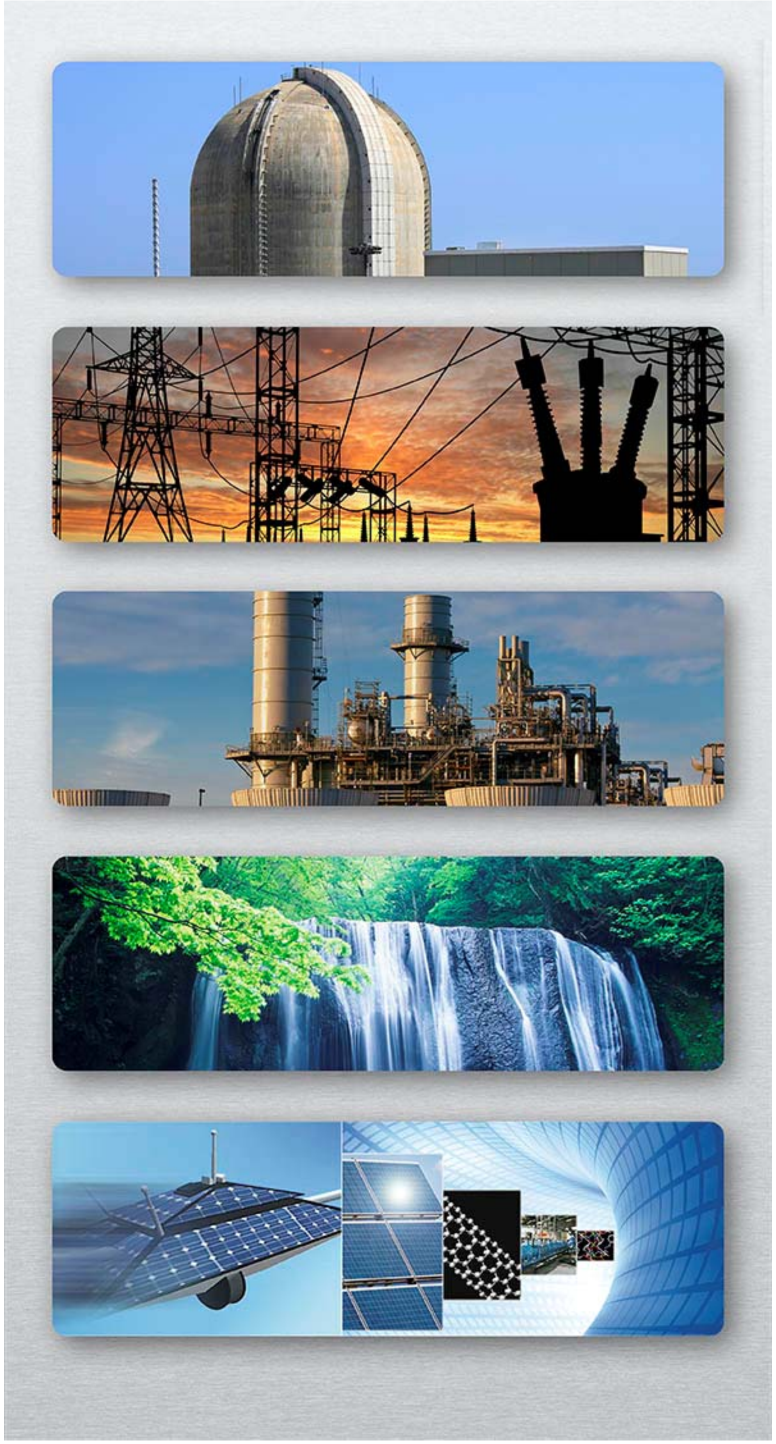


Overview of EPRI Research in Nuclear Power: EMC is One Critical Part in Establishing Plant Safety and Reliability

E-BEARS: Electrical & Computer – Baylor Engineering & Research Seminars

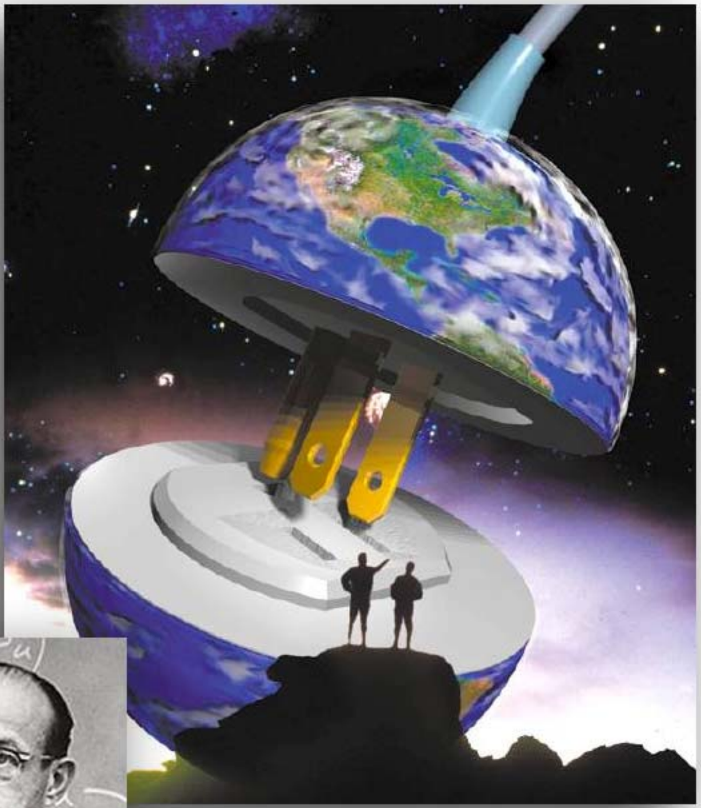
Revised 10/26/11

Philip F. Keebler
Sr. Project Manager - EPRI

BEARS Seminar – Autumn 2011
October 28, 2011

Our Founder & History…

- Founded in 1973
- Independent, nonprofit center for public interest energy and environmental research
- **Collaborative** resource for the electricity sector
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN
  - Laboratories in Knoxville, Charlotte and Lenox, MA



Chauncey Starr
EPRI Founder

Our Mission…

To conduct research on key issues facing the electricity sector…on behalf of its members, energy stakeholders, and society.

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Portfolio Spans the Entire Electricity Sector

Generation

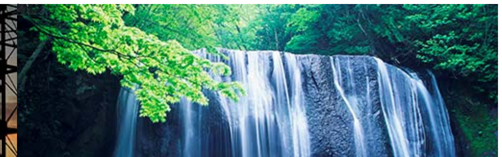
- Advanced Coal Plants, Carbon Capture and Storage
- Combustion Turbines
- Environmental Controls
- Generation Planning
- Major Component Reliability
- Operations and Maintenance
- Renewables

Nuclear Power

- Advanced Nuclear Technology
- Chemistry, Low-Level Waste and Radiation Management
- Equipment Reliability
- Fuel Reliability
- Instrumentation and Control
- Long-Term Operations
- Material Degradation/Aging
- Nondestructive Evaluation and Material Characterization
- Risk and Safety Management
- Used Fuel and High-Level Waste Management

Power Delivery & Utilization

- Transmission Lines and Substations
- Grid Operations and Planning
- Distribution
- Energy Utilization
- Cross Cutting Technologies



Environment

- Air Quality
- Environmental Aspects of Renewables
- Global Climate Change
- Land and Groundwater
- Occupational Health and Safety
- T&D Environmental Issues
- Water and Ecosystems

