Power Grid Reliability

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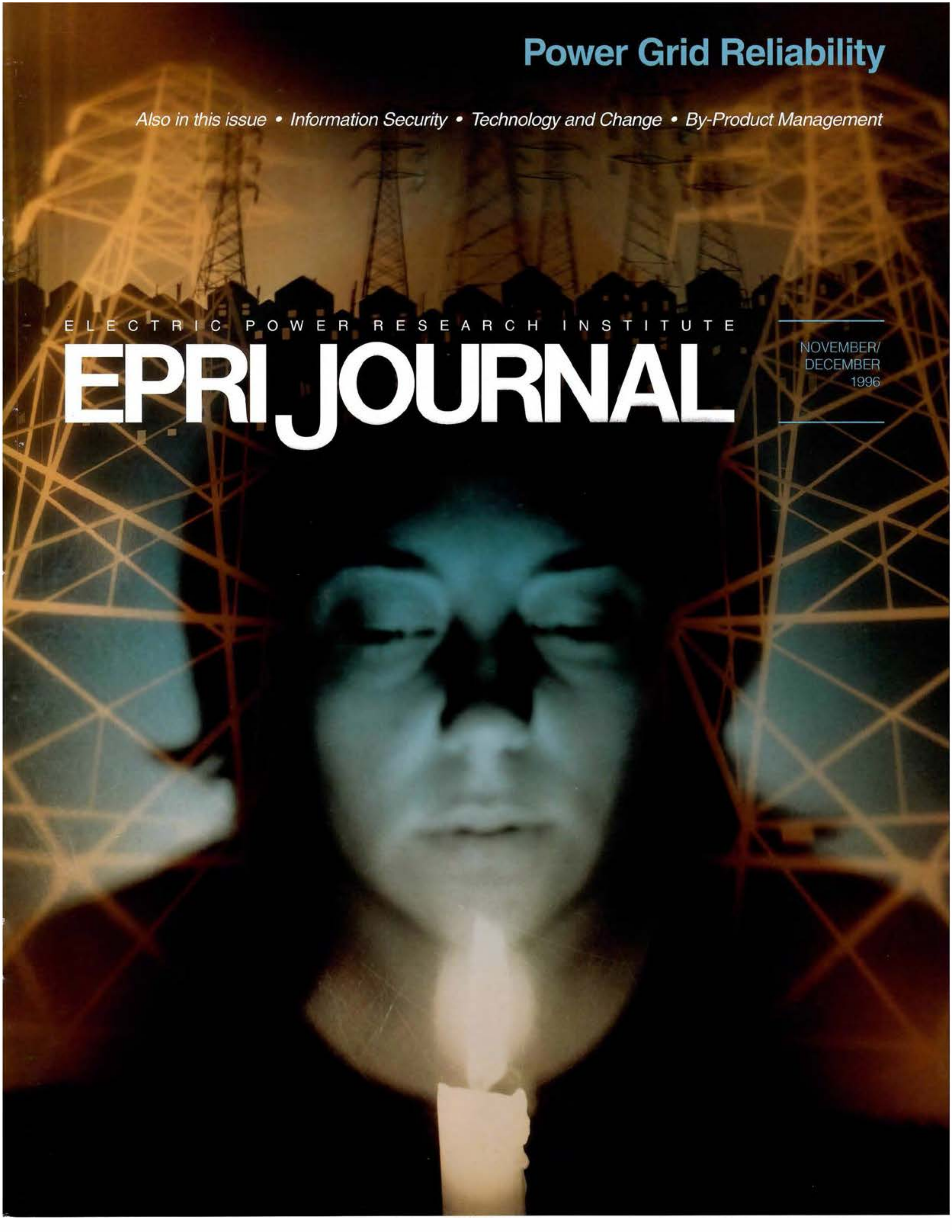

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Cover: This summer's wide-area electricity outages briefly had much of the western United States relying on candle power. (Photograph by Kevin Irby)

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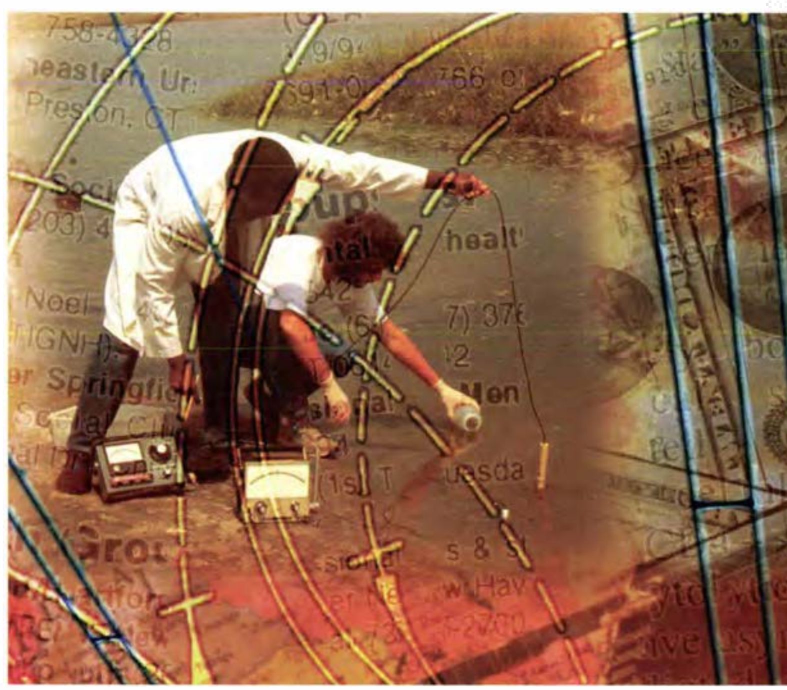


22 Technology and change

Boiler Tube Failure Reference

Boiler tube failure tops the list of availability problems for electric utilities with fossil-fuel-fired power plants. With the release of this three-volume hardcover reference book, *Boiler Tube Failures: Theory and Practice* (TR-105261), EPRI hopes to change that statistic. Poor design, poor operation and maintenance, harsh fireside and cycle chemistry environments, and lack of proper management support are all factors in boiler tube failures. Many failures are repeat occurrences, indicating that root causes are often not well understood. This book brings together the knowledge of the world's leading experts in boiler tube failure, offering comprehensive background information as well as practical details that will enable operating engineers to prevent the problem.

For more information, contact Barry Dooley, (415) 855-2458. To order, call the EPRI Distribution Center, (510) 934-4212.

C-VALU

In their efforts to attract and retain customers in today's competitive business environment, many electric utilities are offering innovative rate options like real-time pricing and time-of-use rates—options that more clearly reflect the true cost of producing electricity. But no matter how much market research has been conducted before such rates are established, it's not always clear how well they will fare among customers.

C-VALU, which stands for customer value, was developed specifically to help provide this needed insight. A user-friendly program with pull-down menus, C-VALU enables utilities to "test-drive" and optimize any number of new pricing designs they are considering. The model simulates the load response of individual customers, indicating how likely they are to prefer a given pricing strategy over their standard electricity rates. Ample data are provided to help users analyze quantitative results.

For more information, contact Connie Smyser, (415) 855-2396. To order, call the Electric Power Software Center, (800) 763-3772.

Horizon Battery

This EPRI-sponsored battery won one of the R&D 100 Awards for 1996, presented by *R&D Magazine* to honor the year's most outstanding products from around the world. Developed by Electrosource with support from EPRI and several individual electric utilities, the Horizon advanced lead-acid battery is among the most promising systems available for electric vehicle applications. Based on a patented design, the battery is lightweight and maintenance-free and offers greater acceleration per unit of weight than any other EV battery in production. The Horizon has a range of more than 100 miles between charges—up to twice that of competing lead-acid batteries. Recharging is quick, taking only one hour for a full charge or half an hour for an 80% charge. Because the battery is modular, it can be configured for use in other zero-emission devices, such as cordless lawn mowers, scooters, lift trucks, golf carts, and power tools. (Another EPRI-sponsored product, STATCOM, also won an R&D 100 Award this year. It is described in the Products department of the May/June 1996 *Journal*.)

For more information about the Horizon battery, contact Jack Guy, (415) 855-2803.
To order, call Electrosource, (512) 753-6500.

Sales Guides

Intensifying competition in the electricity market means utilities must hone their sales and marketing skills in order to prosper. EPRI designed these two easy-to-read handbooks specifically to help with this challenge. *Decision-Making Styles of Business and Industry* (TR-106298) gives utilities insights for better understanding their customers so that sales strategies can be appropriately targeted. The guide describes five common styles that characterize organizations and offers techniques to help utility sales representatives respond to the styles they encounter. The companion report, *Selling Value: How to Build Loyalty With Your Key Customers* (TR-106281), provides tools—such as the double-loop interviewing method and nine customer needs profiles—that will enable utilities to effectively plan and execute customer-focused sales calls. Readers will learn how to custom-design marketing strategies on the basis of customers' needs.

For more information, contact Thom Henneberger, (415) 855-2885.
To order, call the EPRI Distribution Center, (510) 934-4212.

EPRI Brings DSM Expertise to Pacific Rim

In the last five years, the annual demand for electricity in Thailand has grown an average of 12%—more than six times the annual growth rate in the United States. According to the Electricity Generating Authority of Thailand (EGAT), the country will need 12,000 MW more generating capacity over the next decade—at a capital cost of about $35 billion. This estimate assumes the installation of lignite-fired units without pollution controls for sulfur dioxide, a technology that would add at least 25% to the capital cost.

In a country already beset by both air quality and economic concerns, the Thai government believes there's a better way. In 1991, Thailand became the first Asian country to adopt a comprehensive demand-side management (DSM) plan for the power sector. The goal is to save 311 MW of peak power by 1998.

Employed for years by U.S. power companies to manage electricity demand in order to ensure more-efficient power supply use, DSM practices have only recently been discovered by Asian Pacific countries. DSM experts believe they could help relieve some of the region's growing pains. Thailand is just one example of a rapidly expanding Asian economy that is adding new fossil-fired power plants to meet growing demand. Others include China, Malaysia, Indonesia, Korea, and the Philippines. Through its involvement with the Inter-Utility Demand-Side Management Liaison Group, EPRI is providing the knowledge and expertise to help electric utilities in the Pacific Rim region deploy DSM techniques. The international liaison group was established as part of the 18-country Asia Pacific Economic Cooperation (APEC) effort initiated by President Clinton to address balance-of-trade and other issues among the countries—ranging from Papua New Guinea to the United States—that border the Pacific Ocean. Grayson Heffner, one of EPRI's DSM experts, currently serves as vice chairman of the liaison group.

Among other activities, the group has produced a DSM guidebook specifically geared toward Asian Pacific economies. Based on a 1993 EPRI report (*Principles and Practice of Demand-Side Management;* TR-102556), the recently released APEC report offers a step-by-step overview of the DSM process—from planning and program design to implementation evaluation. Also included are case studies of DSM efforts in various Asian Pacific countries, including Thailand.

To reach its 311-MW goal, the Thai government is spending $189 million—less than half the cost of the equivalent in power generating capacity—on DSM measures. These include an energy conservation promotion act that provides grants and low-interest loans for energy efficiency and renewable energy projects and establishes efficiency standards for large buildings and factories. Other strategies include an import tax reduction of 50% for any energy-efficiency equipment and for raw materials used in making energy-efficient products.

As Heffner points out, not only is DSM a less expensive way for countries like Thailand to meet their energy needs, but it can also reduce the amount of power plant fuel the countries have to import and can help relieve air quality problems. He says that implementing DSM practices in Asian Pacific countries now—as the move toward privatization gains momentum—is particularly important. "The concern is that because energy efficiency lacks an institutional home, it could just disappear with the advent of privatization," he says. "But if these countries adopt sound DSM practices now, demand-side management will find a place—perhaps as a value-added service to utility customers."

In other DSM efforts resulting from the APEC liaison group, EPRI has been hired as a consultant to evaluate ongoing DSM programs in various APEC countries. So far, Heffner has completed DSM evaluations for Korea Electric Power, China Light & Power, and Hong Kong Electric.

■ *For more information, contact Grayson Heffner, (202) 293-6340.*

Spanish Utility Funds Fossil Power Plant Research

With a national commission looking into industry deregulation and with looming competitive pressures to make fossil power plants more productive, Spain's electric utilities are facing a future not unlike that confronting many U.S. utilities with major investments in fossil generating assets. In both countries, cost reduction and life extension technologies are growing priorities. Moreover, several older Spanish fossil power plants will be converted to burn gas following the completion of a major pipeline from Algeria, part of a nationwide commitment by Spain's utilities to obtain as much as 12% of electricity generation from gas by 2000.

As a result of discussions at an international seminar in Bilbao in 1995, at which Tony Armor, director of EPRI's Fossil Power Plants Business Unit, delivered a keynote address, Spain's largest investor-owned utility—Iberdrola—is cofunding EPRI fossil plant maintenance, life optimization, and asset management targets. Formed by the 1992 merger of Hidroeléctrica Española and Iberduero, Iberdrola generates the electricity for about 41% of Spain's population and accounts for 27% of total domestic production. Iberdrola's 17,000 MW of generating capacity includes 5000 MW fired with fossil fuels.

Armor, Michele Blanco of his staff, and Ed Gray of the Generation Group business staff met with senior Iberdrola executives in Madrid for two days last June and developed a focused list of the utility's top priorities for collaboration. "Iberdrola is very interested in applying new methods and approaches for conducting power plant maintenance in a more competitive environment," says Blanco. One area of anticipated focus that could lead to a project startup early next year involves the adaptation of an important EPRI product to Iberdrola's plants: the Boiler Maintenance Workstation.

An Iberdrola fossil-fired plant

Other EPRI products expected to be of immediate use to Iberdrola include boiler and turbine-generator condition assessment and life extension guidelines. Predictive and reliability-centered maintenance approaches developed by EPRI will also be used by Iberdrola.

Technology will also flow in the other direction. It is anticipated that at its fossil plants Iberdrola will evaluate for EPRI a European-developed nondestructive evaluation technique for detecting flow-assisted corrosion in plant piping. And Blanco notes another area of interest to EPRI: "Iberdrola has world-class experience with laying up fossil plants for swift return to service if needed. The utility will be writing guidelines for plant layup that could prove valuable to U.S. utilities as they reserve some generating assets for strategic competition."

The Fossil Power Plants Business Unit's relationship with the Spanish utility builds on and extends a cooperative relationship with EPRI's Nuclear Power Group that goes back several years. Additional partnerships and collaborative activities are possible as the cofunding relationship with Iberdrola evolves.

■ *For more information, contact Michele Blanco, (415) 855-8705.*

Finnish Utility's Turbine Alignment System a Success at TVA

Utilities are under increasing competitive pressure to operate fossil generating plants at higher capacity factors while minimizing operating and maintenance costs. As a result, many utilities are trying new technologies for active or on-line condition monitoring to diagnose and analyze incipient problems in operating equipment before they can lead to (or lengthen) costly outages.

Recently, in a collaborative effort with EPRI, the Tennessee Valley Authority became the first U.S. utility to demonstrate the laser-based Turbine Diagnostics and Analysis System (T-DAS), developed by the Finnish utility Imatran Voima Oy (IVO). T-DAS is a portable, easy-to-install, on-line system for diagnosing and quickly correcting misalignment of turbine-generator sets. Misalignment can result from thermal expansion when turbine-generators are started from a cold shutdown following a maintenance outage.

Already used at 60 locations around the world, T-DAS is being commercially introduced here by IVO, Finland's leading utility in the international energy business. TVA and EPRI cooperated with IVO in optimizing T-DAS for several demonstration applications. In the first, TVA used the system to verify high-pressure-turbine alignment at its coal-fired Paradise plant in Kentucky. By shaving one day from a planned maintenance outage there, T-DAS paid for itself more than twice over. It is expected to provide considerable additional savings in replacement energy costs by reducing downtime at TVA plants over the next several years.

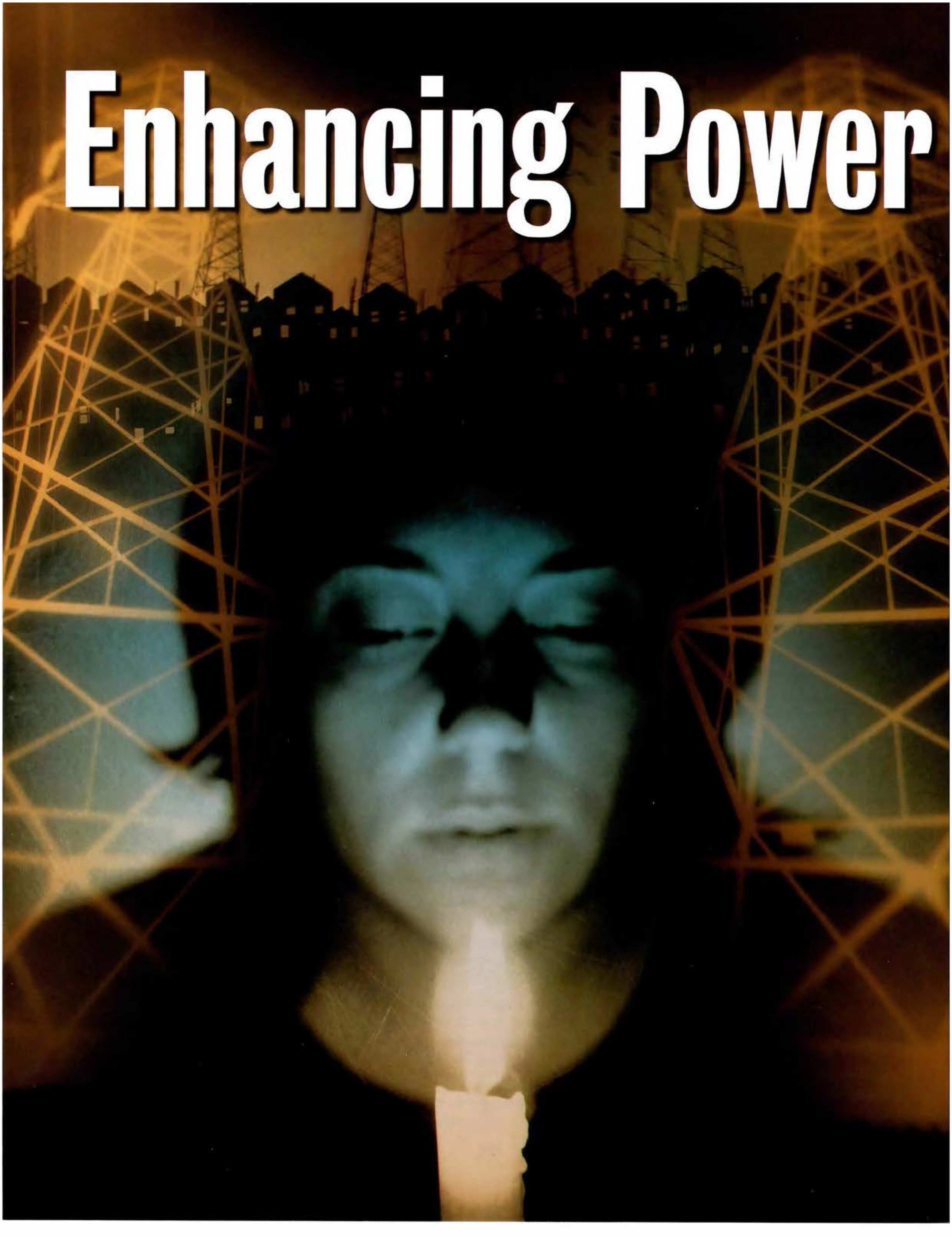
"Using T-DAS together with vibration analysis, a utility can quickly observe the effects of misalignment on dynamic loads at the turbine bearings," says Tom McCloskey, EPRI's manager for turbomachinery. In a typical application, visible-laser units are placed on tripods on the turbine-hall floor beyond the turbine foundation's expansion joint. Laser beams are directed toward charge-coupled device (CCD) sensors mounted by magnets onto the turbine-generator bearing pedestals or standards. To monitor the on-line dynamic movement of a series of steam turbines and a generator, T-DAS can accommodate up to 8 lasers and 16 CCD sensors. For root-cause problem diagnosis, up to 16 process signals and 8 three-dimensional vibrations are monitored simultaneously.

