The Future of Electricity Markets?

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ELECTRIC POWER RESEARCH INSTITUTE

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Cover: Utilities may soon be managing their bulk power needs by trading electricity futures in industrywide options markets.

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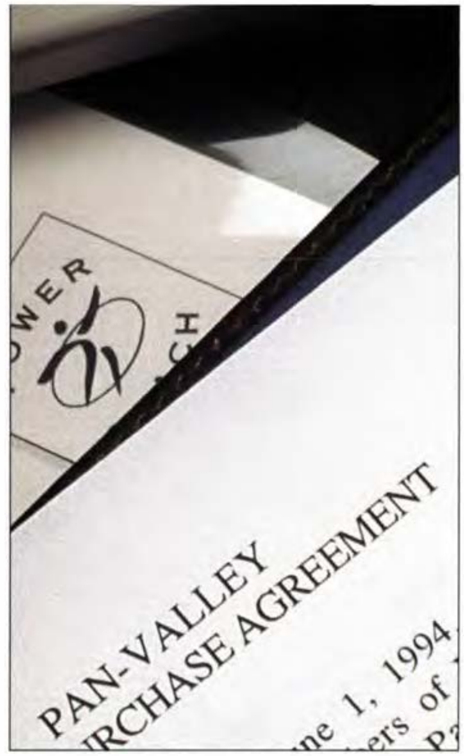

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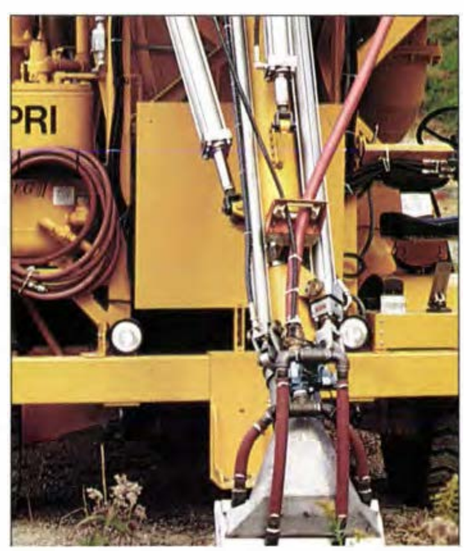

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Guide for Selecting Space-Conditioning Systems

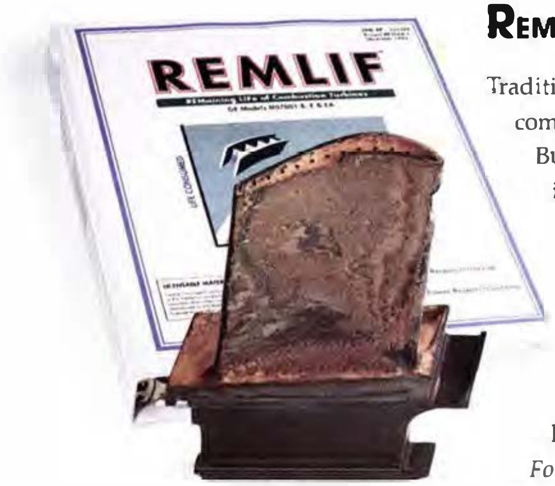
This handbook (TR-103329) provides all the information a utility marketing representative needs to help commercial customers select the best space-conditioning systems for their facilities. Whether the facility is a hospital, a supermarket, an office building, or a university, the guide offers useful information on the many variables to consider in the selection process. Users can rank 24 heating, ventilating, and air conditioning systems according to how well they fit into 13 building types and satisfy 6 load-shaping objectives and 17 customer needs. Work sheets are included to help utilities more clearly define customer needs.

For more information, contact Mort Blatt, (415) 855-2457. To order, call the EPRI Distribution Center, (510) 934-4212.

IRP-Manager

Now required of utilities in some 40 states across the country, integrated resource planning (IRP) involves the examination of a wide range of demand-side and supply-side resources to find the most cost-effective way to meet the needs of electricity customers. The best strategies may include a mix of traditional generation resources like gas-fired power plants and more innovative options like demand-side management programs. Although individual planning tools may help assess each of these options separately, many of the tools are not well suited for integrated planning. In contrast, IRP-Manager is an integrated toolbox of planning capabilities. Among other tasks, it simulates demand and resources chronologically, automatically develops resource strategies, and performs decision analyses to manage risks. Also, the program can interact with other planning models, such as EPRI's DSManager, EGEAS, and HELM.

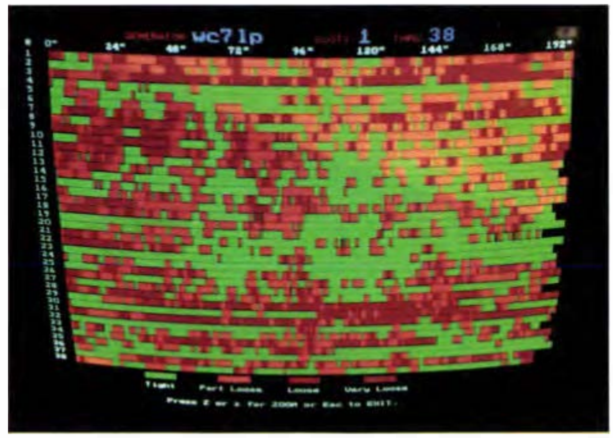
For more information, contact Jerry Bloom, (415) 855-2796. To order, call Richard Running at Electric Power Software, (612) 473-1303.



REMLIF for Maximizing Turbine Life

Traditionally, utilities have planned outages for the replacement of turbine components largely on the basis of advice from equipment manufacturers. But the REMLIF software program offers a more reliable method for assessing the life span of these components, using real-life data from operating turbines. REMLIF can be used to predict the remaining life of hot-section and other turbine components and to project the future life of these components under various operating conditions. Aside from helping to optimize the timing of outage schedules and inspections, REMLIF can help reduce life-cycle costs and maximize component life. It can also be used to identify ways to modify engine operation to extend the life of turbine components.

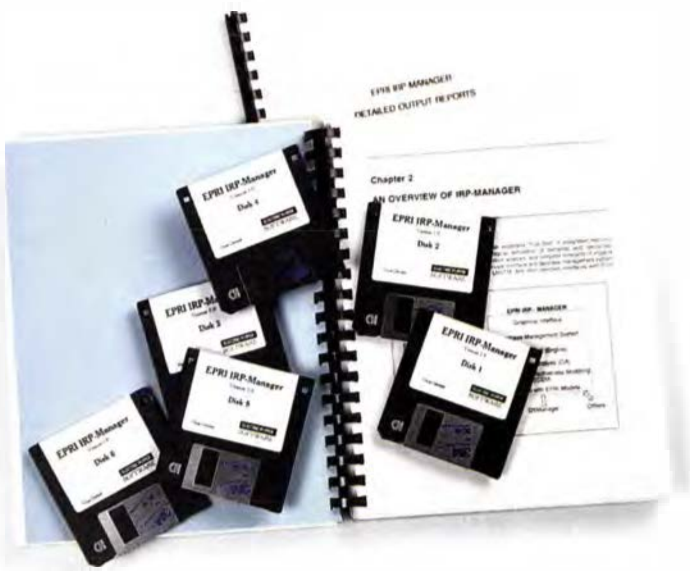
For more information, contact Tom McCloskey, (415) 855-2655. To order, call Henry Bernstein at Southwest Research Institute, (210) 522-3240.



Wedge Tightness Detector

Loose wedges can cause electrical failure in utility generators. Until now, there's been no reliable, operator-independent means of determining whether generator wedges are tight enough. EPRI's recently released Wedge Tightness Detector meets this need. Manufactured by VinTek Inc., the detector consists of a probe that gathers information about each wedge, an electronic processor that deciphers these data, and a software program that displays the resulting information in the form of either a map or a summary report. For a typical generator the entire assessment takes about 4 hours—less than half the time required by the traditional hand-tapping technique. A laptop computer may be ordered along with the Wedge Tightness Detector, or the detector can be hooked up to a laptop or desktop computer already on hand.

For more information, contact Jan Stein, (415) 855-2390. To order, call Victor Neeley at VinTek, (509) 735-0383.



GENTECH for Advice on Fossil Plants

Overwhelmed by the array of EPRI products available to address fossil plant issues? GENTECH™ is designed to help you out. This software matches given problems with the EPRI products developed to address them. Its economic model evaluates and ranks competing EPRI technologies designed to assist with issues such as availability, capacity, heat rate, and operation and maintenance. GENTECH's evaluations also address factors—such as retrofitting difficulties and the duration of outages required—that are hard to define or quantify exactly but must be considered in the decision-making process. GENTECH offers on-line help, Windows compatibility, graphic displays, and the ability to print on-screen text.

For more information, contact Greg Lamb, (415) 855-2449. To order, call the Electric Power Software Center, (800) 763-3772.

Studying Forests and Grasslands for Carbon Sequestration

Many short-term experiments have indicated that higher levels of carbon dioxide in the air stimulate photosynthesis and thus the rate of absorption of CO_2 from the atmosphere. This suggests the possibility that, on a global scale, rising atmospheric CO_2 concentrations might be ameliorated by the increased sequestration of carbon in plants and soils. Little is known about the long-term response of ecosystems to elevated CO_2, however, and both theory and some experimental evidence suggest that plant growth enhancement may not be sustained for long periods in natural ecosystems.

To develop more information about this long-term feedback mechanism, EPRI is sponsoring research on the response of two important ecosystems—forests and grasslands. Both act as major repositories of carbon. In forests much of the carbon is stored above ground, while grasslands can sequester large amounts of carbon below ground in soil organic matter. Forest results to date show a significant growth response to elevated CO_2 only when the level of nitrogen in the soil is high. Experiments on grasses initially indicated a significant response even when the supply of nitrogen is limited, but recent results are more similar to the forest results.

The grassland studies are being conducted in controlled-environment greenhouses by the Commonwealth Scientific and Industrial Research Organization in Canberra, Australia. Pots of the grass *Danthonia richardsonii* are subjected to CO_2 levels about twice normal, while receiving either low, medium, or high levels of nitrogen—a productivity-controlling nutrient in most terrestrial ecosystems.

After nearly three years, the experiments indicate that the CO_2-enriched atmosphere causes grass to accumulate about 50% more carbon than normal when high levels of nitrogen are available. At low and moderate nitrogen levels, the accumulation is less than 20% above normal. Higher CO_2 concentrations apparently improve the efficiency with which plants utilize nitrogen, thus increasing the carbon-to-nitrogen ratio in all major parts of the plant system, including litter. Water use efficiency—a measure of growth rate per unit of water consumption—also improves at all nitrogen levels.

These results suggest that only well-fertilized grasslands could play an important role in sequestering increasing

amounts of CO_2. There is a suggestion, however, that the rate of carbon storage may be declining with time, so the study is being extended. The long-term consequences of higher carbon-to-nitrogen ratios also need to be explored, since a higher ratio might slow the decomposition of litter and thus reduce the amount of nitrogen available to fertilize the next generation of plants.