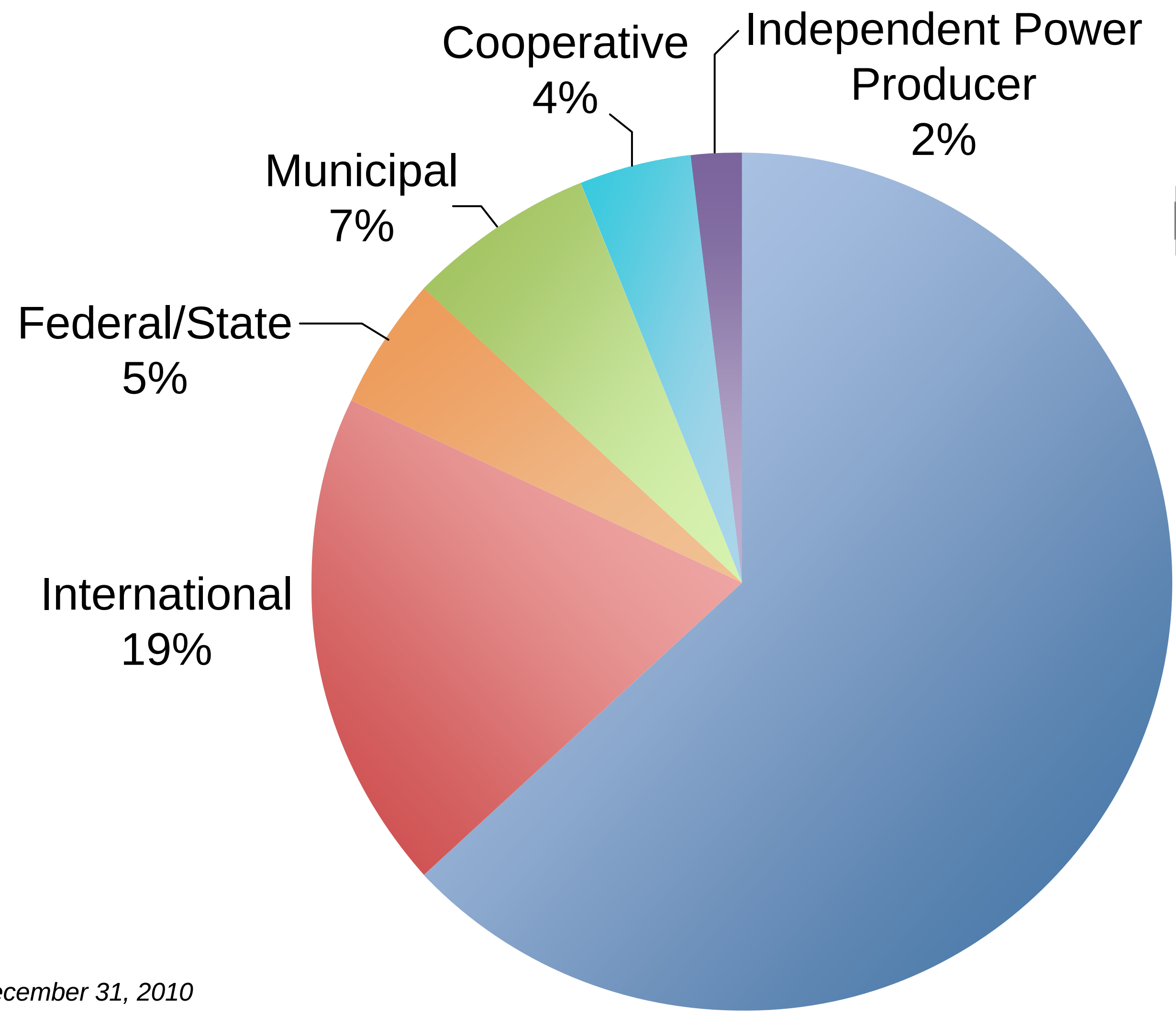
EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Our Members…

- 450+ participants in more than 40 countries
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 18% of EPRI's research, development and demonstrations
- Programs funded by more than 1,000 energy organizations

ELECTRIC POWER RESEARCH INSTITUTE

EPRI Member Breakdown
By 2010 Annual Research Portfolio Funding



December 31, 2010

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Research Areas

- Materials Degradation / Aging
- Fuel Reliability
- Used Fuel and High-Level Waste Management
- Nondestructive Evaluation and Material Characterization
- Equipment Reliability
- Instrumentation and Control
- Risk and Safety Management
- Advanced Nuclear Technology
- Chemistry, Low-Level Waste and Radiation Management
- Long-Term Operations

2012 Research Offerings

- View the 2012 Nuclear Research Portfolio

Related Links

- EPRI Quality Program Manual (PDF 147KB)

Program Websites

(Login Required)

Nuclear

Developing safe, reliable, economical, and environmentally responsible technologies that enable the long-term operation of existing nuclear plants and the deployment of advanced nuclear power plants.

Spotlights

Constellation Energy Nuclear Group Demonstrates Advanced Technologies for Inspecting Concrete Containment
October 24, 2011

EPRI Launches Nondestructive Evaluation (NDE) Modeling and Simulation Center to Enhance NDE
October 17, 2011

Relay Aging Management Guidelines Target Age-Related Degradation
October 10, 2011

Powder Metallurgy Offers Reduced Cost and Lead Time for Complex Components
October 3, 2011

EPRI Develops Guidelines and Design Criteria for Field Programmable Gate Arrays
September 26, 2011

Events Calendar

Debris Best Management Practices Workshop
Nov. 3-4, 2011

All Nuclear Events

Newsletters

Library of EPRI nuclear-related newsletters, with some available in multiple languages.

- View all of the Nuclear newsletters

Member Testimonials

Hear what nuclear industry professionals have to say about EPRI, its research programs, and how to put EPRI research results into action. View the testimonials.

Product List and Implementation Categories

(Login Required)

EPRI's research products can be implemented in a number of different ways. The Nuclear Sector has developed a simple categorization tool to aid users in resource planning as it relates to the review and application of

Core Drivers

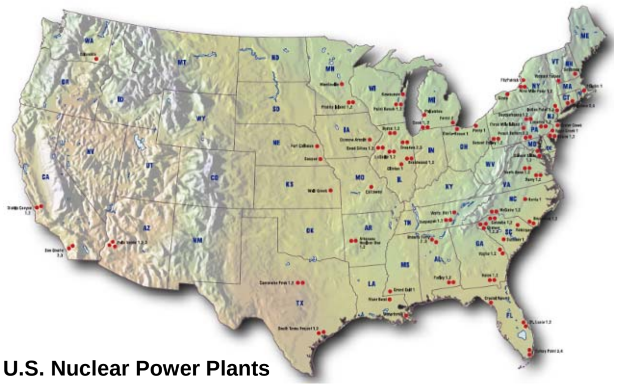
Maximize the safe utilization of existing nuclear assets

Enable the deployment of advanced nuclear technologies

Assess long-term sustainability of nuclear energy

Collaboration

U.S. Participants



U.S. Nuclear Power Plants

Source: NEI Website, 2009

- All U.S. nuclear owners/operators
- 104 reactors

Non-U.S. Participants

- 20 countries, >220 reactors

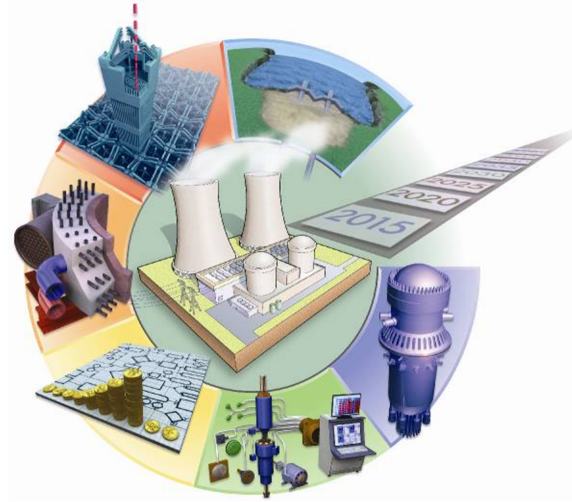
Global Breadth and Depth

- >75% of the world's commercial nuclear units

Participants Encompass Most Nuclear Reactor Designs

Thought Leadership

- **Long-Term Operations**
  - License renewal commitments
  - Technical basis for extended operations
- **Operational Issues**
  - Water availability and impacts
  - Cable aging, buried pipe, radiation management
  - Fukushima implications
- **Regulatory Environment**
  - Accepted positions being re-visited
  - Public confidence
- **New Plant Deployment**
  - Risk reduction via technology
  - Small modular reactors



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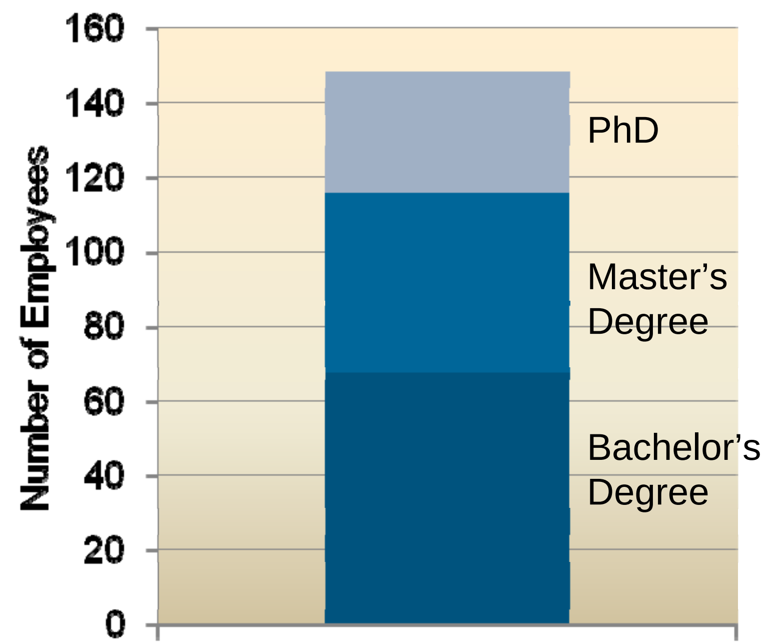
Industry Expertise

