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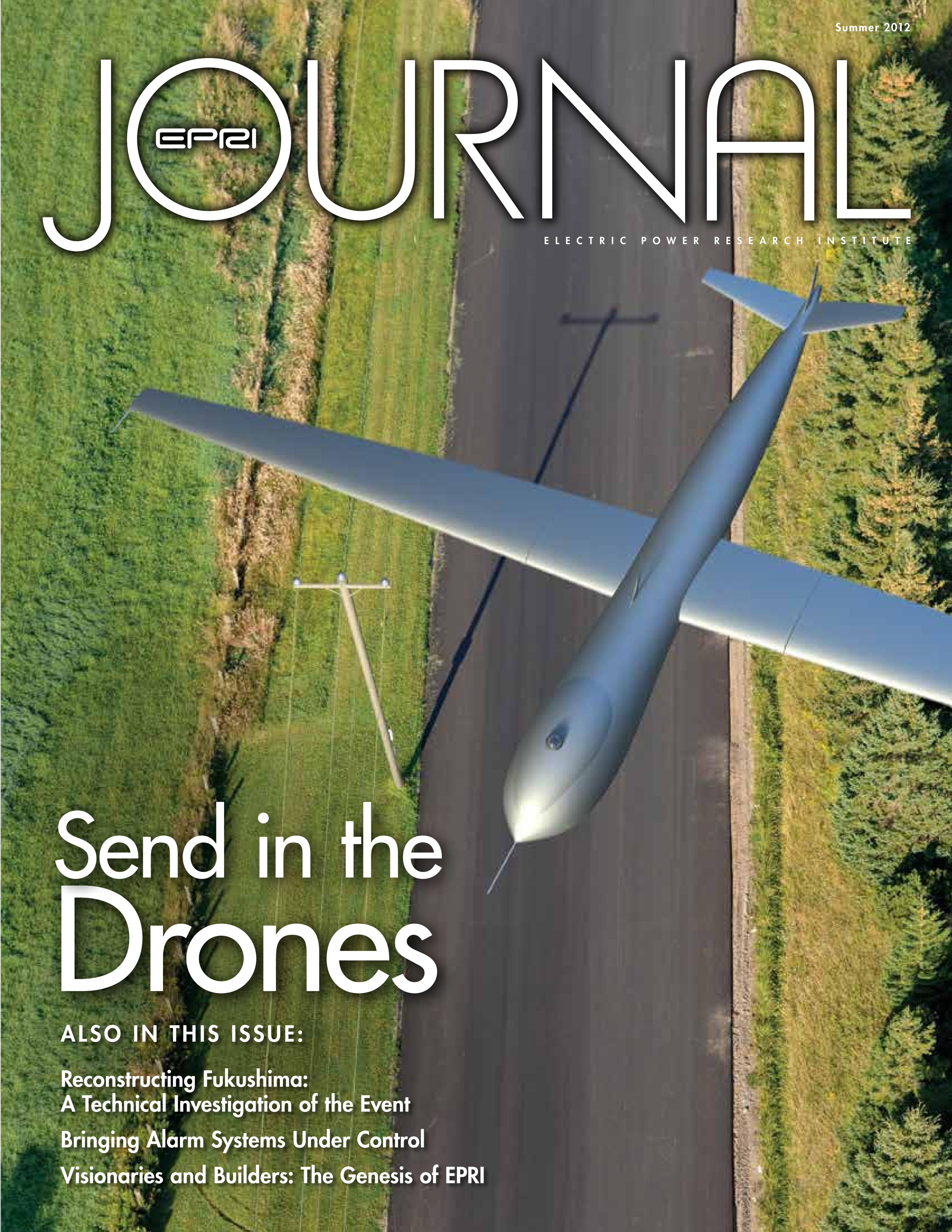

Send in the Drones

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Reconstructing Fukushima:
A Technical Investigation of the Event

Bringing Alarm Systems Under Control

Visionaries and Builders: The Genesis of EPRI

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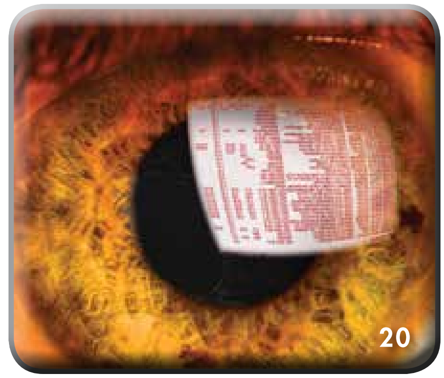

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VIEWPOINT

by Mike Howard, President and CEO, EPRI

The Long View, the Big Picture, and the Small Screen

Two things are essential in research and development (R&D): Take the long view, and look at the big picture. There's a third imperative I'd like to add: Make use of the small screen. By small screen I mean the smart phones and tablet computers that are becoming the cornerstone of our work and everyday lives.

EPRI's Research Advisory Committee, along with Enel, Eskom, and E.ON AG, recently hosted the International Technology Innovation Summit. We brought together chief technology officers and R&D leaders from around the world to look at technologies, economic and social trends, and the ways that electricity providers are driving R&D.

Arshad Mansoor, EPRI's senior vice president of research and development, led a discussion at the summit in which we examined the potential of these small-screen devices to drive significant change for electricity providers. From the launch of smart phones, their sales surpassed 500 million units in just over four years. Since the release of Apple's iPad tablet in 2010, more than 67 million units have been sold. That equals about one iPad per 100 people, and the number continues to grow at a fast pace.

In the past couple of years, EPRI researchers have rapidly expanded the scope of our work and thinking with respect to mobile applications and the electricity sector. You will see more on this in the coming months and years.

Already, Commonwealth Edison and other utilities are equipping their customers to monitor their usage and pay their bills or to check the status of power outages. We can see already how the once clunky programs and processes of load control will be replaced with something that is more real-time, intuitive, and user friendly, which will be essential for the interactive grid of the future.

Likewise, utility workers will use the smart phone's camera, GPS, and custom-made tools and applications to monitor, diagnose, and correct problems in power generation and delivery




systems. Some of these problems might even be detected in real time and fixed much more rapidly than they are today.

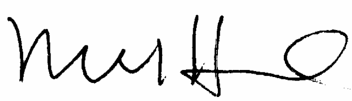
Social media and engaging applications have the potential to spark new interest and participation in customers' energy monitoring and use. Forty years ago, if a power company opened a drive-in window to facilitate bill payment, it was considered meeting the customer halfway. In the future, if utilities don't cross the digital divide, they won't meet most of their customers at all.

Social scientists have described Generation Z—those born beginning in the early 1990s—as "digital natives." Many of these people will never write cursive, carry a clipboard, mail a letter, or read a technical R&D report in a bound copy (even now, bound books are being replaced by digital editions). I can reasonably predict that none of them will deliver a monthly payment check to the local utility branch office or have a friendly conversation over the back fence with the neighborhood meter reader. It is partly with this generation in mind that we are creating an app for this publication, beginning with the iPad. (See inside back cover.)

In mid-2012, EPRI released its findings from a study of the energy required to charge an Apple iPad. Focusing on the leading example of tablet computers at the time, the study provided an opportunity to direct the public's attention to energy use, at both the personal level and the aggregate level. The release was reported in more than 2,000 media outlets in more than 24 countries,* and it provided us at EPRI with a clear indication of the value and interest these devices hold for consumers.

It's fair to say that this release has prompted much greater awareness of energy use by a range of devices and will result in more consideration of the implications for the devices and overall energy use. It also reminds us that the competitive drive to improve battery performance, even in these small devices, could have implications for larger batteries, electric transportation, and energy storage. Those are all part of the same big picture.

As I consider the long view, it is hard to imagine a future without the small screen. As I scan the big picture, it is equally difficult to imagine all of the changes that will result.



Michael W. Howard
President and Chief Executive Officer

* *The first big wire service story was generated by someone's posting a "tweet" on Twitter.*

SHAPING THE FUTURE

Innovative approaches to upcoming challenges

The Effects of CO_2 on Groundwater

Capturing carbon dioxide emissions from industrial sources and injecting the CO_2 deep underground in geologic formations is one of several options being considered to manage carbon emissions. Much of the work on carbon capture and storage has focused on the science and mechanics of the capture process. However, to make the capture and storage option viable, gain public acceptance, and avoid exchanging one environmental problem for another, stakeholders must understand the potential environmental risks associated with an unexpected release of CO_2 from a geologic storage reservoir. One such risk involves breach of containment and subsequent migration of CO_2 into shallow storage-site aquifers containing potable groundwater.

Although the risk of CO_2 migration from a storage reservoir is considered to be very small with proper site selection/characterization and a regulatory framework designed to oversee, monitor, and control risk, EPRI initiated a three-year field study in 2010 to assess the potential impact that a controlled release of dissolved CO_2 could have on shallow groundwater. In addition to investigating the effects a CO_2 leak could have on drinking water, the study will help define protocols for early detection and monitoring of CO_2 in potable drinking water aquifers.

Capturing Real-World Data

The study simulates a hypothetical CO_2 leak from a deep geologic storage reservoir into an underground source of drinking water by injecting carbonated groundwater into saturated sand and observing the effects. One particular concern is that CO_2 migration to an underground drinking water formation could mobilize heavy metals by changing the pH of the water, causing materials from the formation's rock to leach into the water. The study is expected to clarify such geochemical interactions.

Other goals are to calibrate and validate computer models used to predict the fate and transport of CO_2 and metals, provide the knowledge needed to formulate future strategies for remediating any CO_2-impacted groundwater, and inform stakeholders of the environmental risks associated with CO_2 storage.

Experiment Setup and Initiation

Researchers began the work by using hydrological, geophysical, and geochemical techniques to establish a baseline characterization of the site's groundwater quality and hydrogeological heterogeneity. This baseline is the reference point for comparing pre- and post-injection results and concluding whether CO_2-induced impacts have occurred. Characterization of site sediments and evaluation of reactive transport mechanisms were

augmented with laboratory-based studies that helped determine the best approaches to pursue on site.

The project team initiated baseline sampling in October 2010 and continued sampling throughout 2011 up to the time of dissolved CO_2 injection. The sampling was supplemented in July 2011 with geophysical monitoring using complex electrical tomography to evaluate changes in electrical resistivity and phase during injection and to help track the position of the dissolved CO_2 and chemical changes in the groundwater system.

The baseline groundwater samples were found to contain trace metals and major ion concentrations that were either below their respective detection limits or very stable with time. Iron, molybdenum, manganese, and sulfate exhibited the greatest fluctuations in concentration. Baseline measurements were made both under static hydraulic conditions representative of the natural groundwater flow system and under the dynamic conditions characteristic of pumping and injection.

The research team developed and installed an innovative fluid-delivery system to carbonate the groundwater and inject dissolved CO_2 into the subsurface. A tracer test using argon dissolved in the groundwater allowed researchers to establish groundwater travel times and evaluate formation properties, such as hydraulic diffusivity. This information was then used to design the monitoring program for the subsequent dissolved CO_2 injection experiment.

The injection process began in October 2011 with a controlled release of dissolved CO_2 into a groundwater formation approximately 50 meters below the earth's surface. Water quality is being closely followed at monitoring wells located 10–20 meters away from the injection point. Final results of the project are expected to be published in early 2013.

For more information, contact Robert Trautz, rtrautz@epri.com, 650.855.2088.

Prism 2.0 Evaluates Pathways to Environmental Compliance

Power generation companies are facing difficult decisions about how to respond to current and pending U.S. Environmental Protection Agency (EPA) regulations. As currently outlined, the rules will require utilities to comply with new standards for mercury and air toxics by 2015, for cooling water intake structures by 2018, for SO_2 and NOx emissions by 2018, and for coal combustion residuals (fly ash) by 2020.

Meeting these new standards will require extensive equipment retrofit at a cost that may not be practical for many aging coal plants. Under its Prism 2.0 project, EPRI is clarifying the options and unknowns by calculating the impact of pollution control costs, including changes in the generation portfolio, generation capacity, expenditures, and electricity prices.

The Value of Flexibility

To ensure an assessment that is both specific and robust, the study employs EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model—a macroeconomic model of the national economy that incorporates regional variables and sectoral detail in electric power production, energy demand, and transportation. US-REGEN considers broad, economy-wide variables, including changes to natural gas prices and decreases in economic output that may result from higher energy prices or required additional expenditures in the power sector.

The analysis considered two potential pathways for environmental compliance, one based on a "current (high) course" and the other on an "alternate (flex) path." While both achieve the same level of overall compliance, the flexible approach assumes additional time to phase in NOx and air toxics retrofits, allowing for development of innovative, less expensive technology options and the ability to optimize systems as they are installed.

Results of this first phase of Prism 2.0 show that flexibility would have a great effect on outcomes. Under the current course, only 202 gigawatts (GW) of the existing 317 GW of coal-fired capacity would remain financially viable, with about 61 GW being retired. The future is unclear for the remaining 54 GW, with decisions to retire or retrofit depending on market-specific factors, such as the cost and performance of competing generation options, changes in power prices, trends in demand, the price of natural gas, and whether regulatory frameworks provide for cost recovery. With the flexible course, 288 GW of capacity could be retrofitted economically for continued operation, with 25 GW retired and only 4 GW in question. The analysis calculates that this path could reduce costs to the U.S. economy by about a third, saving $100 billion while achieving the same level of compliance.

In addition to the regulatory challenges, the power sector is also facing uncertainty in the price of natural gas. EPRI's analysis indicates that with a lower projected price by 2020 of about $4/million Btu, just over 100 GW of coal-fired generation (1/3 of the existing fleet) could be retired. A flexible path for compliance strategies, with lower fixed costs, would still reduce this impact.

Advanced Technology Options

The benefits of the flexible approach rely on the availability and deployment of pollution control technologies that would increase efficacy and reduce costs. Although not included in this analysis, EPRI's view is that additional advanced pollution control technologies could be made commercially available as part of an accelerated demonstration and deployment effort. These include advanced selective catalytic reduction systems that have a greater nitrogen oxide removal rate; advanced coal cleaning, which removes pyrites, ash, trace metals, and other pollutants prior to combustion; and a sorbent activation process that enables lower-cost mercury removal.

More Analyses to Come

While the pending EPA rules are of critical concern to power producers, they are not the only regulations on the horizon. Two additional projects under Prism 2.0 involve similar assessments of economic impacts and technology options under a proposed federal clean energy standard and under a New Source Performance Standard that would define CO_2 emission limits for new fossil generation. Both projects are expected to be completed by the end of 2012.

For more information, contact Francisco de la Chesnaye, fdelachesnaye@epri.com, 202.293.6347.

A New Weapon for Storm Responders:

Send in the Drones

The computer screen in the command center shows an aerial view of a dusty road and field, lined on the periphery with trees. The operator deftly manipulates the joystick to get a closer look at the terrain with his drone's high-resolution video camera. He's not looking for a camouflaged al-Qaeda hideout in Afghanistan; he's in Nebraska, trying to determine where a recent storm has wind-whipped tree branches against power lines, bringing down a rural distribution circuit.

THE STORY IN BRIEF

Unmanned aircraft may become utilities' new eyes in the skies, providing more timely and accurate damage assessments in the wake of major storms and helping to deploy crews more efficiently and restore service more quickly.

The scenario is still in the future, but not that far off. EPRI recently completed preliminary tests showing that drones equipped with high-resolution cameras, global positioning systems, and sensors can be valuable tools for damage assessment. The unmanned aircraft, which can be small and light enough to be cradled in a technician's hands, can quickly survey devastated areas that are difficult to reach by truck because of poor road conditions and obstacles, such as downed trees. In fact, their use could substantially reduce costs and cut the response time by hours if not days, said Matthew Olearczyk, senior program manager for distribution systems research at EPRI and the head of the drone project. The project is now working on defining technical specifications and designs that will make drones suitable for utility use.

"Today, utilities send people out with trucks, clipboards, and cell phones to look for equipment damage. They can report only so much, and sometimes the assessment crew can't even get to the problem," Olearczyk said. "Tomorrow, we'll fly the unmanned aerial vehicles to the damage area, where we'll have the information technology system in place to provide analyses. We can save people's lives with the system. That's why it's so cool."

EPRI plans to work with some of its utility members to conduct test flights that will clarify how the aircraft should be modified or customized to handle different terrains and weather conditions and to meet other requirements. The project will also look at different cost models to verify that utilities could get good value for investment in unmanned aircraft.

Military Tech Origin

Using drones for reconnaissance isn't a new idea and has become increasingly important and prominent in U.S. military operations in Iraq, Afghanistan, and Pakistan. This prompted Olearczyk to look into whether drones could help utilities overcome some of the toughest and costliest problems in their field operations.

One of the biggest challenges is identifying and analyzing damage after a big storm so that repair work can be prioritized. Although neighboring utilities are more than willing to deploy crews and lend other support after a natural disaster, the overall operation still needs accurate, prompt data from the trouble spots, which can be in remote areas with limited access. "The tricky part is where to send people," Olearczyk said. "Putting the right crews to work quickly is where the lowest-hanging fruit is for us."