■ *For more information, contact Lou Pitelka, (415) 855-2969.*

Genetically Engineered Bacteria May Enable In Situ PCB Cleanup

Researchers at the University of Tennessee believe that they have found a way to extract polychlorinated biphenyl (PCB) compounds from the ground and render the resulting material nonhazardous without ever lifting a shovel. Central to the process is a genetically engineered strain of surfactant-degrading bacteria developed by Curtis Lajoie, a researcher at the university.

Formerly incorporated in transformers during the manufacturing process, PCBs are carcinogenic and are high on the Environmental Protection Agency's list of priority pollutants. Although most of the old PCB-containing transformers at utility substations have been replaced, some were damaged during use and spilled PCBs into the ground, posing a potential threat to water supplies. The standard practice for cleaning up small, concentrated spills is to excavate the contaminated soil and incinerate it to remove the PCBs. Not only is this procedure time-consuming and costly, but it poses a potential hazard to the people performing the work and raises concerns about liability after the material leaves the site.

It is no secret that surfactants, which reduce the interfacial tension between liquids and solids, are effective in removing PCBs from soil. But the problem is how to get rid of the PCBs once they are extracted. Although biphenyl, the backbone of PCB compounds, is a good source of carbon for feeding naturally occurring PCB-degrading bacteria, the chlorine in the PCB compounds makes it difficult for these bacteria to grow without the addition of more biphenyl. But biphenyl is a hazardous waste—not something a utility wants to add to a site it is trying to clean up. The breakthrough by Lajoie offers a way around this obstacle. Using molecular biology techniques, he inserted a set of genes from a naturally occurring PCB-degrading bacterium into a bacterium that degrades surfactants. The resulting genetically engineered strain can feed on the surfactant while it degrades the PCBs.

PCB-contaminated soil

Lajoie has applied for a patent on the process. The Tennessee Valley Authority is awaiting approval from the EPA to conduct a field test of the process at one of its substations. TVA and EPRI have collaborated with the University of Tennessee researchers to conduct laboratory tests of the process and extensive assessments of the site. "The substation is typical of many sites throughout the TVA power system in terms of the type of construction used and the activities that have gone on there," says Mary Jim Beck, TVA's manager for the project. "If successful, the process will likely find wide application in the utility industry."

Details of the procedure are still being fine-tuned, but the researchers say it will involve a sprinkler system that will scatter a water-dissolved surfactant over the contaminated area. Alice Layton, the University of Tennessee's manager for the project, says that the process also holds promise for use with other types of hazardous chemicals.

■ *For more information, contact Bob Goldstein, (415) 855-2593.*

What we must strive for is . . . "workable competition." By public and private policies, we can hope to improve the efficiency with which market prices reflect underlying individual needs, desires, and wants against the background of true costs of goods.

—Paul Samuelson, Nobel laureate in economics

by John Douglas

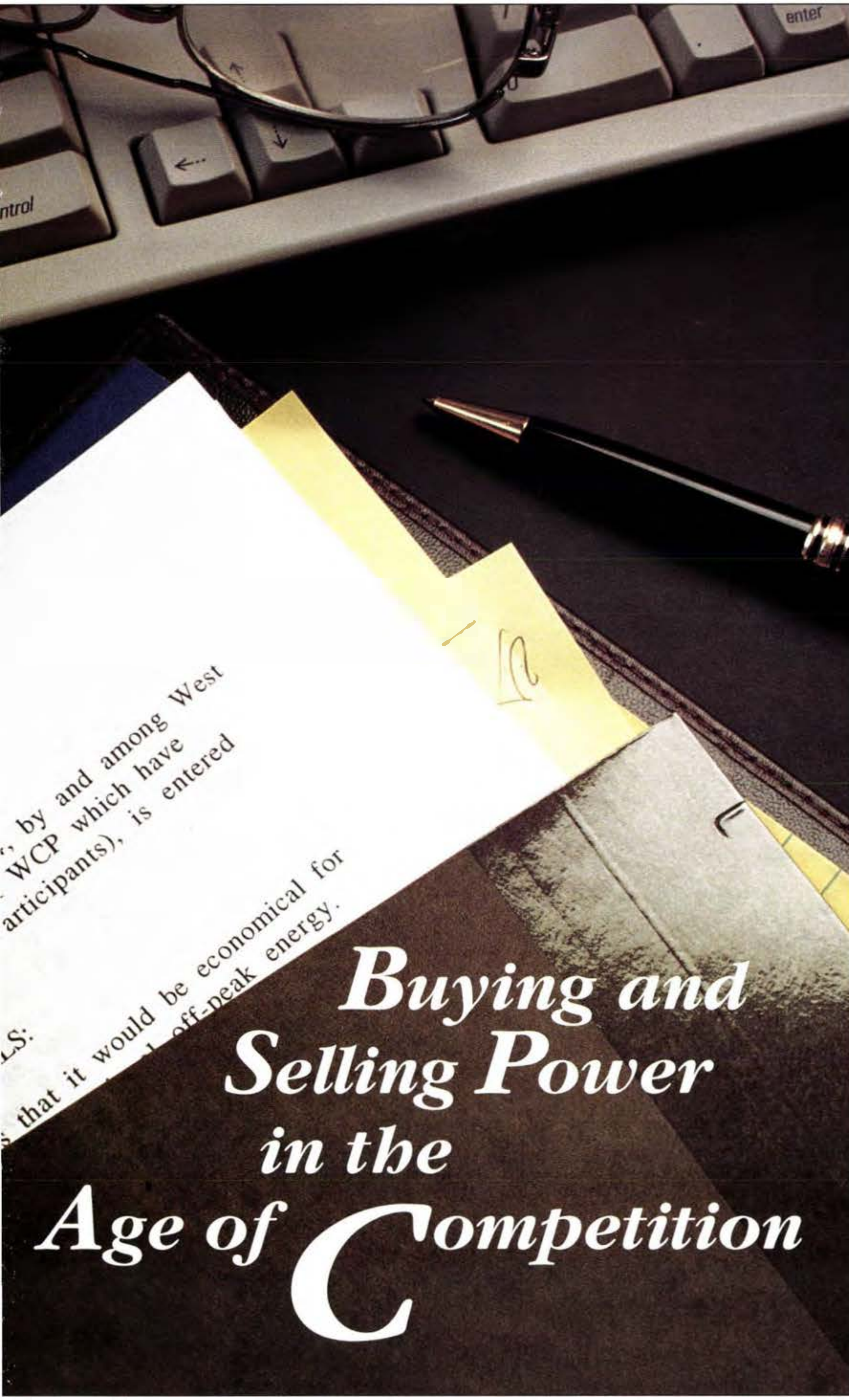
The American electric power industry is currently in the throes of striving for just such a workable competition. Driven by the converging forces of deregulation, technological revolution, and evolving customer expectations, electric utilities are having to compete as never before at both the wholesale and retail levels. At times the transition has been particularly wrenching, with some utilities going through painful internal restructuring and others being caught up in external consolidation. Increasingly, the key to success in this more competitive environment is anticipating and actively responding to the forces that are shaping the new markets for electric power.

Such market management is the subject of pioneering research being conducted in EPRI's Utility Resource Planning & Management Program. On the wholesale side, this research centers on the development of powerful analytical methods to support utility decisions regarding new opportunities in the bulk power market. Research on retail market management is concentrated on developing innovative price-differentiated services that can enhance the value of electricity to customers and also foster a utility's long-term financial competitiveness.

"Fundamentally, market management is about utility and customer choices," says Riaz Siddiqi, who manages EPRI research in this area. "The choices include the timing of bulk power purchases, the selection of flexible retail prices to attract customers and improve load factors, and the allocation of investment dollars. Such choices are becoming more important as markets recognize that electricity can be packaged to serve a variety of diverse wholesale and retail market segments. Moreover, a utility's choices in one market affect its opportunities in others. Because of this increasing complexity, utilities are demanding better systems to help them make their market management choices—and that's what we're trying to provide them."

Bob Aldrich, the EPRI vice president who has overseen the Institute's work in this field to date, adds: "Our objective is to enhance the capability of our member utilities to manage their participation in markets in a way that will benefit both them and their customers. Initial results from joint research with utilities—for example, with the Tennessee Valley Authority on wholesale market management and with Georgia Power Company on real-time pricing—suggest that this is a very exciting and promising research area."

Beginning this year, EPRI's market management activities will be tied in more closely to the Institute's power delivery work. "Addition of these activities to the Power Delivery Group complements our ongoing research program, particularly in the area of power system operations," says Karl Stahlkopf, vice president for the group. "Specifically, we can now offer util-



Buying and Selling Power in the Age of Competition

THE STORY IN BRIEF
Changes in regulatory policy have set the stage for a far more volatile and competitive marketplace for electric power—both wholesale and retail. Bulk power sales are moving from cost-based pricing to market-based pricing, accompanied by the development of futures contracts and other trading options. Retail power sales are moving from regulated prices in franchised utility service territories to a choice of suppliers who compete on the basis of marginal-cost-based pricing. EPRI offers member utilities several products they can use to manage participation in these markets and, in turn, to help their customers compete more effectively in the global marketplace.

ities new business analysis capabilities they can use in adapting the innovative technologies we have developed to enhance the value of the power system as a strategic asset."

Wholesale markets: increased uncertainty

About 40% of the electricity generated in the United States is sold by the producing utilities to other utilities through wholesale transactions. The value of these transactions is now about $35 billion a year and growing rapidly. Some of the reasons for this growth are economic. For example, it may be cheaper for utility A to buy power from utility B during peak load periods than to bring its own most expensive generating plants on-line, much less build a new plant. In addition, there may be seasonal factors: utility A may sell power from its hydroelectric plants to utility B during the spring runoff and then buy power from utility B during the autumn dry spell.

Regulatory factors are also accelerating the growth of wholesale transactions. The National Energy Policy Act of 1992 requires utilities to make their transmission systems accessible to so-called third-party producers. Thus utility A must allow utility B to use its transmission lines to sell power to utility C, even though utility A may not be otherwise involved in the transaction. Further complicating the picture is the rise of independent (nonutility) power producers, who must also be granted transmission access to make bulk power sales.

Traditionally, the bulk power market has consisted primarily of coordination transactions among neighboring, interconnected utilities. Over the last decade, however, the number, types, and volume of wholesale transactions have expanded severalfold. Along with rapid growth, the bulk power sector has also seen the development of innovative market mechanisms like the Western Systems Power Pool, which now includes more than 60 utilities in an area that covers approximately the western third of the United States plus British Columbia. Transactions within the pool can be conducted according to special Federal Energy Regulatory Commission (FERC) rules that allow for market-based pricing within upper and lower limits. Previously, transaction prices were cost based, and the participating utilities required specific prior authorization from FERC. Further developments in the bulk power market include the establishment of special brokering and marketing units by utilities and independent third parties.