- 50% of nuclear technical staff have PhD or masters degree
- 35% of nuclear program and project managers have utility and field experience
- Global perspective…nuclear staff come from more than a dozen countries

Degree Credentials of Nuclear Technical Staff



Source: EPRI Employee Data Report

Key Interfaces

Institute of Nuclear Power Operations

Nuclear Energy Institute

Industry Collaboration

Strategic Alignment

Active Engagement

Frequent Communications

US Nuclear Regulatory Commission

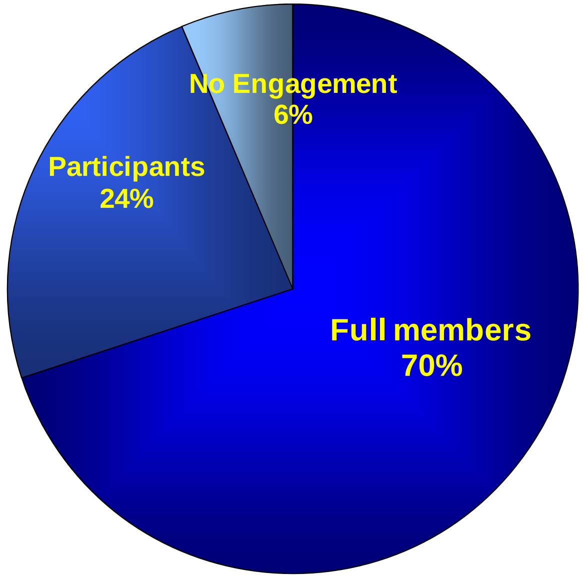
US Department of Energy

Bi- and Multi-Lateral Agreements with Global Research Institutes, National Laboratories, Universities and Vendors

Global Participation

Full Members:

- ***All 26 U.S. Utilities (USA)***
- ***British Energy (UK)***
- ***CEZ (Czech Republic)***
- ***COG (Canada & Romania)***
- ***CFE (Mexico)***
- ***Chubu (Japan)***
- ***EDF (France)***
- ***Eletronuclear (Brazil)***
- ***ESKOM (S. Africa)***
- ***KHNP (S. Korea)***
- ***NASA (Argentina)***
- ***Rolls Royce (UK)***
- ***TEPCO (Japan)***
- ***UNESA (Spain)***



Note: Excludes China, Russia, Iran, Pakistan, India, Ukraine, and Armenia, where EPRI cannot engage.

Worldwide Nuclear – 366 GWe
Full members: 242 units
Partial participants: 88 units

EPRI ELECTRIC POWER RESEARCH INSTITUTE

2011 Research Areas and Programs

Action Plan	Programs
Materials	Primary Systems Corrosion
	Steam Generator Management
	BWR Vessels and Internals
	PWR Materials Reliability
	Welding Repair and Technology Center
Fuel Reliability	Fuel Reliability
Used Fuel/High-Level Waste Management	Used Fuel/High-Level Waste Management
Long-Term Operations	*Base program beginning in 2012*
Nondestructive Evaluation	Nondestructive Evaluation
Equipment Reliability	Nuclear Maintenance Applications Center
	Plant Engineering
	Instrumentation and Control (EMC included here)
Risk and Safety Management	Risk and Safety Management
Advanced Nuclear Technology	Advanced Nuclear Technology
Chemistry, Low-Level Waste and Radiation Management	Low-Level Waste and Radiation Management
	Decommissioning Technology Development
	Water Chemistry

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Strategic Planning – Roadmaps

- Drive concise communication
- Define end point, end product, end user
- Inform funding and resource allocations
- Engage all stakeholders
- 58 in use or in draft form as of August 2011

Full integration of roadmaps into research planning by end of year.

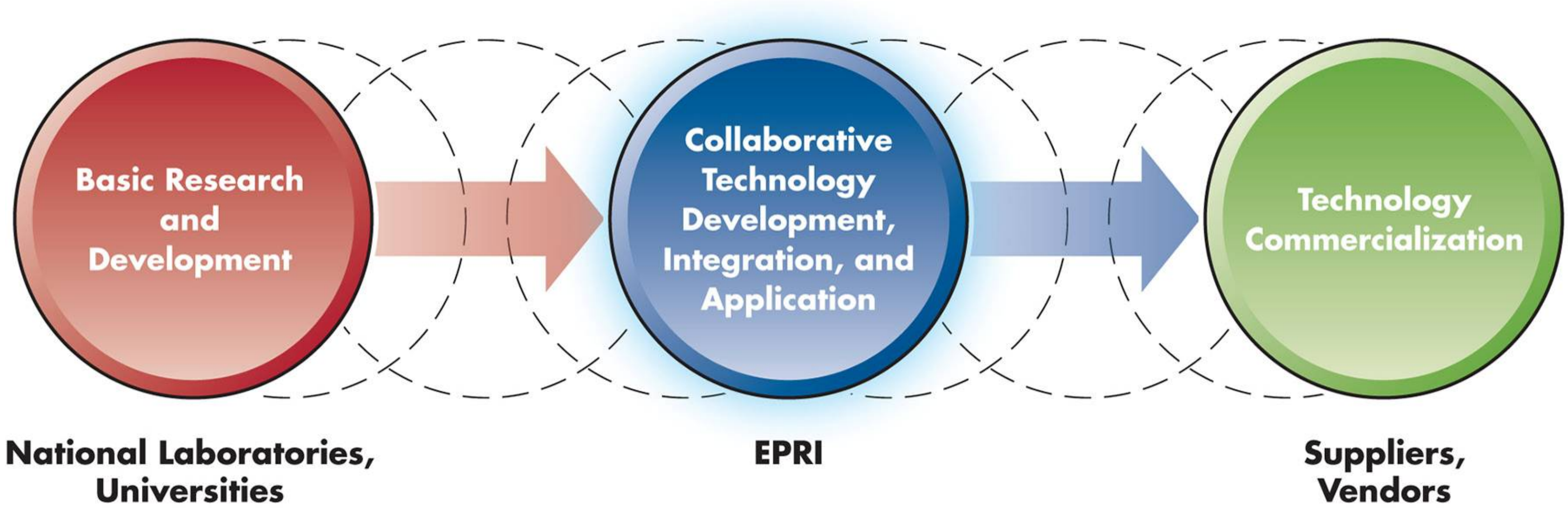
Roadmap Diversity

Action Plan	Number	Example Technical Gap
Materials	16	Welding of Irradiated Materials for Reactor Internals
Fuel Reliability	6	PWR Grid-to-Rod Fretting
High Level Waste	4	Used Fuel Extended Storage
NDE	6	Concrete Characterization and NDE
Equipment Reliability	8	Digital Instrumentation & Control Implementation
Risk & Safety	5	Risk Assessment Methodologies for External Hazards
Advanced Nuclear	3	Configuration Management for New Plants
Chemistry/LLW/RM	9	Water Chemistry for Reducing Radiation Fields
Long-Term Operations	1	Equipment Life-Cycle Management
TOTAL	58	29

