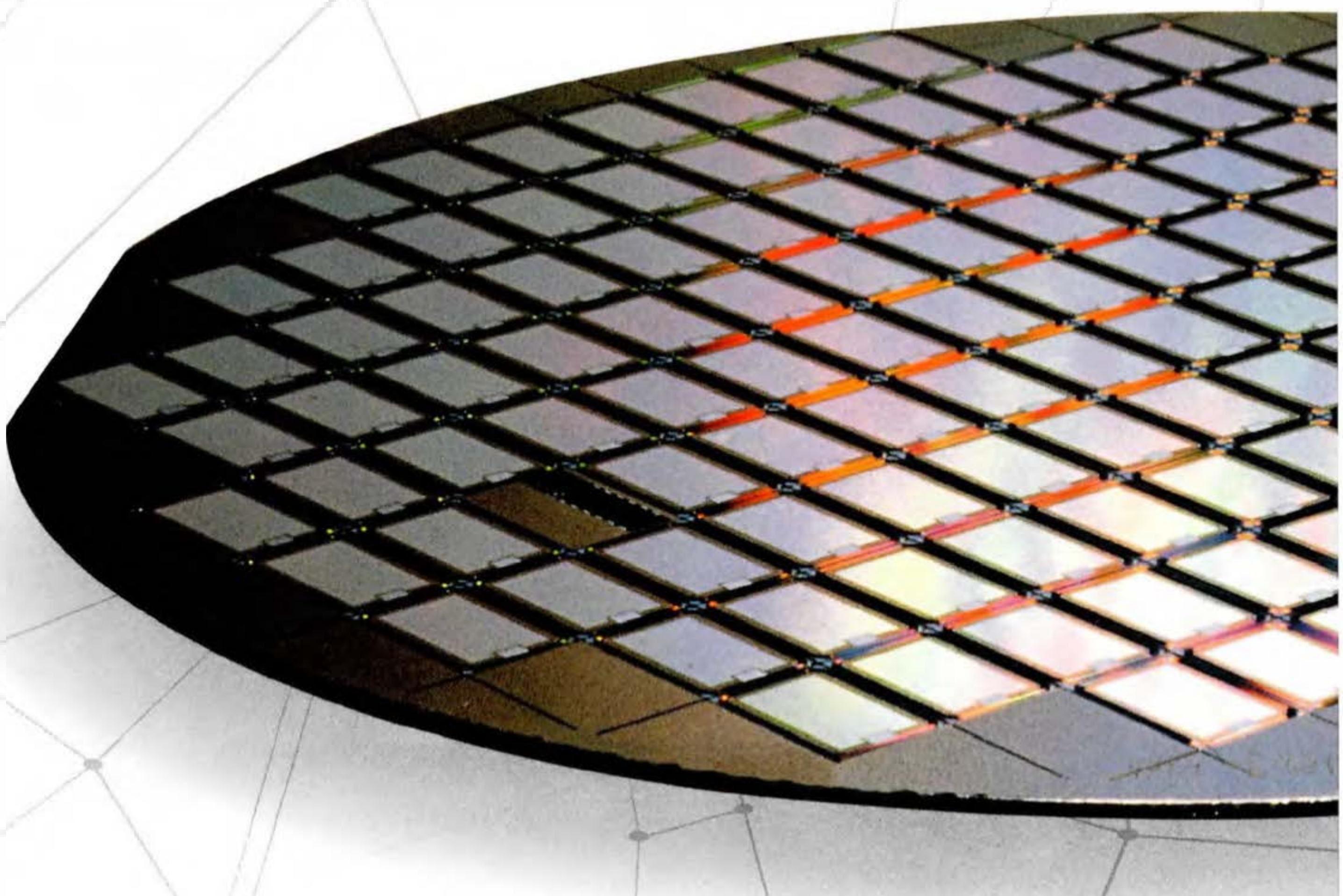
The Delivery System of the Future

Also in this issue • Risk Perception • Regional Air Quality

ELECTRIC POWER RESEARCH INSTITUTE

EPRI JOURNAL

OCTOBER/NOVEMBER
1992



EPRI JOURNAL is published eight times each year (January/February, March, April/May, June, July/August, September, October/November, and December) by the Electric Power Research Institute.

EPRI was founded in 1972 by the nation's electric utilities to develop and manage a technology program for improving electric power production, distribution, and utilization.

EPRI JOURNAL Staff and Contributors
David Dietrich, Editor
Taylor Moore, Senior Feature Writer
Leslie Lamarre, Senior Feature Writer
Susan Dolder, Technical Editor
Mary Ann Garneau, Senior Production Editor
Jean Smith, Staff Assistant

Brent Barker, Manager
Corporate Information

Richard G. Claeys, Director
Corporate Communications Division

Graphics Consultant: Frank A. Rodriquez

Address correspondence to:
Editor
EPRI JOURNAL
Electric Power Research Institute
P.O. Box 10412
Palo Alto, California 94303

Please include the code number on your mailing label with correspondence concerning subscriptions.

Cover: The thyristor—a solidstate switching device—is the basic building block for a family of electronic controllers that will revolutionize power transmission systems in the twenty-first century.

FACTS: Now, the Payoff

EPRI's pioneering efforts to create a new generation of control technologies for utility transmission systems are beginning to pay off. Three solid-state controllers developed as part of the FACTS (flexible ac transmission system) program are now being prepared for utility demonstration. In the short term, this means that EPRI members who have backed the development of FACTS technology will be the first to realize its benefits for increasing system capacity and directing power flow with unprecedented precision. Over the long term, FACTS will bring a revolutionary transformation to power networks around the world.

As this month's cover story points out, the widespread adoption of FACTS technology could save U.S. utilities tens of billions of dollars over the next few decades. Yet, as the current demonstrations show, the transition to higher-capacity, higher-reliability transmission systems can be smooth and gradual. New solid-state equipment will not immediately replace older, mechanical systems but rather will add new capabilities when and where they are needed most.

FACTS demonstrations are now under construction or detailed specification development at the Bonneville Power Administration, the Tennessee Valley Authority, and the Western Area Power Administration. These farsighted utilities have chosen to work closely with EPRI because of their own particular needs and visions of the future. But FACTS technology has also begun to attract worldwide interest, and hardware development activity that does not involve EPRI funding is growing.

These milestones may justifiably bring satisfaction to those researchers and utility sponsors who have worked for more than a decade to bring FACTS to fruition. But much more work remains to be done, and the pace of R&D must now accelerate. In addition to the three solid-state controllers now being prepared for utility service, three more are ready for immediate development and several others deserve careful consideration. EPRI is therefore reaching out to potential partners to join in a collaborative effort that can hasten these promising technologies to commercialization.

Narain G. Hingorani
Vice President, Electrical Systems

RESEARCH UPDATE

32 **Solid Oxide Fuel Cell Development**

Ongoing efforts to reduce the operating temperature of solid oxide fuel cells from 1000°C to about 700°C could make such systems economically competitive with other power-generating technologies.

34 **CAMRAQ: Comprehensive Regional Air Quality Modeling**

The Institute has fostered the formation of an international consortium whose goal is to develop comprehensive modeling systems for the analysis of ozone concerns, acid rain, and other regional air quality issues.

38 **CAES Geology**

EPRI has developed a methodology for identifying, screening, and ranking potential compressed-air energy storage sites, along with a process for cost-effectively matching aboveground turbomachinery to subsurface storage conditions.

41 **C^2ALM: Control Center Advisor for Load Management**

A prototype expert system for optimizing interruptible rate decisions is helping dispatchers at New England Electric System plan load interruptions for maximum benefit.

43 **Ultrasonic Pipe Simulator**

Nuclear component inspectors can now demonstrate their skills on an ultrasonic pipe simulator that enables playback of prerecorded ultrasonic data gathered from a representative pool of component samples with well-characterized defects.

12 Ashley Brown

20 Risk Perception

DEPARTMENTS

30 **Tech Transfer News**
45 **New Contracts**
47 **New Technical Reports**
50 **New Computer Software**
51 **Events**
52 **Contributors**

EPRI JOURNAL

Volume 17, Number 7 October/November 1992

EDITORIAL

FACTS: Now, the Payoff

COVER STORY

4 **The Delivery System of the Future**

Based on advanced solid-state controllers, the flexible ac transmission system—FACTS—promises to truly transform the nation's power delivery system in the coming decades.

FEATURES

12 **Ashley Brown: Seeing the Prudence of Risk**

An Ohio utility commissioner and EPRI advisor believes that applying new electricity technology may be less risky than avoiding it.

20 **What Are You Afraid Of?**

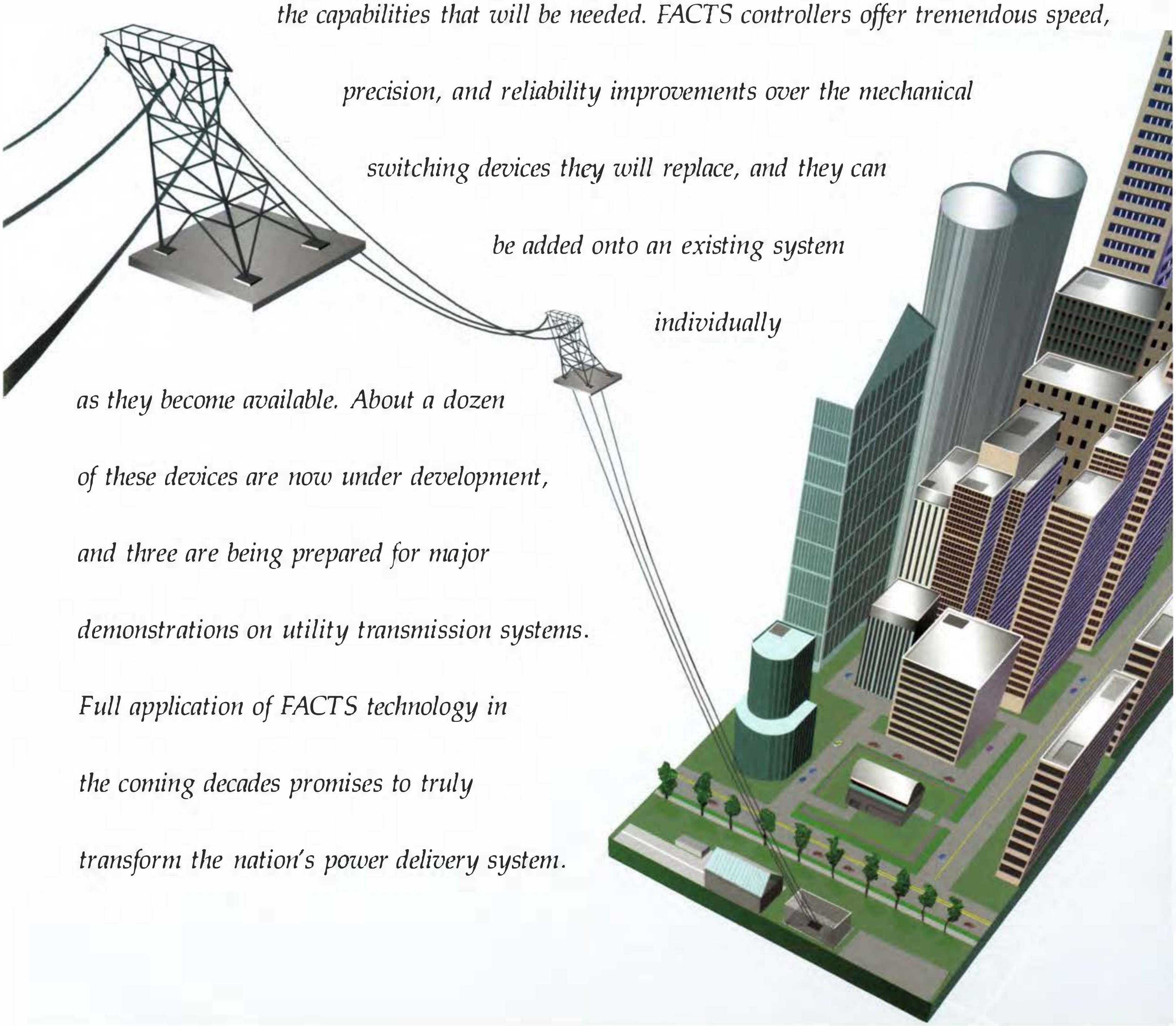
Utilities and other organizations that manage risk are seeking to better understand how the public perceives risk and to incorporate these factors into their communications and decision making.

4 FACTS

The Delivery System of the Future

BY JOHN DOUGLAS

THE STORY IN BRIEF *The demands of the twenty-first century, with increased growth and interconnection of power grids, will stretch existing delivery systems to their limits and create new requirements for flow control, system stability, and capacity enhancement. Flexible ac transmission systems (FACTS), based on advanced solid-state controllers, incorporate the capabilities that will be needed. FACTS controllers offer tremendous speed, precision, and reliability improvements over the mechanical switching devices they will replace, and they can be added onto an existing system individually as they become available. About a dozen of these devices are now under development, and three are being prepared for major demonstrations on utility transmission systems. Full application of FACTS technology in the coming decades promises to truly transform the nation's power delivery system.*



AFTER MORE THAN A DECADE OF EFFORT, a new generation of electronic power control devices is about to enter utility service, with the promise of revolutionizing ac transmission. Since the earliest days of electric power, engineers have wrestled with a basic conundrum: although high-voltage alternating current facilitates low-loss transmission over long distances, it is difficult to control. The new devices, which utilize large solid-state switches called thyristors, will help utilities increase transmission system capacity while reducing susceptibility to power disturbances and enhancing the control of power flow. With EPRI funding, three kinds of thyristor-based controllers are now being incorporated into utility demonstration facilities.

In high-power applications, thyristors enjoy two great advantages over the mechanical devices—circuit breakers, transformer tap changers, shunt capacitor switches, and the like—that now control the ac power system. First, they are much faster than the alternatives and can redirect power in a fraction of a cycle. As a result of this high-speed control capability, these devices will be able to perform functions, such as counteracting transient disturbances on a transmission line, that could not even be contemplated with mechanical controllers. Second, mechanically switched devices tend to wear out and thus are generally operated sparingly. For example, a transformer used to compensate for shifting load is generally limited to less than a dozen motor-driven tap changes a day—with a full-range variation requiring more than a minute to complete. Thyristor-based controllers, on the other hand, can switch power twice each cycle without wear.

Thyristor controllers can provide unprecedented opportunities to regulate ac transmission, increasing or decreasing power flow on specific lines as desired and responding almost instantaneously to nascent stability problems. The result, known as a flexible ac transmission system (FACTS), will enable utility networks to operate like giant integrated circuits—to be more highly automated, self-correcting, reliable, and productive. In addition, greater flexibility will mean that utilities can operate their transmission systems closer to inherent thermal limits (the point at which lines literally become hot enough to sag too much) rather than adhering to the lower rating on many lines imposed by concerns about system stability or about overloading one of the parallel paths. A typical 500-kV line, for example, might have a rating of 1000 MW, compared with a 3000-MW thermal limit.

The potential economic benefits of increased loading of existing transmission lines are both varied and substantial. In the first place, building new lines can be much more expensive than upgrading existing lines—if new ones can be built at all in the face of mounting environmental opposition and the difficulty in obtaining new rights-of-way. Using an average cost for new lines of $500,000 per mile, increasing U.S. transmission (230–765 kV) by using FACTS technology could save utilities more than $6 billion in avoided construction costs per 10% average capacity increase. Such an increase can occur only over a long time, but in the next few years utilities are expected to begin using FACTS controllers to increase the capacity of specific lines by as much as 100% to meet rising demand. In many cases, though, it may be necessary to combine the application of FACTS technology with the upgrading of existing lines or the construction of new lines.

Large savings can also be realized from reduced generation reserve margins—the generating capacity needed to serve as backup rather than to meet actual demand for electricity. By using FACTS controllers to strengthen transmission ties between various control areas and power pools in the country, utilities can share generation reserves more productively and may thus be able to reduce reserve margins from the current level of 20% of total capacity to 15% by 2020. Assuming 1.5% annual load growth, such a reduction would mean that about 45 GW of new generation would not have to be built, representing avoided-cost savings on the order of $50 billion.

"Today's transmission systems are being asked to do things for which they were never designed," says Narain Hingorani, EPRI's vice president for electrical systems. "Bulk power transactions between utilities are increasing rapidly at the same time that independent power producers are demanding access to the utility transmission networks. FACTS will help ease the potential risks to system integrity and the inefficiencies that can result from these competitive forces. Already, with the demonstrations of FACTS technology now getting under way, we can begin to address some of the bottlenecks. As FACTS evolves and penetrates further into the system, utilities will increasingly reap the economic advantages of avoided line construction costs and reduced generating margins. I predict that in the long run FACTS will revolutionize the North American power system, with electricity flowing through thyristor devices several times before delivery to customers. The transmission system will be utilized to its full potential, power will flow along the desired routes, and power system outages will be prevented from spreading to wider areas."

B E N E F I T

Flow Control FACTS technology offers unparalleled control of power transmission. By increasing or decreasing flow on specific lines, utilities can tailor delivery strategies to best utilize their systems and reduce problems associated with loop flow.

The challenge of ac power control

The speed and precision of FACTS devices provide new ways to solve some inherent problems of ac power control. In a complex transmission network, ac power flows between a power plant and a load center over numerous lines, not just the most direct, "contract" path. This phenomenon, known as loop flow or parallel path flow, represents a costly nuisance for utilities whose lines are affected even though they are not parties to the intended transaction. More seriously, ac transmission systems are subject to a variety of disturbances that may cause instabilities, ranging from a temporary surge caused by a lightning strike to low-frequency oscillations that may contain enough energy to twist a generator shaft.

Controlling an ac power system is complex. Because of constantly changing electric and magnetic fields, the movement of current along a line is influenced not only by the line's resistance but also by the presence of inductance and capacitance; the combined influence of these three is called impedance. Also, in ac transmission, power flows from the end of the transmission line with leading voltage to the end with lagging voltage; the magnitude of power increases with the degree of leading, called phase angle. To increase power flow on a line, one can either raise the voltage or phase angle or lower the line's impedance.

A major thrust of FACTS is to develop devices that control the flow of ac power by changing the impedance of a transmission line or the phase angle between the ends of a specific line.

Two other inherent problems also confront ac transmission system designers and operators. The first is that the energy required to maintain the electric and magnetic fields associated with power lines and equipment must be supplied by reactive power (the unit of measurement for which is the volt-ampere reactive, or VAR). Sometimes called the cholesterol of power systems, reactive power may overload lines, create losses, and result in voltage sags. To reduce these problems, some FACTS devices are being designed to control the flow of reactive power; this approach is commonly known as providing VAR compensation for a line.

The other inherent problem is that ac networks are subject to a variety of instabilities—transient and dynamic instabilities, for example, and subsynchronous resonance (SSR), in which the movement of current involves additional frequencies below the fundamental 60 Hz. Subsynchronous oscillations may carry considerable energy and exert potentially destructive torque on moving equipment, such as generators, if they couple with the mechanical frequency of the equipment. Because of their speed, various FACTS devices will be used to damp transmission system instabilities in addition to performing their other functions.

What might be called the first generation of FACTS controllers includes two thyristor-based devices that have found limited use on utility systems for several years. The first, a static VAR compensator (SVC), has been used since the mid-1970s and addresses the problem of maintaining voltage within acceptable limits on long, heavily loaded lines. When large inductive loads, such as industrial motors, come on-line far from the power source, voltage may sag abruptly. Later, as the load lightens, voltage may increase too much. The addition of shunt capacitance helps support the voltage in such cases, while shunt inductance holds it down. SVCs use thyristor control to add such shunt reactors or capacitors as needed. The first SVC demonstrating voltage and stability control for a utility transmission system was developed with EPRI funding and began operation in 1978 on the Minnesota Power & Light system, providing support to a 115-kV line supplying large motor loads at a taconite grinding mill. The main drawback of SVCs is that if voltage falls too low—that is, when support is needed most—their effectiveness diminishes.

The second existing FACTS controller is the NGH-SSR damper, invented by EPRI's Narain G. Hingorani to counteract subsynchronous resonance. Such SSR instabilities can arise as an undesirable side effect of adding series capacitors to a transmission line to lower its impedance and increase power flow. During the early 1970s, after the shaft of a turbine generator belonging to Southern California Edison was damaged by SSR, series compensation on a major 500-kV transmission system had to be reduced, resulting in lower power transfer capability. The first NGH-SSR damper, designed by Siemens, was installed on this system in the mid-1980s. It proved capable of restoring some power transfer capacity by introducing thyristor switches to bypass part of the current wave from the series capacitors when SSR was present. This thryistor-controlled switch, with series inductor and resistor, was the first installation to demonstrate the change of series capacitor impedance by sustained operation of the switch at less than 180° and the first to demonstrate protection, bypass, and reinsertion of a series capacitor. It was, in fact, the forerunner of the latest designs of the most important new controller, the thyristor-controlled series capacitor (discussed below).

Second-generation FACTS

Now, with advances in thyristor capabilities, a second generation of FACTS con-

B E N E F I T

Stability Protection The incomparable speed of thyristor switching enables FACTS controllers to counteract transient disturbances on lines almost instantly. And because the devices are solid-state, their reliability is far better than that of mechanical switches.

trollers is beginning to emerge. About a dozen thyristor-based devices have been identified as having potential to improve the performance of ac systems; six are being considered for development as part of EPRI's proposed 10-year collaborative R&D plan for FACTS. Three of the new controllers are now being prepared for utility demonstration.

The thyristor-controlled series capacitor (TCSC) provides a way to increase the flow of power on selected lines without having to worry about the stability problems previously associated with series capacitors. The quick response of thyristors enables the TCSC to quickly dampen power swings and thus permit increased power transfer over lines that are now stability-limited. This second-generation FACTS device, which is based on conventional thyristors and which incorporates an enhanced NGH-SSR damping control function, will greatly improve power flow control.

EPRI conducted a TCSC feasibility study for a fictitious but representative long radial transmission system limited to 2000 MW by transient stability concerns (i.e., concerns about severe reactions that occur within seconds after a fault). The study showed that the application of a TCSC could increase the power transfer to 3000 MW. In this case, the TCSC was estimated to cost $16 million and it was projected to yield an annual benefit of $51 million—for a payback period of only four months.

A second TCSC study involved power transfer across a key interface in a complex network, currently limited to 5000 MW by concerns about dynamic stability (i.e., the system's sensitivity to changes in operating conditions). The addition of a TCSC capable of modulating capacitance by 28% would make it possible to increase power transfer to 6200 MW while maintaining system stability. The estimated cost of the TCSC was $47 million, and it was projected to produce an annual benefit of $68 million—resulting in a payback period of less than 9 months.

A second FACTS controller is the static condenser (STATCON), which is a shunt compensation device that can provide VAR support to maintain voltage on long, heavily loaded lines while simultaneously enhancing system stability. The STATCON is the first FACTS device to require gate-turnoff (GTO) thyristors for its operation. With its GTO thyristors and a small energy-storing capacitor, the STATCON exchanges VARs between phases of a transmission circuit by absorbing energy for part of a cycle and then returning it at another part.

Sometimes referred to as an advanced static VAR compensator, the STATCON actually has very different operating characteristics than SVCs, which it will probably replace. Most important, because the VAR output of a STATCON is more independent of voltage over a wide range, the device's performance does not degrade with sagging voltage as much as that of an SVC does. In addition, STATCON response is faster than SVC response, and there is an option to add significant energy storage capability, which could compensate temporarily for even complete outages on a power system.

The third FACTS controller is the thyristor-controlled phase-angle regulator (TCPR), designed to modify the phase angle between the two ends of a transmission line by injecting a variable voltage in series with the line. The effective phase shift is approximately proportional to the magnitude of the injected voltage. A TCPR added to a line could be used either to enhance or to reduce power flow on that line, thus counteracting loop flow. The speed of TCPR response means that it can also improve the transient stability of a transmission system and damp other oscillations, such as SSR.

"These three basic controllers fit into power systems in different, complementary ways, and we need all three of them," says Stig Nilsson, a program manager in the Electrical Systems Division. "Together with other FACTS controllers that will come later, they can help optimize the economy of the whole power system. The beauty is that utilities can add these devices piecemeal, as needed, rather than having to initially overbuild in anticipation of future growth, as is often the case when adding new transmission lines."

B E N E F I T

Increased Capacity FACTS controllers allow transmission lines to be loaded closer to their thermal limits, in some cases actually doubling their capacity. This can significantly reduce the need for building new lines.

Utility demonstrations

The first of the new FACTS controllers to be demonstrated on a utility transmission system is the thyristor-controlled series capacitor. In 1991 American Electric Power began testing a thyristor control switch on one phase of a series capacitor bank at its Kanawha River substation in West Virginia. The Western Area Power Administration is also testing a TCSC system, which was built by Siemens and installed at WAPA's Kayenta substation in Arizona. This system is located at the midpoint of a 200-mile, 230-kV line and increases power transfer on the line by 100 MW. Under EPRI sponsorship, construction of the largest TCSC installation, which will feature a full range of controls, began this year on a 500-kV transmission line at the Slatt substation of the Bonneville Power Administration (BPA), in northern Oregon. General Electric is developing the TCSC technology, including special 100-mm-diameter thyristors, and is constructing the field installation. Testing is scheduled to begin in the second quarter of 1993.

The Slatt site was chosen particularly for its suitability for demonstrating system control—including power flow scheduling, SSR damping, and stability enhancement—and as a location where equipment performance could be evaluated under high-stress conditions, such as high fault currents. Portland General Electric is also participating in this project by allowing one of its generator units to be used in tests of the TCSC's ability to damp SSR. By regulating power flow on parallel lines, the Slatt TCSC will enable BPA to reduce line losses during periods of heavy utilization, which often occur in the spring.

"This TCSC demonstration is the flagship of FACTS," project manager Ben Damsky declares. "Conditions at the host site are typical of the highest stress levels expected on North American transmission systems, so the adequacy of the design can be well tested. We expect that this type of TCSC will become commercially available sometime in late 1993 or early 1994, following the Slatt demonstration."