TVA is using the system for alignment quality control before and after turbine-generator overhauls and for diagnostic troubleshooting. For purposes of quality control, turbine behavior is analyzed during the first startup for comparison with subsequent measurements before and after maintenance. TVA says T-DAS should help it plan maintenance overhauls better and extend the time between them.

IVO's U.S. representative for T-DAS, Tapani Karhinen, can be reached at (210) 522-6585.

■ *For more information, contact Tom McCloskey, (415) 855-2655.*

Enhancing Power



Grid Reliability

The Story in Brief **The power outages that hit the western third of the United States and parts of Canada this past summer refocused attention on the reliability of our nation's interconnected power grid. Previously thought by many to be rock solid, the power grid is now being viewed as a system under increasing strain from a power transaction market that will continue to grow as a result of industry deregulation. While institutional changes like the mandating of operating practices will almost certainly enhance system reliability, technological advances, some of which are now being implemented, promise a major improvement as well. EPRI is developing a range of technology-based solutions, including information-gathering systems, better analysis tools for power dispatchers, and more effective devices for power system control and operation.**

KEVIN IRBY

by Steve Hoffman

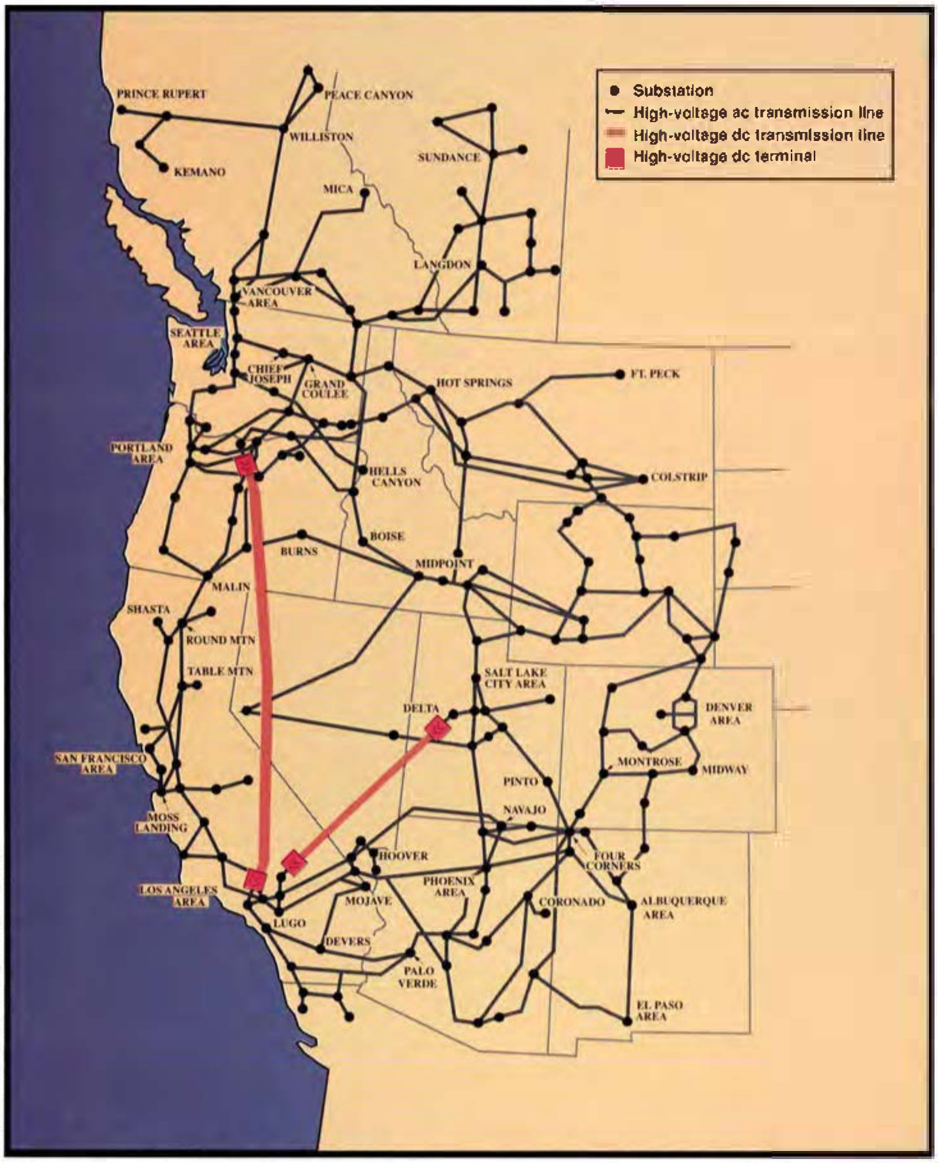
On August 10, 1996, a transmission line near the Columbia River in Oregon sagged into a tree and shorted out. While not a common occurrence, the loss of the line was not seen as a cause for concern, since other lines in the area automatically picked up the load. But this particular short circuit had greater significance. It was the first in a chain of events that resulted in the second largest power outage in U.S. history—a disturbance that covered a vast territory of 1.8 million square miles in 14 states and 2 Canadian provinces.

The causes of the outage that day are now coming into focus. Record heat, high energy consumption, and large power transfers led to line sags, power system oscillations, and a collapse of voltage in the Pacific Northwest. The result was the opening of the Pacific Interties—the main north-south arteries of power transmission along the West Coast—and a sequence of transmission line trips that split the western grid into four parts. Like its cousin, the less severe July 2, 1996, outage originating in Idaho, the August 10 disruption is becoming one of the most analyzed events in electric power's 114-year history (see sidebar, page 10).

But less important than the specifics of that day are the outage's ramifications. The August 10 event has caused many to ask what the industry is doing to improve power grid reliability. "Clearly, no one solution will ensure reliability of the electricity grid," says EPRI's Karl Stahlkopf, vice president for power delivery. "A multidimensional strategy of both institutional and technological solutions is needed."

Organizations like the North American Electric Reliability Council (NERC) will address institutional issues—for example, mandating more communication between utility system operators. Technological solutions are the province of EPRI, the only major collaborative R&D organization currently conducting power grid research in the United States. Some R&D projects under way at the Institute long before the 1996 outages are now beginning to bear fruit, and others promise a near-term impact.

In energy control centers, on transmission lines, and in substations, utilities and power pools are beginning to deploy EPRI technologies to enhance grid reliability. These technologies include devices that increase grid capabilities, software that provides timely, more detailed information to operators, and expanded data measurement and communication techniques. But understanding how these technologies work together to enhance reliability requires a closer look at the interconnected power grid and the stresses being placed on it.



JOHN HALER/PACIFIC NORTHWEST NATIONAL LABORATORY

INCREASING STRESS ON THE GRID **The complex, interconnected web of transmission lines, power plants, and other power system components that compose the North American power grid has been called the largest machine ever created. Given the growing number of power transactions, each of which must be carried over the grid, the reliability of that machine is being severely tested. The western portion of the grid (shown here) was the site of two widespread outages last summer.**

Stressing the grid

The North American power grid is made up of four distinct interconnections—western, eastern, Texas, and Quebec. Each interconnection is a complex integrated web of transmission lines and power plants, with hundreds of thousands of relays, controls, and other components. Although this grid has been running smoothly, it is not impervious to increasing stresses from a variety of sources.

The limited construction of new transmission lines is one factor in the increased stress on the grid. Over the past decade, electrical loads have grown at an average annual rate of 2%. Yet in the same period, little new transmission capacity has been installed, largely because of the high cost of such lines (about $1 million per mile for a 500-kV line) and the difficulty in obtaining new rights-of-way. "No one wants new construction in their backyard, a problem that affects the construction not only of power delivery equipment but also of freeways, dams, and airports," says Stahlkopf. "The result is that the existing transmission system is being called upon to perform functions on a scale for which it was not originally designed."

While not a direct cause of the western outages, the transition to competitive electricity markets is expected to place further stress on the transmission network. The desire to obtain the lowest-cost generation leads to an increase in the number of power transactions, all of which are carried over the transmission grid. By virtue of the interconnected nature of the grid, low-cost power generated in one area can be used to meet load in another area. Thus, for example, in the Western Systems Coordinating Council (WSCC) region of NERC, where this year's outages occurred, seasonal power transfers are common. In the summer, low-cost hydroelectric power generated with

WIDE-AREA OUTAGES UNCOMMON **The majority (approximately 90%) of customer outages in the United States stem from problems with distribution system equipment, the primary cause being weather-related damage. A downed distribution line or a fault on a pole-mounted transformer, for example, could cause a neighborhood outage. A substation transformer failure could affect a section of a town and many hundreds of customers. Last summer's wide-area outages, in contrast, resulted from problems on the high-voltage transmission grid and propagated across a multistate area via the interconnected power grid, affecting millions of customers. While outages due to transmission failures typically may occur 15–20 times a year, an outage of the magnitude seen last July 2 and August 10 is very unusual. The last event of that magnitude, the great New England blackout, was in November 1965.**

Clerk figures sales receipts on paper bag.

Family reads by flashlight.

PHOTOGRAPHS BY MERI SIMON/SAN JOSE MERCURY NEWS

Loss of stoplight causes traffic backup.

water from snowmelt in the Pacific Northwest can be sold to highly populated areas on the West Coast. Conversely, in winter, when the runoff ceases, relatively low cost power from nuclear plants in California can be sold to meet electricity needs in the Northwest.

This ability to transfer power is one of the advantages of the interconnected design of the grid. The design also inherently affords redundancy of power generation and transmission capability. The downside is that when serious problems develop in one part of the network, their effects can be felt at points far away from the initial disturbance.

A need for information

Technological solutions can help the interconnected grid operate reliably in the face of these stresses. Given the difficulty of constructing new transmission lines, these technologies must enable better use of the equipment that is now in place. To effectively implement this option, the industry must make smarter use of existing assets and add devices that extend the capability of existing equipment.

But to accomplish these tasks, operators will need more timely and more useful information than they have today. Operators now have periodic access to only basic information on the state of the power system in their own service area—voltages, currents, and on-off status of equipment—and have almost no real-time data on neighboring utility power systems. In past decades, the amount and type of information available has been sufficient for an operator to reliably run the power system in the utility's area.

All this is changing. The forces stressing the transmission network necessitate the routine operation of the power grid closer to its limits. Against this backdrop, operators must contend with disturbances that can lead to instability in just seconds, as occurred on July 2. What's more, the interconnected nature of the grid means that events hundreds of miles outside a utility's service territory can have an impact on its system. To operate power systems reliably, dispatchers need more detailed information about conditions on their own system, as well as on neighboring systems.

This calls for an upgraded infrastructure of data measurement, integration, processing, interpretation, and communication over the entire North American power grid. As daunting as this task sounds, one key aspect—the way the data will be communicated and the data "language" to be used—has already been determined by in-

The Dominoes Fall on August 10

WEINBERG & CLARK

SEVERAL KEY CONDITIONS set the stage for the August 10, 1996, power outage, such as record heat in the West and Pacific Northwest and record energy consumption throughout the region. These conditions, combined with an abundant supply of water behind dams throughout the Northwest, led to heavy transfers of low-cost power from hydroelectric plants in that area to California. Early in the afternoon, the California-Oregon Pacific AC Intertie was loaded to 4350 MW (its limit is 4800), while the Pacific DC Intertie carried 2850 MW (its limit is 3100). Such power transfers that late in the hydroelectric generation season were highly unusual. At the same time, other transmission lines were heavily loaded with other power transfers, including 1000 MW from Montana to the Northwest. Output at the Dalles hydroelectric plant on the Columbia River was severely restricted to allow water flow for fall chinook salmon, and the Keeler 500/230-kV transformer in Portland was out for modifications, restricting voltage support from the Keeler static VAR compensator.

At 2:06 p.m. (Pacific daylight time), the Big Eddy–Ostrander 500-kV transmission line from The Dalles, Oregon, to East Portland sagged into a tree and relayed out. Forty-six minutes later, another 500-kV line, running from the John Day Dam to Salem, Oregon, sagged into a tree. Using the tools and information available to them, Bonneville Power Administration operators did not identify a threat to the power system and hence, following standard procedures, did not attempt to return the lines to service, alert neighboring utilities, or take any other action. However, subsequent detailed analysis has made it clear that at that point, the system was already straining to maintain voltage at acceptable levels; the lines that relayed out were crucial to voltage support.

The next significant event was the loss, at 3:42 p.m., of the 500-kV Keeler-Allston line, which was carrying 1300 MW when it sagged into a tree. As voltage fell, current increased; within minutes, another line overloaded, and the dominoes began to fall. The McNary plant generators, subjected to overexcitation, automatically tripped off as a protection against damage, and their contribution to system generation fell by 860 MW in 73 seconds. Then, unexplained grid power system oscillations began in which voltage and power transfers fluctuated wildly. As two parts of the system fought each other, power transfers fluctuated by ±1000 MW and ±60 kV. Within minutes, several more lines tripped on low voltage and both the Pacific AC and DC Interties opened (no longer carried power).

With the loss of so many lines, power could no longer be transferred from one part of the western United States to another, and the 14 western states and 2 provinces in Canada broke into four islands. Ordinarily, such system separation is orchestrated so that each island has approximately enough generation to meet its load. But since the scheme designed to trip certain relays and create these optimal islands was out of service, suboptimal islands formed. In a valiant effort, Alberta, Canada, hung on as long as possible in an attempt to bolster system voltage, but its system's protective equipment finally succumbed to the huge inertia of the Western Interconnection, forming an island.

Massive outages prevailed throughout the western United States and Canada for several hours. In the southern island, Southern California Edison alone lost 1.8 million customers. But the hardest hit island was northern California, where 10,000 MW of load was shed (turned off), representing roughly one-half of Pacific Gas and Electric Company's load. Connections to the Northwest and southern California were reestablished in about three hours, and 90% of PG&E's load was restored by 9:00 p.m. (nearly all by 11:00 p.m.). In all, the August 10 outage affected 4 million customers across one-third of the geographic area of the United States and parts of Canada.

While the costs of the August 10 outage have not been quantified, widespread outages clearly create enormous losses of business and industrial productivity. In fact, transmission and distribution power outages cost U.S. business an estimated $29 billion annually in lost productivity. And interim measures, like those temporarily adopted this year while the outage was studied, come at a price. For example, the restriction of power transfers across the Pacific AC Intertie to 67% of the previous limits as a precaution is costing millions of dollars in higher power generation costs, as some utilities are forced to run expensive peaking units much more than usual. □

ternational agreement. A team of utilities and control room equipment vendors led by EPRI has developed the international standard TASE.2 (known in America as the Inter–Control Center Communications Protocol, or ICCP), which provides an affordable common way to communicate between utility control centers.

The real-time exchange of information between control centers on such variables as line flows, transformer tap positions, and the on-off status of breakers allows operators to take actions that can go a long way toward minimizing the scope and impact of outages. All major vendors of energy management systems—the packages of operating software and hardware used in control centers—are offering ICCP products, and more than 100 utilities and power pools are now shifting their systems to ICCP use.

Wide-area measurement

Establishing the data communications protocol was just the beginning. The Bonneville Power Administration (BPA) and the Western Area Power Administration (WAPA), along with other utilities, have undertaken a sizable portion of the remaining data infrastructure task and are implementing a dynamic information backbone for the western power system. These two large federally owned utilities have been working with the U.S. Department of Energy, the U.S. Bureau of Reclamation, other WSCC utilities, two national laboratories, EPRI, and others in a DOE-EPRI project called the Wide Area Measurement System (WAMS).

Originally called the Western System Dynamic Information Network, or WesDINet, WAMS is designed to be a network of networks, featuring advanced products for data servicing and work-team communications. One such product is BPA's portable power system monitor (PPSM)—a building block and interactive workstation for wide-area monitoring networks. A second element is Macrodyne's phasor measurement unit (PMU), which is capable of precise measurement of voltages and phase angles (important parameters for stability analysis).