Roadmaps are living documents

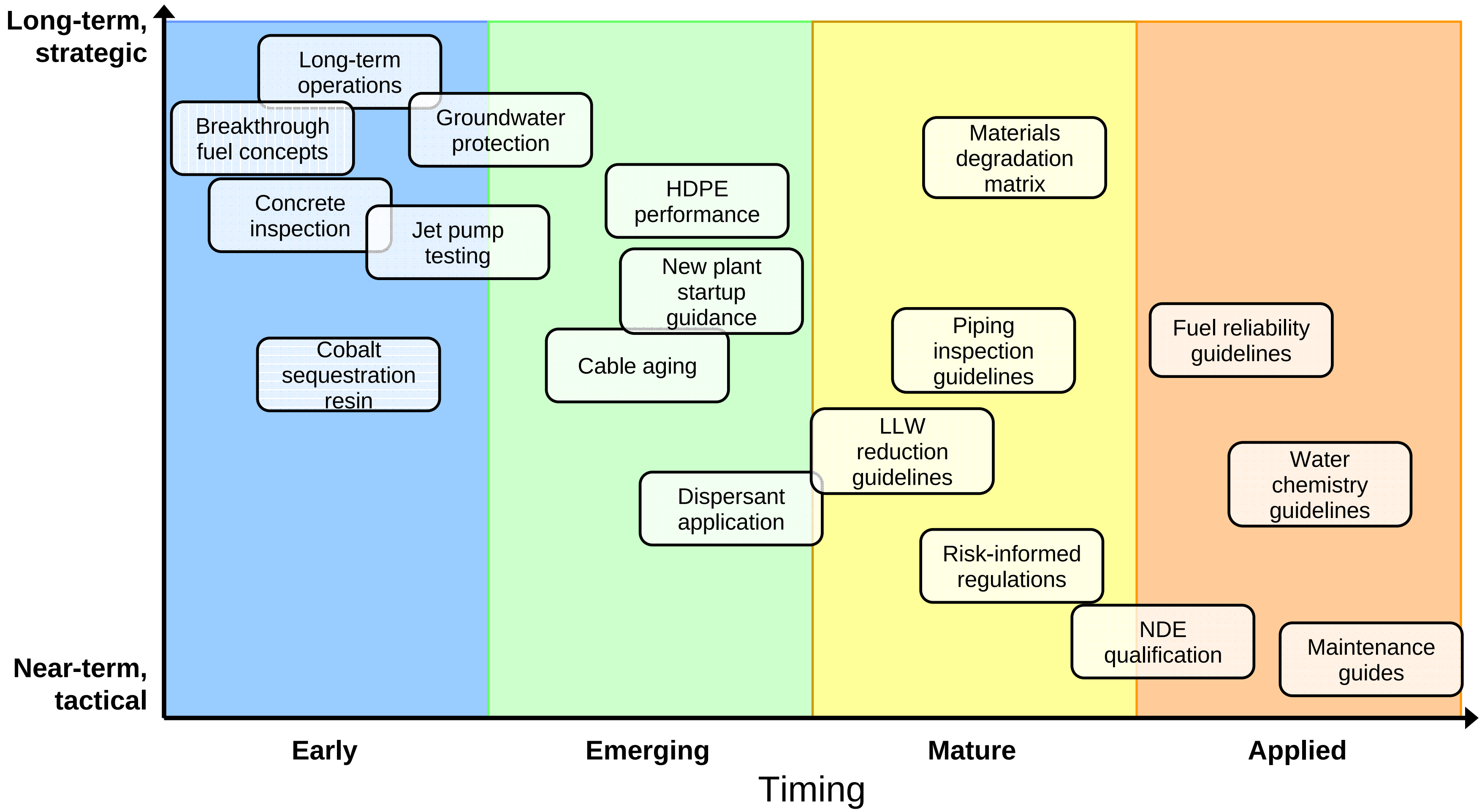
Our Role…

Help Move Technologies to the Commercialization Stage…



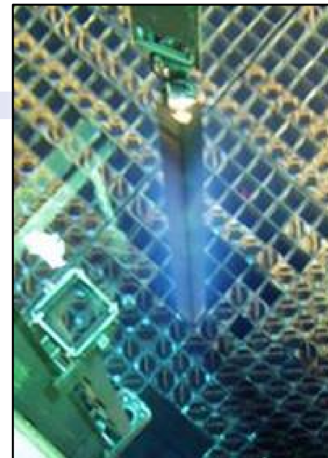
Technology Accelerator!

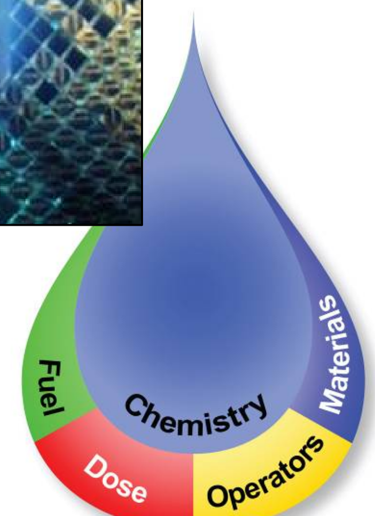
Nuclear Research Life Cycle
(Representative, Not Comprehensive)



Varied Product Slate

- **Technical Guidelines**
  - Examples: fuel reliability, water chemistry, internals inspection, EMC
- **Maintenance and Process Guidebooks**
  - Examples: feedwater maintenance, air-operated valve maintenance, dispersant application sourcebook
- **Technology Development**
  - Examples: Capillary electrophoresis, online noble chemical addition, buried pipe inspection techniques, cobalt sequestration resin
- **Software**
  - Examples: Falcon fuel analysis software, CHEMWORKS, MAAP accident analysis code
- **User Groups**
  - Examples: Pump Users Group, Large Electric Motor Users Group, CHEMWORKS Users Group, EMI Working Group
- **Site Assists/Expert Assistance**
  - Examples: Subscriber Requested Assistance, Low-Level Waste Assessments, Radiation Source Term Assessment, BWR Cycle Chemistry Evaluation, EMC/EMI





EPRI Nuclear Research

Managing Nuclear Radiation Embrittlement: Primer Update

Reactor pressure vessels—the thick steel containers that hold the fuel rods in a nuclear power plant—play a crucial role in maintaining the integrity of the reactor core. Over time, however, neutrons created by the fission reaction gradually reduce the toughness of the vessel's steel walls by a process of embrittlement. In June 2010, EPRI released a primer designed to help nuclear engineers understand embrittlement. The document provides the basic information and tools necessary to design and implement an embrittlement management program and to comply with regulations for maintaining adequate vessel fracture toughness.

Embrittlement is the main threat to reactor pressure vessels during the life of a nuclear power plant. Vessels made from steel that contains a higher proportion of copper and nickel tend to be most susceptible to embrittlement. And, in general, pressurized water reactors are more susceptible than boiling water reactors because they are exposed to more neutrons from the core. Significant vessel embrittlement can constrain nuclear plant operations. Although no vessel has ever ruptured due to embrittlement, the phenomenon contributed to the shutdown of at least one nuclear power plant. The Yankee Rowe Nuclear Power Station in Massachusetts, one of the oldest plants in the United States, closed because the cost of work necessary to address the issue of vessel embrittlement made operating the plant economically unfeasible.

The primer—an update of two earlier EPRI reports—addresses regulatory changes in the past decade as well as new findings with respect to the science of vessel embrittlement. The document also reviews some of the U.S. Nuclear Regulatory Commission regulations pertaining to reactor pressure vessels, such as pressure temperature operating curves, or P/T limits. These limits outline the pressures and temperatures the operator must abide by to maintain the risk of vessel fracture at an acceptably low level. Historically, plant operators have calculated P/T limit curves using a deterministic approach that considers prior data and experience. The primer discusses a more sophisticated risk-informed approach for tabulating P/T curves that achieves the required safety goal while allowing more flexible operating limits.

EPRI's primer also addresses prevention and mitigation of embrittlement. If embrittlement has already occurred, annealing the reactor pressure vessel can restore some of the steel's strength. The procedure has not been employed on an operating commercial nuclear plant in the United States, but it has worked for several Russian reactors. Because mitigation of embrittlement can be time consuming and costly, prevention is typically a better option.

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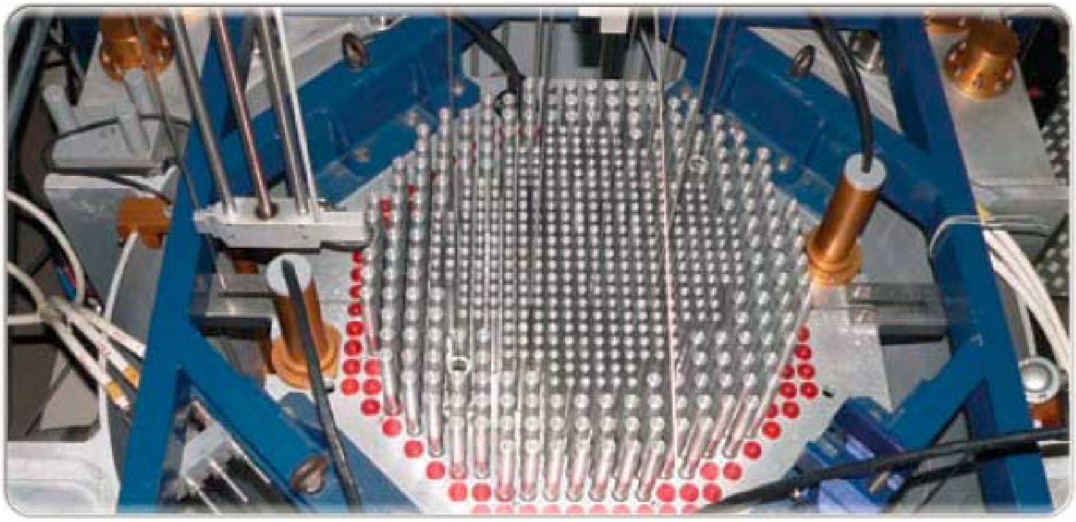
EPRI Nuclear Research



Achieving Electromagnetic Compatibility in Advanced Nuclear Plants

Instrumentation and control (I&C) systems in nuclear power plants contain sensitive electronic components. Although these systems are housed in metal cabinets for mechanical, environmental, and seismic protection, wireless devices that emit electromagnetic signals—such as cell phones, walkie-talkies, and digital cameras—can interfere with their operation. Maintenance equipment such as welding units can also create electromagnetic interference (EMI). Wireless devices and other types of portable electronic equipment that emit electromagnetic signals can potentially shut down a plant. EPRI's guidance report on electromagnetic compatibility (EMC) can help plant operators minimize the risk of EMI in advanced nuclear power plants. The report serves as a valuable training tool to help I&C engineers and plant designers understand EMI and the threat it poses in nuclear power plants.