The first domestic demonstration of the STATCON on a utility transmission system is being prepared under EPRI sponsorship at the Sullivan substation of the Tennessee Valley Authority (TVA), in northeastern

The Evolution of Thyristors

FACTS has been made possible by the continuing development of thyristors with higher power-switching capacity. The original thyristor, sometimes called a silicon-controlled rectifier, was invented in the early 1960s at General Electric as a high-voltage counterpart to the transistor. Constructed with four silicon layers—instead of three, as in a transistor—the conventional thyristor is a one-way switch that conducts when a turn-on pulse is sent through its gate layer but can be turned off only when current returns to zero at the end of a cycle. Such thyristors currently constitute the bulk of solid-state control devices for utility-scale power applications, including high-voltage dc converters and some early FACTS controllers. Advanced thyristor wafers are nearly 6 inches in diameter, and they have a peak switching capacity of about 25–30 MW. Many individually packaged wafers are stacked to form devices that can control power in the thousands of megawatts.

Some newer FACTS controllers, however, must be able to interrupt current in mid-cycle, and thus they require a gate-turnoff (GTO) thyristor. Such devices have been commercialized and are finding increased use in applications like variable-speed motor drives. Advanced GTO thyristors have a peak switching capability of about 15 MW, and there have been a few utility demonstrations of GTO technology. GTO thyristors, however, are more costly and have inherently higher losses than conventional thyristors, so considerable research is under way to find a more efficient substitute.

Small electronic devices, such as digital watches, depend on metal-oxide-semiconductor (MOS) integrated circuits for their high speed and low energy losses. Now, with coordinated funding from various sponsors, including EPRI, such integrated circuits are being incorporated into the top layer of thyristors to turn them on and off. The first commercial MOS-controlled thyristor (MCT), recently introduced, has a peak switching capacity of 120 kW, which makes it suitable for industrial applications. MCTs with the capacity required for utility use (2–4 MW) are expected to become available by around 1997. Although no FACTS devices have yet incorporated MCTs, this technology will probably replace GTO thyristors once it becomes available. In addition to reducing losses, the MCT is able to take advantage of a new type of packaging that could make it much less bulky and expensive than a GTO thyristor. ■

TCSC: Thyristor-Controlled Series Capacitor

What it does: *Allows increased power flow on selected lines*
How it does it: *Changes line impedance*
Technology developer: *General Electric Company*
Thyristor type: *Conventional thyristor*

Demonstration site: *Slatt substation, northern Oregon*
Host utility: *Bonneville Power Administration, with assistance from Portland General Electric Company*
Demo startup: *Spring of 1993*
Expected commercial availability: *1993–1994*

Tennessee. Rated at 100 million volt-amperes reactive (MVAR), this unit is being developed and installed by the Westinghouse Science and Technology Center and is scheduled to go on-line in 1995. Following on EPRI-sponsored design work, an experimental, 1-MVAR STATCON was installed in 1986 by ESEERCO at Orange and Rockland Utilities to demonstrate the feasibility of using GTO thyristors at high power levels. Other STATCON demonstrations at lower ratings have also been reported, but these are based on more-costly converter concepts.

The Sullivan site was chosen because it is one of the few locations on the TVA system that can utilize the full range of reactive power output—both capacitive and inductive—from the prototype STATCON. One bus at the substation tends to experience low voltages during peak load conditions, while another experiences high voltages during light load conditions. In addition, this location provides an opportunity to investigate the ability of the STATCON to damp power oscillations that are expected to appear.

In day-to-day operation, the Sullivan STATCON will be used to regulate voltage during load buildup so that the tap changer on a transformer bank can be used less often. This action, which is not the main purpose of the STATCON installation, is expected to extend the life of the transformer bank significantly. During major disturbances, such as loss of the transformer bank during winter peak conditions, the STATCON is designed to respond rapidly and maintain voltage until conventionally switched shunt capacitors at other substations can be brought on-line—thus preventing a voltage collapse that could affect the general area. Without the STATCON, TVA might have to construct another transmission line into the area.

Commercialization of this STATCON technology is expected to follow the Sullivan substation demonstration, perhaps by late 1995. A second phase of STATCON development by EPRI—including the addition of significant energy storage capability and the capability to supply or absorb real power as well as VARs—is also planned. Demonstration of this advanced STATCON is expected during the latter half of the decade. Separately, these STATCON developments will be adapted for use on distribution systems, as part of EPRI's research on custom power.

Demonstration of a thyristor-controlled phase-angle regulator is being considered by various utilities, although a host site has not yet been selected. Two major options are currently under consideration. In the first, EPRI and WAPA are developing specifications for a retrofit TCPR that would augment mechanical tap changers on transformers, providing faster response and reducing changer wear. Three versions are being evaluated, one each from General Electric and Westinghouse and a third that is being designed by ABB Italy (with cofunding from ENEL, the Italian electric power research organization). Prototype demonstration of one of these concepts is expected by the end of the decade.

At the same time, the development of a new TCPR product is being studied by EPRI and Minnesota Power. This device, which would be able to derive maximum benefit from the use of thyristors, is expected to have a high-speed phase-shifting capability of 30° on a 230-kV line. The research objective is to begin field tests on the new product in 1996.

One possible site for a retrofit TCPR is WAPA's Liberty (Arizona) phase-shifting transformer, which helps control the flow

STATCON: Static Condenser (Shunt Compensator)

What it does: *Provides VAR support to maintain voltage on long, heavily loaded lines while enhancing system stability*
How it does it: *Exchanges VARs between phases of a transmission circuit by absorbing energy for part of a cycle and returning it at another part*
Technology developer: *Westinghouse Science and Technology Center*
Thyristor type: *Gate-turnoff thyristor*

Demonstration site: *Sullivan substation, northeastern Tennessee*
Host utility: *Tennessee Valley Authority*
Demo startup: *1995*
Expected commercial availability: *Late 1995*

of power to southern California from power plants in adjacent states. This transformer provides the largest power flow control per degree of phase shift within the Western Systems Coordinating Council area, and the addition of thyristor control could increase the system's capability of transferring power to California by 200 MW or more, depending on the design.

A proposed tie between Minnesota Power and Ontario Hydro—in International Falls, Minnesota—is a site that has been studied for the application of the new TCPR product. Currently the transmission systems of these utilities do not have a link, and preliminary studies show that a 150-MW tie would be economically attractive. However, because of transfers across the U.S.-Manitoba border nearby, serious voltage swings might limit power flow on the proposed tie to 100 MW. The addition of a TCPR would solve this voltage problem and enable the new line to reach its thermal rating. In addition, the International Falls TCPR would help damp power oscillations that sometimes occur in this region, as well as improve the U.S.-Manitoba interface.

Other elements of FACTS

EPRI is also planning the development of three additional FACTS controllers, and more may be added as the need arises.

The thyristor-controlled braking resistor (TCBR) is intended to serve as a compact, low-cost alternative to the mechanically switched braking resistors now in use. Installed near power plants, braking resistors prevent excessive acceleration of generators following loss of load on their transmission lines. With the addition of thyristor switches, these resistors will also be able to damp oscillations on the power system following transient disturbances. Completion of TCBR prototype development is expected before the year 2000.

A thyristor-controlled series reactor can be used on transmission lines that require rapid load reduction or limiting of fault current. It could also complement a TCSC in situations where higher inductive series compensation is required. In such applications, the use of these devices together may in some cases provide a lower-cost alternative to a phase-angle regulator. Design of the series reactor is scheduled to begin in the mid-1990s, after further study of potential control strategies and ways of minimizing hardware costs.

A thyristor-controlled voltage limiter can protect utility equipment from overvoltages and thus permit system operation that would not otherwise be possible. (Overvoltages may result, for example, from capacitor switching or from the dropping of a large load from a heavily compensated line.) A low-power version of this device was recently installed by New York State Electric & Gas on a thyristor-switched shunt capacitor, and design of a high-power version is scheduled to begin in the mid-1990s.

In order for these FACTS controllers to perform effectively, a variety of software advances must be made concurrently. To evaluate system response, utility planning and design engineers need analytical tools that incorporate models of thyristor-based devices. So far, models of the TCSC, STATCON, TCPR, and TCBR have been incorporated into key EPRI power system codes. These models will be refined as demonstration programs and application studies progress. In addition, performance models for other FACTS controllers will be developed.

As FACTS controllers are increasingly deployed on power systems, operators at dispatch centers will have to learn how to use them effectively for enhancing system security and handling more bulk power transactions. Specifically, operators will need computerized decision support tools capable of rapidly analyzing complex alternatives so that they can adjust the response mode and dynamic settings of FACTS controllers for changing system conditions. Although the high-speed response of FACTS controllers will remain automatic, some integrated control from a dispatch center will be needed to ensure that the devices do not counteract each other.

"FACTS represents a fortunate convergence of technological opportunity and utility necessity," says Karl Stahlkopf, director of the Electrical Systems Division. "Thyristors embody the second silicon revolution—they are the high-power equivalent of integrated circuits and electronic intelligence. Thyristor-based controllers will make possible a smarter power system just as the system faces unprecedented demands for bulk transfers and third-party access. EPRI's work over the last decade has made FACTS possible. Now, as a new group of FACTS devices approach utility demonstration, we're reaching out to potential cofunders in hopes of accelerating this revolution through an international collaborative R&D effort." ■

TCPR: Thyristor-Controlled Phase-Angle Regulator

What it does: *Shifts power flow between parallel lines to counteract loop flow*
How it does it: *Injects a variable voltage in series with a line to increase or decrease power flow*
Technology developer: *To be determined*
Thyristor type: *Conventional thyristor*
Demonstration site: *To be determined*
Host utility: *Discussions proceeding with the Western Area Power Administration and Minnesota Power*
Demo startup: *Mid-1990s*
Expected commercial availability: *Late 1990s*

Background information for this story was provided by Narain Hingorani, Karl Stahlkopf, Stig Nilsson, Ben Damsky, Neal Balu, and Harshad Mehta of the Electrical Systems Division.

by Ralph Whitaker

ASHLEY BROWN WORKS FOR AN INSTITUTION, coordinates the efforts of a larger network of institutions, and addresses an unending stream of heavily institutional problems. For nearly 10 years he's been a member of the Ohio Public Utilities Commission (PUC). It's an energetic and sophisticated regulatory body, and Brown's experience there has drawn him into nationally visible responsibilities with the National Association of Regulatory Utility Commissioners (NARUC).

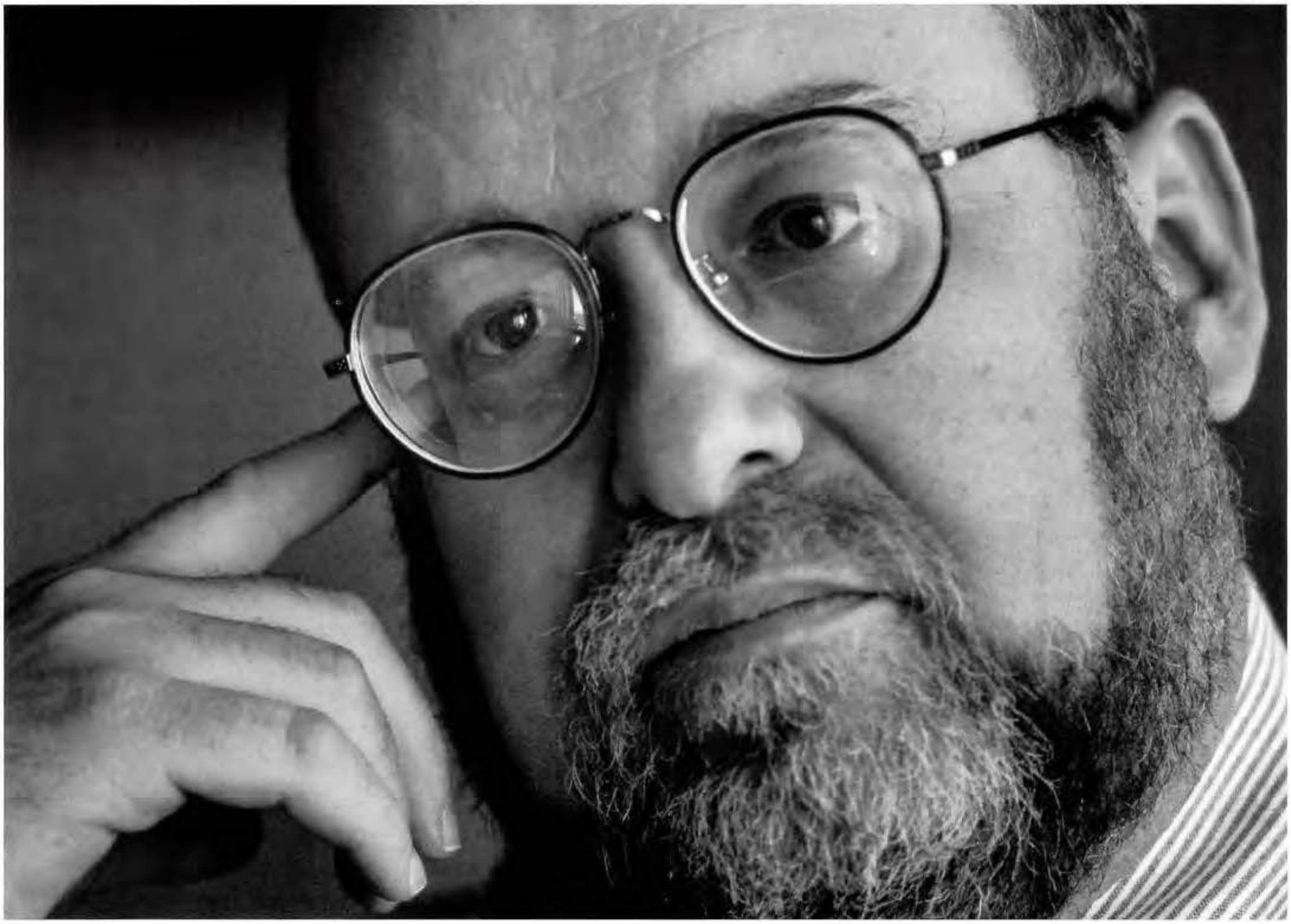
In particular, he chairs NARUC's Electricity Committee and sits on the board of its National Regulatory Research Institute. Both positions engage him in the varied conflicts that arise out of new power technologies, changing economic conditions, and different management practices—not to mention the varied laws of the 50 states.

But Brown always carries with him the sense of a dictum from Senator Hubert Humphrey, Minnesota's "happy warrior" on the national political scene 25 years ago. "You judge governmental institutions," Brown paraphrases, "by how they treat the least powerful and least influential among us." The philosophy unwaveringly brightens his daily work in regulation. "Do I enjoy what I do?" he asks rhetorically. "I love it. As a friend once told me, 'Appointing you to the PUC is like giving a kid free access to the candy store.'"

Small wonder that Brown became one of seven utility regulators named by NARUC to EPRI's Advisory Council. Members of the Council engage in give-and-take with EPRI's top executives, review the Institute's plans and budgets, and comment on its management of research and development, all with an eye to how EPRI's work "fits" their perceptions—individually or collectively—of U.S. energy

ASHLEY BROWN: Seeing the Prudence of Risk

He studied history to understand social change, then law to learn how it can be guided. Now an Ohio utility commis-



sioner, a national figure in electricity regulatory matters, and a member of EPRI's Advisory Council, Brown concludes that developing and applying new technology can be more prudent—less risky—than avoiding it.

needs. The Council's advice is far from monolithic; Brown and his colleagues are some two dozen men and women drawn from various U.S. professions, economic sectors, and areas of public interest, among them today education, science, law, finance, civil rights, manufacturing, conservation, and medicine.

Learning to question

Ashley Brown, like everybody else, is a creature of time and place, only perhaps a little more obviously so. He was born in 1946 and raised in Cincinnati, an emphatically conservative bastion, where his lawyer father specialized in defending First Amendment cases. "In his time, my father probably represented more unpopular causes than anyone in the city," Brown declares.

He reminisces of the irony that Charles Keating, recently embroiled and brought down in the nation's savings and loan scandal, was once "the chief opponent of obscenity in Cincinnati, while my father was regularly painted by the press as a guy defending smut dealers. I also remember," he adds, "a couple of classes at school where my teachers didn't appreciate what he was doing."

Brown doesn't offer any straightforward characterization of his childhood home life, because his mother was progressively disabled by multiple sclerosis. "It was difficult to have a routine in those circumstances," as he puts it, and from elementary school years on, Ashley and his younger brother and sister were raised mostly by their father. "But my father's family all lived in Cincinnati at the time, and they—aunts and uncles too—were a very close extended family."

Also, Brown's father used his own career and reputation as a home-teaching tool—which probably helped keep the children in line. As Brown tells it, "There was always a lot of questioning. It was encouraged. Nothing was taken for granted. All of us became a little rebellious, but it wasn't against our parents; it was through our activity in things like the antiwar movement." He was thus well rehearsed when social change came to center stage during the 1960s—and he would accept at least occasional roles.

But Brown's high school years were mostly a positive challenge. He attended a "magnet" college preparatory school, intellectually elite and ethnically diverse, drawing from the whole city; and he assumed he'd go straight on to college and become a lawyer. Indeed, he entered Bowling Green University in the fall of 1964.

But life there accelerated the questioning. Brown and his peers felt, figuratively at least, that they were near where "the center of social change was going to be." The perception led him to change his major from law to education; he would do graduate work in history and thereby have a better lens through which to study society's patterns of cause and effect. Then, through teaching, perhaps he and others could unravel those patterns and weave constructive change.

Of that time and decision Brown recalls feeling that he was "the only kid in college during the sixties who went home and listened to his father tell him how conservative he was!" By his own account, however, he was pushing here and there: active in war protests, challenging Bowling Green's admissions policies where data suggested that black students were being discouraged. Also, events in his senior year were pivotal.

This was the spring of 1968, the highly charged Democratic campaign season after Lyndon Johnson withdrew from presidential contention. First came the death of Martin Luther King, Jr., "one of my heroes," Brown readily admits. "I'd been in civil rights marches, back in high school and also while I was in college." The assassination of Robert Kennedy two months later hit Brown especially hard because, as a campaigner for Eugene McCarthy, he was closely tracking Kennedy's run for the presidential nomination. Graduation was not the usual celebratory event.

Choosing for social change

Brown had been accepted for graduate school and his planned study of history, but the sweep of events turned him toward a more immediate service opportunity, the Peace Corps. He even drew an assignment that matched his stated preference: university teaching in northeastern Brazil. But just when he was expecting specific travel instructions, the Peace Corps telephoned him with the astonishing and devastating news that "we're disinviting you."

After nearly 25 years, Brown's sharply worded description is telling. "I didn't find out why," he goes on, "until eight or nine years later, after the Freedom of Information Act had passed. I sent for my file and found they were trying to weed out people opposed to the Vietnam War. That's sort of unfathomable—who did they expect to get?"

Brown's opinions aside, military service wasn't even an option for him, much less a threat. A minor impairment put him well down the draft priority list. And graduate school was no longer an automatic choice, because Brown had conscientiously turned down his earlier acceptances. But fast networking among family friends turned up a suddenly vacant teaching assistantship at the University of Cincinnati. "The only thing I had to change was my specialty. Cincinnati had no courses in Latin American history, so I wound up with a master's degree in Afro-American history. Timewise, though, I didn't miss a beat."

Married a year and a half later, at the end of 1969, Brown finished his master's thesis in 1971 and was off to New York University for his doctorate. For two years it was full-time school and part-time teaching; then, almost the opposite. But

Brown found a disappointingly slack market for history teachers, and his dissertation moved to the back burner. He was a social worker at Harlem Hospital for a year, then an elementary school teacher in East Harlem and, still later, in the South Bronx.

It was career decision time again, and this time law won. Ashley and Susan Brown returned to Ohio, where he entered the University of Dayton law school with the plan of joining his father's practice in criminal law and civil liberties. But once more, alternatives turned in his mind. Perhaps symbolic of pending change, Brown's first daughter joined the family in 1977 just a week before he took the bar examination.

By then he had thought it through, starting with his heroes in the law, who included Thurgood Marshall and Clarence Darrow—and his own father. "I knew I didn't want to be a corporate lawyer," he says emphatically. "My focus was on the guys who were willing to take up social change, who saw the law as a process for progress in society, for channeling social change—guys who were using the law to accomplish positive, beneficial social ends."

In retrospect, it thus seems almost preordained that Brown should enter public service. He did exactly that, working successively as legal advisor, staff attorney, and counsel for three Dayton-area public and quasipublic bodies during the next six years. Each affiliation was progressively more visible: the regional planning commission, the city legal aid society, and the county fair housing center.

Sunshine laws [which require public deliberation of all issues] inhibit truly collegial give-and-take. The press and public experience a sanitized outcome—free of error but also devoid of creative reasoning and largely without any obvious explanation of how a decision was reached.

While with the regional planning commission in 1978, he filed a lawsuit over an apparent instance of insurance company "redlining"—canceling a policy in a geographic area for reasons that amount to racial discrimination. The case dragged through the courts for nine years, and Brown eventually used vacation time from his PUC position to try the case in U.S. District Court, where he established in law for the first time that insurance redlining is a civil rights violation.

Helping institutions respond

Brown's work regularly injected him into Ohio politics. He thus became well known among Democratic party regulars, although even now he prefers to describe himself as a progressive liberal. He campaigned twice for the Democratic governor Richard Celeste. Then, in 1983, the Public Utilities Commission membership was expanded from three to five appointees—with geographic and professional qualifications newly required for candidates.

"I was a 'two-fer,'" says Brown. "Besides being an attorney, I had credentials as a consumer advocate and I got along well with the party leaders." The combination was a winning one; he took his PUC seat and read of his appointment in Dayton's two newspapers. "The Democratic paper cheerfully quoted the chairman of the governor's PUC nominating council, who said I was a strong personality and change-oriented. The Republican paper described me as a left-wing demagogue and party hack!"

Membership on the Ohio PUC offered Brown a clear opportunity to apply law on behalf of constructive social change. He was a known quantity in that respect, but he had to come up to speed on specific issues. According to Brown, "One of the hottest was what to do about people who aren't able to pay their utility bills. Commission policy had been all over the place from one year to the next, and neither the utilities nor the customers had any idea how or if service would be cut off. We wanted to create some permanence." The result was a series of hearings that yielded a percentage-of-income (15%) payment plan for customers below a specified income level.

"Every utility in the state, except one, initially opposed the plan," Brown admits. "It's criticized because it's not pay-for-use. Some accounts are always in arrears, so as an economist would say, we aren't sending consistent price signals. But our rationale was that you can't send price signals to somebody who has no discretionary income."

Brown concludes that Ohio's innovative scheme remains one of the most progressive in the nation, and its success honed his curiosity about regulatory issues beyond Ohio. Convinced that national and even international matters may influence state policies, he became engaged in NARUC affairs as a means of seeing the bigger picture. "NARUC is very useful for

It's not clear that utility companies will all have generation, transmission, and distribution. There will be less vertical integration, and we're going to see more and more competition in the bulk power market.

that, because there's a lot of interchange with your colleagues around the country."

Brown doesn't see state regulatory practices becoming rigorously uniform, but he welcomes the opportunity that state commissioners have to coordinate policy nationally through NARUC. "For example, what issues ought to be state-determined? Or what's needed in national energy legislation? And we call attention to such things as contradictory energy pricing policies in the Federal Energy Regulatory Commission and the Securities and Exchange Commission."

Certainly Brown sees no single philosophical direction in the Electricity Committee, which he chairs. "It's a diverse group. I think our central focus is on the tools available to regulatory bodies—tools to protect consumers, to formulate electricity policies." In this connection, he mentions the work of the National Regulatory Research Institute, of which he is a longtime board member. NRRI, the research arm of NARUC and, like it, supported by the states, has investigated such issues as regional electricity transmission access and pricing. Notably and recently, it has researched the efficacy of so-called sunshine laws, which require regulatory (and many other) public bodies to conduct virtually all their deliberations in public.

Brown emphatically endorses the NRRI conclusion that sunshine, in fact, often clouds matters, at least so far as the public interest is concerned. "Sunshine laws inhibit truly collegial give-and-take," in Brown's own experience. "Commissioners don't want to alienate their colleagues, expose their own ignorance, or reveal patterns of reasoning that could be exploited by directly interested parties." Unable to convene privately, all together, they "discuss" issues by memo, talk one-on-one, or fall into unwarranted reliance on staff members. "The press and public—if they attend meetings at all—experience a sanitized outcome," Brown concludes. "It's free of error but also devoid of creative reasoning and largely without any obvious explanation of how a decision was reached."

Answering strategic questions

Are there discernible trends in electricity regulation? Brown is cautious. "Nothing overall, nothing that uniform," he says, "but there's clearly a trend in favor of integrated resource planning and a trend toward demand-side management and efficiency growth."

These concepts have heavy technological components as well as institutional implications for utilities and others of the electric power community. Mentioning them turns Brown to EPRI and its constituency, and to their strategic responses in the years ahead.

How is EPRI doing? Overall, fine, in Brown's opinion. Like others, he is relieved that Institute funding is moving up, not alone by the voluntary subscription of more utilities but also by the inauguration of matching-fund arrangements for member-designated R&D efforts. Called tailored collaboration, the new practice complements EPRI's basic program, which has to acknowledge a very broad range of R&D (doing so at least somewhat according to regional need factors and the institutional weight of utility categories within EPRI's membership).

"EPRI struggles most in areas where its members are sensitive," Brown says. "It tends to tread gingerly, trying to balance its public role with its members' perceived needs." But he adds that this is also where EPRI ultimately does best. "A classic example is electromagnetic fields, EMF research. EPRI took a real leadership role with the utility industry: 'This issue is here. It's an obvious matter of public concern. We don't know the science. If EMF isn't harmful, great, but let's find that out. If it is harmful, then what can we do to lessen public exposure?'"

It's only a short step from this sort of R&D initiative to EPRI's strategic posture with what it learns. Brown is thinking about EPRI's membership—the kinds of institutions that are included and where they are. "How will the Institute position itself? Is it going to be the research arm of the vertically integrated utilities? What about foreign utilities, or nonutility generators?" He's also looking beyond institutional constituencies, toward the whole of society. "Will EPRI apply its objective, dispassionate research to electricity issues raised by anyone, or is it going to be part of a competitive edge exclusively for the organizations that are permitted—and choose—to join?"