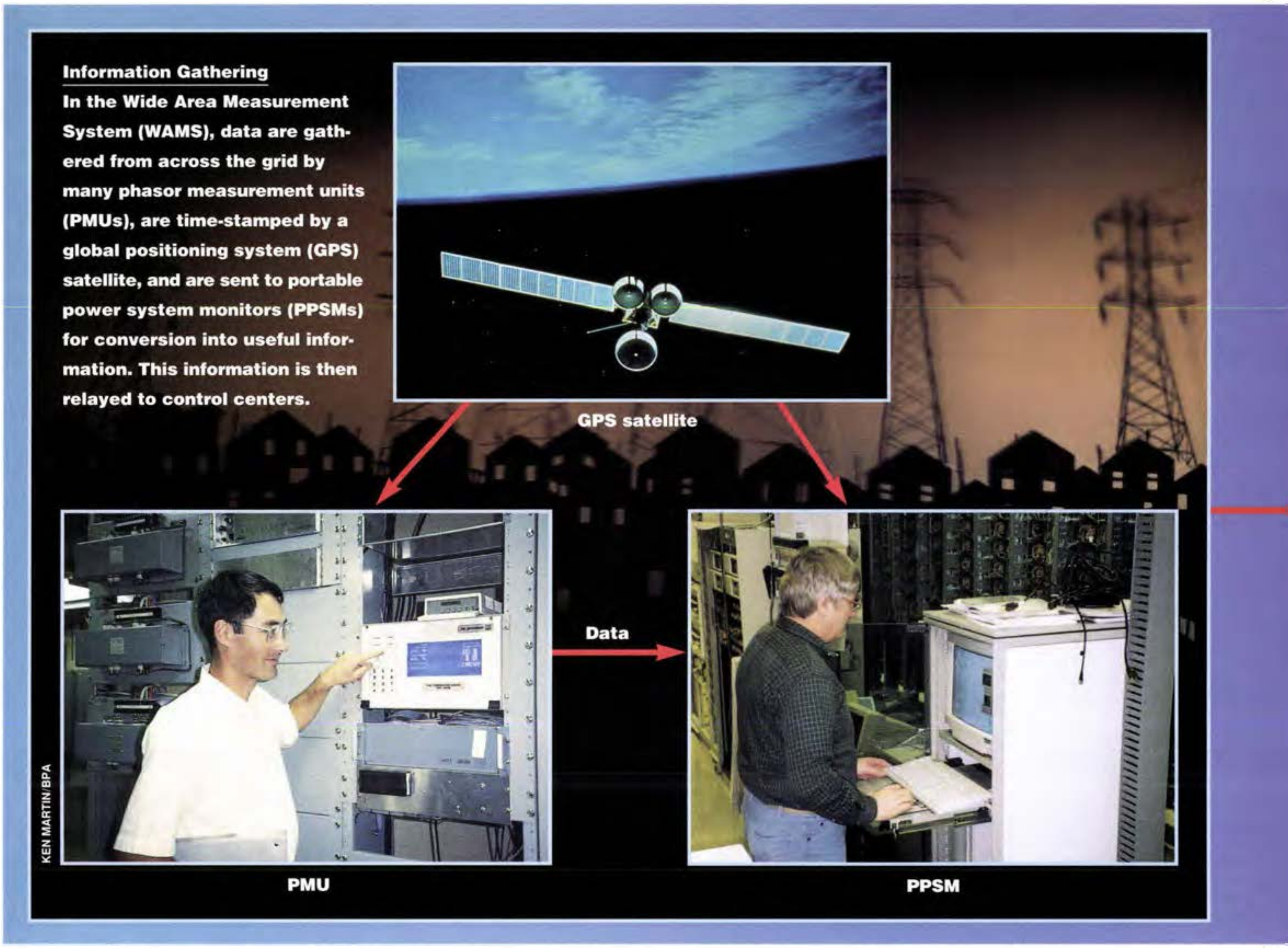
At critical locations on the power system, WAMS participants are deploying PPSMs and PMUs in pairs. Both units can be time-calibrated via a global positioning system satellite link so that each data point can be stamped within 1 microsecond of its collection. Each PPSM archives, displays, and routes PMU data, as well as data from other instruments like analog transducers and digital fault recorders.

A major step in the transition from analog measurement technology to digital technology on power systems, WAMS provides better data at higher sampling rates. Most analog instruments respond too slowly to provide additional information at rates above 10 samples per second. By comparison, PMUs yield useful data at up to 30 samples per second, and PPSMs can collect sensor data at rates of up to 5000 samples per second. These high data rates provide system engineers with a much sharper view of the performance of power electronics equipment.

Another advantage of the high data rates is longer integrated recordings of multiple parameters—like those provided by aircraft flight recorders. A PPSM at BPA's Dittmer control center, for example, collects and archives 96 channels of data for two weeks. These integrated recordings are very useful for deciphering power system failures.

"Once data are converted to useful information, the real fun begins," explains EPRI project manager Dejan Sobajic. "Then, operators, planners, maintenance personnel, and others can take beneficial actions." For example, control center information tools could continually assess the arriving data streams and make recommendations to operators for both preventive actions, aimed at avoiding an outage, and corrective actions, aimed at minimizing an outage's impact and severity.

WAMS now comprises about 20 operating PPSMs and PMUs at utilities throughout the western United States. Applications include central monitoring and a variety of local uses, such as modeling generator response and scheduling generator maintenance. However, the direct application of WAMS to wide-area control is not yet a re-



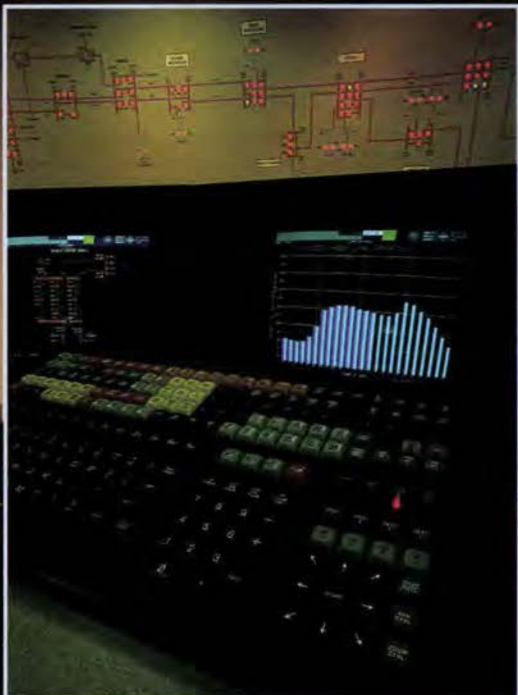
Information Gathering
In the Wide Area Measurement System (WAMS), data are gathered from across the grid by many phasor measurement units (PMUs), are time-stamped by a global positioning system (GPS) satellite, and are sent to portable power system monitors (PPSMs) for conversion into useful information. This information is then relayed to control centers.

COMPLEMENTARY TECHNOLOGIES TO ENHANCE RELIABILITY **Several key systems and technologies, already commercially available or now emerging, will fit together to enhance the way power system operators work. In utility control centers across North America, operators will receive more timely and more useful information on the operation of their power systems. They will input these data into various analysis tools to identify ways of improving operation. After deciding what actions to take, the operators will use advanced controllers to carry out the actions on the power systems.**

ality. While PPSM recordings helped unravel the detailed chain of events and causes of last summer's outages, WAMS is not far enough along in development to perform the automatic control actions needed to prevent or mitigate such outages. Still, information derived from WAMS could be used to develop wide-area control functions as early as 1998.

One of the appeals of WAMS is its almost limitless applications. Beyond using the gathered information to enhance reliability via control and operation, WAMS can assist with operational planning tasks, such as next-day planning for optimal operation, and power system equipment maintenance tasks. This latter activity has an important link to power grid reliability because even well-operated power systems will become unreliable if improperly maintained. Equipment outage data from WAMS can be used in maintenance optimization programs, such as reliability-centered maintenance (RCM). Developed in the nuclear power and commercial aircraft industries, RCM uses a statistical method to determine optimal maintenance intervals, enabling equipment owners to perform maintenance cost-effectively—on the right component at the right time. EPRI has already demonstrated that the application of RCM can reduce substation maintenance costs by 25% while increasing reliability (see "The Maintenance Revolution," *EPRI Journal*, May/June 1995). The availability of WAMS data is expected to make RCM even more effective.

EPRI's Power Delivery Group and Strategic R&D joined the WAMS project over a year ago and are funding a wide range of efforts to speed its implementation. With BPA and Pacific Northwest National Laboratory, EPRI is developing a full-scale WAMS test plan. Initially used for testing in connection with the BPA-WAPA implementation, the plan will serve as a model for later tests in other regions of the country. EPRI is funding testing that will demonstrate the PPSM's ability to monitor such



Analysis and Decision Making
In the control center, analysis tools like EPRI's on-line software for voltage security assessment will advise operators on preventive and corrective actions. The operators will use this information to make operating decisions.

Taking Action
The operators' decisions will be implemented on their power systems by a family of advanced power electronics controllers called FACTS devices, which will support voltage and divert power flow in optimal directions.

signals as generator reactive power—an important indicator of voltage stability margin. "By sponsoring workshops and documenting industry findings," says EPRI's Gail McCarthy, director of Strategic R&D, "we're also disseminating information on WAMS technology and encouraging the sharing of experience to accelerate its development."

In a related EPRI effort, several WSCC utilities have installed PMUs and will soon begin sending voltage and phase angle data to one end of the Pacific DC Intertie, the Sylmar converter station. These data will most likely be accessed there through local PPSM facilities for integration and distribution on the PPSM network. "Interarea modes of oscillation," says EPRI project manager Rambabu Adapa, "are a significant threat to wide-area power security and reliability. Collecting these data at Sylmar may allow us to damp these oscillations by modulating control of the intertie." EPRI expects to throw the switch on these PMU additions, in collaboration with the participating utilities, by the end of 1996.

"Sharing data across utility service area boundaries," says Stahlkopf, "supplies the wide-area view of the system that operators need to enhance the reliability and economy of system operation." Wide-area measurement paves the way for wide-area control, with consequent improvements in grid reliability.

Going on-line

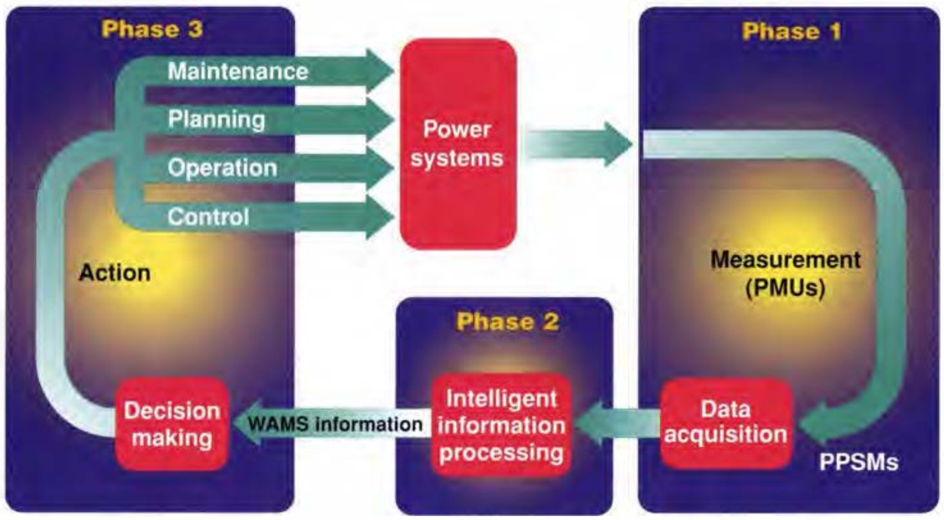
An early application of WAMS information will be to ensure voltage security and dynamic security on the power system. Voltage security involves maintaining voltage at an acceptable level systemwide and avoiding voltage collapse. Dynamic security addresses the problem of operating closer to the system's stability limits—the highest level at which it can operate in stable fashion—without jeopardizing reliability. On-line systems in the control center that continually take in power system data and update system evaluations can accomplish both of these tasks effectively.

Two on-line EPRI software packages, VSA (Voltage Security Assessment) and DSA (Dynamic Security Assessment), promise exciting capabilities in these areas. "On-line VSA and DSA are unlike anything currently used at control centers," explains EPRI's Dominic Maratukulam, who manages VSA. "When we implement them at utilities in 1997, they will warn operators of events on the system that could lead to reduced security and will suggest both preventive and corrective actions."

But on-line VSA and DSA will be beneficial even before wide implementation of WAMS. "If on-line VSA and DSA had been available and in place in control centers throughout the West, both of this summer's outages might have been avoided," says EPRI's Gerry Cauley, target manager for grid operations and planning. "These systems tell you when you're approaching the edge of stability and what you can do to back away from the precipice." For example, on-line VSA and DSA would have recognized the potential effects of the first two incidents of line sagging on August 10 and would have recommended various preventive actions to operators before further deterioration of the system.

VSA looks at the power system every 15–20 minutes (or immediately after a line or equipment outage) and examines a large number of contingencies—disturbances that could have an adverse effect on security. It identifies the 20 or 30 contingencies with the greatest potential for trouble, and for each, it indicates what would go wrong if it occurred, what operators can do immediately to minimize its impact, and what to do after the event if it does occur. If one of these critical contingencies would cause power congestion in a particular area, operators can rearrange generation by ramping up some units and decreasing the output of others to minimize the contingency's impact should it occur.

Using VSA's fast simulation routine, operators can test preventive actions they are considering. The routine, an accelerated version of an industry-accepted EPRI stability program, is based on simplifying assumptions and runs 10 times faster than real time, enabling operators to quickly predict the ramifications of their proposed actions. VSA also periodically indicates a relative measure of system security. After using the software for some time on a particular system, operators will learn that when the measure exceeds certain levels, they must take action immediately to avoid outages.



FUTURE OF WAMS **Ultimately, WAMS will expand beyond the role of data acquisition and monitoring (phase 1) to encompass information processing (phase 2) and decision making and implementation, involving a variety of wide-area power grid control, operation, planning, and maintenance actions (phase 3).**

"On-line VSA and DSA not only increase reliability but also increase your system's stability limits because they help you understand your system better," explains Stahlkopf. Utilities can use VSA and DSA in conjunction with another on-line EPRI analysis tool, TRACE (Transfer Capability Evaluation), to determine the maximum amount of power they can transfer over their lines. "These tools allow you to squeeze more out of your existing assets, so you'll be able to send more power down a corridor with confidence," says Stahlkopf.

EPRI and BC Hydro are working together to develop on-line VSA on the basis of a widely used off-line precursor (VSTAB); this effort is nearing completion. In 1997, on-line TRACE will be available and on-line DSA will be demonstrated.

Get the FACTS

WAMS gathers data for input to such on-line analysis tools as VSA and DSA. But if these data and the subsequent analyses call for actions to be taken on the power system, how will they actually be carried out? Power flow through the grid is very difficult to control because mechanical devices are too slow to switch alternating current cycle by cycle. As a result, power flows in the direction it "wants" to flow—along parallel paths of least resistance. What's more, existing equipment, such as capacitors, can provide only so much voltage support. How can power flows be redirected to enhance reliability in certain situations? Since building new transmission lines is usually not an option, some other hardware is needed that can work with existing lines to enhance their capabilities. FACTS (Flexible AC Transmission System) devices meet this need.

FACTS technology will make utility networks operate like giant, high-tech integrated circuits. These power electronics devices offer the same advantages that integrated circuits offer—speed and precision—but scaled up in power by a factor of some 500 million. Conceived by EPRI engineers, FACTS is a family of high-speed electronic controllers expected to revolutionize utility transmission systems in several ways. The devices will significantly increase the utilization of installed capacity while reducing susceptibility to power disturbances (see "The Delivery System of the Future," *EPRI Journal*, October/November 1992).

Beyond these advantages, FACTS devices will play a major role in enhancing system reliability in two ways—automatically and through operator-initiated actions. In the first case, FACTS devices placed at strategic locations on the grid can provide an instantaneous response to a disturbance by injecting reactive (voltage) support into the system or changing power flows in a fraction of a cycle (less than 0.0167 second), a time frame too quick for human action. In the second case, operators can specify certain functions for the devices to carry out—preventive actions before outages or corrective actions after disturbances. These actions include diverting power from one line to another and injecting reactive power to stabilize voltage.

In either case, FACTS devices can serve to reinforce weak points in the system—points of power congestion that prevent needed transfer of power—and improve reliability. "A wide-area region," explains Cauley, "can be visualized as a large flat-roofed tent supported by poles of various heights. The places where the roof of the tent sags the lowest are the weakest parts of the system. Substituting longer poles to prop up the tent is analogous to installing FACTS devices at those points. Since the reliability of the system is often a function of its weakest points, bolstering those points increases overall system reliability."

"FACTS is not just a promise for the future but a reality today," says Stahlkopf. "Two decades of pioneering EPRI research is paying off now for utilities participating in demonstrations of FACTS technology." Indeed, FACTS devices are now available at commercial prices and terms from major manufacturers. Several of these devices have been installed at utilities in the United States, including BPA, WAPA, and the Tennessee Valley Authority (TVA), and one is currently being installed at American Electric Power (AEP).

In November 1995, the first of one type of FACTS device—a static synchronous compensator called STATCOM—began operation at TVA's Sullivan substation. This ±100-MVAR compensator will help support transmission system voltage in a wide area of eastern Tennessee. The use of an advanced solid-state electronic switch—the gate-turnoff thyristor (GTO)—enables STATCOM to regulate voltage without expensive external capacitors or reactors. STATCOM also responds quickly to damp major disturbances on the system. "These devices will not only improve reliability but provide a means for us to increase capacity in an economic way," says William Museler, TVA's vice president for transmission and power supply.

The newest and most versatile controller developed through EPRI's FACTS program is the unified power flow controller (UPFC). Key to UPFC function is a new three-level valve configuration of GTOs capable of simultaneously controlling all three basic transmission system parameters—voltage, line impedance, and phase angle. Able to direct power flows through specific lines of a transmission network, the UPFC can also react almost instantaneously to counteract disturbances on a transmission line, improving system stability.

AEP has approved the installation of this type of FACTS device for use in eastern Kentucky. "The Inez area is a large, important area on our power system, representing over 2000 MW of load," says Bruce Renz, AEP's vice president for transmission and distribution services. "In one device, the UPFC enables control of power flow into and out of the area, effectively maintains voltage throughout the area, and improves stability." AEP intends to deploy several more UPFCs across its seven-state transmission system.

Software is now available to help utilities determine whether FACTS devices are the right solution to their problems and, if so, which of the types available to date—STATCOM, UPFC, or a third device called a thyristor-controlled series capacitor—best meets their needs. EPRI's Power System Analysis Package (PSAPAC), a suite of nine off-line analysis computer programs, can model and evaluate the benefits of FACTS devices on specific utility systems. These programs are also being used to analyze the July 2 and August 10 disturbances.

This PSAPAC application highlights another key factor in maintaining power grid reliability—system planning and design tools, which play a crucial role in maintaining reliability over the long term. PSAPAC helps planners model what happens on the power system under various scenarios. A related tool, EPRI's TRELSS (Transmission Reliability Evaluation for Large-Scale Systems) software, provides a quantitative measure of system reliability, enabling engineers to evaluate alternative system reinforcements.

FACTS technology is the ultimate tool for getting the most out of existing equipment via faster control action and new capabilities. But there is another way of improving grid asset utilization—knowing when you can push equipment beyond its standard, typically conservative, rating. EPRI's dynamic thermal ratings method addresses this task. In this technique, weather conditions—the factors that largely affect how much load can be placed on grid equipment—are tracked in real time. Ratings for each line can be adjusted on-line by feeding these data into software that models the effects of ambient temperature and wind speed on a transmission line's load-carrying capacity. Even during periods of high energy consumption, the program is usually able to identify additional capacity on some lines that can safely carry power over routes that may improve system security. This method can be used in conjunction with FACTS devices to optimize power transmission over a wide area of the grid.

New demands

A large part of the interconnected power grid in place today uses equipment designs of the 1950s and 1960s. But the demands of today's world are much different from those of 30 years ago. In addition to load growth and increasing power transfers across the grid, electrical loads themselves are changing. Microprocessor-based technologies, for example, have proliferated in manufacturing, agriculture, entertainment, home automation, and other areas, elevating the importance of reliable power. At the same time, deregulation is thrusting further change on the electric utility industry.

"The challenge, then," concludes Stahlkopf, "is to make the transmission system—and the distribution system, for that matter—sufficiently reliable to meet the demands placed on it today and in the future." To achieve this broad goal, the same technologies that are proliferating as loads can be applied as solutions on the power grid. High-speed data transfer, advanced telecommunications, artificial intelligence, and power electronics are—with the foresight of utilities, EPRI, DOE, and others—being applied to enhance grid reliability. We need these technologies now and will soon have them, ensuring that the North American power grid remains the most reliable electric system in the world. ■

Background information for this article was provided by Karl Stahlkopf, Gerry Cauley, Rambabu Adapa, Ali Vojdani, Dominic Maratukulam, Dejan Sobajic, and Abdel-Aty Edris of the Power Delivery Group; Gail McCarthy of Strategic R&D; and William Mittelstadt of BPA and John Hauer of Pacific Northwest National Laboratory.