The report addresses nine key challenges, including how to implement a spectral frequency management plan, how to maintain EMC in the face of increasing high frequencies, and how to simplify the process for meeting EMC regulatory compliance. By addressing these challenges during the design process, operators can eliminate problems before new plants come on-line. The document also describes how to develop an EMC protection system that divides responsibility for ensuring compatibility into six levels.

One of the key challenges in nuclear power plants is how to avoid "exclusion zones"—areas around I&C equipment where operation of wireless devices and other equipment is prohibited because of EMI concerns. Such zones make it difficult for plant workers who routinely communicate using walkie-talkies or cell phones. As utilities start designing new plants, they may be able to reduce or even eliminate exclusion zones by making some vital EMC performance changes.

First, I&C equipment can be designed to be less susceptible to failure due to EMI. EPRI is leading the development of new EMC standards within the United States to determine not only how to make I&C equipment less prone to failure, but also how to implement EMC compliance tests that ensure that equipment won't fail in the presence of a more cluttered and energetic electromagnetic environment. Second, EMC protection for sensitive I&C equipment can be improved by using EMC-rated system cabinets that use EMC seals around the doors and vents and EMC-rated feed-throughs around power and data cables.

Finally, EPRI also is working with some manufacturers of equipment such as digital cameras to reduce emissions levels. For example, when the camera's flash goes off, a charge is released, creating emissions levels known to cause EMI problems with equipment in nuclear plants. Better shielding and filtering of the components inside flash units could provide enhanced EMC performance. Improvements in all of these areas may eventually eliminate the need for exclusion zones in nuclear plants.

As new high-frequency technologies hit the market, EMC management will assume a larger role in plant design, installation, operations, and maintenance. However, if the new design tools available in the electronics design industry are employed by I&C equipment designers, the challenges will be easier to address. By applying EPRI guidelines, plant operators can minimize the risk of a shutdown due to EMI.

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EPRI Nuclear Research

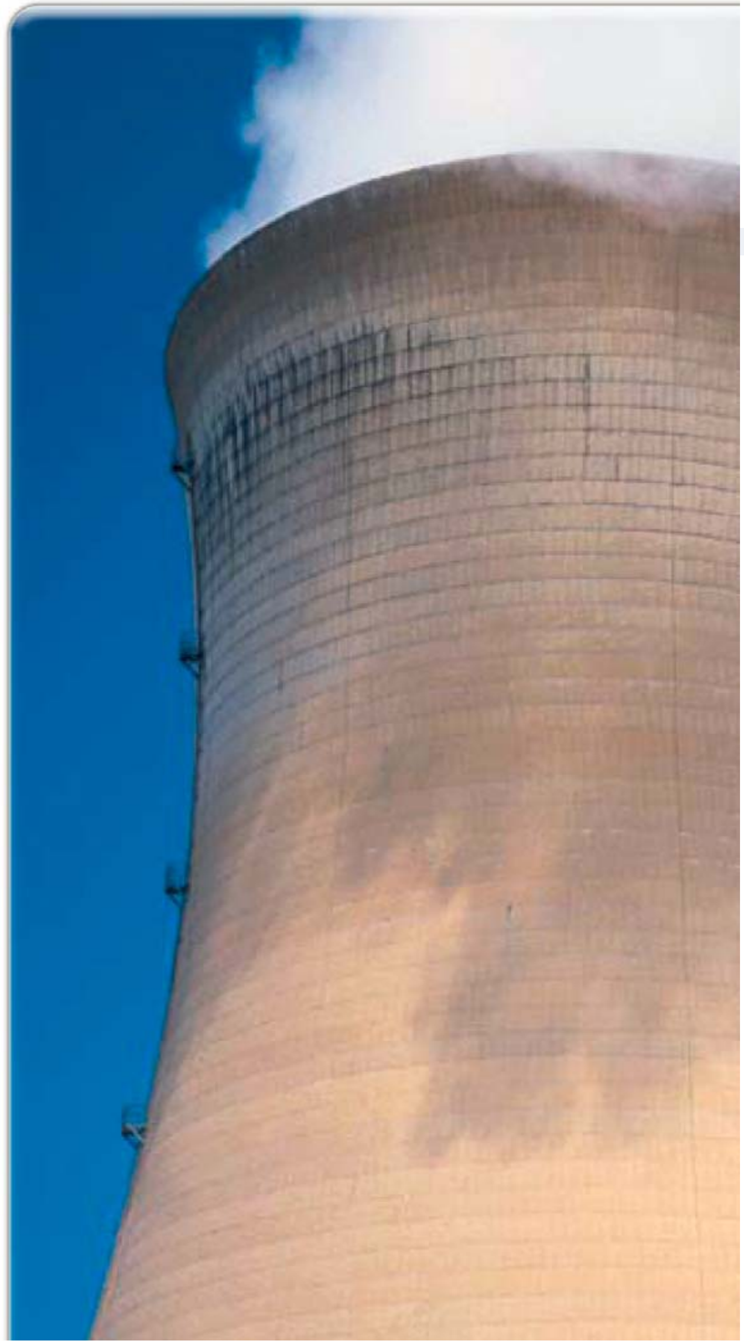
New Tools Assess the Integrity of Concrete in Nuclear Plants

Concrete is a key element of nuclear power plants, found in everything from the cooling towers to the used fuel storage facilities. The material is generally resistant to aging, becoming stronger over time as it cures. But high temperatures, freeze-and-thaw cycles, and exposure to radiation and chemicals can damage even the sturdiest concrete structures. Not every sign of wear and tear is visible, so EPRI is working to develop tools that can help see flaws deep inside the structure without damaging it—so-called nondestructive evaluation (NDE) methods.

NDE tools exist for other materials, such as metals. However, seeing inside concrete without damaging it is especially difficult because the material is a heterogeneous mix that varies with the composition of the local aggregate used. As plants apply to extend their operating licenses beyond 40 years, the need for new tools to test integrity of dry cask storage containers, used fuel pools, cooling towers, containment buildings, and other structures will grow. Several NDE techniques have already been developed, and EPRI is working to design new ways of detecting and characterizing potential damage.

In 2011, EPRI installed fiber-optic strain gauges on some concrete structures at Ginna Nuclear Power Plant in upstate New York to measure real-time strain on the steel cables running through pre-stressed concrete. This included the concrete containment building. Engineers at Ginna periodically pressurize and depressurize the containment building to make sure it's not leaking. During the most recent such test, EPRI researchers also measured the strain induced by such tests using digital image correlation. In a separate project, EPRI engineers are examining how radiation can damage concrete in the reactor cavity's walls and vessel supports, which may lead to the development of new NDE techniques to characterize such damage.

EPRI will be investigating how corrosive materials like chlorides and boric acid affect concrete. Boric acid is found in used fuel pools at pressurized water reactors, and chloride damage can come from seawater or other sources. Researchers at the Materials Aging Institute in France—a collaborative R&D institute funded by EPRI, the French utility EDF, and the Japanese utilities Tokyo Electric Power Co. and Kansai Electric Power Co.—have already begun looking at the effects of boric acid on concrete. At the same time, the commercial sector is searching for new NDE methods to image voids, cracks, and other internal defects. The most promising techniques will likely be tested in the field in the next five years.



