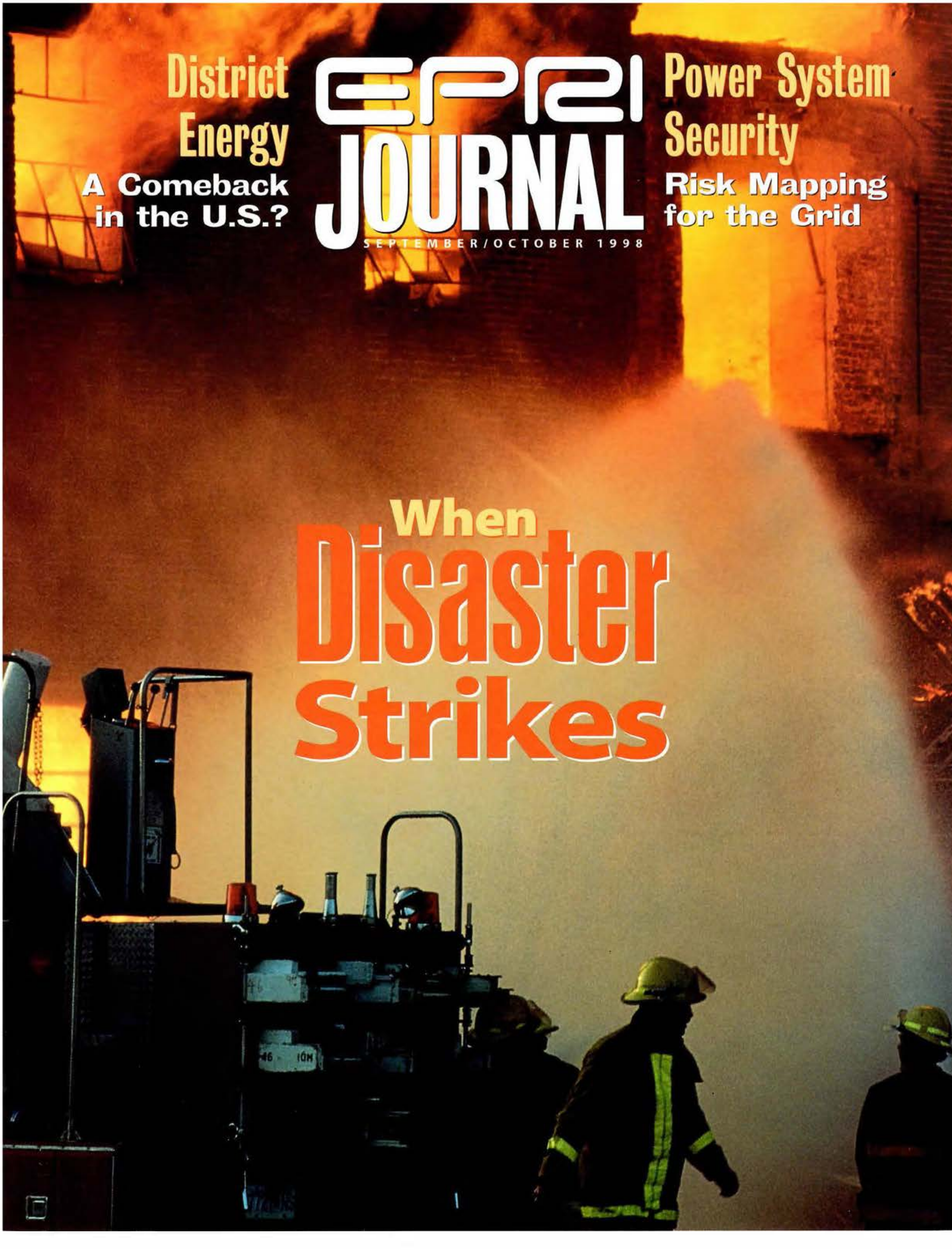

EPRI JOURNAL

SEPTEMBER/OCTOBER 1998

District Energy
A Comeback in the U.S.?

Power System Security
Risk Mapping for the Grid

When Disaster Strikes

About EPRI

EPRI creates science and technology solutions for the global energy and energy services industry. U.S electric utilities established the Electric Power Research Institute in 1973 as a nonprofit research consortium for the benefit of utility members, their customers, and society. Now known simply as EPRI, the company provides a wide range of innovative products and services to more than 700 energy-related organizations in 40 countries. EPRI's multidisciplinary team of scientists and engineers draws on a worldwide network of technical and business expertise to help solve today's toughest energy and environmental problems

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EPRI Journal Staff and Contributors

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JEAN SMITH, *Editorial Assistant/Circulation*
KATHY MARTY, *Art Consultant*

JANET L. RUNYAN, *Director, Communications*
CLARK W. GELLINGS, *Vice President, Client Relations*

Address correspondence to:
Editor-in-Chief
EPRI Journal
P.O. Box 10412
Palo Alto, CA 94303

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COVER: Whether the disaster is fire, flood, or earthquake, planning and cooperation are the keys to effective community recovery. (Photo © 1998 Jurgen Vogt/TIB)

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Editorial

Priming the Pump in South Africa

It has become generally accepted that increased electrification is a key requirement for sustainable growth in developing countries. The reason for this is clear: electricity's intrinsic attributes of flexibility, precision, reliability, and efficiency lie at the heart of industrial productivity, economic growth, environmental quality, and technological progress. Financing and constructing the thousands of gigawatts of power plants that will be needed for global development over the next 50 years will be no easy task. But even if we do get the generation and delivery infrastructures built, we have solved only part of the problem.

For many countries, the goal of spurring national economic and industrial growth is simply too far up the sustainability pyramid to be the first order of business. In South Africa, for example, there is a lack of basic services and infrastructures in rural communities, which generally have little or no community health care and even lack appropriate water supplies. For electrification to truly advance the quality of life in the developing world, first these basic needs must be addressed as a foundation for further progress. In South Africa, where tuberculosis, typhoid, cholera, and malnutrition are widespread, disease reduces the capacity to earn money, leading to conditions that increase the risk of more disease. The primary need is to break the cycle and to start the process of improving the community's capacity to become self-sustaining. In a sense, we must prime the pump—invest on the local level to improve the capabilities of the country's human resources.

This is, in fact, the goal of the South African government's Reconstruction and Development Program (RDP). Many organizations, both inside and outside South Africa, have begun to inject funding into the country under the RDP umbrella. In 1996, EPRI and ESKOM—one of the world's largest utilities, supplying more than half the electricity in all of Africa—formed the South African Centre for Essential Community Services (SACECS), whose activities are aligned with the RDP. Through SACECS, EPRI and ESKOM will make EPRI's technologies and skills available for use in South Africa and will adapt the technologies as necessary for the conditions there. This is not a one-way investment, however: South Africa has complementary technologies that EPRI will help apply elsewhere in the world.

SACECS's focus is the transfer of electrotechnologies that impact health care and water management in rural communities. Technologies for improving the quality of drinking water are high on the list, including electrochemical disinfection, ultraviolet disinfection, and reverse-osmosis desalinization. Ultraviolet germicidal irradiation, being demonstrated in South African health care facilities, holds great promise for slowing the tuberculosis epidemic in the country, since it may be effective even on drug-resistant strains of the disease. Microwave sterilization of infectious medical wastes is also being demonstrated in hospital settings. Under the RDP, communities are empowered to take ownership of this improved infrastructure as it is developed.

The task ahead is enormous, but the opportunities for positive impact are great. We at EPRI are pleased to partner with ESKOM in developing, demonstrating, and deploying beneficial electrotechnologies; we have a deep commitment to the use of energy and technology to improve the quality of life in South Africa and elsewhere. Certainly, we are excited about expanding the use and value of electricity in all parts of the world. But perhaps even more important is demonstrating that cooperative projects involving cross-cultural partnerships can pay off in substantial ways. Making such relationships work for the common good is one of society's urgent challenges—one that will increasingly define our global future.

Don Baker
Vice President, EPRI International

Contributors

When Disaster Strikes (page 8) was written by Leslie Lamarre, *Journal* senior feature writer, with technical assistance from Ralph Bernstein and Jim Oggerino of EPRI's Energy Delivery and Utilization Division.

RALPH BERNSTEIN is manager of the Disaster Planning and Mitigation Technologies Target. He came to EPRI in 1992 after 13 years with the IBM Palo Alto Scientific Center, where, as a senior technical staff member, he was responsible for geoscientific and medical image processing R&D. Before that, he worked at the IBM Federal Systems Division in Gaithersburg, Maryland. Bernstein holds two degrees in electrical engineering—a BS from the University of Connecticut and an MS from Syracuse University.

JIM OGGERINO, a project manager for disaster planning and mitigation research, has served in a number of research application, technology transfer, market penetration, and market assessment positions since joining EPRI in 1984. Previously he was employed for 13 years in General Electric's Nuclear Power Division, where he carried out utility application and marketing activities for accounts in the United States, the Far East, and Switzerland. Oggerino holds a BS in nuclear engineering from North Carolina State University.

District Energy: Combining Heat and Power (page 18) was written by Taylor Moore, *Journal* senior feature writer, with technical assistance from Tony Armor and Walter Piulle of EPRI's Energy Conversion Division.

TONY ARMOR is director of generation technology development. Before assuming this position, he served for seven years as director for fossil power plants. He joined EPRI in 1979, following 11 years with General Electric in the Large Steam Turbine–Generator and Energy Systems Divisions. Earlier he was a professor of environmental engineering at the University of the South Bank, London, and a professor of mathematics at the University of Westminster (formerly London Polytechnic). Armor has a BS in mathematics and an MS in mining engineering from the University of Nottingham, England.

WALTER PIULLE retired earlier this year after more than 22 years of managing EPRI R&D, most recently as the target leader for district energy. Before joining EPRI in 1975 as a project manager for air quality control, Piulle held a series of management and engineering positions during eight years at the Buell Emissions Control Division of Envirotech Corporation. He has a BSEE degree from the Pratt Institute of Technology.

Charting Power System Security (page 26) was written by science writer Paul Haase, with technical assistance from Dejan Sobajic and Nick Abi-Samra of the Energy Delivery and Utilization Division.

DEJAN SOBAJIC, manager of the Grid Operations and Planning Department, came to EPRI in 1993 after five years as engineering manager at AI Ware, Inc. While there, he also conducted research at Case Western Reserve University on intelligent systems and their use for power system operation and control. Sobajic holds bachelor's and master's degrees in electrical engineering from the University of Belgrade, Yugoslavia, and a PhD in systems engineering from Case Western Reserve University.

NICK ABI-SAMRA is manager of system planning in the Grid Operations and Planning Department, with responsibility for projects in transmission reliability, system security, risk and decision making, and power system modeling. Before joining EPRI in 1997, he spent nearly 20 years at Westinghouse, with responsibilities that ranged from transmission and distribution system design to the design of electrical systems for U.S. Navy ships and submarines. He holds a bachelor of engineering degree from the American University of Beirut and an MS in electric power engineering from the University of Missouri.

Products

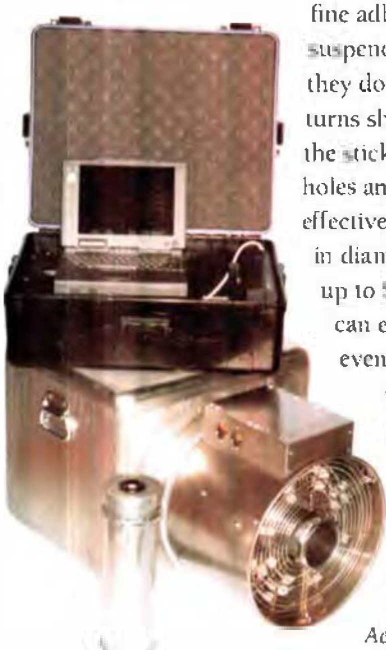
Deliverables now available to EPRI members and customers

DFD Process

EPRI's Decontamination for Decommissioning (DFD) process won an R&D 100 Award for being one of the most technologically significant products of the year. DFD is a chemical process for removing radioactive contamination from shut-down nuclear power plants. It uses a mixture of fluoroboric acid and potassium permanganate to dissolve the radioactive corrosion products, which are then collected on ion-exchange resin. The process was used by EPRI licensee Alaron Corporation to remove and recycle material from retired heat exchangers. Consumers Energy also applied it to the reactor coolant system of its Big Rock Point BWR, which shut down in August 1997 after 35 years of successful operation. The EPRI licensees who carried out that application, PN Services and Bradtec Ltd., subsequently decontaminated Maine Yankee Atomic Power Company's PWR. Sponsored by *R&D Magazine*, the R&D 100 Award is one of the most prestigious honors in applied research.
■ *For more information, contact Chris Wood, (650) 855-2379.*

Aerosol Duct Sealing

Each year, leaks in the air ducts of residential heating and cooling systems cost consumers some $5 billion, wasting about 20% of the energy used for space conditioning in an average home. Fixing the often hard-to-reach leaks by conventional methods is time-consuming: the leaks must be located before they can be patched, and afterward the ducts must be retested to ensure that the repairs have been successful. Aerosol duct sealing offers a far more efficient solution to the problem. Conceived and patented by a Lawrence Berkeley National Laboratory scientist, this new technology sprays fine adhesive particles into air ducts. A fan suspends the particles in the airstream so that they don't stick to duct walls. As the airstream turns sharply through holes in the duct walls, the sticky particles adhere to the edges of the holes and build up seals. The technique is effective for leaks as large as 1 inch (2.5 cm) in diameter. Homeowners not only can save up to $300 annually on utility bills but also can enjoy increased comfort due to more-even heating and cooling. The technology was developed and tested with support from EPRI, the California Institute for Energy Efficiency, the U.S. Environmental Protection Agency, and the U.S. Department of Energy.
■ *For more information, contact John Kesselring, (650) 855-2902. To order, call Aeroseal Inc., (800) 945-5557.*



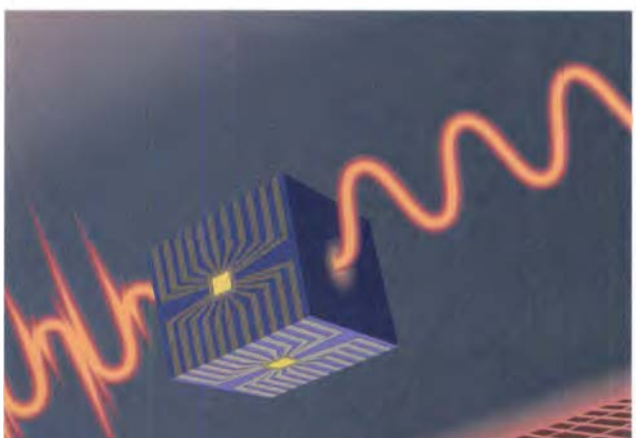
Daylighting Design

Owing largely to a lack of easy-to-use, objective design guidelines, lights near windows remain on in most commercial buildings, wasting energy and money. This report, *Daylighting Design: Smart and Simple* (TR-109720), provides the practical design and implementation information required to avoid this problem. Building owners, facilities managers, architects, engineers, lighting designers, and energy auditors can use the simple guidelines presented in the report to make smart design decisions that take advantage of natural daylight. Covering retrofit installations, new buildings, and major renovations, the report can also help utility representatives provide sound advice on the cost-effective design and use of buildings, windows, and lighting controls to create comfortable, energy-efficient workplaces.
■ *For more information, contact John Kesselring, (650) 855-2902. To order, call the EPRI Distribution Center, (510) 934-4212.*

Cable Digest

The recently released *Distribution Cable Research Digest 2000* (BR-110693) updates and expands on previous EPRI cable research digests, released in 1989 and 1992. A comprehensive 40-page document, the digest presents new information on insulation and shield materials and describes changes in jacket technology and other advances. It offers background material on the industry's past problems with premature cable failure, as well as detailed information about the improved cables available today. Also reviewed are construction specifications for long-life distribution cable, operating issues (such as lightning protection), techniques for removing jammed cables, and options for diagnostic tests.

▪ *For more information, contact Bruce Bernstein, (202) 293-7511. To order, call the EPRI Distribution Center, (510) 934-4212.*



Power Quality Toolbox

Power quality problems cost U.S. businesses a considerable amount of money in lost productivity. Electric power companies working to address this growing problem can now count on a new EPRI product, the Power Quality Toolbox, to help. The toolbox consists of two IBM-compatible CD-ROMs—one focusing on wiring and grounding, the other on voltage sag. The Wiring and Grounding Analysis Tool provides engineers with an easy-to-use framework for collecting information during site surveys of commercial and light industrial power systems. The tool has a detailed, on-line help system that includes wiring and grounding reference information. The Voltage Sag Analysis Module is an analytical tool for calculating the annual voltage sag disturbance profile for a given customer site. It gives power quality engineers an efficient way to evaluate the impact of transmission and distribution faults on voltage sags at the customer site.

▪ *For more information, contact Sid Bhatt, (650) 855-8751. To order, call the Electric Power Software Center, (800) 763-3772.*

Around the World

Focus on international projects and alliances

Plant Simulator Helps Train Australian Operators

EPRI's Compact Simulator technology, already used by dozens of U.S. utilities for cost-effectively training operators of fossil power plants, is now also being used down under—helping train plant operators across Australia to meet national competency standards. Energy and Telecommunications Training Australia (ETTA), a division of the Central Gippsland Institute of Technical and Further Education, has outfitted a mobile trailer with the necessary hardware and is using a reference plant simulator model licensed from EPRI to provide on-site operator training and certification. EPRI's Simulator and Training Center in Kansas City, Missouri, installed the simulator software, along with the Intelligent Tutoring System, on the ETTA computers in early 1997; since then, the trailer has been making the rounds of various Australian power plants.

"This represents the first commercially licensed use of our simulator technology by a nonmember organization and is the beginning of what could prove to be a good source of revenue for EPRI," says Ron Griebenow, director of the Simulator and Training Center. Griebenow notes that several international member utilities—including South Africa's ESKOM, Britain's PowerGen, and Spain's Unión Eléctrica Fenosa—have expressed interest in using reference models from EPRI's Fossil Plant Simulator Library, a collection of about 30 simulator models based on specific fossil plants. Developed in collaboration with the plant owners, these reference models can be customized for use by other utilities with similar plants.

With the Compact Simulator technology, power plant systems and operations can be simulated as effectively as with traditional, component-based mainframe simulators but at a fraction of the cost. Moreover, says Griebenow, "from our experience working with member utilities, we believe that 70–80% of the goals most companies have for simulator-based operator training can be achieved with a reference plant simulator model for about 10% of the cost of building a plant-specific simulator from scratch."