THE STORY IN BRIEF **Responding to interest expressed by many member utilities, EPRI is launching strategic core research in information security to help companies better protect power system operations, business-sensitive and private customer data, and networks from unauthorized access or use. Although the threat of computer security breaches has been relatively low and isolated in the past and break-ins have been few, the increasing use of networks for various business activities suggests that such risks will rise. EPRI expects to work through an existing strategic alliance with the Department of Energy to tap the expertise of the national laboratories in beefing up utilities' information security systems and practices.**

Tighter Security for Electronic Information

Throughout the world of business, data and information are increasingly the raw materials used to create value, which in turn generates revenues and puts profits on the bottom line of a company's balance sheet. The electric utility industry is no exception; outside the national defense establishment, few industries rival electric utilities in their use of data communications, much of which directly supports the operation of interconnected high-voltage transmission systems and local distribution grids.

The far-flung national infrastructures for telecommunications, energy, transportation, banking and finance, water supply, emergency services, and government operations are recognized as vital both to the economic security and to the defense of the United States. Physical threats—from terrorists or criminals of either domestic or foreign origin—to tangible property in these infrastructures have long been of high-level concern to government law enforcement, defense, and intelligence agencies, as well as to executives of the many private companies that own and operate parts of the infrastructures.

Now a new category of threat must be included in credible risk assessments of critical infrastructures—cyber threats, or electronic, radio-frequency, or computer-based attacks on the information and communications components that are used to control the infrastructures. The proliferation of computers for communications and business applications, coupled with the explosive growth of public and private networks for sharing data and images, is making the companies that rely on them increasingly vulnerable to vandalism, theft, and worse by malicious hackers, sophisticated criminals, and even unscrupulous competitors or angry workers.

by **TAYLOR MOORE**

PHYSICAL ACCESS CONTROL

Security systems that control and monitor entry to offices and facilities where computers and workstations are located are a front line of defense against unauthorized use. Their effectiveness may be diminished, however, as remote access to corporate information systems by telecommuting workers and from satellite offices becomes increasingly common. And access security does not protect against risks to system security posed by employees.

Electric utilities are becoming major users of new types of computer communications networks. More than 100 U.S. utility organizations have public sites on the Internet's World Wide Web. And, as in other industries, some utility organizations (including EPRI) are building private, internal networks—so-called intranets—that link business operations within a company and connect the company to its customers on-line. Some of these intranets depend on the Internet; others do not.

In addition, many utilities are looking at using the Internet for interactive communications with customers. Two utilities are working with the Department of Energy to demonstrate two-way communication of energy use information over the Internet. Meanwhile, as the wholesale power market moves toward deregulation, larger amounts of electricity will be traded and resold daily across greater distances. Electric utilities are working with federal energy regulators to develop a real-time market information system for electricity trading that will carry continuously updated information on spot prices, bids, transactions, and available transmission capacity. Although intended to be accessible only to companies actually in the electricity business, the real-time system nonetheless would be implemented through the Internet, for which security applications are not yet fully developed.

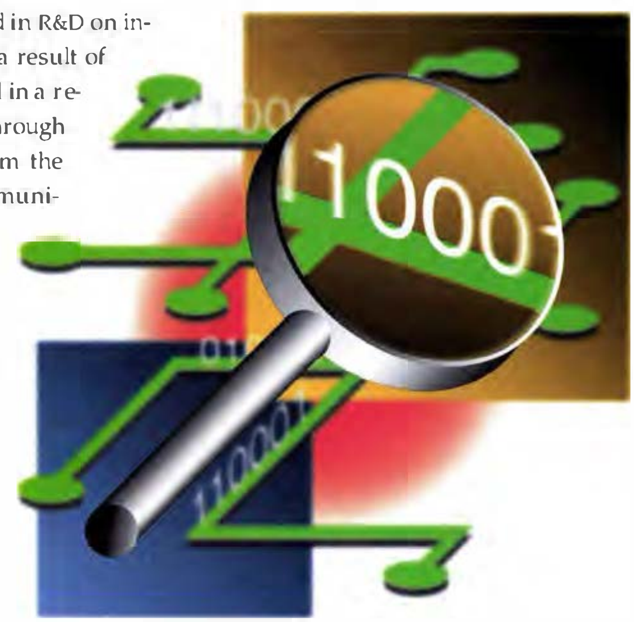
"The trends in communications and computer technologies and the direction that utilities are moving in the current market environment are clearly telling us that information is becoming more valuable and critical to business profitability and, in turn, more attractive to people who would use it for nefarious purposes," says Ron Skelton, a project leader for advanced information technology on EPRI's Strategic R&D staff. "Utilities have a rapidly growing need both to share and to protect valuable information assets—a need that is far greater today than in the regulated environment of the past."

EPRI is becoming involved in R&D on information security both as a result of the strong support indicated in a recent member survey and through a request for assistance from the National Security Telecommunications Advisory Committee. NSTAC, an independent federal advisory panel composed of chief executives of the country's leading telecommunications and information systems companies, has been investigating the current status of electronic information security in the electric power industry as part of a broader response to a request from President Clinton to assess the vulnerability and risks to information systems and communications networks in key civilian infrastructures.

EPRI assisted NSTAC's Information Assurance Task Force in gathering input from electric utilities on their needs for and concerns about information security with two confidential questionnaires that were circulated earlier this year. The task force's assessment of the risks to information security for the key infrastructures of electric power, finance, and transportation (including fuel supply) are expected to be integrated with other NSTAC assessments of the telecommunications network into a final report to the president in 1997.

As part of the greater government and industry focus on vital national support systems, President Clinton in July ordered the creation of the Commission on Critical Infrastructure Protection, for which the NSTAC assessment will provide important input. Nearly a dozen executive branch departments and agencies are represented on the commission, with the Departments of Defense and Justice asked to provide specific support.

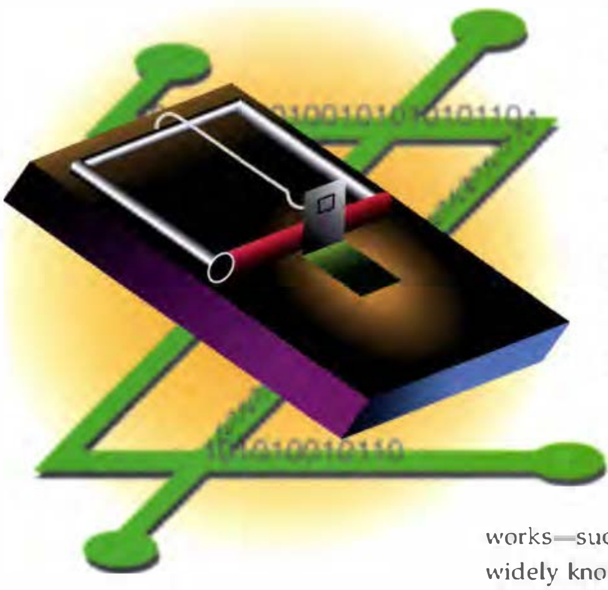
Both departments have direct experience with computer security breaches. Last August, the Justice Department's World Wide Web site was vandalized by computer hackers. And the General Accounting Of-



AUDIT CHECKS AND TRAILS

Special software can monitor and track each operation on a particular document or application, creating audit trails that can be analyzed for patterns and operations indicative of unauthorized system use. But such software generally runs on large computer systems and cannot audit all activity in a network of computers. Moreover, audit trails cannot prevent system intrusions.

fice said in a report to Congress last May that Department of Defense data suggest there may have been as many as a quarter million computer attacks on DOD systems in 1995 alone, of which an estimated 65% were successful, with the number of attacks doubling each year.



TRAPS AND SNIFFERS **Some information system security software works like a cyber bloodhound, actively searching system files and monitoring network activity for patterns of on-line user behavior that could betray unauthorized entry or the presence of implanted virus programs. Various types of system traps containing nonsensitive decoy data can be set to lure and divert intruders or hackers.**

Utilities respond to questionnaires

Information system managers and other executives at about 60 major utilities responded in detail to two questionnaires EPRI developed to gather input for the NSTAC Information Assurance Task Force. Of those responding, 95% indicated that they believe EPRI should become involved with information security R&D on the industry's behalf, according to Skelton. "Strong support was indicated for this work to be included under EPRI's core Strategic R&D program," he adds.

Summarizing results of the industry survey, Skelton says that most utilities perceive a need and are willing to share information about their information security, including experiences with security breaches and protective practices. "A small number of significant security breaches of utility information systems have occurred," explains Skelton, "and utilities currently employ fairly modest protection and audit practices." Generally, utilities are most concerned today about internal threats to information security and perceive that widespread and lengthy disruption of their businesses from computer attack is unlikely. On the other hand, many utilities acknowledge that internal business priorities are limiting attention to information security.

"A significant number of utilities have a perception that private computer networks are reasonably secure. Because of economic pressures, there is a clear trend toward increasing use by utilities of public networks—such as the Internet—that are widely known to be less secure than other kinds of networks," Skelton adds. Fully 40% of those responding said that they expect the industry to make general use of unsecured, public computer networks for many business activities in the future. So-called mission-critical applications, however, such as are involved in operating power plants and power systems, will continue to use primarily private networks.

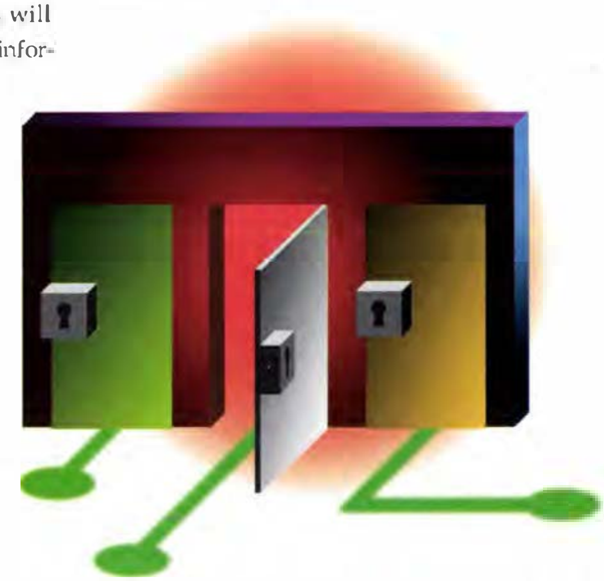
Many member utilities also indicated sharp concern that the coming competitive market environment and broader use of electronic communications networks will adversely affect the security of their information systems.

A significant percentage of the responding utilities reported that they employ one or more intrusion detection methods—including audit trails, access control triggers, traps for implanted viruses, and secure gateways—for information system security. Most utilities, however, reported that they have no information security personnel other than user ID password administrators. Nearly half of the utilities responding said that they review their information system security less often than once a year or not on a regular basis.

A substantial fraction of the utilities responding to the EPRI questionnaires indicated that they believe that unauthorized electronic access to the utility's information and control systems could potentially have a serious impact on the regional power supply for 24 hours or more.

Asked for their ideas about effective ways to provide information system security, many utilities cited authorization verification systems, network firewall systems, encryption, and improved system security policies and practices. Yet it was noted that firewalls may be minimally effective against the greatest security threat currently perceived—that from alienated employees, a not unlikely prospect in an era of mergers and consolidation. Utilities generally perceive a great potential in the future for network application firewalls, encryption technology, and hacker-resistant operating systems to provide increased information security.

FIREWALLS **Electronic hardware and related software are available that limit access to applications or areas of corporate information systems, differentiating among various types of users and rejecting attempts to access sensitive data or control functions. Firewalls at the application level are seen as a promising technology for improving the security of utility information systems.**



A report on results from the survey and interviews with member utilities, which will be provided to NSTAC for its report to the president, is only part of the initial EPRI response to growing member concerns about information security. "We have already identified several areas where we expect to be doing work on behalf of our members," says Skelton. A workshop held in September by the Customer Systems Group's Information Systems & Telecommunications Business Unit featured an overview of the state of the art in information system security and introduced a draft set of policies, practices, and guidelines utilities may consider for improving enterprise system security. Attendees also heard about the latest in information security products and services from various vendors.

ENCRYPTION The use of a coding algorithm to convert digital data into scrambled form for secure transmission is a highly specialized, still-emerging field of computer science. The code, or key, may be used to verify the authenticity of keyholders or to make information incomprehensible to all but keyholders. Already extensively applied in defense and government information systems as well as in some business applications, encryption is increasingly viewed as a necessary and effective means of ensuring the privacy of sensitive communications, such as customer billing data, over public computer networks like the Internet.

EPRI is preparing a general report on information security that will include summaries of information presented at the workshop and a consensus draft of best policies, practices, and guidelines. The report, to be available to members, will include the results of two studies being conducted for EPRI by DOE's Pacific Northwest National Laboratory. These involve analyses of various perpetrator and threat scenarios and of current trends in information system security. A section on the current state of the art in system security technology, to be prepared with the assistance of DOD agencies, will also be included.

Leveraging an alliance with DOE

As EPRI's research effort in information security evolves, says Skelton, "we expect to work closely with DOE as part of the existing EPRI-DOE alliance," particularly with two of the national laboratories: Los Alamos and Lawrence Livermore. "They already have quite a lot of expertise and a lot of information security measures in place that we can leverage on behalf of the private sector and the utility industry. The labs and DOE are very interested in working with us on this," Skelton adds.

The national laboratories that are responsible for weapons design, weapons testing, and maintaining the safety of the nuclear arsenal have developed and used some of the most sophisticated information security systems in the world, including firewalls and high-level data encryption. But security breaches of some computer systems still succeed, even at these and other national laboratories, which have also developed intelligent network monitors, as well as decoys and traps, to constantly search for and attract unauthorized users who are system intruders.

"Encryption technology clearly can provide the information security that electric utilities need," says Skelton, "but the research questions revolve around how best to apply the technology economically at the appropriate level. As with any security system, there is a trade-off between cost and the degree of risk that can be tolerated. So we will be attempting to define the appropriate level of security relative to the risk involved for everything from the dynamic management of the power grid itself down to the two-way communication of metering and price data between utility and customer."

Bridging the security gap

Two likely collaborations with the DOE laboratories are examples of the handful of anticipated near-term projects that Skelton calls gap analysis and research. "The gap refers to what separates the current state of the art in information system security from where utility communications security is today," Skelton explains. "What would it mean to bring utility communications security up to the state of the art? Utilities operate in some very demanding, real-time environments that stretch the state of the art, and we had better know where those limits are—and not just today, but looking ahead, because the state of the art is a moving target."

A first likely association with the DOE laboratories involves security incident reporting. "We need a clearinghouse where utilities can report information about security breaches or attempted break-ins and get help," says Skelton. Lawrence Livermore National Laboratory already maintains such a security incident clearinghouse for all DOE facilities. "We're talking with both Livermore and Los Alamos about how we might emulate what they're doing for utilities or perhaps contract with one of them to provide a clearinghouse service for our members," Skelton adds.

A second area of anticipated EPRI cooperation with the labs involves a DOE-funded project that is already under way with subsidiaries of two member companies: Enova Corporation's San Diego Gas & Electric (SDG&E) and Central and South West Corporation's Customer Choice & Control. They are working with the Los Alamos laboratory to develop a two-way customer communications interface that would use the Internet's World Wide Web to send and receive energy use data.

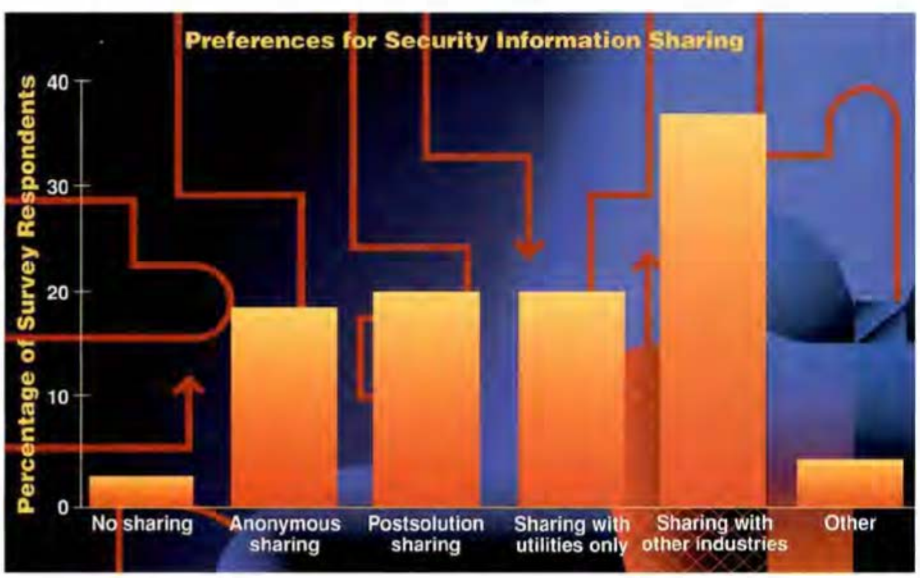
EPRI is expanding the scope of the SDG&E work, in a project with the utility, to include objectives that address the need for private, secure customer data communications. "For a utility-customer communications environment of the future, we need to think in terms not just of telemetered data but also of people-oriented information like pictures and graphics that could appear on someone's television screen," notes Skelton. "This kind of interface may pose different security requirements."

Other gap analysis and research projects in information security involve the Power Delivery Group. Work is under way with Los Alamos on data encryption for the Inter–Control Center Communications Protocol, which is used for communications between utility energy management computer systems. The application of network intrusion testing and detection technology in power system operations is likely to be investigated with the help of experts at both Livermore and Los Alamos.

Measures to increase information security can also have a downside. Skelton hopes to explore with experts the potential performance penalty that could be imposed on various utility computer systems and networks if data encryption were broadly applied. "This must be factored into the real cost of information security," Skelton points out. "The cost could be inconsequential for a bulk power transaction with large monetary value but prohibitive for customer metering data that are automatically transmitted every few minutes or for real-time control of power transmission systems."