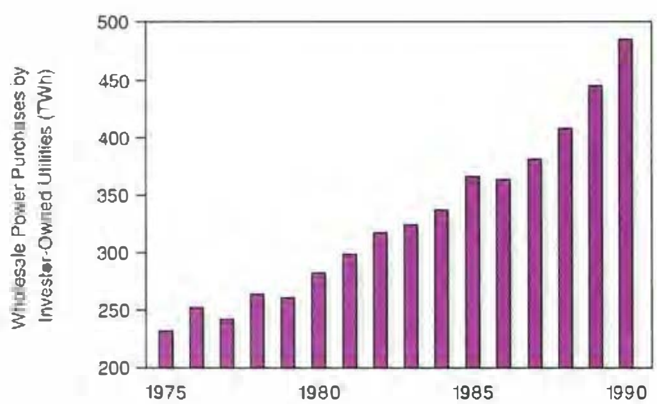
When a utility conducts wholesale transactions, it generally has two goals: to improve its competitive position by obtaining electricity for its customers at the lowest possible cost, and to elevate its bulk power unit as a company profit center. The main problem it faces is increasing uncertainty. Not only must a utility be able to deal with familiar uncertainties related to fuel costs, shifting loads, and weather impacts, but it must also deal with a larger number of market participants and face greater uncertainty in the price of bulk power. As electricity comes to be treated more and more as a commodity—with spot prices and competitive bidding—greater and greater price volatility can be expected in the wholesale market.

The immediate challenge of coping with increased uncertainty and volatility in bulk power markets is complicated by the need to consider related, long-term implications for utility system planning and operation. "Traditionally, electric utilities have had virtually complete control over their sources of supply and delivery—that is, generation and transmission," Siddiqi explains. "If the current forecasts of greater complexity in bulk power markets come to pass, the premise of full control that has been at the heart of all utility decision making will have to be changed. EPRI's wholesale market management research is therefore focused on developing tools to help utilities make decisions in a more complex bulk power environment."

Helping with wholesale

In the future, buyers and sellers of bulk power will have a greater variety of choices to make, involving more complicated relationships among a larger number of participants. Increasingly, wholesale power transactions will entail contracts between traditional utilities and independent power-brokering and -marketing entities. To help utilities make such wholesale market management decisions under conditions of heightened uncertainty, EPRI is conducting three projects: the development of POWERCOACH®, a system for evaluating short-term transactions; the development of POWERMIX™, a system for designing suitable long-term contracts; and options analysis and design for hedging against price volatility.

POWERCOACH is a software package to help schedulers at utility control centers make decisions about bulk power transactions. Previous software to analyze such trans-



GROWTH OF BULK POWER TRANSACTIONS **Wholesale power purchases by investor-owned utilities have increased rapidly during the last decade. Further acceleration of this trend is expected over the next several years because of regulatory changes that provide greater access to transmission systems and encourage the development of innovative market mechanisms. (Information courtesy of Resource Data International, Inc.)**

WESTERN SYSTEMS POWER POOL **More than 60 utilities are now linked in a wholesale power market that operates through direct interties between about 30 transfer nodes. The power pool facilitates market-based pricing of bulk electricity transactions within limits set by the Federal Energy Regulatory Commission. (Information courtesy of Resource Data International, Inc.)**

actions was based on deterministic models for costing out production impacts. Such models were essentially static, using a single methodology to make selections from a fixed set of alternatives on the basis of a specific set of data. Uncertainties were simply assumed away or subjected to a limited scenario analysis.

In contrast, POWERCOACH uses an expert system type of approach to analyze decisions on the basis of multiple objectives—including not only cost minimization but also net margin requirements—while incorporating a utility's own risk preferences regarding bulk power transactions. Uncertainties are explicitly addressed, as is the value of obtaining additional information. Typical output includes transaction strategies (should the utility commit to a transaction at this price, or wait?), a comparison of market alternatives (what are the risks and potential benefits of each?), and an analysis of key uncertainties (how sensitive is the decision to a given uncertainty, and how much would it be worth to know more?).

The commercial version of POWERCOACH was released in December 1993 after a development and testing program that involved some 30 utilities. Designed for use on personal computers with a Windows interface, POWERCOACH derives its name from the way it coaches the user through the structuring and analysis of a decision.

POWERMIX is designed to help analyze long-term wholesale contracting strategies under similar conditions of uncertainty. Although still under development, it has been used by several utilities to design sales contracts and make long-term bids for bulk power purchases. Eventually the model will be expanded to include the evaluation of demand-side management bidding and options contracts.

Options analysis is expected to become increasingly important as the bulk power market continues to expand and become more sophisticated. Long established in other commodities markets, options are contracts that give the holder the right to buy or sell something at a given price (the "strike" price) within a given time. Such contracts themselves may then be traded through a separate options market.

For utilities, the development of options for wholesale power could provide potential benefits for both price stability and system reliability. By locking in the ability to buy a given amount of electricity at an agreed-upon price, a utility could hedge against price volatility in the day-to-day bulk power market. Purchasing the contract would amount to paying an insurance premium to make the utility's revenue or cost stream more predictable. Alternatively, a utility might be concerned about whether it would be guaranteed adequate power to meet anticipated shortages. It could then contract with a utility anticipating a surplus to obtain power during the critical period.

Joint research conducted by EPRI and Pacific Gas and Electric Company has led to the development of a prototype analysis tool called the Options Procurement System (OPS). This system is designed to help a utility identify potential energy shortfalls and then determine the best portfolio of options to deal with reliability concerns. As envisioned, OPS would help fill a planning gap between short-term (daily or weekly) bulk power transactions and long-term transactions (i.e., transactions covering more than five years) aimed at improving reliability.

The next step in this research is to design feasible options instruments and, eventually, to carry out options-trading experiments. Such experiments might involve a variety of electricity options, such as options on power purchases (an option to buy a given number of kilowatthours of power from another utility), options on power reserves (payments by a power pool to secure the rights to future reserve generation for emergencies identified by OPS), and financial agreements (options used for price stabilization through hedging).

Retail markets: differentiated products

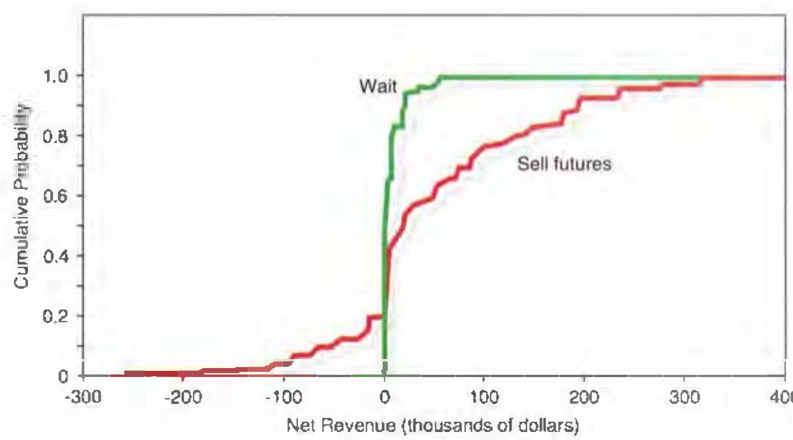
It does little good for a utility to obtain or generate power at the lowest cost if it cannot package the power to sell competitively at the retail level. Because retail customers now expect greater choice in power delivery, a utility must devise a product menu and a price structure that promote its customer base and ensure its financial viability. EPRI's intent in retail market management research is to provide information and analytical tools that member utilities can use in establishing their own retail market management programs.

The revolution in the retail power market reflects profound changes in the basic reality that has long governed utility retail service: that electricity is an undifferentiated product provided by a franchised monopoly at a fixed, regulated price. During the 1980s, this paradigm was challenged as customer choice expanded to include time-of-day pricing, the option of interruptible service, and wider use of various conservation technologies. Now, major industrial customers in some parts of the country can make an even more basic choice—they have gained the right to select their electricity provider. As a result, utilities must compete for these customers—against each other, against nonutility suppliers, and against other energy sources. "The successful competitors," says Siddiqi, "will be those who embrace the retail market management concept—by offering differentiated products and services that enhance the value of delivered power."

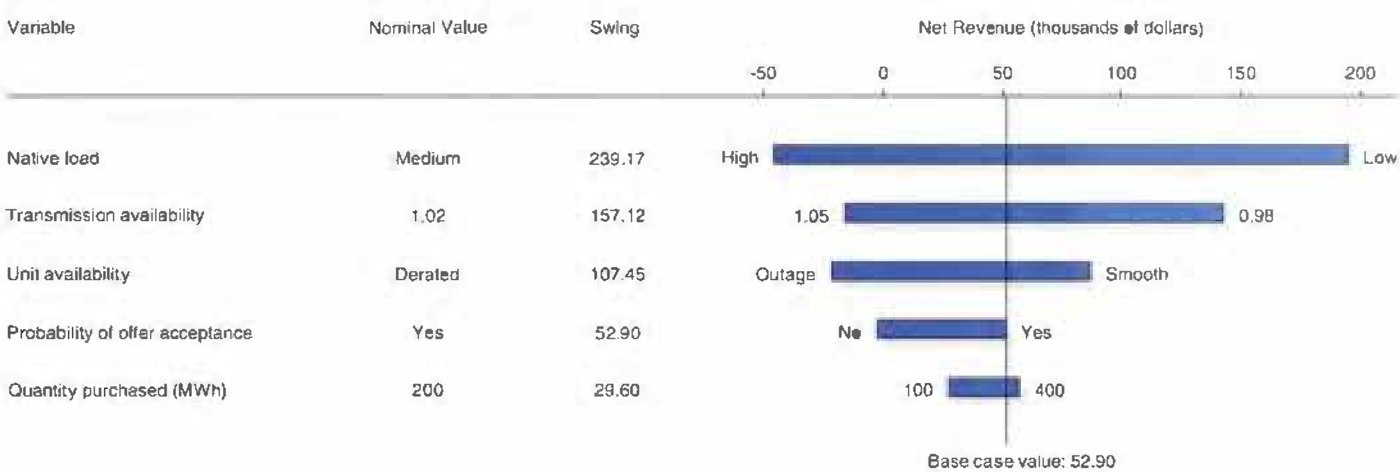
The most important element of product differentiation is to provide customers with more choices—choices that cater to their specific needs and priorities. Traditional demand-side management programs took a first step in this direction by providing a variety of incentives for customers to change specific consumption patterns. EPRI's 1992 survey of DSM programs found that more than 19 million utility customers are currently covered by such programs.