Brown warns that questions of this kind must be resolved. And, wearing his opinion on his sleeve, he goes on to say, "My personal view is that EPRI should be the research arm of the electricity industry, in the broadest sense." Why? "Because there's so much public-interest content that should be shared—for example, environmental and safety-related research. These kinds of issues take precedence over proprietary rights." Apart from research itself, Brown also speaks of technology transfer, say, to Third World nations. "Should EPRI seek full cost recovery for that or do it as a matter of public interest?"

Dealing with risk

Brown's manner suggests an inevitability about these questions of strategic positioning, and even about their answers. He supplies context with his expectation for the future. "It's not a clear assumption that companies will all have generation, transmission, and distribution. Those will be seen as discrete services. There will be less vertical integration, and we're going to see more and more competition in the bulk power market."

This kind of future will be driven largely by economic, social, and political pressures. And there will have to be legal and regulatory permission for some changes. Brown acknowledges all these and adds a particular note of his own. "I think it will also be driven by the level of risk aversity that the utility industry has displayed. Some companies have elevated risk aversity to theology! But they often incur more risk than if they weren't trying to avoid it." A utility may be skittish about the evident and calculable risks of building new generating capacity, for example. But if in fact there is a demand for that capacity, Brown points out, somebody else is likely to step in, accept the risk, and make the money.

Also from his regulatory experience, Brown cites utility uneasiness over how emissions trading, to be permitted under the newly amended Clean Air Act, will work in practice. Emission allowances will be allocated annually to many individual generating units—each allowance representing one ton of sulfur dioxide. But operating conditions and times aren't specified; thus, utilities will be able to buy, sell, trade, and even "bank" allowances, so long as each unit's actual emissions are covered by valid allowances. "Utilities are very concerned about how regulators will treat all this, what we're going to expect from them. Some are so risk-averse that they simply aren't going to deal with the system; they're going to stay entirely out of it."

The fallacy Brown goes on to describe here is the flat conclusion that there can't be any imprudence if there hasn't been an overtly risky action to start with. "In some instances this may be true," he says, "but the assumption that if you do nothing, you're safe, you can't be found imprudent—in my view, that's being paralyzed by your fear of risk. What regulators must do is make such excessive risk aversity risky in itself."

Furthermore, Brown points out, regulatory bodies don't try to eliminate risk. One of their jobs is to simulate in a monopoly

The assumption that if you do nothing, you're safe, you can't be found imprudent—in my view, that's being paralyzed by your fear of risk. What regulators must do is make such excessive risk aversity risky in itself.

setting what would happen in a competitive market. "Nothing is risk-free in the competitive market, so there shouldn't be a risk-free strategy for utilities. With respect to the general public, business will inevitably perform worst when there's only minimal risk. That's how you get fat and lazy."

There is benefit, of course, in some degree of certainty. And the existence of regulation implies that it can be achieved. Says Brown, "I think regulators need to create the right kinds of incentives and disincentives. They need to aim for an environment with both reward and risk, where the greatest reward comes from the greatest benefit to the public and the greatest risk comes from the greatest loss to the public. We need to figure out the symmetry in between."

Supporting collaborative research

A future in which EPRI membership goes beyond the electric utility industry, or one in which the factors of a broader electricity industry are internally competitive: In either case, can collaborative research survive? Should it?

Open competition among U.S. organizations that are or could be EPRI members would seem to threaten the Institute's survival. But if the world is seen as a single competitive arena, there is incentive for EPRI members to hang together. Ashley Brown offers several lines of thought, some of them mutually exclusive. As he talks, he points out problem areas and registers opinions but offers few predictions.

According to Brown, some economists argue that collaborative efforts hinder research progress because they "trap" capital; that is, they move it in a planned direction, isolated from market forces that might distribute or direct it differently in time or place. "There's an element of truth, of course," he admits, "but I think there are some real benefits. One is cross-fertilization. It's not just what EPRI's project managers and research teams do or learn; it's the sharing of that information with members, and then the members getting together on their own problems and solutions." Even in a competitive market, Brown insists, some R&D dialogue is better than none at all. "If you need a better mousetrap, you're better off if all the people with mousetrap ideas get together."

Competitive markets trap capital in their own way, he adds, by making it completely unavailable for any useful amount of R&D. "During the 1980s, the U.S. business community unquestionably emphasized instant gratification. We didn't think about the long term, not even in government—and R&D was underfunded as a result. Instead, we focused on short-term results, high degrees of leverage, and risk aversity."

Mentioning short-term results reminds Brown that the electric utility industry until about 20 years ago was among the least short-term-oriented industries in the nation. Electricity demand growth was more certain, and a relatively long view of R&D was acceptable, whatever the level of funding.

"Collaborative research builds a culture that preserves that view. A free-market R&D atmosphere discourages it," says Brown. He also agrees that collaborative effort more easily amasses the very large funding needed for much of today's electric power research—"although an economist might say that someone will throw more money at an opportunity if he has a direct stake in it than if he is sharing it with collaborators."

Given the forces that continually tear away at long-term thinking, Brown seems to endorse outright educational efforts to foster it, to expose the destructive effects of choosing the short-term rationale alone. One thing that helps, he believes, is the EPRI boardroom. "It is entirely removed from any utility's corporate boardroom—

Nothing is risk-free in the competitive market, so there shouldn't be a risk-free strategy for utilities. With respect to the general public, business will inevitably perform worst when there's only minimal risk. That's how you get fat and lazy.

a different setting for a different kind of decision." He points out that EPRI board members come together with a shared background in the problems of electric power production and delivery.

In contrast, Brown observes, board members of an individual utility are likely to represent much more diversity of background and consequently less command of the technology issues that may come before them. "I feel more comfortable," he concludes, "that decisions on the direction and content and magnitude of the industry's R&D are made in the cultural setting of EPRI."

gree of equity or efficiency."

Even if the words sound heavy, the man himself does not. Ashley Brown is having fun. He admits he doesn't accomplish everything he struggles for, but "you know, I'm a historian, and I know that society takes two steps forward and then one step backward—maybe two steps backward!

mand-side gains in productivity by electrotechnology users are, in effect, a credit against their out-of-pocket costs. And reliability has value, too. "Most important today, I think, is that we're becoming sensitive to the environmental cost of looking only—or mainly—at supply-side options."

As Brown sees it, demand-side mea-

During the 1980s, the business community unquestionably emphasized instant gratification. We focused on short-term results, high degrees of leverage, and risk aversity. We didn't think about the long term, and R&D was underfunded as a result.

Choosing an agenda

Talking with Ashley Brown is easy. His fascination with regulatory work comes across in his candor. He operates under his own sunshine law, and that includes frequent dialogue with himself in order to stay on course. "In regulatory work—or any public position, for that matter—I think it's critical to have an agenda and a sense of direction. That doesn't mean you need to be driven or messianic in your approach, but the absence of an agenda makes you pretty ineffective."

Brown's agenda is wrapped up in that Hubert Humphrey watchword about governmental institutions—in his own case, "trying to make the Ohio PUC responsive to the folks who have the least ability to influence it. That includes developing the tools to shape policy and regulate in ways that advance the public interest, whether it's social equity or economic efficiency—and then establishing the appropriate de-

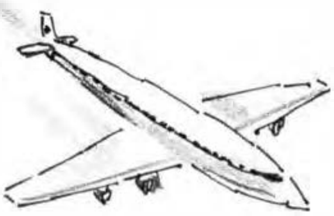
"The people who make a difference in history are the ones who have a vision of what they want to do and are willing to take personal risks to do that. It would serve no purpose to be in public office and not be willing to take risks."

Searching for a current example in his regulatory work, he mentions integrated resource planning (IRP) and learning to meld the private interest (of a utility) with the public interest (of the least influential citizens). "We know that IRP doesn't always hinge on the out-and-out cheapest energy option. We need to look for the least cost all around, taking into account everyone who has a stake of any kind."

A utility's plant costs, fuel costs, operation and maintenance costs, delivery costs—these are obvious supply-side cost increments. But Brown points out that de-

sures open new service and profit opportunities for utilities. Also, defining a wider universe in which to identify and assess costs paves the way for internalizing environmental costs previously borne by society at large—those least influential citizens. The regulator's challenge in all this is to come up with the needed new measures of costs and devise the changed incentive system in which to apply them.

It's easy to see why Ashley Brown gets up early in the morning. "There's no job in state government," he says, "that impacts as many people's lives as being a public utility commissioner. Some way or another, everyone is touched by what you do. You have enormous potential to do good, and it would be a horrible waste not to seize the opportunity." ■



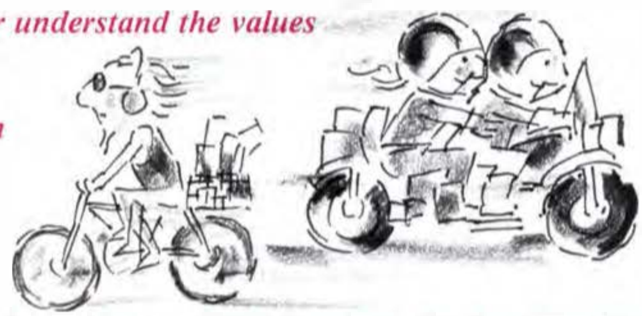
What Are You AFR

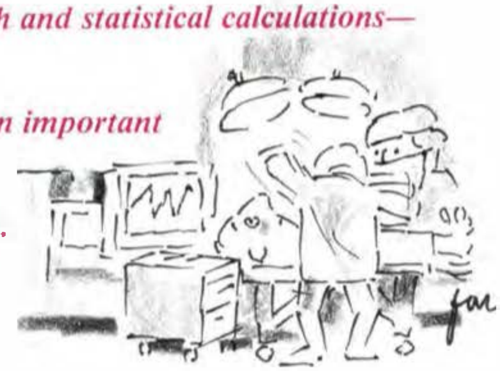
THE STORY IN BRIEF *Increasingly today, organizations involved in managing risks are paying closer attention to how people perceive potential hazards. As these groups are finding out, understanding the factors that go into the public's perception of risk is critical to communicating effectively and making responsible decisions. This increased sensitivity to public concerns represents a shift from previous practice, which was based on the assumption that the public's lack of scientific knowledge was the*

AID Of?

by Leslie Lamarre

main factor preventing laypeople from agreeing with risk experts. As risk researchers across the country strive to better understand the values that the public incorporates into its perception of various risks, organizations that manage risks are making more of an effort to involve the public in decision making. In the meantime, the science of risk assessment—based on biological research and statistical calculations—continues to evolve, providing an important foundation for decisions on risk.





A FEW YEARS AGO, SOCIOLOGY PROFESSOR WILLIAM FREUDENBURG gave 300 of his students at the University of Wisconsin at Madison a survey that asked whether they would support the establishment of a hazardous waste facility in their hometowns. The students responded overwhelmingly in the negative. The survey then informed them that the chances of dying as a result of living near such a facility were about one in a million. Only a few of the students changed their minds. Then they were told that this risk of death was less than that from smoking cigarettes. This information made them oppose the facility even more.

The final response made Freudenburg curious. "Why?" he asked them. "Because we've all heard that before," said one cynical student, to the delight of others in the room, who burst into laughter.

Not only does this small example illustrate that the public perceives risk differently than the experts who compute the probability figures; it also indicates that trust is an important influencing factor in the public's perception of risk.

The significance of trust may seem obvious, but the prevailing theory within the scientific community used to be that lack of technical and scientific knowledge was the main factor preventing the public from seeing eye to eye with risk experts. "By and large, the scientific community used to think—and still does—that if only the public had the same scientific background, they would agree on risk," says Freudenburg. But a number of studies conducted over the past two decades have shown that lack of scientific understanding is only a small part of the problem, and probably not the most essential part. Rather, the key difference between the public view of risk and the expert view is that the public incorporates subjective values or issues—such as trust, equity, and whether a risk is new or familiar—into its perception of various hazards.

While this has generally been recognized for some time within the community of scientists who study risk perception, it has only recently begun to influence the broader scientific community, including government agencies and industries involved in managing risk. But there appears to be a trend—a philosophical change—under way in which members of this broader scientific community are taking a closer look at the public's perception of risk in an effort not only to communicate more effectively but to listen better. These groups are finding that while some public concerns are subjective, they are legitimate; and while they may not fit into an expert's definition of risk, they must be accounted for in the decision-making process.

Understanding how the public perceives risk is critical today as societal concerns about potential dangers continue to escalate. This is why EPRI and other research organizations are investing in in-depth studies on risk perception. Electric utilities, among other organizations responsible for managing risks, are becoming more sensitive to such public concerns. In the electric power industry the concerns run the gamut of utility operations, ranging from nuclear waste to electric and magnetic fields. "Risk perceptions have a life of their own, in a sense," says Paul Slovic, president of Decision Research, a consulting firm specializing in risk, and a psychology professor at the University of Oregon. "These perceptions can influence regulatory agencies, they can influence the behavior of consumers, they can create stiff opposition to technical projects. They can have great social, political, and economic impacts, so it's important for any organization or industry that deals with risk to understand the public's perspective."

As individual case studies indicate, recently heightened efforts by electric utilities and other organizations involved in managing various risks are helping to improve the level of understanding between the public and the risk managers. These organizations are now involving the public in the decisionmaking process in meaningful ways, giving individuals a certain amount of control in the process while getting their messages across more effectively. Not only does such involvement help to build trust, but it also helps smooth the decision making, contributing to cooperative rather than antagonistic involvement.

Public perceptions

Risk researchers have long acknowledged that there is a large gap between the public's perception of risks and the experts' assessment of risks. In fact, in his seminal article for *Science* magazine that launched the field of risk assessment in 1969, Chauncey Starr, president emeritus of EPRI, recognized that the public has a much higher tolerance for voluntary risks than for involuntary or imposed risks. Yet expert risk assessors evaluate risks in terms of their probability of causing injury, cancer, or death without taking into consideration such psychological factors as voluntariness. The case of nuclear power illustrates the result of this disparity: despite risk experts' low estimates of the probability of fatalities, this advanced technology still concerns the public.

Self-imposed risks such as rock climbing or skiing come with a sense of individual control, which makes these risks of less concern. Also, unlike the benefits of nuclear power, which are distributed across society, the benefits of self-imposed risks are enjoyed directly by the individual. In addition, whenever the individual desires, he or she may choose not to bear the risk. And as Starr wryly observes, "We are loathe to let others do unto us what we happily do to ourselves." With involuntary risks, individuals lose their sense of control over the situation and hence feel the risk as greatly increased.

The significance of this sense of control is just one example of how members of the public incorporate values, as well as facts,

Risk Studies at EPRI

Virtually all staff members of EPRI's Environment Division deal with risk assessment to some degree. The Environmental Control Systems Department provides information on various pollutants as emitted at the source and develops control options for managing these pollutants; the Land and Water Quality Studies and Atmospheric Sciences programs explore how the pollutants travel through various media; and the Health Studies and Ecological Studies programs offer insight into the impact of the pollutants on human beings and ecosystems.

The Environmental Risk Analysis Program gathers information from all these groups and synthesizes it into a useful form for decision making. (The division's Electric and Magnetic Fields Health Studies Program is an exception to this arrangement in that it conducts its own risk assessment.) The Environmental Risk Analysis Program aims to help utilities address risk issues in a scientifically sound, quantitative manner. Now seven years old, the research program encompasses three components: risk assessment, risk management, and risk communication. "It's unrealistic to say that we can eliminate all risks, because society doesn't have unlimited resources," says Hung-Po Chao, manager of the program. "The challenge is to find a balance between costs and risks in the face of uncertainty. That's really the bottom line: to help make better decisions."

The risk assessment component of the program explores the levels of exposure experienced by people and ecosystems, and how physical responses vary with different exposure levels. This involves compiling and organizing information on the sources of potential harm, the exposures themselves, and the consequences of hazardous agents or activities. To help utilities assess risks associated with their facilities and operations, EPRI has developed a number of tools, including several microcomputer-based models. Two such models are AERAM, which calculates human health risks from the inhalation of airborne toxic emissions, and ORGRISK, a model for estimating exposures to waterborne organic chemicals released from utility sites. Currently, models are being developed to address greenhouse gases and to perform multimedia risk assessments for power plant emissions and discharges.

The risk management component of EPRI's risk analysis program provides frameworks for integrating the results of risk assessments with options for reducing exposures. The frameworks are contained in computer models that provide a decision analysis technique that analysts can use to look at a range of possible outcomes and compare the benefits and costs associated with alternative strategies. (For example, the SITES model developed by EPRI helps utilities make decisions on what kind of action should be taken at contaminated sites. One utility used this model to determine what further action it should take at a manufactured gas plant site where several wastes were present and soil had been contaminated with polychlorinated biphenyl and furan.) In the early 1980s, when EPRI's research in this area got under way, the frameworks dealt with air quality concerns. Currently risk management frameworks are being developed for electric and magnetic fields (EMF) and greenhouse gases, among other emerging issues.

The risk communication facet of EPRI's risk analysis program involves the development of methods for communicating about environmental and health risks, as well as direct assistance for utilities that are establishing and refining educational programs. The research is geared toward helping utilities effectively convey risk-related information to a wide range of audiences. As discussed in further detail in the main article, EPRI is currently sponsoring research projects to clarify how trust is created and destroyed and how people perceive certain risks.

EPRI's main efforts in risk communication have addressed exposure to electric and magnetic fields. EPRI has cosponsored the development of a 45-page brochure that covers what is known about the health risks of EMF. The Institute has also developed *A Handbook for Communicating Potential EMF Risks* (EN-7046). Written specifically for utility staff members, it provides a step-by-step guide for designing risk communications on electric and magnetic fields. A more recent document, *Sourcebook for Utility Communications on EMF* (TR-100580), covers the science of EMF, discusses risk communication principles, and offers guidance to utilities on designing public participation programs. Another EPRI report, *Risk Communication Manual for Electric Utilities* (EN-7314), offers more general guidance on risk communication with the media, regulators, and the general public. □

WHAT'S MOST RISKY? IT DEPENDS ON WHOM YOU ASK

Members of the public perceive risks differently than risk assessment experts. Typical differences are illustrated in the list below, which is based on surveys in the late 1970s that asked laypeople and experts to rank a group of activities, substances, and technologies according to their riskiness (1 represents the highest perceived risk).

	Public	Experts
Nuclear power	1	20
Motor vehicles	2	1
Handguns	3	4
Smoking	4	2
Motorcycles	5	6
Alcoholic beverages	6	3
General (private) aviation	7	12
Police work	8	17
Pesticides	9	8
Surgery	10	5
Fire fighting	11	18
Large construction	12	13
Hunting	13	23
Spray cans	14	26
Mountain climbing	15	29
Bicycles	16	15
Commercial aviation	17	16
Electric power (nonnuclear)*	18	9
Swimming	19	10
Contraceptives	20	11
Skiing	21	30
X-rays	22	7
High school and college football	23	27
Railroads	24	19
Food preservatives	25	14
Food coloring	26	21
Power mowers	27	28
Prescription antibiotics	28	24
Home appliances	29	22
Vaccinations	30	25

*Includes coal mining and other energy production activities as well as electrocution

into their perception of risks. In contemplating risks, they take into consideration how much they trust the organization involved, how catastrophic a single accident could be, how familiar or uncertain the risk may be, and whether a given risk is distributed equitably, among other concerns. For this reason, laypeople have a different meaning in mind than experts do when they use the word *risk*. In fact, studies dating back about 15 years show that when laypeople are asked to rank risks in terms of numbers of deaths per year, their figures are fairly close to the numbers that the risk experts generate. However, when they are asked to rank items in terms of "riskiness," which involves making a judgment about risk, their lists show few similarities to those of the experts.

The experts, meanwhile, focus on numbers that are intended to be an objective representation of potential danger, uninfluenced by personal values. But while statistics may be the tools of the experts' trade, the public is not accustomed to relying on these kinds of tools in its thinking. As Starr puts it, "It doesn't matter if there's a one-in-a-million chance of an accident happening at a nuclear power plant. As long as there is a possibility that it could still happen tomorrow, the public will be concerned." Essentially, the statistical approach ignores the psychological and sociological effects, and as a result, it cannot tell us how the public will react to certain risks.

Twenty years ago the scientific community generally believed that the layperson's response to risk was largely irrational. The scientific community tended—even more then than now—to equate rationality with scientific objectivity. In an effort to reassure the public, organizations that managed risk undertook communications programs that incorporated statistics provided by expert risk assessors. Typically, the early communications material compared unfamiliar, feared risks with familiar activities. For instance, literature from the technical and scientific communities in the late 1970s informed the public that living near a nuclear power plant is safer than riding a bicycle.

As the producers of this information

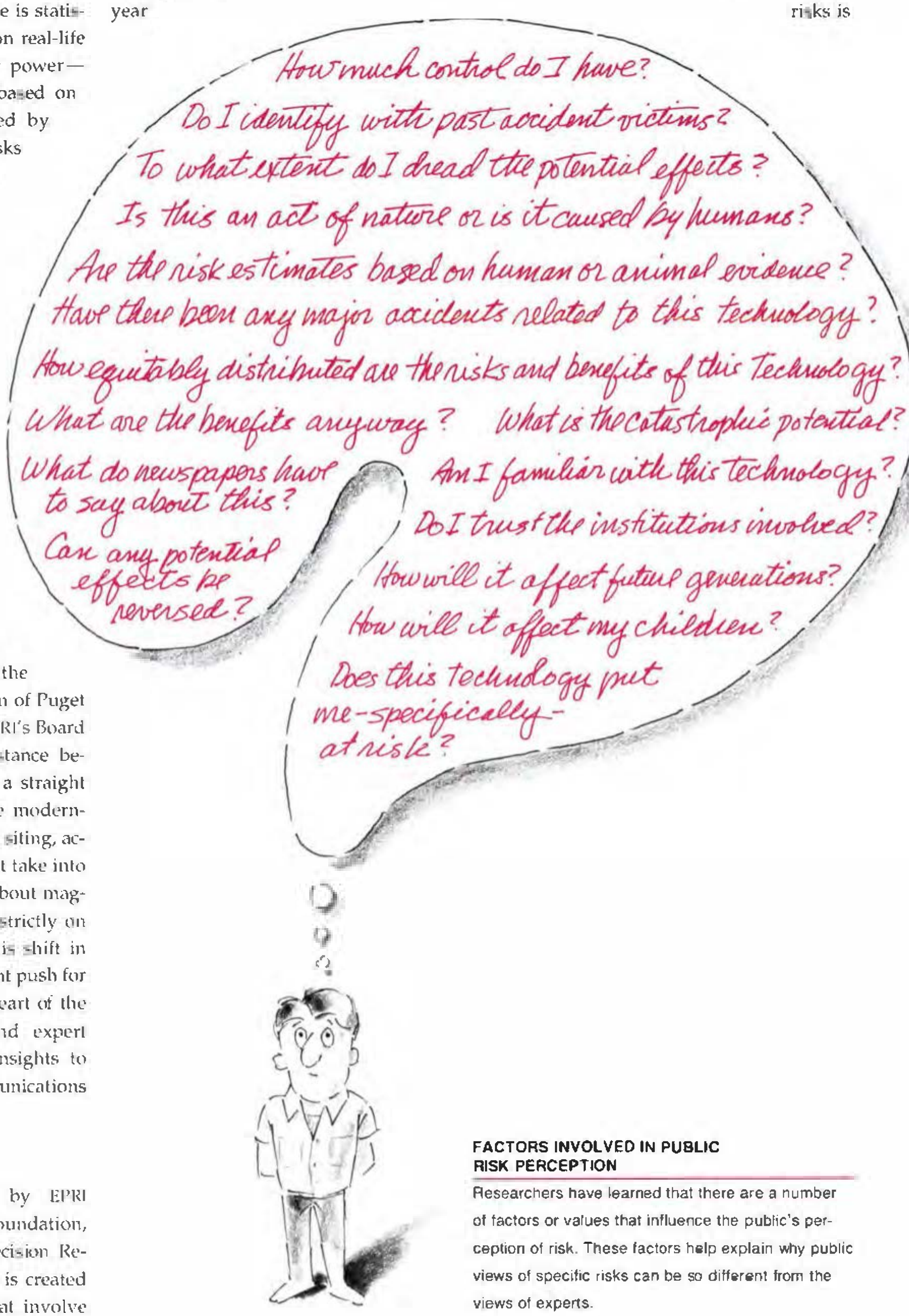
later learned, there are a number of problems with this type of comparison. First, as Slovic points out, "It's comparing apples and oranges." One case poses a voluntary risk, while the other is involuntary. Adding to the difference between the two cases, the risk of riding a bicycle is statistically well known and based on real-life data, while the risk of nuclear power—a much more recent risk—is based on numerical predictions generated by computer models. In short, risks are not one-dimensional, as the early communications brochures may have implied, and the complexity of their nature is reflected in the public's response to them.

As one might suspect, these early communications efforts were not very successful. Today, social and psychological factors are much more accepted as valid concerns. Subjective values are still not viewed as "reliable evidence," but they are no longer considered irrational. In the words of John W. Ellis, chairman of Puget Sound Power & Light and of EPRI's Board of Directors, "The shortest distance between two points is no longer a straight line." Ellis was referring to the modern-day process of transmission line siting, acknowledging that planners must take into consideration public concerns about magnetic fields rather than relying strictly on an engineering perspective. This shift in perspective is reflected in a recent push for research that is getting to the heart of the differences between public and expert views on risk and gleaning insights to incorporate into major communications efforts.

Revelations in risk

Through research cosponsored by EPRI and the National Science Foundation, Slovic and his associates at Decision Research are exploring how trust is created and destroyed in situations that involve risk. "People have a low level of trust in managers of various types of risk, and as long as they have a low level of trust, risk communications are not likely to be successful," he notes. Slovic's two-year study aims to identify ways that electric utilities can gain and maintain public trust.

Part of the reason for the public's distrust in organizations that manage risks is



FACTORS INVOLVED IN PUBLIC RISK PERCEPTION

Researchers have learned that there are a number of factors or values that influence the public's perception of risk. These factors help explain why public views of specific risks can be so different from the views of experts.

that the public feels a lack of control over the risks. In addition, the public recognizes that these groups often have a vested interest in continuing operations that involve risk. To make matters worse, as Slovic points out, the public is accustomed to using adversarial approaches to resolve problems, which is quite evident from our increasingly visible system of litigation.