Griebenow points out that to more effectively meet the needs of international utilities, the reference models can be cost-effectively modified to accommodate 50-Hz electrical equipment and the International System of Units.

ETTA initially licensed a reference simulator model based on the 136-MW coal-fired McMeekin plant of South Carolina Electric & Gas Company. It also has expressed interest in using a combustion turbine combined-cycle plant simulator. The Intelligent Tutoring System installed in ETTA's mobile trailer is a PC-based expert system that is connected to the simulator network. The system monitors the trainees' interaction with the simulator and provides prompts and advice on how to improve simulated plant and operator performance.

In the marketing material for its simulator-based power plant and process control training, ETTA cites its alliance with EPRI and notes that the Compact Simulator technology could have a major impact on Australia's power industry, which heretofore has not widely used simulators because of the high costs of custom-developed systems. According to ETTA, the opportunity to demonstrate theory in a practical environment will enhance development of the entry-level knowledge required to earn national certification in steam plant operation from the Australian Council for Training Curriculum.

Moreover, an advantage of being able to take the mobile classroom to customer sites, ETTA points out, is that if a situation arises that requires all personnel back at the work site, training can be halted and the simulation frozen and stored in memory until the training can resume.

Australian facilities expected to host visits by the ETTA mobile classroom include Alcoa of Australia's Anglesea station, Edison Mission's Loy Yang B station in Victoria, the Newport station in Victoria, the Ron Goodin and Pine Creek stations in the Northern Territory, and Australian Paper's Maryvale mill. ETTA is also targeting other customers with similar facilities, including oil refineries, industrial process steam plants, paper mills, and aluminum producers.

■ *For more information, contact Ron Griebenow, (816) 235-5620.*

Partnership With BC Hydro on Water and Wastewater Center

The EPRI family of application-focused technical centers will get a new member in October, with the opening of the Water and Wastewater Center in Vancouver, British Columbia. The result of collaboration between EPRI and BC Hydro, the center aims to build on and extend EPRI-sponsored research by demonstrating and promoting new electrotechnologies for water treatment and wastewater processing. It will be operated by BC Hydro, which will work with various of its industrial customers to evaluate ozonation, ultraviolet and pulsed ultraviolet treatment, membrane separation, and other technologies, as well as related supervisory control and data acquisition systems.

The center will offer field services, including technical support and consultation in assessing the feasibility of specific solutions for customer needs, technology training for interested stakeholders, and energy audits of water and wastewater plants to identify ways to improve plant efficiency. It also plans to develop electrotechnology demonstration projects.

"Our first objective is technology transfer," says BC Hydro's Grad Ilic, the center's director. "We plan to build a network of customers and collaborators where field services could be made available or demonstrations could be conducted. We will get information to industrial customers through our sales network, direct contacts, and partnerships with organizations that have specific mandates and their own contacts in the water and wastewater industries." These organizations are likely to include the American Water Works Association Research Foundation, the Water Environmental Research Foundation, and various Canadian organizations.

"In addition to providing technical information about relevant electrotechnologies, we will get R&D and demonstration projects going with specific customers—projects focused on the needs and priorities of those customers as identified in market research," adds Ilic. "We expect to rely heavily on EPRI and the Community Environmental Center in St. Louis for technical support and innovative problem solving."


COURTESY GREATER VANCOUVER REGIONAL DISTRICT

Annacis Island wastewater treatment plant, Vancouver

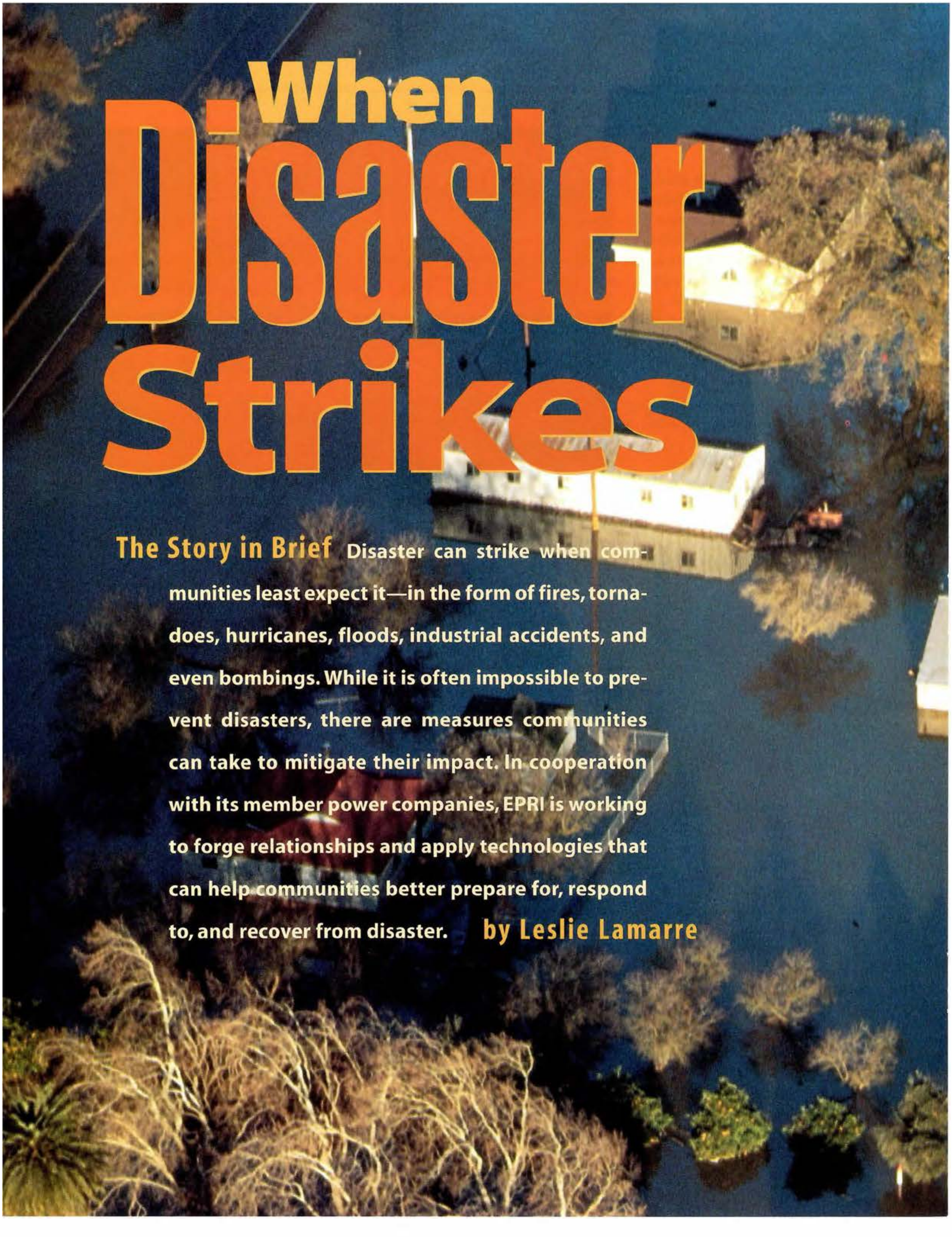
Ilic notes that in the Vancouver area a new solids-discharge surcharge for wastewater is causing difficulties for many of BC Hydro's industrial customers. "We want to work with these customers to review their plant operations and identify technologies that could help them reduce their surcharge costs. We plan to combine our existing Power Smart electricity end-use auditing services with the center's work in order to look at energy and water holistically. Building on our good relationships with municipal and industrial customers, we will serve as a broker between them and technology providers and consultants."

Recent occurrences of *Cryptosporidium* bacteria contamination in the untreated drinking water supplies of two towns in British Columbia spurred BC Hydro's idea for the center, says Ilic. "We thought, here is an opportunity for us as an electricity provider to educate the public and also to promote electrotechnology solutions, such as ozonation, that can greatly improve the quality and safety of drinking water."

The Greater Vancouver Regional District is currently building two large water treatment facilities, which are expected to be in operation by the year 2000 or 2001, and a representative of the district will sit on the Water and Wastewater Center's technical advisory board. "We expect to learn a lot about the operation of the new treatment plants, which will use ozonation," says Ilic, "and we hope to have representatives of other communities and industrial customers visit them to learn about the technology's advantages and possibly consider it for themselves."

EPRI is cofunding the Water and Wastewater Center through tailored collaboration with BC Hydro. "Helping customers improve water quality or environmental compliance and reduce their costs will help forge closer ties and better customer relations," says Darlene Cathcart, BC Hydro's senior vice president for marketing and customer services. "We hope to leverage our partnership with EPRI to help us meet a common objective—spreading awareness of electrotechnologies that not only can help protect human health and the environment but also could enhance our ability to work with customers."

■ *For more information, contact Keith Carns, (314) 935-8598.*



When Disaster Strikes

The Story in Brief Disaster can strike when communities least expect it—in the form of fires, tornadoes, hurricanes, floods, industrial accidents, and even bombings. While it is often impossible to prevent disasters, there are measures communities can take to mitigate their impact. In cooperation with its member power companies, EPRI is working to forge relationships and apply technologies that can help communities better prepare for, respond to, and recover from disaster.

by Leslie Lamarre

A crippling ice storm in the Northeast. Raging wildfires in Florida. A deadly tsunami in Papua New Guinea. Our nation and our world are increasingly bombarded by large-scale disasters.

"If, as many experts believe, we are entering a period of more frequent and more severe weather events, this year may be just a precursor, a hint of what is to come," says James Lee Witt, director of the Federal Emergency Management Agency (FEMA). "Increased evaporation from the ocean caused by higher global temperatures is likely to increase the number and severity of floods, severe winter storms, and mud slides. The shifting of rain events may bring widespread drought and an increased incidence of wildfires. The odds are that tornadoes and hurricanes will be more intense."

This is not to mention disasters caused by human activities (such as bombings, arson, industrial accidents, and the use of chemical and biological weapons) that can similarly stun and even disable both small communities and metropolitan areas. Indeed, disasters, whether due to the forces of nature or humankind, are becoming a bigger part of our lives. As FEMA reports, the death toll from U.S. disasters in the first eight and a half months of this year exceeds that for all of last year: 392 deaths as of September 17, 1998, compared with 168 for all of 1997. Insured disaster losses in the second quarter of 1998 topped $3.4 billion—the highest on record. FEMA has spent an average of nearly $2.5 billion per year on weather-related disasters in the past five years; that's 150% more than the average yearly cost for the previous five years. The average annual tab for natural disasters in this country? About $15.5 billion, according to the Insurance Research Council. This figure includes insured losses as well as relief from such federal agencies as FEMA, the Small Business Administration, the Department of Housing and Urban Development, the Federal Highway Administration, and the Internal Revenue Service.

Disasters, whether caused by natural or human forces, are playing a bigger role in our lives than ever before—resulting in hundreds of deaths and billions of dollars in damage annually and severely disrupting the lives and livelihood of survivors.

PHOTOS PAGES 10–11: AP/WIDE WORLD PHOTOS

Part of the problem is a pattern of increasingly severe weather events. Another factor is population growth. As more people inhabit the world's continents, increasing numbers of dwellings and businesses, together with the infrastructure that supports them, are creeping into hazard-prone areas. It is estimated that more than half of the U.S. population now live in such areas. Also, as society relies on more-sophisticated electrical products and systems, the repercussions of power outages become more severe. For instance, in the United States—as in other advanced industrialized nations—the proliferation of the computer technology that has revolutionized the workplace has also made society more vulnerable when it comes to disaster. "Our entire society has become more susceptible to economic loss due to power outages than at any other time in its history," notes Karl Stahlkopf, EPRI vice president for energy delivery and utilization. "In 1990,

the cost of power outages in the United States ran about $27 billion. That figure has probably more than tripled today." (Stahlkopf's estimate includes all power outages, not just those resulting from disasters.)

Recognizing the increasing incidence of catastrophic events, disaster experts across the United States are responding with a variety of efforts designed to reduce the impact of disasters and to speed recovery. For instance, last year FEMA launched Project Impact, a national initiative aimed at building disaster-resistant communities. The agency significantly ramped up that effort in June of this year, adding 50 communities—one in every state—to the original seven pilots. Similarly, the property casualty segment of the insurance industry, through its Institute for Business and Home Safety, is sponsoring a Showcase Communities program to demonstrate steps that communities can take to reduce their vulnerability to disaster. The first showcase community was designated in July of last year. Also last year, EPRI established its Disaster Planning and Mitigation Technologies (DP&MT) Target. Encompassing a wide range of EPRI expertise in disaster-related work, the target offers members and their customers information and help in applying disaster-mitigating technologies and in establishing and managing Disaster Recovery Business Alliances (DRBAs). Both activities help utilities and their communities better prepare for, respond to, and recover from all kinds of disasters.

Eye of the storm

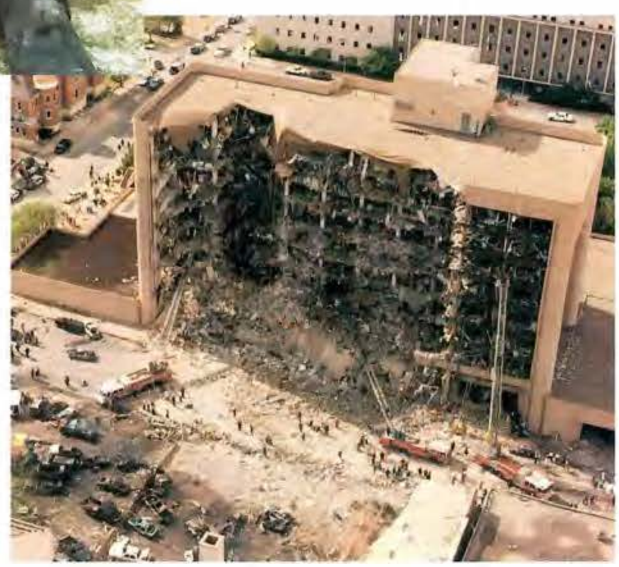
Power companies are in a unique position when it comes to large-scale disaster. Because they are an integral part of society's critical infrastructure, their role is crucial in disaster recovery. And yet very often—especially during natural disasters—they themselves are victims of the calamity.

Perhaps at no time in recent memory was this irony more evident than last January, when a devastating ice storm walloped southern Canada and the northeastern United States, plunging millions of electric power customers into darkness for weeks.

The five-day storm was the worst of its kind in the history of the entire region and the most costly natural disaster in Canadian insurance history. It deposited ice as thick as 4 inches (10 cm) on electric utility systems. The weight of this ice and the force of the wind snapped wooden power poles like toothpicks, crumpled steel transmission towers into heaps of contorted metal, and brought high-voltage transmission lines to the ground. In the words of Kenneth Tompkins, director of corporate communications for Niagara Mohawk Power Corporation, "It was a storm the likes of which we've never seen before and hope never to see again."

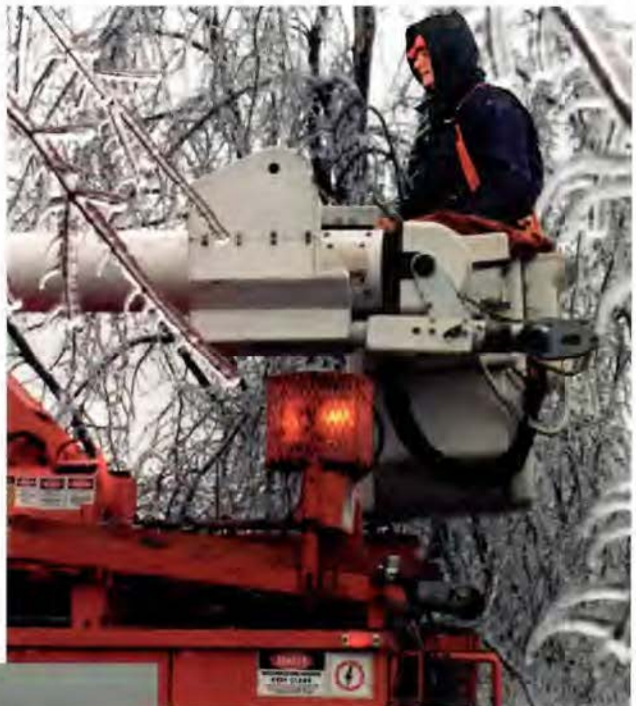
Among the hardest hit utilities in the United States, Niagara Mohawk lost over 85% of its transmission and distribution infrastructure in the affected area. Damage was most severe in its northern region, where some 120,000 customers—over 95% of the utility's customer base—lost power. The storm knocked more than 70 transmission lines out of service, damaged nearly 200 transmission structures and 8000 poles, and made it necessary to replace 2000 transformers. The losses totaled over $125 million—more than six times the $20 million in damage the utility sustained in its next-worst weather event, a lightning and wind storm on Labor Day of this year.

Without electricity, many communities came to a standstill. Schools shut down,



post offices halted deliveries, and a number of businesses closed their doors--some forever. Gas stations without backup generators had no way to pump gas. Houses were dark and cold, and food spoiled in disabled freezers. Homes depending on wells with electric pumps even lacked running water. Freezing residents took refuge in community shelters or moved in with friends and relatives lucky enough to have been spared the outage. With ATMs on the blink, many people couldn't get cash. Many restaurants that might have helped feed stranded residents found themselves unable to do so; food had spoiled in their own freezers, and road closures due to downed trees and wires made getting fresh supplies extremely difficult.

Recovery from this disaster did not come quickly or easily for the region's electric utilities. Many local utility crew members had problems of their own at home. To help out, utilities from as far away as Hawaii sent crews. Some personnel stayed in hotels with no heat or lights. Others slept on the floors of school gymnasiums or firehouses or even in their own trucks. "The outages we've experienced in the past were not of this geographic magnitude," says Tompkins of Niagara Mohawk, noting that the area in northern New York that lost power is nearly the size of Massachusetts. "Accommodations anywhere in the vicinity of the problem were without power."



COURTESY HYDRO-QUEBEC

The devastating ice storm of January 1998, which paralyzed eastern Canada and the northeastern United States, dramatically illustrated how power companies not only are crucial to disaster recovery but are very often the victims of calamity themselves.

Niagara Mohawk sent more than 4000 workers into the field to respond to the storm. Traditionally, restoration plans call for transmission equipment to be repaired first, then distribution equipment. But since getting power to feed and shelter the crews and to gas up their trucks was a priority, transmission and distribution repairs had to be made simultaneously. The utility also deployed numerous emergency generators—with a total capacity of 17 MW—throughout the affected region. Power restoration took 23 days, and residual repairs continued through the spring and into the early summer. The visible scars—trees split in two, fallen branches and limbs—still remain.

