the Internet of Things could truly integrate electric power and telecommunications, unlocking the potential of distributed energy resources and other emerging technologies.

EPRI's Integrated Grid initiative is working in diverse areas to integrate solar photovoltaics, storage, electric, smart meters, and other distributed devices at what is sometimes termed the "edge." For utility operations and planning, this offers immense potential to enhance grid efficiency, security, and sustainability—and to expand services and customer choices.

But for the grid to become truly integrated, all of its software and hardware must communicate and coordinate their operations. This is where "architecture" becomes instrumental.

EPRI's Technology Innovation program launched research to create an "Architecture for an Integrated Grid," providing a common language and set of rules for interacting systems and devices. This will lay the foundation for an information and communication technology infrastructure that enables compatibility and functionality of devices across the grid, including computer-based enterprise systems; utility-owned transmission, distribution, and generation assets; and customer-owned distributed energy resources.

"There are millions of interconnected devices on the grid today, but they are not integrated," said EPRI Technical Leader Karen George. "They do not speak the same language."

Today utilities use proprietary, legacy information and communications infrastructures that require custom-engineered solutions for each new system. This leads to "accidental architectures" that impede access and the flow of data needed for reliable grid operations, explained George.

From 'Accidental' to Intentional

EPRI's research is intended to provide software, tools, and test beds that help the electric power industry transform its various accidental architectures into one that is uniform, intentional, and nonproprietary.

"We are creating the architecture for the integrated grid," said George. "It's like the connectors in a Legos set. It enables everything to fit together."

"The idea is to enable utilities to adapt their existing systems and devices, to foster innovation of new applications, to enhance overall cyber security and communications, and to integrate distributed resources," added Matt Wakefield, director of EPRI's Information, Communication, and Cyber Security program.

All four EPRI research sectors are involved, along with other research initiatives such as the Smart Grid Interoperability Panel, the Grid 3.0 initiative, and the Wi-SUN Alliance.

In all, about three dozen organizations, initiatives, and companies are participating in the research, including utilities, technology vendors, laboratories, universities, government, and industry groups.

"For us to be successful in developing and implementing a common language, we need broad industry collaboration and adoption," said Wakefield.

The Five Pillars

EPRI's Architecture for an Integrated Grid project consists of five interrelated pillars at various stages of development:

- **Pillar One: The Enterprise Interoperability Platform**. The hub of the architecture, this network of software and computer hardware enables utility information and communications infrastructures to integrate legacy, new, and future systems. The EPRI-developed Common Information Model facilitates this interoperability. Research focuses on computing across different communication buses.
- **Pillar Two: Open Application Platform**. Similar to the way smart phones serve as platforms for apps, this computer-based platform will enable electric meters and other utility devices to "learn new tricks" after being installed, explained EPRI Principal Technical Leader Ed Beroset. With meters, for instance, utilities could load apps for power quality monitoring, billing data collection, and outage notification. For meters and other equipment, EPRI is helping vendors use advances in microprocessors and software to turn their products into platforms for innovation.
- **Pillar Three: Open Telecommunications**. Similar to how Wi-Fi and Bluetooth support communication among phones, computers, and other consumer products, EPRI is working with vendors to enable wireless, wired, and power-line-carried data transfer among grid devices and enterprise systems. In 2016, EPRI will complete a set of software to improve grid communications across the integrated grid architecture.

- **Pillar Four: Cyber Security**. The expansion of electronic data collection and exchange on the grid creates potential security vulnerability. EPRI will develop approaches that provide cyber security for the enterprise interoperability and open application platforms. This year, EPRI is working with the Smart Grid Interoperability Panel to enhance cyber security for its Open Field Message Bus initiative.
- **Pillar Five: Distributed Energy Resources**. EPRI is developing software and other tools to integrate distributed energy resources. For example, EPRI's OpenDERMS software enables utilities to manage distributed resources with data from smart inverters, providing an interface with grid operations.

EPRI has launched laboratory and field demonstrations of software, tools, and test beds to examine how each pillar supports the architecture.

Loading Apps onto Smart Meters

In 2015 at EPRI's Knoxville laboratory, researchers demonstrated that an EPRI-designed electric meter could support an application to verify the meter's proper operations.

"That's especially important after hurricanes, ice storms, or other severe weather that causes blackouts, because sometimes parts of the grid are reassembled a bit differently during restoration," said Beroset.

Later this year, EPRI will update the application programmable interface used in the demonstration meter and integrate it into a commercial device.

Communication Collaboration

Also in 2016, EPRI will complete software to improve communications across the integrated grid architecture. EPRI is developing the software with the Wi-SUN Alliance and has begun testing its application with advanced metering infrastructure and distributed energy resources.

Using this software, EPRI is working with vendors to achieve interoperable communication networks enabling data exchange among utilities, various models of meters, distributed energy resources, and distribution automation. With this open communications platform, third-party software programmers also can contribute enhancements.