Drones will also be a big help for utilities and cities as they work together to take stock of damaged roads and respond to emergency calls, noted Sanjay Bose, vice president of central engineering at Consolidated Edison. "By having an unmanned aerial vehicle, you can quickly assess and overlay on a map what resources you'll need, share information with municipalities to help them plan their road clearings, and really make an impact on restoration," Bose said.

A 2008 Edison Electric Institute reliability report showed that bad weather contributed to 67% of power outage minutes and that most damage after a big storm is incurred by distribution lines and equipment. In a survey, 14 utilities reported that the repairs necessitated by 81 major storms in their territories between 1994 and 2004 cost more than $2.7 billion.

Olearczyk's research led him to New Mexico State University, which works closely with the military on developing unmanned aircraft systems. To assess utility use of drones, EPRI and the university conducted a series of tests at the university's flight test center, examining the performance of various aircraft technologies and associated technologies, such as high-resolution video cameras. Tests showed that video images of power lines from up to 7,000 feet above ground carried enough detail to help a utility figure out the extent of damage, the types of repairs needed, and the places to dispatch its crews.

EPRI and the university will next give closer scrutiny to different types of aircraft—looking at their performance, control systems, and ability to carry surveillance equipment.

While large aircraft would in principle be able to carry more reconnaissance tools, they would likely also cost more to operate, maintain, and store. The ideal may prove to be a drone small enough to piggyback on a truck or SUV for easy transport and light enough for one person to carry and launch. The type of fuel used to power a drone may determine how high or

far it can go per mission. The military, which is very concerned about any interruption to its fuel supply lines on the battlefield, has developed unmanned aerial vehicles that can run on all sorts of fuels, from diesel to gasoline to batteries. Some can even run on solar power.

The project will field-test different video cameras, which will play a crucial role in gathering accurate, usable information. Sophisticated cameras already exist that can home in on a blade of grass from 7,000 feet, but a utility may not need the highest-tech cameras available. One important variable for utilities to consider in this regard will be vegetation and terrain. A utility territory that is largely characterized by shrubs and grassland—providing a relatively unobstructed view of a utility's equipment—would require less sensitive equipment than would terrain obscured by tall trees.

Olearczyk said his project will also determine the optimal altitude and angles for running drones and shooting videos.

Information Technology Needs

Designing suitable drones is only part of the project. To make full use of unmanned vehicles, utilities will need to integrate, process, and present the data collected by the drones. "Utilities' information technology systems are unique in scope and architecture, and there is a huge range of applications. Integrating the IT systems will be a crucial part of the process," Olearczyk said.

EPRI will study three areas for integrating an aircraft's communication system with a utility's IT system: the outage management system, the geographical information system, and the asset management system.

The outage management system is the brain during a storm response and assessment campaign. Utilities use it to collect outage information, identify and prioritize repair work, provide public updates of the storm damage and the amount of time it will likely take to restore power, and coordinate the system's response with government agencies.

The geographical information system uses maps and charts to create a location database and track equipment in the field, and it's able to cover wide and remote areas. Such technology has been used for decades, mostly by other industries, although Dominion Electric relied on such a system after Hurricane Isabel in 2003. The system has proven effective in communicating visual information in real time. Incorporating still and video images from drones and presenting them on maps shouldn't be too difficult. Utility workers will not only be able to identify hot spots but will also be able to look for patterns and trends, and they will be able to view the maps on their mobile devices.

The asset management system is used by a utility's engineering and accounting departments to describe and keep track of the company's power plants, substations, and other equipment in the field. This system can be linked with the geographical information system to provide drone operators with technical specifications of the damaged equipment and the tools that will be needed to repair it.

Field Trials

EPRI will conduct field trials in eight U.S. locations over the next 12 months to determine which surveillance and flight technologies work best in different topographies and weather conditions, Olearczyk said.

The success of the project will depend not just on determining good combinations of technologies, performance, and cost but on the Federal Aviation Administration's willingness to loosen rules that restrict civilian operation of unmanned vehicles—rules designed primarily to ensure the safety of commercial airliners.

Currently, nonmilitary operators of drones must apply for certification before putting the aircraft to use. The process can be long, and the FAA can exercise its discretion in denying an application. At the urging of law enforcement agencies, which also foresee value in using drones for their work, the FAA will be reconsidering some regulations within the next two years. That could help persuade utilities to give unmanned aerial vehicles a try.

Another key part of the project is to frame ownership models that can make drones a cost-effective option for utilities, according to Olearczyk. Utilities could buy and operate their own aerial vehicles, or they could contract with a service provider. Neighboring utilities could share their unmanned aircraft to lower costs.

With enough deployment by utilities, law enforcement agencies, and others, drones could become portable and affordable enough to be good for several years before having to be replaced by newer and better models, much the way people swap out their older iPhones for newer ones, Olearczyk said. Other industries considering drones for field operations include oil and gas producers, meteorological service providers, and forestry organizations. In Japan, drones flew over the Fukushima nuclear power plant to take stock of its condition and radiation levels after the earthquake and tsunami in 2011.

To maximize the investment in a drone, a utility could use it for transmission line inspection, Bose said. Using an unmanned aerial vehicle would require less fuel and impose fewer risks than sending in a regular aircraft, which if crashed would likely cause greater damage.

Deploying drones regularly also improves security. "Many utilities up in the Midwest have many thousands of substations, and you can't keep them all staffed and inspected every day," Bose said. "You can use the unmanned aerial vehicles for added security in addition to storm damage assessment, increasing the reliability and reducing the cost of an operation."

This article was written by Ucilia Wang. Background information was provided by Matthew Olearczyk, molearcz@epri.com, 704.595.2743.

Matthew Olearczyk is a senior program manager in the Power Delivery and Utilization Sector, with current research activities focused on distribution systems. Before joining EPRI in 2005, he was principal for a management and technical consulting company and prior to that worked at PSE&G in various supervisory and management roles. Olearczyk received a B.S. degree in engineering from Widener University, Chester, Pennsylvania.

Drones for Transmission Networks

EPRI is working on projects that will put drones to work on both distribution and transmission networks. While Olearczyk focuses on developing drones for distribution line assessments, a parallel project is considering unmanned aircraft for transmission line inspection. Aside from storm damage assessments, drones could perform tasks that improve the maintenance of the transmission network and prevent outages—for example, assessing vegetation encroachment.

Using unmanned vehicles can greatly reduce the time and costs of doing transmission line inspection. Currently, utilities use manned aircraft for aerial surveys and send crews out for on-site surveillance. These methods take a lot of time and money, and sending people out comes with safety risks. Drones could reduce all three.

EPRI considered unmanned aerial vehicles for transmission network operation and maintenance in the late 1990s, and tests conducted then showed that drones with fixed or rotary wings could be a good fit for line inspection. But the sensors weren't good enough to correctly identify the position of transmission structures or to identify component defects or other problems.

Sensor technologies and global positioning systems have improved significantly since then, making the idea worth another look. EPRI work on drone technologies for line inspection and other transmission services is now being planned, with laboratory tests and field demonstrations expected to take place by the end of 2012.

YouTube™

To view a field interview with Matthew Olearczyk, please visit our YouTube channel at www.youtube.com/EPRIVideos.

Reconstructing Fukushima:
A Technical Investigation of the Event

In the year since the Fukushima Daiichi nuclear accident, the nuclear industry has investigated matters ranging from the actual accident sequence to plant design, emergency preparedness, decision making, and communications. EPRI has supported recovery efforts and various technical analyses—both during and after the crisis—and is conducting an array of research activities aimed at providing safer nuclear plant operations. To this end, it is especially important that the industry have a complete understanding of the events at Fukushima Daiichi and their potential implications. EPRI is particularly suited to address this challenge.

THE STORY IN BRIEF

Drawing on decades of research, extensive technical expertise, and experience gained from the Three Mile Island and Chernobyl accidents, EPRI provided timely support during the Fukushima Daiichi crisis and is now engaged in a number of efforts to better understand the event and its implications for the global nuclear fleet. Insights from these efforts will enhance safety, improve emergency response, and help avoid future accidents.

Overview of the Accident

The broad outline of the accident is fairly clear: Units 1, 2, and 3 of the six-unit Fukushima Daiichi site were in service at the time of the earthquake. Safety systems responded as designed; as soon as excessive seismic activity was detected, control rods were automatically inserted into the reactor cores, stopping the fission reactions. The magnitude 9 earthquake—the fourth largest in recorded world history—caused no major damage to the reactors themselves but did damage the receiving circuit breakers for the site's power lines, cutting electricity from Japan's grid.

The tsunamis, which were far beyond the design basis for the site, arrived approximately 40 minutes later. They caused flooding that shorted out all AC power from the backup diesel generators and emergency battery power at Units 1 and 2. Without electric power, only those few components of the emergency core cooling systems powered by steam in the core remained in operation. Within a few days, those failed also or lost power from backup batteries.

As water levels dropped in the reactors, the cores began to overheat. Overheating caused oxidation of the fuel rods' zirconium cladding, which reacted with the surrounding water to liberate hydrogen gas. Without power for instrumentation, operators could not monitor reactor conditions and eventually had to vent the containments to avoid failure from rising pressure. During venting, hydrogen explosions occurred in Units 1 and 3.

Efforts to stabilize and cool the reactor cores continued through December 2011, when Tokyo Electric Power Co. (TEPCO) declared safe cold shutdown of the three reactors.

Real-Time Response

EPRI provided information to help with decisions throughout the accident and subsequent recovery. "We have quite a body of work—thousands of experiments and tens of thousands of pages of research devoted to understanding nuclear accidents, starting with investigations of Three Mile Island in 1979," said Ken Canavan, EPRI director of plant technology. "We did not tell TEPCO what they should do, but we did help them understand the phenomena that were occurring."

"For example, after the emergency cooling water boiled away, they injected seawater into the reactors," said Rosa Yang, EPRI senior technical executive. "They had no choice at the time, but then they had to ask, 'What happens now?' We had data from experiments on the effect of chloride on stress corrosion cracking of the materials, so we provided advice on how to mitigate the adverse effects of seawater on plant components and the likelihood of component failure."

In its efforts to maintain cooling, TEPCO faced another major challenge—millions of gallons of water were being contaminated by radioactive material (primarily cesium) from the reactor cores, as well as chloride and organic compounds from the seawater. This water had to be stored and cleaned before it could be reused or discharged into the environment.

An EPRI study, published just a few months before the accident, had identified a type of improved zeolite with superior cesium-absorption properties. "We offered that information to TEPCO, and they asked if it would be possible to get a cleaning system in place before their rainy season began in June," said Yang. "We provided our technical input, and TEPCO then worked with manufacturers to get the system built and delivered to Fukushima. It was a real push, because TEPCO had to start processing the water before they ran out of storage space."

Reconstructing the Details

EPRI researchers are leading a coordinated global effort to gain a detailed understanding of the progression of events at Fukushima Daiichi. "It is a lot like reconstructing a plane crash, except that there is no flight recorder," said Yang. "Because they lost all of their power, we have limited data from the accident."

The limited data, combined with the

complexity of the accident and an inability to visually inspect the damaged reactors, presented a problem best addressed by EPRI's Modular Accident Analysis Program (MAAP). This computer code can simulate operation of a nuclear power plant under a variety of accident conditions. "We used MAAP several times during the course of the accident to get an understanding of the damage at the different reactors," said Canavan.

EPRI is using MAAP and a three-dimensional thermal hydraulic analysis code called GOTHIC to perform the technical evaluation. "The challenge is to create a scenario that matches what we have observed," Yang said. "Say we believe there was a certain amount of water in the reactors at a given time, and our model indicates a hydrogen explosion should occur 10 hours later. If the explosion actually happens 20 hours later, we have to ask ourselves what assumptions might have been wrong. We have to try different scenarios—maybe there was more water, or less water, or perhaps something else was going on that we didn't expect.

"Once we see that the code matches what we know happened, then we can start to make other inferences. If MAAP correctly predicts what happened at a given time and then again at a later time, we can use the code to tell us what happened in between. The goal is to gain an understanding of what equipment worked, and for how long. Once we trust the code, we can ask other questions. What if we tried another course of action? Would it have affected the consequences? Maybe a piece of equipment lasted longer than expected. How could that have helped us?"

Validating the code through use of a real-world event will make MAAP more useful in simulating accident scenarios in the future, providing information that plant operators can use to improve the effectiveness of response actions and mitigate future accidents. One of the lessons learned from Fukushima is that certain phenomena not currently modeled by the code need to be included. For example, cleaning up the reactors will require knowing the location and extent of damage to the fuel and the containment vessels, so that proper shielding and equipment can be designed to efficiently remove the core debris.

Improving Emergency Response

The MAAP analyses are expected to have a longer-term effect on the industry's emergency planning. When an emergency arises, nuclear power plant operators refer to Severe Accident Management Guidelines (SAMGs), which provide detailed instructions for actions to stabilize conditions and prevent reactor damage or radiation release.

The technical basis for SAMGs was last updated in 1992. Events at Fukushima have raised questions about the scope and effectiveness of SAMGs, especially under extended loss of AC power.

EPRI is using new knowledge from the accident and from other research to update the technical basis. The MAAP technical evaluation will provide more than just a replay of the events of a single accident. The benchmarked code can be used to play out other scenarios and other types of accidents, identifying vulnerabilities and comparing the effectiveness of many mitigation strategies.

SAMG issues being explored in the update include use of cooling water of varying quality, control of combustible gases, multiunit effects, loss of ultimate heat sink, and spent fuel pool cooling. The updated technical basis will evaluate the viability of various actions during accident conditions, such as the operation of isolation condensers for boiling water reactors, and venting and ventilation of reactor and auxiliary buildings. EPRI will complete its updated technical basis report this summer; the reactor owners groups will develop refined guidance by the end of the year; and U.S. nuclear plants will have until the end of 2014 to implement the updated guidance. International utilities that participate in the owners groups will have access to the same updated technical guidance.

Role of the Design Basis

Every nuclear power plant is constructed in accordance with a design basis, which details the types and magnitudes of events and hazards that the plant must be able to withstand without damage. These scenarios might include flooding, earthquakes, high winds, transportation accidents, low temperatures, component failures (such as a break in a large pipe), and loss of ultimate heat sink. In assessing the design basis, nuclear plants also use probabilistic risk assessments, which calculate the likelihood of an event and the probability that prevention and mitigation systems will function as designed. By focusing on the events that have significant probabilities, designers can determine where to draw the line so that each plant provides high levels of protection against the greatest risks, along with safety measures appropriate for more marginal events and risks.

The Fukushima Daiichi accident demonstrated that mistakes in the design basis can have significant implications. First, the initial assessment estimated a maximum tsunami height of 3.1 meters, based on historical records. In 2002 and 2006, theoretical calculations led to estimates as large as 5.7 and 6.1 meters, respectively. However, these calculations assumed an earthquake would result only from a single fault segment rupture, and that simultaneous ruptures across multiple fault segments would never occur. The March 11 earthquake proved this assumption to be mistaken.

Another area for improvement is the assumption that electric power would always be available from the plant itself, from Japan's grid, or from on-site backup batteries and diesel generators. The Fukushima Daiichi accident demonstrated the need to reevaluate assumptions about the types and number of backup systems, water supplies, and portable equipment, along with the need to ensure that these systems are adequately protected from damage when events exceed the design basis.

Fukushima has highlighted many issues that could lead to vulnerabilities if not fully understood and addressed where necessary.

Changes will certainly be made on the basis of lessons learned, leading to safer nuclear plant design and operation in the future.

This article was written by Cliff Lewis. Background information was provided by Ken Canavan, kcanavan@epri.com, 704.595.2731; Rosa Yang, ryang@epri.com, 650.855.2481; and Andrew Sowder, asowder@epri.com, 704.595.2647.

Ken Canavan, director of the plant technology group in EPRI's Nuclear Sector, is responsible for research related to equipment reliability, maintenance, instrumentation and control, and risk and safety management. Before joining EPRI in 2003, he worked in the areas of safety and risk analysis at Data Systems & Solutions, ERIN Engineering and Research, GPU Nuclear, and Toledo Edison. Canavan holds a Bachelor of Chemical Engineering degree with a minor in nuclear engineering from Manhattan College.

Rosa Yang, senior technical executive, leads EPRI's engagement with Asian utilities and entities to identify and implement collaborative research programs related to nuclear power. She also manages EPRI interactions with U.S. government and research institutes. Before coming to EPRI in 1987, she worked for General Electric, where she developed the company's fuel design and licensing code. Yang received a B.S. degree in nuclear engineering from the National Tsing Hua University in Taiwan, and M.S. and Ph.D. degrees in the same field from the University of California at Berkeley.