The damage from this kind of disaster could not realistically have been prevented. "The utilities designed their systems for the most severe conditions that could be expected to occur in 100 years, and they got a once-in-500-year storm," says Ralph Bernstein, program manager for EPRI's DP&MT Target. In Niagara Mohawk's case, distribution equipment is designed to withstand an ice buildup of 0.5 inch (1.3 cm) and transmission equipment a buildup of 1 inch (2.5 cm)—standards that exceed the recommendations of the National Electrical Code. But with a buildup of 2–4 inches (5–10 cm) during the January storm, the systems were clearly overwhelmed.

As the utility noted in a report to the State of New York Department of Public Service, released in June, it is not practical to build lines to withstand such extreme conditions. For example, a distribution line that can withstand up to 3 inches (7.5 cm) of ice would require supporting poles every 60 feet (18 m) instead of the typical 225 feet (69 m). Not only would such a design be unsightly and environmentally intrusive, but it would also be prohibitively expensive. Redesigning the utility's entire electrical system to withstand 3 inches of ice would cost more than $4 billion and still would not prepare it for the 4-inch ice buildup that accumulated in some areas during the storm. Nor would it fully protect the system against damage from falling trees.

Business factor

Utilities aren't the only businesses devastated by disasters. As January's ice storm clearly illustrated, disaster can have a big impact on virtually any business in harm's way. That storm closed Montreal's central business district and shut down shopping malls in upstate New York. In Vermont, maple syrup farmers lost entire groves of trees. New York dairy farmers who couldn't store their milk or get it to processing plants were forced to dump about half their usual production every day. Chemical producers in Canada weren't able to meet customer demand, suffering hundreds of thousands of dollars a day in production losses.

Physical damage, loss of power, and restricted public access can bring local business to a standstill for days or weeks, sometimes leading to the permanent closure of commercial establishments.

Similar examples of business hardship can be found in the wake of almost any disaster. After the Oklahoma City bombing, 40 blocks of the city's downtown area were barricaded for over 30 days. "During that time, businesses were crippled—4000 of them," says Jim Oggerino, who manages the DRBA portion of EPRI's DP&MT Target. "Business owners and customers simply could not get in." In the end, he notes, local, state, and federal agencies learned that they probably hadn't needed to restrict access for so long. But there was no reversing the consequences: 200 businesses shut their doors for good. Another 20 fear they'll never fully recover and are considering filing for bankruptcy.

The problem is that individual businesses are usually left out of the loop in traditional disaster planning. In the public sector, emergency authorities, utility service providers, emergency medical teams, and others have well-developed emergency response procedures and can generally coordinate well with disaster relief organizations. However, the recovery of essential commerce and trade has been left to chance, market forces, or ad hoc liaisons created in the chaotic aftermath of a disaster. The negative implications are significant enough for businesses at any time. But in today's environment of just-in-time manufacturing, the problems can be especially severe.

A number of experts are stressing the need for increased attention to business recovery from disasters. After all, they note, a community cannot fully recover from disaster until its businesses recover. Says EPRI's Bernstein, "If your residents don't have jobs, they can't pay their bills or buy local goods. And you lose tax base. Quick and coordinated recovery of basic commercial networks—utilities, food and water distribution, telecommunications, financial services, transportation and fuels, and broadcast media—is the key to the timely recovery of local business, the viability of neighborhoods, and the continuity of government."

James Bronson, assistant professor of business management at the University of North Dakota, notes that business assistance typically comes in the form of loans and that few other types of assistance are available for private industry after a disaster. Bronson managed a survey of the business climate in Grand Forks, North Dakota, in the wake of the flood of April 1997, which resulted in the evacuation of the entire city of 60,000—one of the largest urban evacuations since that of Atlanta, Georgia, during the Civil War. The worst disaster in U.S. history on a per capita basis, the flood caused $2 billion in damage in Grand Forks and its sister city, East Grand Forks. That amount equals 12% of North Dakota's gross state product; half of it was the result of property and inventory losses by commercial and industrial establishments.

Less than 10% of property in the community was insured for flood damage, so recovery efforts strained many businesses, particularly small shops whose owners were also trying to rebuild their homes. Overall, recovering from the flood reduced business equity by more than $400 million, wiping out equity altogether in many companies. As of May 1998, about 150 businesses had not yet reopened their doors. Of those that survived, 31.7% report that their debt level is higher.

The EPRI response

EPRI is among a number of public and private organizations that are working to minimize the impact of disasters. EPRI's approach includes three key elements: developing disaster-related technologies, identifying other useful technologies from the public and private sectors, and implementing DRBAs in the private business community. These elements will help utilities and their customers prepare for, respond to, and recover from unavoidable disasters. In some cases, the technologies will prevent or mitigate disasters.

Business participation in disaster planning and recovery is a relatively new trend—one that is being supported by the federal government via FEMA (through its Project Impact initiative) and by the insurance industry (through its Showcase Communities program). The roots of EPRI's DRBA effort date back to 1994, when EPRI conducted a workshop and a study to identify ways the electric power industry could help communities mitigate power-outage-related losses caused by natural disasters. The goal of the study soon expanded into a broader vision. With analytical assistance from the insurance industry, other lifeline industries, researchers, and government agencies like the U.S. Department of Energy and FEMA, EPRI identified the need for a disaster-planning and restoration process that would engage stakeholders from private as well as public sectors. The result was EPRI's DRBA program. The intent of this initiative is to establish DRBAs in communities across the country to provide a vehicle for much-needed business input into disaster planning, mitigation, and recovery.

Each DRBA is a collaborative organization—an alliance of businesses in a community in which the local power company plays an important role. The alliance works with chambers of commerce and local, state, and federal government agencies, as well as volunteer disaster-planning organizations, to help ensure a community's market recovery after a disaster. The local DRBA leads the business community in disaster mitigation initiatives and coordinates the exchange of information with public-sector emergency operations centers. Existing DRBAs have working relationships with numerous groups, including the American Red Cross, the Central United States Earthquake Consortium, the Association of Contingency Planners, the National Emergency Managers Association, and the Institute for Business and Home Safety.

Typically, the business sponsors of a DRBA form a community steering group, which collects and analyzes area-specific business data. Results indicate what areas of vulnerability exist, what issues the DRBA will have to address, and what priority should be assigned to each issue. Each DRBA member organization helps fund the administration of the DRBA and any special programs that result. Some businesses balk at the prospect of funding disaster planning. Mary Carrido, national president and CEO of the Association of Contingency Planners and a disaster recovery and mitigation expert who helped develop the DRBA concept, offers this perspective: "Spending the money to develop an organization like this is minimal compared to what businesses would lose in market share because of a devastated community." According to Carrido, for every dollar spent on mitigation and prevention, $12 is saved on response and recovery.

Both FEMA's Project Impact initiative and the insurance industry's Showcase Communities program recognize the need

After the Storm

Omaha Public Power District recently experienced the largest and most damaging snowstorm in its history. The October 1997 storm downed power lines, poles, meters, and other equipment throughout OPPD's service territory. The company's response to the outage was comprehensive and immediate. Still, some customers remained without power for many days. With funding assistance from EPRI, OPPD sought an external assessment of its restoration effort.

The assessment covered several key areas, including the emergency restoration plan and its execution, routine maintenance and tree-trimming practices, system design and technology utilization, staffing levels, and response approaches. The report resulting from the assessment, issued in February of this year, includes key recommendations about how OPPD might improve its response to such an event.

Some positive factors for the restoration effort were the routine maintenance practices already in place at OPPD, which have kept the company's electric power system in good condition, and the utility's effective tree-trimming program, which kept the October snowstorm's tree-related damage from being much worse than it was. Further, OPPD has a service restoration plan in place that its personnel know well and actively apply. This was evident during the storm, when all the plan's steps were carried out and organizational support was set up to ensure its integrity.

A distribution line felled by a severe snowstorm in OPPD's service territory

As for potential improvements, the report states that OPPD might have been able to restore more customers sooner if an early damage assessment mechanism had been in place to alert it that many additional resources would be required in the restoration effort. The magnitude of this storm also highlighted the need for a formalized plan for responding to the information needs of the media and customers.

Among the study's specific recommendations are the following:

- Set up separate areas of responsibility during emergency restoration efforts to handle logistics, information, and planning
- Increase the use of mutual aid resources and contractors (for services like tree trimming and line construction), and reconfigure OPPD resources to manage outside resources in a more effective manner
- Develop a comprehensive media plan and mandatory drill exercises
- Create a multidimensional damage assessment model and process
- Continue work on customer communications system plans and enhancements

for business community input as well. In fact, one of the 14 criteria for becoming a showcase community is to establish a DRBA. The Showcase Communities program also emphasizes—among other things—the adoption of model building codes, participation in the national flood insurance program, provision of mitigation training to building design and construction professionals, and promotion of hazard awareness in the local community.

Although the federal initiative doesn't indicate a preference for DRBA or any other model involving business in disaster planning, it clearly recognizes the importance of business participation. As a FEMA press release states, "A critical part of Project Impact involves enlisting the active support of businesses across the country in taking measures to protect their companies, their employees, and their communities." In each community that's designated disaster resistant, local partnerships among government, the business sector, and individuals provide funding, in-kind services, technical support, and labor for a range of disaster-related activities—from retrofitting public buildings to better withstand hurricanes to holding seminars on flood-proofing homes.

The city of Evansville is a focal point of the Southwestern Indiana DRBA, established by EPRI. Through workshops like the one shown here, government agencies and disaster recovery organizations receive valuable input from members of the local business community on how to effectively restore local commerce in the wake of a disaster.

Model community

Underscoring the similarity of principles among the EPRI, FEMA, and insurance industry programs, one of the three communities in which EPRI has to date established DRBAs has also been named a showcase community and a disaster-resistant community. Located in southwestern Indiana, that community consists of the city of Evansville (which lies on the banks of the Ohio River bordering Kentucky), the surrounding metropolitan area, and Vanderburgh County.

The city of Evansville and Vanderburgh County (total population 168,000) sit atop the New Madrid fault. Although the community has not experienced any serious earthquake activity, it did have a tremor in the 1960s, and the potential for a more serious quake is there. Besides, the region has had its share of other disasters—floods, ice storms, tornadoes, and an airplane crash.

"Our goal each year is to make the community safer than it was the year before," says Barbara Cunningham, executive director of the area planning commission for Evansville and Vanderburgh County. "We felt that establishing a DRBA here would help strengthen the government–business sector coalition working on disaster preparedness."

Initiated by its stakeholders in 1997, the alliance includes the local utility, Southern Indiana Gas and Electric Company, and 20 major businesses. Among these are Whirlpool, GE Plastics, Toyota, and Citizens Insurance. The alliance works with a variety of nonprofit and government organizations involved in disaster planning, including the Central United States Earthquake Consortium, the Indiana State Emergency Management Agency, the Metropolitan Evansville Chamber of Commerce, and the Evansville–Vanderburgh County Emergency Management Agency.

"The survivability of the community is more important than that of any one industry," says Dennis Sledd, an account executive at Southern Indiana Gas and Electric and treasurer of the DRBA. "There are a lot of lifeline industries that need to work together in an effort to overcome and mitigate all types of disasters." Sledd notes that electric utilities bring an especially valuable perspective to DRBAs. "Unlike most businesses, utilities are faced with disasters all the time. We react to them on a regular basis," he says, "so there's a lot we can bring to the table in terms of contingency planning."

Thanks to the efforts of the Southwestern Indiana DRBA, the business community now has a seat at the table in the emergency operations center in north Evansville, where police, fire, medical, and electric utility personnel and others gather in the event of a disaster to plan a coordinated, effective response. In the meantime, the DRBA is helping lay the foundation for this response. Working with partners in the community, business representatives in the alliance are helping identify the bridges, transportation routes, buildings, and other critical infrastructures that should open first after a disaster like an earthquake. "Right now, it's all based on traffic count," says Sledd. "But the busiest roads might not necessarily be the ones that move commerce."

Through this DRBA, local companies have also identified the minimum electrical load needed to support their critical business function—valuable information for the local utility. And they've learned that even with a backup generator they need to plan. "A lot of companies think that since they've got a generator, they'll be back in business even if they lose power," says Sledd. "What they forget to determine is how long the generator will run, where the fuel to continue its operation will come from, and, if the road to that supplier is blocked, how else the fuel can get there. What the DRBA does is raise awareness of the vulnerability of various businesses so that contingency plans can then be made."

Experts say the positive working relationship between public and private sectors in the Southwestern Indiana DRBA is a model for other communities. "The state, county, and city management people are sitting down and planning meetings with business representatives," observes Carrido. "That is unprecedented. You'll find very few communities in which you have the kind of trust for that to happen. But we believe it's possible anywhere."

So far, EPRI has established two other DRBAs—one in Memphis through the Tennessee Valley Authority and one in Rye, New York, through Consolidated Edison Company. Rye's DRBA is just getting under way this year, but the alliance has already identified specific projects of interest, including the installation of a sophisticated backup generating system at a community shelter, the Rye Country Day School gymnasium. Rye also has been named a FEMA disaster-resistant community.

EPRI is finalizing agreements to establish DRBAs in other areas, including the entire state of Rhode Island. One of the country's most densely populated states, Rhode Island has good incentive, given that it has 420 miles (680 km) of coastline and that two-thirds of its population live in the state's hurricane-vulnerable coastal areas. Other DRBAs in the planning stages include one in Santa Ana, California, and one in Desert Hot Springs, California.

EPRI is pleased with the success of these partnerships. Says Oggerino, "Community groups are collaborating with one another now. Rather than just making internal or individual disaster plans, they're developing external, integrated vulnerability analyses and market recovery plans to take care of everyone in the community. And it's beginning to pay off. We are starting to see momentum in the various communities."

Technological edge

The ability to draw on EPRI's 25 years of work in science and technology is an effective inducement for many communities thinking about becoming associated with the DP&MT Target through their utilities. Indeed, EPRI's experience includes the development of technologies and expertise relevant to a wide range of catastrophes, from fire ant invasions of electrical equipment to major power plant outages. Over the years, EPRI researchers have violently shaken and yanked transmission towers until they've crumpled, zapped underground cables with lightning bolts, and triggered explosions in underground vaults—all in the name of learning how to prevent or mitigate disasters.

One of EPRI's most widely deployed disaster-related technologies is the National Lightning Detection Network (NLDN), operated by Global Atmospherics, Inc. (GAI), of Tucson, Arizona. The network consists of strategically placed electromagnetic sensors that relay cloud-to-ground lightning data via communications satellites to the NLDN control center for processing and distribution. Through the network, power companies can see the resulting real-time information displayed on a map of the United States and can use it to anticipate, track, and analyze lightning strikes in and near their regions. The network was developed in the mid-1980s by the State University of New York under contract to EPRI and was then improved by GAI, also under EPRI contract. It is now taking off in the international market,

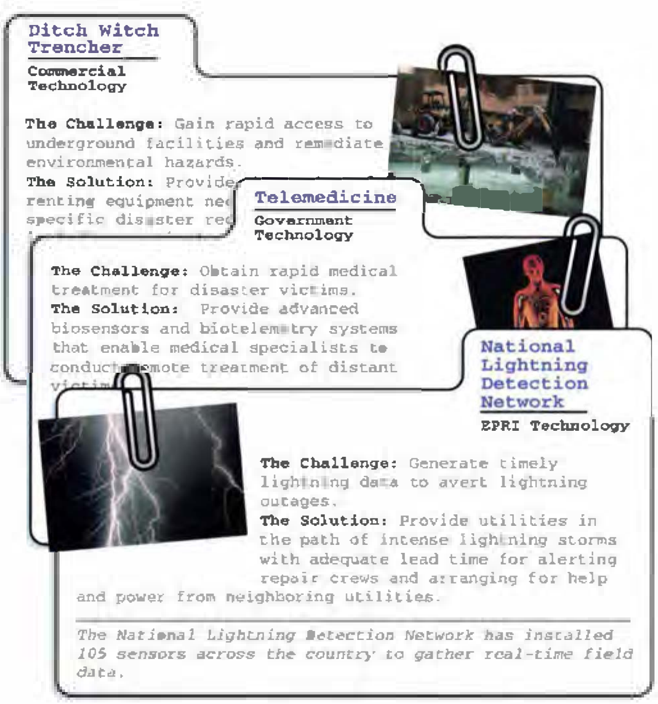
EPRI researchers evaluated over 1500 useful disaster-related technologies available from EPRI and the public and private sectors to come up with the 175 (including these 3) highlighted in a recently released inventory.

Partnering to Prepare for Disaster

EPRI is teaming up with the Federal Emergency Management Agency on a study aimed at better defining the electric power issues associated with recovery from a hurricane or a northeaster. The results will be particularly relevant to coastal communities, where damage can occur from either high winds or flooding.

The initial goals of the study, which is expected to get under way shortly and to take about six months to complete, include the following:

- An analysis of existing design standards and practices that address high wind loads for overhead lines
- A determination of how best to make decisions about the use of overhead versus underground distribution in areas subject to high winds and flooding
- A study of the need for redundancy at critical facilities
- The identification of capital improvement and maintenance issues associated with reducing downtime after a disaster
- A discussion of service connection problems
- The development of a guideline that defines acceptable restoration times
- A review of mechanisms for financing capital improvement and maintenance projects



The National Lightning Detection Network has installed 105 sensors across the country to gather real-time field data.

with networks operating in some 25 countries and on every continent.

"This is one of the EPRI technologies we think could be very useful in southwestern Indiana," says Sledd of Southern Indiana Gas and Electric, noting that his utility purchases data from the network on a regular basis. "If people are interested and will support it, then we may choose to become part of the network ourselves."

The lightning network is one of 175 disaster-related technologies highlighted in *Disaster Planning and Mitigation Technologies: Interim Technology Inventory Report No. 2* (TR-108972-V2), released in June. The report provides an inventory of technologies relevant for disaster planning, prevention, mitigation, and recovery; it updates the first version of the inventory, published last fall.

To develop the inventory, researchers evaluated over 1500 technologies from three sources: EPRI, the public sector (including DOE's national laboratories and the National Aeronautics and Space Administration), and the commercial sector (including vendors producing disaster-related products). The report also offers 10 technology information briefs on key products. Each brief describes a specific challenge, a technology solution for that challenge, its cost, the availability of the featured products, and the experiences of those who have used them. Earthquake mitigation for power systems, reduction of ice damage to overhead power lines, power plant fire protection and suppression, and advanced treatment for electrical burns are just some of the issues covered in these briefs. EPRI intends to update the technology inventory periodically.