The largest group of participants, more than 6 million, take part in some form of load control program. Typically this type of DSM involves remote control of customer equipment, such as a residential air conditioner or water heater. By turning off the equipment during peak hours, a utility can delay investment in new peaking generators, reduce bulk power purchases, and, in the extreme, prevent blackouts from overloaded circuits. Other types of DSM programs range from simply showing customers how they can become more energy-efficient to providing large cus-

POWERCOACH SOFTWARE ANALYZES BULK POWER TRANSACTIONS **Risk profiles reveal the advantages of alternative trading scenarios. By waiting to trade on the spot market, the utility in this example can be sure it won't lose money, but its maximum profit would be only about $80,000 and the chances are only about fifty-fifty that it would make any profit at all. By contracting in advance to sell power at a certain price, the utility could increase its potential profit to more than $300,000, but it would face a 20% probability of actual loss on this transaction.**

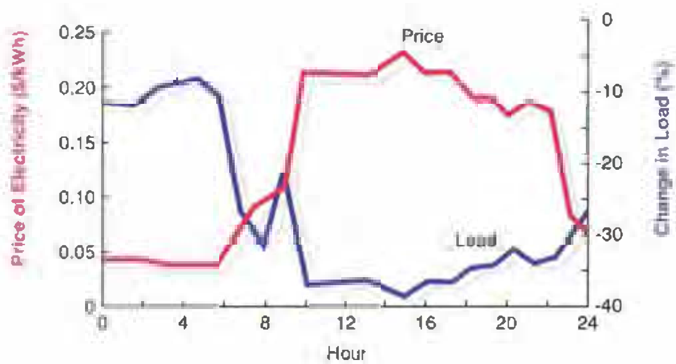


Numerous factors determine the potential profit or loss a utility might experience by contracting to sell power at some future time. Through sensitivity analysis, POWERCOACH can show how specific parameters—such as the size of native load and the availability of transmission facilities at the specified time—could affect net revenue, thus indicating where efforts should be focused to resolve uncertainties.



tomers with standby generators.

CUSTOMERS RESPOND TO PRICE CHANGES After inaugurating its Hourly Integrated Pricing Program (HIPP), Niagara Mohawk found that it could manage load reductions by large industrial customers more cost-effectively through that approach than through interruptible service programs. This graph shows typical customer response to HIPP prices on the highest-priced day of the year.



Retail market management addresses the entire set of utility market objectives and the need for greater reliance on price mechanisms to offer customer choice in core markets. Recognizing customer diversity is key, since average load shapes obscure major differences in demand patterns. A study at Niagara Mohawk Power Corporation, for example, found little correlation in the hourly loads of the utility's major industrial customers; in other words, the rate at which they used power during peak hours varied widely. Similarly, a study of residential customers at another utility found that their power consumption during peak hours ranged from 19% to 55% of their total consumption on a high-demand day. These differences indicate that curtailing service during peak hours would be much more effective with some customers than with others. Conversely, it appears that some customers are much more willing than others to accept reduced usage: an EPRI survey found that outage costs to customers ranged from negligible to $64 per unserved kilowatt-hour.

As in wholesale markets, EPRI is facilitating the development, implementation, and evaluation of retail market management options. In particular, it is seeking out utilities that face retail service challenges and are willing to undertake tailored collaboration projects that offer innovative service options to meet emerging needs. In such projects, an EPRI quick-start team first works with the utility to define its needs, then assists in service design and provides technical support to help implement the new services. Finally, the team conducts an evaluation of responses to the new service option.

Toward real-time pricing

Matching diverse needs with differentiated products at prices determined by supply and demand is, of course, what market economics is all about. The challenge in establishing more-competitive retail markets for electric power is how to improve the efficiency (to use Paul Samuelson's words) of translating supply and demand into price. During a critical period of peak demand on a hot summer afternoon, for example, the marginal cost of supplying power may increase by 20–50 times. Trying to recover this cost through adjustments in a fixed standard price is usually inefficient in economic terms, meaning that the overall amount paid by customers turns out to be higher than necessary. Worse, some customers—typically those in the commercial sector—may wind up paying a disproportionate share, thereby presenting an attractive target for the utility's competitors.

EPRI is currently working with several utilities to devise price structures that more realistically match retail price to the cost of supplying power, while giving customers greater choice and providing load relief during critical periods. An important analytical tool to facilitate this work is C-VALU, a demand simulation model developed by EPRI and first tested at Niagara Mohawk. C-VALU combines load shapes for various customers with information on the ability of those customers to shift load in response to price changes or curtailment. It then determines probable customer response to proposed market management options and calculates the resulting load and revenue impacts on the utility system. Also under development is a service options model, which will analyze the impact of retail market management on utility supply and demand. The model will thus provide an explicit link to wholesale market management and will give utilities the capability of modeling and evaluating portfolios of price-differentiated services.

Simulations using C-VALU and data gathered from Niagara Mohawk industrial customers have revealed dramatic differences in impact between load management schemes based on price differentiation and those based on service interruption. When the customers were charged $0.50/kWh for 6 hours during a critical demand period, they reduced load voluntarily in ways that revealed marginal outage costs of only $0.13/kWh for the forgone load. When an interruptible service program was used instead—and the utility curtailed loads to produce the same total load reduction as in the first case—the outage cost to customers was $1.19/kWh of unserved load. This nearly 10-fold difference results from the fact that price changes give customers greater choice than do curtailments, allowing them to configure usage more easily. In turn, flexible pricing provides utilities not only a more cost-effective way of improving system load factors but also a method of stimulating demand during off-peak hours.

Because of such potential benefits, utilities are considering ways to move toward real-time pricing (RTP)—a variable price structure that approximately reflects current marginal supply costs. In practice, real-time prices are usually hourly prices announced a day in advance. A recent survey conducted for EPRI by Laurits R. Christensen Associates of Madison, Wis-

PRICING FOR A COMPETITIVE EDGE The use of real-time pricing (RTP) has enabled Georgia Power to attract new customers, such as the Sara Lee Knit Products plant, located in northeastern Georgia. During the first 15 months of the RTP experiment, the innovative service option helped bring $500 million of new investment into Georgia, adding 3000 jobs to the state economy.

consin, reveals that 14 utilities have some form of RTP in effect, while others are evaluating its feasibility. Most of the RTP programs involve small numbers of customers (only five programs have more than 20 participants), but the reception so far has been encouraging.

Two case studies

In 1988, Niagara Mohawk began offering a plan called the Hourly Integrated Pricing Program (HIPP) to large industrial customers, who receive notification by electronic mail of hourly prices for the next business day. Currently the program has 38 customers, representing about 326 MW of load.

HIPP involves a two-part rate structure: a standard tariff that applies to the customer baseline load (CBL), derived from the customer's own historical demand pattern, and a real-time price that applies to load levels that differ from the CBL. The customer pays the utility the real-time price for load that exceeds the CBL, and the utility rebates the customer at the real-time rate for load that falls below the CBL. The two-part rate structure means that if a customer's load pattern does not change, neither will the customer's bill; but if change is to occur, there will be strong economic incentives to shift load to off-peak hours. The two-part rate also reflects a utility's embedded capital costs and provides a hedge against market volatility.

To quantify the benefits of HIPP, Niagara Mohawk became the first utility to conduct a controlled experiment examining RTP impacts. The eight-month experiment, conducted in 1988, involved nine customers in a test group that used HIPP and another eight customers in a control group. This study revealed a spectrum of customer responses to HIPP, and comparison with the control group confirmed that these responses were not the result of chance correlations. Participants in HIPP achieved load reductions of as much as 36% during the highest-priced hours, when the rate was $0.24/kWh.

The largest controlled RTP experiment to date is being conducted at Georgia Power, with EPRI collaboration. The program, called RTP-X, entails a two-part tariff similar to that used at Niagara Mohawk, with a standard access charge based on the CBL and an hourly differential rate based on marginal cost. The price schedule is posted daily by electronic mail for the next business day. A two-year demonstration of RTP-X began in 1992 with 25 customers in a test group and another 25 in a control group—together representing about 650 MW of load. Separately, Georgia Power has recently begun providing hour-ahead real-time pricing with interruptible service, termed RTP-IS, representing about 450 MW of load. The Georgia Public Service Commission has recently granted permanent tariff status to RTP-X.

So far, the RTP-X demonstration has shown not only an ability to affect the load patterns of existing customers but also an ability to attract new customers. During the first 15 months of the experiment, the new service option brought approximately $500 million of new investment into Georgia, which resulted in the addition of 3000 jobs and increased Georgia Power's annual revenue by more than $13 million. In addition, Standard & Poor's recently cited real-time pricing as a factor positively influencing Georgia Power's credit rating.

"The electric power market in Georgia is very competitive," says Mike O'Sheasy, manager of rate research and design at Georgia Power and chairman of EPRI's Retail Market Management Advisory Group. "Any new load of more than 900 kW is open for bid by many electricity suppliers within the state, not to mention the competition from utilities in other states to attract new load to their areas. In one recent case, we were competing with Virginia and Mexico for a major textile plant. The company eventually chose to locate in northern Georgia. We couldn't have attracted that account without real-time pricing."

Among existing customers, a variety of load pattern changes have been observed in response to RTP-X. Some customers have increased load throughout the day, even during some hours when prices are very high, because the overall average price is still quite low compared with conventional rates. Others have increased usage when the price is low and reduced it when the price is high. Still others have used the new rates to lower overall electricity consumption by reducing usage at high-priced times but maintaining baseline usage the rest of the day. Through the RTP-X program, customers have seen their average electricity cost per kilowatthour decrease by about 5% while their kilowatthour usage has increased by more than 10%.

"The emerging global economy is forcing utilities to provide ways for their customers to lower energy costs," concludes O'Sheasy. "Now the choices are between a relatively high guaranteed rate and a volatile real-time price. Eventually there will be a myriad of products in between, from which customers can choose on the basis of their risk aversion. I believe that within two years you will see most utilities begin to offer some kind of real-time pricing—but by then we'll be offering a plethora of choices. And I think that in three to four years there may even be tradable options for retail power."

A glimpse of the future

Not surprisingly, such a vision of rapid change has met with some skepticism within the U.S. electric utility industry, but there already exists a model abroad that can provide a glimpse of the possible future here. In the United Kingdom, government ownership of utilities has been replaced by privatization and deregulation. As a result, pricing options have proliferated and customers with more than 100 kW of demand are able to choose their supplier.

Real-time prices are provided in half-hour increments and are based on bids taken a day in advance from suppliers, who sell to a central power pool. Rather than using a customer baseline load to set a standard rate around which real-time prices may fluctuate, the British system uses contracts to provide a hedge against market volatility. The most basic of these hedging mechanisms is called a contract for differences (CfD). Such a contract enables the buyer to lock in a given price for a specified load profile over a certain period of time. Customers are now beginning to actively trade in these contracts.

As competition for retail electricity service increases in the United States, retail price volatility can be expected to increase, just as it has in Britain. In turn, utilities and their larger customers will seek to hedge against this price uncertainty by trading CBLs or CfDs to limit the adverse effects of price variation. The resulting market climate should free electricity buyers and sellers to conclude increasingly flexible contracts at the retail level. In April, the California Public Utilities Commission proposed new regulations that would allow all electric power users, including homeowners, the right to choose their electricity supplier by 2002. Other state regulatory boards are considering similar action.