"This would be a major step in creating an open architecture for an integrated grid because currently vendors of meters and other devices use proprietary interfaces that are not interoperable," said Wakefield.

Wearables Integrated with the Grid

EPRI has developed and demonstrated a prototype of a wearable Raspberry Pi computer for utility maintenance workers. A line worker, for instance, can use it to record still images or video of damaged transmission equipment, along with its geospatial coordinates. The device then generates maintenance work orders that are sent to an open-source workflow management software (called OpenWMS) via an interface supported by EPRI's Common Information Model.

The wearable computer—an important data-exchange building block for enterprise interoperability—can be used for work scheduling and other applications.

This fall, the team will update OpenWMS to support additional routine service messages. Many possible applications are under consideration.

"There's a lot of potential for worker safety," said George. Wearable computers could include sensors to measure invisible threats such as an electrical charge in a fence. Maintenance workers could use wearable computers to view augmented reality images of underlying utility infrastructure when visiting customer sites.

Vendors of wearable computers are using EPRI's cloud-based test harness to confirm that message formatting is accurate. This enables vendors to focus on the specifications and pricing of their devices.

Managing Distributed Energy Resources

As with smart meters and other grid devices, the different manufacturers and models of solar and other distributed energy resources challenge seamless communications. To address this, EPRI uses its OpenDERMS tool.

"OpenDERMS helps to aggregate the services of individual distributed resources and translate their different languages into one cohesive language," said George. "Utilities can't control deployment of these resources, but OpenDERMS can help manage them."

This year, EPRI is further developing the interoperability of OpenDERMS. Using the Common Information Model and another set of standards called MultiSpeak, EPRI is equipping OpenDERMS to receive web service messages so that it can manage and integrate communications between enterprise systems and distributed energy resources.

EPRI has used the test harness to validate these messages. As with vendors of wearables, knowing that communication is seamless enables distributed energy resource vendors to focus on their products.

EPRI will support utilities in applying OpenDERMS to grids in their service territories.

The Architecture for an Integrated Grid will enable the electric sector and society to benefit from the connected systems and devices in the emerging Internet of Things—an outcome that would surely impress Edison and Bell.

Key EPRI Technical Experts

Karen George, Matthew Wakefield, Ed Beroset

First Person—From "Moonbeam Gas" to Shale Revolution to What's Next

What Plentiful, Low-Cost Natural Gas Means for the Electric Power Sector

The Story in Brief

Vello Kuuskraa, President of Advanced Resources International and an internationally recognized expert on natural gas supply and markets, was among the first analysts to predict the North American fracking boom. Drawing from his deep understanding of natural gas resources and the technologies required to convert them into productive reserves, Kuuskraa speaks with *EPRI Journal* about the implications of the shale revolution for the electric power sector, the outlook for natural gas markets and prices, and how power companies can navigate potential price volatility.

EJ: How has your career shaped your current perspectives on natural gas supply and markets?

Vello Kuuskraa

Kuuskraa: When starting my work on natural gas resources nearly 40 years ago, I wanted to better understand how progress in technology could change the size, productivity, and economic viability of resources and expand the natural gas market.

My first major project was in 1978. It led to a three-volume report for the Energy Research and Development Administration (ERDA) on the status and potential of unconventional gas, which includes shale gas, tight gas, and coalbed methane. It examined how investments in research and technology could make these resources a bigger part of domestic supply.

The following year, my company provided much of the geological foundation and reservoir engineering to help ERDA and the Gas Research Institute implement numerous field demonstrations that enabled these resources to become economically viable. The projects included coalbed methane in Alabama and New Mexico, tight gas in the numerous basins of the Rockies, and the shallow Antrim

Shale in the Michigan Basin. A crowning achievement was my work with Mitchell Energy on the Stella Young #4 well. This Barnett Shale well in Texas demonstrated that if you increase contact with a natural gas reservoir using a slant or horizontal well and shatter the reservoir with high-intensity hydraulic fracturing, you could make deep shale gas resources much more productive and economic. The Stella Young #4 was three times more productive than the previously drilled Barnett Shale wells. Then I helped Southwestern Energy make the next major shale play, the Fayetteville Shale, commercially viable.

EJ: You were among the first analysts to predict the natural gas fracking boom in North America. How did you see it coming, and how did others in the natural gas industry react?

Kuuskraa: Through the Gas Research Institute demonstration projects and later engineering and geological services for the natural gas industry, I had the benefit of seeing firsthand the results of properly applying hydraulic fracturing and horizontal wells to coalbed methane, shale gas, and tight gas resources. I also knew from my company's extensive set of basin-by-basin, play-by-play resource assessments that the unconventional gas resource base was massive.

In the early 1980s, I built my company's unconventional gas resource, economics, and production model with two unique attributes—fine-grained resource data and an ability to project impacts of advancing technology on future well performance and costs.