Slovic's study is intended to enhance our understanding of the nature of trust and its role in risk management. It aims to identify the individual, technical, and organizational behaviors required to build and maintain trust. So far, the researchers have interviewed some 500 people in the Eugene, Oregon, area. Invited in small groups, the people have responded to questionnaires and surveys involving hypothetical events that take place in the context of risk management. For instance, the researchers are comparing the impact of a negative event, such as a nuclear power plant accident, with that of a positive factor, such as consistently good performance by the electric utility that owns the plant, and trying to quantify the relative strength of the positive and negative factors. This work is intended not only to lead to more-effective communications but to provide insight on how to improve the decision-making process.

Working toward the same goals, research centered at Carnegie Mellon University is exploring the thought processes that individuals use as they perceive issues involving risks. Psychologists have been studying such thought processes, known as mental models, for more than 30 years to better understand how people think about issues as diverse as technology, drugs, and international tensions. The use of mental models in studies of risk perception is much more recent, having begun only about five years ago.

The Carnegie Mellon researchers, who are headed by Granger Morgan and Baruch Fischhoff, reconstruct mental models through extensive interviews featuring open-ended, nonleading questions. The idea is that an individual's mental models may contain critical misconceptions that can lead to erroneous conclusions, even if that person is otherwise well informed. Identifying these problem areas allows for more-effective communications that address specific misperceptions. Rather than communicating from a foundation of expert assumptions, as in past unsuccessful communications attempts, risk managers can orient communications to the public's perceptions.

One of the earliest studies conducted by the Carnegie Mellon group explored the problem of radon, a radioactive gas that is naturally present in some soils and can seep into buildings and accumulate. Researchers found that many people do, in fact, understand that radon is a colorless, odorless gas that causes cancer. The problem is that some people associate radioactivity with permanent contamination, which radon does not cause. This misunderstanding may have discouraged homeowners from testing for radon, because they assumed there would be nothing they could do if they did detect a problem. Another misunderstanding led other people to believe that simply opening windows would solve the problem.

The Carnegie Mellon study followed the U.S. Environmental Protection Agency's release of a brochure in 1986 called "A Citizen's Guide to Radon." The brochure was part of a major EPA communications initiative to combat the radon problem, which is estimated to cause between 7000 and 30,000 lung cancer deaths per year, according to the EPA. The Carnegie Mellon study resulted in two brochures that proved to be much more effective than the EPA's brochure, according to reader surveys. For instance, readers of the EPA brochure knew that the health effects of radon were delayed. But when asked what they could do to reduce high radon levels in their homes, 43% of them answered "Don't know" and 9% answered "There's no way to fix the problem." By comparison, nearly all readers of the two revised brochures (100% for one brochure and 96% for the other) answered "Hire a contractor to fix the problem."

EPRI is hoping that research in mental models will help improve communications in two sensitive areas for the electric utility industry: electric and magnetic fields (EMF) and climate change. As part of its overall risk program (see sidebar), the Institute is sponsoring studies at Carnegie Mellon that strive to enhance understanding of how individuals perceive both issues. While the EMF study is fully funded by EPRI, the climate change research is cosponsored by the National Science Foundation.

Some common misperceptions have been identified in the early stages of research on these topics. One problem with EMF is that many laypeople do not understand how quickly field strength falls off with distance from the source that generates magnetic fields. On the issue of climate change, some individuals wrongly believe that holes in the stratospheric ozone layer lead to increased temperatures.

Decisions, decisions

The kind of work being undertaken by researchers like Slovic, Morgan, and Fischhoff represents a new wave in risk communications, reflecting a trend in philosophical thought among the organizations in private industry and government that are sponsoring the work. This trend involves an increased sensitivity to and awareness of how the public perceives various risks.

Increasingly today, electric utilities and other organizations that manage risks are finding innovative ways of involving the public in the decision-making process. "There is a definite trend," says Chris Whipple, a risk specialist and former EPRI employee who is now vice president of Clement International, an environmental and health consulting firm. "Electric utilities, chemical manufacturers, and other industrial entities are finding that in many cases it's to their advantage to involve the public at an early stage."

This is exactly what the Bonneville Power Administration learned a decade ago when the utility tried to erect a transmission line that cut across western Montana. According to Peter Johnson, the utility's administrator (chief executive officer) at the time, BPA was accustomed to being welcomed with open arms when its workers arrived to bring power into rural areas. But this was not the case in Montana. One day two utility surveyors were greeted by a farmer with a shotgun who ordered them away from his property. Other employees were harassed by residents in restaurants when the local patrons found out that they worked for BPA. Things got so bad that the utility provided special unmarked vehicles for employees working in the region.

The problem was that a span of the planned line cut across a valley in the town of Missoula, obstructing the view. The line and its access roads also sliced through grazing land, which farmers did not appreciate. "We had been looking at the problem through limited filters—as engineers and technicians, but not as citizens of Montana," Johnson recalls. "As a result, I think, we had been insensitive to their concerns." Johnson initiated a dialogue with the governor, traveling regularly to Montana to meet with him, and called in a consultant to help mount a broad initiative for public involvement. Through resulting public involvement programs, BPA held regular meetings with residents and even met with the editorial board of the local newspaper, letting them "tear us to shreds," as Johnson recalls.

While BPA heard the community's concerns, it also expressed its own—including its responsibility to erect an efficient and cost-effective line in a timely manner. In the end, the utility rerouted a couple of sections of the line, tucking the span that was to slice through the valley in Missoula behind a ridge. According to Johnson, the changes did not result in a significant additional expense. In fact, if they had been incorporated initially, the line would have been cheaper to build, because some of the transmission towers that were redesigned wound up costing less. "As the BPA administrator, I reflected on this and wondered why we didn't do it in advance," Johnson recalls. He says public involvement is now ingrained in BPA's procedures.

While the BPA case did not involve issues of risk per se, it illustrates the precise struggle—between individual values and the concerns of technologists—that consistently crops up in risk management. In this instance, the individual concerns included property values as well as aesthetics. As with risk-related cases, a lack of trust influenced the public's perception in the early stages of the project. Once the utility acknowledged the public's concerns and involved residents in the decision-making process, the focus became the more practical task of designing a line that satisfied both the utility and the public.

Jim Creighton, president of Creighton & Creighton, a consulting firm that has been providing BPA overall guidance on its public participation programs for the past 10 years, says this kind of involvement is becoming more common for risk-related projects. "There's been a surge of interest from utilities, particularly in the last two or three years," he says, noting that much

RISK COMMUNICATION: MUCH HAS CHANGED

This kind of risk comparison chart, routinely employed in the early days of communication on risk, now carries a warning label: readers of the risk communication manual in which it appears are advised that use of the chart may damage their credibility. Today risk communication experts recommend avoiding such comparisons because the numbers strictly represent the risk of death and do not acknowledge other aspects of risk that are important to the public.

ANNUAL RISK OF DEATH IN THE UNITED STATES

Cause	Risk per Million Persons
Motor vehicle accidents	240.0
Home accidents	110.0
Falls	62.0
Motor vehicle/pedestrian collisions	42.0
Drowning	36.0
Fires	28.0
Inhalation/ingestion of objects	15.0
Firearms	10.0
Accidental poisoning	
Gases and vapors	[illegible]
Solids and liquid	6.0
Electrocution	5.3
Tornadoes	0.6
Floods	0.6
Lightning	0.5
Tropical cyclones and hurricanes	0.3
Bites and stings [illegible]	[illegible]

WARNING!
USE OF DATA IN THIS TABLE
FOR RISK COMPARISON PURPOSES
CAN DAMAGE YOUR CREDIBILITY

The Evolving Science of Risk Assessment

Risk assessment serves as an important foundation for decisions on a variety of health and safety issues, providing numerical estimates that offer a scientific rationale for those decisions. One of its first uses in industrial societies was to estimate technological risk, such as that pertaining to the safety of buildings, bridges, dams, and other structures. Today risk assessment is used for estimating the risk posed by all kinds of technologies and substances, from airplanes to hazardous waste sites to air emissions. While the assessment of risk impacts has traditionally focused on human health, the science has recently begun to explore the more complicated issue of impacts on ecosystems.

Over the decades, risk assessment has become much more sophisticated and complex. For example, the Environmental Protection Agency and other organizations initially applied formal risk assessment only to cancer-causing substances. Within the past five years, however, they have begun to apply this tool to noncarcinogenic substances as well, such as those that may pose a risk to reproductive and neurological systems.

Another change is that risk assessment is beginning to take advantage of emerging knowledge on biological mechanisms that determine the precise, ultimate impacts of potentially harmful substances. For instance, past studies labeled unleaded gasoline a carcinogen because exposure to it, through inhalation, was associated with kidney tumors in male rats. The data from these studies were then extrapolated to estimate the health risk to exposed humans. However, biologists have since learned that the metabolic processes of male rats are unique, a finding that calls into question the validity of the extrapolation to humans.

The exposure levels used in risk assessments also are becoming more realistic. In the past, individual exposures, which help determine how harmful specific risks are, were often based on unlikely periods, such as 24 hours a day for 70 years. Today's risk assessors are striving to come up with time frames that more accurately reflect maximum likely exposures.

EPRI is one of an increasing number of organizations that are working to advance the science of risk assessment. Across the country, research is being conducted at university laboratories, such as the Center for Risk Analysis at Harvard's School for Public Health; at the EPA and other government agencies; and at private agencies, such as Resources for the Future in Washington, D.C. Those relying on risk assessment for decision making are primarily agencies of the federal government, including the EPA, the Food and Drug Administration, and the Department of Energy. State government agencies also rely heavily on risk assessment for their regulatory decisions. While some states assess their own risks directly, others rely on federal estimates.

As the risk assessment process begins to incorporate additional factors, it is becoming more challenging but also more accurate. "There is no doubt in my mind that there is a trend toward heavier use of risk assessment in this country," says Hung-Po Chao, manager of EPRI's Environmental Risk Analysis Program. "Risk analysis is indispensable in that it provides a method of articulating a scientific basis for decisions and a way to characterize uncertainties in a useful form for risk management." □

of the interest has been driven by the EMF issue. "The result is a new spirit of cooperation in decision making on sensitive issues." Utilities are not the only ones getting involved. Chemical companies and waste treatment firms are among the other organizations working more closely with the public.

Martha Rozelle, a principal with Dames & Moore, an environmental engineering consulting firm, stresses the importance of meaningful public involvement. Public hearings, she says, are not effective enough. The public must be involved in the process early, before a site for a given project is selected. It is important to work with people in relatively small groups and to maintain regular contact, she says. "We're not talking about giving the public everything they want," she notes. "We're talking about listening to their concerns and accounting for those concerns in the final decision." This involves finding out what people's priorities are and what kinds of trade-offs they are willing to accept, and making an effort to build a consensus.

This type of exchange is already taking place in the electric utility industry, through what is now widely known as the collaborative process for developing demand-side management programs. Utilities in at least five states have used the collaborative process, working together with public-interest groups, environmental organizations, and other traditional adversaries. One successful collaborative effort in California led to agreements on new energy efficiency programs and financial incentives for utilities to implement such programs. The collaborative process has proved to be an effective method of trust building, offering a model for cooperative decision making that can also be effectively applied to risk issues.

The bottom line

The challenges of resolving the conflicts between public and expert perceptions of risk are significantly magnified on the national level, where policymakers must juggle decisions on a host of competing risk-related issues.

The science of risk assessment, based on statistical analysis, helps federal agencies distinguish important risks from low-level risks. On the basis of risk assessment, the EPA considers indoor air pollution (including radon) and lead poisoning to be high-level risks. But these are not the risks that matter most to the public, according to the EPA. Rather, the public is generally more concerned with what the EPA's experts call low- to medium-level risks, including hazardous wastes, oil spills, acid rain, pesticides, and nuclear power plants.

The conflict between these views creates difficulties when it comes to determining where federal money should be spent and how much should be spent. This is a common problem among other government agencies too. Since public concerns help propel congressional action, much federal money gets spent on issues the government's experts do not consider the top priorities. For instance, the United States spends $3.6 billion annually to clean up drinking water contamination, while it spends $6.1 billion annually on hazardous waste sites. Risk assessors' figures indicate, however, that the emphasis in spending should be the reverse. (Hazardous waste sites are estimated to cause between 0 and 500 deaths a year, while drinking water contamination causes an estimated 400 to 1000.)

The EPA's Science Advisory Board has recommended that the agency use scientific analysis to prioritize risks. The idea is to get the most bang for the EPA's buck—high-level risks would receive the most money, while low-level risks would receive the least. Though few observers would argue with the idea of providing the most benefit for the federal dollar, the issue of precisely how to do that is an entirely separate matter and calls into question the very definition of risk. In order to define the severity of a particular hazard, risk assessors must take numerous factors into account. But where should they draw the line? To what extent can the possibility for human error or even organizational problems, which can influence risk, factor into statistics on probability of injury or death? What about other concerns, such as the potential for harm to the natural environment? How about the threat to property values, recreational opportunities, or aesthetics?

Clearly, as such social and psychological issues are incorporated into assessments of risk, the line between scientific risk assessment and risk perception becomes blurred. This issue has helped fuel the controversy over the use of risk analysis for prioritizing risks, one factor preventing the EPA from adopting the recommendation of its Science Advisory Board. Also helping fuel this controversy is the issue of how to assess risks that can't be directly measured, as can the risk of driving an automobile. For instance, how does one assess the risk imposed by climate change when experts in this field do not agree among themselves on the severity of the problem? Risk analysts have developed computer models that help calculate relatively new risks like this, which incorporate much uncertainty.

As policymakers continue to deal with such questions on a case-by-case basis in the decision-making process, researchers continue to work toward obtaining some definitive answers. "Practitioners in risk analysis quickly develop humility when faced with the practical issues," Starr concedes. "But inadequate as it may be, risk assessment is better than anything else available."

Indeed, regardless of its uncertainties, risk assessment still offers some scientific basis for decisions on risk. And as researchers like Freudenburg, Slovic, Morgan, and Fischhoff help us better understand how individuals perceive risks, the utility industry and others involved in managing risks will learn not only to communicate better but to make the decision process much more effective. "It's really up to the risk managers to make the effort to undertake this change," says Whipple. "They need to learn how to listen to the public better and how to account for their concerns, because the public is not going to change." ■

Background information for this article was provided by Hung-Po Chao and Anthony Thrall, Environment Division; Gordon Hester, Integrated Energy Systems Division; and Chauncey Starr, President's Office.

TECH TRANSFER NEWS

EMWorkstation Offers Integrated Electric and Magnetic Field Analysis

As interest in electric and magnetic fields surrounding power lines increases, utility engineers must be able to quantify the fields, evaluate alternative designs for transmission and distribution systems, meet regulatory requirements, and respond to customer inquiries.

Hand-held measuring devices record only the electric and magnetic field strength at the time a measurement is made. In contrast, EPRI's EMWorkstation (Electric and Magnetic Fields Workstation)—a recently released integrated software package—combines five computer models into a single framework that allows engineers to calculate both types of fields at various locations under different conditions. For example, EMWorkstation can estimate electric and magnetic field magnitudes in a particular neighborhood when power lines are heavily or lightly loaded.

The EMWorkstation software allows users to calculate both fields from any type of transmission or distribution power line and to perform basic modeling of human exposure to the fields from the lines. If field strengths and human activity within fields are known, utilities can then calculate human exposure from the fields. For example, a farmer may be interested in the level of his exposure when he is working below a power line. Using EMWorkstation, a utility staffer could model this situation and calculate the exposure.

"Every EPRI member is likely to have a use for EMWorkstation, because electric and magnetic field issues affect all electric utilities," says John Dunlap, manager for magnetic fields in EPRI's Electrical Systems Division and the project manager responsible for developing the workstation. "I expect that the most common use will be by utilities who want to explore magnetic field management techniques when designing transmission and distribution lines."

EMWorkstation, which was developed jointly by the Electrical Systems Division and the Environment Division, can model lines to address the most fundamental questions a utility is likely to have about electric and magnetic fields from power lines. All the workstation programs, which have been thoroughly field-tested by EPRI member utilities, are fully integrated, so data are easily transferable. Some modules even share a common database.

EXPOCALC and ENVIRO (two Microsoft Windows applications) are the principal modules in the initial version of the workstation. EXPOCALC models electric and magnetic fields in the vicinity of overhead power lines and quantifies human exposure to these fields by using an activity systems model approach that integrates time and location with field intensity. The effects on an electric field of shielding by such objects as trees and buildings can be modeled. ENVIRO, which can share data with EXPOCALC, calculates electric fields, magnetic fields, and audible noise produced by overhead transmission lines.

DATACALC and STAR (two MS-DOS applications) analyze data from magnetic field recording instruments. DATACALC analyzes and communicates data collected by the Electric and Magnetic Field Digital Exposure Meter (EMDEX). STAR performs a similar function for the EPRI Stand-Alone Recorder (STAR), downloading data from the STAR logger. The fifth module in the workstation, BLANKET, is an MS-DOS application that models magnetic fields produced by electric blankets.

EMWorkstation will run on any IBM-compatible microcomputer that can operate Microsoft Windows. Users with questions can call a toll-free hotline at (800) 225-3357 to receive free technical support. In addition, next year EPRI will organize EMWorkstation users groups for training purposes and to promote an exchange of ideas about how to make the best use of the software.

Version 2.0 of EMWorkstation is planned for release in 1993. Future modules will allow users to calculate magnetic fields in residences as well as in substations. ■
EPRI Contact: John Dunlap, (415) 855-2298

AMP: Connecting Applications Centers

EPRI members now have direct access to Customer Systems Division R&D applications centers and offices through a communications support network called AMP. By subscribing to this network, a utility end-use professional can call a single 800 number to order products and services or to talk with technical staff at any of the 16 centers and offices. In addition, AMP distributes monthly packages that contain new publications from the centers and offices and provide information on upcoming events, videos, software, ongoing research, new projects, and training and workshop opportunities.

When AMP was established in 1988, its primary mission was to provide technical support that would assist utilities in the transfer of electrotechnologies through

EPRI's industrial applications centers. The program has now been expanded to provide a menu of services for all of EPRI's end-use centers and offices. Publications are the cornerstone of AMP's aggressive technology transfer programs. Short, easy-to-understand documents produced by individual EPRI centers and offices can assist marketing specialists, customer service staffs, or the customers themselves in evaluating a candidate technology for implementation.

Utilities can participate in the AMP program as a benefit of EPRI membership. Each utility staff participant—whether from marketing, economic development, customer service, or R&D development—receives an individual AMP card that provides direct access to the program's products, services, and technical experts. Currently, AMP has 1430 individual subscribers, representing 132 EPRI member utilities and 5 international participants. They call the 800 number a total of 300 times a month, on average, to order center publications or obtain technical assistance. During the first nine months of 1992, for example, some 155,000 publications were distributed by AMP in response to requests from subscribers.

Customized services are also available. For example, AMP designed a day-and-a-half training program for industrial marketing representatives of Union Electric Company of St. Louis. This program featured sessions on the operation and application of various electrotechnologies, including demonstrations of each. When a sales representative of Indianapolis Power & Light was preparing to call on a major dairy, AMP helped him get information about the dairy product freeze concentration pilot project in Wisconsin and put him in touch with a representative of the Dairy Research Foundation.

For talking with technical staff in their areas of expertise, AMP provides toll-free access to the following centers and offices: Customer Assistance Center (demand-side management, software support, and training), Center for Materials Fabrication, Center for Materials Production (with separate Foundry, Mining, and Precious Metals offices), Chemicals & Petroleum Office, Food Office, Pulp & Paper Office, Textile Office, Center for Electric End-Use Data, Electric Transportation Information Cen-

ter, Lighting Information Office, Power Electronics Applications Center, Thermal Storage Applications Research Center, and Commercial Building Air Conditioning Center.

These centers and offices are located throughout the United States in order to access specific technical expertise and to provide a liaison to important groups of end users. "The AMP network provides a convenient way for EPRI members to tap nationwide resources for information, technical support, and technology transfer," says Virginia Hess, program manager for communications in the Customer Systems Division. "That's our goal: to be regionally represented but centrally linked."

For further information about AMP, including how to become a subscriber, please call (800) 4320-AMP. ■

EMF Sourcebook Helps With Customer Communication

Increasing public concern that exposure to electric and magnetic fields (EMF) may cause adverse human health effects poses difficult communications problems for utilities. Uncertainty about the existence and nature of EMF risks makes it impossible to respond to public concerns with definitive answers, and the complex scientific research aimed at providing answers is difficult to explain to public audiences.

In the absence of a scientific or industry consensus on EMF, some utilities have adopted policies to provide a basis for responding to customers and employees. A new EPRI report provides a menu of methods individual utilities can use to interact with the public about EMF concerns—methods for clearly conveying the current scientific understanding and explaining corporate positions. The report, which includes examples of message development and readily comprehensible information about EMF, is designed to help utilities achieve appropriate levels of public involvement in EMF issues.

The EPRI report, *Sourcebook for Utility Communications on EMF*, TR-100580, incorporates and expands on material originally developed by the Tennessee Valley Public Power Association as a handbook on EMF. This material includes background information and descriptions of specific communications techniques for discussing EMF issues and obtaining public participation. The EPRI sourcebook also presents guidance for developing EMF risk communication programs and describes three alternative utility policies on EMF, including the reasoning behind these policies and communications information consistent with them. By outlining methods for interacting with the public, the sourcebook can help utilities select the combination of approaches that best matches their policies and circumstances. ■ *EPRI Contact: Gordon Hester, (415) 855-2696*

CORRECTION

The recent *EPRI Journal* article on electrical burn treatment (September 1992, pp. 16–21) failed to list New York State Electric & Gas Corporation as a sponsor of the groundbreaking work being done at the University of Chicago. NYSEG has, in fact, been one of the largest supporters of this research, and we regret having inadvertently left the company off the list of project sponsors.

Exploratory Research

Solid Oxide Fuel Cell Development

by Rocky Goldstein, Generation & Storage Division

Most fuel cells now in use or under development contain liquid electrolytes for ion conduction. (Phosphoric acid cells and molten carbonate cells are the most common.) There are problems with liquid electrolytes, however, that tend to reduce fuel cell service life; these include evaporation, corrosion, and migration of chemical constituents from one cell part to another.

Solid oxide fuel cells (SOFCs) use a solid electrolyte that minimizes some of these electrolyte management problems. Laboratory tests of single SOFCs indicate that they could last more than 10 years, compared with an expected service life of about 5 years for liquid-electrolyte cells. A solid electrolyte also makes it possible to build cells that are extremely small—5 to 10 kW or perhaps even smaller—using raw materials that cost as little as $7 to $15/kW. Although these advantages have been well understood for some time, significant technological barriers must be surmounted before SOFC systems can become a commercially viable energy production option.

Materials and fabrication challenges

Present-generation SOFCs are composed of thin layers of ceramic materials: an yttria-stabilized zirconia (YSZ) electrolyte, a lanthanum manganite cathode, a nickel cermet anode, and a lanthanum chromite (or, in some cases, metallic) interconnector (Figure 1). These materials were selected during the early years of SOFC development on the basis of materials and information available at that time. YSZ was selected for the electrolyte because it had the highest ionic conductivity of all materials known to be stable in the chemical environment of a fuel cell. At an operating temperature of 1000°C, its conductivity meets the 0.1 $(\Omega \cdot cm)^{-1}$ requirement for fuel cell applications.

The 1000°C operating temperature required by the YSZ electrolyte has advantages and disadvantages. It provides high-quality waste heat that can be used for cogeneration applications and industrial processing, and it enables the cell to make direct use of hydrocarbons as fuel, eliminating the need to have external processing facilities for reforming hydrocarbons into hydrogen-rich gas. However, the high-temperature SOFCs have a lower electrochemical efficiency than other types of fuel cell because a larger percentage of the energy from the electrochemical reaction is released as heat. Also, their materials tend to diffuse from one layer to another, causing changes in the chemical properties of cell components and reducing service life.

ABSTRACT *Fuel cell technology is the most efficient system known today for converting fossil fuel to electric energy. Solid oxide fuel cells (SOFCs) are potentially the most economical of existing fuel cell technologies, primarily because they are more compact and are expected to offer a longer, relatively trouble-free service life. Ongoing efforts to improve SOFCs focus on reducing operating temperatures from 1000°C to about 700°C. If successful, these efforts could make SOFC systems economically competitive with other power-generating technologies.*

A 1000°C operating temperature also limits the choice of materials for electrodes, interconnectors, and such structural components as gaskets and tie-rods. Because high temperatures tend to weaken metals and increase their corrosion potential, more-expensive rare earth ceramics must be used. This limitation makes cell fabrication more difficult and expensive—different ceramics have different coefficients of expansion, which can result in cracking during manufacture.

An operating temperature near 700°C would improve SOFC thermodynamic efficiency, reduce interdiffusion problems and fabrication costs, and make it possible to use less-expensive metal electrodes without sacrificing the benefits of high-quality waste heat and direct use of hydrocarbon fuels.

EPRI's Generation & Storage Division and Office of Exploratory & Applied Research are sponsoring four approaches aimed at developing SOFCs capable of operating near 700°C. The first approach involves creating very thin layers of a stable, high-temperature ion conductor, such as YSZ, to reduce its resistance losses when used at lower operating temperatures. The second approach is to find ways of enhancing the chemical stability of known low-temperature ion conductors, which do not ordinarily survive well in the reducing environment of a fuel cell. The third approach is to synthesize entirely new classes of materials with desirable ion conductivity and stability characteristics. The fourth approach involves searching for proton-conducting materials that could be used instead of ion conductors as SOFC electrolytes.

Lowering resistance losses

One EPRI-sponsored project is investigating methods of depositing very thin films of known electrolyte materials for use in moderate-temperature SOFCs. Researchers at Northwestern University are experimenting with reactive magnetron sputtering to create thin films of YSZ electrolytes and silver-YSZ cermet oxygen electrodes (RP1676-14). Magnetron sputtering, a technique commonly used for large-scale semiconductor processing, provides good control over the properties and morphology of finished products.