Andrew Sowder is a senior project manager specializing in the management of used nuclear fuel and high-level radioactive waste and the analysis of advanced nuclear fuel cycles. Before joining EPRI, he served as a physical scientist and foreign affairs officer at the U.S. Department of State, addressing international nuclear safety and radiological security issues. Sowder received a B.S. in optics from the University of Rochester and a Ph.D. in environmental engineering from Clemson University. He is a certified health physicist.

Allaying Spent Fuel Pool Concerns

During the Fukushima crisis, attention focused mainly on Units 1, 2, and 3. Unit 4 was undergoing maintenance, and all of its fuel had been moved from the core to the adjacent spent fuel pool, where it was kept submerged in water. While the pool was believed to be undamaged, an explosion occurred in the Unit 4 building four days after the tsunami, raising concerns that catastrophic water loss might have occurred that could lead to fuel heat-up, a so-called zirconium fire, and large releases of radioactive material.

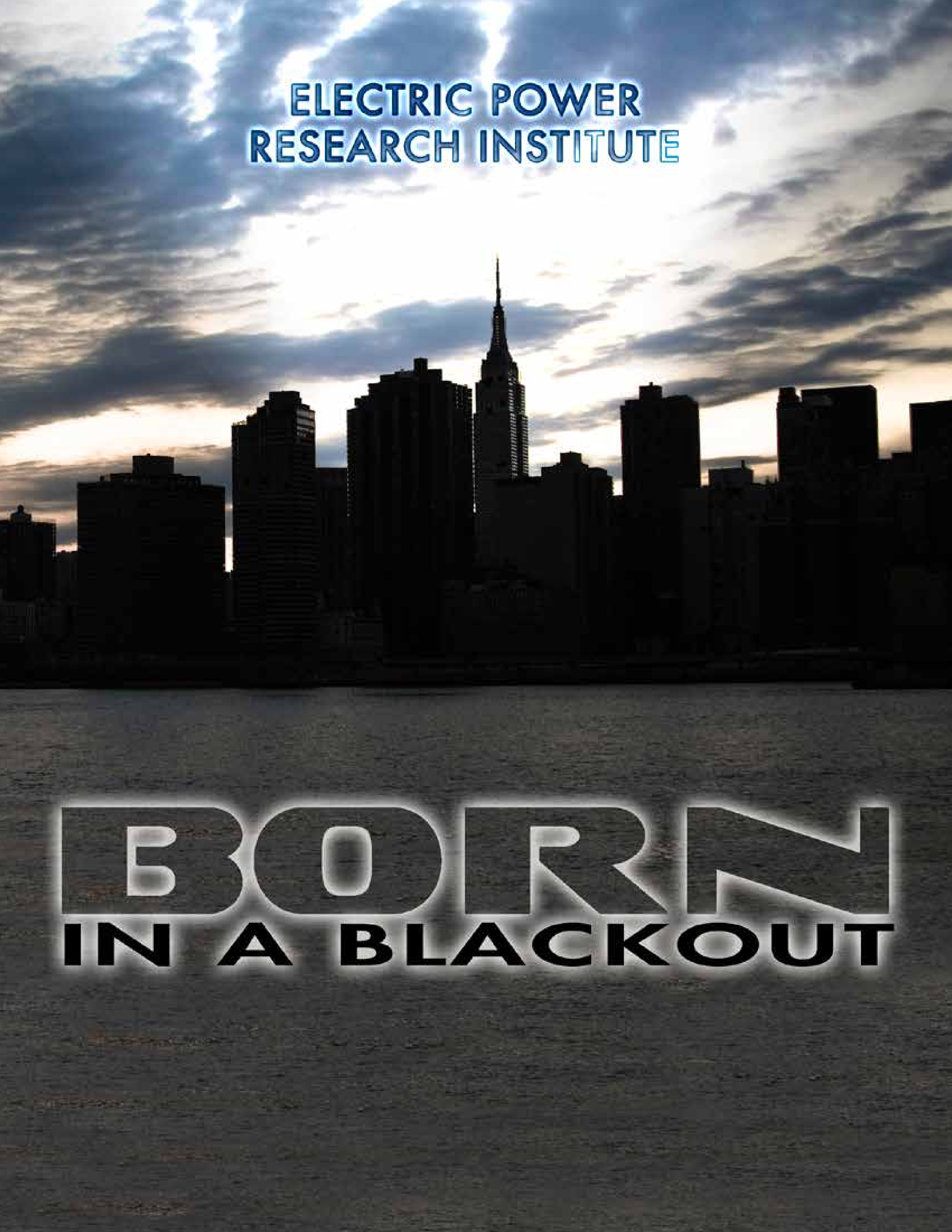
"Normally people wouldn't be concerned about the spent fuel pool so soon after loss of cooling, but the unexpected damage to Unit 4 and possible involvement of the fuel pool held potential implications for spent fuel pools everywhere," said Andrew Sowder, EPRI senior project manager. "To address this concern, EPRI began evaluating emerging theories explaining the Unit 4 damage—and there were a lot of them."

The greatest concern was that the pool's water might have boiled away. "Our analysis indicates that trouble starts when the water level drops to around the mid-point of the fuel and effective cooling is lost," said Sowder. However, the time required for this to occur was estimated to be 12 to 14 days at Fukushima Daiichi, not 4.

As more information became available, EPRI was able to rule out many of the theories, and evidence began to suggest that the Unit 4 explosion was caused by hydrogen generated in Unit 3 and conveyed through shared exhaust piping. This theory was corroborated by subsequent TEPCO inspections, which also showed that water had remained in the Unit 4 pool and that the fuel was in good condition.

"In terms of the broader industry, what we learned was that we need better, more timely information about the status of spent fuel pools," said Sowder. "When that explosion occurred, we didn't know the real condition of the pool until weeks later. If we had had better instrumentation, we could have avoided the worry about whether something catastrophic had occurred in the pools."

Better computer models for spent fuel conditions would also have been helpful. EPRI is improving the MAAP software to reflect lessons learned and has initiated a research project to perform more detailed probabilistic risk analysis of spent fuel pool events.


ELECTRIC POWER
RESEARCH INSTITUTE
BORN
IN A BLACKOUT

It was rush hour in Manhattan on a cold November day in 1965 when the lights went out, elevators stopped, and 800,000 people found themselves trapped inside the subways. New Yorkers were not alone in their frustration. The largely independent power systems of the Northeast, which had progressively been integrated into a grid for purposes of enhanced reliability, had failed massively. What began as a single trip on a 230-kilovolt line near the Canadian border cascaded in radial fashion over 80,000 square miles in a matter of minutes. From New Jersey to Ontario, the Great Northeastern Blackout left 30 million people without electricity. Historic in scale and impact, it starkly demonstrated the nation's growing dependence upon electricity and vulnerability to its loss. It marked a watershed for the industry and triggered the creation of EPRI.

Although power was largely restored within 12 hours, the ripple effects of public and political criticism of the blackout continued for years. Ten reliability councils were established to set standards, share information, and improve coordination among electricity providers, offering some reassurance. But some in the U.S. Congress were troubled by the nation's utter dependence on a fragmented industry for which there was no unified planning. How, they asked, could 3,500 entities—divided by geography, tradition, size, and philosophy of ownership—be physically integrated and relied upon to operate as a unified system?

THE STORY IN BRIEF

Thanks to a convergence of forces, the right people, and extraordinary leadership following a brief but seminal crisis, EPRI was thrust from concept to reality in less than a year. On its 40th anniversary, EPRI remembers the challenges, personalities, and plans that reframed the institute from a political quick fix to an enduring but adaptable engine of progress and innovation for the electricity industry.

Impending Federal Intervention

Federal intervention loomed, and by 1972 congressional hearings were under way. After conducting the hearings, Warren Magnuson, chairman of the Senate Commerce Committee, and Ernest Hollings, one of the ranking Senate majority members, became convinced that utility companies were too heterogeneous, and commercial vendors too narrowly focused, to undertake the broad, long-term R&D required for the future. They proposed taxing utilities 1% of gross revenue to fund a federally run R&D organization for electric power.

The prospect of federal action galvanized the utilities. Industry leaders at the time, including Shearon Harris, chairman and CEO of Carolina Power & Light and president of the Edison Electric Institute (EEI), and Charles Luce, chairman and CEO of Consolidated Edison, with the support of the National Association of Regulatory Utility Commissioners (NARUC), proposed a one-year stay in order to establish a new electric power research institute. They promised the Senate Commerce Committee that if they couldn't get an industry-wide organization launched, funded, and off the ground within one year, they would return and lend the senators their personal support for creating a federal agency.

What they had in hand was something called the Greenbook, an almost utopian blueprint for a $30 billion, 30-year R&D plan that had been put together by an industry committee during the 1960s and published a year before the hearings, in 1971. The prescient Joseph Swidler, chairman of the Federal Power Commission, had planted the seed years earlier. Addressing the members of EEI in 1963, he'd said, "The nation's number one industry cannot afford the risk of lost opportunities and delayed progress that is inherent in the present lack of system or direction in research." This admonishment had led to the establishment of the Electric Research Council, a committee to bring the disparate utilities together to frame the Greenbook's R&D portfolio. Although the council proved only an interim solution, it offered an ambitious overview of advanced technology at a time when electric power demand was still expected to double every 10 years. Trends pointed to a future that was simply unsustainable, given the industry's technology base at the time. Fission, fusion, advanced fossil assets, and renewables, among other resources, would be needed if the industry were to continue to grow as it had for the previous 40 years.

Despite senatorial skepticism, Harris and Luce made their case and in March 1972 set about finding the right person to establish EPRI by year's end. The qualifications they sought were those of "an internationally respected scientist with uncommon administrative ability." For recommendations they turned to, among others, Chauncey Starr, dean of the School of Applied Engineering at UCLA. He was also on their short list. In 1971, Starr had written a seminal paper for *Scientific American* titled "Energy and Power," and Harris had been struck by its "clarity, persuasion, and logical thrust." He talked to Starr about the proposed new entity at a conference shortly after the Senate hearings, and Starr's response was, "The way you describe it, I might be interested in it myself." His proviso was that it be something of "genuine significance."

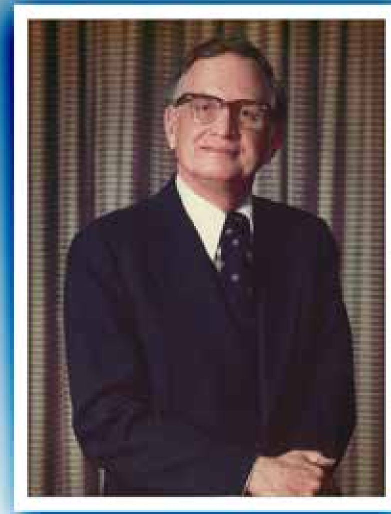
Joseph Swidler, chairman of the Federal Power Commission, pushed for comprehensive utility industry R&D in the early 1960s.

The New York Times.

POWER FAILURE SNARLS NORTHEAST; 800,000 ARE CAUGHT IN SUBWAYS HERE; AUTOS TIED UP, CITY GROPES IN DARK

Johnson Restates Goals in Vietnam

The Great Northeastern Blackout of 1965 brought the issue of electric power reliability to a head and prompted federal action.



EEI President Shearon Harris negotiated a one-year deferral in Senate action in order to establish a utility-directed research organization.

The Pillars of EPRI

Starr laid out his vision and conceptual framework for a voluntary, industrywide R&D organization in a three-page letter to Harris, who found it compelling but quite a bit larger in scope and purpose than he and other industry leaders had envisioned. With his broad background in public service, industry, and academia, Starr saw technology as integral to the public good and believed that electricity in particular was preeminent in shaping modern society. This view became one of the pillars of EPRI. "For decades, I had believed that one cannot separate hardware from its use and its impact on society as a whole. One of my values is that a scientist, an engineer, a toolmaker must not simply develop a piece of hardware, drop it into the middle of a social situation, and walk away. He has to have a continuity of concern."

In his letter, Starr wrote, "I believe that it would be important to involve in EPRI's studies not only technical specialists but also those deeply concerned with environmental and social impacts. EPRI could thus provide a device for making such opinion leaders a party to national problem solving."

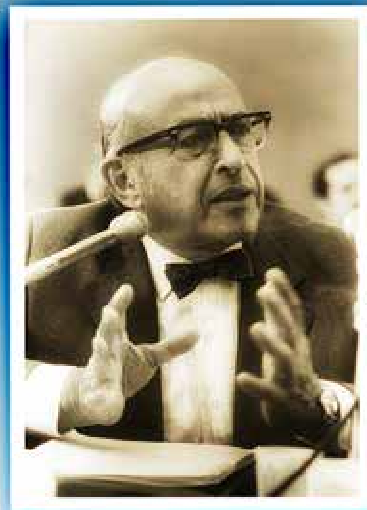
He made it clear that he was not interested in running a technical fix-it shop, and Harris gave him running room to elaborate his vision. Recalling this gestation period some years later, Starr said, "Especially intriguing was unbounded R&D scope, ranging from applied science to end use and across all energy forms. It was an opportunity to push my vision of electrification as a basic shaper of society."

Public trust became another guiding principle—which Starr referred to later as key to "the soul of EPRI." He laid out the rationale for this in his letter to Harris: "EPRI will be a quasi-public corporation with particularly sensitive ethical responsibility as a trustee of public funds. Because it will undoubtedly be subject to public scrutiny, it should be prepared to publicly justify its activities." To build and sustain public trust, EPRI's research would have to be done with "complete objectivity, thoroughness, and intellectual integrity."

A third pillar of Starr's vision was to forge teamwork among top-notch scientists and engineers to "turn visionary accomplishments into practical use." Starr told Harris he knew where the people were and by offering them the combined package of "creativity and idealism," he could draw the best into the enterprise. Some he would hire as full-time research managers at EPRI; others he could pull together in virtual space, in what we would today describe as a network. He told Harris, "I do not conceive of EPRI having its own hardware laboratories. I believe there are ample facilities in industry, universities, government institutes, and non-profits for almost any type of R&D program. I would expect that with very little encouragement, these institutions would be pleased to increase their facilities if research support could be counted on."

Harris seized upon one particular advantage offered by this model: the organization wouldn't have to grow lab by lab, building by building, but could, at least in theory, come into being nearly fully formed. It had a second advantage that Harris likely did not appreciate at the time. An EPRI professional manager could create a team for any given project, uniquely combining expertise to fit the task. Someone from Stanford, for example, could be teamed with someone at GE, along with a third team member from Pacific Northwest Labs. Starr recounted later, "When significant results started to flow early, all those doubts about virtual R&D faded."

The Greenbook, produced by the newly established Electric Research Council, outlined an ambitious 30-year blueprint for R&D.



Founding President Chauncey Starr refined the Greenbook's technical and organizational vision in helping create the ultimate blueprint for EPRI.

Getting Started

The opportunity to build such an R&D institution was simply too great for Starr to turn down. He was 60, comfortably settled at UCLA and about to take a sabbatical, but the job would culminate a lifetime of prodigious achievement.

He accepted the offer, convinced the Senate committee, started up operations in two rooms in Los Angeles in January 1973, held a press conference, and went to work on the single most important task—hiring staff. His method was to hire good people, provide minimal coaching, and let them get things going with maximum freedom. He resisted building by the "org chart," choosing instead to build the organization around the strengths and interests of the key individuals he hired. With the able administrative assistance of David Saxe and Ric Rudman, he recruited vigorously and used McKinsey and Company to find the number one spot in the country desired by professionals. Their survey pointed to the San Francisco Bay Area, and Starr set up EPRI headquarters in Palo Alto. By September of that first year, he had 20 people on board, and by the end of the year, 100. Later asked to name his greatest achievement, he said it was the people he hired in that first year, because they in turn found the rest of the staff—the best in their respective fields.

Before accepting the job, Starr issued a bold caveat to the industry leaders—a no-strings, hands-off approach from the EPRI board of directors for the first five years. His staunch independence required extraordinary trust, which Harris and the other CEOs gave him. The CEOs would concentrate on selling the voluntary organization to utilities, and he would concentrate on making their investment pay off. "I had no doubts, no quivering at the knees about being able to work at this task. It was something that professionally I knew how to do."

Building in a Feedback System

As a counterbalance to Starr's independence, the EPRI board worked to make sure that the new institute remained tethered to the real world. They created an industry advisory structure of technically focused committees. It served as a form of adaptive intelligence to bring the industry's priorities to bear in directing the institute and, in response, infusing new ideas, technology, and opportunities into the industry. Moreover, the industry would serve as the primary test bed for technology that it would ultimately use.

Gathering committee members from different utilities to address common problems created informal, highly valuable networks that would help knit the industry together technically. Many consider the industry committee structure one of the most ingenious and important organizational elements of EPRI's formative years. In time, it broadened the institute's original long-term focus to include solving critical near-term and mid-term problems.