In the 1990s, when I began presenting our natural gas outlook under the headlines "The Future is Unconventional" and "Progressing from Fears of Scarcity to Expectations of Plenty," there was considerable skepticism. Some attendees at an industry conference even called these unconventional resources "moonbeam gas." Much of this attitude was from other energy forecasting firms and industrial companies that had bought into Alan Greenspan's guidance that massive imports of liquefied natural gas would be the only solution to the upcoming natural gas supply crisis. With natural gas demand increasing and offshore wells and other domestic conventional resources getting depleted, others in the industry didn't believe unconventional gas could fill the gap.

"Still, I see considerable uncertainties for the outlook for natural gas use by the power sector."

EJ: How has the shale gas revolution affected the U.S. power sector's natural gas consumption? What do you see for future demand?

Kuuskraa: With increased availability of lower cost natural gas supplies and emphasis on lowering CO_2 emissions, the use of natural gas in the U.S. electric power sector jumped from 17 billion cubic feet per day (Bcfd) 10 years ago to more than 27 Bcfd this year, making it the largest fuel source for power generation. With nearly 20 gigawatts of new natural-gas-fired capacity due to come online in the next three to four years—mainly to replace older, less efficient coal units—I expect continuing growth in natural-gas-fired power generation, though at a less spectacular pace than in the past decade.

Still, I see considerable uncertainties for the outlook for natural gas use by the power sector. These include the timing for implementing the Clean Power Plan, the extent to which natural-gas-fired capacity will be needed as backup power for intermittent wind and solar generation, and the reliability and affordability of carbon capture and storage technology to make natural-gas-fired plants a zero CO_2 emissions source.

With continuing changes in the sources and locations of new supplies, I expect power companies to follow a variety of strategies to integrate with natural gas supply to support its reliable delivery to power plants. Recent examples include Southern Company's purchase of AGL Resources, the largest natural gas distributor in the

United States; Southern Company's acquisition of half of Kinder Morgan's Southern Natural Gas; and Duke Energy's proposal to acquire Piedmont Natural Gas. Other power companies may look to purchase or build natural gas storage and potentially even acquire production assets as hedges against future price volatility.

EJ: How does natural gas consumption in the electric power sector vary regionally in North America?

Kuuskraa: The South, even with substantial coal and nuclear plants, is the "600-pound gorilla" of natural gas consumption for power generation, using more than 16 Bcfd to generate more than 40% of its power. With significant nuclear and hydropower and a history of limited, higher cost natural gas before the onset of the Marcellus Shale, the Northeast offers growth opportunities when pipeline restrictions are overcome. The Midwest is still dominated by coal-fired power generation, with natural gas accounting for only 15% of generation, but the increasing westward flow of low-cost Marcellus and Utica shale gas makes this market ripe for expansion. The West—with low-cost coal, substantial hydropower, growing wind and solar power, and increasingly stringent carbon regulations in California—uses nearly 5 Bcfd of natural gas to generate about 30% of its power. It represents a challenging market area unless natural-gas-fired power can achieve zero CO_2 emissions with carbon capture and storage.

With the installation of new pipelines and the reversal of northward-flowing pipelines to move Marcellus and Utica gas south, I expect the Southeast to provide the bulk of the next phase of market growth for natural-gas-fired power generation.

"Having a reliable outlook for oil prices now becomes important for domestic electric power companies."

EJ: What are the risks of the electric sector becoming more reliant on natural gas?

Kuuskraa: Today's low-cost natural gas resource base and price situation is very different from those at the turn of the millennium when new gas-fired plants were stranded by high gas prices. Back then, new supply from offshore deep water resources and exploration for conventional gas fields had long lag times, resulting in extensive periods of price volatility. Therefore, a significant rise in natural gas prices was needed to bring on additional supply, drive down demand, and balance the market. Today, the large, lower cost shale and other unconventional gas supplies, with many active wells, can be brought to market much more quickly—within months instead of years. This reduced the lag between price signals and availability of new supply and decreased the need for longer term price increases to drive out demand. Periods of price volatility will be shorter than in the past. As a result, electric utilities that rely more on natural gas have lower supply and price risks now than they did 10–15 years ago.

To better understand this risk, it's critical to understand the nature of the natural gas cost-supply curve that sets long-term prices. Our company's approach has been to build a natural gas supply resource database characterizing the diversity of all the natural gas basins, plays, and smaller areas within plays in North America, including their break-even prices and resource volumes. This enables us to define a natural gas cost-supply curve comprised of nearly 1,000 distinct segments. We link our detailed database to our technology progress, resource depletion, and economic models to capture the dynamic nature of production, enabling reliable supply and price projections with fine-grained local and regional detail. Electric utilities can manage and reduce price and supply risks by understanding the natural gas cost-supply situation in their regions, and by integrating power plants with appropriate natural gas transportation, storage, and supply.

EJ: During the polar vortex of 2014, regional constraints in natural gas supply and distribution led to price spikes and strained U.S. power systems. How do you expect such events to impact the natural gas–electric interface?

Kuuskraa: There will be unexpected events, such as another polar vortex, that will stress the U.S. power and natural gas supply systems and create price volatility. In my view, however, these periods of price volatility will be much shorter than in the past because of the different nature of today's natural gas resource base, as I previously discussed.