Today's high-temperature SOFCs use a perovskite material—strontium-doped lanthanum manganite—as the oxygen electrode. This electrode is also a source of resistance losses in high-temperature cells. Reducing operating temperatures from 1000°C to 700°C would permit the use of metals, such as silver, in the oxygen electrode. Electrodes that include metals do not present the resistance problems associated with electrodes containing only perovskites. They are also less expensive and easier to fabricate.

The ultimate goal of this project, cosponsored by EPRI and the Gas Research Institute (GRI), is to build a moderate-temperature SOFC based on a design developed at Northwestern. The design calls for electrodes composed of very thin (less than 10 µm) layers of catalytically active oxides—doped ceria on the fuel electrode side and bismuth oxide on the oxygen electrode side—deposited on a YSZ electrolyte layer also less than 10 µm thick. (Figure 2 shows an example of a thin YSZ film.) Thus the electrolyte layer would be much thinner than the 1-mm layer of YSZ now used in high-temperature SOFCs. Ceria, bismuth oxide, and YSZ have reasonably similar thermal expansion properties, and deposition of very thin layers of these oxides would not significantly complicate cell fabrication.

An SOFC built according to this thin-film design is expected to exhibit fuel efficiencies greater than 50% at a power density of about 0.5 W/cm^2 when operated at 750°C. The design promises to offer reductions in materials costs and could be easily incorporated into stacks with high power-to-weight and power-to-volume ratios. The most recently tested cell had a total thickness (electrodes and electrolyte) of less than 20 µm.

Figure 1 Present-generation solid oxide fuel cells feature thin layers of ceramic electrodes and electrolyte. In this planar design, composed of flat cells, fuel gases and oxidant flow between the layers.

Other approaches

Researchers at the University of Utah are investigating methods of stabilizing composite bismuth-zirconia and cerium-zirconia electrolytes so that they can be used in a moderate-temperature SOFC (RP8002-30). The researchers are testing the effectiveness of using electrochemical vapor deposition (EVD) as a means of creating a very thin zirconia coating to protect the electrolyte from chemical reduction.

During 1991 an EVD apparatus was designed and constructed. The design was validated by using the apparatus to successfully deposit thin films of zirconium chloride. The apparatus was then used to fabricate a lanthanum manganite cathode support for use in future experiments. The results of initial attempts to deposit thin films of ceria are encouraging, and additional experiments are under way.

Researchers at Argonne National Laboratory are attempting to synthesize entirely new materials that have desirable ion-conducting properties and remain stable at moderate operating temperatures (RP2706-5). In work that began in late 1988 under the joint sponsorship of EPRI, GRI, and the U.S. Department of Energy, investigators have identified some of the properties that are fundamental to potentially useful electrolyte materials. For example, some candidate ion conductors similar in atomic configuration to calcium fluorite have crystal structures that include "tunnels," or empty spaces, large enough to accommodate the passage of oxide ions. In addition to these fluorite-type materials, candidates include sheelites, orthosilicates, wurlites, framework materials, and new perovskites (Figure 3).

To date, investigators have identified two promising types of materials: a bismuth-aluminum system and a framework material. Results have been encouraging, and fabrication and testing of complete fuel cells made with these materials are under way.

Investigators at Stanford University (RP8002-11) and the Institute of Gas Technology (RP3070-36) are evaluating the possibility of using known proton conductors as SOFC electrolytes. When a proton conductor is used, protons (H^+) move from cathode to anode, and water is produced at the cathode. By contrast, ion-conducting electrolytes pass negative ions (O) from anode to

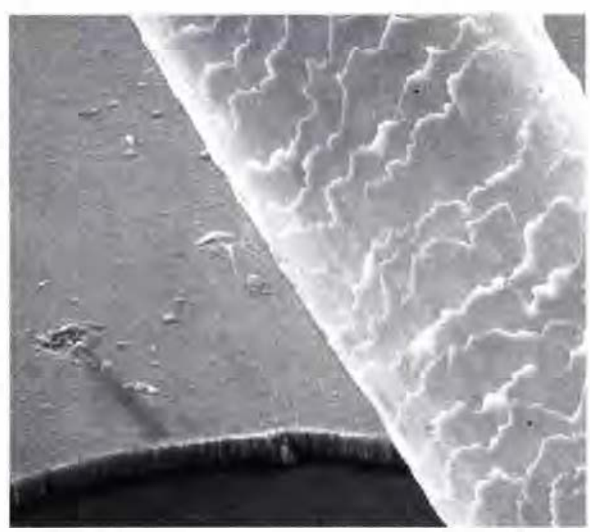
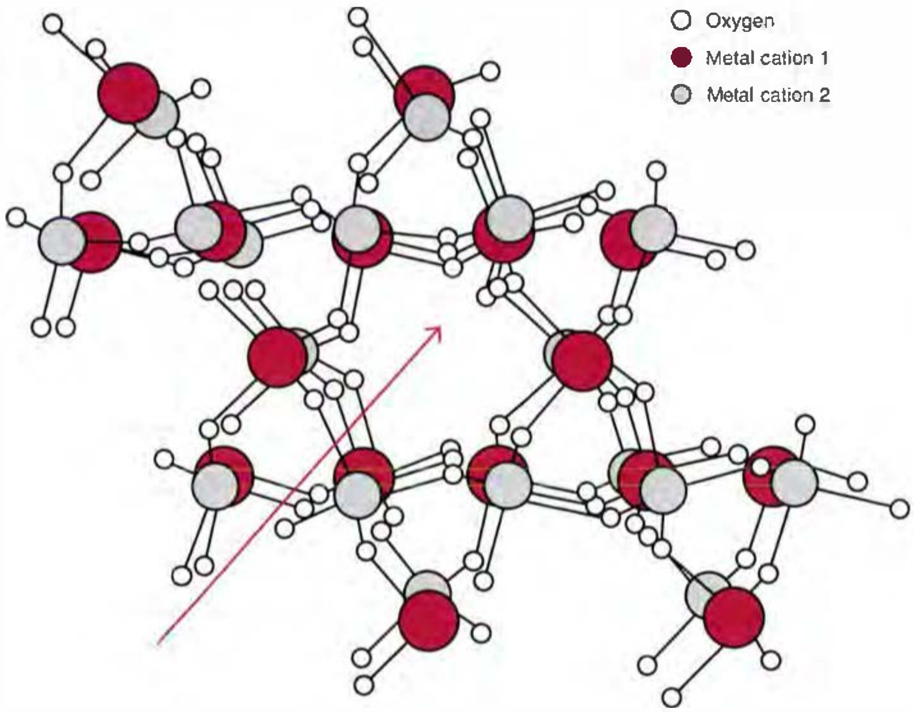


Figure 2 Scanning electron micrograph of a human hair superimposed on a 3-µm-thick YSZ film. Researchers at Northwestern University and the University of Utah are investigating the use of very thin films in fabricating SOFC electrolytes. The objectives are to reduce resistance losses and enhance stability at moderate operating temperatures.

Figure 3 Researchers at Argonne National Laboratory have synthesized new ion-conducting materials that look promising for use in moderate-temperature SOFCs. These materials—for example, the generic orthosilicate shown here—have a crystal structure with "tunnels" (arrow) large enough to accommodate migrating oxide ions.



cathode, and water is produced at the anode. Barium cerate has already shown potential for SOFC electrolyte application, and both projects are exploring methods of fabricating this new material.

The future of SOFCs

SOFCs have the potential to become economically competitive with other power-generating technologies because of their simplicity of design and, ultimately, their low manufacturing costs. Their advantages are expected to include high efficiency, modularity, fuel flexibility, and unprecedentedly low emission levels. Although much work remains to be done to make SOFCs cost-effective, programs like those described in this article are beginning to yield positive results. For example, two 5000-hour tests of 3-kW units have been run by Westinghouse in Japan; a 25-kW unit is also being tested in Japan; and a 100-kW unit is being built for testing in southern California. System planners should look forward to the introduction of SOFC technology at the turn of the century.

Atmospheric Sciences

CAMRAQ: Comprehensive Regional Air Quality Modeling

by D. Alan Hansen, Environment Division

Utilities, industry, and government agencies face a considerable challenge in determining how best to respond to air quality issues related to the atmospheric impacts of man-made emissions. These issues range from visibility impairment to acid rain to global climate change.

Many who are charged with understanding, studying, or controlling air quality problems have come to agree that there is a pressing need for regionally integrated solutions to these problems, and that one of the best ways to plan and select emissions management options is to use numerical air quality models. Modeling and computer science have achieved a level of maturity that in the relatively near term should allow convenient and skillful simulations dealing with multiple issues. Further, field studies are yielding many quality-defined data sets to support comprehensive evaluations of model performance.

There is also growing agreement that sharing resources is the most efficient way to achieve joint objectives. The days of large field data collection and modeling studies funded by a single agency appear to be over. Regional air quality–related environmental issues are so large and so complex that single agencies cannot justify mounting programs adequate to provide definitive assessments.

Recognizing all these factors, EPRI took the initiative and embarked on the formation of the Consortium for Advanced Modeling of Regional Air Quality—CAMRAQ. The express purpose of this effort is to collaboratively develop tools for meeting the air quality challenge.

The basis for the commitment to models is that they alone enable researchers to investigate alternative futures in a quantitative sense. For example, they make it possible to take a single set of conditions, perturb those conditions in many ways—change the emissions, the climate, the meteorology, the surface characteristics, and so forth—and simulate outcomes. Those outcomes can then be analyzed for likely consequences and weighed for their ability to meet not only the primary objective of protecting air quality but also such ancillary criteria as maximizing the benefit-cost ratio. The most versatile and complete of these models are referred to as comprehensive modeling systems (CMSs) because of the breadth and depth they must have.

To make these modeling systems practical tools for problem solving, however, advances must be made in several areas: our understanding of the scientific underpinnings of the models, our ability to quantify their reliability in terms of predictive accuracy, the computational power needed to exercise the models, their accessibility and ease of use, the ways in which their output is displayed, and how the models are interfaced to effects and risk assessment and management modeling systems. CAMRAQ intends to advance along all these lines.

ABSTRACT *As part of its long-standing research on regional air quality, EPRI has embarked on a project to develop a comprehensive modeling system for providing unique scientific guidance on emissions management options to industry and regulators. As the system evolves, interim versions can be used to address such problems as ozone nonattainment, visibility impairment, and acid rain. To leverage its investment and that of others in pursuing this goal, EPRI has fostered the formation of an international consortium of some 20 organizations—the Consortium for Advanced Modeling of Regional Air Quality, or CAMRAQ.*

Origins

Encouraged primarily by the positive experience of EPRI's participation in collaborative field measurement and modeling studies, and convinced of the feasibility of the CMS concept, in 1989 staff in the Atmospheric Sciences Program initiated a project on tropospheric model development and evaluation. The goal was to produce a practical comprehensive modeling system that could be used to assess any conceivable air quality issue. The project tied together in an integrated framework a number of collaborative, regionally specific field studies and associated modeling exercises in which EPRI was already involved. It was to begin with two planning workshops and was scheduled to last about 10 years.

The U.S. Environmental Protection Agency, as part of a federal initiative on high-performance computing and communications, is planning to develop a modeling system (called Models 3) analogous to CAMRAQ's CMS. The EPA is also participating in CAMRAQ, and this relationship is expected to have several advantages: the EPA will benefit from the advances CAMRAQ generates in the broader scientific arena, CAMRAQ will benefit from selected spin-offs from the Models 3 development process, and—since Models 3 and the CAMRAQ products will all ultimately be part of a consolidated CMS—the community at large will benefit from the availability of a greater diversity of modeling tools.

Other modeling systems similar in some ways to those proposed by EPRI and the EPA have been designed or implemented by the U.S. Department of Energy, the Forest Service, and the Nuclear Regulatory Commission. However, the true groundwork for the science required by a CMS was laid by the development of the following three modeling systems, considered comprehensive by the standards of the time:

- RADM (Regional Acid Deposition Model), developed initially for the National Acid Precipitation Assessment Program under EPA sponsorship
- ADOM (Acid Deposition and Oxidant Model), the Canadian equivalent of RADM, funded by the Ontario Ministry of the Environment (OME), the Atmospheric Environment Service of Environment Canada (AES), Umweltbundesamt (the German federal environmental agency), and EPRI
- STEM-II, developed at the Universities of Iowa and Kentucky under multiple sponsorship

All three systems operate on a fully three-dimensional Eulerian grid; require the generation of meteorological fields by separate mesoscale models for, among other things, advecting air within the grid; have preprocessors for the input of emissions; treat gas-phase photochemistry in moderate detail; and simulate cloud chemistry and physics, including gas and particle scavenging, and wet and dry deposition. The complex formulation and internal interaction characterizing these models challenge our ability to interpret why they respond as they do. Nonetheless, recent exercises in which EPRI has been participating—exercises that involve several cycles of evaluation, diagnosis, and improvement—are paying off in increased insight into the models' responses and in better definition of the accuracy of their predictions. With this information, we can address the questions of what are appropriate modeling applications and how much confidence can be placed in the answers.

When EPRI staff began promoting the CAMRAQ concept, they found a very receptive environment. Air quality planners and regulators were eager to have more reliable, practical, and convenient modeling tools than were available to them. And budget-conscious agency managers were looking for opportunities to stretch their dollars through jointly funded ventures.

The CAMRAQ planning workshops were held in November 1990 and March 1991. Joining EPRI as sponsors were the American Petroleum Institute, the Defense Nuclear Agency, DOE, EPA, the National Oceanic and Atmospheric Administration, and the Canadian agencies AES and OME. The first workshop assembled atmospheric scientists, research managers, air quality regulators, and regional modelers. Its objectives were to introduce the concept of a CMS to the community at large; to describe the sponsors' missions and their modeling applications and expectations; and to set priorities for atmospheric research according to its value to CMS development and evaluation.

The second workshop brought the research managers and modelers from the first workshop together with computer scientists in order to stimulate interdisciplinary cross-fertilization. It was based on two premises: that to make a CMS a practical reality, modelers must be aware of and apply the latest in computer technology, soft and hard; and that they must make their needs known to the computer science community so that the latter's efforts can be targeted toward meeting those needs.

After each workshop, the sponsors and other interested individuals met to lay the foundation for CAMRAQ.

Table 1
COLLABORATIVE FIELD MEASUREMENT AND MODELING STUDIES

Study	Dates	Estimated Cost ($ millions)	Major Sponsors
SOS (Southern Oxidants Study), SORP (Southern Ozone Research Program), SERON (Southeastern Regional Oxidant Network)	1990–1996	60	Duke Power, EPA, EPRI, Southern Electrical System, Tennessee Valley Authority
EMEFS (Eulerian Model Evaluation and Field Study)	1988–1993	47	Atmospheric Environment Service of Environment Canada, EPA, EPRI, Florida Electric Power Coordinating Group, Ontario Ministry of the Environment
SJVAQS/AUSPEX (San Joaquin Valley Air Quality Study/Atmospheric Utility Signatures: Predictions and Experiments), SARMAP (SJVAQS/AUSPEX Regional Model Adaptation Project)	1988–1993	20	California Air Resources Board (ARB), Chevron, EPA, EPRI, Pacific Gas and Electric, San Joaquin Valley cities and counties, Western States Petroleum Association
EUROTRAC/EUMAC (European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents in the Troposphere Over Europe/European Modeling of Atmospheric Constituents)	1987–1995	15	European governments
Denver Air Quality Studies/Brown Cloud II	1987–1993	8	State of Colorado, Denver Chamber of Commerce, EPA, EPRI, Motor Vehicle Manufacturers Association (MVMA), Public Service Company of Colorado
SCAQS (Southern California Air Quality Study)	1985–1987*	14	ARB, ARCO, Coordinating Research Council, EPA, EPRI, Ford, General Motors Research Laboratory, MVMA, South Coast Air Quality Management District, Southern California Edison (SCE)
SCENES (Subregional Cooperative Electric Power, National Park Service, Environmental Protection Agency, and Department of Defense Study)	1984–1990	13	Department of Defense, EPA, EPRI, National Park Service, Salt River Project, SCE

*Modeling and data analysis continuing.

Objectives

The consortium's objectives are to develop, evaluate the performance of, and apply comprehensive modeling systems for the analysis of air quality issues on regional and smaller scales. The modeling systems, which will be used for assessing emissions management options, should be:

- Suitable and acceptable for regulatory applications
- Accessible to all participating organizations
- Able to simulate key atmospheric and air-surface exchange processes influencing the issues under study so that optimal solutions to multiple, interactive problems can, in principle, be found
- Modular in order to promote ready understanding of model structure and facilitate the upgrading of process representations and other programmed components
- Readable and self-documenting
- Menu-driven to enable use by nonexperts
- Capable of being exercised in distributed, heterogeneous computing environments, wherein any reasonable number of advanced computers can work on the problem simultaneously, efficiently, and speedily
- Able to access on-line data sets necessary for model input and evaluation
- Able to display output data in graphic, geographic, and other symbolic forms to facilitate the interpretation and communication of results

CAMRAQ's subsidiary objectives are to coordinate research and collaborate on projects in order to leverage investments and avoid wasteful redundancies; to contribute to the advancement of knowledge in the atmospheric sciences and encourage application of the results, and to access, adapt, and adopt advances in the mathematical and computer sciences that will contribute to achieving the overall CAMRAQ objective.

Many of the participating agencies have substantial research on global issues under way as part of the massive, international effort to elucidate the causes and consequences of climate change. There is no intention to duplicate this effort; rather CAMRAQ aims to complement it and to focus on regional and smaller-scale applications of air quality models, including those dealing with climate change impacts.

The government and nongovernment organizations involved with air quality use a variety of models in fulfilling their missions. Unfortunately, these air quality models have very different genealogies and often target localized issues. They have different levels of explicitness and embody a wide diversity of underlying assumptions. Thus, when different models are applied to the same issue, the results often vary. Moreover, single- or limited-issue models may perform very poorly if applied to other issues.

Models typically have evolved over many years, have been designed and programmed by individuals having a wide range of skills and following no standardized methods, have not been adequately evaluated or compared, are not well documented, and are not computationally efficient. The approach CAMRAQ has adopted is designed to remedy these shortcomings.

The result should be CMSs that are constructed from a hierarchy of user-selectable models. At the top will be the most complete and explicit schemes possible for estimating emissions, representing tropospheric processes, and estimating initial and boundary conditions. Lower in the hierarchy, process representations will be less explicit (i.e., more highly parameterized). When field data are not available for model input, users will be able to select pretabulated data sets establishing conditions judged to be typical for the modeling domain. Consistent underlying assumptions will be maintained throughout the hierarchy to make the various CMS configurations as comparable as possible. The performance of each selectable configuration will be evaluated through sensitivity analyses and against field data sets of defined uncertainty to determine the level of confidence that can be placed in the individual simulations produced. Thus, as envisioned by CAMRAQ, a CMS can be used for anything from rapid screening exercises for narrowing choices among widely divergent solutions to full-blown, research-quality, multi-issue assessments.

Organization

CAMRAQ is organized very simply. Participating agencies (see the accompanying list) are symbolically bound by a memorandum of understanding that articulates shared goals and a willingness to cooperate in achieving those goals. Guidance is provided by a committee with one person from each organization desiring representation. It elects a chairperson annually; the current chair is from EPRI. The committee meets three or four times a year to discuss research coordination, share information, review and approve collaborative projects, and consider and recommend new initiatives. Ad hoc subcommittees are formed to address selected programmatic issues as they arise. Committee members use the electronic network Internet for the exchange of news, text, data, and models.

EPRI conducts feasibility studies on proposed activities, serves as a clearinghouse for coordinating the administration of collaboratively funded activities, produces a newsletter, provides liaison between consortium participants, and organizes workshops. It also sponsors a contractor to help administer CAMRAQ.

Only initial steps have been taken to coordinate the research of the individual CAMRAQ agencies. Descriptions of the agencies' relevant research have been compiled and distributed to steering committee members for review. The next step will be to formulate a set of recommendations for redirecting elements of the individual programs to mount a more efficient and economical effort.

CAMRAQ MEMBERS

U.S. Federal

- Defense Nuclear Agency
- Department of Energy
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Oceanic and Atmospheric Administration (NOAA), Aeronomy Laboratory
- NOAA Atmospheric Research Laboratory
- NOAA National Meteorological Center
- National Park Service
- National Research Council
- U.S. Army Atmospheric Sciences Laboratory

State and Local

- California Air Resources Board
- Northeast States for Coordinated Air Use Management
- South Coast Air Quality Management District

Industry

- American Petroleum Institute
- Chevron Research Corporation
- Electric Power Research Institute
- Pacific Gas and Electric Company
- Southern California Edison Company

International

- Environment Canada, Atmospheric Environment Service
- EUROTRAC/EUMAC
- Ontario Ministry of the Environment

Collaborative activities

CAMRAQ continues a general trend toward collaboratively funded research in the face of complex air quality issues and budget constraints. Table 1 is a representative list of recent collaborative projects for which subsets of CAMRAQ participants are key funders and planners. The results of these and other studies will be available to further the consortium's objectives as well as those of the individual study sponsors.

A competition among teams to design a CMS framework based on articulated user needs and cutting-edge computer and network capabilities (including the recommendations from the earlier workshops) is a hoped-for next step. This framework is expected to incorporate emerging CAMRAQ products into the evolving CMS.

Plans for collaborative projects include:

- Establishment of a generally accessible distributed data archive to support model development, evaluation, and application
- Recoding of today's advanced modeling systems for execution in a distributed computing environment that has at least one massively parallel computer
- Production of a workbook on tropospheric chemistry that presents critically evaluated kinetic, thermodynamic, and mechanistic data
- Review, critique, and performance comparison of mesoscale meteorological models
- Assessment of needs and provision of a means for ensuring that future generations of coupled meteorological and air quality models are fully compatible, computationally efficient, and interactive
- Establishment of a generally accessible distributed, heterogeneous computing environment and standardized user interface for exercising the evolving CMSs and interpreting their output

In addition to the CMS framework design competition, other early collaborative efforts will focus on advancing computational and data-handling capabilities for building an infrastructure to facilitate model access and use. These technological aspects are considered a high priority. Within the next two years, a distributed data archive should be designed and functional; the recoding of an advanced modeling system for running in a distributed computing environment should be completed, and a prototype user interface for selecting input data, selecting model configurations, running the models, and creating visual displays combining model output with other data should be ready for testing.

Improving the scientific understanding of tropospheric chemistry and physics will be a continuing effort, and no specific time lines for scientific deliverables have been developed. Many of the participating agencies already have under way strong efforts on the scientific underpinnings of modeling systems. To facilitate progress, many aspects of atmospheric research will be coordinated between agencies, and all participants will be encouraged to collaborate.

It is expected that advanced comprehensive modeling systems with user-friendly interfaces will be available by the end of the decade. In the meantime, interim versions will be evaluated and made available for specific applications.

Compressed-Air Energy Storage

CAES Geology

by Ben Mehta, Generation & Storage Division

The country's first compressed-air energy storage (CAES) plant was started up by Alabama Electric Cooperative (AEC) on May 31, 1991. The solution-mined cavern for this plant, which is located in McIntosh, Alabama, had been expected to involve considerable construction risk. However, AEC's experience has shown that cavern construction risk can be successfully minimized by performing standard geotechnical investigations and by using vendors with previous experience in gas storage. In fact, the McIntosh cavern proved to be the least risky, most reliable part of the plant.

In the wake of AEC's success, several other utilities are considering the construction of CAES plants in their service areas and hence are interested in geologic investigations of prospective sites. It now appears that if the complexities and heterogeneities of the subsurface geologic formations are properly understood, siting is not a critical-path activity for CAES development.

ABSTRACT *Compressed-air energy storage (CAES) is a modular, fast-responding, environmentally attractive technology that can help utilities make the best use of generation and transmission resources. Alabama Electric Cooperative started up the first U.S. CAES plant in May 1991, and several other utilities are now investigating the potential for CAES siting in their service areas. EPRI is supporting these efforts on a cost-sharing basis. The resulting products include a methodology for identifying, screening, and ranking potential sites and a methodology for cost-effectively matching aboveground turbomachinery to subsurface storage conditions.*

McIntosh cavern development

AEC first considered the availability of suitable CAES sites in its service area, which includes much of southern Alabama and the Florida panhandle. On the basis of site-specific geotechnical information and favorable logistics, the utility selected the McIntosh salt dome site, located in Washington County, Alabama, about 40 miles north of Mobile.

With EPRI cosponsorship (RP2615-6), AEC drilled two test wells at the proposed plant site in 1987 to select the specific location for the cavern. The first well was drilled near the site's southwestern boundary to define the shape and edge of the salt dome formation, as well as to determine the chemical and structural properties of the salt and the characteristics of its caprock. This well proved to be very close to the salt dome boundary. Also, analysis of salt core samples from this well revealed the presence of carnallite, a potassium salt ($KCl \cdot MgCl_2 \cdot 6H_2O$) that is 20–30 times more water-soluble than normal rock salt. Seams of carnallite could cause solution-mining irregularities in the cavern shape, resulting in an unstable cavern.

The second test well was drilled near the center of the salt dome, and salt core analysis did not reveal the presence of carnallite. The cavern well was subsequently drilled at this location. During solution-mining, the brine from the process was carefully monitored for carnallite impurities. The second test well was completed to provide additional access to the cavern and was later used in an innovative dewatering scheme (described below).