SYSTEM MANAGEMENT PRACTICES **Strict control of user IDs and passwords is but the tip of the iceberg of information system management practices—practices that together can provide a high degree of security and protection against unauthorized access. Other measures include procedures that ensure the integrity of new software before it is placed in service. Meanwhile, advanced user ID verification technologies such as fingerprint and retinal recognition are also emerging.**

NEXT STEP: SECURITY INCIDENT CLEARINGHOUSE **An important, near-term priority of EPRI's strategic research to improve information system security for electric utilities is the establishment of a clearinghouse on incidents of system security breaches. Information about such incidents could be reported to the clearinghouse for dissemination to other utilities. As shown in the graph, a recent EPRI survey of information security personnel at member utilities found broad support for sharing information about system security incidents, even with other industries. EPRI expects to work with the Department of Energy's Los Alamos and Lawrence Livermore National Laboratories in this effort, perhaps emulating for utilities the computer security clearinghouse that Livermore maintains for DOE facilities.**

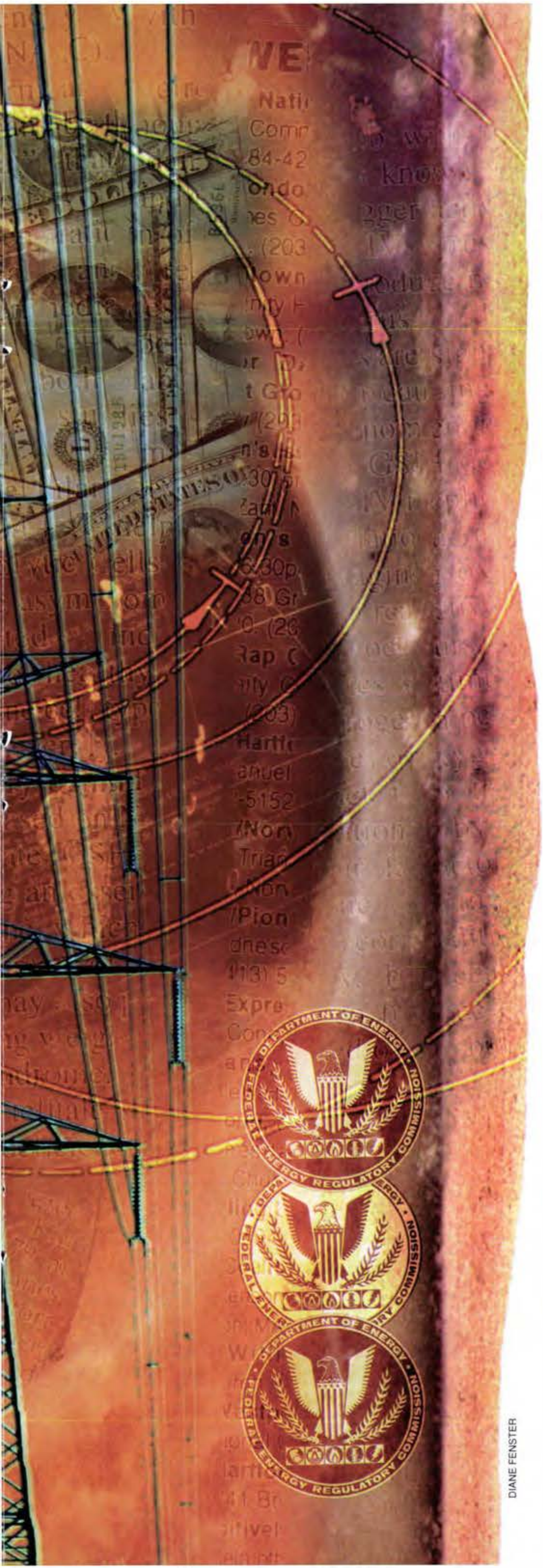


Stopping virtual crime in cyberspace

Despite the increased productivity and expanded communications options that the widespread use of computers has made possible, the potential for criminal use cannot be ignored by businesses planning to make major use of public networks in an age when computer hacking is not even a crime in some countries, notes Skelton. "The utility industry has reached the point where using networks and information systems without effective measures for information security is no longer prudent management practice," he adds.

Increasingly, utilities recognize the need to maintain a realistic awareness of the potential technical and economic risks through targeted R&D that is focused on the industry's unique needs. "Computer attacks are a kind of semiorganized crime that is still in an infant state," says Skelton. "The utility industry has not been much of a target up to now but could become one in the future. The sky is not falling, but utilities are beginning to equate the protection of their information assets with the numbers on the bottom line." ■

Background information for this article was provided by Ron Skelton of Strategic R&D.



DIANE FENSTER

TECHNOLOGY *and the* TRANSFORMATION *of the* ELECTRICITY INDUSTRY

How does technology lead to change in industry, and what role will it have in a deregulated utility environment? EPRI's Advisory Council and Board of Directors met to debate the issue at the Institute's annual Summer Seminar, held August 5 and 6. The Journal's former editor-in-chief reports on the meeting.

BY BRENT BARKER

Historically, the outcome of deregulation has been similar for many industries. The industry disaggregates; the volume of products and services climbs while real prices fall; and profitability and shareholder value go in all directions, as individual companies search for an effective competitive position. Research is initially cut back, particularly by high-cost producers, but quickly becomes a wellspring of competitive advantage for the survivors. "The pattern has repeated itself time and again—in telecommunications, banking, airlines, interstate transport, and natural gas," said Richard Balzhiser, then president and CEO of EPRI, in his keynote address at the Institute's latest Summer Seminar. The seminar, titled "The Electricity Industry and Technology: The Coming Transformation," was held August 5–6 in San Diego.

An examination of the forces that pushed and pulled these industries into new market structures can tell utilities much about the deregulation process and about the place of technology as both an initiator of change and a facilitator of competitive success, according to Balzhiser. In tracing the process of deregulation, he cited four common threads.

First, technology has proved to be a destabilizing force, with deregulation most often triggered by the creation of a low-cost bypass of the existing infrastructure system. Trucking provided an alternative to railroad freight; microwave, satellites, and wireless provided an easy bypass of AT&T; and distributed electricity generation is poised as a potential bypass of the utility transmission and distribution system. Second, information technology (IT) has contributed across the board—revolutionizing oil and gas exploration, lowering the barriers to entry in industries as diverse as banking and airlines, and now opening the door for outside competition in electricity-based services. Third, in large part the transformative technologies—from gas turbines to computer networks—have benefited from decades of public and privately funded R&D, much of it defense-related and channeled into use by the private sector. And fourth, once triggered, deregulation accelerates through marketing innovations in packaging, pricing, and promotion, expanding business opportunities and providing much-needed differentiation among companies.

Balzhiser's keynote address set the stage for panel discussions on three technological areas now transforming the electric utility industry: distributed resources, T&D systems control, and information and communications technologies. The discussions were led by EPRI vice presidents George Preston, Karl Stahlkopf, and Clark Gellings, respectively, and were followed by an active, open exchange among the more than 50 seminar participants from EPRI's Board of Directors and Advisory Council. Conversation about the industry's future ranged widely but returned time and again to several major themes: the central role of the customer, the impact and timing of enabling technologies, the changing roles and responsibilities of electricity providers, the pathway through regulatory uncertainty, the necessity of a global perspective, and the implications for EPRI.

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Enabling technologies are redefining the business

An array of enabling technologies that have emerged in the last decade are allowing utilities—and new players in the power field—to focus more intensely on utility customer needs. Distributed resources provide a number of location-specific benefits, from cost reduction to cogeneration and enhanced power quality. Electronic T&D technologies open a competitive marketplace for electricity consumers while providing enhanced system services—from removing bottlenecks to providing grid support. And information and communications technologies have made the customer more visible, raised customer choice to a new level, and begun to fundamentally alter business relationships. As in most other industries, market power is shifting from manufacturers and suppliers to retailers and customers.

Distributed resources George Preston opened the panel discussion on the future role, penetration, and timing of distributed generation. Mike Gluckman, formerly with EPRI and now president of Tristar Ventures Corporation, said that "gas-fired repowering, gas-fired combined cycles, and gas-fired combustion turbines are the most likely economic choice, but 150-MW units are probably going to be the smallest competitive units." The reason goes beyond low capital cost: "Minute-to-minute management of fuel is the real moneymaker, and here larger plants have an advantage."

With gas turbines accounting for over 50% of new capacity additions, distributed generation now sets the competitive benchmark for new generation. Nevertheless, their competitive position with respect to existing generation is much less advantageous—partly because of production costs and partly because of excess capacity. The marginal production costs for 80% of U.S. coal and nuclear plants are comparable to those of combustion turbines (around 2¢/kWh), allowing old plants to compete on a cash-flow basis. Excess capacity is also slowing the growth of distributed generation. As Chris Poindexter, chairman and CEO of Baltimore Gas and Electric Company, pointed out, "There is an electricity bubble, similar to the gas bubble, and not much in the way of distributed resources will be needed until this excess capacity is used up—perhaps in five years."

Other factors are speeding the deployment of distributed generation, however. Poindexter said, "After taking 27 years to put a 500-kV ring around the Washington-Baltimore area, we want to find new ways to avoid T&D investments—and distributed generation can help do that." Henry Linden of the Illinois Institute of Technology talked about the advantages of cogeneration: "In the United States, there are 5–6 quads of heat load that can be served with units of less than 50 MW. Kaiser Permanente Hospitals is installing fuel cells that are 82% efficient because they can use the waste heat to serve a 24-hour-a-day hot water requirement. This brings power costs down to below 7¢/kWh." Other participants reminded Linden that although this is remarkable for fuel cells, you can still buy bulk power today at 3¢/kWh.

Ultimately, the market penetration of distributed generation will depend on the emerging economic climate. Gluckman described a new commercial paradigm for distributed generation as "one involving multiple products, multiple owners, and multiple customers," and he encouraged utilities "to look for opportunities to partner with customers, fuel suppliers, and others." Leonard Hyman, a consultant formerly with Merrill Lynch, also envisions the "rise of the virtual utility—companies that may or may not own assets—as strongly encouraging the growth of distributed generation." What particularly concerns Hyman, however, are efforts by utilities to recover stranded costs, which would artificially drive business toward distributed generation, and the difficulty of determining what the payment for network services should be. The cost of network services is bound up in the utility price, giving independent competitors an opportunity to avoid network costs—a market distortion that, left unresolved, will surely be exploited.

The American public is unwilling to construct new power plants and transmission lines. There is a lot more we can do with the existing system, and FACTS is there to help. –Lynn Draper, American Electric Power

T&D systems control Karl Stahlkopf opened the panel discussion on the delivery issues of today and tomorrow by referring to the outage of July 2, which left eight western states without power. "It's a problem of complexity, of trying to use a system not designed for today's challenges. How do we maintain reliability when we're handling as many bulk power transactions in one hour as we used to handle in one day? We're likely to see more of these outages." As if on cue, the western states from Canada to Mexico went dark the following week in the even more severe August 10 outage.

John Kessinger, general manager of energy management at Westinghouse Electric Corporation, outlined the impact and timing of new electronic technologies developed from EPRI research and now being brought to bear on the problem: "In the 1993–1998 time frame, we are bringing the basic enabling products—FACTS [Flexible AC Transmission System] devices, Custom Power technology, storage—into the marketplace. From 1997 to 2000, we will see their applications expanded and integrated to create local systems. And after 2000, we will begin to see them applied in large-scale integrated systems." The intent, added Stahlkopf, "is to optimize the flow on the whole continental grid—to link FACTS-controlled systems on a grand scale." Granger Morgan, head of the Department of Engineering and Public Policy at Carnegie Mellon University, cautioned that even though the technology might be there, "short-term research agendas may not yield the knowledge needed to reliably operate a large number of FACTS systems together."

Lynn Draper, president and CEO of American Electric Power Company, underscored the near-term commercial advantages of the new electronic controllers "in an age when the American public is unwilling to construct new power plants and transmission lines. There is a lot more we can do with the existing system, and FACTS is there to help. We are installing the world's first unified power flow controller. It gives us voltage support, increases line capacity, and extends the market reach of new generation." Kessinger added that in the longer term, "the real value of FACTS will come from breaking system congestion and blockage, and the real value of Custom Power will come from differentiating businesses."

Information and communications technologies Clark Gellings opened his panel discussion by pointing out that the new information and communications technologies are now broadening the boundaries of the traditional utility business, unleashing vast new business opportunities for delivering energy and information services, and lowering barriers to entry. Peter Schwartz, chairman of Global Business Network, brought the full implications home: "First, information technology is a *relationship technology.* Application of IT begins to change relationships—industry to industry, business to business, supplier to customer. This is the big transformation facing not only this industry but all industries. Second, if you survive, you will be in the telecommunications business."

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Schwartz described our age as a "historical discontinuity," driven by three curves of technical change: the doubling of microprocessor power every 18 months; growth of 10% a week in Internet use; and exponential growth in information storage, "allowing you soon to carry around your personal chip containing everything you need or want." He foresees a near-term explosion of alternative information and telecommunications technologies, leading to "extreme market confusion in the next five years and massive failures for those companies who bet on the wrong horse."

But more significantly, on a broader scale Schwartz envisions the power of information technology to realign most industries. "IT allows you to take a business apart and put it back together in new ways. The electric utilities, like the telecommunications and cable industries, are fragmenting—what we call 'unpacking of the system'—while other industries, such as pharmaceuticals, finance, and entertainment, are consolidating."

As industries begin to blend together, it is not always clear which is expanding and which is contracting—or which will retain the upper hand at the time of industry convergence. Gellings pointed out that although electric utilities have several trump cards (e.g., 100% customer access, right-of-way, installed fiber) that should give them an advantage vis-à-vis cable and telephone, it is really the customer who retains the upper hand in today's economic climate.

The central role of the customer

In American business, the customer was once at the end of the line—remote, massed, largely unknown, and satisfied with a few choices and heavy advertising. Today the customer is at the front of the line, increasingly driving business from the ground up. David Bodde of the University of Missouri described the shift in other sectors of the economy: "Competitive power in the automobile industry shifted from the car manufacturers to the car dealers. The same thing happened in the retail business—power shifted from the producers of hammers, T-shirts, and deodorants to the Walmarts. Why? Because the retailers are closer to the customer, and they understand the customer." IT has transformed customer intelligence. Voluminous yet intimate knowledge of the customer can be captured and digested through "fine grain" information technology and used to drive upstream production processes, which, because of new IT capability, are increasingly able to handle personalized orders. IT, said Schwartz, "has reversed the polarity of business."

In the utility industry, as in other industries, this reality has shifted the battle lines of competition. "The future will entail a fight for the customer," said Corbin McNeill, president and COO of PECO Energy Company. Customer choice, burgeoning at both the wholesale and retail levels, is giving electricity more of the characteristics of other customer-driven businesses. Customer retention is now central to survival, and it depends on gaining superior knowledge and penetrating insights into key accounts.

"As a combination company, we are focusing on customer retention, customer satisfaction, profitability, and asset utilization," said Baltimore Gas and Electric's Poindexter. "We are now using market research to identify priority customers we want to retain . . . and customers we are willing to let go. We have found that most customers don't want to get into the utility business; they want us to come beyond the meter and operate their energy equipment so that they can focus on their own core business."

Moving onto the customer premises to provide operations and innovation as well as kilowatthours is at the heart of the future envisioned by Richard Balzhiser and his successor as EPRI's president and CEO, Kurt Yeager. In this future, according to Yeager, utilities "expand into the business of delivering productivity." In many ways, such a portfolio approach parallels a strategy used by banks, insurance companies, and other financial institutions to tie the customer into multiple services.

"The key to the future is owning the customer relationship," concluded Gellings, who strongly believes that technology can provide new leverage for a positive relationship, offering a bundle of interrelated services without intruding on the privacy of the home or office. But several others cautioned that the competition for the customer, notably from outside the industry, is building and should not be underestimated. Schwartz painted the starkest picture: "In the new world order, the customer is everything. Bear in mind that Microsoft's objective is to get control of the customer. Which ones? Every customer. They want to be the interface to everything. Stay alert—when you lose the connection to your customer, you have lost everything."

Perhaps the Achilles' heel of such attempts at customer control by Microsoft and other software giants is the fact that information systems can listen only to what customers say they want, and, according to Schwartz, "history shows that customers don't know what they want." In one experiment he cited, in which an entire town was hooked up with advanced interactive capabilities, customers ended up not using the high-end services everyone predicted, or shopping, or watching movies-on-demand. About 70% of the time they ended up watching each other through strategically placed cameras, creating the electronic equivalent of the front porch. The upshot is that there are always surprises and vast opportunities that can be developed beyond prediction and beyond current preferences. These are the regions that Yeager described as the latent, unarticulated, and unmet needs that will form the core of tomorrow's business. The entrepreneurial instinct to anticipate future needs goes beyond the realm of information technology.

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The changing roles and responsibilities of electricity providers

The new industry configurations that will emerge from the "unpacking and repacking" of electricity, cable, and telecommunications are not yet clear. Linda Stuntz, an attorney and a former deputy secretary at the Department of Energy, suggested that "the question is, what business do the electric utilities want to be in? Generation, wires, or services? It may not be possible to be in all three businesses at the same time, if the Schaefer [industry restructuring] bill is indicative of where we are heading. There is real suspicion of wires people getting into the services business." In contrast, PECO's McNeill described his full-service approach to business expansion: "Utilities need to be leaders in pursuing opportunities. We are already in the telecommunications business with an investment in a PC-based interface for energy services. We need open architecture to allow the business to grow—to bring in new players as well as new, unforeseen services. In the end, I think utilities will come to recognize themselves as being infrastructure managers."

All of this points toward what Yeager called "the industry we are becoming"—a disaggregated model that includes those becoming broad infrastructure managers, those expanding into the productivity business, and those focused on being strategically allied with their customers. For the moment, however, Yeager described the industry in terms of six discrete pieces, each evolving into a separate business: generation, transmission, distribution, power marketing, energy and information services, and information-based management tools. Once these pieces are separated, the opportunities for repacking the system to greater commercial advantage would presumably become clearer. Gas, telecommunications, and/or various services might become integral to various repacking schemes.

"We must rethink everything," said Mike Gluckman, noting that the best technology and the best strategy or approach today may not translate into the competitive environment. "We are facing massive and ever-accelerating restructuring. It will become a way of life for at least the next 10 years. And certainly all of today's distinctions—between independent power producers, nonutility generators, and exempt wholesale generators, for example—will disappear." How can one prepare? Some leading utilities have taken their destiny into their own hands through mergers, restructurings, diversification, and international investment. A number of participants mentioned the foray of U.S. utilities into the United Kingdom and Scandinavian markets, not so much for long-term investment but as learning expeditions to acquire firsthand knowledge large as regulatory uncertainty peaks. The seminar participants eagerly joined the debate after Stahlkopf set the stage: "FERC orders 888 and 889 encouraged independent system operators [ISOs] to take over management of transmission assets while leaving ownership in the hands of the utilities. Six ISOs are forming around the United States, but the operational rules are yet to be written. In essence, the industry is making it up as it goes."

Bob Gee of the Texas Public Utility Commission and chairman of NARUC's Committee on Electricity characterized the cur- of the system during the interim. "Without clarity of rules and responsibilities, reliability may suffer," said Stahlkopf. "It is unclear who will pay for upgrades and for the installation of new capacity on the transmission system." In a nation rapidly embracing a digital economy, reliability on the system level and power quality on the local level will become increasingly important and increasingly valuable. The seminar participants suggested that the American tolerance for outages is not very high and that a succession of outages could well lead to a national political dialogue about

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about competitive markets several years ahead of the pack.

Nevertheless, implicit in the seminar discussions of radical change was the lingering dichotomy of competitiveness and public service. One could sense that there was no interest in abandoning the social contract or the obligation to serve, despite the vulnerability it might pose as the storm of competition gathers. Historical ties to local regions are profound, and it will not be easy for U.S. utilities to culturally uproot themselves and assume the more nomadic culture of today's high-tech international businesses. All this seemed to underscore the deep concern expressed about the future of transmission operations—the central glue holding the disaggregating pieces together in the broad public interest.