Again, closer integration of power plants with natural gas transportation, storage, and supply can help power companies avoid shortages and manage price volatility.

"With the installation of new pipelines and the reversal of northward-flowing pipelines to move Marcellus and Utica gas south, I expect the Southeast to provide the bulk of the next phase of market growth for natural-gas-fired power generation."

EJ: How do you expect North American natural gas production, demand, and prices to change over the next 10 years? Are there factors that could cause price volatility?

Kuuskraa: With modest increases in natural gas consumption by the electric power and industrial sectors, plus strong increases in pipeline exports to Mexico, and liquid natural gas exports to other countries, I expect a significant increase in demand for U.S. natural gas—10 Bcfd over the next 10 years. The resource base is sufficiently robust to meet this demand without excessive price increases.

A number of factors will affect the efficiency with which supply and demand are balanced. One is the amount of natural gas produced from tight oil formations, which represents 20% of total U.S. natural gas production. Continued low oil prices will result in lower natural gas production from these formations and therefore less supply and higher prices. Having a reliable outlook for oil prices now becomes important for domestic electric power companies. A second factor is the availability of natural gas imports from Canada, where a similar unconventional gas revolution has dramatically expanded supply. In my view, this will enable Canada to continue providing significant exports to the United States.

"One key [research] area is assessing the North American natural gas supply-cost curve and how the race between the competing forces of resource depletion and technology progress is playing out in different areas."

EJ: In the media, we can find many expert projections about natural gas prices. How can nontechnical readers view these with a critical eye?

Kuuskraa: Projections for prices range from "low forever" to "sharply rising," causing considerable uncertainty for nontechnical and technical readers. Some of this reflects valid uncertainties, but many "flavor of the month" projections reflect emotion and hope rather than analytical rigor. To help decide which experts to trust, readers should look at their track records—have their projections generally been on- or off-target? Readers can also evaluate the consistency of an expert's projections. Do they fluctuate dramatically from month to month, or do they provide a consistent year-to-year trend with accommodations for short-term price volatility? This will help the reader understand if there is analytical rigor and a valid supply-cost curve behind the projections. When a

projection changes, does the expert provide a sound rationale? Finally, is the expert neutral, or does he have some "skin in the game"?

EJ: What research is needed to help U.S. electric utilities determine the most reliable, cost-effective use of natural gas?

Kuuskraa: One key area is assessing the North American natural gas supply-cost curve and how the race between the competing forces of resource depletion and technology progress is playing out in different areas. Also important is gauging the extent to which deployment of intermittent wind and solar generation will require closer integration with natural-gas-fired generation. The power industry can also benefit from examining the benefits, costs, and risks of greater integration of electric power generation with natural gas transmission, distribution, storage, and supply, and from sponsoring research and field demonstrations of CO_2 capture and storage from natural-gas-fueled power plants.

The views and opinions in this interview do not necessarily reflect the views of the Electric Power Research Institute.

EPRI Examines the Electric–Natural Gas Interface

Natural gas markets are rapidly changing, and EPRI is building an advanced model to better understand the drivers and dynamics of supply, demand, and interregional delivery. This project will assess energy and environmental policy proposals related to natural gas and inform utility investment decisions on new natural-gas-fired generation, environmental retrofits, and additional natural gas delivery capacity.

EPRI's Environment Sector offers EPRI members the opportunity to participate each year in a Natural Gas Interest Group—a collaborative forum for power companies to improve their understanding of the supply, demand, and pricing of natural gas and the implications for the electricity sector. Participants learn about relevant research at EPRI and elsewhere, discuss emerging natural gas–electric issues, and have opportunities to engage with regulators, developers, and scientific, engineering, and environmental organizations.

Innovation

Predicting Failures with EPRI's Transmission Asset Database

Records on Nearly 50,000 Components from 80 Utilities Inform Asset Planning and Budgeting

By Matthew Hirsch

Twenty years ago, EPRI's utility collaborators started reporting the premature failure of polymer insulators on high-voltage transmission lines where rubber had worn out from exposure to high electric fields or the seals had failed.

Polymer insulators are widely used in the utility industry because they are smaller, lighter, and less expensive than glass and ceramic insulators. Utilities needed to know how many were susceptible to failure and whether the problem could be narrowed down to a subset of units.

"It's tough to convince utility executives that they need to spend $30 million to replace polymer insulators just because field workers at their own company are reporting that some of them are failing," said Dr. Andrew Phillips, EPRI director of transmission and substations.

Using EPRI's growing database on performance of transmission assets, utilities had information about 388 failures of polymer insulators on high-voltage transmission lines dating to the late 1970s. This helped them isolate the problem to one out-of-business vendor.

"Utilities have used this data to remove from service an entire inventory of polymer insulators of a specific family, make, and model and improve grid reliability," Phillips said.