"A key to utility success in today's more competitive environment is an integrated strategy of market management at both the wholesale and retail levels," concludes Riaz Siddiqi. "In the wholesale market, that means maximizing the value of assets through carefully chosen bulk power trades. In the retail market, it means optimizing sales to customers by recognizing their diversity and offering them a portfolio of products from which to choose. Increasing the economic efficiency of the American electric power industry as a whole in this way will enable our customers to compete more effectively in the emerging global marketplace." ■

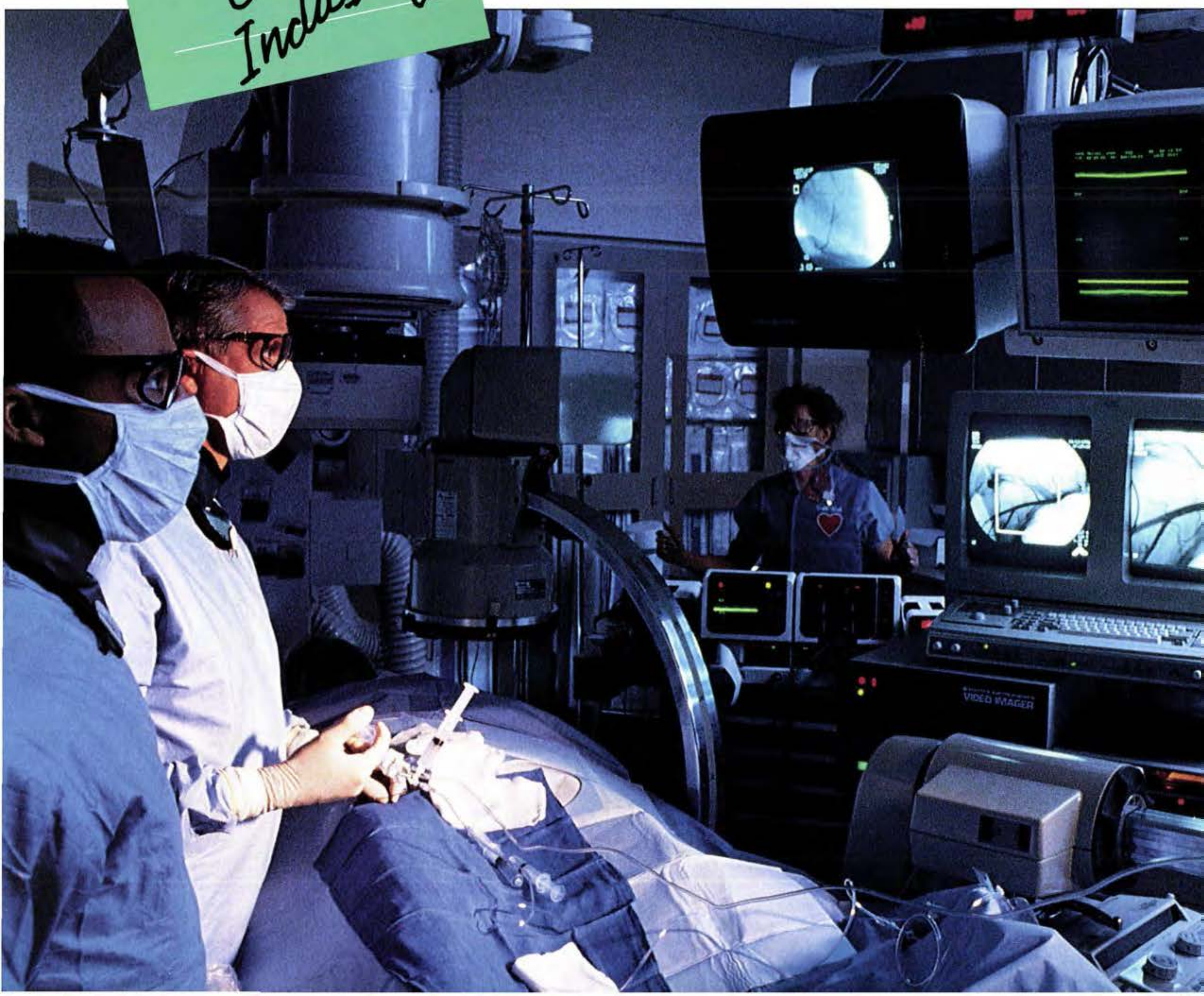
Background information for this article was provided by Riaz Siddiqi, Power Delivery Group

POWER ℞ FOR The Health Care Industry

by Leslie Lamarre

Doctors and nurses at the small Kansas hospital were stumped. As often as twice daily, the $1 million CAT scanner that they used to get a closer look at patients' brains, chests, and abdomens would inexplicably shut down. Sometimes the problem would occur in the middle of a scan, spoiling the X-ray images already taken. This meant the entire procedure had to be repeated, costing the hospital a considerable amount of time and money, not to mention a little embarrassment.

As it turned out, the CAT scanner was the victim of a power quality problem. And thanks to the diagnosis of a power quality consultant, a relatively minor adjustment to a controller resolved the problem. As high-tech electrical equipment becomes increasingly common in the modern health care environment, issues such as power quality are arising more and more frequently. And many health care facilities don't have the in-house expertise to address them.



To help electric utilities meet this market need, EPRI has launched a broad effort called the Healthcare Initiative. Power quality is just one of the many issues addressed through the initiative, which is geared toward hospitals, nursing homes, long-term-care facilities, blood banks, and other health care establishments. "Just as doctors can recommend a good nutrition program to keep their patients healthy, electric utilities can recommend systems and practices to keep a health care facility operating smoothly and cost-effectively," says EPRI's Myron Jones, manager of the initiative.

Through the Healthcare Initiative, EPRI is working together with its member utilities to get the word out on research results already available to help the health care industry. Simultaneously, the Institute is stepping up its R&D efforts to better serve this market segment. Research currently included in the initiative falls into four categories: power quality and energy management, building performance, environmental health and safety, and airborne-disease control. More projects may be added as further needs are identified. Participants in the initiative, including utilities, their health care customers, and trade associations, meet three times annually and attend seminars on timely issues.

The Story in Brief While electricity has had a huge impact on the health care community through the development of highly sophisticated diagnostic tools and procedures, more-mundane electrotechnologies offer substantial opportunities as well. From innovative lighting techniques to energy management systems to new technologies for medical waste disposal, advanced electricity-based technologies can enhance health care services and help cut costs when facilities know where and how to apply them. Recognizing that few hospitals and clinics have the in-house expertise to fully exploit such opportunities, EPRI has launched an initiative to help utilities deliver the Institute's research results to this crucial customer segment. The resulting partnerships promise to be of mutual benefit to the utility and health care industries as they both move through a period of substantial change.

Formally established early this year, the Healthcare Initiative arrives on the scene in the heat of the national debate over health care reform, and that is no coincidence. From EPRI's perspective, this time of change provides a perfect opportunity for electric utilities to help their health care customers reduce their costs and improve their operations. Aside from addressing these immediate objectives, the initiative is also intended to help member utilities establish bonds with their health care customers that will survive the competitive market forces just beginning to gain strength in the electric utility industry.

The health care industry is an important market segment for electric utilities across the country. The nation's 7300 hospitals alone, with their extensive electronic equipment, intensive lighting, and around-the-clock operation, consume more electricity than most other single commercial customer segments—some 50 billion kWh a year. This is equivalent to roughly 2% of the electricity consumed annually in the United States. The health care industry is also a big employer, providing jobs to some 4 million people nationwide.

"When a health care facility does well, its community does well, and so does the electric utility," says Bill Drewery, a marketing manager with Entergy Corporation, an active member of the Healthcare Initiative. "These are customers we do not want to lose. We want to keep them as happy and healthy as possible by serving them the best we can."

Nonlinear loads

The problem with the CAT scanner at the Kansas hospital is just one example of the many power quality problems that afflict the health care industry today. Generated by such electrical disturbances as harmonics and voltage surges and sags, power quality problems can scramble computer data, blur X-ray images, and even destroy valuable equipment. Such mishaps are becoming more prevalent because of the growth of so-called nonlinear loads, which draw electricity in an irregular waveform. These loads consist of electronic equipment that is both sensitive to common electrical disturbances and disruptive in itself, introducing disturbances back onto the power line.

Hospitals, clinics, and other health care facilities are particularly vulnerable to power quality problems, since they are crammed with sophisticated electronic equipment like CAT (computerized axial tomography) scanners, MRI (magnetic resonance imaging) machines, heart catheters, linear accelerators, and X-ray stations. According to Marek Samotyj, who manages EPRI research on power quality, the nonlinear electrical loads of most commercial establishments today average about 17%. By comparison, the nonlinear loads of hospitals are significantly higher, now approaching an average of 30%. Says Samotyj, "You can't put an infinite number of nonlinear loads like computers in a building. There is a threshold at which these computers will begin to interact with each other." Also, he notes, a high concentration of nonlinear loads increases the likelihood that these loads will be interrupted by other equipment, such as the adjustable-speed drives employed in heating, ventilating, and air conditioning (HVAC) systems. Only life-support systems, which are typically wired to their own power supplies, are spared exposure to potential interference.

In the case of the CAT scanner in Kansas, the shutdowns coincided with the start-ups of the hospital's chiller system. Upon starting, the chiller's large induction motor would draw a very high current for a brief time, causing voltage to drop, or sag. A controller designed to protect the scanner against damage from such voltage variations would sense the sag and switch the scanner off.

The hospital contacted its local utility, which in turn called in Ward Jewell, an electrical engineer and an associate professor at Wichita State University, which is a member of the Power Quality Testing Network, managed by EPRI's Power Electronics Applications Center (PEAC). Jewell determined that the controller could be set at a less sensitive level and still offer adequate protection.

"It sounds like a simple solution, but that diagnosis took extensive work," says Richard Smith, a power quality engineer with PEAC in Knoxville, Tennessee. PEAC, which maintains a database of typical power quality problems and their solutions, has established a file of information from this case study for future reference. Says Smith, "If this type of problem comes up again, we will be able to recommend the same approach to solving it."

The Kansas hospital was fortunate that its problem could be resolved through a relatively simple adjustment. The more common solution to a voltage sag problem is to install power-conditioning equipment, such as an uninterruptible power supply system, which can be very expensive.

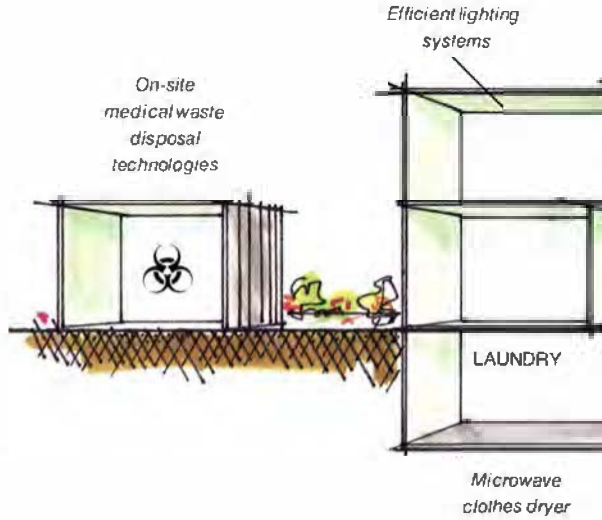
Some of the bigger health care establishments in the country have their own power quality experts on staff to determine the best solution for a given problem. But many of the smaller businesses don't; often they depend on their local utility for this advice. Experts at PEAC can help member utilities diagnose power quality problems. The center is equipped with a test facility at which it can duplicate virtually any such problem.