The pathway through regulatory uncertainty

Who will assume responsibility for maintaining system reliability during the transition to an open marketplace? Who will make the investments to maintain and upgrade the system? These questions loom

rent regulatory dilemma as a "fracture of jurisdiction and pricing" leading to possible stalemate. "State commissions want jurisdiction over the unbundled system, yet FERC, drawing on the interstate commerce provision, wants to assert control over retail," Gee explained. "FERC does not now have jurisdiction over retail generation, so I see a real conflict if FERC were to gain jurisdiction over retail transmission. Historically, FERC has had jurisdiction over wholesale; the states, jurisdiction over distribution. The dividing line is in dispute Once the transmission system is unbundled, the issue of jurisdiction may be in court for years." Granger Morgan, searching for a better alternative to a protracted federal-state court battle, suggested the creation of "multistate entities whose jurisdiction is congruent with the ISOs'." And Tom Kuhn, president of the Edison Electric Institute, suggested that the parties focus on establishing the economic incentives. "Once the incentives are in place, jurisdiction will sort itself out."

All of this will take time. Stahlkopf and others stressed their concern about investment paralysis and eventual degradation

the costs and benefits of deregulation itself. One way or another, they concurred, we will have reliable power in this country. A $6 trillion economy is not going to let the incremental investment in a $200 billion industry jeopardize the future.

The necessity of a global perspective

EPRI executives Yeager and Balzhiser have been making the case for some time that electricity is a growth business and that one of the Institute's strategic roles is to "expand the pie" of electricity application, both domestically and internationally. Several participants challenged Balzhiser's assertion that the U.S. electricity market could expand by 50% over the next 10 to 15 years through sustained innovation. Considering recent developments in the competition between electricity and gas in new homes, they felt the forecast was too optimistic. In contrast, Bob Galvin, chairman of the Executive Committee at Motorola, said he saw the figure as far too conservative, even constraining. "To me, 50% seems overly conservative. I would look for multiples. The opportunity to enhance the service to society with energy ought to be multiplied three to five times in the course of 15 years."

Much of Galvin's optimism rests upon

his international outlook, derived from the reality that 95% of Motorola's business in the next 10 years will be outside the United States (in direct proportion to the global population). But he sees a nexus between communications and energy worthy of international advance. "We must take a more aggressive attitude toward international energy system investment to increase the size of the pie. Energy and communications are the basic infrastructure requirements of society. We have to make another couple of billion people more productive so that they can earn incomes that will have a discretionary component; this creates a market for all the other things that people want to sell, which builds a full economy and lifts the quality of life."

Electricity supply is not yet a global business, but the trend is clearly in that direction. American, European, and Asian suppliers are eagerly pursuing new opportunities in the emerging nations. John Sawhill, president of the Nature Conservancy, observed that "international competition continues to be a force behind deregulation in many countries." Galvin suggested that EPRI members should not let the opportunity of providing the new infrastructure for some 2 billion people slip away: "We should be immensely more interested in how our institutions will carry this resource to the rest of the world, regardless of the technology. As an offensive strategy, building this infrastructure represents the creation of an enormous market. Defensively, if we don't do it, others will, and they may put in the wrong kind of energy systems."

Yeager added that the international dimension has now become integral to EPRI's strategy. "Our members expect EPRI to be a global player, to draw in the best technology from around the world, and to expand opportunities abroad," he explained. "We receive about 10% of our revenues from international affiliations—members, cofunders, and alliances. We intend to be selective but nevertheless expect to double or triple this revenue in the next few years."

The implications for EPRI

Implications for EPRI were woven through the discussions during the entire seminar. The participants seemed to reach a consensus that EPRI's role should continue to broaden—to integrate the energy and information services now pacing the industry, to pursue the burgeoning opportunities in overseas markets, and to encompass the sometimes conflicting requirements of members seeking to balance competitive advantage and social benefit. This last item is a central challenge facing the industry and the nation in the next decade. Responsibility for the broad public interest, including R&D, is devolving to lower levels in both the public and private sectors, without any clear sense of the end point. Chauncey Starr, EPRI's founding president, captured the dilemma from the Institute's standpoint: "The key premise is that the EPRI scientific and technical programs are in the public interest. This has been true historically and is true today. The public role is *not* being challenged. It is the support that is at issue. The national utility industry objective has become unstable, and the industry may not continue to support R&D of this type in a competitive environment."

National R&D road map One idea that gathered force during the two days of discussion was the creation of a national electricity R&D road map, which would lay out the essential energy, economic, and environmental needs to be addressed by R&D in the coming decades and identify the fundamental gaps in knowledge. The map would be directed at the policymaking community and would reveal the essential leverage to be gained from a coordinated R&D approach. It would also allow organizations like EPRI and the national laboratories to carve out appropriate niches and begin to work together in new ways. Bob Galvin said that Motorola created such technical road maps 25 years ago for engineering purposes. As they became more sophisticated, they were scaled up and eventually used to create an industrywide road map for the semiconductor industry. That map helped guide the formation of Sematech, of which Galvin was a founder.

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Yeager drew a parallel between the concept of the road map and the so-called Green Book, which laid out the technical vision of the electric utility industry in the late 1960s and was used to guide the formation of EPRI in 1972. Like the Green Book, he said, the road map would "reinforce the sustaining role of science and technology to electricity stakeholders." Questions arose about the breadth of the road map. Given that the gas, electricity, and telecommunications industries are beginning to come together, some seminar participants suggested that the road map be broadened to include all three industries. Yeager said it would be as broad as is practical. Bob White, president emeritus of the National Academy of Engineering, warned against making it self-serving, while Craig Glazer, chairman of the Ohio Public Utilities Commission, said that it should not be developed to serve everybody and everything. "I developed one for the state," Glazer recalled, "but I would never do it again. Without clear guidance about who was to decide what went into the strategy, we ended up with a Christmas tree, hung with everybody's pet R&D project. It was a list, and not a very useful one."

Implicit in the pursuit of the road map is continuing support, public and private, for collaborative R&D. The situation was summarized by EPRI's Ric Rudman, who is serving as chair of the Council of Consortia, an organization composed of R&D consortia from around the country: "There is general retrenchment in R&D, and collaborative work is not immune. Nevertheless, collaborative R&D is alive and well. It is being used as the basis of creating entirely new markets—new platforms for competition—as well as to deal with existing markets in new ways. Where collaboration is in trouble, there are unique organizational problems."

David Bodde asked the participants to explore new directions. "Our technical institutions are all under pressure, and this economic climate is calling for new approaches to value-added research and for new sources of funding. We should be looking at innovative products and services that can support the institution—such as spinning off new companies built with EPRI technology, or creating, in partnership with our member companies, pools of investment capital to build portfolios of advanced technology in startup companies." Granger Morgan said, "It's time to become more creative. We need better policy tools to support R&D. If we have a charge, for example, it shouldn't have to be centrally collected. It might yield better results if system operators could invest directly in the R&D organization of their choice—say, a university or a laboratory. Only when a specific choice was not made would a charge be leveled that would go into a national pool to be allocated."

The key premise is that the EPRI scientific and technical programs are in the public interest. This has been true historically and is true today. The public role is *not* being challenged. It is the support that is at issue. The national utility industry objective has become unstable, and the industry may not continue to support R&D of this type in a competitive environment. -Chauncey Starr, EPRI

New funding mechanisms A number of suggestions were made to strengthen EPRI funding, particularly in areas vulnerable to cutbacks in public-good R&D. Consultant Susan Tierney, formerly assistant secretary of energy at DOE, suggested a tax credit for R&D "so that it doesn't flow through DOE or the appropriations process." The possibility of a wires charge to fund "stranded benefits"—notably public-good R&D—was raised several times, but nearly everyone thought that such a charge would be difficult, if not impossible, to obtain. "The discussion of a wires charge has an air of unreality," said Linda Stuntz. "Anything that flows against cheaper electricity is unlikely to happen." Randy Hardy, administrator and CEO of the Bonneville Power Administration, concurred. "This faces enormous obstacles. System benefit charges are still a tax by any other name."

Leonard Hyman suggested that the industry become more entrepreneurial in its approach to R&D funding. "Look at eastern Europe. They need you the most and can afford you the least. Why not look for other forms of payment? Why not barter? If they don't have hard currency, ask for a stake in their future. See what they offer."

Hardy drew the seminar to a close by reminding the participants of the transcendent need in our society for symmetry to "match up who pays for what with who benefits from what." ■


CAULEY


MARATUKULAM


SOBAJIC


EDRIS


SKELTON


BARKER

Enhancing Power Grid Reliability (page 6) was written by science writer Steve Hoffman with assistance from members of EPRI's Power Delivery Group.

Gerry Cauley is target manager for grid operations and planning. He came to EPRI in 1991 and initially focused on research strategies and technologies for power system control centers. Previously he worked for General Physics Corporation for 10 years, eventually managing the firm's training services for power system operations. Cauley also served with the Army Corps of Engineers. He holds a BS in electrical engineering from the U.S. Military Academy at West Point, an MS in nuclear engineering from the University of Maryland, and an MBA from Loyola College.

Dominic Maratukulam, manager for power systems design, joined the Institute in 1987 after several years with Systems Control, Inc. Earlier he worked for 10 years at BC Hydro in Vancouver, where he concentrated on software development, system studies, and substation planning. Maratukulam received a BS in electrical engineering from the Indian Institute of Technology, an MS in materials science from the University of Washington, and an ME in electrical engineering from the University of British Columbia.

Dejan Sobajic, manager for power systems control, came to EPRI in 1993 after five years as engineering manager at AI Ware, Inc., where his responsibilities included coordination of software design and development, strategic planning, and market evaluation. While at AI Ware, he also conducted research at Case Western Reserve University on intelligent systems and their use for power systems 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.

Abdel-Aty Edris, manager for FACTS (Flexible AC Transmission Systems), came to EPRI in 1992 from ABB Asea Brown Boveri. In his 11 years at ABB, his responsibilities included analysis work on HVDC power systems and the development of new concepts for improving power system performance. From 1990 to 1992, Edris served at ABB's Transmission and Relaying Center in Pittsburgh. He holds three degrees in electrical engineering: a BSc from Cairo University, an MS from Ain Shams University, also in Cairo, and a PhD from Chalmers University of Technology in Sweden. ■

Tighter Security for Electronic Information (page 16) was written by Taylor Moore, *Journal* senior feature writer, with assistance from Strategic R&D's **Ron Skelton.** As manager for advanced information technology, Skelton is responsible for assessing emerging information technologies and assisting EPRI member companies with business case development, strategic planning, and the integration of computing and telecommunications systems. For 20 years before he joined EPRI in 1991, he held similar positions at Continental Telecom, Aetna Life and Casualty, and Apple Computer. Skelton earned a degree in communications engineering in London, England. ■

Technology and the Transformation of the Electricity Industry (page 22) was written by **Brent Barker** from information presented at the most recent EPRI Summer Seminar. Barker is currently the Institute's manager for strategic and executive communications. Earlier he served for 12 years as editor-in-chief of the *EPRI Journal*. Before joining the Institute in 1977, Barker spent four years as a private communications consultant and as an analyst for URSA, an economics consulting firm. He also worked as an industrial economist and staff author at SRI International and as a commercial research analyst at USX Corporation. He graduated in engineering science from Johns Hopkins University and earned an MBA at the University of Pittsburgh. ■

Distributed Resources

DOE, EPRI Team Up to Put Wind Turbines on Distribution Lines

Traditionally, electric utilities have deployed wind technology much like any other power generation technology—using it to produce relatively large quantities of electricity, which is passed on to high-voltage transmission lines. Now a variety of market factors—including low-cost surplus power availability, uncertainty about the impact of electricity industry restructuring, and increasing competition—are forcing utilities to consider a different approach.

As is the case with other types of power generation, utilities are considering scattering smaller wind power generating units throughout their service territories and tying them not to the transmission system but to distribution lines. The concept is called distributed resources and focuses on smaller, modular units of power generation as a supplement to the output of traditional central-station power plants. Advantages include the ability to serve growing peak loads locally, deferring the need to increase the capacity of transmission and distribution facilities; quicker installation and lower financial risk than for large central-station plants; and increased fuel diversity.

Electric utilities are deploying smaller clusters of wind machines. Shown here are two 500-kW turbines from a 12-unit wind farm in the service territory of West Texas Utilities.

In the realm of wind power, this approach means that rather than deploying a sea of turbines on the scale of that along California's Altamont Pass, smaller clusters of turbines would be deployed throughout a utility's service territory. And rather than passing the combined output of the group through a transformer that steps up the voltage to the transmission level, the collective power of the small cluster could be passed directly on to a distribution line. Aside from its other advantages, the new approach saves the cost of the interconnection equipment.

Electric utilities are getting a chance to test the concept of distributed wind turbines in an effort initiated last summer by EPRI and the U.S. Department of Energy—phase 3 of the Wind Turbine Verification Program. Projects selected for funding are to include at least two wind turbines and to produce a combined output between 500 kW and 5 MW. The projects will entail plant design, construction, startup, acceptance testing, and performance monitoring and documentation during the first two years of commercial operation. Substantial technical and management assistance in each of these areas will be available from both DOE's National Renewable Energy Laboratory and EPRI. The program will cover 10–50% of the project costs, with projects of higher risk getting more funding. Interested utilities are now submitting proposals, from which between three and five projects will be selected by the end of the year.

Established in 1992, the Wind Turbine Verification Program was designed to evaluate early commercial wind turbines deployed at several sites developed by U.S. electric utilities. The program is funded through contributions from DOE, host utilities, and EPRI, with EPRI managing the program on behalf of all funders.

■ *For more information, contact Chuck McGowin, (415) 855-2445.*

Clean Water

Electrotechnology to Benefit Park Animals

Polar bears, penguins, sea lions, and other water-loving animals at the Central Park Wildlife Center in New York City will soon enjoy healthier habitats made possible by advanced, electricity-based water purification technologies.

In a pilot project sponsored by EPRI, the New York Power Authority (NYPA), and the Central Park Wildlife Center, researchers will select and install water purification technologies at the center early next year. The researchers are currently evaluating the facility's water quality needs and drawing up equipment specifications. A comparative evaluation of specific electrotechnologies—including ozonation, electron-beam radiation, and treatment with ultraviolet light—will begin in January to determine

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Polar bear exhibit at New York City's Central Park Wildlife Center

which is most appropriate for the center.

Traditionally, zoos employ chlorine systems to keep the pools of their furry and feathered residents clean. But chlorination can corrode water system components, and the chemical can be difficult to handle properly. In addition, chlorine is problematic for some species, such as aquatic birds, whose natural protective oil coating is broken down by the chemical.

Moreover, research has shown that chlorine treatment is not as effective at destroying certain parasites and contaminants as alternative systems using electrotechnologies. For instance, ozonation kills cryptosporidium, a pathogenic cyst against which chlorine is ineffective. In the ozonation process, ozone is produced by an electric corona discharge through air or oxygen and is then bubbled through the water. Besides destroying parasites, viruses, and bacteria, ozone is very effective at eliminating organic matter and odors. The result would be not only purer water for the animals but also better visibility in the exhibits for visitors. Another advantage is that live fish could be added to the exhibits, enabling animals to hunt for food as they would in a natural setting. This would be a healthy supplement to the regular manual feedings and also provide some entertainment for the animals.

Researchers aim to have an electricity-based water purification system in place by spring, the beginning of the center's busiest period. The system will run for one year, during which the researchers will monitor its performance. The hope is that this very visible demonstration will encourage the use of electrotechnologies for water purification in similar aquatic park settings. The Central Park Wildlife Center has over 750 animals and receives 750,000 visitors every year. The center is part of the municipality of New York City, NYPA's biggest customer. As Hildegaard Link, a spokesperson for NYPA, describes it, "It's a great showcase location."

■ *For more information, contact Rande Wilson, (800) 424-EPRI.*

Residential Cooking

High-End Induction Cooktop Under Development

It's no secret that gas has one advantage over electricity in the cooking market. Home and professional chefs alike enjoy the immediate response of a gas burner—a capability not available with conventional electric coil heating elements. Yet an electrotechnology does exist that provides the advantage of fast heat control. Called induction cooking, the technology has been commercially available for more than a decade. Because it has never been actively promoted and is relatively expensive, however, it has not been widely adopted in the marketplace. EPRI is hoping to change this scenario.

In a project initiated this fall, EPRI is funding the development of a sophisticated induction cooktop for the residential sector. Wolf Range Company, the manufacturer working on the prototype, has successfully developed and marketed high-end residential gas ranges. These stainless steel icons are now as common as subzero refrigerators and granite countertops in today's gourmet home kitchens. Wolf believes there is a similar market segment for gourmet induction ranges, and EPRI agrees.

Unlike electric resistance heating technology, induction heating enables direct, instantaneous temperature control. Rather than sending electricity through a coil that heats up because of its resistance, induction technology passes the power through a high-frequency inverter and then through a coil beneath the cooktop surface. The coil in turn generates a magnetic field that interacts with the magnetic materials in various pots and pans, causing the cookware to heat up. Because the system won't heat anything but magnetic metals, it is extremely difficult for users to burn themselves on the cooktop. This safety feature and the ease with which the smooth-surfaced cooktop can be cleaned contribute to the technology's attractiveness.

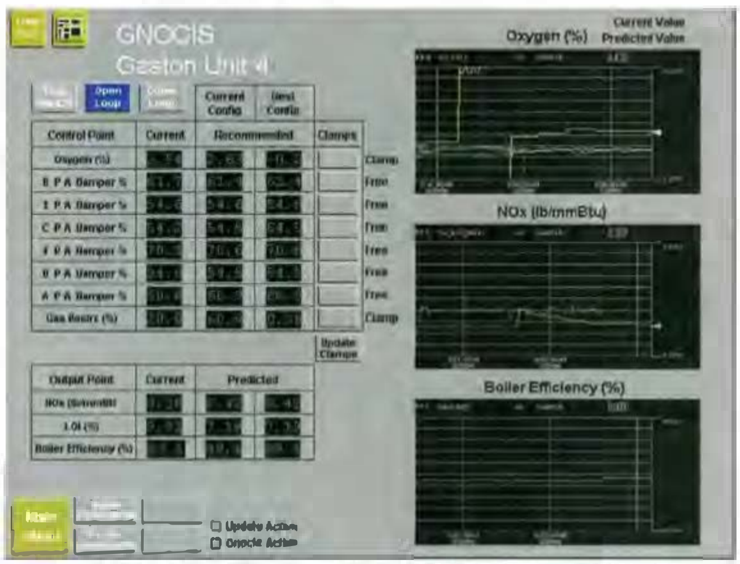
Wolf Range Company is contracting with Luxine, Ltd., a supplier of induction technology products and expertise, for the development and evaluation of the prototype cooktop. Plans are for a prototype with four heating elements to be ready for testing and demonstration by next April. The technology is expected to be commercially available by the end of 1997. The cooktop is the first of what EPRI envisions as three phases of induction cooking technology development. The second step will be to develop a four-element cooktop with an electric griddle; the third, to develop a freestanding range complete with cooktop, griddle, and oven.