The performance database groups 11 transmission assets, such as insulators, transformers, circuit breakers, and conductors. It contains records from 80 utilities in the United States, Canada, the United Kingdom, Malaysia, Taiwan, and Australia, including 43,213 in-service assets, 4,746 failures, and 1,832 assets that have been retired or taken out of service. EPRI is incorporating analytics into the database. For instance, utilities have also used it to develop a year-by-year prediction of substation transformer and circuit breaker failures along with strategies for spare parts inventory and online monitoring. The North American Transmission Forum (NATF), an industry association that enables utilities to share information outside the regulatory arena, is a key collaborator in expanding the database.

Strength in Numbers

Thirty years ago, when transmission equipment failed, an asset manager would record and file descriptions of the equipment and causes of failure. Although such records may now be on the manager's computer hard drive or a networked drive, analyzing such data remains time-intensive, making it difficult to plan and budget for equipment repair and replacement.

Even if a single utility has a well-structured database recording its own failure data, the data set's small number of component failures and different component applications make it statistically invalid. By combining such data from across the power industry, EPRI's database provides a data set statistically valid for making informed asset management decisions on when to replace, refurbish, monitor, and buy spares for specific assets. It also enables utilities to make inferences on performance by asset family, make, model, application, and age.

Staff at participating utilities log into EPRI's system to enter failure data, including type of component, manufacturer, photos, and laboratory reports. EPRI experts review all inputs before posting to the database.

Utility experts can view data in charts, graphs, and other formats and analyze a catalog of their component failures alongside related failure data from the rest of the industry, providing a benchmark for performance. Users can sort and chart industry-wide failures by component type, cause, manufacturer, rated voltage, location, and other attributes, helping to identify high-risk units and informing decisions on R&D priorities. For example, one company concerned about its 69-kilovolt transformers determined that it would have to acquire 18 spares to account for aging equipment with a high probability of failure.

Data security is essential to the project's success and growth. To preserve confidentiality, utilities can view their own data but only aggregated data from other utilities.

This year, EPRI is expanding the database to track performance for 14 new components in overhead power lines, substations, and underground transmission, and another 17 are expected to be added in 2017 (see table below).

A Growing Database of Transmission Assets		
Assets in Current Database	**Assets to Be Added in 2016**	**Assets to Be Added in 2017**
Overhead Line Components		
Conductors	Arrestors	Foundations
Connectors	Glass, porcelain, guy strain insulators	Marker balls
Polymer insulators	Shield wire	Dampers
Structures		All-dielectric self-supporting and optical ground wire fiber-optic cable
		Switches
		Hardware
Substation Components		
Bushings	Coupling capacitor voltage transformers	Reactors
Transformers	Arrestors	Connectors
Circuit breakers	Current transformers and voltage transformers	Post insulators
	Capacitor banks	Raceways
	Disconnect switches	Ground grid
	Electromechanical relays	Digital relays
		Control cable
Underground Components		
Extruded joints	Pipe-type cable systems (including joints, terminations, cable, accessories, and cathodic protection)	Self-contained, fluid-filled systems (including joints, terminations, cable, and accessories)
Extruded termination		
Extruded cable		

Key EPRI Technical Experts

Andrew Phillips, Bhavin Desai

Technology At Work

Alternative, Well-Engineered Weld Repairs in Grade 91

By Garrett Hering

After years of service at high temperatures in coal- and natural-gas-fired power plants, even the strongest steel components succumb to routine wear and tear. For Grade 91 steel tubing, piping, and other components, repairs such as field welding and post-weld heat treatment can be difficult.

Until recently, the National Board Inspection Code (NBIC) did not include guidelines specific to weld repairs of Grade 91 steel. As a consequence, owners and operators of power plant components fabricated from this material have had to follow rules for new plant construction, which require the use of a matching filler metal and post-weld heat treatment. EPRI and others, however, have documented that such approaches are not appropriate for all weld repairs. Post-weld heat treatment is costly, often complex, and can cause signification degradation of the material's performance.

"Weld repairs can be complex, and many component failures have occurred because of improper heat treatment," said John Siefert, EPRI's principal technical leader for research on alternative approaches. "Grade 91 steel is increasing in use, and changes are being made in the repair rules."

Code Revisions

Since 2010, EPRI's Fossil Materials and Repair Program has collaborated with key stakeholders in the power generation industry to develop well-engineered alternatives for Grade 91 steel tubing in steam boilers at coal plants and heat recovery steam generators (HRSGs) at gas plants, as well as in piping and other components.

As outlined in recent EPRI guidelines, these options avoid post-weld heat treatment. For internal boiler and HRSG tubing repairs, for example, the welding method relies on a nickel-based filler material. For repairs of balance-of-plant Grade 91 steel piping and other components, alternatives include nickel- and iron-based fillers and a reduced temperature post-weld heat treatment.

To initiate a code review, EPRI engaged with NBIC members, which include chief boiler inspectors for U.S. states and Canadian provinces. In 2015, NBIC formally approved EPRI's approach for tubing inside boilers and HRSGs, codifying it in Welding Method 6 in Part 3, Repairs and Alterations. Subsequent discussions have resulted in methods to address balance-of-plant repairs outside boilers and HSRGs. The code's 2017 edition may add these in a supplement, pending final determination later this year.