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EPRI Nuclear Research

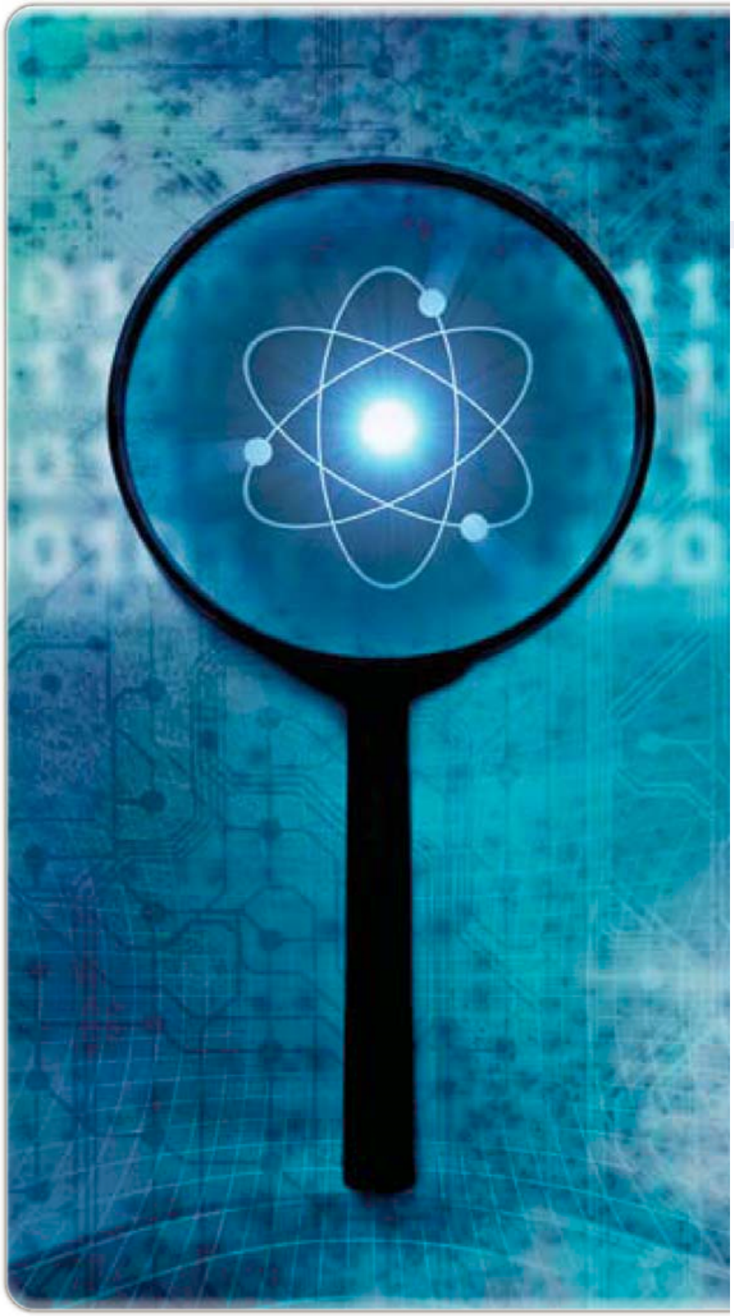
Keeping Nuclear Plants Safe from Cyber Attack

In 2010, various media outlets reported that a computer worm called "Stuxnet"—designed to hijack control systems—had infected an Iranian nuclear fuel enrichment facility. This potential vulnerability highlights the need for more safeguards as nuclear plants replace old analog electronics-based instrumentation and control systems with programmable digital systems. In October 2010, EPRI released a cyber security guideline that will help nuclear plant managers ensure that new digital systems comply with federal regulations designed to keep nuclear reactors safe from cyber attacks.

Cyber security is not a new concern. In the wake of the 2001 terrorist attacks, the U.S. Nuclear Regulatory Commission (NRC) mandated that nuclear power plants consider cyber security threats that could expose the public to radiation. The NRC also requires nuclear power plants to maintain grid reliability. Therefore, the EPRI guideline also addresses systems that, if hacked, don't directly pose a radiological risk, such as the balance-of-plant control systems.

EPRI's new cyber security guideline provides procedures for implementing cyber security controls in 138 different areas, from passwords and wireless connections to encryption and intrusion detection. The document also provides four increasingly complex examples of how to apply the procedures in an operating nuclear plant. The examples range from a simple, firmware-based programmable relay without digital connections to other systems to a main turbine-generator control system with digital assets both in the control room and on the turbine floor. Although demonstrating compliance with all controls requires extensive documentation, many controls can be addressed with existing plant programs such as the design change process and configuration management program. Plant owners and operators who incorporate cyber security into the design process early can make the final assessment of digital systems a much simpler process.

Because a variety of cyber security recommendations already exist, instead of developing controls and procedures from scratch, EPRI researchers built on existing guidance—primarily that issued by the Nuclear Energy Institute in 2009. Although the EPRI guideline cannot substitute for a detailed cyber security assessment, it can help plant managers prepare for that assessment and ensure that new digital systems will pass. This year, the team will release a training module outlining how to use the guidelines. The training will provide a brief, multimedia overview of the guidelines and procedures.



EPRI Power Delivery Research

Billions and Trillions: Assessing the Benefits and Costs of a Smart Grid

Today's electric grid was not designed to meet the needs of a restructured marketplace, the increasing demands of a digital society, or the growing use of renewable power. That's why the industry is moving toward a modern grid that can monitor, protect, and automatically optimize the operation of all its interconnected elements—everything from central and distributed generators to household appliances—would provide significant benefits. In April 2011, EPRI released an assessment of the costs and benefits of upgrading the electrical grid. The analysis suggests that deploying a smart grid will require a net investment of between $338 and $476 billion and reap benefits between $1.3 and $2 trillion.

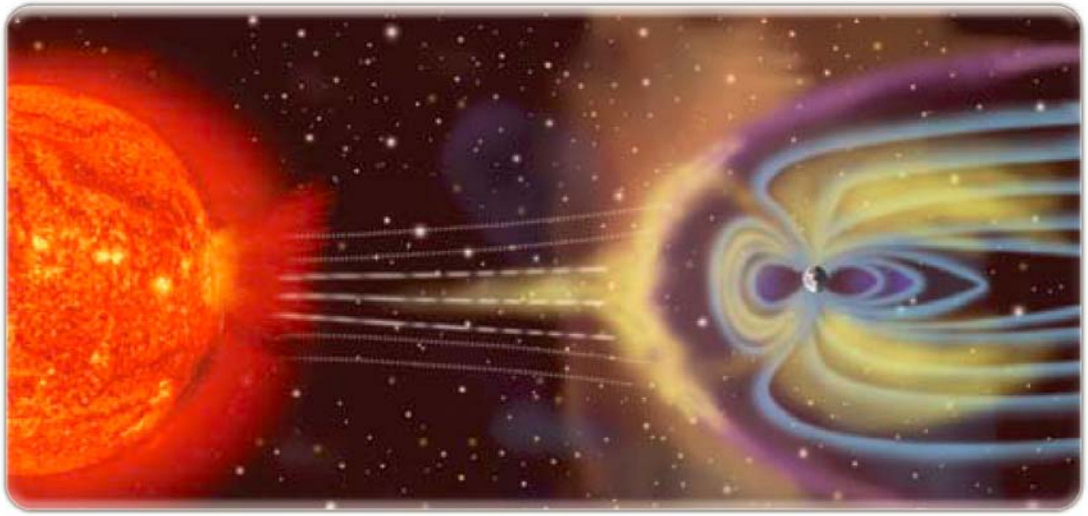
In today's power system, electricity flows in one direction from large power plants to customers. Although the smart grid would still rely on large, centralized generation, it would also incorporate energy storage installations and both central station and distributed renewable generation facilities. In addition, the smart grid would have enhanced sensory and control capability to accommodate these distributed resources as well as electric vehicles, efficient smart appliances, and consumer participation in energy management.

The smart grid will offer multiple benefits, including more reliable power delivery, enhanced cyber security, greater efficiency, and better support for renewable energy and electric vehicles. The smart grid may also help consumers manage electricity costs as they gain greater access to pricing information and more control over their consumption.

To analyze the cost of deploying the smart grid, the EPRI team looked at advanced technologies in four areas: transmission, substation, distribution, and customer interface. The analysis indicates that deploying the smart grid will require an investment level of between $17 and $24 billion per year over the next 20 years. The costs include the infrastructure to integrate distributed energy resources and to achieve full customer connectivity, but exclude the cost of generation, the cost of transmission expansion to add renewables and meet load growth, and customer costs for smart-grid ready appliances and devices.