Meanwhile, NARUC pushed to supplement the industry advisory committees with an independent advisory council that would give EPRI guidance on how its research could best promote the public interest. The EPRI Advisory Council was composed of nontechnical people whose backgrounds ranged from business and education to regulation and labor. It became known as the "conscience of EPRI" and was instrumental during the early years in stressing the growing importance of environmental and conservation considerations in research and development.

A Sustainable Model

Shearon Harris had inherited an audacious plan for a national R&D organization and parleyed with a skeptical Senate, betting that he could bring the new entity to life if he could find the right person to lead the effort. Chauncey Starr brought to the table an even bolder vision, the talent and leadership to make it thrive, and the persuasive powers to convince an industry to take its technical destiny into its own hands. On the combined vision and strengths of these two men, EPRI has stood the test of 40 years, and just as its founders did in 1972, it continues to look far down the road.

This article was written by Brent Barker.

DATELINE EPRI

News and events update

ROBOTICS TEAM TOURS LENOX LAB

LENOX, Mass. — A group of high school students from Frederick Douglass Academy in the Bronx, New York, visited EPRI's Lenox power delivery laboratory in May to learn more about electricity and the practical aspects of energy research. These students, part of the Harlem Knights robotics team, were on their way to Massachusetts to compete in a robotics competition with other schools from across the United States. The team was particularly interested in EPRI efforts to develop robotic technologies for improving utility asset management.

WATER ISSUES HEAT UP SUMMER ADVISORY COUNCIL UPDATE

LOUISVILLE, Ky. — EPRI's Water and Ecosystems team held its annual Summer Advisory Council program update to discuss research associated with the Ohio River. The meeting showcased more than 30 years of data being used to examine cumulative impacts to aquatic populations from power plant operations on the Ohio. These data sets are also being used to develop a test case for the Water Prism watershed risk assessment tool and to facilitate a water quality trading program for nutrients such as phosphorus and nitrogen; with three states nearing an agreement on a framework, stakeholders in the Ohio River Basin could begin interstate trading by the end of the year.

EPRI/NERC GEOMAGNETIC DISTURBANCE ANALYSIS WORKSHOP

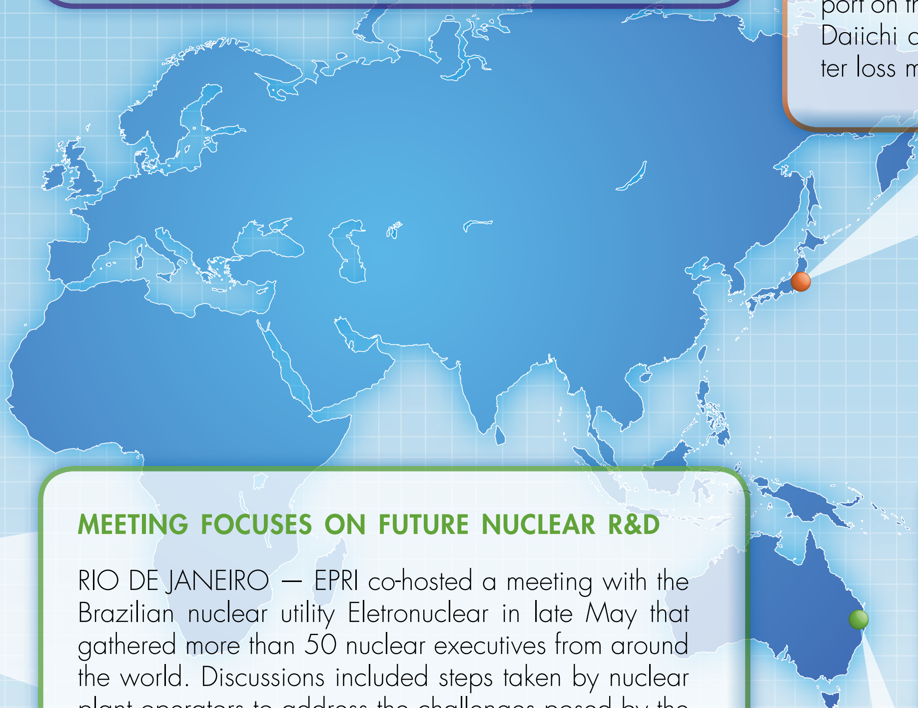
ATLANTA, Ga. — EPRI and the North American Electric Reliability Corporation (NERC) held a workshop at NERC headquarters in April to inform utility engineers about solar storm phenomena and provide participants with tools and training for analyzing their own companies' vulnerability to geomagnetic disturbances. Topics covered by EPRI and industry experts included space weather, calculation of geomagnetically induced currents, geo-electric field calculation, transformer/system response, and system planning analysis.

EPRI TAKES ON DEVELOPMENT OF HRSG SPECS

Charlotte, N.C. — The June expert meeting on boilers, piping, and heat recovery steam generators (HRSGs) focused on the design of cycling units, with an emphasis on development of HRSGs that can match the capabilities of the current lines of fast-startup combustion turbines. Six major equipment manufacturers in attendance asked EPRI to assemble a best-practices specification for HRSGs that would comply with prevailing requirements, including ASME and European codes. The manufacturers agreed to work together in supplying information and guidance for the new specification.

EPRI RELEASES KEY REPORTS ON FUKUSHIMA

TOKYO – EPRI has released several reports examining technical issues associated with the Fukushima Daiichi nuclear plant accident. The information and lessons learned captured in these reports will advance global understanding of nuclear plant accident scenarios and inform decisions related to plant design, safe operation, and emergency planning. A report on the underlying technical factors leading to the loss of critical reactor systems provides a detailed review of the plant's design basis, examines the plant's response capabilities with respect to seismic and tsunami events, and compares the plant's design capabilities with actual events. A report on the behavior of the spent fuel pools at Fukushima Daiichi addresses early concerns that catastrophic water loss might have occurred in the pools.



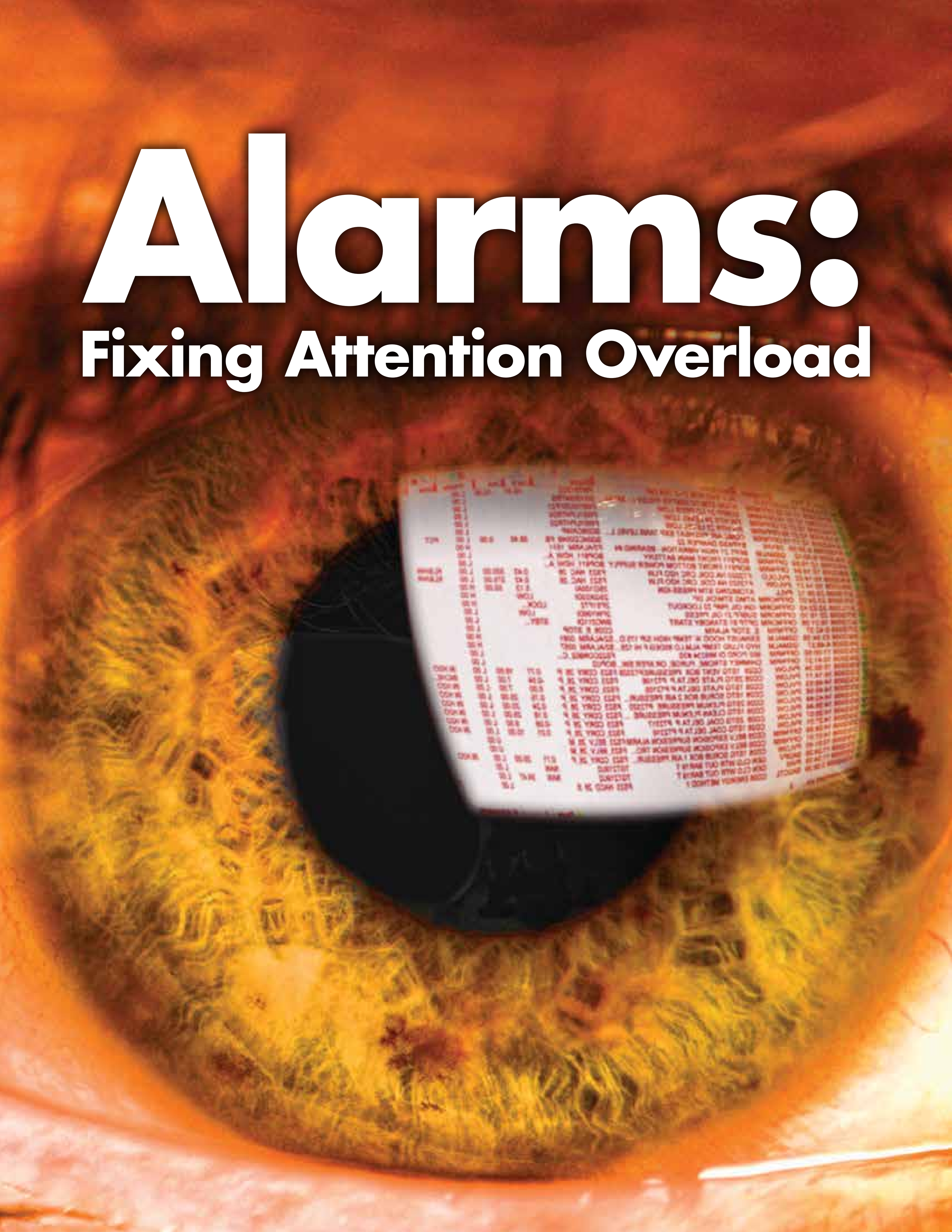
MEETING FOCUSES ON FUTURE NUCLEAR R&D

RIO DE JANEIRO — EPRI co-hosted a meeting with the Brazilian nuclear utility Eletronuclear in late May that gathered more than 50 nuclear executives from around the world. Discussions included steps taken by nuclear plant operators to address the challenges posed by the Fukushima Daiichi accident; opportunities to incorporate advanced digital instrumentation and control technology into nuclear plants; and design, fabrication, and manufacturing strategies that can facilitate the successful start-up and ongoing operation of new nuclear power plants. Round-table discussions in each of these areas produced tangible input for future R&D planning. Meeting participants also toured Brazil's fuel fabrication facility and the Angra site, where a third nuclear unit is under construction.

AUSTRALIAN WORKSHOP ZEROS IN ON FOSSIL PLANT RELIABILITY

BRISBANE, Australia — More than 200 utility representatives from Australia, Malaysia, New Zealand, and the United States attended an April workshop on major component reliability, sponsored by EPRI in conjunction with 17 vendors and original equipment manufacturers (OEMs). The meeting highlighted solutions and R&D applications for plant maintenance, equipment reliability, and risk assessment and management from eight EPRI Generation Sector programs, and afforded opportunities for technology transfer among utility attendees and presentation of new technologies by vendors and OEMs.

Alarms:
Fixing Attention Overload



The power plant operators diligently scanned the banks of monitors that relayed the status of the plant's components and processes. Airflows, water flows, fuel flows, temperatures, pressures, voltages, and thousands of other variables had to be monitored and controlled within specified ranges. Any condition or reading outside the plant's prescribed parameters triggered the control room's sophisticated digital alarm system, alerting the operators with a flashing text message and an audible tone calling for corrective action.

But this plant's alarm system had been built and programmed to "overachieve." Every day—sometimes every hour—hundreds or even thousands of flashing messages cascaded down the alarm display, accompanied by sounds from a variety of electronic beepers, buzzers, and bells. Many alarms were redundant or insignificant, and the operators had learned they had no choice but to tune them out. Critical warnings of serious problems could be lost in the flood of flashing text and noise, which could hinder the operators' ability to perform effectively and could contribute to equipment damage and, in some cases, a plant shutdown.

The problem of poorly performing alarm systems is widespread in industries involved in process control, including petrochemical refining, pharmaceutical manufacturing, minerals processing, and power generation. In many cases, investigations of major industrial accidents have shown that overloaded, bypassed, or ignored alarm systems played a significant role.

"Research in human factors shows that one alarm in 10 minutes, or 150 per day, is acceptable," said Wayne Crawford of EPRI's Operations Management and Technology program. "Up to two alarms in 10 minutes, or 300 per day, is considered the maximum manageable rate. Yet some plants average more than 1,000 alarms per day, and that number may increase exponentially during an upset. Operators have difficulty analyzing and acting upon each of those alarms, and as a result, they have to ignore many of them."

THE STORY IN BRIEF

Inside power plant control rooms, operators rely on alarms to alert them to abnormal conditions. Research has shown that many control rooms have become overburdened with low-priority alarms, which can overwhelm operators and interfere with timely and appropriate responses. EPRI has developed guidelines to help plant owners optimize these alarm systems, making operators more effective and plants more reliable.

Advances in technology contributed to alarm proliferation. In the pre-digital age, a typical alert system was an annunciator panel or light box, a simple series of lighted indicators connected to a process parameter—for example, the airflow to a coal pulverizer. A deviation outside a specified range would cause lights to flash and a horn to sound. The relative importance of different alarms might be indicated by different-colored lights. This simpler approach had its benefits, but concern for expense and space limited the number of alarms.

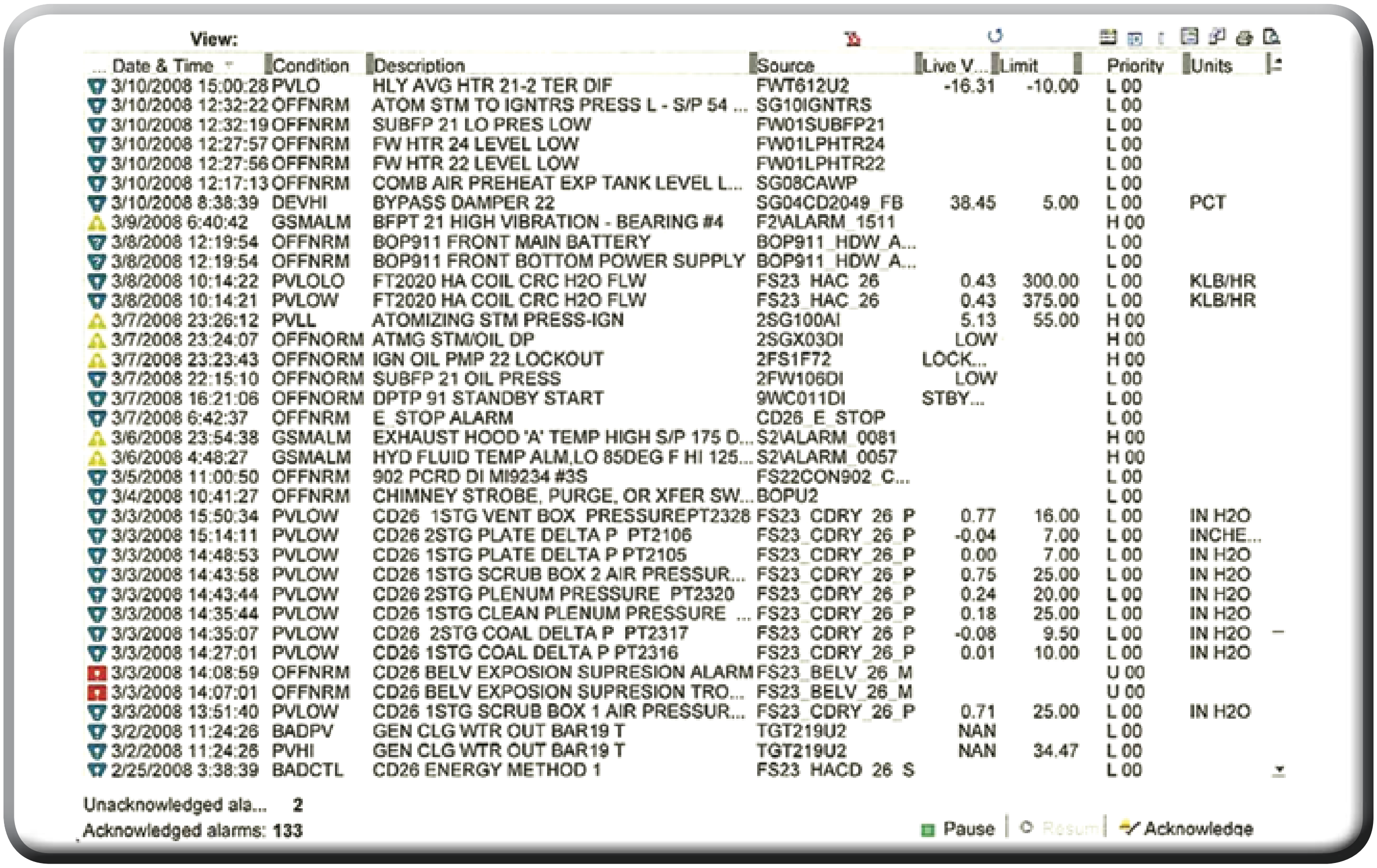
Overburdened with Low-Priority Alarms

Computer-based distributed control systems changed this. Alarms no longer were delivered via light boxes but appeared as lines of text on a display screen, sometimes flashing or accompanied by an audible tone to draw the operator's attention. A manual action—the push of a button or click of a mouse—is usually required to acknowledge the warning and quiet the tone or stop the flashing. Digital alarms are easy and cheap to install, making it economical to add alarms for many more variable process values, or "points," such as equipment on/off states or temperatures, pressures, and flows from various plant components.