Transfer to Industry

EPRI is prioritizing transfer of the methods to industry. With support from EPRI staff and guidelines, the Tennessee Valley Authority (TVA) in 2014 repaired a Grade 91 steel valve on the main steam line at its Southaven combined-cycle–natural-gas plant near Memphis.

As the world's first such repair without post-weld heat treatment, it validated the approach, documented $5,000 in cost savings, and reduced the outage by three days—avoiding about $1 million in lost electricity sales.

"The outage time savings could vary by a few hours depending on pipe and component sizes," said Dale Sielski, a metallurgical engineer and welding services specialist at TVA.

In 2015, American Electric Power (AEP) achieved similar savings by applying EPRI's approach to a boiler tube at its coal-fired Cardinal Plant Unit 2 in Ohio. The repaired tube continued to operate without problems until it was replaced four months later. EPRI is evaluating the integrity of the repaired tube to assess the component lifetime enabled by such repairs.

"That's important because it can take a year or longer to receive replacement components after they are ordered, as some must be fabricated first," said AEP Principal Welding Engineer Michael Crichton, who helped inform EPRI's best practices guide. Based on EPRI's evaluation, which includes destructive testing, AEP and other power companies will gain further insights into the long-term performance of alternative weld repairs.

"EPRI will continue transferring its weld repair research to industry, while developing targeted guidance on additional common components and connections," said Siefert. These include small-bore connections, where smaller steam pipes connect to main steam pipes or headers, and other welded joints. EPRI also plans to develop weld repair approaches for components made with other steels used in power generation.

TVA's Sielski welcomed the additional research plans while cautioning, "Any procedure you develop is only as good as your welder's willingness to follow the actual steps and not add creativity."

Key EPRI Technical Experts

John Siefert, Jonathan Parker

Technology At Work

It's Your Move: Enhancing Ergonomics at Power Companies

EPRI Tool to Help Utilities Prioritize More Than 100 Ergonomic Interventions

By Matthew Hirsch

During recent site visits with EPRI and several member utilities, Dr. Richard W. Marklin, Jr. was pleased to observe that many power companies have replaced manual tools with battery-powered versions designed to put less stress on the body.

"Battery-powered tools have come a long way over the past 20 years," said Marklin, a Marquette University mechanical engineering professor and EPRI principal investigator who has worked with electric utilities for two decades to reduce physical stress and workplace injuries.

With a manual compression press, one of the most physically stressful tasks for line workers is crimping electrical connectors to hold together two power line sections. Ergonomics researchers have found that only 1% of females and 50% of males can exert the force needed to make one manual crimp of a connector. Using a battery-operated press, nearly everyone can perform this common task. Current battery-powered models are smaller and lighter than older models, and they use an inline, rotating grip instead of a pistol-grip to reduce strain on joints (see photo).

Battery-powered crimping tools
(photo courtesy of Dr. Richard Marklin)

Manual crimping tools
(photo courtesy of Dr. Richard Marklin)

The use of battery-powered tools is one recommendation in a series of seven handbooks that Marklin's team has produced with EPRI's Occupational Health and Safety Program over the past 15 years to help utilities reduce occupational injuries and related costs. Handbooks are written for specific groups of utility workers, such as overhead line workers, underground and substation technicians, and mechanics and electricians. They highlight tasks with risks of injury along with interventions to reduce injuries and improve safety. According to EPRI's ongoing Occupational Health and Safety Database study, about 3% of line workers have ergonomics-related

injuries each year, and all injuries to line workers accounted for 28% of medical claim costs for electric utility workers from 1995 to 2013. “These results have revealed the high percentage of medical claims costs related to ergonomic injuries and helped focus our research priorities in this area,” said Dr. Lovely Krishen, program manager of EPRI’s Occupational Health and Safety Program.

“Members have reported a decrease in ergonomic-related injuries after adopting EPRI-recommended interventions,” said Krishen. “It is satisfying to see direct safety benefits from this research.”

Now EPRI, Marklin, and Duke Energy are developing a decision tool to help utilities quickly prioritize and apply the approximately 100 ergonomic interventions described in the handbooks. When completed in 2017, the software will integrate a decade of data from four utilities on ergonomic interventions, along with information from the EPRI handbooks on each intervention’s potential time savings, occupational health benefits, and cost to implement.

Utilities can use the tool to compare interventions with respect to potential costs and benefits. Comparisons will be possible both within an occupational group and across groups, such as overhead line workers and manhole/vault workers.

Site visits were integral to the tool’s development, relying on the first-ever formal survey of utilities’ ergonomics interventions over the past decade. During visits to four major electric utilities, Marklin and EPRI researchers asked safety personnel to answer three questions about each of the 100-plus interventions in the handbooks:

1. Did the utility consider changing work processes?
2. Did the utility then change work processes?
3. If so, why?

EPRI-member utilities have been implementing recommendations in the handbooks for 15 years, and the preliminary survey results confirmed that among the most common interventions are replacing manual tools with battery-powered versions.