"We believe that first pursuing market penetration at the high end makes the most sense," says EPRI's Wayne Krill, who is managing the project. "Once the technology becomes viable in the marketplace, then we can go after the mass market."

■ *For more information, contact Wayne Krill, (415) 855-1033.*

Utilities Sought to Demonstrate NO_x Control Advisor

The 1990 Clean Air Act Amendments have created additional incentives for utilities to optimize the trade-off between emissions of nitrogen oxides and performance (e.g., heat rate) at all fossil generating units. EPRI's Environmental Control Business Unit has developed software—an on-line, closed-loop enhancement for a power plant's digital control system—that can achieve this optimization by continuously providing the control system with optimal settings for combustion equipment.



Sample screen from GNOCIS demonstration at Alabama Power's Gaston steam plant

Called GNOCIS—Generic NO_x Control Intelligent System—the software can provide settings that either minimize NO_x within specified constraints (mainly heat rate, unburned carbon, and other regulated emissions) or result in least-cost operation with an optimal trade-off between NO_x and thermal performance. Built on artificial neural network technology, the system "learns" the NO_x and performance response operating envelope of a particular unit. While it can act as an advisor, GNOCIS is meant to be used as a closed-loop supervisory controller.

Designed to accommodate all types of fossil fuels and combustion firing geometries, the precommercial version of GNOCIS has been demonstrated on three coal-fired boilers in the United States and the United Kingdom. Two other utility demonstrations are under way. EPRI is seeking additional member utilities to demonstrate the system with a range of fuels and firing configurations at fossil plants that are equipped with digital control systems. Some upgrades to plant instrumentation may be necessary to obtain the maximum benefits from a GNOCIS installation. A monitor for unburned carbon is recommended. Six-month demonstration projects requiring a budget of about $250,000 per unit are eligible for tailored collaboration funding.

GNOCIS has been developed by Southern Company Services (SCS), PowerGen, and Radian International under EPRI management, with additional funding from the U.S. Department of Energy and the United Kingdom's Department of Trade and Industry. SCS and Radian are the commercializers for GNOCIS in North America.

"By continuously optimizing the NO_x-performance trade-off, utilities can increase their confidence in meeting short-term emissions goals while also minimizing each unit's generating cost," says Jeff Stallings, EPRI project manager. "For units that are marginally above the NO_x emissions limit, GNOCIS may make it possible to avoid low-NO_x-burner retrofits."

■ *For more information, contact Jeff Stallings, (415) 855-2427.*

Next-Generation Ultrasonic Inspection System Put to Test

Assessing the reliability of turbine rotors and predicting their remaining life are key concerns of many utilities that operate nuclear power plants. Service-induced cracks in keyways and bores of shrunk-on turbine disks have been found in many low-pressure-turbine designs, and cracking in disk attachment areas is a potentially widespread problem. Whatever their location, cracks in nuclear turbine disks are generally attributed to an intergranular stress corrosion mechanism. The EPRI Turbine Inspection System (ETIS), which recently completed several years of testing at the Institute's Nondestructive Evaluation Center in Charlotte, North Carolina, is an automated, second-generation ultrasonic inspection system that can support current examination techniques as well as advanced crack detection and sizing methods that are even more reliable and repeatable.

The NDE Center began testing the ultrasonic scanner in 1991 in support of turbine-related project work and for on-site field demonstrations with utilities. An automated version of

ETIS mounted in a transportable rack

ETIS was completed in 1994 and has since been used at the NDE Center to support the development of turbine disk keyway and blade attachment inspection techniques. The work at the center has provided ample opportunity to assess the system's capabilities in various operating modes. In addition to its usefulness in performing ultrasonic inspections with current techniques, ETIS can support advanced methods, including time-of-flight diffraction and focused immersion testing.

ETIS features commercially available equipment—a pulse generator and data acquisition hardware—and has four-channel capability, which enables a wide range of setups. Although designed primarily for turbine disk inspection applications, the system has enough flexibility to function as a general-purpose automated ultrasonic inspection system. It has convenient features for calibration, for acquiring data, and for interfacing with third-party hardware. ETIS has been successfully interfaced with external phased-array ultrasonic equipment to support blade attachment NDE work.

A recent technical report (TR-106040) describes ETIS and how it operates, summarizes information from the user's manual, and relates experiences with specific applications.

■ *For more information, contact Jack Spanner, (704) 547-6065.*

Allegheny Power Boosts Engineering Productivity With DEWorkstation

To optimize its distribution operations and maintain adequate system voltage, Allegheny Power continually analyzes system designs and performance by means of a labor-intensive, time-consuming process. But like many utilities, Allegheny Power found in the early 1990s that it lacked sufficient computing and human resources to perform several analyses because of the difficulty of navigating the analytical software that was available.

Every circuit analysis, for example, required a utility engineer to consult hand-drawn system maps and create a special data set. Databases with some of the information needed for distribution analysis, such as customer billing data and information on utility facilities and equipment stocks, were not linked. Different data formats required by various software applications meant that a data set assembled to answer one question could rarely be used to answer another one. And since Allegheny Power used analytical software from several vendors, engineers had to learn each program's interface and could not switch easily among applications.

To address these constraints and help improve its distribution system performance, the utility joined forces in 1992 with EPRI and Virginia Polytechnic Institute to develop advanced software for distribution engineering analysis. The product of this collaboration—the Distribution Engineering Workstation—is now available to EPRI members. DEWorkstation includes applications for analyzing power flows, line impedances, capacitor placement, and fault currents. All applications use a common graphical interface, and results from one analysis can be used in another.

"Importantly, DEWorkstation has the flexibility to draw on data from many sources and to link to regularly updated utility databases like customer information systems, weather data, and automated circuit maps," notes Harry Ng, a project manager for distribution systems in EPRI's Power Delivery Group. "Since the integrated data environment allows all applications to share a common database, it relieves analysts of having to create a new data set for each analysis that is performed."

Allegheny Power is currently testing DEWorkstation and estimates that 25–30 engineers and analysts will use it regularly. By substituting the workstation for more-laborious methods for circuit analyses and other tasks, the utility expects to double engineers' productivity, saving more than $25 million over the next 20 years. The new software will also allow the utility to improve distribution system performance by conducting certain analyses that previously had been deferred as too labor-intensive.

A three-volume user's manual (EL-7249, Vols. 3–5) is available from the EPRI Distribution Center. The DEWorkstation software is available from the Electric Power Software Center, (800) 763-3772.

■ *For more information, contact Harry Ng, (415) 855-2973.*

Land and Water Quality

Comanagement of Combustion By-Products

by Ishwar Murarka, Environment Group

ABSTRACT *From the combustion of fossil fuels, the electric utility industry annually generates 80 million tons of high-volume by-products—fly ash, bottom ash, boiler slag, and flue gas desulfurization sludge. These by-products are often comanaged with low-volume wastes—for example, boiler cleaning liquids, coal pile runoff, and coal mill rejects—in utility storage and disposal facilities. Although the Environmental Protection Agency determined in 1993 that the regulation of high-volume by-products as hazardous is unwarranted, it deferred a decision on comanaged wastes until 1998. To ensure that appropriate information is available to the EPA for that determination, which could affect most utility disposal sites, EPRI and its collaborators are engaged in a four-year research effort. The research includes a survey of utility comanagement practices, field studies at 14 comanagement facilities, and studies of specific wastes.*

The electric utility industry generates more than 80 million tons of fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) sludge each year from the combustion of fossil fuels. Collectively, these are referred to as high-volume combustion by-products. About 25% of the high-volume by-product material is used for construction and other applications, while most of the remaining 75% is disposed of in utility-owned landfills or impoundments.

In the course of fossil fuel combustion, utilities also generate several other wastes, such as boiler cleaning liquids, wastewater treatment sludges, water purification residues, coal pile runoff, and coal mill rejects. These are collectively termed low-volume combustion wastes, although some may contain a substantial amount of liquid. Utilities often comanage some or all of these low-volume wastes with their high-volume wastes in storage and disposal facilities.

EPRI is conducting a four-year research program to evaluate the comanagement of low-volume and high-volume combustion by-products in utility disposal facilities. The information and results obtained from this research are critical inputs to a scheduled 1998 regulatory determination by the Environmental Protection Agency on the comanagement practice. For this determination, comanaged wastes include all low-volume combustion wastes, whether hazardous or nonhazardous, and high-volume wastes when disposed of with low-volume wastes. Given this broad definition, the regulatory determination could potentially affect most utilities and most active and inactive disposal facilities.

Regulatory background

The 1980 Bevill Amendment to the Resource Conservation and Recovery Act (RCRA) temporarily exempted fossil fuel combustion by-products from Subtitle C (hazardous waste disposal) regulations, pending a study of the by-products by the EPA and a subsequent determination on if and how to regulate them. In 1988, the EPA completed its first study and submitted a report to Congress containing the finding that with respect to high-volume wastes, the practices of the electric utility industry and the regulatory oversight by states were adequately protective of the environment and human health. Subsequently, in its regulatory determination, published in the *Federal Register* on August 9, 1993, the EPA concluded that "regulation of the four large-volume fossil fuel combustion wastes as hazardous waste under RCRA Subtitle C is unwarranted" (58 FR 42472).

However, the EPA deferred a decision on a second group of wastes associated with coal and other fossil fuel combustion, called remaining wastes. Remaining wastes include oil combustion by-products; fluidized-bed combustion wastes; and low-volume and high-volume wastes that are "co-disposed, co-treated, or otherwise co-managed." Further study of remaining wastes was determined to be necessary. As part of a negotiated consent decree, the EPA is required to complete a study of remaining wastes by September 30, 1997, with a final regulatory determination by April 1, 1998. Remaining wastes continue to be exempt from hazardous waste regulation until that determination is completed.

Research approach

To ensure that the relevant information is available to the EPA for the 1998 regulatory determination, EPRI, the Utility Solid Waste Activities Group (USWAG), and individual utilities are collaborating on a four-year research effort to characterize current management practices, the quantities and chemical composition of various comanaged wastes, and the environmental distribution of constituents that can potentially be released from comanagement facilities.

The research program includes the following areas, which are summarized in the rest of this article:

- A survey of utility comanagement practices
- Field studies at 14 utility comanagement facilities
- A study to define the characteristics of coal mill rejects containing pyrites and to explore options for the management of those rejects
- A study of oil combustion by-product characteristics and management practices
- Preliminary characterization and assessment of combustion by-products generated from the use of alternative fuels, either alone or with other (fossil) fuels

Utility survey

To obtain baseline information on utility practices, all power plants with at least 100 MW of coal-fired generating capacity were sent a questionnaire regarding comanagement at their high-volume coal combustion by-product (CCBP) disposal facilities. The objective was to gather information on the prevalence of comanagement in the industry and to determine what types of wastes were most frequently comanaged. A special effort was made to obtain a broad-based response in order to ensure that the results were representative of the industry.

The survey produced information on 264 active disposal facilities—145 dry facilities (landfills or other dry fills) and 119 wet facilities (impoundments). The facilities are operated by 88 utilities and are located in 35 states; more than two-thirds are located east of the Mississippi River. The surveyed facilities dispose of an estimated 63 million cubic yards (48 million cubic meters) of high-volume by-products annually, about 80% of the total volume generated in the United States. Of the 264 facilities, 42% are lined sites; 31% employ leachate collection systems; and 57% perform regular groundwater monitoring.

As expected, the survey found that most utilities (80%) comanage one or more low-volume wastes in their high-volume waste disposal facilities. The practice is more common at wet disposal facilities (92%) than at dry facilities (70%). Also, the number of individual wastes comanaged is greater for wet disposal facilities than for dry facilities.

Table 1
Percentage of Facilities Comanaging Low-Volume Wastes

Low-Volume Waste	Utility Survey (264 facilities)	Field Studies (14 facilities)
Coal mill rejects/pyrites	55%	64%
Floor drains, sumps	49%	100%
Demineralizer regenerant	44%	100%
Air heater wash	42%	79%
Coal pile runoff	42%	64%
Boiler blowdown	39%	50%
Water treatment waste	38%	71%
Boiler chemical cleaning waste	37%	86%
Area (storm water) runoff	35%	86%
Low-pressure service water	24%	21%
Wastewater treatment waste	23%	14%
Laboratory waste	22%	21%
Cooling tower blowdown	22%	57%
Dredged solids/water	10%	64%
Asbestos	7%	8%
Demolition waste[1]	5%	21%
Contaminated soil	5%	8%
Sanitary waste[1]	2%	36%

[1]Information on these wastes was not specifically requested in the survey.

The wastes most frequently comanaged are coal mill rejects, floor drain discharge, demineralizer regenerants, air heater wash, and coal pile runoff. Each of these five wastes is comanaged at more than 40% of the facilities surveyed (Table 1). With the exception of coal mill rejects, these waste streams are also frequently used in makeup water for ash sluicing and FGD systems.

The survey results show that comanagement is commonly used at utility disposal sites. This finding suggests that the 1998 determination has the potential to impact disposal operations at a large percentage of coal-fired power plants. Although most of the low-volume wastes are inherently of very low risk, a few—such as pyritic coal mill rejects, demineralizer regenerants, and boiler chemical cleaning wastes—have characteristics that merit further assessment under field disposal conditions.

Field studies

The central objective of the field study component of the research is to collect and analyze a comprehensive set of high-quality field and analytical data from 14 utility disposal sites across the country. This information will be used to determine whether unique and discernible changes in groundwater quality can be attributed to comanagement practices or to comanaged wastes. Eleven comanagement facilities are currently being studied under this project. Investigations at three other comanagement facilities have been completed, and technical reports are already available.

Field study sites were selected to obtain a representative sampling in terms of comanaged waste types, comanagement practices, and geographic location. Since the number of potential waste comanagement scenarios that could be evaluated is significant, a procedure was developed to identify those that are most critical to the utility industry and are representative of the broad spectrum of waste types and management practices.

Site selection was a three-step process: initial screening to identify potential sites, primarily on the basis of the survey results and a general knowledge of management practices at individual utilities; narrowing the field to about 20 candidate sites on the basis of site-specific criteria like waste characteristics, hydrogeology, geographic location, and facility design, age, and size; and selecting final sites on the basis of geographic distribution, initial field reconnaissance, discussions with plant personnel, and willingness of the utility to participate in the study. Table 1 gives the types of low-volume wastes comanaged at the field study facilities. Table 2 and the accompanying map show site characteristics and locations.

Each field study consists of six elements: identification of waste types and waste-handling practices; sampling of selected individual waste streams; geochemical characterization of wastes and pore water in the comanagement facility; hydrogeologic characterization; groundwater sampling and analysis; and identification of land use practices and groundwater users in the vicinity of the site.

For each site, a waste flow diagram is developed to describe routing and approximate average volumes of each comanaged waste. Samples are collected and analyzed from certain waste streams, selected on the basis of volume, accessibility, discharge frequency, and waste characteristics. Some low-volume wastes, such as boiler chemical cleaning wastes, are generated intermittently or infrequently and cannot be sampled as part of this study. Characteristics of individual waste types will be used to develop a chemical signature for each.

Cores and pore water are collected at each disposal facility to characterize the in-place comanaged waste. Exploratory cores in the form of split-spoon samples are obtained for visual identification and measurement of geochemical indicators (e.g., pH, redox potential, and electrical conductivity). At selected locations at each site, 5-foot cores are then collected in plastic-lined core barrels for detailed geochemical analyses, including total composition and mineralogic analysis. Pore water is extracted by centrifugation and subjected to full analysis for dissolved constituents. These data are compared with the individual waste stream characterizations to determine whether the effects of these streams can be identified within the disposal facility.

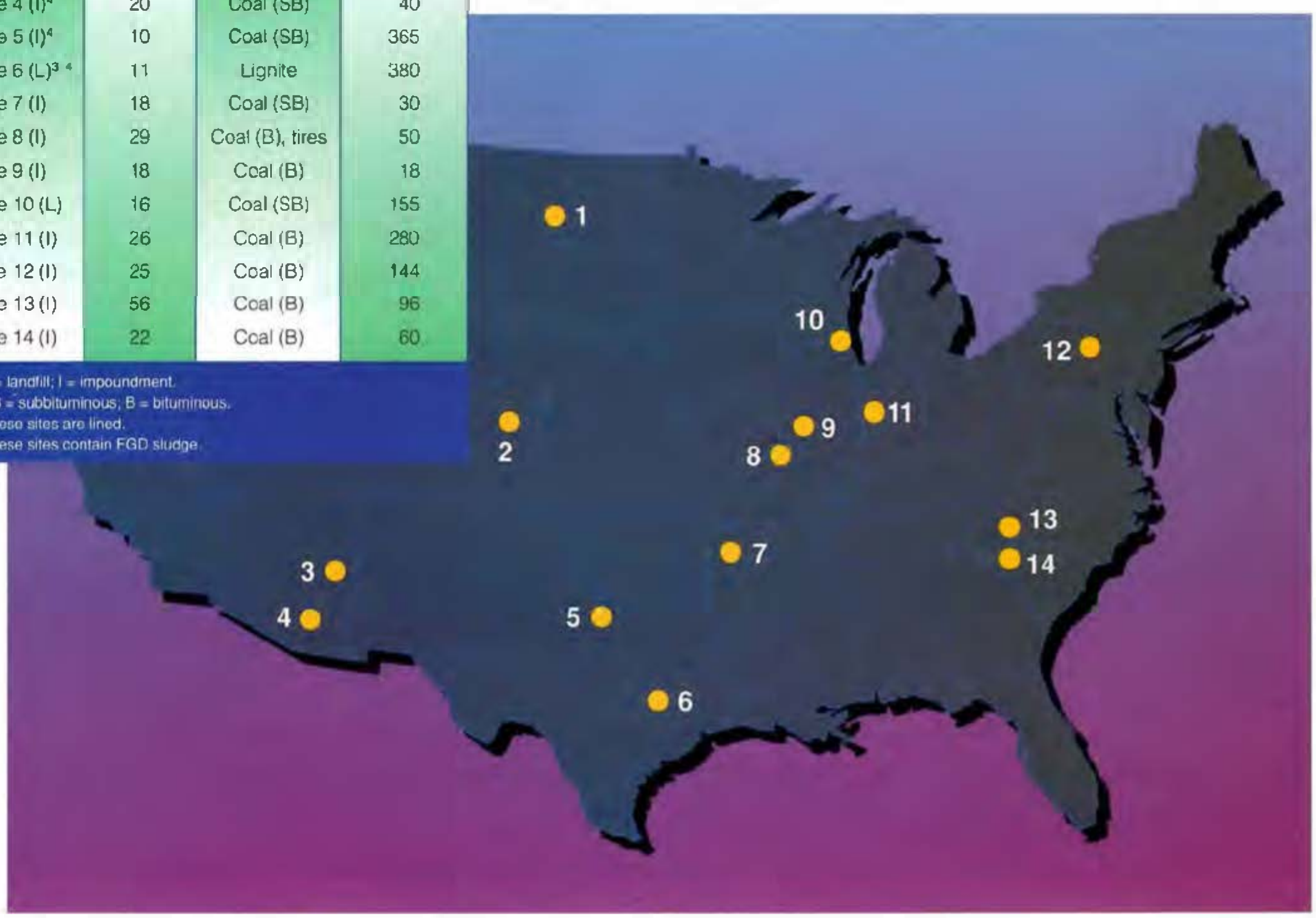
Finally, hydrogeologic characterization and groundwater sampling are used to assess the comanagement facility's effects, if any, on groundwater. Initially, 5 to 10 soil borings are used to define geologic conditions in the vicinity of the disposal facility. Then about 10 to 15 monitoring wells are installed to define groundwater flow conditions and groundwater quality distribution. The wells include at least one upgradient location and a transect along at least one flow path downgradient of the facility, screened at multiple depths. Two to three rounds of groundwater samples are collected at each facility to establish variability on a temporal scale.