"In distributed control systems, alarms are a software construct, not a hardware construct," said Crawford. "There is virtually unlimited room for alarms and little or no cost to implement them; no installation or wiring is necessary. This latitude gave rise to more and different types of alarms, which could be created with a few keystrokes. Although the intent was to better inform operators, the result was often a massive overconfiguration of alarms for inconsequential conditions. In some cases, alarms are used to transmit miscellaneous pieces of status information rather than to notify operators of situations requiring action."

Analysis shows that a few "bad actor" alarms often contribute disproportionately to alarm overload. The cast of bad actors includes chattering alarms, which actuate and clear three or more times per minute; fleeting alarms, which signal short-duration events; stale alarms, which remain continuously in effect for 24 hours or more; and duplicate alarms, which result when a process condition produces simultaneous, different alerts that signify the same problem. These bad actors can cause an alarm flood, which begins when the alarm rate exceeds 10 alarms in 10 minutes.

Like movie credits, the flood of alerts can scroll down the display much faster than they can be read, potentially creating a human error trap in which an operator



View:

... Date & Time	Condition	Description	Source	Live V...	Limit	Priority	Units
3/10/2008 15:00:28	PVLO	HLY AVG HTR 21-2 TER DIF	FWT612U2	-16.31	-10.00	L 00	
3/10/2008 12:32:22	OFFNRM	ATOM STM TO IGNTRS PRESS L - S/P 54 ...	SG10IGNTRS			L 00	
3/10/2008 12:32:19	OFFNRM	SUBFP 21 LO PRES LOW	FW01SUBFP21			L 00	
3/10/2008 12:27:57	OFFNRM	FW HTR 24 LEVEL LOW	FW01LPHTR24			L 00	
3/10/2008 12:27:56	OFFNRM	FW HTR 22 LEVEL LOW	FW01LPHTR22			L 00	
3/10/2008 12:17:13	OFFNRM	COMB AIR PREHEAT EXP TANK LEVEL L...	SG08CAWP			L 00	
3/10/2008 8:38:39	DEVHI	BYPASS DAMPER 22	SG04CD2049_FB	38.45	5.00	L 00	PCT
3/9/2008 6:40:42	GSMALM	BFPT 21 HIGH VIBRATION - BEARING #4	F2\ALARM_1511			H 00	
3/8/2008 12:19:54	OFFNRM	BOP911 FRONT MAIN BATTERY	BOP911_HDW_A...			L 00	
3/8/2008 12:19:54	OFFNRM	BOP911 FRONT BOTTOM POWER SUPPLY	BOP911_HDW_A...			L 00	
3/8/2008 10:14:22	PVLOLO	FT2020 HA COIL CRC H2O FLW	FS23_HAC_26	0.43	300.00	L 00	KLB/HR
3/8/2008 10:14:21	PVLOW	FT2020 HA COIL CRC H2O FLW	FS23_HAC_26	0.43	375.00	L 00	KLB/HR
3/7/2008 23:26:12	PVLL	ATOMIZING STM PRESS-IGN	2SG100AI	5.13	55.00	H 00	
3/7/2008 23:24:07	OFFNORM	ATMG STM/OIL DP	2SGX03DI	LOW		H 00	
3/7/2008 23:23:43	OFFNORM	IGN OIL PMP 22 LOCKOUT	2FS1F72	LOCK...		H 00	
3/7/2008 22:15:10	OFFNORM	SUBFP 21 OIL PRESS	2FW106DI	LOW		L 00	
3/7/2008 16:21:06	OFFNORM	DPTP 91 STANDBY START	9WC011DI	STBY...		L 00	
3/7/2008 6:42:37	OFFNRM	E_STOP ALARM	CD26_E_STOP			L 00	
3/6/2008 23:54:38	GSMALM	EXHAUST HOOD 'A' TEMP HIGH S/P 175 D...	S2\ALARM_0081			H 00	
3/6/2008 4:48:27	GSMALM	HYD FLUID TEMP ALM,LO 85DEG F HI 125...	S2\ALARM_0057			H 00	
3/5/2008 11:00:50	OFFNRM	902 PCRD DI MI9234 #3S	FS22CON902_C...			L 00	
3/4/2008 10:41:27	OFFNRM	CHIMNEY STROBE, PURGE, OR XFER SW...	BOPU2			L 00	
3/3/2008 15:50:34	PVLOW	CD26 1STG VENT BOX PRESSUREPT2328	FS23_CDRY_26_P	0.77	16.00	L 00	IN H2O
3/3/2008 15:14:11	PVLOW	CD26 2STG PLATE DELTA P PT2106	FS23_CDRY_26_P	-0.04	7.00	L 00	INCHE...
3/3/2008 14:48:53	PVLOW	CD26 1STG PLATE DELTA P PT2105	FS23_CDRY_26_P	0.00	7.00	L 00	IN H2O
3/3/2008 14:43:58	PVLOW	CD26 1STG SCRUB BOX 2 AIR PRESSUR...	FS23_CDRY_26_P	0.75	25.00	L 00	IN H2O
3/3/2008 14:43:44	PVLOW	CD26 2STG PLENUM PRESSURE PT2320	FS23_CDRY_26_P	0.24	20.00	L 00	IN H2O
3/3/2008 14:35:44	PVLOW	CD26 1STG CLEAN PLENUM PRESSURE ...	FS23_CDRY_26_P	0.18	25.00	L 00	IN H2O
3/3/2008 14:35:07	PVLOW	CD26 2STG COAL DELTA P PT2317	FS23_CDRY_26_P	-0.08	9.50	L 00	IN H2O
3/3/2008 14:27:01	PVLOW	CD26 1STG COAL DELTA P PT2316	FS23_CDRY_26_P	0.01	10.00	L 00	IN H2O
3/3/2008 14:08:59	OFFNRM	CD26 BELV EXPOSION SUPRESION ALARM	FS23_BELV_26_M			U 00	
3/3/2008 14:07:01	OFFNRM	CD26 BELV EXPOSION SUPRESION TRO...	FS23_BELV_26_M			U 00	
3/3/2008 13:51:40	PVLOW	CD26 1STG SCRUB BOX 1 AIR PRESSUR...	FS23_CDRY_26_P	0.71	25.00	L 00	IN H2O
3/2/2008 11:24:26	BADPV	GEN CLG WTR OUT BAR19 T	TGT219U2	NAN		L 00	
3/2/2008 11:24:26	PVHI	GEN CLG WTR OUT BAR19 T	TGT219U2	NAN	34.47	L 00	
2/25/2008 3:38:39	BADCTL	CD26 ENERGY METHOD 1	FS23_HACD_26_S			L 00	

Unacknowledged ala... 2
Acknowledged alarms: 133

Pause | Resume | Acknowledge

In modern power plant control rooms, alarms appear as lines of text on a display screen, often flashing or accompanied by an audible tone. Plant operators may be deluged with over a thousand such alerts a day. (Photo courtesy Honeywell Experion PKS)

could miss a critical alarm and fail to take corrective action that would prevent equipment damage or a plant shutdown.

"It's fairly simple to determine if operators are overloaded," said Crawford. "Digital control systems can count the number of alarms that occur, and if the number exceeds 300 per day, the operators are overburdened to the point they can miss a critical alarm."

Alarm Management Guidelines

EPRI collaborated with member utilities and alarm management experts to develop best practices to improve alarm management in power plant control rooms. The report, *EPRI Alarm Management and Annunciator Application Guidelines* (1014316), reviews fundamentals of alarm management, common alarm problems and solutions, and case studies.

The guidelines employ a seven-step methodology derived from hundreds of successful projects to improve alarm system performance:

Step 1: Develop and maintain an alarm philosophy to provide comprehensive guidelines for alarm management and an optimal basis for alarm selection, priority setting, and system monitoring. A key aspect is establishing the alarm's purpose. For example: Alarms shall be used to notify the operator of abnormal situations requiring operator action.

Step 2: Collect data and benchmark results to establish current alarm system performance.

Step 3: Resolve "bad actor" alarms that are responsible for most of the alarm overload.

Step 4: Document and rationalize the system through a comprehensive review to ensure that it complies with the principles in the alarm philosophy. "Documentation and rationalization correct many common problems, because when the alarms were originally created, they did not follow any type of integrated plan," said Crawford. "In this step, many alarms are adjusted or deleted."

Step 5: Implement alarm audit and enforcement technology so the system's configuration cannot be changed without authorization.

Step 6: Implement real-time alarm management by installing advanced alarm capabilities to address specific issues. For example, "alarm shelving" safely suppresses nuisance alarms so the underlying problem can be corrected.

Step 7: Control and maintain the improved system through an ongoing program that monitors key performance indicators and corrects problems as they occur.

"Once these steps have been taken and the guidelines implemented, plant operators can rely on the alarm system for early warning of conditions that warrant their attention and action," said Crawford. "This early warning and responsive action can result in fewer equipment failures and in operation that stays within the design operating parameters. Ultimately, this leads to longer equipment life and more efficient operation."

Making Operators More Effective

Public Service of New Mexico (PNM) was the first utility to use the guidelines. Operators at PNM's San Juan Generating Station, a four-unit, coal-fired, 1,800-MW plant, experienced on average more than 1,000 alarms per day—with a peak of nearly 15,000 alarms per day. Alarm flooding occurred eight times per day, and the 10 most frequent alarms accounted for nearly 80% of the total. Deluged with alarms that were insignificant, duplicative, or "crying wolf," operators could become complacent and not take proper corrective action if necessary.

San Juan plant operators and engineers worked with an EPRI project team to apply the alarm guidelines, focusing on the first four steps of the process. Subsequently, alarms were used only to alert operators of abnormal conditions and situations where operator action was required. Duplicate alarms were targeted for elimination. This reduced San Juan Station's alarm rate by 87%, to 135 alarms per day, well within the best-practices benchmark of 150 per day. The percentage of days when the number of alarms rose above the manageable level was reduced from 80% to 8%.

On the heels of PNM's pioneering application, Nebraska Public Power District (NPPD) implemented the guidelines at its Gerald Gentleman Station, a two-unit, coal-fired, 1,365-MW plant near Sutherland, Nebraska. From an average of 441 alarms per day, the plant cut the number to 130 per day.

"Reducing the daily alarms by 70%–90% in these two cases had an extremely positive impact on the plant operators," said Crawford. "Operators can now be proactive in monitoring plant equipment status and preventing abnormal conditions from developing—rather than reacting to an ever-ringing alarm signal. They are now in control of the plant, not merely being distracted by an ineffective alarm system."

Gathering Momentum

PNM's and NPPD's projects have spurred similar efforts at fossil power plants across the country.

In a joint initiative with EPRI, Tennessee Valley Authority (TVA) is implementing the guidelines at multiple coal and combined-cycle power plants to increase operators' situational awareness so they can be more proactive in plant operations. Systems at these plants typically were configured by vendors using a conservative approach and a philosophy of "if it can be alarmed, configure it," according to Elliott Flick, TVA vice president of fossil engineering. For example, benchmarking showed the Bull Run plant's alarm system was configured to respond to more than 68,000 individual points and was presenting operators with more than 6,800 alarms on an average day, with alarm floods occurring more than eight times per day.

The TVA-EPRI project team performed "bad actor" resolution and alarm documentation and rationalization for Bull Run that is bringing the plant's alarm rate into line with the EPRI best practices. The number of configured alarm points has been cut from 68,801 to 2,911—a key step in bringing the number of alarms within industry best-practice standards. The project team is also tackling overloaded systems at TVA's Widows Creek and Gallatin coal plants and at the Lagoon Creek combined-cycle plant, with more plants to follow.

The benefits are straightforward and easily justified, considering the costs incurred when an operator misses an important alarm, according to Flick. Preventing a 24-hour forced outage at the 900-MW Bull Run plant, for example, would save $712,800.

Arizona Public Service (APS) and the New York Power Authority (NYPA) have also begun implementing the EPRI guidelines. APS is applying the guidelines at its Redhawk plant, the project's first combustion turbine combined-cycle plant. NYPA is implementing the guidelines and has committed to improving alarm system displays, including graphics of critical parameters that operators can use to correct conditions before they trigger an alarm.

The EPRI report *Alarm Management Implementation* (1023146) details the steps utilities can follow in analyzing their systems and creating the philosophy and rationalization documents.

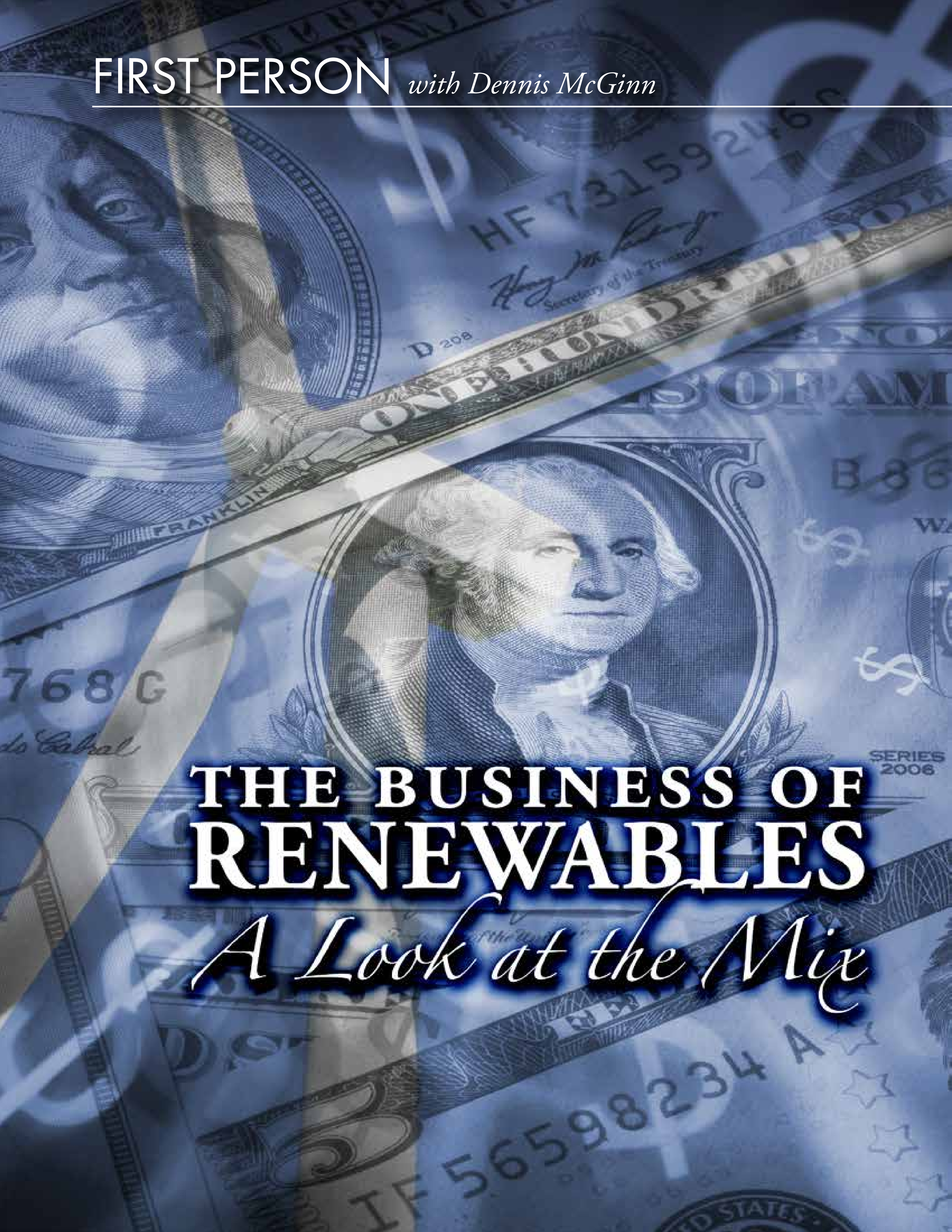
Further Work

Building on these successful implementations, EPRI researchers are seeking additional ways to make alarm systems and control room operators more effective. For example, lessons learned from utility implementations may be included in future updates to the guidelines. Improving operator situational awareness through high-performance human-machine interface technology that encompasses control room ergonomics, superior graphics, and standardized alarm nomenclature is another potential area for further R&D. A recent EPRI report, *Operator Human-Machine Interface Case Study* (1017637), compares different types of graphics at a power plant.

"We aim to be the control room operators' advocates," said Crawford. "Our goal is to help operators be as effective as they can be. That means not overloading them with unnecessary alarms, but rather giving them alarm information they can use to keep plants operating safely, reliably, and economically."