Bucket Truck Controls: Next in Line for Ergonomic Redesign

For years, the EPRI ergonomics research team has heard anecdotal reports from overhead line workers about how operating the aerial bucket on a bucket truck can tire arm and hand muscles. Workers reported that the typical pistol grip used for bucket control causes muscle fatigue in the forearms.

Informed by years of research with EPRI’s members, development is underway for a pistol grip powered by the same batteries used in common cutter and crimping tools to reduce the force needed for operations and to decrease muscle fatigue.

Slated to be ready for service in 2017, replacement should be simple, requiring only the removal of four bolts and the old grip, and attaching the new one with similar fasteners.

Key EPRI Technical Experts

Lovely Krishen

Technology At Work

Ringhals Adopts EPRI Guidelines for Nuclear Safety

Swedish Utility Saves a Decade of Research Time

By Brent Barker

In the 1980s, Sweden decided to phase out nuclear power by 2010, but policy changed in 1999, allowing all but two nuclear plants to plan for operation beyond 40 years. Although reactor safety inspections had always been rigorous in Sweden, the nuclear utilities did not have aging management programs.

Swedish utility Ringhals AB is preparing for continued operation of its pressurized water reactor Units 3 and 4 as they approach the end of their 40-year licensing periods in 2021 and 2023, respectively.

"The Swedish nuclear regulator requires that we have an effective aging management structure, and we need to apply it fairly rapidly to meet the regulator's deadlines," said Pal Efsing, senior specialist in materials mechanics at Ringhals. "We got a late start and turned to EPRI for support." Based on previous engagement with EPRI, Efsing suggested that Ringhals join EPRI's Materials Reliability Program to gain access to more than 30 years of research on aging of materials and aging management.

"My view was that if we adopted the system built in the U.S. around the U.S. Nuclear Regulatory Commission's Generic Aging Lessons Learned report and the associated EPRI guidelines to inform compliance, we should be able to meet our deadline," said Efsing. "This would also make it easier for our regulators to benchmark our measures and discuss them with other regulatory bodies."

Aging Management in the United States: An Approach Refined Over Many Years

In the United States, life extension had become a pressing concern by 2000. In 2009, the first of the pressurized water reactors would reach the end of its 40-year operating license, with others following in quick succession. Forty years of continuous irradiation and intense mechanical, thermal, and pressure loading takes a toll on components.

In 2001, the U.S. Nuclear Regulatory Commission (NRC) published the first version of the Generic Aging Lessons Learned report as the technical basis for license renewal. It called for a detailed aging management program backed by solid research and approved by the NRC for a 20-year renewal.

"From the outset, the U.S. regulators pointed to the aging issues that they were most concerned about for license renewal," said EPRI Technical Executive Al Ahluwalia. "They required nuclear operators to prove that they will effectively manage the aging process during extended operations."

EPRI served a key role in informing the industry's response. "To begin, we assembled a team of world experts and said, 'Here are the plants, the materials, and the exposures in different parts of the reactor. Tell us what can go wrong,'" said Ahluwalia. "The result was a comprehensive Material Degradation Matrix."

Then, EPRI worked with plant owners to identify those areas of greatest consequence in terms of safety and economics, and the resulting Issue Management Table had four areas of concentration:

- Reactor core internals (the biggest concern for aging management)
- Areas where the control rod drive mechanism penetrates the reactor's upper head

- Areas where nozzles carry water in and out of the reactor vessel
- Bottom-mounted instrument nozzles that route instrumentation into the reactor core to measure radioactivity

“This table effectively became our bible, guiding us on where to focus our research,” said Ahluwalia.

Following years of research in these areas, EPRI published a series of Inspection and Evaluation Guidelines that operators can use to develop aging management programs and meet NRC requirements.

“These guidelines tell operators where, when, and how to inspect, laying out a rigorous schedule,” said Ahluwalia. “Following them in an aging management program covers 70–75% of compliance.”

Applying EPRI’s Guidelines in Sweden

U.S. reactors are on average about 10 years older than those in Sweden, and the timing of Ringhals’ access of EPRI’s guidelines was fortuitous.

“By implementing the EPRI way of aging management, we probably saved 8 to 10 years of our own research time,” said Efsing. “Further, we should be able to accelerate our safety review process by as much as 5 years and save at least $5 million in avoided costs.”

For these efforts, EPRI’s Materials Reliability Program and Ringhals received a 2015 EPRI Technology Transfer Award.