The McIntosh cavern has about 19 million cubic feet of usable volume. The original design called for a volume of 15 million cubic feet, assuming isothermal cavern conditions during the compression and expansion cycles. For the McIntosh plant design parameters, however, the potential increase in cavern air temperature during a possible 41-hour continuous compres-

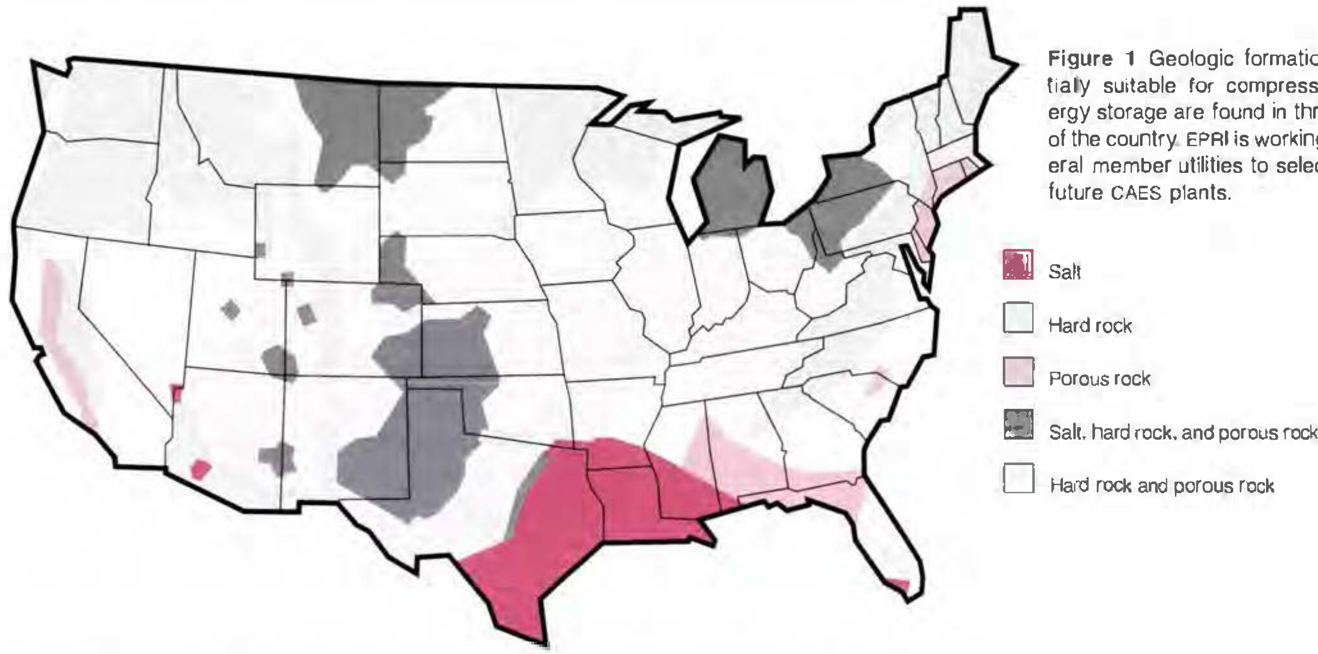


Figure 1 Geologic formations potentially suitable for compressed-air energy storage are found in three-fourths of the country. EPRI is working with several member utilities to select sites for future CAES plants.

sion mode was calculated to be 35°F (RP2894-5). Such a temperature change requires a larger cavern volume—as much as 30% larger than in the isothermal case. (The calculations are sensitive to initial conditions, the assumed heat transfer coefficient, cavern wall salt temperatures, air pressure changes, and salt thermal conductivity.) Since it is relatively inexpensive to mine extra volume once a solution-mining plant is in place, AEC elected to revise the design volume from 15 to 19 million cubic feet. (Plant performance tests conducted in August 1992, which involved 26 hours of continuous generation followed by 41 hours of compression, demonstrated that the cavern volume is sufficient to operate the plant according to specifications.)

The original project schedule defined cavern solution-mining, dewatering, and initial pressurization as critical-path elements. As solution-mining progressed, several factors contributed to extending the cavern completion schedule. To compensate for this delay, the dewatering and cavern pressurization scheme was modified. The original schedule called for complete dewatering of the cavern through the main CAES well before the permanent CAES wellhead was installed and the cavern was pressurized by portable compressors. The schedule allowed for about 190 days from the start of dewatering to the attainment of adequate cavern air pressure for turbomachinery testing.

The modified dewatering method, developed by EPRI, entailed simultaneous dewatering from the test well and air pressurization through the main well. This approach saved about 130 days on the plant construction schedule. If the test well had not been available for dewatering, AEC could have met the commercial operation date only by settling for a smaller storage volume. AEC estimated that this innovative dewatering scheme saved as much as $9 million in avoided costs.

CAES siting

The importance of extensive preconstruction geotechnical site evaluation cannot be overemphasized. As the histories of many underground construction projects have shown, most cost overruns and schedule delays result from the belated discovery of adverse geologic features or a failure to recognize their significance. Hence, in considering CAES, an important first step for a utility is to determine if appropriate geology exists in its service area. The geology must meet both physical and economic criteria to be suitable for CAES. Geologic formations offering potential sites—including porous rock, hard rock, salt domes, and depleted gas reservoirs—are available in roughly three-fourths of the United States (Figure 1).

In many respects, the storage of compressed air is similar to the underground storage of natural gas. The natural gas industry has 75 years of storage experience that provides a wealth of siting and operating know-how. That industry's excellent record has demonstrated that storage facilities can be cost-effective, reliable, safe, and environmentally acceptable. Many of the gas storage facilities, which are located near gas demand centers and along the gas pipeline network, were built in depleted gas fields, porous rock, and salt caverns. Gas storage and air storage do differ in that gas is stored for seasonal cycles whereas CAES plants involve daily or weekly cycles. Also, there are differences in the physical and chemical properties of air and gas that must be accounted for in designing air storage reservoirs.

Today, CAES plants are usually designed to use natural gas as the primary fuel and oil as the secondary fuel. For reliable operation, it is important to have an uninterruptible source of high-pressure gas at a CAES plant. The similarities in the geologic requirements and construction methods for gas and air storage facilities may make it convenient to develop gas storage adjacent to a CAES plant soon after completion of the CAES cavern. For example, a gas storage cavern is being constructed adjacent to the AEC McIntosh site in the same salt dome. The reliability and cost savings afforded by nearby high-pressure gas fuel storage are attractive features. Since the deregulation of the natural gas industry, utilities have increasingly recognized the value of storing gas fuel for power production in order to take advantage of lower-price gas contracts and ensure reliable gas supply during periods of high demand.

The selection and evaluation of preferred sites require engineering analysis to match CAES turbomachinery to the subsurface conditions. The turbomachinery train must be designed to accommodate the range of underground air storage pressures and temperatures experienced during plant operation. The aboveground machinery must also be designed with respect to environmental constraints and specific utility requirements, such as the CAES plant operation cycle and certain economic variables (cost of fuel and incremental off-peak electricity). Capital and operating costs for the machinery, the balance of plant, and underground storage determine the commercial attractiveness of CAES plants.

Many utilities have completed CAES geology screening and economic system planning analyses with positive results. EPRI plans to assist a number of utilities in building CAES plants. In the near term, the emphasis will be on nonsalt geologic formations: porous rock, hard rock, depleted gas fields, and existing mines and caverns. EPRI is now cosponsoring site exploration, identification, and evaluation tasks with several of its member utilities (Table 1).

Table 1
CAES GEOLOGY APPLICATION PROJECTS

Utility	Geology Type	Status
Alabama Electric Cooperative	Salt dome	First U.S. CAES plant (19-million-ft^3 cavern) operational since May 31, 1991
Carolina Power & Light	Rock caverns and porous rock	Many sites identified
Centerior Energy Corp.	Existing salt caverns	Cavern data acquired and conversion options evaluated
Duke Power	Rock caverns	Many sites identified
Florida Power Corp.	Rock caverns and porous rock	Potential sites identified and evaluated
Indianapolis Power & Light	Porous rock and existing caverns	Many sites identified
New York State Energy Research & Development Authority, Niagara Mohawk, New York State Electric & Gas, New York Power Authority	Salt, hard rock, porous rock, and existing caverns	Site evaluation in progress
Pacific Gas and Electric	Depleted gas reservoir	Exploratory drilling, coring, and core testing completed
Public Service Electric & Gas	Porous rock and abandoned mines	Porous rock site evaluation in progress
Southern Company Services	Salt caverns	Detailed cost model of a salt-based CAES plant being developed
Tennessee Valley Authority	Depleted gas reservoir	Preferred reservoir site identified; exploratory drilling in late 1992
Union Electric	Porous rock and abandoned mines	Many sites identified
Western Area Power Authority	Salt, hard rock, porous rock, and mines	Site evaluation in progress

The feasibility of air storage in porous rock was established by successful field testing in a deep saline aquifer at Pittsfield, Illinois (EPRI reports GS-6671 and GS-6688). This experiment involved the injection, withdrawal, and storage of compressed air in daily and weekly cycles. The airflow delivery and storage pressure responses observed during the field testing were predictable on the basis of engineering principles and practices used in the natural gas storage industry.

The only unexpected finding at Pittsfield was that the stored air showed oxygen depletion—from a nominal level of 22% (by volume) to less than 10%—during a 12-month period of inactivity after completion of the air-cycling tests. A geochemical reaction with iron pyrites in the porous rock was identified as the cause of this phenomenon, which occurred only during the extended dormant period. Air withdrawn during the active cycling period did not show any loss of oxygen. The topic of oxygen depletion has been studied under RP8000-9 and is discussed in detail in V. S. Welch, M. W. Dann, and B. Mehta, "Predicting Oxygen Depletion in Reservoir Environments," a paper presented at the 65th annual technical conference of the Society of Petroleum Engineers, held in New Orleans in September 1990 (SPE 20721, pp. 85–96).

EPRI has developed a methodology to identify, screen, and rank potential CAES sites. Studies with member utilities using this methodology have evaluated various geologic formations, including porous and hard rock, existing mines, and depleted gas fields. The evaluation process uses the Geologic Information System (GIS) for the digital mapping of pertinent geologic data and also considers such logistical information as the location of power plants and electricity and gas transmission routes. Candidate sites are ranked on the basis of cost and performance comparisons.

These steps must be undertaken for each potential site:

- Matching available equipment to geologic conditions (the pressure and temperature ranges of the stored air may limit or dictate the choice of turbomachinery)
- Determining the reservoir's viability, the adequacy of reservoir volume for meeting energy storage requirements, and the potential for future expansion
- Estimating site-specific capital and operating costs on the basis of overall plant design and host utility requirements

When sufficient geologic information is available, an EPRI-developed computer program that integrates above- and below-ground design parameters can be used to establish a conceptual configuration of the overall plant. On the basis of both the geologic data and economic input, the program computes the following information:

◻ Major underground storage parameters, including optimal depth, maximum and minimum operating pressures, total volume requirements, and, for porous rock formations, the number and configuration of wells

◻ The maximum power and energy that can be generated and stored in the geology

◻ Overall plant performance characteristics, such as heat rate and energy ratio

◻ Differences in capital and operating costs for the various types of formations, taking into account aboveground equipment, engineering and construction, and underground storage development

EPRI's geologic R&D and application projects have provided some useful insights into potential CAES sites. They have found that existing and abandoned mines may offer attractive options for conversion to air storage service, as may depleted natural gas storage reservoirs. Also, salt caverns used for brine production or for liquid hydrocarbon storage may be considered for air storage.

Other recent and ongoing CAES geotechnical research involves the study of geochemical oxidation of porous rock core samples, subsidence monitoring at McIntosh, porous media site investigations with several utilities, the study of unlined rock storage caverns in Norway, and cooperation with Israel and Japan in their CAES plant construction activities. Many geotechnical papers were presented at the Second International CAES Conference, sponsored by EPRI in San Francisco last July (proceedings forthcoming). EPRI also holds CAES geology workshops annually.

EPRI has become a leading resource on the use of geologic media for compressed-air energy storage. Member utilities are encouraged to contact EPRI staff for help in evaluating the applicability of CAES to their systems and the suitability of their local geology for CAES development.

Power System Operations

C²ALM: Control Center Advisor for Load Management

by Rambabu Adapa, Electrical Systems Division

ABSTRACT *Utilities are increasingly turning to interruptible rate programs, a form of demand-side management, to defer generation, transmission, and distribution capacity additions. As the number of customers participating in these programs grows and as utility-customer contracts become more complex, power system dispatchers face difficult choices in deciding how to make the best use of the programs. EPRI has developed a prototype expert system that is helping dispatchers at New England Electric System plan load interruptions to realize maximum benefits. A production-grade version of the system, now being developed, will extend this capability to other utilities.*

In today's competitive environment, many utilities are helping customers manage their energy needs to make the most efficient use of both customer and utility resources. Demand-side management (DSM) can help utilities improve load shape and defer the need for new generating capacity, thereby minimizing electricity costs. New research indicates that for similar reasons DSM can also have a significant impact on transmission and distribution systems.

To help utilities realize the benefits of DSM, EPRI's Customer Systems Division has been providing methods and information for assessing energy markets and for designing, implementing, and evaluating DSM programs. It has developed various software packages, guidelines, and other tools to achieve these goals.

As a result of these and other efforts, utilities are implementing a wide variety of DSM programs. One important group of these programs addresses load management. Load management aims at meeting the load shape objectives of peak clipping, valley filling, and load shifting. Peak clipping—the reduction of system peak loads—can be implemented through interruptible rate programs (also called interruptible load programs, curtailable rate or load programs, or direct load control programs). Under these utility rate offerings, customers who agree to accept interruption of their power are billed at lower rates. Utility-customer contracts typically stipulate the amount of power to be interrupted, the time of day of potential interruption, and the maximum number of interruptions.

The increasing use of these contracts and their increasing complexity make a power system dispatcher's job more difficult. When the dispatcher anticipates insufficient reserve capacity, the interruptible loads of customers enrolled in these rate programs can be curtailed to help remedy the problem. But choosing which customers' loads to interrupt is a difficult task: reserve requirements must be met at the lowest cost without violating contract conditions. The manual dispatching techniques currently employed do not address the diversity of options available or the need to coordinate their use.

Under RP2944-5, EPRI has developed a prototype expert system to help dispatchers optimize control center strategies for managing interruptible loads. This system forecasts the need for interruption, identifies and ranks customers whose power can be interrupted, and suggests appropriate actions. The Power System Planning and Operations Program of EPRI's Electrical Systems Division is managing this project, in cooperation with the Customer Systems Division's Demand-Side Management Program.

Desktop expert

Called the Control Center Advisor for Load Management (C^2ALM), the new knowledge based tool will provide benefits to utilities through increased efficiency in the use of interruptible rate programs. These benefits include avoided costs (i.e., marginal-cost savings resulting from reductions in peak load), reductions in lost sales, and increased productivity (i.e., savings in the time and resources required to make decisions in the control center).

The C^2ALM prototype is a desktop workstation that is supporting system dispatchers at the project's host utility, New England Electric System (NEES). The prototype automates the collection and management of the contract, customer, and system data necessary for developing interruptible load dispatch strategies. It contains a knowledge base to help dispatchers understand and integrate these data. And equally important, the prototype is packaged with a graphic user interface that allows dispatchers to interact with the advisor, display dispatch solutions, and view the impact of decisions on system load.

The C^2ALM prototype analyzes various input data, including actual hourly loads, a three-day load forecast, plant availability schedules, and the contract terms. Using its built-in dispatching and contract expertise, it makes recommendations to the dispatcher.

Dispatchers must first decide whether interruptible load options will be needed to meet the expected system load. Making this decision entails forecasting near-term load, determining available system capacity, and displaying and evaluating system status.

When a NEES dispatcher decides to reduce load, the C^2ALM prototype uses the expert system to produce a dispatch solution. This solution is a set of interruptible rate program customers and the times at which each interruption should begin and end. This process comprises several steps. First, eligible customers are identified on the basis of the terms of their contracts and their interruption histories. Then this list of customers is ranked on the basis of such factors as future availability for interruption and the cost of interruption. Finally, C^2ALM calculates the impact of these customers on system load.

To perform this analysis, C^2ALM uses a knowledge base that stores the expertise of dispatchers and contract managers. It also manages a relational database to maintain up-to-date contract terms and interrupted-load history. Each day, before dispatching operations are conducted, the expert system determines customer eligibility and priority. Then, when the NEES dispatcher sets a load reduction goal, C^2ALM calculates a dispatching solution. To handle the many combinations of customers and start times, C^2ALM uses a heuristic approach that pursues parallel solutions and, like a human dispatcher, scores them to eliminate unproductive choices. C^2ALM then presents the solution that meets the reduction goal and best meets utility objectives.

The NEES system dispatcher can accept the solution, modify it, or rerun it with different customers. The dispatcher makes the final decision about whose power to interrupt.

Prototype applications

The C^2ALM prototype is a planning tool in that it helps dispatchers plan, hours or days in advance, the best use of available interruptible load. Since most utilities experience their peak system load in the afternoon or early evening, a dispatcher would typically run C^2ALM in the early morning. This allows sufficient time to examine options, fine-tune projections, and actually interrupt customer loads if that is deemed appropriate.

C^2ALM is also useful for planning a few days in advance. For example, if a three-day heat wave is expected to push loads to high levels, the dispatcher might want to interrupt a substantial portion of customers' loads each day. But contract terms might prohibit interruption on consecutive days. C^2ALM considers these terms when ranking customers for interruption.

The prototype accommodates any type of interruptible rate program. Some programs target residential customers and small commercial and industrial customers, while others are aimed at larger commercial and industrial customers. In some programs the utility has actual control over the customer loads, while in others the customer must actually flip the switch. Some programs call for the interruption of a particular end use, while others involve the interruption of a portion of load, regardless of end use. C^2ALM accounts for all such variations in contract terms.

NEES dispatchers also can use the C^2ALM prototype to examine, after the fact, compliance with the interruptible rate program. For example, at the end of the day, the system indicates how many customers were contacted for interruption and which ones complied and which did not; it also indicates the load impact of each interruption. This information can help NEES dispatchers decide which customers to interrupt in the future.

Commercial version

The successful performance of the C^2ALM prototype at NEES has demonstrated that applying expert system technology to the management of interruptible loads is feasible. However, the prototype is not sufficiently generic for widespread utility use. The next step, now under way, is to create a commercial-grade product that any utility can use to manage interruptible loads and to rank interruption options on the basis of cost as well as capacity limits.

This next-generation expert system will be implemented in an open-systems environment to minimize implementation cost. Industry standard products will be used whenever possible. For example, a 486-based personal computer and the Microsoft Windows interface will be used, since utilities can easily obtain and maintain this hardware and software. NEXPERT/OBJECT, a Neuron Data, Inc., product that is portable and interfaces with relational databases, will serve as the expert system shell. Libraries of modules with well-defined external interfaces accessible to users will be created. Finally, to integrate C²ALM into existing networks, it will be designed according to UCA (Utility Communications Architecture) and DAIS (Database Access Integration Services) standards.

The Analytical Sciences Corporation, or TASC—the EPRI contractor that developed the C²ALM prototype with the cooperation of NEES—has begun work on the production-grade version. It is expected to be available to utilities next year. This general-purpose workstation will be capable of handling a broad range of interruptible load options and dispatching criteria.

Nondestructive Evaluation

Ultrasonic Pipe Simulator

by Soung-Nan Liu, Nuclear Power Division

ABSTRACT *ASME Section XI, Appendix VIII, requires ultrasonic inspectors to demonstrate their inspection capability on samples of power plant components that contain both critical and noncritical defects. However, the availability of such samples is limited because sample construction is very expensive and access to components removed from plants is restricted. EPRI has developed an ultrasonic pipe simulator that enables inspectors to play back prerecorded ultrasonic data gathered from a representative pool of well-characterized samples. Inspectors can use their own ultrasonic testing instruments for the playback, which adds another degree of realism to the simulation.*

The utility industry's concern about the reliability of nuclear power plant component inspection is reflected in Appendixes VII and VIII to Section XI of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. These recently approved appendixes require that ultrasonic testing (UT) inspectors demonstrate their inspection capability to a peer group that includes Nuclear Regulatory Commission, utility, and third-party reviewers. The demonstration must be conducted on samples representative of the components a candidate is scheduled to inspect in a nuclear power plant.

Performance demonstration is mandated for the entire population of UT inspectors who hope to work in nuclear plants. This requirement creates two logistical problems: ensuring access to samples so that candidates can prepare for demonstration, and ensuring sample security.

Valid certification of UT personnel requires preservation of the anonymity of samples to ensure that inspectors "learn" the sample set through experience rather than through secondhand information. Otherwise, the samples may be rendered useless for examination purposes. At the same time, access to samples is important to performance demonstration candidates. Practicing and refining their procedures on samples will help them improve their chances of achieving a certifiable demonstration.

The performance demonstration requirement returns inspectors to precertification status. Experienced and novice inspectors alike will need to be trained for performance demonstration. Although the intent of Appendix VIII is to increase confidence in UT inspection, it may also decrease the number of qualified inspectors, thus raising the cost of retaining those who are qualified. Predemonstration training, with access to samples, will be essential to preserving the already limited pool of inspectors.

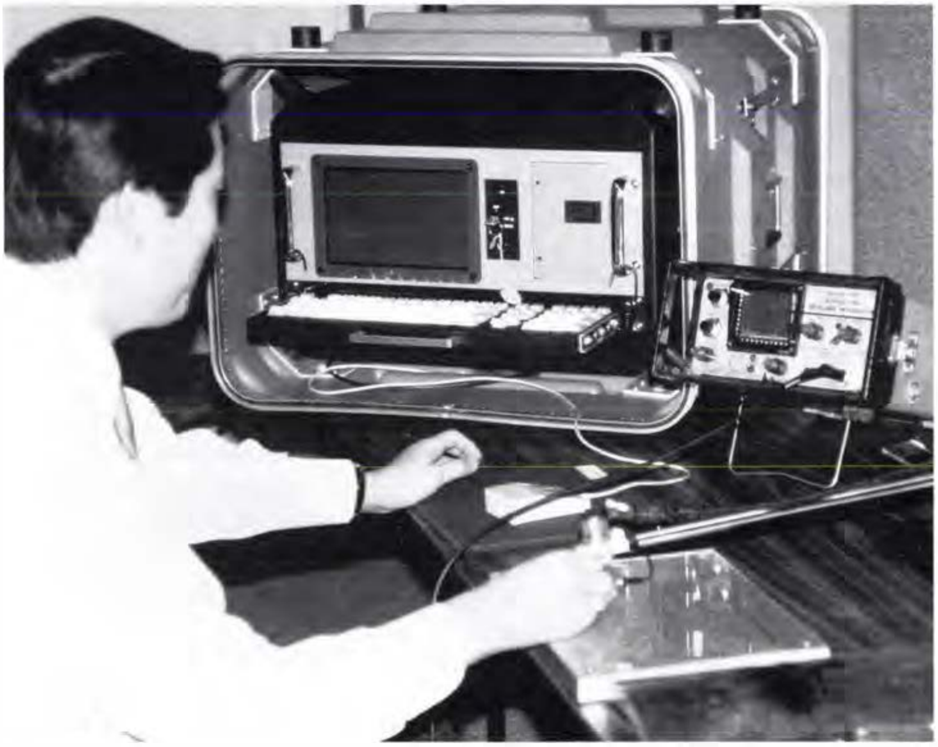
A cost-effective solution

EPRI has sponsored the development of an ultrasonic pipe simulator (UPS) that offers a cost-effective approach to ensuring both sample access and sample security. The UPS is a personal computer–based vehicle for multiplying existing samples into a portable and virtually inexhaustible database of samples for use by UT inspectors. Moreover, the way in which the UPS implements the database guarantees security.

Sierra Matrix, Inc., developed the UPS for EPRI under RP3148-1. In cooperation with the EPRI Nondestructive Evaluation Center, Sierra Matrix recorded ultrasonic inspection data in a format compatible with the special computer hardware necessary for real-time playback of the data. The UPS is configured to drive a variety of ultrasonic field instruments, allowing users to customize its application to their specific needs. Users can also proceed at a pace that best suits their learning style.

The UPS has two modes: data acquisition and inspection training. Ultrasonic data must be recorded and stored in a way that facilitates faithful real-time playback. In the data acquisition mode, the UPS can accommodate existing databases or can be used to acquire new data. Manual and automated data acquisition options are available.

Figure 1 The personal computer-based ultrasonic pipe simulator plays back prerecorded ultrasonic data on a standard field instrument. Its realism, portability, and sample-generating capability promise to make the UPS an effective, economical tool for training and testing ultrasonic inspection personnel.



In the training mode, the UPS user is given a test block about the size of a typical mouse pad. On this block are etched the salient features of the component being simulated—for example, a zero location for calibration of position, the borders of welds, and an outline of the scan area. As the trainee scans the test block with an inoperable transducer, the UPS, under computer control, recalls stored waveforms and displays them on the trainee's UT instrument (Figure 1).

Because the digitally stored waveforms are passed through a digital-to-analog converter before being input into the trainee's instrument, they appear continuous on the instrument screen. The display responds to the transducer movements in real time, and the signal is interrupted when the transducer is not in contact with the test block. The UPS also simulates transducer skew and electronic noise. Thus trainees experience the same "look" and "feel" they would encounter in a field inspection.

IGSCC training

In its first application, the UPS will support the training of UT inspectors in the detection and sizing of intergranular stress corrosion cracking (IGSCC) in piping. The UPS will be configured to represent ultrasonic IGSCC piping data obtained both from the EPRI NDE Center IGSCC database and from IGSCC pipe samples available at the center. These samples are service-removed and are thoroughly documented with respect to ultrasonic characteristics and physical (cracking) condition. The NDE Center has used the samples effectively for several years in its IGSCC detection and sizing courses.

Unlike the physical samples at the NDE Center, the digital samples stored in the UPS can be manipulated to simulate new specimens. Database management techniques can be used to create various combinations of the digital samples, much as many different mosaics can be created by rearranging a set of tiles. Thus a very large population of samples is possible. Moreover, security is easily achieved, since only the test administrator need know the components of a sample and how they are arranged. Also, the sample supply is completely portable: the test administrator can take the UPS to any training site.

The UPS has been demonstrated for several EPRI member utilities, who have responded enthusiastically about its implementation as a training aid. Limited applications of the system to evaluate its usefulness for training have also had positive results.

To use the UPS, the administrator, trainer, or trainee simply connects it to a UT instrument. Before a training exercise, the user can run the UPS options that allow the creation of samples, as described above. Also, the decisions a trainee makes during an exercise can be recorded to facilitate evaluation.

Benefits

The UPS can reduce the cost of training, testing, and performance demonstration. Because of the simulator's ability to generate multiple samples from the digital data, fewer physical samples need be available for training. The portability of the UPS saves utilities the expenses incurred when personnel must travel to a site where physical samples are inventoried.

The UPS can also be used on a component scheduled for destructive assay. After the assay, a postmortem analysis using the UPS data can be performed to correlate the ultrasonic responses with the component's physical aspects.