Of EPRI's forthcoming disaster-related products, the poststorm damage assessment system appears to be the top priority for power companies. Currently under development, this technology uses remote sensing data from aerospace programs—data developed for military and other civilian applications—along with computer and digital imaging technology to deliver visual images of poststorm damage in near real time. The system will offer a high-resolution, bird's-eye view of utility transmission and distribution systems in the context of surrounding geography. The idea is to allow utility personnel to quickly assess the extent of any physical damage resulting from a storm, locate the damaged systems and facilities, access unobstructed routes, and plan needed repairs. This summer EPRI tested a prototype of the system, with positive results. By the end of the year, detailed data from test runs should be available.

To enhance its own technology development, EPRI has signed an agreement with Sandia National Laboratories to cooperate in identifying and bringing to market products that will help mitigate the impact of disasters. The goal is to take advantage of the years—and sometimes decades—of government-sponsored research Sandia has put into developing technologies for national security. Many of these products could be extremely valuable to EPRI members and the communities in their service territories. In some instances, Sandia's technologies directly complement technologies EPRI has developed. For instance, a geographic information system (GIS) that Sandia has enhanced for use at its own facilities could be a great asset in EPRI's poststorm damage assessment system. Sandia's GIS provides the location of both underground and aboveground electrical networks in the context of buildings, streets, and other landmarks.

This virtual reality tool can simulate a disaster site in three dimensions for training purposes. EPRI and Sandia National Laboratories are cooperating to identify other advanced Sandia-developed technologies that could be modified for disaster mitigation applications.

Other Sandia technologies could be valuable to utilities and communities. For instance, Sandia has developed virtual reality tools for training experts in the remote handling of nuclear reactors. These tools, which simulate a disaster site in three dimensions and enable users to modify the virtual environment, could also be used to train firefighters, police officers, ambulance crews, and others who are the first to respond to a disaster. Sandia originally developed this technology for DOE. It has since been used in other applications, such as training security specialists on removing hostages. The technology would need further development to tailor it to the needs of specific communities.

Bernstein notes that members of the DP&MT Target can take advantage of EPRI's tailored collaboration and cofunding options to help customize technologies of interest and apply them to their own specific situations. EPRI can also provide target members with information about how well these technologies performed in past disasters. And target members can influence the direction of EPRI's research, steering it toward the development of entirely new technologies to address their emerging needs.

EPRI vice president Karl Stahlkopf says that EPRI members should envision the target as a continuously updated toolbox. Over time, he says, the lessons learned from an increasing number of utilities experienced in disaster will be incorporated so that the best practices and technologies will be identified. These approaches can be adopted by other utilities to solve their own and their customers' problems. "We can't stop a disaster from striking," concludes Stahlkopf, "but we can certainly help minimize its impacts, improve response, and speed the recovery process." ■

Background information for this article was provided by Ralph Bernstein and Jim Oggerino, Energy Delivery and Utilization Division.

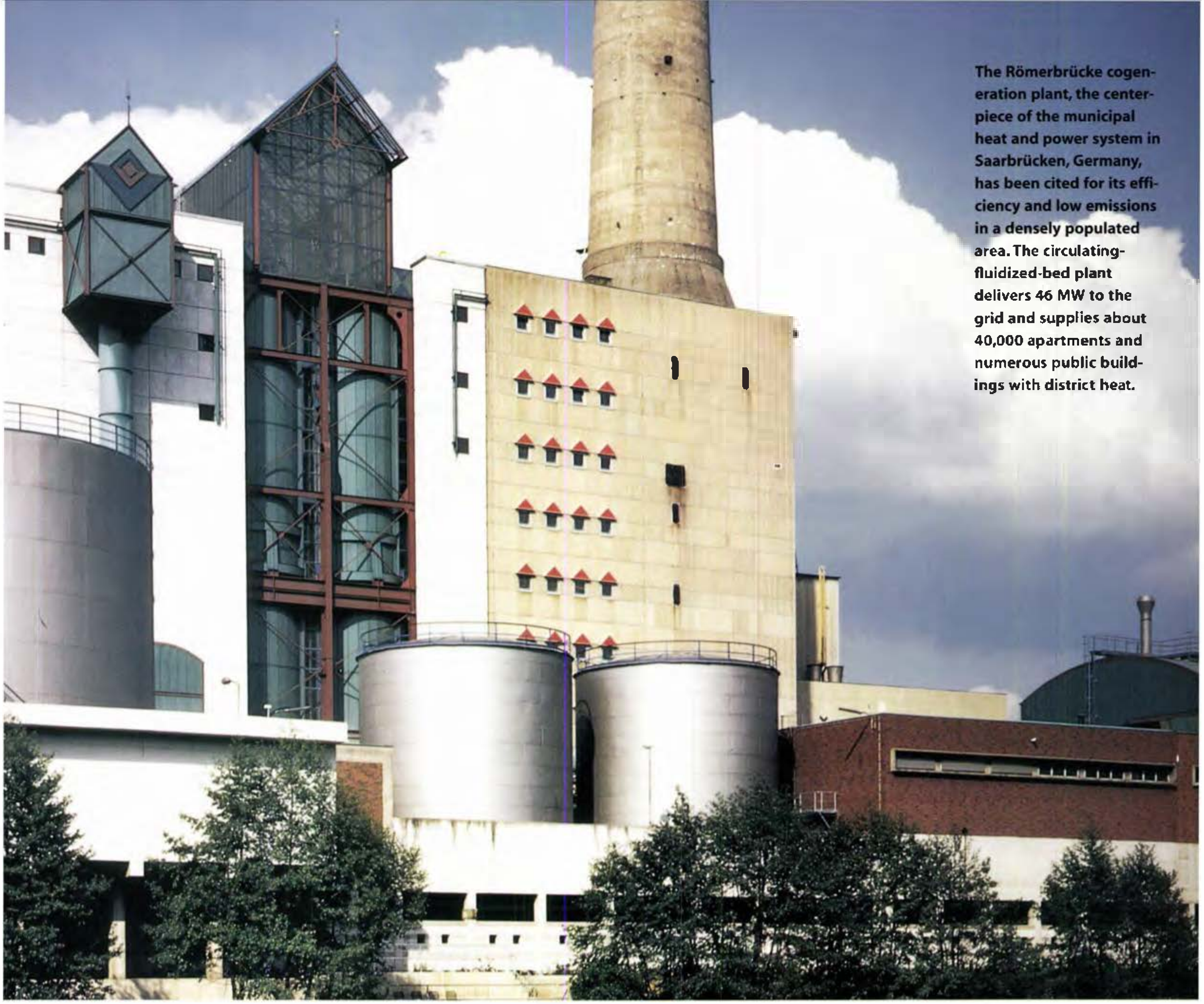
DISTRICT ENERGY: Combining Heat and Power


COURTESY ABB KRAFTWERKE

The Story in Brief A high-efficiency cogeneration application that provides both electricity and thermal energy for heating and cooling could be set for a revival in the United States, following decades of deployment in Europe. The renewed interest in district energy systems stems from their strategic value to utilities in helping retain commercial customers while maximizing the use of fossil plant assets and reducing pollutant emissions. The potential of these systems to dramatically lower carbon dioxide emissions by raising energy conversion efficiency—in some cases, more than doubling it—could propel district energy to more widespread adoption in the future. EPRI offers an R&D target designed to help member companies develop district energy as a profit-enhancing business.

by Taylor Moore

The dawn of the electric age in the late nineteenth century was preceded—and, in part, made possible—by the era of steam power. The first commercial system for district heating in the United States began operating in Lockport, New York, in 1877, providing steam to multiple buildings from a central plant. In New York City, the first district steam heating system—featuring a half-mile main along Wall Street, in what is today's financial district—began operating six months before Thomas Edison's steam-driven Pearl Street power station generated its first amperes of direct current in 1882. Within only



The Römerbrücke cogeneration plant, the centerpiece of the municipal heat and power system in Saarbrücken, Germany, has been cited for its efficiency and low emissions in a densely populated area. The circulating-fluidized-bed plant delivers 46 MW to the grid and supplies about 40,000 apartments and numerous public buildings with district heat.

a few more years, electric utilities were envisioning the distribution of exhaust steam from power plants to heat nearby buildings.

New York City's electrical distribution system eventually far surpassed the steam system in terms of load, number of customers, and service area. But the district steam system—operated, as is the electrical system, by Consolidated Edison Company of New York—remains the largest such system in the country today, bigger than the next several systems combined. It has over 100 miles (160 km) of mains and pipes that serve about 2000 customers in Manhattan (from the Battery to 96th Street), including some of the city's largest buildings. The system delivers more than 34 billion Btu of clean energy a year for heating, cooling, domestic hot water, and such other uses as sterilization and food processing.

District steam heating systems have been operating nearly as long in several other cities, including Philadelphia, Indianapolis, Detroit, Lansing, Boston, Milwaukee, and San Francisco. More recently, smaller district energy systems that circulate lower-temperature hot water have been installed in Springfield, Massachusetts, and Jamestown and Buffalo, New York. District energy plants provide both heating and cooling at John F. Kennedy International Airport in New York City and at Pittsburgh International Airport.

In Europe, where high fuel costs have long provided a strong incentive to use energy efficiently, the cogeneration of electricity and thermal energy for distribution to customers' buildings is common in many urban areas. To serve their densely populated cores, most European cities have what are called combined heat and power (CHP) utility systems. Efficient and low in emissions, European CHP systems vary in size. At one end of the scale are the large urban systems in the countries of central and eastern Europe that formerly had planned economies. These systems feature extensive networks of massive hot water pipes, which also fill year-round heated swimming pools. At the other end of the scale are the systems of shallowly buried, insulated steel pipes that circulate hot water from central stations and some distributed power plants in cities, towns, and villages throughout the Nordic countries.

Finland's capital, Helsinki, is a prominent example of the application of district heating. There, district cogeneration and heating-only plants provide over 90% of the total energy for space heating, the most in any western European city. Nationwide, more than 2 million Finns, or 40% of the population, live in homes served by district heating systems, which were introduced in the 1950s.

Another example is Berlin, soon to be restored as the capital of Germany. The place where European district heating was pioneered in 1912, Berlin is home to the world's largest district heating infrastructure. In September 1997, the reconstructed, state-of-the-art Mitte combined-cycle power plant began providing electricity, hot water, and chilled water to a large, revitalized central historical district. Once the cultural heart of cosmopolitan Europe, the area includes Potsdamer Platz, the Brandenburg Gate, and Alexanderplatz—landmarks that are now being joined by new corporate centers for ABB, Daimler-Benz, Sony, and others.

Long favored in colder, northern climates, district energy systems are increasingly being developed in such other countries as the United Kingdom, Italy, Greece, and Turkey.

Expanding environmental appeal

Thanks to several decades of application and development in Europe, the technology for district heating and cooling has evolved to an advanced state and is now available in a competitive supply market. The original purpose of saving fuel has expanded to include minimizing atmospheric emissions.

Modern cogeneration and heating plants use fluidized beds or other advanced combustion technologies designed to fire several different fuels—including peat, wood, gas, coal, and even hay—and to produce low emissions. Air quality studies in Finland's major cities have confirmed that district heating plants, where emissions controls were first applied, have resulted in substantially reduced emissions of sulfur oxides, nitrogen oxides, and carbon dioxide. Because boilers for space heating in customer buildings can be eliminated, utilities can gain credits for reducing pollutant emissions—credits that can be applied toward expanding other generating facilities. And when used with non-chlorofluorocarbon-based chillers for space cooling, district energy systems can also eliminate the need for vapor compression cooling equipment with ozone-depleting refrigerants.

In recent years, CHP systems have become especially appealing to government officials, policymakers, and environmental scientists concerned with reducing the risk of global climate change due to increasing atmospheric loading of CO_2 and other so-called greenhouse gases. Because CHP systems can have overall energy efficiencies that are more than double those of most electricity-only fossil fuel power plants, CHP is coming to be seen as a key element of sustainable energy development strategies—for example, in the rapidly growing cities of developing countries and for repowering and infrastructure redevelopment in central and eastern European countries. By distributing thermal energy that would otherwise be lost as waste heat from power generation, the CHP approach dramatically increases the efficiency of energy use and thus reduces the amount of CO_2 produced per unit of energy. And customer boilers and their CO_2 emissions are eliminated.

Moreover, the large potential for converting some of the unused generating capacity at aging urban fossil power plants—in the United States, for example—to serve new or expanded district energy systems could be significant in the event that CO_2 emissions reductions are mandated as part of efforts to implement international treaty commitments concerning global climate risks. "If carbon dioxide limits are imposed in the future, many existing fossil steam plants may not be able to operate competitively with 30–40% fuel use efficiency," says Walter Piulle, who retired from EPRI earlier this year after 22 years in fossil plant and cogeneration-related R&D. "Converting a power plant to provide district heating can increase fuel use efficiency to 85%."

Utility-operated fossil plants that have the lowest heat rates average slightly less than 10,000 Btu/kWh, and even the most

COURTESY JOSEPH TECHNOLOGY CORP.

All the electricity and heating and cooling energy used at New York City's John F. Kennedy International Airport is supplied by this district energy plant.

Major rebuilding is under way in the heart of Berlin as the city prepares to resume its role as the capital of a united Germany. The central district's historical landmarks will be joined by corporate centers like the multipurpose complex Sony plans to open by 2000. Berliner Kraft und Licht AG, the local utility, has repowered its Mitte plant with advanced combustion turbine combined-cycle technology and added an absorption refrigeration facility, thus enabling the plant to supply the entire district with electricity, hot water, and chilled water. Designed for 90% fuel utilization and 100% waste heat recovery, Mitte is among the most efficient and environmentally compatible plants of its kind in the world.

COURTESY ABB KRAFTWERKE

Mitte combined-cycle plant

R. SCHAFER/SONY BERLIN

Artist's conception of the Sony Center, superimposed on a site photo

efficient supercritical boilers with double reheating of feedwater can rarely do better than 8500 Btu/kWh. But converting a generating unit to supply district heating can bring the effective heat rate down to the equivalent of about 6000 Btu/kWh. "This is clearly a significant step change in the efficiency of converting fossil fuels to energy," says EPRI's Tony Armor, director of generation technology development.

Building on its earlier work on fossil plant heat rate improvement, including investigations of recent European innovations in district heating and cooling technologies, EPRI is providing strategic business and technical information to nearly 30 companies that are funding a new R&D target called District Energy for Load Retention and Growth. The target also provides tailored collaboration funding support for companies that want to install or demonstrate district heating systems for customers. The information available to target funders integrates much of EPRI's technology R&D results from the past 25 years regarding the optimization and adaptation of fossil plant steam boilers and turbines.

"District energy systems can be an opportunity for utilities to make money in a largely unregulated business," says Armor. "Several utilities have already capitalized on the opportunity, and others are considering adapting existing fossil plants to also produce thermal energy for sale in the form of steam, hot water, or chilled water. We're working with a substantial number of utilities that are interested in developing a district energy business."

The changing business climate

According to Piulle, the business climate for district energy has recently been improving as a result of the convergence of several factors. These include industry restructuring and deregulation, lower technology costs, changing customer preferences, and a growing recognition of district energy's positive impact with respect to CO_2 emissions.

As part of a $6.3 billion package of energy-related tax incentives to encourage the use of technologies that reduce or minimize greenhouse gas emissions, the Clinton administration has proposed a 10% investment tax credit for cogeneration and district energy systems meeting minimum efficiency criteria. Although similar incentives may be adopted in other countries, the outlook for congressional enactment of the proposed U.S. tax incentives is clouded by political opposition to the Kyoto Protocol treaty, which commits the United States, Japan, and most European countries to phased reductions of greenhouse gas emissions.

In some areas, utility industry restructuring in anticipation of retail market deregulation and a more competitive business environment is adding to the momentum that has been building in the U.S. district energy market. "In the last few years, a number of new district energy systems owned by utilities or new subsidiaries have begun operating," Piulle notes. Among them are several chilled-water systems. And Public Service Company of Colorado is building a district chilled-water distribution system that is intended to eventually serve most of the air conditioning needs of downtown Denver.

Some utilities considering new district energy systems are evaluating the prospects for producing additional revenues by installing fiber-optic communication cables along with hot water pipes, as Commonwealth Edison Company and Atlantic Electric have already done. Fiber-optic lines make it possible to offer customers a variety of communications services in addition to district energy.

Competition among utilities and energy service companies is to some extent driving a consolidation of companies that choose to pursue district energy systems as a strategic business opportunity; other utilities have chosen to quit the district steam business and have sold their systems. After Con Edison, the next-largest provider of district energy in the United States is NRG Energy, a subsidiary of Northern States Power Company. NRG owns stakes in and operates various independent power and cogeneration systems and district heating and cooling systems in Minneapolis, San Diego, San Francisco, and Pittsburgh (in partnership with Thermal Ventures). Other utilities or subsidiaries that have business interests in district energy systems include Mid-America Energy Resources (a subsidiary of Indianapolis Power & Light's parent company, IPALCO Enterprises), DQE Energy Services (a subsidiary of Duquesne Light Company's parent, DQE), and Wisconsin Electric Power Company.

One of the largest independent power producers and developers with extensive involvement in industrial and commercial cogeneration and district energy systems is Trigen Energy Corporation, based in White Plains, New York. Serving more than 1500 customers, Trigen produces energy at 30 plants (in 22 locations) with a combined capacity of over 4400 MW (thermal). Customers include industrial complexes, commercial and office buildings, colleges and universities, hospitals, residential complexes, hotels, sports arenas, and convention centers. At many of its cogeneration facilities, the company employs what it calls trigeneration, producing steam or hot water, electricity, and chilled water.

In a joint venture with Coors Brewing Company, Trigen upgraded the Colorado brewery's thermal energy system, raising its efficiency to double the previous average, increasing fuel use efficiency to 70%, and cutting CO_2 emissions in half. In Philadelphia, Trigen partnered with PECO Energy and NRG to build a new gas turbine combined-cycle plant that supplies PECO with 150 MW of power and Trigen with up to 1.5 million pounds of steam per hour (190 kg/s) for use in the city's downtown steam system. Trigen says it heats about 6000 buildings in 14 cities—including Chicago, Trenton, and Tulsa—and Nassau County, New York.

"The true strategic business opportunity that district energy systems offer utilities is not just better utilization of existing power plant assets but the critical retention of major customers," notes EPRI's Armor. "On-site cogeneration facilities for industrial users of heat and electricity are clear targets for generation suppliers. And, of course, district energy also represents a potential attraction for new customers when it is coupled with incentives—for example, lower electric and thermal energy charges than customers were previously paying."

District energy systems in Europe supply steam or hot water to buildings as well as electricity to the local grid. While most combined heat and power (CHP) plants are coal fired, some are fired with gas or oil—or even biomass, such as wood or crop wastes. Newer district energy plants employ fluidized-bed boilers and combined-cycle technology.