The field studies began in the fall of 1995 and will continue through the middle of 1997. Data are analyzed by a variety of sta-

Table 2
Field Study Disposal Facilities

Site and Type[1]	Plant Age (years)	Fuel Type[2]	Facility Area (acres)
Site 1 (L)[3, 4]	15	Lignite	40
Site 2 (L)[3]	15	Coal (SB)	20
Site 3 (I)[4]	16	Coal (SB)	—
Site 4 (I)[4]	20	Coal (SB)	40
Site 5 (I)[4]	10	Coal (SB)	365
Site 6 (L)[3, 4]	11	Lignite	380
Site 7 (I)	18	Coal (SB)	30
Site 8 (I)	29	Coal (B), tires	50
Site 9 (I)	18	Coal (B)	18
Site 10 (L)	16	Coal (SB)	155
Site 11 (I)	26	Coal (B)	280
Site 12 (I)	25	Coal (B)	144
Site 13 (I)	56	Coal (B)	96
Site 14 (I)	22	Coal (B)	60

[1]L = landfill; I = impoundment.
[2]SB = subbituminous; B = bituminous.
[3]These sites are lined.
[4]These sites contain FGD sludge.



tistical and graphic methods, and analytical groundwater models are used to assess the transport and fate of key constituents. A technical report is prepared for each site as the work at that site is completed. A final report synthesizing the results for all 14 sites and presenting overall findings will be prepared at the conclusion of the field study project.

Coal mill rejects

Coal mill rejects are commonly comanaged in high-volume CCBP disposal facilities. Previous EPRI research has found that, under oxidizing conditions, pyrite from the rejects dissolves to produce acidic leachates with high concentrations of iron and sulfate, along with some trace metals. However, under reducing conditions, pyrites do not produce acidic, high-iron, high-sulfate leachates.

As part of the current research, EPRI is characterizing the chemical composition and oxidation potentials of mill rejects and examining how oxidation can be controlled to reduce or eliminate the formation of acidic leachates. EPRI research is also investigating the benefits of regrinding coal mill rejects and burning them in boilers. The results of this research will be incorporated in a technical report to be completed in early 1997.

Oil combustion by-products

The 1998 determination by the EPA will also address the regulation of by-products generated by oil-fired power plants. Oil combustion by-products (OCBPs) are generated in much smaller quantities than CCBPs for two reasons: only a few boilers produce electricity by burning oil, and the ash content of oil is an order of magnitude lower than coal's. The total annual volume of OCBPs in the United States is estimated to be approximately 30,000 cubic yards (23,000 cubic meters), less than 0.05% of the annual volume of CCBPs. Most fuel oil use is concentrated in Florida, New York, and the New England states.

The objective of the OCBP study is to assemble and synthesize existing data on by-product characteristics and the potential environmental impacts related to current management practices. Topics being covered include the distribution of oil-fired combustion in the United States, types and volumes of by-products generated, management methods, total composition and leaching characteristics of OCBPs, and groundwater quality at OCBP management facilities. A final report summarizing this information will be completed in early 1997.

Alternative fuels

Looking to the future, EPRI has initiated preliminary data-gathering efforts on the effects that the use of alternative fuels may have on combustion by-products. The use of alternative fuels, either alone or in combination with other (fossil) fuels, may affect the status of the combustion by-products under the RCRA. Specifically of interest are the combustion of orimulsion and petroleum coke and the coburning of non-fossil-fuel materials (e.g., tires, paper, wood, and contaminated soils) with coal. EPRI is working with individual utilities to estimate the extent to which alternative fuels may be used in the future and to determine what information on by-product characteristics is available.

Conclusion

EPRI is coordinating these various research efforts very closely with USWAG and the EPA to ensure that appropriate data are collected and delivered for a well-informed regulatory determination. In fact, a split-sampling effort is planned in which samples from three of the comanagement sites will be analyzed by both EPA contractor and EPRI contractor laboratories for purposes of data validation and quality assurance.

Quarterly progress meetings are being held to review all research plans and interim results. In order for relevant data to be available to the EPA before the completion of its study in September 1997, all of the research must be completed by June 1997. This ambitious schedule requires the preparation of one to two reports per month from the fall of 1996 through June 1997. EPRI will then continue to work with USWAG and the EPA to provide additional scientific data as necessary through March 1998 for the expected final regulatory determination.

New Technical Reports

Requests for copies of reports should be directed to the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, California 94523; (510) 934-4212. EPRI members that fund the business unit issuing a report can receive the report free of charge (or in the case of bulk orders, for a nominal price). Others should contact the Distribution Center for further information.

Two-page summaries of the reports announced here are available, free of charge, by fax. To receive a summary, call EPRI's Fax on Demand service (800-239-4655) from a touch-tone phone and follow the recorded instructions, using the fax identification number given in the report listing.

CUSTOMER SYSTEMS

EPRI Power Quality Business Unit: Research and Development Plan for Advanced Motors and Drives

TR-101828 Final Report (WO2918-15)
Contractor: Electrotek Concepts, Inc.
Business Unit: Power Quality
EPRI Project Manager: B. Banerjee
Fax ID: 7275

Automation and Energy Management for the Electric Smart House Project

TR-102425 Final Report (WO3163-4)
Contractor: Plexus Research, Inc.
Business Unit: Information Systems & Telecommunications
EPRI Project Manager: L. Carmichael
Fax ID: 7516

Development of Energy Management Strategies for Automated Real-Time Pricing: Control System Enhancements for Thermal Energy Storage and Modulating Building Loads

TR-105501 Final Report (WO2830)
Contractor: Honeywell Technology Center
Business Unit: Information Systems & Telecommunications
EPRI Project Manager: L. Carmichael
Fax ID: 24348

Case Study of an Ice Storage System With Cold Air Distribution and Heat Recovery

TR-105858 Final Report (WO3280-48)
Contractor: Dorgan Associates, Inc.
Business Unit: Commercial Technologies & Services
EPRI Project Managers: R. Wendland, M. Khattar
Fax ID: 24874

Dehumidification Performance of Air Conditioning Systems in Supermarkets: Field Demonstration With Heat Pipe Heat Exchangers in Delchamps Supermarket, Gulf Breeze, Florida

TR-106065 Final Report (WO3656-6)
Contractor: University of Colorado
Business Unit: Commercial Technologies & Services
EPRI Project Manager: M. Khattar
Fax ID: 25234

Dehumidification Performance of Unitary Rooftop Air Conditioning Systems: Kmart Demonstration

TR-106066 Final Report (WO3656-6)
Contractor: University of Colorado
Business Unit: Commercial Technologies & Services
EPRI Project Manager: M. Khattar
Fax ID: 25236

Development of a Microwave Clothes Dryer: Interim Report IV

TR-106246 Final Report (WO3417-1)
Contractors: Thermo Energy Corp.; ASTEX/Gerling
Business Unit: Residential Technologies & Services
EPRI Project Manager: J. Kesselring
Fax ID: 25543

Case Studies of Activity-Based Costing (ABC) Applications in the Electric Power Industry: Lessons Learned

TR-106526 Final Report (WO2343-21)
Contractor: Arthur Andersen Consulting
Business Unit: Retail Market Tools & Services
EPRI Project Manager: P. Sioshansi
Fax ID: 26030

The British Privatization Experiment, Five Years Later: The Winners and the Losers

TR-106528 Final Report (WO2343)
Contractors: London Business School; Competitive Electric Strategies, Inc.; Caminus Energy; St. Clements Services
Business Unit: Retail Market Tools & Services
EPRI Project Manager: P. Sioshansi
Fax ID: 26029

ENVIRONMENT

Epidemiologic Study of Electric Utility Workers Exposed to Magnetic Fields, Vols. 1 and 2

TR-105765-V1-V2 Final Report (WO2964-5)
Contractor: University of North Carolina
Business Unit: Environmental & Health Sciences
EPRI Project Managers: L. Kheifets, R. Black
Fax ID: 24726

Analysis of Uncertainties in the Regional Acid Deposition Model, Version 2 (RADM2), Gas-Phase Chemical Mechanism

TR-106433 Final Report (WO3189-6)
Contractors: University of Connecticut, Department of Civil Engineering; University of Colorado, Department of Mechanical Engineering; IFU Fraunhofer Institute
Business Unit: Environmental & Health Sciences
EPRI Project Manager: A. Hansen
Fax ID: 25899

GENERATION

Fate of Trace Elements in a 2000-MW Coal-Fired Power Station: PISCES Site 131 Field Chemical Emissions Monitoring Program Emissions Report

TR-105645 Final Report (WO3177-23)
Contractor: PowerGen
Business Unit: Environmental Control
EPRI Project Manager: P. Chu
Fax ID: 26604

Fly Ash Carbon Burn-Out at TVA's Colbert and Shawnee Stations: Site-Specific Application Study

TR-105825 Final Report (WO3497-1)
Contractor: Progress Materials, Inc.
Business Unit: Fossil Power Plants
EPRI Project Manager: T. Boyd
Fax ID: 24815

Residential Fuel Cells: Technology Readiness Assessment

TR-105832 Final Report (WO3934)
Business Unit: Gas & New Coal Generation
EPRI Project Manager: D. Rastler
Fax ID: 24824

New Bern Biomass-to-Energy Feasibility Study

TR-106062 Final Report (WO3407-30)
Contractors: Weyerhaeuser; Stone & Webster Engineering Corp.; Amoco; Carolina Power & Light Co.; U.S. Department of Energy
Business Unit: Renewables & Hydro
EPRI Project Manager: J. Turnbull
Fax ID: 25228

Inverted Draft Tubes to Improve Suction Performance of Vertical Pumps

TR-106266 Final Report (WO3456-1)
Contractor: University of Iowa
Business Unit: Fossil Power Plants
EPRI Project Manager: J. Tsou
Fax ID: 25580

Evaluation of the Modular Inclined Screen (MIS) at the Green Island Hydroelectric Project: 1995 Test Results

TR-106498 Final Report (WO3672-1)
Contractors: Stone & Webster Environmental Technology & Services; Alden Research Laboratory, Inc.
Business Unit: Renewables & Hydro
EPRI Project Manager: C. Sullivan
Fax ID: 25990

Demonstration of Ash Utilization in the State of North Dakota

TR-106516 Final Report (WO2422-13)
Contractor: University of North Dakota
Business Unit: Environmental Control
EPRI Project Manager: D. Golden
Fax ID: 26014

NUCLEAR POWER

Guidelines and Criteria for Nuclear Piping and Support Evaluation and Design, Vol. 10: Small Bore Piping Guidebook

TR-101968-V10 Final Report (WO2967-2)
Contractor: Duke Power Co.
Business Unit: Nuclear Power
EPRI Project Manager: H. Tang
Fax ID: 26503

The Influence of Microstructure on Environmentally Assisted Cracking of Alloy 718

TR-104927 Final Report (WO2181-5)
Contractor: Massachusetts Institute of Technology
Business Unit: Nuclear Power
EPRI Project Manager: L. Nelson
Fax ID: 23416

Evaluation of the EPRI Turbine Inspection System (ETIS)

TR-106040 Final Report (WO3148, WO2857)
Business Unit: Nuclear Power
EPRI Project Manager: J. Spanner
Fax ID: 25190

Development of a Solid-State Reference Electrode for High-Temperature Aqueous Environments Containing Hydrogen

TR-106602 Final Report (WO3173-2)
Contractor: SRI International
Business Unit: Nuclear Power
EPRI Project Managers: T. Passell, P. Millett
Fax ID: 26151

POWER DELIVERY

Location of Faults on Primary Distribution Systems With Multiple Tee or Y Connections

TR-106267 Final Report (WO3996-1)
Contractor: AT&T Bell Laboratories
Business Unit: Distribution
EPRI Project Manager: H. Ng
Fax ID: 25587

EPRI Engineering Calculator, Version 1.01: User's Guide

TR-106268 Final Report (WO3079-5)
Contractor: BSG Alliance/IT, Inc.
Business Unit: Distribution
EPRI Project Manager: H. Ng
Fax ID: 25589

Outdoor Aging of Polymeric Cable Terminations

TR-106322 Final Report (WO3356-1)
Contractor: Arizona State University
Business Unit: Distribution
EPRI Project Manager: B. Bernstein
Fax ID: 25686

Guidelines for Control Center Application Program Interfaces

TR-106324 Final Report (WO3654-1)
Contractors: Macro Corp.; Wisconsin Power and Light Co.; Southern Company Services
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: D. Becker
Fax ID: 25692

Fiber Distribution in Utility Customer Networks

TR-106353 Final Report (WO3567-1, WO3674-6)
Contractors: Ennis Associates; First Pacific Networks
Business Unit: Distribution
EPRI Project Managers: L. Carmichael, W. Blair
Fax ID: 25752

Assessment of FACTS Requirements on the PSE&G System: Subsynchronous Resonance Mitigation Options for the Pennsylvania–New Jersey–Maryland Interconnection

TR-106463 Final Report (WO3789-6, WO3022-2)
Contractor: General Electric Co.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: R. Adapa
Fax ID: 25945

Analytical Studies to Demonstrate Additional FACTS Technologies on the New York State Transmission System

TR-106464 Final Report (WO3789-3, WO3022-15)
Contractors: New York Power Authority; Power Technologies, Inc.
Business Unit: Substations, System Operations & Storage
EPRI Project Manager: R. Adapa
Fax ID: 25947

STRATEGIC R&D

Fuel Information Systems In a Changing Utility Business

TR-106636 Final Report (WO3611-6, WO4110-2)
Contractor: Resource Dynamics Corp.
Business Unit: Strategic R&D
EPRI Project Manager: J. Platt
Fax ID: 26200

EPRI Events

DECEMBER

12–13
CHECWORKS Users Group Meeting
Colorado Springs, Colorado
Contact: Denise Wesalainen, (415) 855-2259

12–13
Corrosion-Resistant Coatings Technology Workshop
Palo Alto, California
Contact: Andrea Duerr, (415) 855-2640

12–13
Reliability-Centered Maintenance Training Workshop
Orlando, Florida
Contact: Predrag Vujovic, (415) 855-2991

JANUARY 1997

5–9
1st World Congress on Microwave Processing
Lake Buena Vista, Florida
Contact: Eileen Mauro, (614) 421-3440

21–22
Plant Leak Reduction Working Group
New Orleans, Louisiana
Contact: Linda Suddreth, (704) 547-6141

28–31
Pressure Relief Valve Applications, Maintenance, and Testing
Orlando, Florida
Contact: Jeanne Harris, (800) 745-9982

29–31
Predictive Maintenance Program: Development and Implementation
Long Beach, California
Contact: John Niemkiewicz, (800) 745-9982

FEBRUARY

3–5
Air-Operated Control Valve Applications, Maintenance, and Diagnostics
Orlando, Florida
Contact: Jeanne Harris, (800) 745-9982

11–13
Fluid-Film Bearing Diagnostics
Long Beach, California
Contact: John Niemkiewicz, (800) 745-9982

13–14
Municipal Water and Wastewater Program Meeting
Santa Monica, California
Contact: Kim Shilling, (314) 935-8590

17–19
Substation Equipment Diagnostics Conference
New Orleans, Louisiana
Contact: Michele Samoulides, (415) 855-2127

19–21
Magne-Blast Circuit Breaker Users Group Meeting
Philadelphia, Pennsylvania
Contact: Linda Suddreth, (704) 547-6141

22–26
Environmental Concerns in Rights-of-Way Management
New Orleans, Louisiana
Contact: John Goodrich-Mahoney, (415) 855-5256

MARCH

2–5
EPRI EMF Seminar
New Orleans, Louisiana
Contact: Robert Kavet, (415) 855-1061

3–6
Intermediate Underground Transmission Course
San Antonio, Texas
Contact: Kathleen Lyons, (415) 855-2656

3–6
Power Quality Conference: PQA '97 North America
Columbus, Ohio
Contact: Lori Adams, (415) 855-8763

3–6
2d International Workshop on Corrosion in Advanced Power Plants
Tampa, Florida
Contact: Michele Samoulides, (415) 855-2127

18–21
Advanced Check Valve Monitoring and Diagnostics
Logan, Utah
Contact: Jeanne Harris, (800) 745-9982

24–27
Hydrogenerator Maintenance Course
Boston, Massachusetts
Contact: Denise Wesalainen, (415) 855-2259

25–27
1997 International Clean Water Conference
Baltimore, Maryland
Contact: Christine Lillie, (415) 855-2010

APRIL

14–16
Predictive Maintenance and Refurbishment
Florence, Italy
Contact: Susan Bisetti, (415) 855-7919

MAY

7–9
Midas Users Group Meeting
Phoenix, Arizona
Contact: Susan Marsland, (415) 855-2946

12–16
1997 Continuous Emissions Monitoring Conference
Denver, Colorado
Contact: Michele Samoulides, (415) 855-2127

19–21
Substation Reliability-Centered Maintenance
Dallas, Texas
Contact: Denise Wesalainen, (415) 855-2259

20–22
Effects of Coal Quality on Power Plants
Kansas City, Missouri
Contact: Susan Bisetti, (415) 855-7919

JUNE

10–12
5th International Conference on Cycle Chemistry in Fossil Plants
Charlotte, North Carolina
Contact: Michele Samoulides, (415) 855-2127

10–12
Predictive Maintenance Program: Development and Implementation
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

15–18
7th International ISA POWID/EPRI Controls and Instrumentation Conference
Knoxville, Tennessee
Contact: Susan Bisetti, (415) 855-7919

16–19
Power Quality Conference: PQA '97 Europe
Stockholm, Sweden
Contact: Lori Adams, (415) 855-8763

JULY

21–23
1997 International Low-Level-Waste Conference
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

23–25
EPRI/ASME Radwaste Workshop
Providence, Rhode Island
Contact: Michele Samoulides, (415) 855-2127

29–31
Fluid-Film Bearing Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (800) 745-9982

AUGUST

12–14
Cooling Tower Conference
St. Petersburg, Florida
Contact: Susan Bisetti, (415) 855-7919

25–29
SO_2/NO_x/Particulates/CEM Symposium
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

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EPRI JOURNAL

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