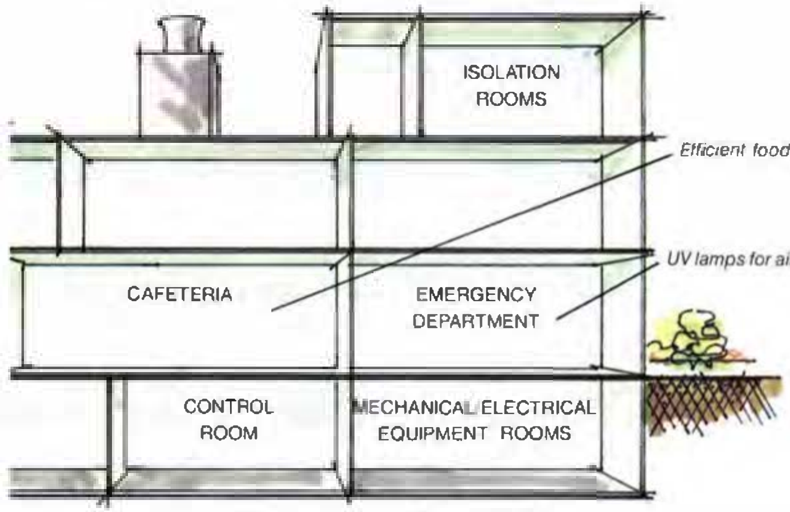
Through the Healthcare Initiative, EPRI researchers are compiling data retrieved during the monitoring of electronic equipment at a variety of medical facilities, including the hospital in Kansas. These data will go into a statistical model the researchers are developing to help utilities readily diagnose the power quality problems of their health care customers. According to Samotyj, the model will also allow utilities to assess the overall quality of power they provide to health care customers in their service territories. The other facilities monitored range from a small rural hospital in Salinas, California, to a large medical clinic at the University of New Mexico.

The dollar factor

Although electricity use can be a significant chunk of a health care facility's operating budget, health care businesses have not typically viewed it as a candidate for cost cutting. Riaz Siddiqi, who manages

RESEARCH FOR A BETTER HEALTH CARE ENVIRONMENT
From air conditioning systems to laundry rooms, health care facilities like hospitals have much in common with other commercial establishments. For this reason, the health care industry can benefit from the wealth of EPRI research results aimed at other commercial market segments. EPRI's Healthcare Initiative combines such applicable research results with new R&D efforts geared specifically toward health care customers. Pictured are just some of the EPRI-sponsored technologies and techniques that may help improve the health care environment and lower costs.





EPRI's research on market management, explains. "Hospitals and other large electricity users in the health care industry are not production-oriented facilities like industrial customers," he says. "The industrial customers have staff members devoted to energy management, and they are very aware of how their energy use can be optimized."

For instance, an air products manufacturer—for whom electricity is literally a raw material for the production of gases like Freon, nitrogen, and oxygen—may regularly alter production processes to save money on the company's electric bill. By contrast, hospitals and other health care facilities are service oriented. As a result, many of them have viewed electricity use as an uncontrollable necessity in the delivery of services.

But in the new environment of reform in the health care industry, establishments like hospitals, clinics, and long-term-care facilities are seeking new ways to reduce the cost of doing business. Larry Doleman, a marketing representative with Pacific Gas and Electric Company who handles all the health care accounts in the utility's service territory, notes that recent mergers and acquisitions in the industry, along with the trend toward increased outpatient service, are leading to drastic changes in the uses of existing health care facilities. He cites a recent report that the hospital bed vacancy rate in the San Francisco area is already 50%.

"What this means to health care facilities," Doleman says, "is that they have to change their energy management strategies considerably. For example, because they may no longer require full use of their buildings, they may no longer need the same HVAC tonnage or the same amount of lighting. This leaves the potential for energy conservation wide open."

Through the Healthcare Initiative, EPRI is encouraging its member utilities to offer energy audits of their health care customers' facilities to identify ways to improve the efficiency of existing energy systems. The staff at EPRI's Commercial Building Air Conditioning (CBAC) Center at the University of Wisconsin at Madison is available to conduct or assist in such audits. Mississippi Power & Light, an operating company of Entergy Corporation, has taken advantage of this opportunity, arranging for CBAC Center expert Harold Olsen to conduct a preliminary on-site assessment at the University of Mississippi Medical Center, MP&L's largest commercial customer.

"We use an awful lot of electricity, and even though we think we do a pretty good job of managing our energy resources here, it always helps to have someone from the outside take a look," says Mark Snow, a senior engineer for the medical center's physical plant. One area for potential savings is the facility's chiller system, which has lost efficiency as the medical center has expanded over the years and added new chillers to handle the additional square footage. Olsen has made some initial recommendations and proposed a thorough energy audit. He is awaiting the response of Entergy, which would cofund the project with EPRI.

Managing energy use

One of the most effective means of controlling electricity costs is an energy management system (EMS). First installed in commercial buildings in the 1960s, EMSs automatically control and coordinate a wide assortment of electrical loads—such as lighting, chillers, and HVAC systems—for maximum energy savings. Typically, EMSs enable complete control from a single computer screen and give an operator the option of modifying set points and control strategies.

More than 30 companies currently design EMSs specifically for hospital and/or extended-care applications, says Larry Carmichael of EPRI, who oversees the Healthcare Initiative's project on power quality and energy management systems. Although nearly all large hospitals have EMSs in place today, many of the systems require upgrading. According to Carmichael, the experience that health care facilities have already gained will help them specify appropriate systems incorporating new EMS technology. He notes that this technology is much more advanced than that of the 1960s. And, he adds, EPRI researchers are developing new EMS controls that can save even more money by responding to the variable-pricing strategies, such as real-time pricing (RTP), now offered by some utilities.

The traditional means of billing large commercial and industrial customers in-

POWERED UP **Hospitals, nursing homes, medical laboratories, and other health care facilities today are packed with sophisticated electronic machines that are sensitive to disturbances on the power line and can even generate disruptions and interrupt each other. EPRI's Power Electronics Applications Center can help utilities diagnose and correct the power quality problems of their health care customers. The Institute's power quality experts are also developing a statistical model for electric utilities to use in diagnosing those problems.**

volves a demand charge based on the customer's highest demand in a 30-day period. Under this system, there is little incentive for conservation, since the highest demand will trigger the same demand charge regardless of the level of daily energy use. By contrast, RTP programs provide customers with daily incentives to save on their electric bills. RTP rates vary with the time of day to more closely reflect the actual cost of producing electricity. The programs are designed to benefit both the customer and the utility; since rates are highest during peak demand periods, customers can save money by shifting their more flexible electricity uses off-peak. Only 14 utilities currently offer RTP programs for commercial and industrial customers, but more are expected to become interested as the electricity market grows more competitive. Ongoing EPRI research is helping member utilities design their own RTP programs.

Utility customers can respond to variable pricing manually, although this method typically makes it impractical—both physically and economically—to take full advantage of an RTP program. A recent EPRI project involving a Marriott hotel in New York City showed that the hotel was able to use its old EMS to respond to Consolidated Edison Company's RTP program and control 250 kW of its 6-MW load. The process was labor-intensive, however, says Carmichael, and required that the hotel engineers plan schedules on paper. After the installation of a new EMS incorporating RTP controls developed by EPRI, the hotel was able to reduce its load automatically by 1.2 MW, saving it $10,000 in a single peak-price week last July. Savings on a regular basis indicate a payback period of about two years.

EPRI is now working with a large hotel in San Francisco to implement a similar EMS that will respond to Pacific Gas and Electric's variable rates. And through the Healthcare Initiative, Carmichael would like to transfer the advantages of the new EMS controls into a health care setting. "We've already seen the enormous benefits that other commercial utility customers have gained from sophisticated control systems," he says. "There's no reason that health care facilities would not enjoy the same benefits."

Indeed, observes EPRI's Ron Wendland, hospitals are similar to a variety of other commercial establishments, which means that they can benefit from the large amount of EPRI research that has been targeted at other market segments. "Hospitals are really microcosms of many different commercial spaces," says Wendland, who manages the building performance project of the Healthcare Initiative. "Their office spaces resemble business offices. They have residential sections much like college dormitories and hotels. And their cafeterias have many of the same needs as restaurants. They even have commercial-scale laundries." The products of EPRI research that are applicable to health care environments range from efficient lighting systems and chlorofluorocarbon substitutes to microwave clothes dryers.

Critical differences

EPRI research is also addressing issues that are unique to health care environments. One of these issues is the need to control diseases carried by a high percentage of the people in these environments. As Myron Jones puts it, "There are transmitters of airborne diseases roaming all over the place. They are in the waiting rooms, cafeterias, gift shops, and hallways. In the old days we used to quarantine these people, but not any more."

Through the Healthcare Initiative, EPRI researchers are exploring a variety of methods for controlling the transmission of illnesses in health care facilities. One fundamental approach is through HVAC systems. The direction and rate of airflow can play a significant role in controlling the spread of bacteria. Yet many hospitals today are in dire need of HVAC system upgrades. "Typically, these buildings have added square footage successively over the past two decades," says Harold Olsen of EPRI's CBAC Center. "In the worst case, the end result is a dysfunctional HVAC system. In the best case, you'll get a system that manages to do its job, but not very efficiently."

One recently publicized study of 115 negative-pressure isolation rooms in St. Louis showed that 45% of the rooms allowed some air to flow into nearby corridors. This practice is prohibited under guidelines issued by the Centers for Disease Control and Prevention (CDC). Specifically designed for patients with life-threatening diseases like tuberculosis, negativepressure isolation rooms are supposed to be equipped with systems that vent air directly outside a building.