COURTESY C. MØLLER

Hot water for heating Vallø Castle in Denmark is provided by a large nearby straw incinerator.

COURTESY ABB CARBON, ABB KRAFTWERKE

This CHP plant in Cottbus, Germany, will use pressurized fluidized-bed technology to burn local brown coal. It is scheduled to be on line by mid-1999 and to eventually replace an old, polluting coal-fired plant.

COURTESY ABB CARBON, ABB KRAFTWERKE

Overcoming obstacles

Even though district energy has multiple economic and environmental benefits, the development or expansion of such systems in the United States has not been economically compelling in recent decades, mainly because fuel costs are much lower here—typically one-third lower—than in Europe. Moreover, most older U.S. systems supply steam, whereas most of the more recently built European systems employ lower-cost, easier-to-install hot water pipes, often along with heat exchangers at individual buildings.

"There are many barriers to the increased use of district energy in the United States despite its benefits and appeal," acknowledges Ishai Oliker, the principal of Joseph Technology Corporation in Woodcliff Lake, New Jersey. Oliker has more than 35 years of experience with the technology, beginning in his native Russia, where he received advanced technical degrees specifically in district energy. At Joseph Technology, he has been involved in many U.S. and overseas district energy projects, and he is thoroughly familiar with the features of various systems around the world.

"In the last few years, the move toward

utility industry deregulation and the rise of unregulated, competitive utility subsidiaries have led to a growing U.S. district energy business, which many utilities have come to see as part of defensive strategies for customer retention," Oliker says. "But even though competition is creating new opportunities in this area, it isn't easy to make district energy a flourishing, profitable business. Installing the underground infrastructure requires a significant long-term capital investment that is not going to be paid back in two years. To achieve economies of scale, you need to have lots of customers to purchase the energy. The systems that serve European cities have thousands of customers; in the United States, in contrast, the Con Edison system has only a couple of thousand customers, and the next-largest systems have no more than a few hundred.

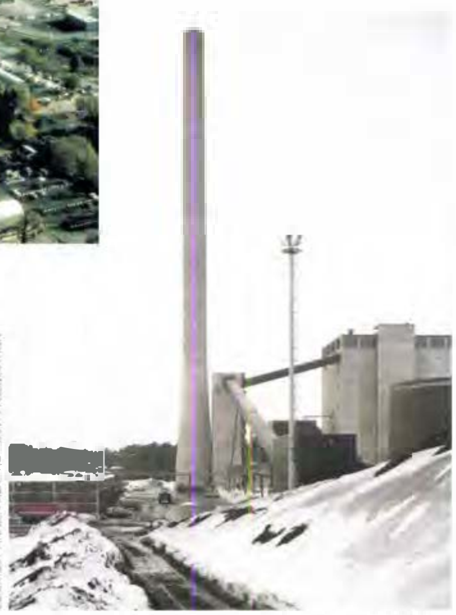
Stockholm Energi's Värtan CHP plant has two pressurized fluidized-bed combustion units that burn low-sulfur coal.

"Also, there is more government planning of economic development in Europe, and governments there have been more open to the creation of incentives for district energy systems. In the United States, all that is available is a limited tax exemption for installing underground pipes."

Case studies highlight opportunities

To help power producers identify economically attractive market opportunities for cogeneration and district energy, in 1996 EPRI produced an assessment based on case studies at five utilities. The project documented consumer and utility benefits of retrofitting fossil steam and combined-cycle plants to provide thermal energy for district heating and cooling loads. Prepared by Joseph Technology, the EPRI report details the technical and economic factors to be considered and documents the process of successfully implementing such plant retrofits.

Case studies were conducted with the Jamestown, New York, Board of Public Utilities, New England Power Company, New York State Electric & Gas Corporation (NYSEG), Niagara Mohawk Power Corporation, and Public Service Company of New Hampshire (a subsidiary of Northeast Utilities). The utilities either already operated or were planning district cogeneration systems. The studies covered a range of district energy system designs and associated turbine retrofits and involved various customer loads, from apartment buildings and downtown financial districts to a university campus and industrial facilities.



Coal-fired district heating plant in Finland

The Jamestown Board of Public Utilities' coal-fired Carlson station was retrofitted for district energy service in 1984. Steam is tapped from one of the station's two 25-MW condensing turbines at a feedwater extraction line; additional district heating load is served by an auxiliary steam header. The steam is condensed in two heat exchangers to produce district supply water at 160–250°F (70–120°C), which is fed through 8 miles (13 km) of underground piping to some 50 downtown buildings. The system initially served only four customers in the immediate vicinity of the power plant; it has been extended incrementally, with new customers added every year since. Because more than 60 customer boilers for heating have been eliminated, air quality in the downtown area has improved. The system continues to grow and to receive broad support and participation from the community (see sidebar, page 24).

At the repowered Manchester Street station of New England Power in downtown Providence, Rhode Island, three late-model gas turbines are coupled with a steam bottoming cycle through a heat recovery steam generator fitted for steam extraction for power augmentation. State utility regulators wanted the station to make steam and chilled water available for sale for various commercial loads in Providence's financial district. But an economic analysis indicated that building a mile-long, two-pipe transmission line would be costly and would have too long an investment payback period to be feasible. In an alternative proposal under consideration, a central district energy pilot plant—including boilers, chillers, pumps, and heat exchangers—would be built near downtown end users. Following successful demonstration and startup of the pilot plant, the feasibility of retrofitting the Manchester Street station for district energy would be reevaluated.

At NYSEG's 122-MW coal-fired Goudey station in Westover, New York, a hot water district energy system was evaluated in connection with proposed turbine retrofits. Steam would be bypassed to condensing heat exchangers, and the hot water produced would be pumped 2 miles (3.2 km) to the State University of New York's Binghamton campus for space heating, domestic hot water, and cooling (by means of existing absorption chillers). The university's peak load is about 44 MW (thermal).

At Niagara Mohawk Power's multiunit coal-fired C. R. Huntley station, two 190-MW baseload generating units were analyzed for district energy production retrofit. The proposed systems would extract steam from boiler reheat inlet lines for direct supply to five industrial customers lo-

Jamestown's Model for District Energy

FOLKS IN JAMESTOWN, NEW YORK, are proud of their growing district energy system and consider it a worthy model for how towns and cities can develop successful systems that yield environmental and economic benefits to customers and the community. "Jamestown's system could be a prototype for how district energy systems should be built in this country," says Douglas Champ, who supervises the system for the Board of Public Utilities.

"Sometimes people start by considering a large system but find the cost is too high, or there isn't enough demand for the energy, to justify installing a large system. We studied it thoroughly and decided to first install a pilot system—for a fairly minimal investment at the power plant—with a hot water line to a city hospital, an industrial customer, and two city garages," notes Champ. "By 1985, we were adding significantly more distribution piping, and we connected another 15 or 16 customers that year. Since then, additional customers have been connected every year."

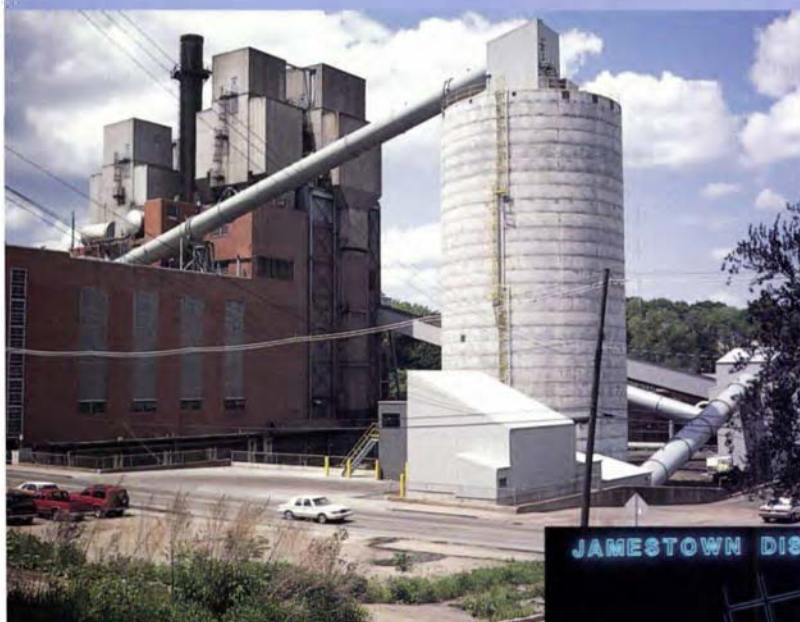
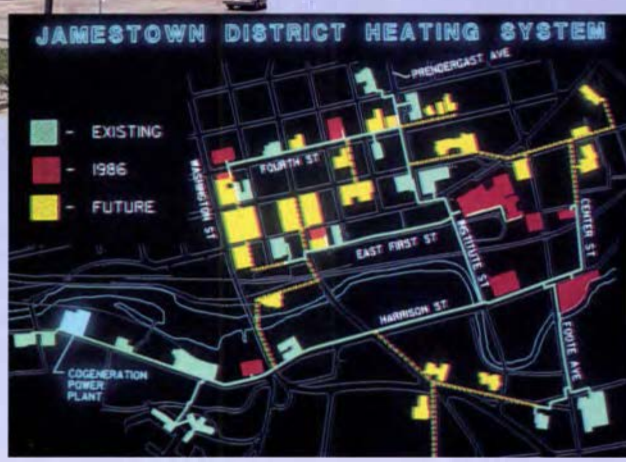


PHOTO AND MAP COURTESY JOSEPH TECHNOLOGY CORP.

In 1984, the two-unit, coal-fired Carlson station in Jamestown, New York, was retrofitted to supply steam for district hot water service. The system now provides about 50 downtown buildings with hot water for domestic use and for space heating and cooling.



Jamestown's district hot water system features all the elements used in today's state-of-the-art systems in Europe, including thin-walled carbon steel piping insulated with a layer of polyurethane and encased in a layer of polyethylene. A low-voltage copper conductor between the pipe and the insulation serves as a moisture detection sensor for quickly locating leaks. Nearly all the piping is shallowly buried beneath sidewalks and terraces; techniques perfected in Europe were used to minimize expansion loops and vaults, which are necessary with steam or higher-temperature hot water systems. Compact heat exchangers at customer buildings extract heat from the hot water at reduced pressure for space heating and cooling and domestic hot water.

Champ says Jamestown's district energy system "has most definitely been a positive experience for the city. It's benefited our customers, who have enjoyed stable energy prices, and we've made an investment in our city's energy future. The district energy system has led to the removal of about 60 customer boilers, most of which were gas and oil fired but some of which burned wood."

One customer—MRC Bearings, a unit of the bearing and steel manufacturer SKF—eliminated two boilers used for space heating at one of its two plants. "The switch has been very advantageous for us," says company executive Pierre Chagnon. "When we first analyzed the economics of connecting to the district heating system, it looked like a break-even proposition. But we found that we missed a lot of additional cost savings. We forgot that going to district hot water eliminated our costs for steam trap maintenance and the water treatment we used to have to do for the boiler. We realized after connecting to the district system that we were enjoying savings we hadn't anticipated."

Chagnon says that MRC Bearings' switch to district heating was consistent with the strong environmental ethic of its parent company. "When we decommissioned our boiler plant, we eliminated several atmospheric emissions permits and reduced emissions dramatically, which was very important to our corporate parent. The move to district heating has had a very positive environmental benefit for our company and also for the community."

Jamestown's district energy system has been so successful that the city recently built a small satellite system to serve about half a dozen buildings on the campus of the local community college, says Champ. And he hopes that work will begin this fall on a small, modular gas-fired boiler substation designed to serve a residential neighborhood and to eventually be connected with the district system. "We want to take the district energy system to individual family homes, which has been done in many parts of Europe but, to my knowledge, has yet to be done in this country. District energy technology could really revolutionize the way many homes will be heated in the future." □

Beyond the fence of a utility power plant, the essential infrastructure for district energy systems is piping to carry hot water or steam to customer buildings and service connections. At each service connection, thermal energy from the district system is transferred to building heating and cooling systems through heat exchangers. Aboveground pipes may be large; in some hot water systems in Russia, for example, they are 6 feet (2 m) in diameter (note the car in the photo). More-recent installations for hot water distribution feature smaller-diameter, polyurethane-insulated flexible piping that is shallowly buried.

Large-diameter hot water pipes in St. Petersburg, Russia

PHOTOS COURTESY JOSEPH TECHNOLOGY CORP.

Flexible hot water piping being installed in Germany

Hot water customer service connection in Jamestown, New York

cated within a mile (1.6 km) of the plant. The peak steam load is 79 MW (thermal). The production of district hot water from turbine crossover extraction steam was also addressed in the study, which evaluated the retrofit plan positively in terms of retaining the industrial customers and improving utility plant utilization.

Public Service of New Hampshire's Schiller station, a 170-MW gas- and coal-fired plant in Portsmouth, already supplies steam through aboveground lines to several nearby tank farms, which use it to heat oil. PSNH evaluated generating hot water with the steam in a new district heating substation, then pumping it through a new distribution system approximately 1200 feet (370 meters) long to a residential community of low-rise apartment buildings. Once the benefits were demonstrated to thermal energy customers and the community, the utility would consider expanding district energy service to downtown Portsmouth. The case study concluded that by pursuing a phased development approach, PSNH could enhance community relations, increase utilization of the Schiller station, and start a new line of business with little risk.

EPRI's case study report outlines a recommended approach for planning and conducting power plant retrofits for district heating and cooling service. It calls for coordinated marketing and customer awareness efforts by all community stakeholders, phased assessment of engineering and financial feasibility, and system implementation in stages, beginning with a pilot project to demonstrate benefits, savings, and reliability. The report also presents detailed recommendations for optimizing plant retrofits and district energy installations.

Building on the insights gained from the case studies and from Joseph Technology's experience with many projects around the world, EPRI is developing a comprehensive, step-by-step guide for planning and developing district energy systems and adapting power plants to serve them. The guidebook is expected to be delivered to target funders in 1999.

Competitive advantages

As the EPRI assessment shows, district energy offers electric utilities a number of competitive advantages. It has strategic value for customer retention and load growth and represents a business opportunity for increasing the value of existing fossil plant assets. District energy systems can also spur a community's economic growth and reduce overall emissions by eliminating individual heating and cooling units in buildings. Utilities around the world are increasingly recognizing the environmental and economic benefits that result from upgrading and repowering fossil plants for district energy.

"District energy shows all the signs of a technology that is going to be increasingly important to society," says EPRI's Tony Armor. "It offers multiple benefits, including enhanced value of fossil plant assets, double the efficiency of conventional fossil plants, the elimination of emissions from individual customer boilers, and the flexibility to use a variety of low-cost fuels—including traditional coal, oil, and gas feedstocks and renewables like biomass, landfill gas, and municipal solid waste." ■

Further reading

Bechtold, K., and M. Pokojski. "Berlin's New Powerhouse," *IEEE Spectrum*, Vol. 35, No. 3 (March 1998), pp. 52–57.

Retrofitting Power Plants to Provide District Heating. Final report prepared by Joseph Technology Corporation. EPRI TR-106027. December 1996.

Background information for this article was provided by Tony Armor and Walter Piulle, Energy Conversion Division.

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Oriens.
Tuchano
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Cabo de Cerrientes
Quiuira Regnū.
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Charting Power System Security

THE STORY IN BRIEF

Avoiding outages on today's highly interconnected transmission grid has become an increasingly difficult challenge. For the past 30 years, electric utilities have relied on conservative risk-avoidance strategies developed after the 1965 New York–New England blackout. Now, with increasing competition and growing demand, transmission utilities are looking for more-realistic safety envelopes for grid planning and operations. In response, EPRI researchers are applying risk-based security assessment to fully chart actual transmission system behavior for the first time.

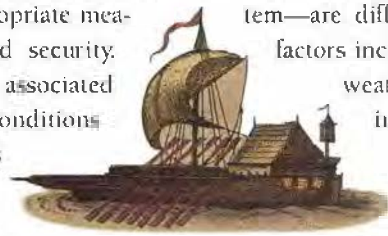
by Paul Haase

MEDIEVAL MAPS AND CHARTS indicated unexplored oceans and imaginary lands beyond the coastal seas known to European cartographers at the time, and these places were commonly depicted as full of great dangers. Hazards thought to exist beyond the known waters included the fearsome sea monsters of myth and legend, boiling-hot equatorial seas, ship-crushing tidal waves, and the dread edge of the world. Renaissance explorers and traders risked these dangers—in their imaginations, at least—when they set sail for the unknown.

Nowadays the belief in such disasters appears to be the fearful thinking of a simpler, unscientific age. However, uncharted regions with unknown dangers exist in modern life as well—for example, in the electricity transmission enterprise. Like a medieval sea chart, a modern "map" of transmission grid behavior shows a safe area, where it is known the grid can be operated reliably, surrounded by large blank regions, where dangers lie and grid behavior is mostly unknown. To avoid these dangers—thermal overload, transient instability, and voltage collapse—transmission operators are constrained to remain within the established safe area, much as medieval traders remained in sight of land for fear of the unknown.

Explorers funded by EPRI are now setting forth to map the uncharted regions beyond the safe area. The maps they make will give transmission planners and operators full understanding of the behavior of their grids, thereby enabling transmission infrastructure to be used to the fullest. "Conventional security methods answer such questions as 'Can our system transfer 800 MW?'" says EPRI's Dejan Sobajic, manager for grid operations and planning. "But with marketplace competition and growing demand for transmission services, grid operators now want to know, 'How much can we transfer?'"

EPRI's new maps are being drawn not in terms of longitude and latitude but in terms of risk, an appropriate measure for the sea of grid security. "Knowledge of the risk associated with various network conditions will allow grid operators and power marketers to weigh the risk against the potential for economic benefit," says Nick Abi-Samra, the EPRI system planning manager who is overseeing the risk-mapping project. "This is a key ingredient to successfully integrating electric power system reliability with market-driven operation."



The limits imposed by security considerations are much lower than the actual capabilities of the system at any given time, and much transmission equipment is underutilized, some significantly so.

Earlier efforts: mapping the known

Nobody worried about system security in the early days of electric power. Engineers and entrepreneurs building power systems from the inventions of Edison and Westinghouse simply connected generators to wires to loads, and it worked. Power flowed, motors ran, lights glowed. For decades various ad hoc approaches to grid operations also worked, but eventually power systems grew so complex that secure operation became an issue for grid planners and operators.