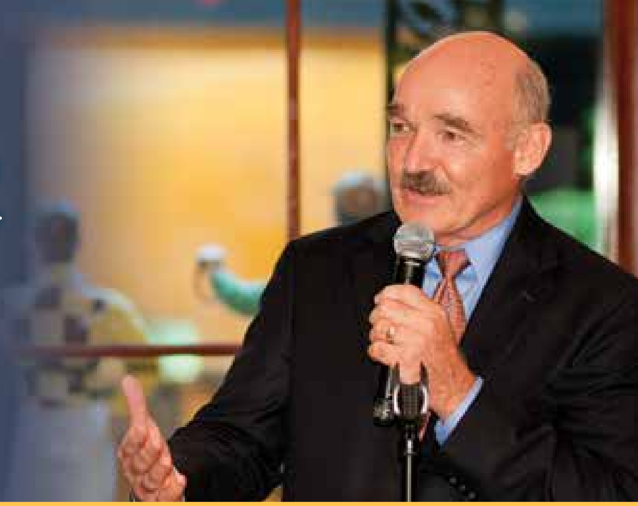
This article was written by David Boutacoff. Background information was provided by Wayne Crawford, wcrawford@epri.com, 704.595.2727.

Wayne Crawford is a senior project manager in EPRI's Generation Sector, specializing in operations, maintenance, and outage management for fossil power plants. Before joining EPRI in 1998, he worked for over 25 years at Progress Energy and for several years as an independent consultant for the utility industry. Crawford received a B.S. degree in nuclear engineering from North Carolina State University.



THE BUSINESS OF RENEWABLES

A Look at the Mix



Vice Admiral (Ret.) Dennis McGinn is president of the American Council On Renewable Energy (ACORE), a nonprofit membership organization that focuses on technology, finance, and policy, providing an educational platform for a wide range of interests in the renewable energy community. ACORE convenes leadership forums and creates energy industry partnerships to communicate the economic, security, and environmental benefits of renewable energy. In this interview with *EPRI Journal*, McGinn discusses some key financial, policy, and business aspects of renewable energy development in the United States.

EJ: Production tax credits for renewables seem to have the proverbial nine lives, but the prospect for any one of those lives never seems certain. How does this affect research and development? And how would you characterize the prospective impacts of this uncertainty?

McGinn: For any emerging business that isn't mature or deployed fully to scale, it's really, really important to have market certainty in policy so that investors and companies can invest in development and scale up manufacturing—so they can go from R&D to demonstrations and then to deployment. As implied by the question, the policy has never been certain, and that has undercut the amount of scale up, technology improvements, and corresponding cost declines that could have been realized. That said, the policies have been helpful—just not as helpful as they could have been. Because the production tax credit is expected to expire on December 31, companies are cutting back on their workforce, on production. They're not developing as many projects as they would have with more policy certainty. Is it a showstopper? No, it's not. It isn't a question of whether renewables will continue to scale up. It's a question of how quickly and how broadly renewables will scale up. The price of installed renewable capacity is trending downward, but that could go even faster if we create a virtuous cycle—if we have the right long-term incentives to increase the availability and reduce the cost of investment finance.

> **"For any emerging business, it's really, really important to have market certainty in policy so that investors and companies can invest in development and scale up manufacturing."** *~ Dennis McGinn*

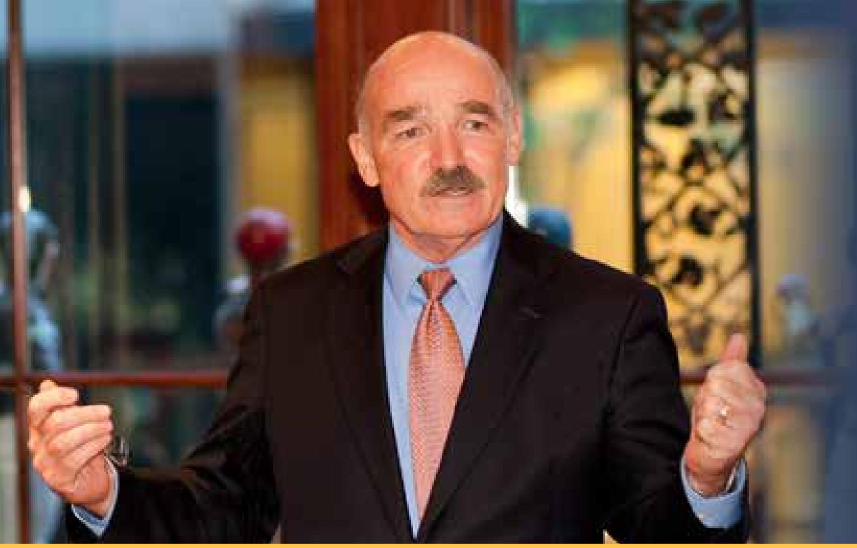
EJ: So in thinking about related issues such as climate, emissions, national security, consumer prices, is it hard for policy makers to bring such issues together when considering incentives?

McGinn: I would say the policy makers, for the most part, don't have a comprehensive, strategic, or long-term sense of what's needed as it relates to our energy portfolio. If we could, as a nation, develop a comprehensive, long-term view of renewable energy, we'd more likely adopt a more stable and beneficial policy that would scale up renewables faster and more broadly. Right now, the nexus between energy security, economic security, and environmental security is being missed and is not evident in the piecemeal policies that we're seeing for the most part. We need policies that result in the best value at the least cost, considering the need for economic, energy, and environmental security, and that will basically give us the most diversified portfolio of energy.

EJ: Climate policy appears to be more "back burner," but there seems to be an underlying consensus that we're going to have to decarbonize the economy at some point. What's your assessment of the climate issue and, in particular, the carbon tax as a potential driver for renewables?

McGinn: If it were carefully crafted, a carbon tax would make a lot of sense for climate change considerations and from economic and energy security perspectives. A carbon tax would help shift our portfolio from one overreliant on fossil fuels for transportation and electricity to one that is more diversified, that creates economic opportunity and energy security. Because of demographic shifts, economic shifts, and the availability of some very good technology for production and distribution of energy, I think we need a mechanism like a carbon tax—but it would have to be very carefully crafted. Done the right way, it could help create a healthier and economically beneficial energy portfolio overall.

EJ: Thinking less broadly, and shifting to the world of carrots and sticks: If you were keeping a scorecard for renewable portfolio standards, how would you score them?



> “In developing a renewable energy project, it doesn’t matter whether the cost is for financing, materials, or labor; cost is cost.”

McGinn: To a significant degree, they have created a much more robust, larger scale, and less expensive renewable energy industry—and they have increased the percentage of energy that we’re getting from renewables. That said, renewable portfolio standards (RPS) vary widely from state to state, and we don’t have one at the national level. For the most part, I give them very high marks for providing the market demand that has been and will continue to be a key driver of our energy diversification.

EJ: Are there sufficient incentives in place to drive renewables once those portfolio standards are met?

McGinn: Generally speaking, across the country, we have a ways to go to meet the renewable portfolio standards. But as we do, a couple of things are going to become evident. First, the cost of delivered renewable energy will continue to go down as we scale up. Second, we’re going to see proof positive of renewable energy’s economic and environmental benefits in various forms and in various parts of the country, both locally and regionally. So I think people will see the value of going above and beyond these important standards.

EJ: When we look at renewables, we typically account for variability of output and the shift to a more distributed model. Anything in these areas that you’ve got your eye on in particular?

McGinn: Utilities, I think, are being really smart in getting the right mix of traditional baseloads, whether it means the use of the cleanest coal technology or, increasingly, the conversion or commissioning of plants that use natural gas. In the case of natural gas and renewables, I think there’s a lot of synergy. The good news for pairing renewables with natural gas capacity is that you can supply firming much more rapidly than you can with a coal or nuclear baseload plant. With fuel costs for wind and solar being zero, once you make the infrastructure investment, these renewables provide a nice price hedge for natural gas. Right now, you’ve got very low natural gas prices, but we know they are going to eventually stabilize with some sort of a global market–driven price. And so I think this combination of low or zero fuel cost for renewable energy and the agility of natural gas to quickly adjust for variability or intermittency is a synergistic combination.

EJ: How much emphasis is ACORE placing on what might be called the renewable business environment?

McGinn: We recently held our latest energy financial forum on Wall Street in New York, where we brought together hundreds of very serious investors to learn how they can make money with wise investments in renewables. ACORE is a business-oriented, fact-based, non-partisan organization that supports the scale-up of renewable energy. The key part of that business is financing. We are seeing growth in the business, some of it due to RPS mandate, some of it due to incentives, and we have case studies, real data, real return-on-investment data that make people more and more confident that renewable energy is a good place to invest.

EJ: So let me ask you a broad question, and pardon the pun. Where do renewables face stiff head winds, and where do they have the wind at their back?

McGinn: I would say the stiffest head winds relate to the availability and high cost of financing. It goes back in some regards to the question about the role of the incentives, the production tax credits,

> “The price of installed renewable capacity is trending downward, but that could go even faster if we have the right long-term incentives to increase the availability and reduce the cost of investment finance.”

etc. Most renewables aren't on a level playing field. The industry is working hard to show financial institutions that these are reliable and profitable investments and that they will be a significant part of our energy portfolio going forward. We're starting to see some innovative thinking about finance, such as the bill introduced into the U.S. Senate recently that extends master limited partnerships (MLPs) to renewables. MLPs could bring to bear larger pools of capital at much lower prices and help level the investment playing field for renewables. So stiff head winds are there, but I think we have some good prospects that are being developed.

EJ: Where do renewables have the wind at their back? Where do you see real momentum or progress?

McGinn: In the technology scale-up—already having good technologies that are proven and are delivering cost reductions. Wind is about 40% cheaper in 2012 than in 2008 because of a combination of improved technology and scale. The same for solar, which is almost 70% cheaper now than in 2008. And in technological innovations, the development of microgrids, for example, and the fact that the Department of Defense and the military services have embraced renewables for mission success and mission effectiveness. When the Department of Defense wants to scale up because it is good for its mission, good for its bottom line, that's a huge tail wind for renewables.

EJ: Where do you want to see more research, more development, more demonstration programs focused?

McGinn: There are demonstrations we could do to help make the smart grid a reality—measuring what is happening on the grid, finding out where critical points of failure are, doing the necessary hardware changes to make the grid more reliable and less costly. There is a lot of value in distributed generation RD&D, and I think we could do more of that. The military is doing some things with microgrids—smart grids on a smaller scale that allow the operator to make least-cost, best-value choices from a variety of power generation sources.

EJ: Looking at grid integration and the smart grid, where would you focus attention?

McGinn: I think we can do a better job in measuring what is happening on the grid—get better sensing information that gives system operators real-time information on how we can get better reliability and at what cost. And we need to make decisions about grid upgrades—transmission capacity, where to augment transformers, what kinds of transformers. We need data analysis that would give return on investment if you were to make those changes. You can manage what you measure, and we can measure at a much finer level of detail than we have in the past.

EJ: This could also give a certain amount of transparency, if you will, to the performance of renewables. By having more data and by demonstrating the value of the data more clearly, could you raise utilities' confidence in renewables?

McGinn: It's all about full cost accounting. What are the real costs? What are the benefits and what are the risks of various forms of electricity, various types of transmission, various uses? If we can get a much better handle on these costs by more accurate and more timely measurement, we can make much better cost-benefit and risk decisions when we consider grid architecture, how we would finance it, and how we would make money off it.

EJ: Looking out to 2020—your personal perspective—what does success looks like for renewable energy by 2020?

McGinn: I would say it's quite doable for us to double the amount of renewable energy in our electricity mix by 2020. Once you get to a certain critical mass in deployment, it tends to accelerate. People get more comfortable with renewables, whether they are operators, ratepayers, or regulators.

EJ: Do you see a sleeper breakthrough or issue on the renewables landscape that could change the game and perhaps surprise some people in doing it?

McGinn: I think a breakthrough would probably not be in the technology, although I could be surprised, but I think rather it would be in the financing. In developing a renewable energy project, it doesn't matter whether the cost is for financing, materials, or labor; cost is cost. And I think that there are some financial mechanisms through which we could see, possibly this year in fact, a significant reduction in the cost of capital, making it much more available for renewable projects. That could be a big breakthrough.

EJ: Money does move technology, doesn't it?

McGinn: It really, really does.

"For the most part, I give [renewable portfolio standards] very high marks for providing the market demand that has been and will continue to be a key driver of our energy diversification."

Electromagnetic Technique Measures Magnetite Exfoliation

A key failure mechanism in fossil fuel power plants with austenitic stainless steel boiler tubes in the superheat and reheat sections is overheating of the boiler tubes when exfoliated magnetite blocks the steam flow inside the tubes. New supercritical boilers are designed with these tubes, which operate at temperatures above 1,005°F (540°C). At these high temperatures, the tubes produce magnetite on their inside surfaces, and when the boiler is taken off line and the boiler tubes cool, the internal magnetite scale can flake off and become trapped in the lower tube bends. Large amounts of loose scale accumulated in the bottom can block steam flow, resulting in overheating, followed by creep fatigue, and, ultimately, rupture of the tubes.

Radiographic techniques—including conventional film radiography, computed radiography using phosphor plates, and digital radiography (DR) using solid-state detectors—can reveal some problems, but these processes are time-consuming, require elaborate equipment setup, and can be difficult to apply to tubes in the center of a bundle. Also, radiation exposure concerns limit the number of personnel that may be deployed in the vicinity simultaneously. In the absence of a proven, efficient nondestructive evaluation (NDE) technique for detecting exfoliation, some utilities have resorted to cutting potentially affected tubes to remove any accumulated magnetite scale as a precaution against tube failure.

The Electromagnetic Approach

EPRI recently conducted a feasibility study and demonstration of an advanced NDE technology, the low-frequency electromagnetic technique (LFET), that offers power plant operators an easier, faster, reliable approach to exfoliation detection. The technique, developed by TesTex Inc., makes use of the fact that the scale formed on the inside of the tubing is more magnetic than the stainless steel from which it is generated. LFET's small, portable scanner, when moved at a constant speed along the outside tube surface, can signal areas with higher magnetic strength, indicating a buildup of magnetite scale in the tube bends. Unlike radiography, which gives a visual density output (like a medical X-ray) that must be interpreted by a qualified reader, LFET produces a digital output that can be computer-analyzed in near real time, saving both time and cost.

Application at Morgantown

GenOn applied the LFET technology, with EPRI's guidance, at its 1,467-megawatt Morgantown Generating Station in Newburg, Maryland. In restarting from a forced outage to repair the pendant platen superheater, the unit had experienced several tube failures in the final superheater's tube assemblies. Rather than risk additional failures, the station operators decided to extend the outage and perform further examinations using the LFET technology. GenOn scanned all of the superheater's 171 assemblies at the lower loops, locating additional tubes with significant plugging. While the technology had been field-tested at one other station, the demonstration at Morgantown represented the first commercial application in the industry.

Portable electromagnetic scanner checks boiler tubes for magnetite

In addition, the GenOn scans included a test to determine the effect of moisture on the LFET technology's detection and measurement capability. Results showed that moisture compacts the magnetite into a denser material that produces a different—but identifiable—signal. These findings will help LFET technicians better identify both dry and wet magnetite and make accurate readings under different operating conditions.

"We consider LFET to be the technique of choice, owing to its considerable time savings over DR," said Jurgen Brat, engineering manager for the Morgantown station. "DR requires a minimum spacing between personnel, limiting the number of crews that can be deployed in the boiler simultaneously. LFET doesn't have this restriction, and when properly adjusted with a calibration sample, the scan results are almost instantaneous. All things considered, the LFET detection and analysis time is just 12%–20% of that needed for DR. The savings can be counted not just in hours, but in days."

GenOn's successful application will increase utility confidence in the ability of the LFET technology to accurately quantify magnetite exfoliation without the cutting and rewelding of boiler tubes and to rank affected tubes for cleaning. The technique will also reduce maintenance costs and help prevent unplanned outages caused by boiler ruptures.

For more information, contact Stan Walker, swalker@epri.com, 704.595.2581.

Fast-Deployable Recovery Transformers

Extra-high voltage (EHV) transformers connect the main arteries of the nation's transmission grid, linking one high-voltage system to another, and some 2,100 of these huge devices are in operation around the country. More than 90% of all power travels to businesses and consumers through EHV transformers, making their potential loss a critical concern for the nation's economy and security. And because electricity powers other critical infrastructure, such as communications, transportation, and water, disaster recovery operations are inevitably paced by the speed with which electricity service can be brought back on line.

Unfortunately, EHV transformers—the grid components most vulnerable to sustained outage—are commonly situated in remote substations, making them difficult to replace in the event of an emergency. They are large and heavy, each weighing around 400,000 pounds, and typically transportable only on specially outfitted railroad cars.

Replacing a damaged unit can be logistically complicated, taking several months even when a suitable spare transformer is readily available. If a new replacement must be ordered from the manufacturer, delivery can take six months to two years. In the meantime, power companies improvise, rerouting power flows through other circuits. While power systems are designed to easily handle the loss of a few transformers, the simultaneous loss of many through a catastrophic natural disaster or an act of sabotage has the potential to severely disrupt power security for months.