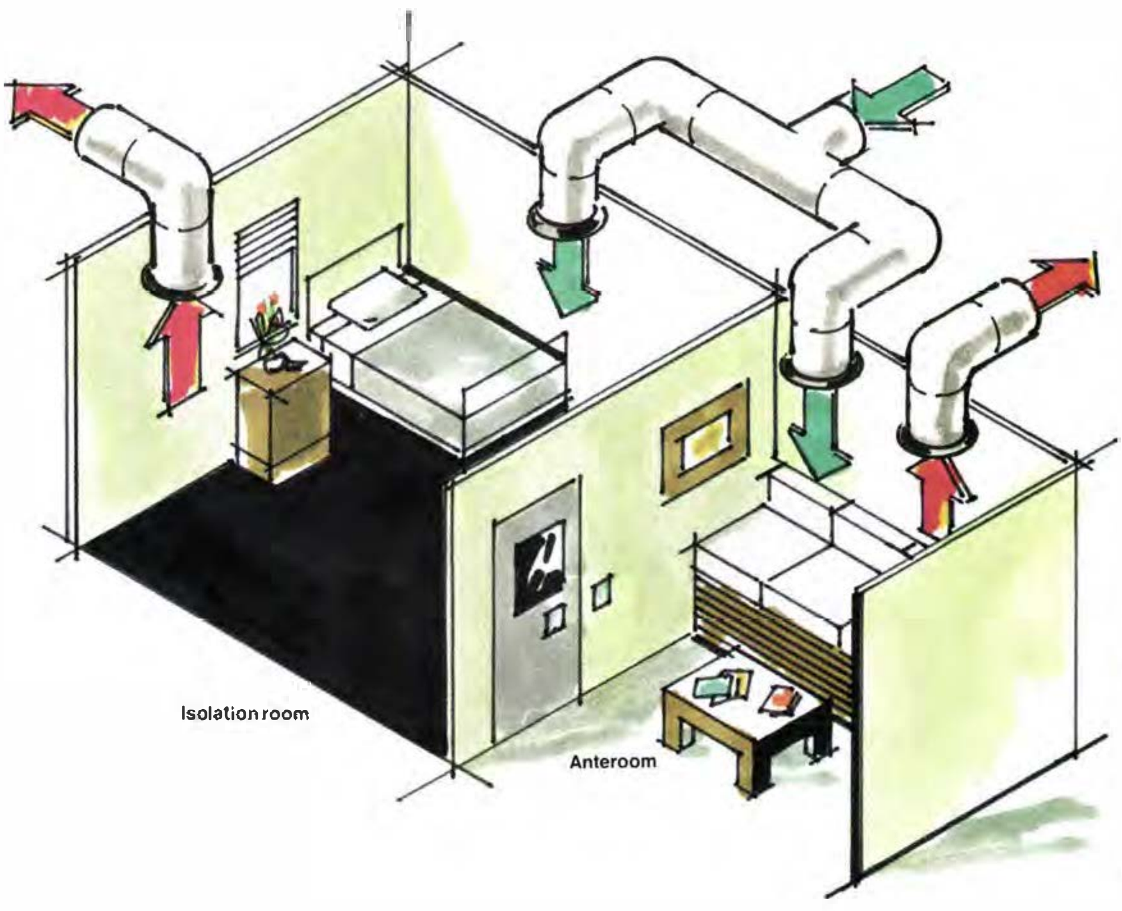
Updated last fall, the CDC guidelines now allow for an alternative in cases where venting isolation room air directly outside is not possible. The alternative is to pass the isolation room air through high-efficiency particulate air (HEPA) filters. HEPA filters are made from an ultrafine cloth capable of removing nearly all particles measuring at least 0.3 micrometer. These filters are already widely used in the health care industry; hospital operating rooms must have them in order to receive accreditation from the American Hospital Association.

The new CDC guidelines also recommend the use of ultraviolet light in waiting rooms, emergency wards, and other common areas to control the spread of airborne diseases like tuberculosis. Although UV lamps have been used occasionally for this purpose over the past 50 years, the practice has not become widespread because of a lack of documentation on its use under controlled circumstances. EPRI is hoping to help change this situation. Together with Consolidated Edison, the Lighting Research Institute, and others, EPRI has joined forces with the National Tuberculosis Coalition to develop a controlled study of the use of UV lamps to prevent the spread of TB.

Presumed to have faded as a serious health issue in the 1950s, tuberculosis is making a strong comeback. What concerns health care specialists is that some of today's TB bacteria are resistant to the antibiotics developed to wipe them out. Ultraviolet lamps provide the critical UV-C wavelength, which is capable of destroying the DNA of many airborne viruses and bacteria, including those responsible for measles, chicken pox, and TB. Although sunlight also provides ultraviolet light, only the UV-A and UV-B wavelengths—which do not have the sterilization capacity of the UV-C wavelength—are able to penetrate the ozone layer in the upper atmosphere. The only negative side effect associated with the use of UV lamps is the potential for temporary eye irritation. But this irritation is easily remedied, Jones says, and occurs only if a person looks directly into a lamp for a prolonged period of time.

Directed by doctors from St. Vincent's Hospital and Harvard Medical School, the National Tuberculosis Coalition study intends to examine the spread of TB among workers and homeless people at shelters with UV lamps in six urban areas across the country. The results will be compared with data obtained from homeless shelters without UV lamps.

THE HVAC FACTOR A properly functioning heating, ventilating, and air conditioning system can play an important role not only in reducing costs for health care facilities but also in controlling airborne diseases. For instance, isolation rooms for patients with infectious diseases must be negatively pressurized, venting air directly outside the building rather than back into the HVAC system. An anteroom helps prevent infected air from escaping into adjacent corridors.



In the meantime, EPRI researchers are working on problems raised by another bacterium common in hospitals. *Legionella pneumophila*, which causes Legionnaires' disease, is naturally present in all water supplies. It affects only people with impaired immune systems, however, such as AIDS patients and organ transplant recipients. The concern is that some hospital cooling towers, which provide a warm, moist environment ideal for *Legionella* breeding, may be close enough to the air intakes of ventilation systems to put such patients at risk. This summer, EPRI will sponsor several demonstration projects on the use of ozone—a form of oxygen commonly used to disinfect water supplies—to kill *Legionella* in cooling towers, which are an integral part of large-scale air conditioning systems.

Technologies for tough issues

One of the biggest issues unique to health care establishments today is that of medical waste. According to the Environmental Protection Agency, health care facilities generate 1.6 million tons of medical waste each year, of which 466,000 tons is infectious. This category includes everything—from syringes to body parts—considered capable of transmitting disease. Nearly 80% of this material is generated by hospitals, with physicians' offices, clinics, and other smaller establishments generating the rest.

Getting rid of infectious waste, also called red bag material, is difficult and costly. In some states, the cost of red bag waste disposal rivals that of nuclear waste disposal. Typically, the high cost is associated with the hiring of private haulers to cart the waste off-site. Off-site disposal also raises concerns about liability in the case of an accident during transportation or a problem at the disposal site. U.S. hospitals have traditionally opted for the lower-cost, lower-risk alternative of on-site incineration. But increasingly stringent clean air regulations over the past two decades have resulted in the shut-

THE UV WAY New guidelines issued by the Centers for Disease Control and Prevention recommend the use of ultraviolet light to prevent the spread of tuberculosis in waiting rooms, emergency wards, and other common areas of health care facilities. The effectiveness of UV lamps in checking the spread of infectious diseases has been recognized for half a century, but the lamps have been used only on an occasional basis. In an effort to make this practice more widespread, EPRI is cosponsoring a controlled study of the use of UV lamps to prevent the spread of tuberculosis in homeless shelters.

down of many on-site incinerators.

Today, only about half of all U.S. hospitals operate on-site incinerators. Many of the others are scrambling to find alternatives and have sought the advice of local utilities. In response, EPRI has produced a software program called the Medwaste Technology Evaluation System, or MATES. Member utilities can use MATES to help their health care customers select the best disposal technologies for their facilities. The Institute is also evaluating or supporting the demonstration of six new electrotechnologies for infectious waste disposal. The processes differ widely, but each is capable of decontaminating red bag material as well as rendering sharp implements like syringes unrecognizable.

THE MEDICAL WASTE BURDEN Increasingly stringent air quality regulations over the years have shut down many of the on-site incinerators used by hospitals for their medical waste. The cost of private haulers to take the waste away is quite high, and off-site disposal also raises concerns about liability, should problems occur during transportation or even after disposal. EPRI has produced a software program that utilities can use to help their health care customers select the best medical waste disposal technologies for their facilities. The Institute is also evaluating or supporting the demonstration of six new electrotechnologies for infectious waste disposal, including the Bio-Oxidizer, shown here.

Among the medical waste technologies that EPRI has funded is the Bio-Oxidizer®. Now commercially available from Bio-Oxidation Inc., the Bio-Oxidizer uses pyrolysis and oxidation to treat a wide range of biohazardous waste, including infected blood, pathological waste, needles, glass, and chemotherapeutic agents. According to John Moran of Bio-Oxidation, the process destroys 100% of pathogens and reduces waste mass and volume by about 95% and 99%, respectively. About 80% of the process energy can be recovered in the form of hot water by the unit's integral heat exchanger.

Waste fed into the Bio-Oxidizer is heated to between 200°F and 600°F inside a pyrolysis chamber, causing organic solids and liquids to vaporize. An induced draft draws the vapors into a two-stage oxidation chamber. In the first stage of the chamber, the vapors are heated to 1800°F; oxygen is mixed with the vapors throughout the heating process to promote oxidation and decomposition. In the chamber's second stage, the oxygen-rich vapors are heated to 1900–2000°F and retained for a minimum of 2 seconds at maximum airflow to ensure complete oxidation and decomposition of all organic material. What's left behind is a sterile, unrecognizable solid residue consisting of glass, clay particles, and small pieces of oxidized metal. Exhaust from the process consists of carbon dioxide, water vapor, and traces of other compounds, all well below the most stringent regulatory limits on air emissions.

The first commercial Bio-Oxidizer unit was installed last August at a 217-bed hospital in Chambersburg, Pennsylvania. John Massimilla, the hospital's vice president for administration, says it was relying on a private hauler to handle medical waste at 38¢ per pound when it decided to install the Bio-Oxidizer. By comparison, the Bio-Oxidizer has cost an average of 21¢ per pound. Moran notes that the unit was installed without the heat exchanger and that adding this element will further increase the unit's efficiency, bringing the cost down to about 18¢ per pound. The hospital has already ordered a second unit. (For information on other medical waste disposal technologies, see the *EPRI Journal*, January/February 1994, p. 44.)

Sophisticated technologies like the Bio-Oxidizer may seem a far cry from cost-cutting concerns. But as Stephen Neal, a researcher with Pacific Gas and Electric, explains, "Most health care customers are going to have to make some sort of investment to comply with environmental regulations anyway. New energy-efficient technologies might be more expensive when they first hit the market, but by working with EPRI through the Healthcare Initiative, we can subsidize the initial installations and help these technologies become more widely used."

The financial assistance and expertise that electric utilities are offering their health care customers are certainly valuable. The challenge for utilities participating in the initiative is to identify the specific concerns of individual health care customers so that the utilities can help deliver the appropriate form of assistance. Staying in touch with the needs of various health care customers is a difficult job. But utilities say this task is well worth the effort, since they are reaping significant benefits. "Strong communication with health care customers will help utilities better serve this market segment," says Bill Drewery of Entergy. "The best thing utilities can do is establish partnerships with health care customers and maintain robust relationships that will survive these years of significant change in the health care industry." ■

Background information for this article was provided by Larry Carmichael, Myron Jones, Marek Samolyj, and Ron Wendland, Customer Systems Group.

As public pressure to move electrical transmission and distribution facilities underground increases, a new generation of technologies promises to make undergrounding more cost-competitive. Some of these technologies, such as a guided boring system based on electronics developed for the cruise missile, are revolutionizing underground construction practices. Others, such as a cable leak locator that works by detecting a tracer gas at parts-per-quadrillion levels, are making underground systems more reliable and easier to maintain. Together, these technologies are fundamentally changing the economics of underground power delivery and are making it more attractive in situations ranging from congested urban areas to environmentally sensitive rural locations.