Transmission security analysis involves so much uncharted territory because grid behavior is fundamentally complex, with hundreds and hundreds of variables. The grid itself is a highly interconnected web of wires, generators, and loads spread across hundreds and thousands of miles. Loading conditions vary greatly from hour to hour and from place to place. And while electricity moves at the speed of light throughout the web—changing the grid's electrical state almost instantaneously as loads are hooked up or shut off—the generators that produce the electricity can take hours to bring on line. Adding to the complexity are changes resulting from deregulation, such as different degrees of market participation by different generation sources.

Because full-scale experiments with a transmission grid are obviously impractical, planners and operators turn to computer simulation for understanding. Yet the inputs for simulation studies—the factors that affect the behavior of the system—are difficult to quantify. These factors include load levels, ambient weather conditions, voltage interruption levels, and more. Even the mathematical equations these inputs feed into are problematic: each component of a grid can be represented by an equation, it is true, but these equations cannot all be solved simultaneously to yield a general description of how a grid behaves. Assumptions and simplifications have been used and have proved reasonable over the years, but only for the ranges in which the grid normally operates.

Grid security became a major issue in 1965 when a blackout hit New York City and much of the northeastern United States during the evening rush hour and left the region without electric power for 12 hours. To forestall future problems, the electricity industry initiated a crash program of research designed to increase understanding of grid behavior and place operations on a secure basis. The goal was to ensure the ability of the transmission system to respond to unplanned but credible failures in ways that would prevent uncontrolled loss of load or cascading outages across the grid.

That effort produced a reliable, if conservative, deterministic technique for assessing transmission security, sometimes called the "N minus one" (N−1) technique because it examines the behavior of an N-component grid that has lost any one of its major components. The North American Electric Reliability Council (NERC) was established in 1968 to coordinate uniform implementation of the new security technique.

"N−1 security is applied step-by-step," says Sobajic. "Grid planners and operators ask, 'What happens if this particular transmission line fails? What happens if this generator goes out of service? What about that transformer?' Each case is analyzed individually and independently."

N−1 assessment in action

In practice, the N−1 technique works like this. First, the transmission grid is scanned by experienced planners, operators, and engineers to identify the components most critical to system operation. Component identification is based on a combination of experience, obvious relationships, worst-case analysis, trial and error, and hunches. Hundreds or thousands of critical components may be identified for a typical transmission grid, including generators, lines, transformers, switches, and controls. These are known as contingencies.

Next, the behavior of the grid is computed for a contingent system in which one of these critical components has been taken out of service. This computation is made with a representative load, generation allocation, and switching configuration. The system is assessed for three types of security—thermal, transient, and voltage. The computations for each security type must be done separately because the important contingencies are usually different for each.

If the behavior observed in the simulation shows the N−1 system is able to deliver prescribed levels of power at certain minimum levels of performance at all transmission nodes, the system is judged secure for that single contingency. If not, it is called insecure. The computation is repeated for various representative loads, demands, and configurations until a boundary is identified that divides the secure and insecure regions for that particular contingency. The critical component is then put back into the system, a different one is taken out, and the computation process is repeated. This process continues until the system has been evaluated for each of its thousand or so individual contingencies.

Finally, all the secure regions for all the N−1 contingencies are plotted together, and the intersection of all the secure regions is outlined. What results is a region whose boundaries identify the operating limits within which the grid in question is N−1 secure. In other words, the region shows the combinations of conditions—power flow, voltage, generation, load, and so on—for which the grid can continue to operate at or above certain minimum performance levels despite the loss of any one major component.

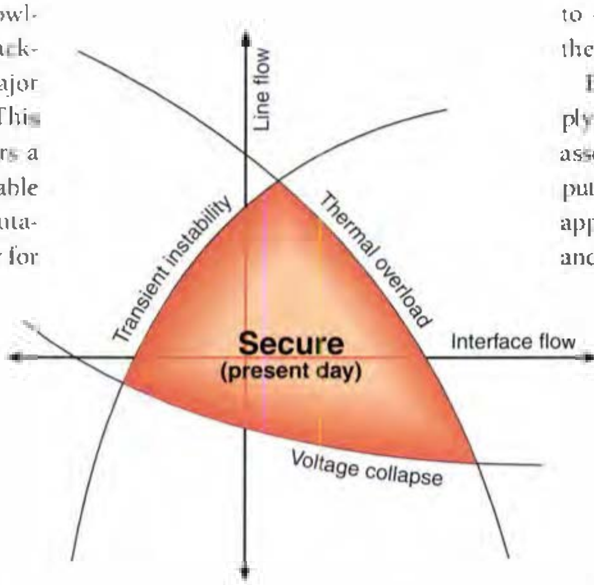
Transmission utilities covered by NERC are mandated to operate their systems within this secure area. As a result, the simulation tools used by utilities to compute grid behavior do so only out to the N−1 security limit. Beyond, where the behavior is "insecure" and unapproachable, grid behavior is not—and with these tools cannot be—calculated. The risk levels of the dangers suspected to lie there are thus unknown.

"The N−1 contingency approach was developed because comprehensive knowledge of global power grid behavior is lacking and the consequences of a major blackout are severe," says Sobajic. "This approach gives operators and planners a handle on grid security at a manageable cost in terms of analysis and computation." But there has been a price to pay for using the N−1 approach. It is a conservative one, requiring a system to be operated in such a way that it remains stable even for the most severe combination of a single failure and a specific worst-case set of operating conditions, however likely or unlikely that combination of failure and conditions may be.

"The problem with traditional N−1 security assessment," says Abi-Samra, "is that, in determining grid operating limits, it treats all security-limiting scenarios as having the same risk. Say that for one set of conditions it is a certain transformer outage that limits operations and for another set of conditions it is the failure of a 70-mile-long transmission line. It's easy to see that the likelihood of a particular transformer going out of service under a specific set of conditions is almost certainly different from the chance that a long transmission line will fail. But for N−1 security, this difference in risk plays no role. Whatever the critical contingency, no matter how likely or unlikely, it determines the operating limits."

As a result, transmission grids tend to be operated in a somewhat inefficient manner, because economical operating conditions are commonly disallowed by N−1 security constraints. To compensate for this inefficiency, grids are overbuilt. Thus the limits imposed by security considerations are much lower than the actual capabilities of the system at any given time, and much transmission equipment is underutilized, some significantly so.

All in all, however, N−1 contingency analysis has proved highly successful over the past 30 years. Bulk transmission security has remained excellent during periods of rapid growth, national recession, and energy crisis. And the costs of conservative grid operation and overbuilding were not a concern so long as they could be spread across large pools of captive customers, as was the case for traditional monopoly utilities. But with competition for wheeling services opening up in the 1990s, transmission utilities have had incentives to reexamine all their costs, including these.



Grid operators avoid power flow problems by staying inside an area bounded by conservative, safe limits for three key dangers: thermal overload, transient instability, and voltage collapse. While it would often be more economical to operate the system outside this secure envelope, today's deterministic methods for calculating grid security can provide no information on how risky it might be to do so.

"Transmission providers are beginning to look outside the N−1 area to see just how insecure it is out there," says Sobajic. "Also playing a role are environmental restrictions limiting the construction of new transmission lines. They are driving providers to explore possible new operating states outside the conventional secure area just to meet the demand for new transmission services."

Mapping the unknown

Thus, like the princes and traders of Renaissance Europe, transmission utilities facing new challenges want to know what lies beyond the known area of the map. How does security change as operating conditions move outside the N−1 area? What is the nature of the unexplored sea of security? These questions are not easily answered, since there is currently no capability for extending deterministic analysis to characterize the uncertainties outside the secure region.

EPRI is taking on this problem by applying the concept of risk-based security assessment. Instead of attempting to compute complete grid behavior, a risk-based approach examines all possible failures and focuses on those that carry nonnegligible risk. In this sense, it is a logical extension of N−1 security assessment, but it differs from that method in that risks are evaluated rigorously and are not restricted to only the most severe contingencies. Risk-based assessments incorporate weighting that reflects how likely various contingencies are to occur.

This approach looks at security and risk the way people do naturally: danger or insecurity is based on the likelihood of something happening and the severity of the effect if it does happen. For example, an inexperienced skier may attempt a gentle slope, knowing that although the chance of falling is quite high, the consequence of a fall on such a hill is insignificant. But the skier wouldn't tackle an expert run: the chance of falling is still high, and on a steep slope the consequence is potentially serious. This kind of thinking is quite common in daily life, even if the component steps are not consciously considered.

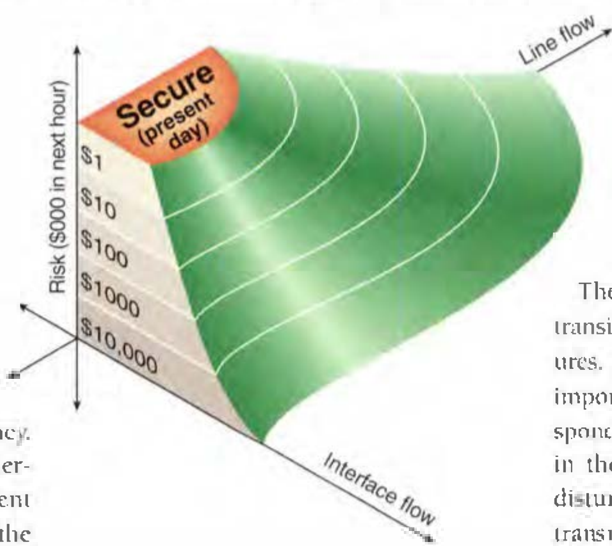
The concept involved here is formally known as probabilistic risk. An event's probabilistic risk is the product of likelihood and severity. Thus a likely event with an insignificant result would not be considered risky, whereas a likely event with a serious consequence would be. Probabilistic risk–based approaches to security have been used for decades in many fields, including the airline and nuclear industries. They are the cornerstone of the insurance business.

"Even now," says Abi-Samra, "traditional power system reliability criteria reflect the basic notions of probabilistic risk assessment. For example, the philosophy of the North American regional reliability criteria is to set less restrictive performance limits for less likely disturbances—that is, you can operate closer to the edge for something that is unlikely to happen than for something that is likely to occur. This kind of thinking represents a qualitative attempt to account for real differences in risk."

The determination of probabilistic risk for a transmission system requires that the actual likelihood and severity of events on the grid be known. To develop this knowledge, EPRI-funded researchers are exploring the activities and physics underlying each type of possible contingency. These fall into three general classes: thermal failures due to overheating, transient stability failures that result from the buildup of wavelike oscillations, and sudden voltage collapse failures caused by voltage levels that are insufficient to sustain power flow.

Consider overheating, for example. A number of thermal failure scenarios are possible when operating a transmission line at a high loading. The fundamental issue is that as the line heats up, it expands and sags. This may result in no problem at all. If the line sags far enough, however, it may touch a tree or the ground and short-circuit because of flashover (which could also be a safety concern). If the day is windy, even a slightly sagging line may swing into a tree or structure and short out (although the wind tends to cool the line, moderating heat gain and sag). Heating can also permanently damage a line's conductor material as a result of annealing, which produces changes in crystalline structure. This damage affects the line's long-term performance, reducing power capacity and shortening life expectancy.

To calculate the likelihood of a thermal failure, the researchers need to know the relationship between power flow and heating for the line in question, the relationship between heating and sag for that line, the amount of clearance required, and expected local wind speed and ambient temperature conditions and their impact on line heating and sag. Together, this information defines the probability that, for given grid and weather conditions, a certain line in a certain location will fail because of flashover. To determine the likelihood of performance degradation due to conductor damage, the researchers also have to know the relationship between heating and annealing.



EPRI's new risk-based security assessment tools map the full range of power grid behavior in dollar terms. For example, this quarter-section representation shows the likely costs of problems resulting from operating the system for an hour at various points outside the traditional secure area. Grid planners and operators can take measured risks by comparing such costs directly against the additional income from temporarily loading up a line for an unusually large power transfer.

Once they have computed the likelihood of both flashover and annealing events, the researchers must determine the severity of each—that is, what's the cost if the line does fail or if its performance is reduced? To determine the severity of failure due to flashover, the system is evaluated with the line removed, and the resulting costs are estimated and totaled. These include typical line repair or replacement costs, damage to other lines and equipment, and average outage expenses. Impacts associated with human safety are assigned very high costs to ensure that even small-likelihood events result in high risk. For annealing, the costs of reduced line performance, lowered capacity, and shortened life are calculated.

Multiplying severity by likelihood for each event and summing the results gives the total probabilistic risk of thermal overload in dollar terms. With this information, an operator or engineer could directly compare the financial risk of heavily loading a line with the payment promised for making a particular power transfer via that line. These calculations define the risks for all cases, even for the loading of a line in excess of its rating, as may be required for temporary operation outside the secure area.

The same sort of analysis is required for transient stability and voltage collapse failures. In the case of transient stability, the important issue is how a power system responds to a major disturbance. Like waves in the open ocean, the largest transient disturbances can build up on the long transmission lines common in western North America. For voltage stability, the key concern is the voltage–power flow relationship required to push electricity through a system of wires. This relationship appears to be chaotic, especially as the point of collapse is approached. The phenomena associated with transient stability and voltage collapse have only recently been discovered—largely as the result of strategic EPRI research over the past decade. Thus, calculating likelihood and severity in these areas is cutting-edge work.

For a complete map of transmission security, risk relationships in all three areas—thermal, transient, and voltage—must be combined, just as for conventional N−1 security. Although considerably more computations are involved in the overall probabilistic risk process than in N−1 security analysis, the rewards of complete knowledge of grid behavior far outweigh the extra effort and expense. "Computer advances make the additional computations manageable," Sobajic notes. "Fast parallel-screening programs can weed out the numerous trivial calculations relating to unlikely and insignificant events. With the information on grid behavior provided by probabilistic approaches, operating strategies can reflect corporate choice, not the limitations of analysis capabilities."

With the information on grid behavior provided by probabilistic approaches, operating strategies can reflect corporate choice, not the limitations of analysis capabilities.

Confidence in security is improved because all the events carrying nonnegligible risk, not just the most severe events, are considered in the analysis. And information is generated for possible operation outside the secure region, providing planners and operators with a map of the whole world of transmission behavior. "In addition," Abi-Samra says, "we can compute cumulative risk over time to evaluate the risks associated with particular operating conditions, energy exchanges, and line loading." Much of the region outside the N−1 secure zone remains a high-risk area that will never be profitably employed by transmission utilities. The risk calculation will reflect this, enabling operators and planners to clearly identify operating regions to be avoided.

"Ultimately, the willingness to take well-considered risks may be what separates the winners from the losers in the deregulated transmission marketplace," says Sobajic. "What we're developing here are the world's first tools to allow transmission risks to be quantified so that planners and operators can make well-informed decisions."

Explorers set sail

EPRI-funded scientists at Iowa State University, led by assistant professor of electrical engineering Jim McCalley, are currently developing frameworks for the risk-based security assessment of thermal limits, transient stability, and voltage collapse. Researchers are also adapting these frameworks for application with EPRI programs used by planners and operators to make security decisions. In addition, the development of an overall grid security framework for real-time operator use is under consideration.

"Probabilistic risk assessment for electric power system security is attractive," McCalley explains, "because it is capable of quantifying not only the risk associated with single, credible events but also the risk associated with catastrophic failures, which are normally classified as low-probability, high-consequence events. It can also account for cascading and double-contingency (N−2) events."

The risk framework for thermal security has already been devised and tested in laboratory simulations. This framework is on its way to being adapted for use with EPRI's TRELSS (Transmission Reliability Evaluation for Large-Scale Systems) program, an industry-standard planning tool for assessing transmission line performance. In addition, the risk framework for voltage security has been developed, and testing is in progress. Plans call for this framework to be adapted for use with EPRI's innovative VSA (Voltage Security Assessment) tool. Research-grade software will be available for both thermal and voltage security by the end of 1998.

A risk-based security assessment framework is still being developed for transient stability, a field that is less well understood. The fundamentals of this phenomenon were researched during EPRI's pioneering work in 1996–1997 to develop the DSA (Dynamic Security Assessment) software, a tool for evaluating the N−1 limits for transient stability. Researchers are building on this knowledge to determine the relationships between likelihood and severity that must be known to compute probabilistic risk. Once these relationships are understood, they will be incorporated into risk frameworks compatible with the DSA tool. Beta software is expected to be ready in late 1999.

And for the ultimate in security assessment, EPRI and Southern Company are exploring the extension of risk-based security assessment concepts to provide transmission system operators with an instantaneous measure of overall grid condition. Such a risk computation tool would give decision makers a single index that accurately reflects the security level of a particular operating condition. The index would be a function of a set of parameters—including generation levels, transmission line flows, and voltages—that characterize the overall reliability and operational health of a transmission grid at any point in time.

"Risk and reward are tied together in competitive markets," says Abi-Samra. "If you look at the American financial market over the long term, the investments with a higher level of risk tend to have a higher return. A $1 investment in stocks in 1871 would be worth over $30,000 today, corrected for inflation, whereas the same $1 investment in safer, short-term treasury bills would pay about $10 now. And a $1 investment in 1871 gold—the safest investment of all, because gold is money—would be worth only a little more than 50¢ today.

"Undoubtedly, the same risk-reward relationship will hold true for competitive transmission markets, but only those transmission utilities that can properly compute risk will prosper. This is exactly the capability EPRI delivers with its risk-based security assessment tools." ■

Background information for this article was provided by Dejan Sobajic and Nick Abi-Samra, Energy Delivery and Utilization Division.

In the Field

Demonstration and application of EPRI science and technology

Fast-Charging Fleet EVs

Widespread consumer adoption of electric vehicles (EVs) ultimately depends on the successful development of advanced battery technologies that can provide driving range and performance comparable to the capabilities of conventional vehicles. Low-cost, high-performance advanced EV batteries are still years away from commercial maturity, but in the meantime, today's EVs can become dependable fleet-service vehicles when used with new fast-charging systems like one recently evaluated with EPRI support.

The advantages of EVs are well known: zero emissions, low operating and maintenance costs, and the use of electricity as fuel. Such disadvantages as short range and lengthy recharge time, however, limit the vehicles' market appeal—even for fleet applications, in which many utilities have already made significant capital investment. Faster charging can partially offset range limitations. Clearly, an EV that can travel only 50 miles per charge would be more attractive to fleet managers if charging took 15 minutes rather than several hours. Until advanced, affordable EV batteries become available, fast-charging depots based on a patented new sequencing process can help improve the return on investment in fleet EVs.

The new sequencing process makes it possible to connect as many as 16 EVs to a single fast-charging unit. To evaluate such a unit in terms of reliability, ease of operation, user acceptance, and supplemental value in enabling EVs to meet duty-cycle requirements in a fleet environment, EPRI sponsored a six-month study in 1997 using U.S. Electricar–converted S-10 pickup trucks owned by the Salt River Project in Arizona.