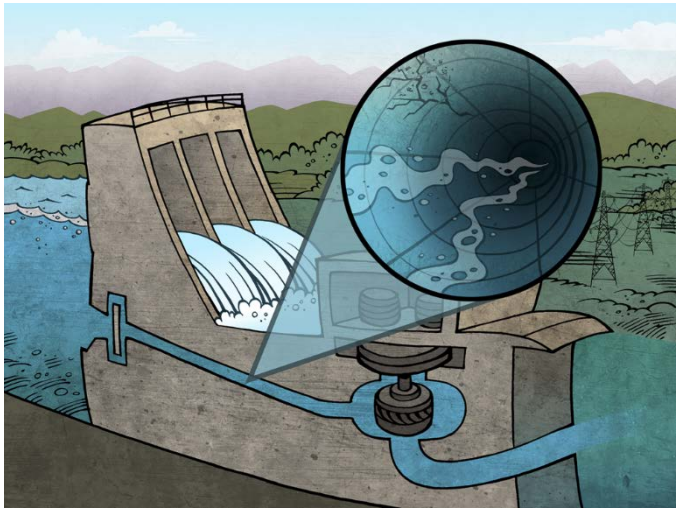
Key EPRI Technical Experts

Al Ahluwalia

R&D Quick Hits

Inspecting Hydropower Plants: Unleash the Robots

EPRI Sizes Up Autonomous, Underwater Inspector-Bots



EPRI research sees significant potential to better inspect hydroelectric plants' underwater structures with autonomous, untethered vehicles. Research also points to the need for additional technology development.

A survey of government agencies, hydropower operators, utilities, and electric cooperatives identified the need for such vehicles to inspect tunnels and penstocks. This can replace the use of divers and help mitigate related safety hazards. Tethered vehicles today can travel only limited distances in hydro plants' tunnels.

To assess the state of the technology, researchers looked far afield, in oceanography, disaster recovery, oil and gas exploration, and other industries. They found 40 manufacturers, 16 inspection companies, and approximately 280 vehicles of various sizes, shapes, and capabilities, along with a range of sensors such as cameras, lasers, sonars, and pressure monitors.

For hydropower inspections, EPRI has active projects to adapt the vehicles, tracking and positioning systems, and sensors, followed by demonstrations at a hydropower facility. Work is also aimed at improving processing and analyzing such inspections' large data sets.

Hydropower provides zero-emissions electricity and its flexible dispatch supports intermittent wind and solar energy. But the aging U.S. hydropower fleet could serve a diminishing role unless better inspection and maintenance can improve its cost-effectiveness. The U.S. Energy Information Administration reports that 85 gigawatts of the United States' 100 gigawatts of hydropower capacity were more than 30 years old as of 2010.

R&D Quick Hits

Smart Inverters Are Getting Smarter

At Four Field Sites, EPRI Demonstrates Standard Grid-Support Functions and Communications

Working on distribution grids in Massachusetts and Michigan, EPRI, DTE Energy, Pepco Holdings, and National Grid successfully demonstrated standardized smart inverter grid-support functions and utility control of inverters using a standard communications protocol. These milestone field tests mark a key step toward enabling grid operators to manage high penetrations of solar photovoltaic (PV) generation, and they are the culmination of a four-year project under the U.S. Department of Energy (DOE) SunShot Initiative to develop, analyze, and test smart inverters in the lab and field.

Prior to this research, there were no standard grid-support functions and communications protocols implemented in inverters. With only manufacturers' proprietary functions and protocols in place, operators have had a difficult time integrating different PV products into distribution grids. Since 2009, EPRI has been working with DOE, DOE's Sandia National Laboratories, and the Smart Electric Power Alliance (formerly Solar Electric Power Association) to define and codify a set of functions and protocols with standards organizations, including the International Electrotechnical Commission.

Other insights from the field tests:

- There is significant value in enabling inverters to automatically adjust their own actions in response to local grid parameters, such as voltage and temperature.
- Communication systems between inverters and grid operators should be configured to detect communication loss quickly, restore connection automatically, and apply logical default settings.
- Inverters need to measure grid voltage more accurately for better performance.
- Demonstrations are needed on distribution feeders with higher PV penetrations.

R&D Quick Hits

Taking the Call Center to the Next Level

Utilities Can Learn from Netflix and Other Successful Companies

Using the data and analytics available today, utilities have the opportunity to transform their traditionally reactive customer call centers into business and information centers, according to EPRI research.

For ideas and inspiration, utilities can look to companies in diverse industries that use customer analytics effectively. Netflix, for example, uses data on what, where, when, and how subscribers watch programming to personalize their viewing experience, and taps its vast database of user behavior to guide development of its original programming.

For utility customer programs, automated analysis of demographic data, consumption history, and past program enrollments can suggest potential preferences, providing call centers with defined opportunities to meet customers' needs. For example, when speaking with electric vehicle or rooftop solar owners, call center operators may inquire about their interest in energy management programs.

Most customer calls are outage reports, billing inquiries, or requests to start or stop service. Analysis of caller identification, outage management systems, bill histories, and other data can help the call center predict the reason for a call and route it to the proper department, preventing customer frustration. Analytics could even be used to notify customers of problems before they call about them. A system can spot unusually high power consumption and automatically alert the customer well before the end of the billing cycle.

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