The analysis updates EPRI's widely cited 2004 assessment, which estimated the cost of implementing the smart grid at $165 billion. The increased costs outlined in the current analysis reflect a more advanced and expansive vision for the smart grid. For example, the previous report didn't take into account electric vehicles.

These cost estimates remain highly uncertain and open to debate. The EPRI team views this analysis as a starting point for discussion and a resource to help the industry make intelligent investment decisions going forward. The report describes the assumptions associated with the cost assessments for full background understanding and to facilitate industry discussion of the estimates.



EPRI Power Delivery Research

Before the Storms: Research Focuses on Geomagnetic Disturbances

When charged particles from solar storms hit earth, they can create rapid changes in the planet's magnetic field. These geomagnetic disturbances induce slowly varying electric currents—called geomagnetically induced currents—that can travel along man-made conductors such as transmission lines, damaging transformers and, in rare instances, interrupting electric service. In 2011, EPRI launched a three-year geomagnetic disturbance research project to assess the state of the science, evaluate the vulnerability of the electric grid, and develop and test mitigation strategies to lessen the impact of solar storms on the electric grid.

Although solar storms are possible at any time, they are statistically more likely during periods close to the solar cycle maxima. The peak of the next solar cycle is anticipated in 2012–2013. As the solar maximum approaches, regulators and utilities have become increasingly concerned about the impact that geomagnetic disturbances could have on the already congested electric grid.

Although the currents induced by these disturbances are small compared to the alternating current flowing through the lines, they can cause serious damage, due primarily to very low frequency signals that can cause saturation in magnetic devices such as transformers. In 1989, millions of people went without service for 9 hours or more after Hydro Quebec's electric transmission system collapsed due to a solar storm. And a recent study by the U.S. Federal Energy Regulatory Commission estimates that geomagnetic disturbances could cause as many as 300 high-voltage transformers to fail, threatening the reliability of the electric grid.

EPRI has been monitoring induced currents from solar storms for the past 20 years as part of the Sunburst project. The project has helped refine the models that researchers use to predict how solar storms will induce currents and potentially impact the electric grid. Much broader in scope than Sunburst, the new project aims to:

- Use detailed models and analysis to determine the likely impact of an extreme event on the North American bulk power system
- Identify available technologies to mitigate equipment damage, reduce interruptions, and speed recovery
- Identify technologies that can be developed to reduce storms' impacts and lower the cost of protection

The EPRI research project has three main components—education, vulnerability assessment, and mitigation methods. First, researchers will assess the state of the science to determine what is known about the impact of geomagnetically induced currents on the electric grid. Second, they will assess the vulnerability of the electric grid. EPRI researchers will create models to investigate how the grid is likely to respond to storms of different magnitudes and durations. Line length, line orientation, and the local geology may all play a role.

Third, EPRI researchers will work to develop and validate operational strategies to mitigate the effects of geomagnetic disturbances as well as mitigation hardware devices. Because of the urgent need for mitigation strategies, the project will focus first on operational preparations that can help reduce impacts during the upcoming solar maximum. When a solar storm is imminent, utilities can minimize the risk to the grid by monitoring system conditions (voltages and currents) and preparing to maximize reserves in anticipation of needing to add generation and voltage support.

EPRI Power Delivery Research

Technologies in Development Could Put Drivers and Utilities in the "Smart Charging" Driver's Seat

Plug-in electric vehicles have the potential in the near term to stress the electric distribution system in early adopter neighborhoods. Although a single car may not draw much power, hundreds of cars charging at the same time in the same distribution circuit could strain the system. However, if the utilities could communicate with the vehicles and coordinate when they charge—so-called "smart charging"—they might be able to circumvent such issues. In 2010, EPRI partnered with General Motors, maker of the Chevy Volt, to develop and demonstrate on- and off-vehicle smart charging technologies for connecting electric vehicles to a smart grid.

The Chevy Volt already allows consumers to specify how and when the car charges, but the vehicle currently has no way to receive commands from the utility smart grid. EPRI researchers are working to develop technologies that enable this capability. The plan is to develop for cars a single interface that enables utilities to influence when and how the car charges. This communication can occur via the car's on-board telemetics system, which relies on a cellular signal, or via an information gateway from the utility to the plug-in electric vehicles (such as an advanced meter or other energy information gateway).

Electric vehicles could also be integrated into home area networks. To facilitate flexibility in the plug-in electric vehicle communicating with diverse smart grid technologies, EPRI has designed and developed a versatile "Swiss army knife" interface module termed the "ulti-protocol router." This router can be on board or off the vehicle, enabling it to communicate with the nearest smart grid node even as it crosses utility boundaries. As part of the three-year project, EPRI researchers will evaluate a range of technologies to identify the most efficient and cost-effective communication approaches.

The project has three phases. In 2010, EPRI and GM completed Phase I, the development of a desktop simulator to model communications between the car and the smart grid. Now in Phase II, researchers are building hardware and software that will go on and around the car. During this phase, this interface system will be packaged inside a removable box. Phase III involves integrating this system into a Chevy Volt vehicle. Although the technology is being developed for the Volt, the system is based on open standards and can be incorporated in other electric vehicles.

Participating utilities will validate the communication technology and assess the impact of their demand response programs. Smart charging would, of course, be optional for drivers, but it is anticipated that utilities will offer pricing incentives for customers to join.

Smart charging technologies will provide multiple benefits: automakers won't have to curtail sales to avoid overstressing the grid, and utilities can phase in system upgrades to support new vehicles.

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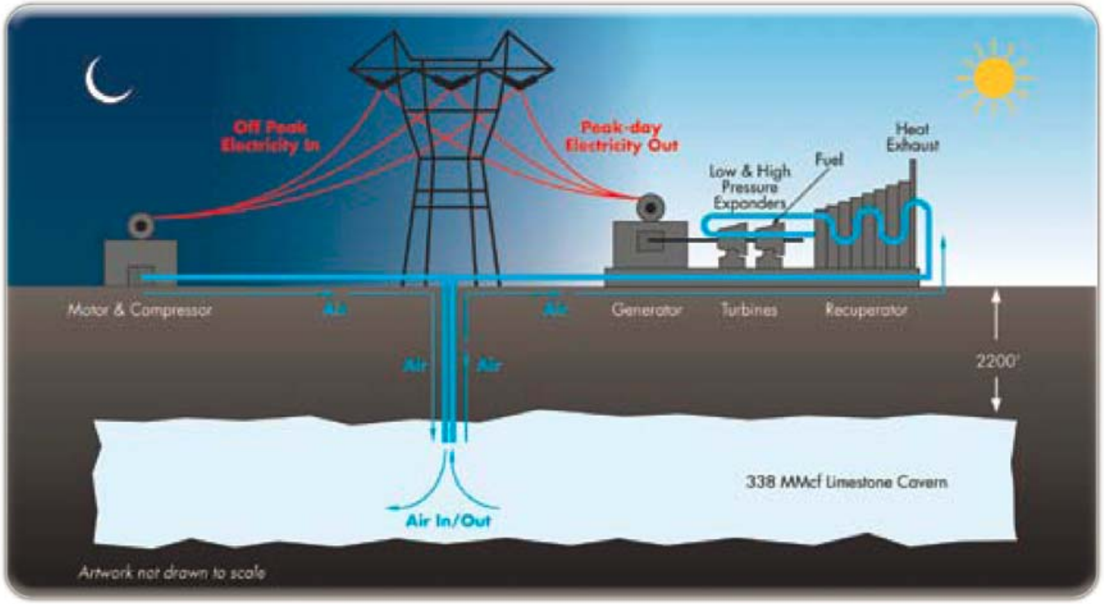

EPRI Power Delivery Research

Simple Concept, Tall Order: Analysis Looks at Energy Storage Applications and Technology Options

Energy storage systems can help improve grid reliability and balance variable renewable generation. Just as transmission and distribution (T&D) systems move electricity across distances, energy storage systems move electricity through time, providing it when and where it is needed. The biggest barrier to the deployment of such systems has been cost. To quantify this barrier, EPRI researchers performed detailed analyses of storage systems in 10 different applications to estimate their value and market potential. The results, part of a recent white paper, indicate that the total U.S. energy storage market could be as large as 14 gigawatts of capacity if energy storage systems could be installed for about $700–$750 per kilowatt-hour.

EPRI researchers identified the top 10 key applications for energy storage. These applications—everything from wholesale energy services to home energy management—support the entire chain of the electrical system. The analysis compared the value of the benefits for each application with the total cost of installing an energy storage system. At present, energy storage systems are expensive. Capturing multiple benefits is key for supporting the business case for energy storage. Applications that achieve the highest revenues do so by aggregating benefits across multiple categories. The study reveals three high-value applications: wholesale services with regulation, commercial and industrial power quality and reliability, and stationary and transportable systems for grid support and T&D capital deferral.