Researchers installed a 150-kW Norvik MinitCharger and four sequencer stations and equipped the EV pickups for a charge current of 198 amperes. The trucks regularly performed jobs requiring a return-to-base midmission recharging. During the study, the sequenced fast-charging stations served as the primary chargers. Data were provided by electricity meters installed on the vehicles, by a MinitCharger data acquisition system, and by study participants. Drivers of the fleet EVs also answered questionnaires at the end of the study.

Among the study's findings were that the sequencing process resulted in an average charge time of 17 minutes and enabled the vehicles to undergo multiple charge cycles in a workday. Users quickly learned how to operate the charging equipment. The study also found that carefully sited charging depots are necessary to make fast charging possible for large service areas. And for EVs to succeed in a fleet environment, suitable drivers must be matched with vehicles in appropriate EV applications.

A technical report on the study of fast charging for fleet EVs (TR-109963) is available from the EPRI Distribution Center, (510) 934-4212.

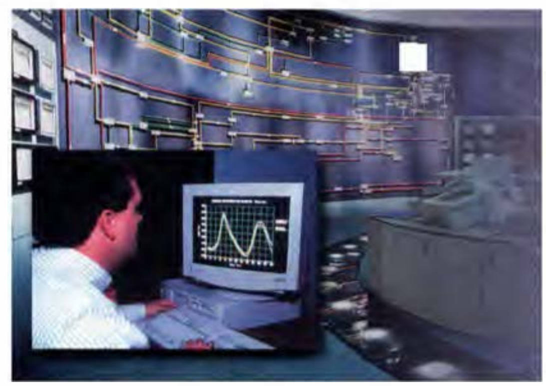
■ *For more information, contact Layla Sandell, (650) 855-2756.*

COURTESY SALT RIVER PROJECT

EVs connected to sequencer stations of a Norvik MinitCharger (behind stations)

Neural Networks for Improved Load Forecasting

Easy-to-use methods for producing accurate short-term load forecasts, which can enhance the reliability and cost-effectiveness of power system operation, are in great demand among electric utilities today. EPRI's Artificial Neural Network Short-Term Load Forecaster (ANNSTLF) links multiple processing units to allow collective performance of a given analysis task, thereby expanding the number of factors that can be considered simultaneously and enabling modeling of complex nonlinear relationships.



ANNSTLF packages neural network technology in a program that can be customized with utility-specific data. The forecaster "trains" itself by examining a utility's past load and such temporal influences as temperature, humidity, and day of the week.

Currently, more than 35 utilities use ANNSTLF as their primary or only short-term load forecasting tool. In a recent survey, 16 utility users reported a variety of reasons for preferring ANNSTLF. For the majority, the most important reason was the program's accuracy. In nearly all cases, ANNSTLF was reported to offer greater accuracy than the utility's former method, typically reducing the mean absolute percentage error (MAPE) by 1–3 points. User data suggest that a 1-point reduction in MAPE can result in savings of up to

$145 per megawatt of peak load. Among the other advantages of ANNSTLF cited were ease of use, computational efficiency, and input error detection.

The users reported two types of economic benefits: ANNSTLF's ease of use produces labor cost savings, and, more important, its accuracy and speed improve decisions that significantly affect operating costs. Most of the cost savings were attributed to improved dispatch decisions and power purchases and higher-margin power sales. For the 16 utility respondents, the annual cost savings ranged from $7600 to $7.6 million.

The respondents were Alabama Electric Cooperative, Allegheny Power, BC Hydro, Buckeye Power, Illinois Power, Kansas City Power & Light, Kentucky Utilities, Madison Gas and Electric, Nevada Power, Northern Indiana Public Service, San Diego Gas & Electric, Salt River Project, Southern Company Services, Tennessee Valley Authority, TU Electric, and Wisconsin Power and Light.
■ *For more information or to obtain ANNSTLF, contact Dominic Maratukulam, (650) 855-7974.*

Cable Remaining-Life Evaluation Yields Savings

Much of the high-pressure fluid-filled (HPFF) cable used by U.S. electric utilities for underground transmission is 20–40 years old. For example, the six HPFF cables at the New York Power Authority's hydroelectric plant on the St. Lawrence River—four 115-kV and two 230-kV cables—were part of the original equipment and have been in service for nearly 40 years. In connection with a program to modernize this 960-MW facility, NYPA is evaluating all components to determine their remaining useful service life and to identify equipment that must be replaced. Secure operation of the cables is critical: a failure of any one means the loss of 25% of the plant's generating capacity.

To support cable remaining-life assessment, NYPA needed timely, research-backed information on the condition of the HPFF cable system—information that would enable the investigators to make a credible recommendation regarding replacement versus continued operation. In early 1997, the power authority, which had supported EPRI research on cable life evaluation and management at the Waltz Mill test facility, requested EPRI's assistance in its St. Lawrence investigation.

By midspring, EPRI investigators were working at the site to obtain a variety of information on the cable system, including physical layout, operating history, operation and maintenance procedures, past diagnostic tests, and system problems. Using this information, they estimated the thermal aging of the cables as a function of conductor temperature and also assessed cable aging associated with mechanical forces. The results of the evaluation were reviewed in conjunction with data from the latest Waltz Mill accelerated cable life testing.

In May 1997, the project investigators reported their findings. They concluded that the St. Lawrence HPFF cable system was in good condition, having operated over its lifetime at or below conductor design temperatures and with very little mechanical stress. Not only was there little justification for cable replacement, they said, but the cables could be expected to operate satisfactorily for at least another 30 years and potentially much longer. The investigators advised NYPA to obtain additional information by conducting fluid dielectric tests on all the cables and accessories during planned outages and to measure the rated voltage dissipation factor for one 115-kV and one 230-kV cable.

By enabling cable replacement to be deferred, EPRI's evaluation and conclusions resulted in one-time avoided-cost savings of about $5.8 million for NYPA. Pleased with the St. Lawrence cable evaluation, the power authority has extended the project with EPRI to include assessment of the HPFF cable systems at its Niagara and Gilboa plants.

The more than 2500 miles of HPFF cable currently installed in the United States represents a significant asset for member companies. The development of a methodology for estimating remaining cable life was part of a broad EPRI research program initiated in 1991 by the owners and operators of HPFF cable systems. The program has been successfully completed, and the results will be documented in a comprehensive technical report to be issued later this year.
■ *For more information, contact Walter Zenger, (650) 855-8943.*

Technical Reports & Software

To order reports, contact the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523; (510) 934-4212. To order software, contact the Electric Power Software Center, 11025 North Torrey Pines Road, La Jolla, CA 92037; (800) 763-3772.

Energy Conversion

State-of-the-Art Weld Repair Technology for High-Temperature and -Pressure Parts, Vol. 7: Weld Repair of Aged Piping—A Literature Review
TR-103592-V7
Target: Boiler Life and Availability Improvement
EPRI Project Manager: V. Viswanathan

Inhibition of IGA/SCC on Alloy 600 Surfaces Exposed to PWR Secondary Water, Vol. 2: Titanium and Cerium Acetate Model Boiler Testing
TR-106212-V2
Target: Nuclear Power
EPRI Project Managers: A. McIlree, T. Gaudreau

Flow-Accelerated Corrosion in Power Plants
TR-106611-R1
Target: Nuclear Power
EPRI Project Manager: B. Chexal

ORAM-SENTINEL™ Development and ORAM™ Integration at Catawba and McGuire
TR-106802
Target: Nuclear Power
EPRI Project Manager: J. Mitman

Improving Maintenance Effectiveness Guidelines: An Evaluation of Plant Preventive and Predictive Maintenance Activities
TR-107042
Target: Nuclear Power
EPRI Project Manager: W. Johnson

Guideline for Reverse Engineering at Nuclear Power Plants
TR-107372
Target: Nuclear Power
EPRI Project Manager: L. Aparicio

Effective Engineering Technical Training at Nuclear Power Plants
TR-107436
Target: Nuclear Power
EPRI Project Manager: L. Loflin

Generic License Renewal Technical Issues Summary
TR-107521
Target: Nuclear Power
EPRI Project Manager: J. Carey

Energy Production Processes in Deuterated Metals, Vol. 1
TR-107843-V1
Target: Nuclear Power
EPRI Project Manager: T. Passell

Environmental Fatigue Evaluations of Representative BWR Components
TR-107943
Target: Nuclear Power
EPRI Project Manager: J. Carey

EPRI LOMI-2 Decontamination Process: Development of an Improved LOMI Process Involving Recycling of Picolinic Acid
TR-108740
Target: Nuclear Power
EPRI Project Manager: C. Wood

Hot Drawing of Hardfacing Alloys
GC-108777
Target: Nuclear Power
EPRI Project Manager: H. Ocken

Fuel Integrity Monitoring and Failure Evaluation Handbook
TR-108779
Target: Nuclear Power
EPRI Project Manager: B. Cheng

PWR Zircaloy Cladding Corrosion Behavior in Peripheral and Interior Rods
TR-108780
Target: Nuclear Power
EPRI Project Manager: B. Cheng

Energy Market Impacts of Electric Industry Restructuring: Understanding Wholesale Power Transmission and Trading
AP-108999
Target: Fuel Supply Management
EPRI Project Manager: J. Platt

Natural Gas Market Regionalization and Implications
TR-109001
Target: Fuel Supply Management
EPRI Project Manager: J. Platt

Blade Life Management System for GE Frame 6B Gas Turbines, Vols. 1 and 2
AP-109196
Target: Combustion Turbine and Combined-Cycle O&M
EPRI Project Manager: R. Frischmuth

Machine Welding Equipment for In Situ Piping Installation and Repairs
TR-109221
Target: Nuclear Power
EPRI Project Manager: V. Viswanathan

On-Line Condenser Fouling Monitor Development
TR-109232
Target: Steam Turbines, Generators, and Balance-of-Plant
EPRI Project Manager: J. Tsou

Improving Existing Fossil-Fired Power Plants: Industry Discussions (Vol. 1, Highlights; Vol. 2, Details)
AP-109342-V1–V2
Target: Steam Turbines, Generators, and Balance-of-Plant
EPRI Project Manager: T. Armor

System and Cost Impact of a Liquid-Processing Test Facility: Assessment of Indian Point-2
TR-109441
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Improved Antimony Removal Using a Chemical Treatment and Microfiltration Process
TR-109443
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Analysis of Advanced Liquid Waste Minimization Techniques at a PWR: Advanced Media, Pleated Filters, and Economic Evaluation Tools
TR-109444
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Heat Stress Management Program for Power Plants: Clothing Update of EPRI NP-4453-L (1991 Report)
TR-109445
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Evaluation of Fish Behavioral Barriers
TR-109483
Target: Hydro Performance Optimization and Asset Management
EPRI Project Manager: C. Sullivan

Heat Rate Improvement Reference Manual
TR-109546
Target: Coal-Fired Boiler Performance Optimization and Combustion NO_x Control
EPRI Project Manager: J. Tsou

Correlative Plant Data Study of Influence of Iron on BWR Activity Transport
TR-109566
Target: Nuclear Power
EPRI Project Manager: P. Frattini

Technical Review of Full-Bed Trials of Low Crosslinked Resins in BWR Plants
TR-109567
Target: Nuclear Power
EPRI Project Manager: P. Frattini

Development of Laser Weld Repair, Cladding, and Heat Treatment Technology for Alloy 600 RPV Penetrations
TR-109919
Target: Nuclear Power
EPRI Project Manager: R. Pathania

Proceedings: Third International Conference on Boiler Tube Failures in Fossil Plants
TR-109938
Target: Boiler Life and Availability Improvement
EPRI Project Manager: B. Dooley

Steam Generator Thermal Performance Degradation Case Studies
TR-110018
Target: Nuclear Power
EPRI Project Manager: G. Srikantiah

Evaluation of Waste Forms for Immobilization of ^{14}C and ^{129}I: Development of Novel Management Scheme for ^{14}C and ^{129}I in Utility LLW Streams
TR-110096
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Phase 2 Development of Procedure Usability Measurement Process (PUMP) Method
TR-110175
Target: Nuclear Power
EPRI Project Manager: J. O'Brien

Distributed Resources Strategic Review: Market Drivers Impacting Future Business Prospects
TR-110245
Target: Distributed Resources for Energy Services and Delivery Enhancement
EPRI Project Manager: D. Herman

Assessment of NO_x Reduction Potential From Combustion Modifications at Illinois Power: Baldwin Unit 1
TR-110498
Target: Coal-Fired Boiler Performance Optimization and Combustion NO_x Control
EPRI Project Manager: D. O'Connor

ORAM-SENTINEL™ Demonstration at Fitzpatrick
TR-110505
Target: Nuclear Power
EPRI Project Manager: J. Mitman

Materials Guidelines for Gasification Plants
TR-110507
Target: Coal Power Systems Development
EPRI Project Manager: W. Bakker

Evaluation of Concrete Containing Fly Ash With High Carbon Content and/or Small Amounts of Wood
TR-110633
Target: Combustion By-Product Use
EPRI Project Manager: D. Golden

Preliminary Evaluation of Factors Leading to Control Rod Insertion Difficulties
TR-110690
Target: Nuclear Power
EPRI Project Manager: O. Ozer

ORAM-SENTINEL™ Demonstration at Sequoyah
TR-110771
Target: Nuclear Power
EPRI Project Manager: J. Mitman

ORAM-SENTINEL™ Demonstration at Watts Bar
TR-110772
Target: Nuclear Power
EPRI Project Manager: J. Mitman

Sodium Chloride Hideout in a Simulated Steam Generator Tube and Tube Support Plate Crevice
TR-110803
Target: Nuclear Power
EPRI Project Manager: P. Millett

Use of High-Carbon Fly Ash as a Component of Raw Mix for Cement Manufacture
TR-110808
Target: Combustion By-Product Use
EPRI Project Manager: D. Golden

Investigation on the Parameters Affecting the De-Icing Salt Scaling Resistance of Fly Ash Concrete
TR-110809
Target: Combustion By-Product Use
EPRI Project Manager: D. Golden

Guideline for Computer-Based Training (CBT) Development, Vol. 2: Applications Database for Utility CBT Products and Services
TR-110965-V2
Target: Simulators, Training, and Production Automation
EPRI Project Manager: M. Perakis

Proceedings: 1998 EPRI Chemical Decontamination Conference
TR-110997
Target: Nuclear Power
EPRI Project Manager: H. Ocken

Opacity Control Guidelines for Oil-Fired Plants
TR-111007
Target: Gas/Oil-Fired Boiler Performance Optimization and Combustion NO_x Control
EPRI Project Managers: T. Facchiano, C. Dene

Preventing Biogas Generation in LowLevel Waste
TR-111019
Target: Nuclear Power
EPRI Project Manager: C. Hornibrook

Calvert Cliffs Nuclear Power Plant License Renewal Application
TR-111031-CD
Target: Nuclear Power
EPRI Project Manager: J. Carey

Axial Compressor Performance Maintenance Guide
TR-111038
Target: Combustion Turbine and Combined Cycle O&M
EPRI Project Manager: R. Frischmuth

Hydro Operational Restrictions Forum: Licensee Workshop Summary
TR-111073
Target: Hydro Performance Optimization and Asset Management
EPRI Project Manager: T. O'Shea

FGD Optimization Workbook
TR-111118
Target: SO_2 and Nonparticulate Opacity Control
EPRI Project Manager: R. Rhudy

chemWORKS™: Primary Shutdown Calculator
Version 1.0 (Windows)
Target: Nuclear Power
EPRI Project Manager: T. Gaudrau

CQIM™ 2.0: Coal Quality Impact Model
Version 2.0 (PC-OS/2)
Target: Coal-Fired Boiler Performance Optimization and Combustion NO_x Control
EPRI Project Manager: D. O'Connor

EPRIdry: Software for Evaluating Spent-Fuel Dry Storage Systems
Version 2.0 (Windows 95)
Target: Nuclear Power
EPRI Project Manager: R. Mahini

Energy Delivery and Utilization

Sparkover Performance and Gap Factors of Air Gaps Below 1 Meter: Analysis of Published Data
TR-106335
Target: Overhead Transmission
EPRI Project Manager: P. Lyons

Disaster Planning and Mitigation Technologies: Interim Technology Inventory Report (Report 2)
TR-108972-V2
Target: Disaster Planning and Mitigation Technologies
EPRI Project Manager: J. Oggerino

Power Quality Diagnostic System: Economic Assessment Module (Final Production Version 1.0.19)
TR-109125
Target: Power Quality
EPRI Project Manager: S. Bhatt

The High-Efficiency Laundry Metering and Marketing Analysis (THELMA) Project, Vol. 4: Distribution Channels
TR-109147-V4
Target: Residential Appliances
EPRI Project Managers: J. Kesselring, R. Gillman

THELMA Project, Vol. 5: Product Demonstrations
TR-109147-V5
Target: Residential Appliances
EPRI Project Managers: J. Kesselring, R. Gillman

THELMA Project, Vol. 6: Product Users—In-Home Interviews
TR-109147-V6
Target: Residential Appliances
EPRI Project Managers: J. Kesselring, R. Gillman

THELMA Project, Vol. 9: Product Users—Further Evaluations
TR-109147-V9
Target: Residential Appliances
EPRI Project Managers: J. Kesselring, R. Gillman

THELMA Project, Vol. 10: Project Synthesis
TR-109147-V10
Target: Residential Appliances
EPRI Project Managers: J. Kesselring, R. Gillman

Vertical Ground Center Heat Exchanger Borehole Grouting: Field Application Studies and In Situ Thermal Performance Testing
TR-109164
Target: Residential Heat Pump Technology
EPRI Project Manager: C. Hiller

Electric Vehicle Fast Charging in Fleet Applications
TR-109963
Target: Infrastructure Deployment and EV Benefits
EPRI Project Manager: L. Sandell

Materials Handling Equipment: Market Analysis (Classes I Through V)
TR-110040
Target: Nonroad Electric Vehicles
EPRI Project Manager: G. Purcell

Distributed Resources Strategic Review: Market Drivers Impacting Future Business Prospects
TR-110245 (see listing under Energy Conversion)

Thermal Performance of Soils and Backfills in Horizontal Ground-Coupled Heat Pump System Applications
TR-110480
Target: Residential Heat Pump Technology
EPRI Project Manager: C. Hiller

Design Testing and Evaluation of an Air Injection Grouting System for Geothermal Bores
TR-110481
Target: Residential Heat Pump Technology
EPRI Project Manager: C. Hiller

Distributed Fiber-Optic Temperature Monitoring and Ampacity Analysis for XLPE Transmission Cables
TR-110630
Target: Underground Transmission
EPRI Project Manager: T. Rodenbaugh