Designing for Speed and Flexibility

A consortium that teams the U.S. Department of Homeland Security's Science and Technology Directorate with EPRI, transformer manufacturer ABB Inc., and CenterPoint Energy Inc. has developed the prototype for a new recovery transformer, or RecX, that could replace a damaged or destroyed unit in a radically shortened time frame—less than a week—to prevent sustained power outages.

The speed advantage comes from an innovative design: in contrast to a conventional garage-sized, three-phase transformer, the RecX is configured as three smaller, single-phase modules that can be transported separately and wired together at the site. Each of the units handles a different phase of the AC input, with the outputs electrically integrated to produce standard, three-phase power. Because the modules weigh only 125,000 pounds each, they can be shipped by road on trailers, adding transport flexibility. The main transformer unit is mounted on a steel sled, providing a platform for the other modules and eliminating the need to pour a new concrete foundation at the site. In addition, installation crews can work on the sections in parallel, shortening the setup time normally required for conventional large transformers.

Recovery transformer set up for transport (photo courtesy of the Department of Homeland Security)

Recovery Test Run

In March, the consortium orchestrated a pilot demonstration for the prototype transformer, simulating an emergency scenario to fully test the RecX and its deployment concept. The RecX units and supporting equipment were transported by truck in a series of strategically deployed convoys from the factory in St. Louis, Missouri, to a CenterPoint Energy substation near Houston, Texas.

The demonstration was very successful. The trucks left the ABB factory on a Monday morning and arrived in Houston Tuesday afternoon. Utility crews waiting at the substation worked around the clock to install and test the RecX units in preparation for energization. By Saturday, the transformer was on line, stepping the 345-kilovolt transmission voltage down to 138 kV for distribution to customers. The RecX will remain operational for at least one year so that engineers can monitor and validate its performance and reliability.

One next step could be to design a version of the transformer that can handle a broader range of step-down voltages so that a single version could replace a greater number of the transformers currently installed. A long-term vision for the program is to store recovery transformers at various secure locations around the country for rapid deployment to utilities in a region as emergencies arise; a full deployment strategy will be needed to identify optimal storage locations and the number and types of transformers to be stored at each site.

For more information, contact Richard Lordan, rilordan@epri.com, 650.855.2435.

Renewables and Wildlife Risks

Deployment of renewable power generation technologies such as wind and solar is growing rapidly in the United States. This expansion has been driven mainly by concerns over energy security, pollution, and global climate change and facilitated by technological advances that are decreasing costs and increasing capacity and efficiency. Wind energy alone accounts for approximately 80% of new capacity brought on line over the last five years, and the U.S. Department of Energy has set a goal of wind energy providing 20% of total electricity by 2030. In addition, many states have renewable portfolio standards in place that will encourage investment in wind and solar projects over the next several years.

Environmental advocacy groups, conservation organizations, and the public are generally supportive of these trends, but the siting, development, and operation of individual projects continue to be challenged by wildlife management issues. Concerns about wildlife risks have threatened to block or delay large-scale development of new wind and solar facilities, since many affected species are protected under federal and state regulations. Wind facilities are under scrutiny for perceived impacts on bats and other avian species, while solar facilities have evoked concerns about state- and federally listed species such as the desert tortoise.

Survey Clears the Air

Companies that have invested or plan to invest in renewable energy projects need information about which wildlife species could be affected, the magnitude of the impacts, and how to manage, mitigate, or offset wildlife risk. To assess the current state of knowledge, EPRI conducted a wide-ranging survey on these issues as part of ongoing efforts to clarify the environmental risks of renewable generation technologies.

In addition to information from the current scientific literature and recent professional events, the survey included interviews with key stakeholders—representatives from utilities, solar and wind development companies, the Nature Conservancy, the Natural Resources Defense Council, the American Wind Wildlife Institute, and state and federal agencies. Leading consultants and university researchers were also interviewed.

The survey findings are presented in a recent EPRI report, *Wildlife Risks of Wind and Solar Power* (1022183). Key conclusions include the following:

- Wildlife risks are technology dependent and site and species specific. While individual fatalities are the standard risk metric, the cumulative effects of habitat loss and degradation on populations and species are the greater concern.
- Collision fatalities at wind farms are generally low relative to the total size and spatial extent of affected bird species, but the risks to bats are less well understood and potentially more severe. The impacts of large-scale solar energy development on desert tortoise and other sensitive species are not yet known.
- Proactive site screening is the most effective, lowest-cost approach for identifying, avoiding, and minimizing wildlife risks. Once a site is selected, timely consultation with regulatory agencies expedites the permitting process and reduces the risk of unexpected delays.
- Quantitative risk assessment and management tools—backed by comprehensive pre- and postconstruction monitoring studies—make it possible to evaluate the efficacy of site selection, design, and mitigation decisions.

The report concludes with a quantitative risk assessment and management case study based on the use of EPRI-developed RAMAS software for modeling the golden eagle population at the Altamont Pass Wind Resource Area in California. Predictions that high local fatality rates would result in an overall population decline have not been realized, highlighting the importance of regional and cumulative impact assessment for populations spanning broad geographic areas.

Ongoing Initiatives

A supplemental project (1023378) has been launched to extend the RAMAS population modeling initiative, and additional work is planned to assess the cumulative impacts of wind energy development on the Indiana bat in the eastern United States. Work also continues on development of an innovative, nacelle-mounted bat detection and protection system, with further testing of the system's capabilities scheduled for 2012 at an operational wind project where a postconstruction environmental monitoring program is in place.

For more information, contact Adam Shor, ashor@epri.com, 650.855.8782.

EPRI Develops 3D Radiation Dose Estimation Prototype

The amount of radiation maintenance workers are likely to receive is a crucial factor in planning nuclear plant outage activities, with dose estimates sometimes affecting task sequence, task duration, team size, shielding options, the use of scaffolding, and other logistical elements. Radiation surveys are currently used to develop worker dose estimates, establish control measures, and brief workers on the radiological conditions they will encounter when entering the work environment. However, these surveys are usually limited in scope and confined to two dimensions, providing little information about dose rate gradients with elevation.

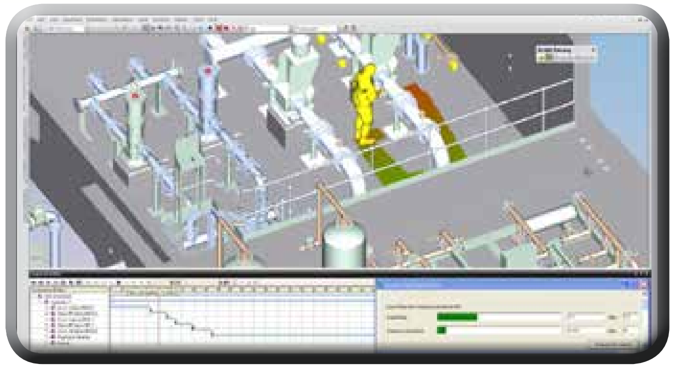
To enhance the value of standard radiation surveys, EPRI developed an algorithm that uses the three-dimensional aspects of radiological conditions to estimate dose rates for locations where workers will actually be positioned. The algorithm is not intended as a standalone application but rather is designed for integration with third-party simulation software packages. A project team that includes experts from EPRI, utility companies, the engineering consortium Fiatech, and several software vendors has produced two versions of a 3D imaging–based prototype for accurately planning work and estimating worker dose.

Prototype Packages with Clear Advantages

The 3D imaging platforms in these simulation packages incorporate the EPRI dose rate algorithm, which uses precise worker positions, task durations, survey data, and technician knowledge of areas with sources of radioactivity to estimate the dose rates and dose for various work activities. The packages can use either traditional survey or real-time dose rate data and can handle mild to significant dose gradients. Combining 3D imaging with survey data and dose rate technologies enhances visual and conceptual comprehension and offers improvements in accuracy, flexibility, and ease of use in determining which dose optimization scenario to pursue.

The 3D image with radiation dose rates can be effective for both planning and training, allowing workers to better visualize and internalize the work environment ahead of time without radiation exposure. Procedures and sequences can be planned more accurately to improve efficiency and minimize radiation dose. The prototype's imaging capability is expected to be especially valuable in planning and designing scaffold builds, with due consideration of how radiation dose rates would affect size, configuration, inventory, and interferences.

Because the prototype can incorporate signals from real-time area radiation monitors and/or wireless electronic dosimeters, it



can provide radiation protection staff with the most recent information as workers prepare to enter a radiation zone. This is particularly important in areas with rapidly changing radiological conditions.

Post-job reviews will also have the benefit of additional information. If a job is being reviewed for exceeding a dose estimate, it may be difficult to determine the exact reason, as the dose rates may have increased, the work may have been extended, or the location of the workers may have caused the additional dose. The real-time dose history can be of great assistance in determining the cause of the high dose.

Demonstrations

EPRI validated its dose rate algorithm in a 2011 pilot-scale demonstration using data from a midwestern nuclear plant, and the 3D software vendors subsequently validated the integration of the algorithm with their individual products. A full-scale demonstration of the prototype products was carried out at the same plant in March of this year.

Each 3D vendor used the same plant maintenance task—replacing a residual heat removal system valve—and worked with plant staff members to recreate the planned task and estimate durations and dose. In addition to showing the work-planning module, the vendors presented options for using their tools to support other plant programs and processes. Observers from other utilities attended the demonstration and provided feedback to the vendors.

Demonstration results and feedback will guide additional adjustments, and the final version of the EPRI algorithm, along with the appropriate documentation, will be available later in 2012 for public use by interested parties. Each of the participating vendors is seeking a host plant to facilitate further development and testing of the prototype in preparation for commercial application.

For more information, contact Phung Tran, ptran@epri,com, 650.855.2158.

Seismic Instrumentation at Nuclear Plants

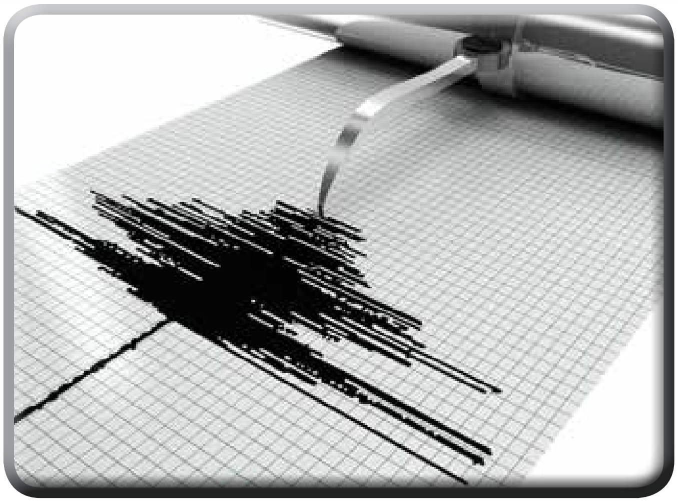
When a U.S. nuclear power plant experiences an earthquake, it must perform certain safety evaluations within the first four hours. For each plant, an operating basis earthquake (OBE) has been established, which defines the ground motion that the plant can be expected to tolerate without incurring damage that could compromise safe operation. If the ground motion exceeds the OBE or if it cannot reliably be established whether the OBE has been exceeded, the plant may need to shut down and remain down until it can be demonstrated that earthquake damage did not jeopardize operational safety.

To accomplish this assessment, the plant must collect and evaluate data related to the time history of the ground motion experienced. EPRI has studied the instrumentation systems needed to collect this information for well over a decade, and its criteria for OBE exceedance were endorsed in 1997 by the U. S. Nuclear Regulatory Commission and were included, with some specific qualifications, in Regulatory Guides 1.166 and 1.167. EPRI has now taken a further look at instrumentation system options to compare their configuration, functional capability, and cost.

Instrumentation Requirements

Although the OBE is often characterized in terms of a single parameter—the peak ground acceleration—it is actually defined by a response spectrum, which relates the maximum acceleration or velocity experienced at a particular location to the range of frequencies associated with the vibrations caused by the earthquake. Also of interest is the cumulative absolute velocity, which represents the additive total of the time-history values; this is the parameter that best indicates the potential for damage to nuclear plant structures.

Both of these parameters are calculated from data collected by a digital triaxial time-history recorder, or accelerograph, which records the motion of the base to which it is attached. These devices are mounted at a free-field point some distance away from the plant buildings to get readings that are not affected by the plant structures; additional accelerographs can be mounted on or within the plant buildings as an option. The instruments must be digital, have a sampling rate of at least 200 samples per second, and cover a frequency bandwidth of 0.2–50 hertz. They must also have battery backup, with pre-event memory sufficient to record the entire earthquake motion, and a storage device that can accommodate rapid data retrieval.



Configuration Choices

EPRI assessed three instrumentation options, labeled as minimum, basic automatic, and complete. The minimum system includes a single free-field accelerograph (unless the plant's OBE specifically requires an additional unit within the plant structure). Staff must go to the free-field equipment and manually download the data to a laptop computer, which is used to calculate the response spectra and cumulative absolute velocity for OBE comparison. Calculations must be completed within four hours of the earthquake.

The basic automatic option adds a dedicated desktop computer that automatically retrieves the accelerograph data and performs the calculations at high speed. Such a capability expedites the process of assembling the information needed to make a decision on whether a plant shutdown is required. The upgrade from the minimum system requires a dedicated cable from each instrument to the computer in the control room, an uninterruptible power supply for the computer, and an operator display.

The complete option adds one or more building- or equipment-mounted accelerographs to supplement the free-field unit and a more robust operator display that is incorporated into the control room annunciator system. The complete system's collection of more extensive response data from within plant structures enables a more comprehensive long-term evaluation of the earthquake's damage potential.

Details on functionality and comparative cost estimates for the three options are available in the EPRI white paper *Seismic Instrumentation at Nuclear Power Plants* (1024889).

For more information, contact Robert Kassawara, rkassawa@epri.com, 650.855.2302.

Pilot Results on Demand Response Raise New Questions

Utility demand response programs offer customers the opportunity to voluntarily reduce their energy use in exchange for more favorable pricing. The success of such programs has been thought to depend on identifying the dynamic rate structures most attractive to consumers and developing technology and information systems that will facilitate their easy use.

EPRI worked with Commonwealth Edison on a pilot project (1023644) to investigate these issues with the help of advanced metering infrastructure (AMI), which allows ComEd to record customers' electricity consumption on an hourly basis and provide ratepayers with timely online access to information on their electricity use.

While the study gathered valuable data on participants' response to different rate options, more basic questions emerged about how participation can best be achieved across a company's broad customer population.

An Unusual Study Design

The pilot project assigned each customer to one of five dynamic rate structures, which are expected to reduce customer loads at strategic times:

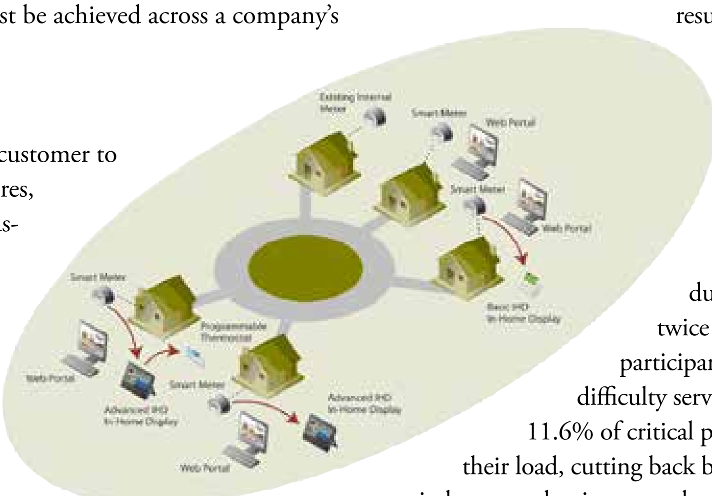
- Day-ahead real-time pricing, conveyed through a new hourly price schedule issued each day
- Critical peak pricing, where the price of electricity increases by $1.74/kWh during peak events
- Peak-time rebate, where the customer is eligible for credits of $1.74/kWh for loads reduced during peak events
- Fixed time-of-use rates, tied to a daily time schedule
- Inclining block rates, tied to the level of each customer's monthly consumption

A control group receiving standard ComEd residential flat rates provided a basis for comparing usage behavior.

All 8,000 participants were invited to sign up for ComEd's eWeb service, which provides access to detailed customer billing information. Selected participants also had access to basic or advanced in-home displays, to a web-based information system, and to the means for regulating their household thermostats at times when load relief was needed. The in-home display continuously presents and updates information, extracted directly from the AMI meter, about household electricity consumption, giving both the current rate of energy use and a historical comparison.