New Contracts

Customer Systems

Project	Funding/ Duration	Contractor/EPRI Project Manager
Residential Ventilation Technologies (RP2417-22)	$69,900 8 months	Energy International/ *J. Kesselring*
Development of the Residential End-Use Technologies Desk Book (RP2892-25)	$109,100 8 months	Aptech Engineering Services/ *J. Kesselring*
Near-Term Field Testing of the Low-Cost Line-Voltage Thermostat (RP2892-26)	$81,000 5 months	Honeywell/ *J. Kesselring*
Electrical Active Suspension Systems: Application to All-Electric Vehicles (RP2918-25)	$67,100 9 months	San Jose State University/ *B. Banerjee*
UNIX-Based Load Data Analysis Workstation Tool (RP2980-20)	$50,000 8 months	Quantum Consulting/ *P. Meagher*
Heat Transfer From Spiral Ground Coils (RP3024-20)	$125,600 14 months	University of Kentucky Research Foundation/ *P. Joyner*
Market and Electricity Demand Analysis of High-Speed Rail and Maglev (RP3025-3)	$75,000 9 months	Argonne National Laboratory/ *E. Riddell*
Preliminary Study of Direct Electrolytic Steelmaking (RP3243-2)	$80,000 12 months	Massachusetts Institute of Technology/ *P. McDonough*
Shock Wave Lithotripsy for Ceramic Core Removal (RP3243-7)	$93,500 23 months	University of Alabama/ *P. McDonough*
DSM Evaluation: Northern States Power and Madison Gas & Electric (RP3269-7)	$142,500 35 months	RCG/Hagler, Bailly/ *P. Hummel*
Building-Code Review With Respect to Electric Vehicle Display, Storage, and Servicing (RP3272-5)	$135,400 9 months	National Conference of States on Building Codes and Standards/ *J. Janasik*
Survey of Utility Electric Vehicle Activities (RP3272-6)	$90,500 5 months	Theodore Barry & Associates/ *J. Janasik*
COOLAID Enhancements and Support (RP3280-24)	$179,400 21 months	Regional Economic Research/ *R. Wendland*
Commercial Dehumidification Technology Transfer (RP3280-27)	$150,700 21 months	Bevilacqua Knight/ *M. Khattar*
Cold Air Diffuser Performance (RP3280-29)	$180,700 23 months	Colorado State University/ *R. Wendland*
Efficient Utilization of Electric Power for the Impulse Drying of Paper (RP3328-3)	$99,000 12 months	Institute of Paper Science & Technology/ *A. Amarnath*
Paper Recycling: Electrotechnology Opportunities and Impact on Electricity Use (RP3328-6)	$53,000 5 months	Simons-Eastern Consultants/ *A. Amarnath*
Residential End-Use Technologies Desk Book: Lighting and Home Automation (RP3415-1)	$152,300 11 months	Energy International/ *J. Kesselring*
Microwave Clothes Dryer Development (RP3417-1)	$483,200 12 months	Thermo Energy Corp./ *J. Kesselring*
Customer Needs Research: Enhancement and Technical Support (RP4001-3)	$189,000 9 months	National Analysts/ *T. Henneberger*

Electrical Systems

Project	Funding/ Duration	Contractor/EPRI Project Manager
EMTP Workstation Development Under MS Windows, UNIX Open Look, and UNIX Motif Platforms (RP2149-13)	$70,300 7 months	Power Computing Co./ *R. Adapa*
Error Reduction in State Estimation Measurements and Modeling Parameters (RP2473-57)	$99,800 11 months	Industrial Research & Development Corp./ *J. Gralow*
Value-of-Service Survey at Duke Power (RP2878-3)	$256,000 14 months	Freeman, Sullivan & Co./ *N. Balu*
FACTS: Evaluation of Flexible AC Transmission System Technologies on the FP&L System (RP3022-19)	$223,300 13 months	Florida Power & Light Co./ *R. Adapa*
Static Condenser Performance Evaluation (RP3023-4)	$158,700 22 months	Swedish Royal Institute of Technology/ *S. Nilsson*
Effects of Switching Transients on High-Voltage Current Transformers (RP3320-1)	$313,300 13 months	BDM Corp./ *S. Lindgren*
Outdoor Aging of Polymeric Cable Terminations (RP3356-1)	$221,000 34 months	Arizona State University/ *B. Bernstein*
Installed Cable Testing: Fault Location and Performance Degradation Estimation (RP3392-1)	$306,200 35 months	Cable Technology Laboratories/ *B. Bernstein*
Cable-Pulling Software Module, CABLPUL+ (RP7913-4)	$135,000 8 months	Power Computing Co./ *T. Rodenbaugh*
Trench Optimization Analysis and Design Program (RP7913-5)	$360,100 15 months	Power Computing Co./ *T. Rodenbaugh*

Environment

Project	Funding/ Duration	Contractor/EPRI Project Manager
Southern Oxidant Study (RP1630-61)	$7,610,000 66 months	University Corp. for Atmospheric Research/ *A. Hansen*
Elemental Speciation of Arsenic in Fly Ash at Ultratrace Levels by Chromatography (RP2485-26)	$108,800 35 months	University of Cincinnati/ *L. Goldstein*
Relationship Between Arsenical-Induced Genotoxicity and Choline Deficiency in Syrian Golden Hamsters (RP2485-28)	$74,300 9 months	Integrated Laboratory Systems/ *J. Yager*
Electrokinetic Removal of Coal Tar Constituents (RP2879-21)	$105,400 17 months	Lehigh University/ *I. Murarka*
NO_x Control Technical Support (RP2916-26)	$185,100 14 months	Decision Focus/ *D. Eskinazi*
Electrostatic Precipitator Technical Support (RP3005-3)	$112,200 10 months	Systems Applications International/ *R. Altman*
Mobile Pilot Plant for Autoclaved Cellular Concrete (RP3176-5)	$400,000 10 months	North American Cellular Concrete Co./ *D. Golden*
Atmosphere-Surface Exchange of Mercury in Forests and Lakes (RP3218-2)	$1,155,400 36 months	Oak Ridge National Laboratory/ *D. Porcella*
Surface Water Risk Management (RP3221-1)	$200,000 12 months	Decision Focus/ *R. Goldstein*
Regional Climate Simulations for Europe (RP3267-12)	$54,600 12 months	Universita Degli Studi, l'Aquila/ *C. Hakkarinen*
Risk Management for Noncombustion Wastes (RP3368-1)	$100,000 12 months	Decision Focus/ *R. Goldstein*
Molecular and Genetic Toxicology of Arsenic (RP3370-6)	$92,000 9 months	University of California, San Francisco/ *R. Wyzga*
Metal-Induced Neoplastic Progression in Human Epithelial Cells (RP3370-8)	$60,400 6 months	University of California, San Francisco/ *L. Goldstein*
Priority-Setting Systems for Allocating Resources for Multisite Investigations (RP3372-1)	$200,000 12 months	Decision Focus/ *A. Thrall*

Exploratory & Applied Research

Project	Funding/ Duration	Contractor/EPRI Project Manager
Nanoparticle-Dispersion-Strengthened Ceramics (RP2426-54)	$150,000 44 months	Lehigh University/ *W. Bakker*
Structure, Morphology, and Distribution of Reactive Elements in Chromium Oxide Films (RP2426-56)	$457,300 48 months	Oregon Graduate Center/ *J. Stringer*
Development of Multidimensional Two-Fluid Model of Turbulent Boiling Flow (RP8006-28)	$55,100 22 months	Arizona State University/ *P. Kalra*
Transport Phenomena in Liquid Crystalline Polymers: Structure-Property Relationship Study for Moisture Impermeability (RP8007-14)	$79,900 36 months	North Carolina State University/ *B. Bernstein*
Plasma Polymerization Technology for Improved Extruded Dielectric Cables (RP8007-17)	$160,000 36 months	University of Missouri, Columbia/ *B. Bernstein*

Project	Funding / Duration	Contractor / EPRI Project Manager
Exploratory & Applied Research (cont.)		
Characterization of Mechanical and Thermal Properties of Advanced Composite Pultrusion (RP8007-20)	$134,300 36 months	University of Mississippi / *B. Bernstein*
Visible-Light-Emitting Diodes Fabricated From Soluble Semiconducting Polymers (RP8007-21)	$450,000 36 months	University of California, Santa Barbara / *S. Alpert*
High-Temperature-Superconductor Flux Lattice Dynamics (RP8009-24)	$171,800 35 months	Stanford University / *T. Schneider*
High-Technetium Field-Effect Switches for Motor Applications (RP8009-27)	$110,000 12 months	University of Maryland / *T. Schneider*
Avoiding Bifurcation Instabilities in Electric Power Systems (RP8010-30)	$208,800 57 months	University of Wisconsin, Madison / *A. Wildberger*
Analysis of a Multiprocessor Performance Accelerator Running ETMSP (RP8010-31)	$278,900 6 months	Performance Processors / *G. Cauley*
Cellular Responses to Low-Frequency EMF: Resonant Effects on Calcium Binding to Calcium-Binding Proteins (RP8011-16)	$162,400 12 months	University of Utah / *C. Rafferty*
Interdisciplinary Research on CO_2 and Climate Using a Three-Dimensional Model Constrained by Isotopic Carbon Measurement (RP8011-20)	$296,300 36 months	University of California, San Diego / *L. Pitelka*
Nonimaging Optics Reflector Designs (RP8012-14)	$149,300 33 months	Ecole des Mines de Paris / *K. Johnson*
Fluorocarbon Mixture Alternatives for R-11, R-12, R-22, and R-502 (RP8013-3)	$349,400 23 months	National Institute of Standards and Technology / *T. Statt*
Weather Forecasts for Use in Load Forecasting (RP8013-10)	$185,000 14 months	Control Command / *B. Maratukulam*
New Approach to Fine Grinding of Coal (RP8013-12)	$340,600 23 months	University of California, Berkeley / *S. Alpert*
Evaluation and Field Demonstration of NOREM Alloys for Hydroelectric Applications (RP9000-14)	$160,300 35 months	Pacific Gas and Electric Co. / *H. Ocken*
Generation & Storage		
Development of Alternative Fuels From Coal-Derived Syngas (RP317-7)	$100,000 21 months	Air Products and Chemicals / *N. Stewart*
Supercritical Wet Oxidation Feasibility (RP1403-[illegible]6)	$83,600 6 months	PSI Technology Co. / *J. Bartz*
Radial-Flow Solid Oxide Fuel Cell Development (RP1676-17)	$399,200 21 months	Technology Management / *R. Goldstein*
Heat Exchanger Expert System (RP1711-12)	$251,000 18 months	Karta Technology / *J. Tsou*
Corrosion Fatigue Initiation in Boiler Tubing (RP1890-10)	$355,000 18 months	Babcock & Wilcox Co. / *B. Dooley*
Battery Storage Benefits Study for Consolidated Edison Company of New York (RP2123-20)	$100,600 9 months	Power Technologies / *S. Chapel*
T&D Benefits of Micro-Superconducting Magnetic Energy Storage (RP2123-23)	$75,000 11 months	Pacific Gas and Electric Co. / *S. Chapel*
Advanced Graphic User Interface Development for Sequential Optimization Engines (RP2147-20)	$125,000 12 months	Decision Focus / *S. Yunker*
Life Assessment of Welded Header and Pipe T Pieces (RP2253-11)	$297,000 84 months	Era Technology / *R. Viswanathan*
Magnetohydrodynamic Power Plant Instrumentation and Control (RP2466-14)	$309,300 44 months	MHD Development Corp. / *A. Cohn*
Micro-Superconducting Magnetic Energy Storage Applied to Electric Rail Transit Systems (RP2572-11)	$50,000 8 months	Pacific Gas and Electric Co. / *R. Schainker*
Conceptual Engineering and Cost Estimate for CAES Plant With CASH Cycle (RP2[illegible]76-5)	$138,000 9 months	Energy Storage & Power Consultants / *R. Pollak*
Maintenance Accounting Reliability System for Combustion Turbine Power Plants (RP2774-10)	$147,800 12 months	Strategic Power Systems / *C. Dohner*
Integrated Gasification–Compressed-Air Storage With Humidification: Technical Support (RP2834-4)	$111,600 12 months	Energy Storage & Power Consultants / *A. Cohn*
Determining the Probable Maximum Flood for Civil Works (RP2917-36)	$118,100 6 months	Bechtel Group / *D. Morris*
Plant and Environmental Control and Optimization System (RP2922-7)	$195,100 12 months	Praxis Engineers / *A. Mehta*
Development of CAES Cost Model and System Planning (RP3049-12)	$85,000 13 months	Southern Company Services / *B. Mehta*
Evaluation of CAES Benefits and Identification of Sites for New York State (RP3049-13)	$195,000 12 months	Energy Storage & Power Consultants / *B. Mehta*
Integrated Energy Systems		
Integrated Resource Planning Data Compatibility: Scoping Study (RP2767-[illegible])	$103,600 8 months	Abacus Programming Corp. / *L. Rubin*
Bulk Power Planning: Market Development and Support (RP3145-4)	$58,900 7 months	Decision Systems International / *R. Siddiqi*
Development of a Reliability Prediction Methodology for a Gasification Combined-Cycle Power Plant (RP3360-1)	$564,400 24 months	ARINC Research Corp. / *J. Weiss*
Nuclear Power		
On-site Replacement of Irradiated Control Blade Pins and Rollers (RP1935-23)	$175,100 10 months	Combustion Engineering / *H. Ocken*
Identification of Circuit Breaker Aging Mechanisms in Field Conditions (RP2409-12)	$187,100 20 months	Grove Engineering / *J. O'Brien*
Main Coolant Pump Seal Maintenance Guide (RP2814-72)	$117,400 16 months	Quadrex Energy Services Corp. / *K. Barry*
Instrumentation and Control Maintenance Guide (RP2814-73)	$[illegible]8,000 10 months	Erin Engineering & Research / *J. Jenco*
Modeling of High-Burnup Fuel and of Failed-Fuel Degradation (RP2905-3)	$52,[illegible]00 8 months	Anatech Research Corp. / *O. Ozer*
Reactor Coolant and Recirculation Pump Seal Maintenance: Measurement and Data-Recording Aids (RP3111-4)	$319,200 21 months	Westinghouse Electric Corp. / *J. Yasutake*
Infrared Inspection Technical Evaluation (RP3235-3)	$50,000 8 months	American Risk Management Corp. / *A. Singh*
Advanced LWR: Piping System Analysis Support (RP3260-26)	$51,000 12 months	ATI Consulting / *C. Welty*
Application of Risk and Reliability Methods to Regulatory Issues (RP3300-3)	$134,200 21 months	Quadrex Energy Services Corp. / *F. Rahn*
Hydrogen Water Chemistry Radiation Control Evaluation (RP3313-4)	$182,300 15 months	NWT Corp. / *C. Wood*
Local Area Network Plant Analyzer Computer System (RP3317-1)	$428,300 20 months	S3 Technologies Co. / *J. Kim*
Rule-Based Deterioration Identification and Management System (RP3343-9)	$17[illegible],400 9 months	Grove Engineering / *M. Lapides*
Development of Process Control Capability Through the Browns Ferry Integrated Computer System (RP3351-2)	$146,000 8 months	Science Applications International Corp. / *J. Naser*
Fire PRA Method and Software Development and Demonstration (RP3385-1)	$700,000 21 months	Science Applications International Corp. / *R. Oehlberg*
High-Temperature Electrochemical Potential Monitoring System (RPS416-2)	$124,400 13 months	NWT Corp. / *P. Paine*
Chemistry Treatment for Enhanced Removal of Steam Generator Tube Deposits: Process Development (RPS416-4)	$64,200 4 months	Gebco Engineering / *L. Williams*
Investigation of Sources of Organics and Cation Conductivity Discrepancies at the Farley Nuclear Plant (RPS416-6)	$218,900 11 months	Adams & Hobart / *P. Paine*
In-pile Zircaloy Corrosion Tests With High Coolant Lithium Content (RP[illegible]102-45)	$510,000 19 months	Institutt for Energiteknikk / *S. Yagnik*

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. There is no charge for reports requested by EPRI member utilities and affiliates. Reports will be provided to nonmember U.S. utilities only upon purchase of a license, the price of which will be equal to the price of EPRI membership. Others pay the listed price or, in some cases (when noted), must enter into a licensing agreement.

CUSTOMER SYSTEMS

Environmental Benefits of Adjustable-Speed Drive Applications
TR-100200 Final Report (RP2951-11); $200
Contractor: JARSCO Engineering Corp.
EPRI Project Manager: M. Samotyj

Electric Motors: Markets, Trends, and Applications
TR-100423 Final Report (RP2613-10); $200
Contractor: Resource Dynamics Corp.
EPRI Project Managers: M. Jones, B. Banerjee

Evaluation of Electric Vehicle Battery Systems Through In-Vehicle Testing: 6th Annual Report (1990)
TR-100657 Final Report (RP1136-33); $200
Contractor: Electrotek Concepts, Inc.
EPRI Project Manager: R. Swaroop

Customer-Focused Planning: Getting Started
TR-100761 Final Report (RP2982-4); $200
Contractor: Putnam, Hayes & Bartlett
EPRI Project Managers: P. Hanser, T. Henneberger

Customer-Focused Planning: Interim Report
TR-100762 Final Report (RP2982-4); $200
Contractor: Putnam, Hayes & Bartlett
EPRI Project Managers: P. Hanser, T. Henneberger

Electric Utility DSM Programs: Terminology and Reporting Formats
TR-100763 Final Report (RP2982-8); $200
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: P. Hanser

Customer-Focused Planning: Concepts and Tools
TR-100815 Final Report (RP2982-4); $200
Contractor: Putnam, Hayes & Bartlett
EPRI Project Managers: P. Hanser, T. Henneberger

Advances in Residential Lighting Technologies
TR-100868 Final Report (RP2034-41); $200
Contractor: Energy International, Inc.
EPRI Project Manager: J. Kesselring

ELECTRICAL SYSTEMS

TLWorkstation™ Code, Version 2.3, Vol. 3: CORRIDOR Manual
EL-6420 Final Report (RP1902-7); Vol. 3, $200
Contractors: BIRL; Northwestern University
EPRI Project Manager: J. Hall

TLWorkstation™ Code, Version 2.3, Vol. 7: ACDCLINE Manual
EL-6420 Final Report (RP2472-6); Vol. 7, $200
Contractor: General Electric Co.
EPRI Project Manager: J. Hall

TLWorkstation™ Code, Version 2.3, Vol. 15: MAG3D Manual
EL-6420 Final Report (RP2472-6); Vol. 15, $200
Contractor: General Electric Co.
EPRI Project Manager: J. Hall

Hybrid Transmission Corridor Study, Vol. 1: Phase 1—Scale Model Development
EL-7487 Final Report (RP2472-6); Vol. 1, $200
Contractor: General Electric Co.
EPRI Project Manager: J. Hall

Waltz Mill Testing of 765-kV Paper-Polypropylene-Paper (PPP) Cable
TR-100422 Final Report (RP7801-7); $200
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: J. Shimshock

Proceedings: Geomagnetically Induced Currents Conference
TR-100450 Proceedings; $1000
EPRI Project Manager: B. Damsky

Proceedings: Expert System Applications for the Electric Power Industry
TR-100623 Proceedings; $200
EPRI Project Managers: M. Lauby, M. Divakaruni, J. Naser

Improved Static VAR Compensator Control
TR-100696 Final Report (RP2707-1); $200
Contractor: General Electric Co.
EPRI Project Manager: S. Lindgren

Fundamental Studies of Tl-Ba-Ca-Cu-O Single Crystals and New High-Temperature Superconducting Compounds
TR-100731 Final Report (RP4000-24); $200
Contractor: University of Colorado, Boulder
EPRI Project Manager: M. Rabinowitz

Prototype Expert System for Load Management, Vols. 1 and 2
TR-100732 Final Report (RP2944-5); $200 each volume
Contractor: TASC
EPRI Project Manager: R. Adapa

ENVIRONMENT

Sourcebook for Utility Communications on EMF
TR-100580 Final Report (RP2955-7); $200
Contractor: Creighton & Creighton, Inc.
Cosponsor: Tennessee Valley Public Power Association
EPRI Project Manager: G. Hester

Analysis and Review of EPA Discharge Monitoring Report for Electric Utilities: Quality Assurance Data
TR-100591 Final Report (RP1851-1); $200
Contractor: TRW, Inc.
EPRI Project Managers: W. Chow, B. Nott

Creosote-Treated Wood Poles and Crossarms: Toxicity Characteristic Leaching Procedure (TCLP) Results
TR-100870 Interim Report (RP2485-9, RP2879-6); $200
Contractors: Environmental Management Services; Radian Corp.
EPRI Project Managers: J. Goodrich-Mahoney, I. Murarka

Physiological, Toxicological, and Population Responses of Smallmouth Bass to Acidification: Lake Acidification and Fisheries Project
TR-101062 Interim Report (RP2346-1); $200
Contractors: University of Wyoming; Oak Ridge National Laboratory; Western Aquatics, Inc.; McMaster University
EPRI Project Manager: J. Mattice

GENERATION & STORAGE

Evaluation of a 510-MWe Destec GCC Power Plant Fueled With Illinois No. 6 Coal
TR-100319 Final Report (RP2773-12); $200
Contractor: Fluor Daniel, Inc.
EPRI Project Manager: M. Epstein

Control System Retrofit Guidelines, Vols. 1–3
TR-100343 Final Report (RP2710-15, -16); $200 each volume
Contractors: Sargent & Lundy Engineers; Black & Veatch
EPRI Project Managers: M. Divakaruni, J. Weiss

Corrosion Fatigue Boiler Tube Failures in Waterwalls and Economizers, Vol. 2: Laboratory Corrosion Studies
TR-100455 Final Report (RP1890-5); Vol. 2, $200
Contractors: Ontario Hydro; Babcock & Wilcox Co.
EPRI Project Manager: B. Dooley

Proceedings: 9th EPRI Conference on Gasification Power Plants
TR-100466 Proceedings (RP1654); $400
EPRI Project Manager: N. Holt

Conceptual Design: 10-Ton-per-Hour Soil-Cleaning Plant
TR-100636 Final Report (RP2991-6); license required
Contractors: Mill Creek Co.; Norwest Mine Services, Inc.
EPRI Project Manager: C. Kulik

Retrofits for Improved Heat Rate and Availability: Low-Level Heat Recovery Economizer Retrofits
TR-100682 Final Report (RP1403-16); $200
Contractor: Gilbert/Commonwealth, Inc.
EPRI Project Manager: J. Bartz

Proceedings: Optical Sensing in Utility Applications
TR-100849 Proceedings; $200
EPRI Project Manager: J. Stein

Proceedings: Power Plant Electric Auxiliary Systems Workshop
TR-100850 Proceedings; $200
EPRI Project Manager: J. Stein

Proceedings: 1991 EPRI Heat-Rate Improvement Conference
TR-100901 Proceedings; $200
EPRI Project Manager: R. Leyse

NUCLEAR POWER

Sourcebook for Plant Layup and Equipment Preservation (Revision 1)
NP-5106 (Rev 1) Final Report (RP2495-15); $200
Contractor: B&W Nuclear Service Co.
EPRI Project Manager: G. Allen

MULTEQ: Equilibrium of an Electrolytic Solution With Vapor-Liquid Partitioning and Precipitation, Vol. 1: User's Manual (Revision 2)
NP-5561 Computer Code Manual (RPS407-30); Vol. 1 (Rev. 2), license required
Contractor: Maxwell Laboratories, Inc.
EPRI Project Manager: P. Paine

Guidelines for Establishing, Maintaining, and Extending the Shelf Life Capability of Limited-Life Items (NCIG-13)
NP-6408 Final Report (RPQ101-10); $200
Contractor: Wyle Laboratories
EPRI Project Manager: W. Bilanin

Water Hammer Prevention, Mitigation, and Accommodation, Vol. 1: Plant Experience
NP-6766 Final Report (RP2856-3); Vol. 1, $200
Contractor: Stone & Webster Engineering Corp.
EPRI Project Manager: M. Merilo

Decontamination Experience During the Cleanup of TMI-2
NP-7157 Interim Report (RP2558-2); $200
Contractor: Pentek, Inc.
EPRI Project Manager: R. Lambert

Integrated Instrumentation and Control Upgrade Plan
NP-7343 (RP3114-59); $200
Contractors: Mollerus Engineering Corp.; Science Applications International Corp.
EPRI Project Manager: C. Wilkinson

Guidelines for the Use of Microcomputer Applications in Safety-Related Activities (NCIG-20)
NP-7376 Final Report (RPQ101-28); $200
Contractor: Vanguard Technetics, Inc.
EPRI Project Manager: T. Mulford

Radwaste Desk Reference, Vol. 2: Transportation and Disposal
NP-7386 Final Report (RP2414-34); Vol. 2, $200
Contractor: Right Angle Industries
EPRI Project Manager: C. Hornibrook

Circuit Breaker Maintenance, Vol. 1, Part 2: Low-Voltage Circuit Breakers—GE AK Models
NP-7410 Final Report (RP2814-40); Vol. 1, Part 2, $16,000
Contractor: Grove Engineering, Inc.
EPRI Project Manager: J. Sharkey

Maintenance Guide for Air-Operated Valves, Pneumatic Actuators, and Accessories
NP-7412 Final Report (RP2814-45); $9500
Contractor: Fossil Technologies, Inc.
EPRI Project Manager: K. Barry

RETRAN-03 (A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems), Vol. 1: Theory and Numerics
NP-7450 Computer Code Manual (RP889-10); Vol. 1, $200
Contractor: Computer Simulation & Analysis, Inc.
EPRI Project Manager: L. Agee

Power Plant Practices to Ensure Cable Operability
NP-7485 Final Report (RP2814-8, -37); $9450
Contractors: Ogden Environmental and Energy Services Co.; EcoTech/Ram Q Industries, Inc.
EPRI Project Managers: J. Christie, W. Johnson, G. Sliter

Electric Motor Predictive and Preventive Maintenance Guide
NP-7502 Final Report (RP2814-35); $11,300
Contractor: Bechtel Group, Inc.
EPRI Project Managers: W. Johnson, V. Varma

Proceedings: Twelfth Annual EPRI Nondestructive Evaluation Information Meeting: NDE Research Progress in 1991
NP-7560-M Proceedings (RP1570-14); $200
NP-7560-SL Proceedings; license required
EPRI Project Managers: S. Liu, M. Avioli