Smart Cards for EV Billing
TR-110692
Target: Infrastructure Deployment and EV Benefits
EPRI Project Manager: L. Sandell

EV Fleet Infrastructure Planning Guide
TR-110702
Target: Infrastructure Deployment and EV Benefits
EPRI Project Manager: L. Sandell

Consumer Benefits of EVs and Plug-In HEVs
TR-110780
Target: Infrastructure Deployment and EV Benefits
EPRI Project Manager: L. Sandell

High-Voltage, Low-Frequency (0.1-Hz) Testing of Power Cables
TR-110813
Target: Underground Infrastructure
EPRI Project Manager: B. Bernstein

Evaluation of Selected Potential Electric Utility Opportunities Associated With Rechargeable Battery Use
TR-110828
Target: Nonroad Electric Vehicles
EPRI Project Manager: G. Purcell

Evaluation of Service-Aged 69- and 115-kV XLPE Cables
TR-110882
Target: Underground Transmission
EPRI Project Manager: W. Zenger

Pharmaceutical Industry Scoping Study
TR-110887
Target: Natural Gas, Petroleum, and Chemicals Industries
EPRI Project Manager: A. Amarnath

Assessment of Extruded 345-kV Cable Technology
TR-110906
Target: Underground Transmission
EPRI Project Manager: W. Zenger

Airport Emissions Quantification: Impacts of Electrification
TR-111000
Target: Airport Solutions
EPRI Project Manager: L. Sandell

Active Harmonic Filter Technology and Market Assessment
TR-111088
Target: End-Use Power Quality Mitigation Systems
EPRI Project Manager: B. Banerjee

■ **Area Investment Strategy Model**
Version 1.01 (Windows)
Target: Distribution System
EPRI Project Manager: S. Chapel

■ **LoadDynamics™: A Model for Developing Probabilistic Forecasts of Load Conditions**
Version 1.0 (Windows)
Target: Distribution System
EPRI Project Manager: S. Chapel

■ **Market Forecasting Workstation**
Version 2.0 (Windows 95/NT)
Target: Producing Successful Product and Service Portfolios
EPRI Project Manager: P. Meagher

■ **PQDS (Power Quality Diagnostic System): Economic Assessment Module**
Version 1.0.19 (Windows)
Target: Power Quality
EPRI Project Manager: S. Bhatt

■ **RBM: Reliability Benchmarking Methodology**
Version 2.0 (Windows)
Target: Power Quality
EPRI Project Manager: A. Sundaram

■ **TIM (Transmission Inspection and Maintenance) System**
Version 2.0 (Windows 95/NT)
Target: Overhead Transmission
EPRI Project Manager: P. Lyons

Environment

In Situ Treatability of Mineral Oil in Soils
TR-108560
Target: MGP Site Remediation and Health Risk
EPRI Project Manager: A. Quinn

Ex Situ Bioremediation of Mineral Oil in Soils: Land Treatment and Composting
TR-108561
Target: MGP Site Remediation and Health Risk
EPRI Project Manager: A. Quinn

Ex Situ Bioremediation of Mineral Oil in Soils: Aerated Pile Treatment
TR-108562
Target: MGP Site Remediation and Health Risk
EPRI Project Manager: A. Quinn

Identification of Arsenic Species in Coal Ash Particles
TR-109002
Target: Air Toxics Health and Risk Assessment
EPRI Project Manager: J. Yager

Material Shielding of Power Frequency Magnetic Fields: Research and Testing Results From the EPRI Power Delivery Center
TR-109550
Target: Electric and Magnetic Fields Management
EPRI Project Manager: F. Young

Estimating Release of Polycyclic Aromatic Hydrocarbons From Coal-Tar-Contaminated Soil at Manufactured Gas Plant Sites
TR-110516
Target: MGP Site Remediation and Health Risk
EPRI Project Manager: I. Murarka

Bed-Sediment Control at Riverside Water Intakes: A Guide for Utility Engineers
TR-110551
Target: Power Plant Water Management
EPRI Project Manager: J. Tsou

Application of the Case-Specular Method to the Los Angeles Study of Wire Codes and Childhood Leukemia
TR-110686 (see listing under Strategic Science and Technology)

Cancer Risk Assessment of Extremely Low Frequency Electric and Magnetic Fields: A Critical Review of Methodology
TR-110721
Target: Electric and Magnetic Fields Health Assessment
EPRI Project Manager: C. Rafferty

Characteristics of Occupational Illness and Injury Databases in Electric Utility Companies
TR-110954 (see listing under Strategic Science and Technology)

EPRICSG

The Retail Market: Business Characteristics, Energy-Use Patterns, and Decision Criteria of the Mass Market Segment
TR-109021-V2
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Buildings With Multiple Businesses and Services: Business Characteristics, Energy-Use Patterns, and Decision Criteria
TR-109207-V2
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Open Market Customer, Vol. 1: Methods and Case Findings
TR-109772-V1
Target: Technology Innovation and 21st Century Strategy
EPRI Project Manager: T. Henneberger

Open Market Customer, Vol. 2: Case Study Assessments
TR-109772-V2
Target: Technology Innovation and 21st Century Strategy
EPRI Project Manager: T. Henneberger

Energy Market Profiles, Vol. 1: 1996 Commercial Buildings, Equipment, and Energy Use
TR-109980-V1
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Energy Market Profiles, Vol. 2: 1996 Residential Buildings, Appliances, and Energy Use
TR-109980-V2
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Energy Market Profiles, Vol. 3: 1996 Industrial Buildings, Equipment, and Energy Use
TR-109980-V3
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Information Management and Business Strategy in Electricity Markets
TR-110305
Target: Technology Innovation and 21st Century Strategy
EPRI Project Manager: T. Henneberger

ReQuest IV™: A Continuing Investigation of the Residential Telecommunications and Electric Marketplaces (Executive Summary)
TR-110816-ES
Target: Understanding Energy Markets
EPRI Project Manager: R. Gillman

Application Opportunities in Wireless Communications
TR-111051
Target: Wireless Applications and Services
EPRI Project Manager: S. Drenker

■ SST: Supermarket Simulation Tool
Version 1.0 (PC-Windows)
Target: Retail Supermarket Establishment Solutions
EPRI Project Manager: M. Khattar

EPRIGEN

Maintenance Work Management Improvement: Improving Culture and Work Process
TR-109734
Target: Plant Maintenance Optimization
EPRI Project Manager: R. Pflasterer

Maintenance Work Management: Best Practices Guidelines—Maintenance Assessment and Improvement
TR-109968
Target: Plant Maintenance Optimization
EPRI Project Manager: R. Pflasterer

Plant Profit Manager 1.0: User's Guide
AP-110376
Target: Generation Asset Management
EPRI Project Managers: D. Gray, D. Rastler

Flexible Midsized Gas Turbine: Preliminary Market Analysis
TR-110860
Target: New Combustion Turbine/Combined-Cycle Design and Risk Mitigation
EPRI Project Manager: A. Cohn

■ PPM: Plant Profit Manager
Version 1.0 (Windows 95/NT)
Target: Generation Asset Management
EPRI Project Manager: D. Gray

Strategic Science and Technology

Machine Welding Equipment for In Situ Piping Installation and Repairs
TR-109221
Program: Strategic Science and Technology
EPRI Project Manager: V. Viswanathan

Proceedings: NDE for Damage Assessment Workshop
TR-110291
Program: Strategic Science and Technology
EPRI Project Manager: V. Viswanathan

High-Temperature Corrosion Research in Progress, 1997, Vols. 1 and 2
TR-110333-V1-V2
Program: Strategic Science and Technology
EPRI Project Manager: J. Stringer

Microwave-Induced Chemical Synthesis Initiative: Strategic Research, 1994–1997
TR-110419
Program: Strategic Science and Technology
EPRI Project Manager: A. Amarnath

Application of the Case-Specular Method to the Los Angeles Study of Wire Codes and Childhood Leukemia
TR-110686
Program: Strategic Science and Technology
EPRI Project Manager: K. Ebi

Corrosion Prevention by Regenerative Biopolymers
TR-110734
Program: Strategic Science and Technology
EPRI Project Manager: B. Syrett

A Review of High-Temperature Performance Trends and Design Rules for Cr-Mo Steel Weldments
TR-110807
Program: Strategic Science and Technology
EPRI Project Manager: V. Viswanathan

Solvent Permeation, Swelling Profiles, and Mechanical Properties of Thin Polymer Films: New Diagnostic Tool for Epoxy and Silicone Insulation
TR-110811
Program: Strategic Science and Technology
EPRI Project Manager: R. Bernstein

A Basis for the Prediction of Insulation Failure in Rotating Machines
TR-110861
Program: Strategic Science and Technology
EPRI Project Manager: J. Stein

Characteristics of Occupational Illness and Injury Databases in Electric Utility Companies
TR-110954
Program: Strategic Science and Technology
EPRI Project Manager: J. Yager

EPRI Events

November

1–4
Annual International Ground-Source Heat Pump Conference
Chicago, Illinois
Contact: Shelly Fitzpatrick, (800) 626-4747

1–4
Power Markets and Resource Management: Making Money in Risky Markets
Washington, D.C.
Contact: Michele Samoulides, (650) 855-2127

2
Business Opportunities for Power Quality Programs
Corpus Christi, Texas
Contact: Marsha Grossman, (650) 855-2899

2–5
Transmission Inspection and Maintenance System Training and Users Group Meeting
Dallas, Texas
Contact: Kathleen Lyons, (650) 855-2656

2–6
Infrared Thermography: Level 2
Long Beach, California
Contact: Esther Blanco, (562) 493-7741

2–6
Supercritical Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

2–13
Ultrasonic Examination Technology
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

3–4
Power Quality Interest Group Meeting
Corpus Christi, Texas
Contact: Marsha Grossman, (650) 855-2899

3–4
Robotics Workshop
Knoxville, Tennessee
Contact: Lynn Stone, (972) 556-6529

3–5
Steam Turbine Performance Monitoring and Diagnostics
Eddystone, Pennsylvania
Contact: Edie McFall, (800) 745-9982

4–5
Lightning Protection Design Workstation 4.1 and 5.0b
Dallas, Texas
Contact: Lynn Stone, (972) 556-6529

4–5
New Product Development
Dallas, Texas
Contact: Lynn Stone, (972) 556-6529

6
Electromagnetic Interference Qualification of Digital Equipment
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

8–11
Fuel Supply Seminar
Cleveland, Ohio
Contact: Megan Boyd, (650) 855-7919

9–11
Decision Analysis for Utility Planning
Tampa, Florida
Contact: Peggy Prater, (650) 855-2951

9–11
PQA '98: Southern Hemisphere
Cape Town, South Africa
Contact: Marsha Grossman, (650) 855-2899

9–13
Simulator Instructor Station Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

9–13
Visual Examination Technology: Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

10–11
Fossil Plant Welding Workshop
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6017

10–12
Introduction to Distributed Control Systems
Kingston, Tennessee
Contact: Eric Toline, (423) 717-2016

11–13
Root-Cause Analysis
Eddystone, Pennsylvania
Contact: Edie McFall, (800) 745-9982

16–17
Containment Inspection: Visual Examination Training, Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

16–18
Advanced Power Quality Workshop
Knoxville, Tennessee
Contact: Martha Powers, (423) 974-8288

16–18
Biodiversity
Savannah, Georgia
Contact: Cindy Layman, (650) 855-8763

16–20
Nondestructive Evaluation (NDE) for Engineers
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

16–20
NDE Instructor Training
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

16–20
Simulator Instructor Techniques
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

17–20
Electricity Book Training and Interest Group Meeting
Atlanta, Georgia
Contact: Peggy Prater, (650) 855-2951

19
One-Day Refresher on Nuclear Utility Procurement
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

19–20
Energy Security Risk Management Forum
Washington, D.C.
Contact: Maureen Barbeau, (650) 855-2474

19–20
Y2K Workshop on Distributed Control System Experience, Natural Gas, and Telecommunications
Orlando, Florida
Contact: Michele Samoulides, (650) 855-2127

30–December 4
Ultrasonic Examination Technology: Level 3
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

30–December 9
Ultrasonic-Testing Operator Training for the Detection of Intergranular Stress Corrosion Cracking (IGSCC)
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

December

1–2
Strategic Connections: Distributed Resources Business Opportunities
Chicago, Illinois
Contact: Sam Braithwaite, (888) 332-8258

1–3
Generator Predictive Maintenance and Refurbishment Conference
Phoenix, Arizona
Contact: Megan Boyd, (650) 855-7919

3–4
Strategic Connections: Knowledge-Driven Competition
Boston, Massachusetts
Contact: Sam Braithwaite, (888) 332-8258

7–9
NDE Technical Skills Training: Level 3 Basic
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

7–9
Power Quality Technical Training
Knoxville, Tennessee
Contact: Karen Forsten, (423) 974-8291

7–10
Advanced Structural Analysis and Design Methods
Haslet, Texas
Contact: Kathleen Lyons, (650) 855-2656

7–11
Combined-Cycle Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

8–10
Root-Cause Analysis
Long Beach, California
Contact: Edie McFall, (800) 745-9982

9–11
NDE Technical Skills Training: Level 3 Specific
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

10–11
CHUG Meeting
Dallas, Texas
Contact: Eryn Schroeder, (650) 855-2259

14–18
Ultrasonic-Testing Operator Training for IGSCC Sizing
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

14–18
Visual Examination Technology: Level 3
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

15–16
Simulator Specification and Procurement Workshop
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

21–23
ASME Section XI Flaw Evaluation
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

January 1999

11–13
Pressure Relief Devices Users Group Meeting
Orlando, Florida
Contact: Linda Suddreth, (704) 547-6061

11–15
Steam Plant Operations for Utility Engineers
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

12–13
EPRI-DARPA Post-Silicon High-Power Electronics
Monterey, California
Contact: Megan Boyd, (650) 855-7919

17–22
4th Y2K Workshop on Embedded-Microprocessor Problems
New Orleans, Louisiana
Contact: Paige Polishook, (650) 855-2010

18–22
Combined-Cycle Operations for Utility Engineers
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

25–29
Drum Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

25–29
NDE of High-Energy Piping
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

February

1–2
Containment Inspection: Visual Examination Training, Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

1–5
Supercritical Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

8–12
Cyclone Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

8–12
NDE Instructor Training
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

15–19
Magne-Blast Circuit Breaker Users Group Meeting
Clearwater Beach, Florida
Contact: Brent Lancaster, (704) 547-6017

16–17
Gas-Electric Partnership Workshops
Houston, Texas
Contact: Dick Schmeal, (713) 963-9307

16–17
Simulator Specification and Procurement Workshop
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

21–24
7th Substation Equipment Diagnostics Conference
New Orleans, Louisiana
Contact: Michele Samoulides, (650) 855-2127

23–25
Simulator Acceptance Test Procedure Workshop
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

24
Water and Energy Conference
Sarasota, Florida
Contact: Kim Shilling, (314) 935-8590

25–26
Municipal Water and Wastewater Program Meeting
Sarasota, Florida
Contact: Kim Shilling, (314) 935-8590

March

1–5
Boiler Operating Theory
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

8–12
Turbine Operating Theory
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

8–12
Visual Examination Technology: Level 1
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

11–12
Workshop on Ground-Penetrating Imaging Radar
Ridgefield, Connecticut
Contact: Andrea Duerr, (650) 855-2719

15–19
Basic Electrical Theory for Power Plants
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

15–26
Ultrasonic Examination Technology: Level 1
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

22–26
Generator Operating Theory
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

29–April 2
Designing, Developing, and Evaluating Training Programs
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

April

5–9
Simulator Instructor Techniques
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

12–14
Power Quality Challenges in the Semiconductor Industry
Tempe, Arizona
Contact: Karen Forsten, (423) 974-8291

12–15
Conference on Power Plant Impacts on Aquatic Resources
Atlanta, Georgia
Contact: Cindy Layman, (650) 855-8763

12–16
NDE for Engineers
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

12–16
Simulator Instructor Station Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

14–16
Forecasting Symposium
Denver, Colorado
Contact: Paige Polishook, (650) 855-2010

20–23
Structured On-the-Job Training Program Design, Development, and Implementation
Kansas City, Missouri
Contact: Cassandra Maslowski, (816) 235-5623

26–28
ASME Section XI Flaw Evaluation
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

May

3–7
Steam Plant Operations for Utility Engineers
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

10–11
Continuous Emissions Monitoring (CEM) Preconference Tutorial
Cincinnati, Ohio
Contact: Michele Samoulides, (650) 855-2127

10–13
Industrial Energy Technology Conference
Houston, Texas
Contact: Sam Woinsky, (713) 963-9336

10–14
Combined-Cycle Operations for Utility Engineers
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

10–21
Ultrasonic Examination Technology: Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

12–14
1999 CEM Users Group Meeting
Cincinnati, Ohio
Contact: Michele Samoulides, (650) 855-2127

17–21
Drum Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

24–27
PQA '99: North America
Charlotte, North Carolina
Contact: Megan Boyd, (650) 855-7919

24–28
Supercritical Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

25–28
Valve Symposium
Lake Tahoe, Nevada
Contact: Linda Suddreth, (704) 547-6061

31–June 4
Cyclone Boiler Unit Operations
Kansas City, Missouri
Contact: Sarah Malinowski, (816) 235-5623

June

2–3
Containment Inspection: Visual Examination Course, Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

7–11
Visual Examination Technology: Level 2
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

12–17
Joint ISA POWID/EPRI Controls and Instrumentation Conference
St. Petersburg, Florida
Contact: Paige Polishook, (650) 855-2010

14–18
ABB Circuit Breaker Users Group Meeting
Charlotte, North Carolina
Contact: Brent Lancaster, (704) 547-6017

14–23
Ultrasonic-Testing Operator Training for the Detection of IGSCC
Charlotte, North Carolina
Contact: Sherryl Stogner, (704) 547-6174

17–18
CHUG Meeting
Portland, Maine
Contact: Eryn Schroeder, (650) 855-2259

21–23
1999 Plant Maintenance Conference
Atlanta, Georgia
Contact: Cindy Layman, (650) 855-8763

22–25
Steam Chemistry: Interaction of Chemical Species
Freiburg, Germany
Contact: Barry Dooley, (650) 855-2458

23–25
5th Piping and Bolting NDE Conference
San Antonio, Texas
Contact: Susan Otto-Rodgers, (704) 547-6072

27–30
Technology Delivery Workshop
San Francisco, California
Contact: Megan Boyd, (650) 855-7919

28
Water and Energy Conference
Vancouver, Canada
Contact: Kim Shilling, (314) 935-8590

29–30
Municipal Water and Wastewater Program Meeting
Vancouver, Canada
Contact: Kim Shilling, (314) 935-8590

EPRI
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