The most unusual aspect of the study's design was its method of recruiting participants. Most pilot projects have used an "opt-in" enrollment strategy, where participants volunteer for the study. While opt-in recruitment typically results in relatively low levels of participation, those who do volunteer are expected to be more active in modifying their energy use.

The ComEd pilot used an "opt-out" design, where participants are chosen randomly and may then request to be excluded from the program. Because it includes additional participants outside of a "conservation active" cohort, the opt-out design could be considered a more realistic model for results across a general population. One of the goals of the ComEd pilot was to test whether offers of dynamic pricing made through an opt-out process would result in a higher level of response from the population as a whole.



Study Results

Statistically significant responses were exhibited by some customers under each of the dynamic rate types, especially during peak events—times once or twice a month when ComEd notified participants that it expected to have more difficulty serving load. Under these conditions, 11.6% of critical peak pricing participants reduced their load, cutting back by an average of 21.8%. Event-period usage reductions were lower for other rate types, ranging from about 14% for peak-time rebates and real-time pricing to 11% for fixed time-of-use rates to 5.6% for inclining block rates.

However, the results were very similar to those of opt-in studies and showed that most of the participants did not change their consumption patterns, even in response to a $1.74/kwh peak-event rate increase. This suggests that opt-out implementation by itself may not be sufficient in getting more customers to adjust their usage when supply costs are elevated. Increased customer engagement is likely to require better communication about the value of responding to price alerts, more information about household electricity consumption, and technologies that make responsive action more convenient for the customer.

For more information, contact Gale Horst, ghorst@epri.com, 865.218.8078.

TECHNOLOGY AT WORK

Member applications of EPRI science and technology

Finding the Best Fix for Air Inleakage Problems

Boiler air inleakage is a stealthy thief of power plant performance. It can throw off the fuel-air balance needed for effective combustion, potentially damaging internal components, increasing unburned carbon, and degrading boiler efficiency. Excess airflow through particulate collection devices, such as electrostatic precipitators or baghouses, sharply reduces collection efficiencies. The increase in flow through a unit's back-pass can also compromise the capabilities of induced-draft fans and, under some circumstances, may cause a unit to be derated. Leakage problems tend to increase with the age of the unit, with years of wear and tear loosening up joints and increased cycling duty promoting erosion and corrosion in the ductwork.

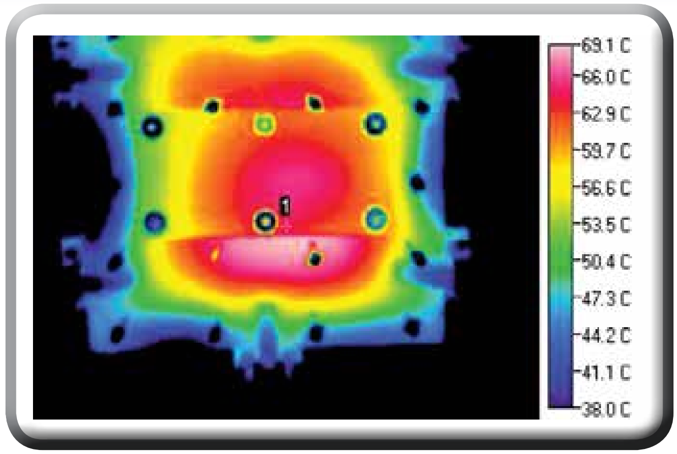
Measuring the oxygen rise from the furnace to the stacks can verify that air inleakage is a problem, but the specific sources and locations of the leaks are difficult to identify. Nearly all components in power plants are covered with insulation, which can hide corrosion and other sources of inleakage. Even when the general location of leakage is known, the ductwork's configuration can hinder easy access or frequent visits by plant personnel. With the ducts between the furnace back-pass and the stack spanning hundreds of feet, the sheer size of the surface area to be inspected increases the difficulty of identifying leak sources. Often the best approach to pinpointing air inleakages depends on the individual plant's design and layout and the experience of the plant personnel in identifying the locations.

Matching Methodologies to Plants

EPRI initiated a first-of-its-kind study to assess the relative effectiveness of four methods for identifying sources of boiler air inleakage: thermal imaging, audits using smoke, audible techniques, and flue gas sampling. EPRI and its research contractors worked with project hosts GenOn, Southern Company, NRG Energy, Ontario Power Generation, and Luminant to clarify the costs, applicability, benefits, and limits of each approach and to determine the options best suited for the host sites.

Typically the research team spent two days at each plant. In some cases, the preferred test method was clear at the outset, and the team spent the entire two days tracking down air inleakage sources and critiquing the method's application and level of success. In other cases, the researchers spent the first day determining which method would work best for the host unit as a whole or for specific areas of the plant and then applied and documented the choice on the second day.

Upon completion of the project, the utilities received a report outlining the evaluation methods used and the inleakage sources identified. The utilities then used the evaluation techniques and the test results to identify other sources of air inleakage and initiated repairs. In at least one case, leakage was reduced to essentially zero.



Thermal imaging provides information on cool spots that may be indicative of air inleakages.

Specific Results, Broad Value

Project results and the documentation developed at the five utility host sites are expected to have a lasting influence on best practices across the industry. "The boiler air inleakage research team gained experience with the mechanics of leaks and developed more effective ways to mitigate efficiency losses," said Todd Wall, a research engineer at Southern Company. "Ultimately, the project results can be applied to reduce heat rate and potential fan limits, providing substantial financial and emissions savings."

Jeff Huang, a senior engineer at Ontario Power Generation, agreed, stressing the combination of cooperative research with a plant-specific outcome: "It was a great experience for us to collaborate with EPRI and fellow utilities on this project. The program results confirmed some of the inherent technical difficulties we faced using the traditional oxygen rise method and brought to light a simple detection method using smoke that had previously been overlooked. For us, a combination of this and the thermal camera method proved to be the most effective."

Detailed information on the investigation techniques and project results are available in the EPRI report *Evaluation of Methods to Identify Boiler Air Inleakage Sources* (1023074).

For more information, contact Sam Korellis, skorellis@epri.com, 704.595.2703.

Fine-Mesh Fish Screens Demonstrated in Sediment- and Debris-Heavy Missouri River

To comply with the developing fish protection regulations of the Clean Water Act, power plants with once-through cooling may need to deploy new screens at water intake structures to prevent fish and shellfish from being drawn into the cooling system. As part of its revision of the act's Section 316(b), the Environmental Protection Agency (EPA) has proposed a requirement that existing power facilities evaluate replacing their current screens—effective for juvenile and adult populations—with fine-mesh (≤2-mm) traveling water screens that reduce the entrainment of smaller organisms, such as eggs or larvae.

Fine-mesh screens are already in use at some U.S. power plants, but the technology has not been installed in environments where the water entering intake structures is heavily laden with sediment and debris. These conditions are common in midwestern river environments and are especially prevalent on the Missouri River and its tributaries. Power plant operators have been concerned that fine-mesh screens would clog, making them ineffective or expensive to use. To support its rulemaking process, the EPA solicited information from midwestern power plants on how these screens would perform in such challenging environments. Several electric power companies asked EPRI to conduct a study evaluating the performance of the screens under these conditions, and EPRI agreed to undertake an independent study.

Demonstration on the Missouri

Kansas City Power and Light Company (KCP&L) volunteered its Hawthorn 9 power station as a test site. Hawthorn 9 was an ideal site for several reasons. Located on the Missouri River, it is a combined-cycle unit used for peaking power and typically operates only from March through October. Thus, during the extended periods when the plant was not operating, KCP&L could continue to run the cooling pumps and the screens without risking any generating capacity if the screens became clogged.

Hawthorn 9 already had coarse-mesh (9.5-mm) traveling (rotating) screen baskets installed, so fine-mesh (2-mm) screen panels were overlaid on one of the existing screen assemblies in late 2009. Having both screen types—the existing coarse mesh and the new fine mesh—operating next to each other made it easy to compare the handling of debris and sediment by the two setups. In addition, the design of the fine-mesh screen allowed for relatively easy removal if it became clogged. During the 20-month test period, which ended in August 2011, power plant workers collected sediment samples and suspended-solids samples from the river and also monitored the river for debris.

Fine-mesh screen panels overlaid on a coarse-mesh traveling screen assembly

River flows during the study period reflected the typical annual pattern for the Missouri River. The screens were exposed to suspended sediment; terrestrial debris, including leaf litter and woody material; agricultural debris, including corn shucks and other crop waste; floating and frazil ice; and human litter from urban and suburban runoff and sewer overflow. The fine-mesh screens operated successfully without clogging or blockage during the entire test period.

According to EPRI's Doug Dixon, "Fine-mesh screens appear to be operable in sediment-loaded rivers, or at least in the main-stem Missouri." KCP&L was so satisfied with the performance of the screen that the utility decided to leave it in place once the study was completed. Michael McMenus, the environmental compliance manager for the Hawthorn plant, noted, "Rather than seeing the data in a report, we got firsthand experience. We found no impact on screen operation or cooling-water flow, and now we know how the screens will operate at our plant."

The technical data from the study (EPRI Report 1024697) have been provided to the EPA, KCP&L, and the other power companies that participated in the study. A final rule for Section 316(b) of the Clean Water Act for existing facilities is expected in July 2012, and although it is not yet known whether this final rule will require the use of fine-mesh screens, companies now have more information to help them decide whether the screens are a viable option for their power plants.

For more information, contact Doug Dixon, ddixon@epri.com, 804.642.1025.

REPORTS & SOFTWARE

Key deliverables now available

The following is a small selection of items recently published by EPRI. To view complete lists of your company-funded research reports, updates, software, training announcements, and other program deliverables, log in at www.epri.com and go to Program Cockpits.

A System for Understanding Retail Electric Rate Structures (1021962)

Reporting on the first in a series of planned studies, this technical update presents a comprehensive system for characterizing and comparing different retail electricity pricing plans, including those enabled by smart grid systems. The study considers traditional uniform rates, inclining (block) rates, time-of-use rates, real-time pricing, critical peak pricing, interruptible/curtailable rates, direct load control, demand bidding, and demand subscription service.

Survey of Emerging Nondestructive Evaluation Technologies (1023082)

This report surveys four nondestructive evaluation techniques for their potential application in the electric power industry: phased-array curvature correction, guided-wave focusing and imaging, laser shearography, and acoustic camera. In addition to background information for each technology, the survey includes discussions of challenges, technical solutions, and potential applications. Active development of laser shearography is recommended for improved boiler tube examination.

Advanced Technology for Groundwater Protection: Automatic Tools and In Situ Sensors for Groundwater Monitoring (1024829)

This report documents the state of technology of automatic and in situ groundwater monitoring technologies and assesses whether they can be used cost-effectively to enhance the current groundwater monitoring capabilities at nuclear power plants. Technologies for automatically detecting tritium were explored, as well as those that monitor nonradiological groundwater characteristics, such as temperature, pH, and dissolved oxygen.

An Engineering and Economic Evaluation of Post-Combustion CO_2 Capture for Natural Gas–Fired Combined-Cycle Power Plants (1024892)

While the development of CO_2 capture and storage technologies has focused primarily on coal-fired assets, future legislation could conceivably require application for natural gas–fired combined-cycle (NGCC) plants as well. This report assesses the technical feasibility, performance, and associated costs of applying full-scale 90% CO_2 capture technology in retrofit and new-build NGCC plants, including comparisons with a reference 556-MWe base plant and potential improvements offered by emerging exhaust gas recycle technology.

Engineering and Economic Evaluation of Central-Station Solar Photovoltaic Power Plants (1025005)

In addition to summarizing the current deployment and technology status of solar photovoltaic (PV) equipment, this report presents the results of an engineering and economic evaluation of conceptual utility-scale solar PV power projects for 22 combinations of six PV technologies and four locations in the United States. The results of this evaluation will be useful to those who are considering investment in utility-scale central-station PV power plants.

Summary of the EPRI Early Event Analysis of the Fukushima Daiichi Spent Fuel Pools Following the March 11, 2011, Earthquake and Tsunami in Japan (1025058)

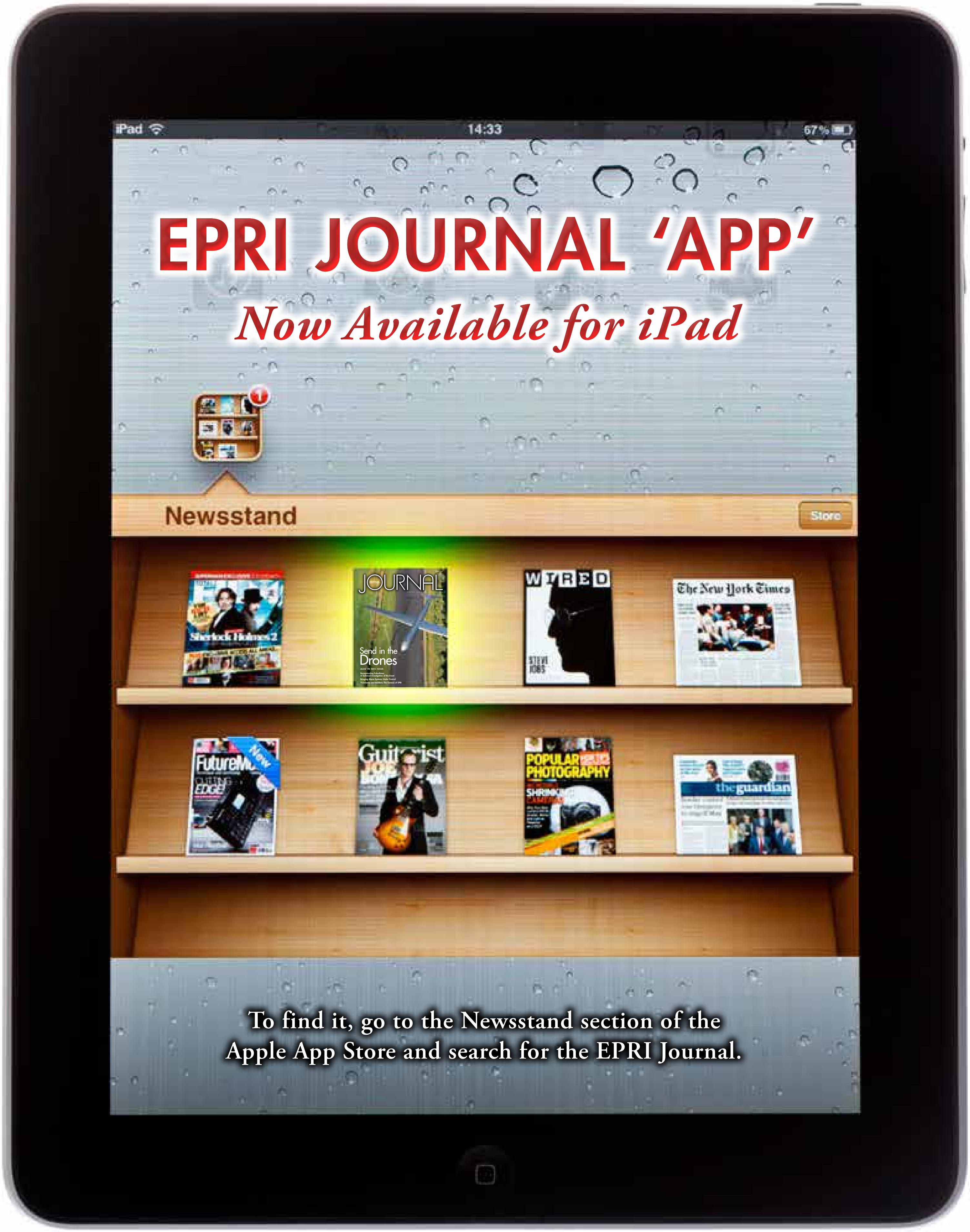
The explosion in the Fukushima Daiichi Unit 4 reactor building—eventually attributed to hydrogen from the Unit 3 reactor—was originally suspected to be caused by hydrogen generation in the Unit 4 spent fuel pools. This technical update compiles individual analyses and assessments of the spent fuel situation developed early in the Fukushima response by EPRI and experts from nuclear utilities, vendors, and national laboratories for the purpose of documentation and for future reference and use.

Solar PV Market Update: Volume 1—Spring (1025103)

Produced on a quarterly basis, this update provides a snapshot of photovoltaic (PV) market information, along with brief EPRI analyses. The document synthesizes data gleaned from a variety of primary and secondary sources, highlighting specific industry issues—including market outlooks, equipment cost and pricing trends, system design and efficiency advances, and changes in the incentive landscape—that are likely to impact utility solar PV investment and planning efforts.

Cyber Security Strategy for the Electric Sector (1025672)

This technical update provides practical guidance to utilities on developing an overall cyber security strategy, developing a risk management process (including risk assessment), and selecting and tailoring cyber security requirements for the electricity sector, with special emphasis on issues raised by smart grid technology. The National Institute of Standards and Technology Interagency Report (NISTIR) 7628, *Guidelines for Smart Grid Cyber Security*, is referenced, along with other source documents and approaches.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