Advanced Imaging Tools and Their Applications for Nuclear Power Plant Operation and Maintenance
TR-100165 Final Report (RP2705-14); $200
Contractor: ENCORE Technical Resources, Inc.
EPRI Project Manager: J. Ketchel

Interim On-Site Storage of Low-Level Waste, Vol. 1: Licensing and Regulatory Issues
TR-100298 Final Report (RP3800); Vol. 1, $200
Contractor: Newman & Holtzinger, P.C.
EPRI Project Manager: C. Hornibrook

Performance Testing and Analyses of the VSC-17 Ventilated Concrete Cask
TR-100305 Final Report (RP3073-1); $200
Contractors: Wisconsin Electric Power Co.; Pacific Northwest Laboratory; EG&G Idaho, Idaho National Engineering Laboratory; Sierra Nuclear Corp.
EPRI Project Manager: R. Lambert

Containment Filtration Systems Tests: Advanced Containment Experiments (ACE) Project, Summary Report
TR-100346 Summary Report (RP2802); $100,000
Contractors: Battelle, Pacific Northwest Laboratories; Westinghouse Hanford Co.
EPRI Project Manager: M. Merilo

Steam Pressure Trends at R. E. Ginna
TR-100371 Topical Report (RPS401-1); $200
Contractor: NWT Corp.
EPRI Project Manager: L. Williams

Pipe Failures in U.S. Commercial Nuclear Power Plants
TR-100380 Interim Report (RP2681); $200
Contractor: Halliburton NUS
EPRI Project Manager: B. Chu

A Database of Common-Cause Events for Risk and Reliability Applications
TR-100382 Final Report (RP3200-2); $200
Contractor: PLG, Inc.
EPRI Project Manager: B. Chu

Demonstration of a Risk-Based Approach to High-Level Waste Repository Evaluation: Phase 2
TR-100384 Interim Report (RP3055-2); $200
Contractor: Risk Engineering, Inc.
EPRI Project Manager: R. Shaw

Balance-of-Plant Heat Exchanger Condition Assessment Guidelines
TR-100385 Final Report (RP2495-9); $200
Contractors: Service Water Working Group; EPRI NDE Center
EPRI Project Managers: N. Hirota, R. Edwards

Guidelines for the Repair/Replacement Welding of Nuclear Service Water Systems
TR-100386 Final Report (RP3232-1)
Contractors: Service Water Working Group; EPRI NDE Center
EPRI Project Managers: N. Hirota, R. Edwards

Effect of Decision Making on Ultrasonic Examination Performance
TR-100412 Final Report (RP3112-1); $200
Contractor: Anacapa Sciences, Inc.
EPRI Project Manager: J. Yasutake

Methods of Quantitative Fire Hazard Analysis
TR-100443 Final Report (RP3000-37); $5000
Contractor: Frederick Mowrer
EPRI Project Manager: J. Sursock

Survey and Characterization of Feedwater Venturi Fouling at Nuclear Power Plants, Vol. 1
TR-100514 Final Report (RP3097-1); Vol. 1, $10,000
Contractor: Babcock & Wilcox Co.
EPRI Project Manager: H. Ocken

Application Guide for PC-Based Nondestructive Evaluation Workstation
TR-100522 Final Report (RP3232-1)
Contractor: EPRI NDE Center
EPRI Project Manager: J. O'Brien

Electropolishing of Replacement Steam Generator Channel Heads at Millstone-2 PWR
TR-100559 Final Report (RP3358-2); $200
Contractors: FinTech, Inc.; Northeast Utilities; Quadrex Corp.
EPRI Project Manager: C. Wood

Endurance Tests of Valves With Cobalt-Free Hardfacing Alloys: PWR Phase Final Report
TR-100601 Interim Report (RP1935-14); $10,000
Contractor: Atomic Energy of Canada, Ltd.
EPRI Project Manager: H. Ocken

TMI-2 Waste Management Experience
TR-100640 Interim Report (RP2558-2); $200
Contractor: Analytical Resources, Inc
EPRI Project Manager R. Lambert

Final TMI-2 Technology Transfer Progress Report
TR-100643 Final Report (RP2558-10), $200
Contractor ENCORE Technical Resources, Inc
EPRI Project Manager: R. Lambert

Effect of Hydrogen Water Chemistry on Ultrasonic Response From Intergranular Stress Corrosion Cracking
TR-100649 Final Report (RPC105-3); $10,000
Contractor: Ishikawajima-Harima Heavy Industries Co., Ltd.
EPRI Project Manager: M. Behravesh

Pilot Testing of Electrochemical Separation of Hydrogen From the BWR Off-Gas Stream
TR-100650 Final Report (RPC101-18), $2000
Contractor Grove Engineering, Inc
EPRI Project Manager: M. Behrevesh

R&D Value Assessments for the Nuclear Corrosion Control Program
TR-100652 Final Report (RPC101-81); $5000
Contractor: Decision Focus, Inc.
EPRI Project Manager M. Behravesh

Stress Corrosion Cracking of Alloys 600 and 182 in BWR Environments
TR-100658 Interim Report (RP2293-1, RPC101-2) $50,000
Contractor: ABB Atom AB
EPRI Project Managers J. Nelson, D. Cubicciotti

Examination of Spent CANDU™ Fuel Following 27 Years of Pool Storage
TR-100674 Interim Report (RP2062-15); $200
Contractor: AECL Research
EPRI Project Manager R. Lambert

Limit-Value Approach for Determining Best-Estimate Code Uncertainties in LOCA Calculations and Plant Applications
TR-100675 Final Report (RP2956-2), license required
Contractor ABB–Combustion Engineering
EPRI Project Managers: J. Chao, P. Kalra

Proceedings: 1992 EEI/UWASTE-EPRI Workshop on At-Reactor Spent-Fuel Storage
TR-100676 Proceedings (RP3290-5), $200
Contractor Energy Resources International, Inc
EPRI Project Manager: R. Lambert

Development of Steam Generator Vessel Database
TR-100677, Tier 1, Final Report (RP3147-2), $200
TR-100677, Tier 2, Final Report; license required
Contractor: Science Applications International Corp.
EPRI Project Manager: S. Liu

MAAP Thermal-Hydraulic Qualification Studies
TR-100741 Final Report (RP3044-1); $200
Contractors: Gabor, Kenton and Associates, Inc.; S. Levy, Inc.
EPRI Project Manager: P. Kalra

MAAP BWR Application Guidelines
TR-100742 Final Report (RP3044-1); $200
Contractors: Gabor, Kenton and Associates, Inc.; S. Levy, Inc.
EPRI Project Manager: P. Kalra

MAAP PWR Application Guidelines for Westinghouse and Combustion Engineering Plants
TR-100743 Final Report (RP3044-1); $200
Contractors: Gabor, Kenton and Associates, Inc., S. Levy, Inc.
EPRI Project Manager: P. Kalra

Transuranic Burning Issues Related to a Second Geologic Repository
TR-100750 Final Report (RP3030); $200
EPRI Project Manager: E. Rodwell

Performance of 9 × 9 Demonstration Assemblies in Dresden-2
TR-100752 Final Report (RP1580-5); $200
Contractor: Siemens Nuclear Power Corp.
EPRI Project Manager: S. Yagnik

Evaluation of Nondestructive Hydrogen Detection Methods in Zirconium Alloys
TR-100753 Final Report (RP1250-22); $200
Contractor: S. M. Stoller Corp.
EPRI Project Manager: S. Yagnik

PWR Advanced All-Volatile Treatment Additives, By-Products, and Boric Acid
TR-100755 Final Report (RPS409-2); $1000
Contractor: San Diego State University
EPRI Project Manager T. Passell

Loop Testing of Alternative Amines for All-Volatile Treatment Control in PWRs
TR-100756 Final Report (RPS409-11); $1000
Contractor: Calgon Corp.
EPRI Project Manager: T. Passell

Advanced Studies in Chemistry Control With Morpholine
TR-100758 Final Report (RPS409-1); $200
Contractor: NUS Corp.
EPRI Project Manager: T. Passell

Borated Stainless Steel Application in Spent-Fuel Storage Racks
TR-100784 Final Report (RP2813-21); $200
Contractor: Engineering Resources, Inc
EPRI Project Manager: R. Lambert

Effect of Organics on Nuclear Cycles
TR-100785 Final Report (RP2977-8); $200
Contractor: Halliburton NUS Environmental Corp.
EPRI Project Manager: T. Passell

Compatibility of PWR Gasket and Packing Materials and Resins With Organic Amines
TR-100794 Final Report (RPS409-4); $500
Contractor: Adams and Hobart Consulting Engineers
EPRI Project Manager: T. Passell

Qualification of Morpholine for Secondary System pH Control in Once-Through Steam Generator Plants
TR-100795 Final Report (RPS409-9); Tier 1, $200; Tier 2, $1000
Contractor: B&W Nuclear Service Co.
EPRI Project Manager: T. Passell

BWR Hydrogen Water Chemistry: Predictive Methods
TR-100805 Final Report (RPC101-23), license required
Contractor: Aptech Engineering Services, Inc.
EPRI Project Manager: J. Nelson

Statistical Signal Processing Methods for Ultrasonic Nondestructive Evaluation
TR-100836 Final Report (RP2614-75); $200
Contractor: Illinois Institute of Technology
EPRI Project Manager: M. Behravesh

Alarm Processing and Diagnostic System
TR-100838 Final Report (RP2902-4); license required
Contractor: Bechtel Group, Inc.
EPRI Project Manager: J. Naser

Proceedings: 1991 EPRI Workshop on PWSCC of Alloy 600 in PWRs
TR-100852 Proceedings (RP3223-1); $1000
Contractor: Dominion Engineering, Inc.
EPRI Project Manager: R. Pathania

Effect of Chromates on IGSCC in BWR Environments
TR-100853 Final Report (RPC101-17); $400
Contractor: Structural Integrity Associates
EPRI Project Manager: R. Pathania

Doffing Procedures for Firefighters' Contaminated Turnout Gear: Documentation for Videotape
TR-100854 Final Report (RP2705-12); $200
Contractors: Yankee Atomic Electric Co.; ENRG, Inc
EPRI Project Manager: J. Ketchel

Ginna Station Steam Generator U-Bend Tube Analysis for Chemical Cleaning Data
TR-100866 Final Report (RPS413-1); $200
Contractor: B&W Nuclear Service Co
EPRI Project Manager: L. Williams

Assessment of Inspection Options for Steam Generator Tubing
TR-100909 Final Report (RPS404-6); license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: L. Williams

Tensile Deformation and Recovery Kinetics of Alloy 690
TR-100910 Final Report (RPS408-3); $200
Contractor: Rutgers University
EPRI Project Managers: C. Shoemaker, A. McIlree

PWR Primary System Chemistry: Experience With Elevated pH at Millstone Point Unit 3 (Progress Report Number 2)
TR-100960 Interim Report (RP2648-1); $200
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: H. Ocken

Correlation of Secondary-Side IGA/SCC Degradation of Recirculating Steam Generator Tubing With the On-Line Addition of Boric Acid
TR-101010 Topical Report (RPS407-7); $2000
Contractor: Dominion Engineering, Inc.
Project Manager: P. Paine

New Computer Software

The Electric Power Software Center (EPSC) provides a single distribution center for computer programs developed by EPRI. The programs are distributed under license to users. EPRI member utilities, in paying their membership fees, prepay all royalties. Nonmember organizations licensing EPRI computer programs are required to pay royalties. For more information about EPSC and licensing arrangements, EPRI member utilities should contact the Electric Power Software Center, Power Computing Co., 1930 Hi Line Drive, Dallas, Texas 75207, (214) 655-8883. Other organizations should contact EPRI's Manager of Licensing, PO Box 10412, Palo Alto, California 94303, (415) 855-2866.

AWARE™: Methodology for the Allocation of Water Resources
Version 1.1 (PC-DOS)
Developer: Decision Focus, Inc.
EPRI Project Manager: Charles Sullivan

BLANKET (EMWorkstation Module)
Version 1.10 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

CEM Database: Continuous-Emissions-Monitoring Utility and Vendor Databases
Version 1.2 (PC-DOS)
Developer: Engineering Science, Inc.
EPRI Project Manager: Rusell Binsol

CIP Database: Concentrations of Indoor Pollutants
Version 4.0 (PC-DOS)
Developer: Lawrence Berkeley Laboratory
EPRI Project Manager: John Kesselring

COMMEND: Commercial Sector End-Use Energy Demand Forecasting Model
Version 3.2 (PC-DOS)
Developer: Regional Economic Research
EPRI Project Manager: Phil Hummel

DATACALC (EMWorkstation Module)
Version 2.20 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

DSMLINK
Version 6.14 (PC-OS/2)
Developer: Stone & Webster Management Consultants, Inc.
EPRI Project Manager: Rambabu Adapa

DSMRank: Demand-Side Management Alternatives Selection and Screening Model
Version 2.0 (PC-DOS)
Developer: Polydyne, Inc.
EPRI Project Manager: Philip Hanser

DYNAMICS
Version 0.99 (Sun-SPARC)
Developer: Decision Focus, Inc.
EPRI Project Manager: Robert Schainker

EGEAS: Electric Generation Expansion Analysis System
Version 6.14 (PC-OS/2, IBM-MVS)
Developer: Stone & Webster Management Consultants, Inc.
EPRI Project Manager: Rambabu Adapa

EGEASPM (Presentation Manager for EGEAS)
Version 6.14 (PC-OS/2)
Developer: Stone & Webster Management Consultants, Inc.
EPRI Project Manager: Rambabu Adapa

EMWorkstation: EPRI Electric and Magnetic Fields Workstation
Version 1.0 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

ENVIRO (EMWorkstation Module)
Version 3.0 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

ETADS: EPRI Tower Analysis and Design System (TLWorkstation Module)
Version 2.2 (PC-OS/2)
Developer: Sverdrup Technologies
EPRI Project Manager: Paul Lyons

EXPOCALC (EMWorkstation Module)
Version 3.0 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

HARMFLO+™: Harmonic Simulation and Analysis Tools
Version 1.0 (PC-DOS)
Developer: Electrotek Concepts
EPRI Project Manager: Rambabu Adapa

IPFLOW: Interactive Power Flow
Version 1.0 (DEC-VMS, IBM-MVS, Prime-PRIMOS, Sun-UNIX, RS6000-UNIX)
Developer: Ontario Hydro
EPRI Project Manager: Neal Balu

MCM
Version 1.0 (PC-Macintosh)
Developer: Tetra Tech, Inc.
EPRI Project Manager: Donald Porcella

NuCM: Nutrient Cycling Model
Version 2.01 (PC-DOS)
Developer: Tetra Tech, Inc.
EPRI Project Manager: Louis Pitelka

PORTHOS
Version MOD-1 (RS6000-UNIX or other UNIX workstations)
Developer: Jaycor
EPRI Project Manager: Govinda Srikantiah

RISKLINK
Version 6.14 (PC-OS/2)
Developer: Stone & Webster Management Consultants, Inc.
EPRI Project Manager: Rambabu Adapa

STAR (EMWorkstation Module)
Version 1.0 (PC-DOS)
Developer: Enertech Consultants
EPRI Project Manager: Giora Ben-Yaacov

EPRI Events

JANUARY 1993

13–15
Acoustic Leak and Crack Detection
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

14–15
Adjustable-Speed Drives as a DSM Tool: Fact or Fiction?
Monterey, California
Contact: Carrie Koeturius, (510) 525-1205

21–22
Dynamics of Interconnected Power Systems
Dallas, Texas
Contact: Gerry Cauley, (415) 855-2832

FEBRUARY

2–3
NMAC 3d Annual Conference and Technical Workshop
Charlotte, North Carolina
Contact: Ken Barry, (704) 547-6040

3–5
Coal-Handling Systems: State of the Future
Pensacola, Florida
Contact: Barbara Fyock, (412) 479-6015

8–10
International Workshop: Nuclear Plant Instrumentation and Control Modernization
Orlando, Florida
Contact: Lori Adams, (415) 855-8763

9–10
Conference on Energy-Efficient Electric Motor Systems
Baltimore, Maryland
Contact: Les Harry, (415) 855-2558

9–11
Conference on Cable Condition Monitoring
San Francisco, California
Contact: Linda Nelson, (415) 855-2127

9–11
2d International Plasma Symposium
Palo Alto, California
Contact: Jane LeGear, (415) 855-2561

17–19
New Equipment and Services for Commercial Foodservice Customers
New Orleans, Louisiana
Contact: Susan Bisetti, (415) 855-7919

22–24
Symposium on Environmental Applications of Advanced Oxidation Technologies
San Francisco, California
Contact: Carrie Koeturius, (510) 525-1205

MARCH

1–3
International Symposium on Improved Technology for Fossil Power Plants: New and Retrofit Applications
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

2–4
NDE for Fossil Plants
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

24–26
6th National DSM Conference
Miami Beach, Florida
Contact: Pam Turner, (415) 855-2010

29–April 2
ETADS Seminar
Haslet, Texas
Contact: Paul Lyons, (817) 439-5900

30–April 1
Biomass and Waste Fuels
Washington, D.C.
Contact: Susan Bisetti, (415) 855-7919

APRIL

1–2
Dynamics of Interconnected Power Systems
St. Petersburg, Florida
Contact: Gerry Cauley, (415) 855-2832

5–8
10th Particulate Control Symposium
Washington, D.C.
Contact: Lori Adams, (415) 855-8763

13–15
Continuous Emissions Monitoring
Baltimore, Maryland
Contact: Linda Nelson, (415) 855-2127

20–22
Achieving Accurate Coal Weighing and Sampling Systems
St. Louis, Missouri
Contact: Barbara Fyock, (412) 479-6015

27–30
Transformer Performance Monitoring and Diagnostics
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

MAY

3–5
Nuclear Plant Support Engineering Products and Issues
Atlanta, Georgia
Contact: Sheryl McBane, (704) 547-6086

5–7
Plant Communications and Computing Architectures, Control Rooms, and Workstations
Tampa, Florida
Contact: Linda Nelson, (415) 855-2127

10–11
Nuclear Plant Performance Improvement
Scottsdale, Arizona
Contact: Susan Otto, (704) 547-6072

19–21
Rotating Machinery Vibration
San Diego, California
Contact: Susan Bisetti, (415) 855-7919

23–27
Stationary Combustion NO_x Control
Miami, Florida
Contact: Pam Turner, (415) 855-2010

JUNE

7–9
ISA POWID–EPRI Controls and Instrumentation Conference (Nuclear and Fossil)
Phoenix, Arizona
Contact: Lori Adams, (415) 855-8763

7–11
High-Voltage Transmission Line Electric Design Seminar
Lenox, Massachusetts
Contact: Jim Hall, (415) 855-2305

8–10
Cooling Tower Performance Prediction and Improvement
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

14–16
Seminar on Advanced Concepts in Line Structure Evaluation Techniques
Haslet, Texas
Contact: Paul Lyons, (817) 439-5900

14–16
Technology Transfer
San Francisco, California
Contact: Susan Bisetti, (415) 855-7919

15–16
Low-Level Mixed Waste Conference
Boston, Massachusetts
Contact: Linda Nelson, (415) 855-2127

15–18
Boiler Tube Failures: Correction, Prevention, and Control
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

29–July 1
Heat Exchanger Performance Prediction
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

Contributors


Hingorani


Stahlkopf


Nilsson


Damsky


Balu


Mehta


Starr


Chao


Hester

The Delivery System of the Future (page 4) was written by science writer John Douglas with assistance from a number of experts in EPRI's Electrical Systems Division.

Narain Hingorani, vice president for electrical systems since 1986, came to EPRI in 1974 after six years with the Bonneville Power Administration. Earlier he spent 11 years in research, teaching, and consulting on the faculties of three British universities. Hingorani has a BS degree in electrical engineering from the University of Baroda in India and MS and PhD degrees from the University of Manchester Institute of Science and Technology in England.

Karl Stahlkopf became the director of EPRI's Electrical Systems Division early in 1992. Before this appointment, he directed the Nuclear Power Division's Safety and Reliability Department, and from 1980 to 1989, he headed that division's Systems and Materials Department. Stahlkopf came to EPRI in 1973 after seven years in the Navy, where he specialized in nuclear propulsion. A University of Wisconsin graduate in electrical engineering, he also holds MS and PhD degrees in nuclear engineering from the University of California at Berkeley.

Stig Nilsson, longtime manager of the Transmission Substations Program, has been with EPRI since 1975. He worked briefly for Boeing Computer Services in the early 1970s and before that was with Sweden's Asea for 11 years, coming to the United States in 1967 for the installation and testing of control equipment on the Pacific Northwest-Southwest HVDC Intertie. He holds an electrical engineering degree from HTL, Malmö, Sweden, and an MBA from Santa Clara University.

Ben Damsky is manager for power electronics systems in the Transmission Substations Program. Before joining the Institute in 1984, he spent 19 years with General Electric, managing engineering projects in a number of areas, including advanced valves for HVDC systems and ultrahigh-power thyristors. He holds BS and MS degrees in physics from Princeton University and the University of Pennsylvania, respectively.

Neal Balu has managed the Electrical Systems Division's Power System Planning & Operations Program since 1988. He came to EPRI in 1979 after seven years at Southern Company Services. Earlier he spent four years on the faculty of the Indian Institute of Technology in Bombay. Balu received an MSc degree from the University of Saskatchewan, an MS from Louisiana State University, and a PhD from the University of Alabama, all in electrical engineering. He also holds an MBA from Santa Clara University.

Harshad Mehta, a subprogram manager in the Distribution Program, has focused on R&D in power electronics and robotics technologies for the last nine years. Before joining EPRI in 1983, he worked at Fairchild Semiconductor as a device research engineer. Mehta received BS and MS degrees in physics from Vikram University in Ujjain, India, and a PhD in electrical engineering from the University of Florida. ■

What Are You Afraid Of? (page 20) was written by Leslie Lamarre, *Journal* senior feature writer, with help from three EPRI sources.

Chauncey Starr, president emeritus of EPRI, founded the Institute in 1973 and served as its president for five years. Previously he was dean of the School of Engineering and Applied Science at the University of California at Los Angeles for six years. That position followed a 20-year career in industry, during which he was vice president of Rockwell International and president of its Atomic International Division. Starr received an electrical engineering degree and a PhD in physics from Rensselaer Polytechnic Institute.

Hung-Po Chao, manager of EPRI's Environmental Risk Analysis Program, came to EPRI in 1979 after serving as a research associate at Stanford University. During the 1981–1982 academic year, he was a visiting assistant professor in the School of Business Administration at the University of California at Berkeley. He received a BS in electrical engineering from Taiwan University, MS degrees in operations research and statistics from Stanford University, and a PhD in operations research and economics, also from Stanford.

Gordon Hester, manager for energy analysis in the Integrated Energy Systems Division, joined EPRI in 1990. He was previously a researcher in risk communications at Carnegie Mellon University. Before that, he was an economic policy analyst for the state of Minnesota for four years. Hester received a BS from Southern Oregon State College and a PhD in public policy analysis from Carnegie Mellon. ■

The Information Service for the Electric Utility Industry

EPRINET™

I Would Like to Make the Connection

• **For U.S. newcomers in 1992 and 1993,** EPRI offers the EPRINET package (software, documentation, and services) at no cost.*

• **For all U.S. participants in 1992 and 1993,** EPRI pays the on-going telecommunications cost* for commercial network dial-in.

• **Plus!** There are no access charges* for U.S. participants.

*Does not apply to nonmember U.S. utilities.

Please Sign Me Up Now

Name ______________________

Title ______________________

Utility/Organization ______________________

Address ______________________

City ______________ State ______ Zip ______

Phone ______________________

EPRI member? ☐ Yes ☐ No

☐ I use an IBM or compatible PC with modem.

☐ I use a Macintosh with modem.

☐ I do not now have all the required equipment. Call me in ___ months.

Connectivity

☐ Tymnet ☐ IIN (IBM Information Network)

☐ Direct long-distance dial-up to an EPRI number in the 415 area code

☐ Host-to-host connection

☐ I will be sharing a computer that is already equipped with the EPRINET software. I need only my own ID and the documentation.

____

(signature)

The Information Service for the Electric Utility Industry

EPRINET™

I Would Like to Make the Connection

• **For U.S. newcomers in 1992 and 1993,** EPRI offers the EPRINET package (software, documentation, and services) at no cost.*

• **For all U.S. participants in 1992 and 1993,** EPRI pays the on-going telecommunications cost* for commercial network dial-in.

• **Plus!** There are no access charges* for U.S. participants.

*Does not apply to nonmember U.S. utilities.

Please Sign Me Up Now

Name ______________________

Title ______________________

Utility/Organization ______________________

Address ______________________

City ______________ State ______ Zip ______

Phone ______________________

EPRI member? ☐ Yes ☐ No

☐ I use an IBM or compatible PC with modem.

☐ I use a Macintosh with modem.

☐ I do not now have all the required equipment. Call me in ___ months.

Connectivity

☐ Tymnet ☐ IIN (IBM Information Network)

☐ Direct long-distance dial-up to an EPRI number in the 415 area code

☐ Host-to-host connection

☐ I will be sharing a computer that is already equipped with the EPRINET software. I need only my own ID and the documentation.

____

(signature)

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST-CLASS MAIL PERMIT NO. 586 PALO ALTO CA

POSTAGE PAID BY ADDRESSEE

ELECTRIC POWER RESEARCH INSTITUTE
ATTN: EPRINET ORDER FULFILLMENT
PO BOX 10412
PALO ALTO CA 94303-9743

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST-CLASS MAIL PERMIT NO. 586 PALO ALTO CA

POSTAGE PAID BY ADDRESSEE

ELECTRIC POWER RESEARCH INSTITUTE
ATTN: EPRINET ORDER FULFILLMENT
PO BOX 10412
PALO ALTO CA 94303-9743

ELECTRIC POWER RESEARCH INSTITUTE
Post Office Box 10412, Palo Alto, California 94303

NONPROFIT ORGANIZATION
U.S. POSTAGE
PAID
PERMIT NUMBER 99
REDWOOD CITY, CALIFORNIA

ADDRESS CORRECTION REQUESTED

October/November 1992

EPRI JOURNAL

EJ-101708