Two of the most promising energy storage technologies are compressed-air energy storage (CAES) and lithium-ion batteries. Compressed air plants—which use off-peak power to pump air into larger reservoirs, such as salt caverns—can provide a cost-effective bulk storage option for long discharge duration. Lithium-ion batteries may become a cost-effective option for shorter durations applications based on their scale of production. Other storage technology options are under development and being deployed in trials.

Because many energy storage options have yet to be validated, testing and validation are key components of EPRI's energy storage program. For example, EPRI is collaborating with New York State Electric & Gas and Pacific Gas and Electric to demonstrate the feasibility of CAES. EPRI has also partnered with Xcel Energy to test and demonstrate a 1.5-megawatt battery system at the company's solar test facility near Denver. EPRI's goal is to achieve cost-effective, safe, reliable energy storage solutions by 2016.

The white paper presents an analytic framework to estimate the benefits and life-cycle costs, and help guide and shape the economic treatment of an energy storage system. This document provides a deep understanding of the energy storage technology landscape, identifies potential applications in the electric energy storage sector, and compares various alternative energy storage technologies by application.

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EPRI Generation Research

EPRI-Led Team Identifies Materials for Advanced Ultra-Supercritical Coal-Fired Power Plants

Utilities face mounting pressure to cut their carbon dioxide emissions. One way to reduce emissions is to increase the efficiency of coal-fired power plants by operating them at higher temperatures and pressures. But the steel alloys typically used to construct steam turbines and boilers aren't designed to withstand the temperatures needed to dramatically increase a plant's efficiency. A decade ago, the U.S. Department of Energy and the Ohio Coal Development Office, together with Energy Industries of Ohio, selected EPRI to be the technical leader of a consortium of U.S. steam turbine and boiler suppliers and national laboratories. The goal was to identify and test alloys that would enable steam turbines and boilers for advanced ultra-supercritical coal-fired power plants to operate at 1400°F. Since then, this consortium has tested a number of different alloys that can withstand these harsh conditions. A March 2011 EPRI report summarizes test results.

For the steam boiler portion of the project, components of concern are the boiler headers and piping, superheater/reheater tubes, and waterwall panels. These components are typically constructed of steel, but steel can't withstand the temperatures found in advanced ultra-supercritical plants. So the first step was to identify new alloys.

The crucial limiting factor of these materials is their inherent creep strength. "Creep" is the tendency of solid materials to deform when exposed to high temperatures and pressures for long periods. Materials in an advanced ultra-supercritical plant must have a 100,000-hour creep-rupture strength of approximately 14,500 psi or higher. The boiler components must also be able to withstand the corrosive conditions produced by high-sulfur U.S. coals as well as avoid steam-side oxidation and exfoliation. The EPRI-led team of government and industry researchers has identified several nickel-based alloys as promising candidates. They evaluated aspects of the candidate materials in seven areas: mechanical properties, steam-side oxidation, fireside corrosion, welding, fabrication ability, coatings, and changes to current design codes.

For steam turbines, the project focused on the highest temperature components in four areas: oxidation and erosion resistance of turbine blades, non-welded rotor materials, welded rotor materials, and castings. Materials and design philosophy for steam turbines are unique to each manufacturer. Alloys are not subject to code approval and thus may or may not have internationally recognized material standards.

The boiler materials development project is scheduled to end in September 2012, and the steam turbine materials development project will end in 2014. The boiler project will continue to accumulate data from long-term creep tests; steam-cooled, in-boiler corrosion loops; and laboratory studies on oxy-combustion and exfoliation rig tests. Additional work will focus on optimizing procedures for executing repair welds on the candidate materials. The steam turbine project will work on casting the selected materials, producing disks for rotors, and extensive mechanical testing of the parts.

As a next step, components made from the most promising alloys will be tested in an operating plant before a commercial-scale 600-megawatt demonstration plant is constructed. Advanced ultra-supercritical plants have the potential to reduce fuel consumption, carbon dioxide emissions, and flue gas emissions as well as saving utilities money.

EPRI Generation Research

Looking Beyond Visual Inspection: Researching Techniques to Detect Flaws in Wind Turbine Blades

Wind turbine blades are expected to last millions of operating cycles. But flaws in turbine blades—either production defects or defects that arise during operation—can cause cracks or other damage, leading to expensive repairs. In severe cases, flaws can lead to catastrophic failure of the blade and damage to the wind turbine. The primary method for examining wind turbine components is visual inspection. However, this method cannot detect flaws that lie beneath the blade's surface. EPRI is working to develop nondestructive evaluation techniques for wind turbine components, including blades. One method capable of examining large surfaces is laser shearography, a technique used in the aerospace industry. In 2010, EPRI researchers demonstrated in the laboratory the feasibility of using laser shearography to assess the health of wind turbine blades.

Defects in wind turbine blades that lie beneath the surface produce slight inconsistencies in the continuity of the blade's surface. These changes are not visible to the naked eye. Laser shearography relies on a shearography camera with a built-in laser. The laser illuminates the blade's surface, and the light reflected off the blade travels into the camera, which relies on "interference patterns" to detect flaws. The technology produces a three-dimensional image of the defect.

EPRI researchers recently tested laser shearography on a wind turbine at the National Renewable Energy Laboratory's test facility in Golden, Colorado. Using this technology, the team detected a large delamination on the high-pressure side of the blade that had not been previously detected. After 25,000 cycles, a crack appeared along the edge of the delamination. During subsequent fatigue cycles, this crack grew until the test was stopped at 2.4 million cycles.

Laser shearography has advantages over other nondestructive evaluation techniques. First, it is one of the few techniques that can be employed once a blade has been installed. Second, EPRI research indicates that the device may work even when mounted on the ground, eliminating the need for a crane or fearless inspector. Third, the laser can scan a relatively large area—on the order of 4 square meters—enabling operators to conduct inspections quickly.

As part of this three-year project, EPRI researchers plan to test laser shearography in the field. Improved shearography techniques will result in more thorough structural assessments of blades by making it easier to detect flaws. In addition, EPRI plans to collaborate with Sandia National Laboratories' Blade Reliability Collaborative in the development of flaw and degradation analysis models. These models will help wind turbine owners and operators determine whether blades with defects must be repaired or replaced. Some flaws may not pose a threat to the structural integrity of the blade.

EPRI Generation Research

Stemming the Alarm Flood: Guidelines Help Plant Operators Make Signal Improvements

Many U.S. electric power plants are now equipped with distributed control systems: digital systems designed to alert the operator to any changes in the operating condition of the plant. These systems contain urgent alarms that require immediate action, but they also contain alarms that require no action at all. As a result, plant operators may receive thousands of alarms in a single day, hindering their ability to respond to real emergencies. To address this issue, EPRI recently developed guidelines to assist power plants in improving their alarm management strategies. EPRI researchers are now working to help power plants implement these guidelines.

Plant operators have a finite ability to respond to alarms. Research indicates that one alarm every 10 minutes (or about 150 per day) is acceptable, and two alarms in 10 minutes (or about 300 alarms per day) are manageable. More than 300 alarms per day can overwhelm a plant operator's ability to analyze each alarm, forcing the operator to ignore alarms. An "alarm flood" occurs when the alarm rate exceeds 10 alarms in 10 minutes.

EPRI recently developed a set of best practices and suggested methodologies for improved alarm management in the power generation industry. The report covers the history and nature of alarm management, the fundamentals of alarm definition, alarm philosophy, common alarm problems and their solutions, and case studies. At the heart of the guidelines is a seven-step methodology for improving alarm systems based on hundreds of successful, real-world alarm improvement projects.

To date, EPRI has applied the first four steps of the seven-step process at two sites. The results have been dramatic. For example, prior to implementing the guidelines, one site experienced an average of 1,060 alarms per day, with a peak of nearly 15,000 alarms. Alarm flooding occurred an average of eight times per day.

EPRI staff worked with plant operators and engineers to develop a site-specific alarm philosophy and helped bring the plant's alarm design in line with that philosophy. Analysis showed that if these steps were implemented, the average daily alarm rate would fall to 135 alarms per day, a drop of almost 90%.

EPRI's alarm management guidelines are designed to ensure that power plant alarm systems alert plant operators only of abnormal conditions that merit their attention and action. Such systems result in fewer equipment failures and keep plant operations within design parameters. Ultimately, this creates longer equipment life and more efficient operation.

Together…Shaping the Future of Electricity