Although even the most ardent proponents of undergrounding admit that it is still generally more expensive than installing overhead lines, comparative costs are cumbersome to establish. There is no reliable rule of thumb. Cost differentials are determined almost entirely by site-specific factors, ranging from the price of an easement for an overhead right-of-way to the difficulty of drilling through a specific mixture of rock and soil. One trend is clear, however: the cost of constructing, operating, and maintaining underground systems is falling rapidly.

"I expect that new construction technologies can cut the cost of installing underground transmission cables by half," declares Ralph Samm, a program manager in EPRI's Power Delivery Group. "We're also developing ways for utilities to increase the loading on their existing underground transmission systems and to extend the expected life of these systems."

As for underground distribution systems, EPRI program manager David Becker adds, "We're currently demonstrating equipment that can reduce construction costs by 15–30% over the next three to five years and lower the cost of operation and maintenance by at least 15% over the same period. These developments are vital because many urban utilities expect that by the year 2000 virtually all of their

COSTS COMING DOWN for UNDERGROUND

THE STORY IN BRIEF Undergrounding of transmission and distribution lines, once considered prohibitively expensive for many locations, is becoming more affordable, thanks to a series of technological breakthroughs. Electronically guided boring rigs, for example, can now drill channels for conduit installation over longer distances in rougher terrains, without the need for trenching. Meanwhile, EPRI-funded researchers have developed a "soft" trenching system for installing cable that sharply reduces the chances of damaging existing underground structures, such as gas pipelines. On the maintenance side, major cost reductions are resulting from new techniques for locating faults and leaks in cables and for refurbishing deteriorated vaults and conduits. Such advances are particularly timely, considering the increasingly strong public opposition to overhead lines.

by John Douglas

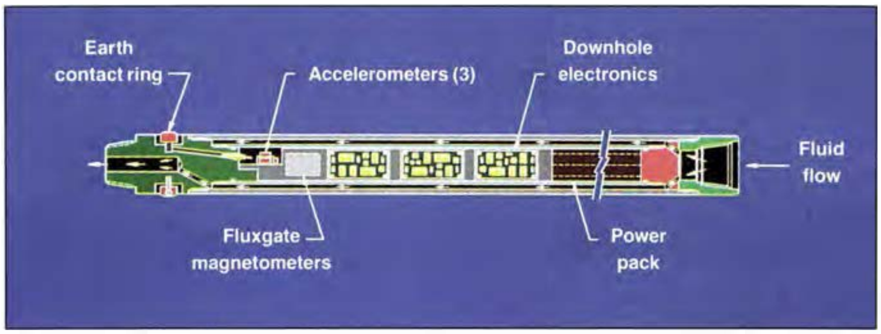
distribution construction—whether new or replacement circuits—will be underground."

New focus on the bottom line

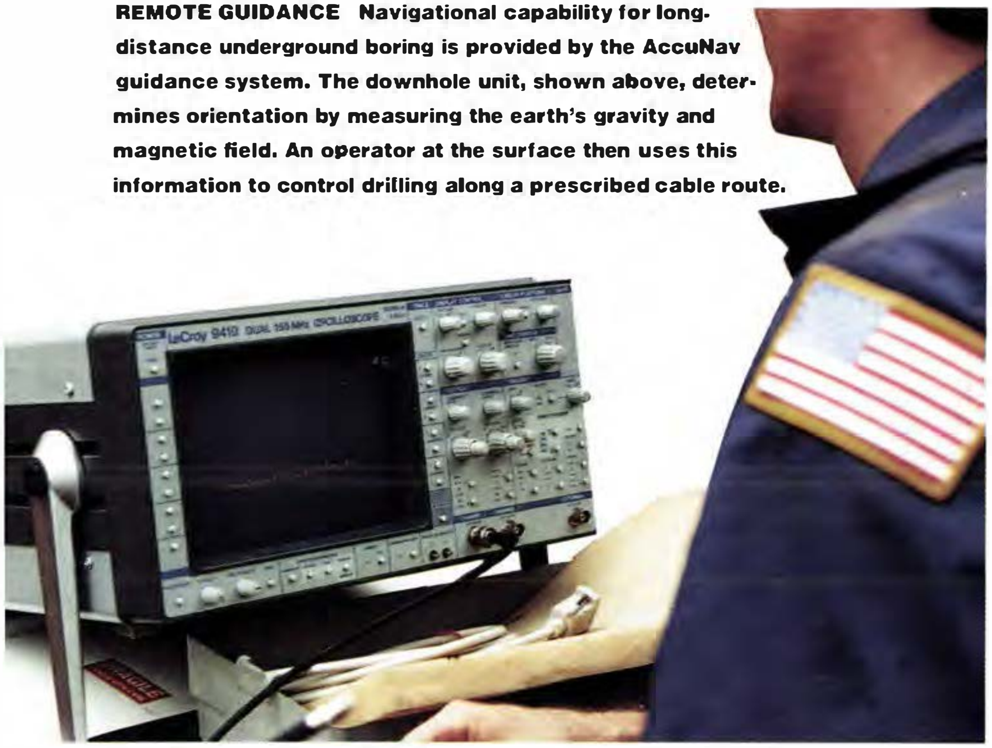
For transmission lines particularly, many utilities have traditionally looked at undergrounding as a forced option—something mandated by public pressure or regulatory fiat—rather than as an opportunity to be considered on its economic merits. That attitude is now being replaced by a new focus on the bottom line and the advantages of underground cable installation in many situations. As a result, research on how to make dependable cost comparisons between overhead and underground power facilities has gained new significance.

One pioneering effort to explore the key factors in such comparisons was a 1987 EPRI study that considered the construction of a new transmission route in a rural area—a situation in which an overhead line should have had a natural advantage. Because of site-specific and operational conditions, however, this was not the case. The overall goal of the study was to bring some consistency to the way in which overhead and underground systems are evaluated, so that they can be compared realistically. For this purpose, a "difficult" route was chosen for analysis, a route featuring road and stream crossings, a range of slopes and soils, a varied terrain of woodlands and pasture, and limited man-made development. The proposed 345-kV transmission circuit was to be approximately 5 miles long, with a design rating of 1800 MVA.

The main finding of the study was that cost ratios of underground to overhead lines were less than 5 to 1, depending on the cable type and installation techniques assumed. These ratios were considerably lower than the ratios usually cited at the time, and the study helped raise utility consciousness about the potential economic advantages of underground systems. Subsequent improvements in underground construction techniques have probably reduced the cost for a rural area even further. And in many congested urban locations, the cost of underground



REMOTE GUIDANCE Navigational capability for long-distance underground boring is provided by the AccuNav guidance system. The downhole unit, shown above, determines orientation by measuring the earth's gravity and magnetic field. An operator at the surface then uses this information to control drilling along a prescribed cable route.



transmission is now actually lower than that of overhead lines if a new right-of-way must be obtained—assuming that regulatory permission for the overhead project can be obtained.

"For transmission systems, the real battleground now lies between these rural and urban extremes," explains John Shimshock, who manages cable testing at EPRI's Waltz Mill Underground Transmission Center near Madison, Pennsylvania. "The most difficult decisions between overhead and underground are now being made in suburbs, new industrial parks, and other areas of rapid growth. And an objective analysis requires considering environmental and reliability factors as well as cost."

These and other considerations can be evaluated by means of EPRI's TLWorkstation™ for overhead transmission lines and UTWorkstation™ for underground transmission systems. PSI Energy, for example, recently used the ACE (alternative cable evaluation) module of UTWorkstation to plan its first underground transmission project, optimizing both design parameters and installation methods. UTWorkstation can also be used for underground distribution applications.

Construction breakthroughs

Construction can account for up to 70% of the total system cost for underground transmission and even more for underground distribution. For this reason, a primary objective of research aimed at lowering the cost of underground systems is to develop a variety of advanced tools that will make cable installation cheaper, faster, and less obtrusive. Particular emphasis is being placed on advanced boring tools, which provide an increasingly attractive alternative to trenching, the traditional construction method.

Since the mid-1980s, utilities have used small guided boring rigs to install distribution cable over relatively short distances at shallow depths. The progress of the drill head underground is measured at the surface by means of a handheld electronic pipe locator. Mini-rigs have proved useful for boring under city streets to depths of about 10 feet—the limit of the pipe locator's reliability. At the other end of the drilling spectrum, the petroleum industry uses guided boring technology that features very expensive downhole sensors and communications equipment and that can create horizontal wells several miles long through oil deposits at great depths under the ocean.

What has been lacking is a relatively inexpensive boring rig that can drill longer holes at greater depths than current mini-rigs can and that has downhole guidance equipment with greater resolution and a higher communications data rate than the larger petroleum industry equipment has. Moreover, to expand the use of boring rigs in transmission applications, new installation methods have been needed to place larger conduits and pull longer lengths of heavier cable. Now, a series of breakthroughs in construction technology developed through EPRI research has made all this possible.

High tech underground

A new remote-guidance system, called AccuNav, brings the high-tech navigational capability developed for cruise missiles literally down to earth for utility drilling applications. The downhole unit, which houses sensors that determine orientation by measuring the earth's gravity and magnetic field, is entirely self-contained and fits in a 10-foot section of the drill assembly. Data from the sensors are processed by an onboard computer and

PUSHING CABLES **Three phases of transmission cable are inserted into a 10-inch conduit in this first demonstration of cable pushers, used in conjunction with pulling winches at the other end of the cable route. By applying these and other advanced technologies, engineers were able to install 2500 feet of 115-kV cable in a single, joint-free length across the Nacoochee Valley of northern Georgia.**

transmitted by electromagnetic pulses up the drill string. At the surface, an operator views the data displayed graphically on the screen of a laptop computer and determines the location of the drill head and whether any directional changes are necessary. With this communications system, AccuNav has an underground range of about 1000 feet; future enhancements, such as the use of a communications wire line or a homing device, are expected to extend the drilling range considerably.

Developed for EPRI by Guided Boring Systems, Inc., AccuNav was first used in a utility application by Pacific Gas and Electric Company in December 1992 to drill a 400-foot passage under a flood control canal in Oakland, California. The drill head was inserted into the ground on one side of the canal and emerged within inches of its target on the opposite bank. PG&E then installed two 5-inch conduits in the borehole.

The most challenging application of AccuNav to date came last summer in Georgia's scenic Nacoochee Valley, where Georgia Power Company used the device to guide the drilling of a 2600-foot channel in four segments. By boring under the valley, the utility was able to bury a 115-kV transmission line that had previously been a source of community irritation in the popular tourist area. Guided drilling also made it unnecessary to trench through the archeologically and environmentally sensitive valley, which contains a Native American burial ground and a state-protected trout stream.

Oglethorpe Power Corporation, the other large power supplier in Georgia, joined EPRI and Georgia Power in the technical aspects of this project. Oglethorpe was interested in advancing the technology for its own use in the state.

Offset bits and hollow ropes

The Nacoochee Valley project provided a showcase for a variety of other innovative underground construction equipment as well. These devices were developed for EPRI by Underground Research, Inc., who also served as prime contractor for the project.

To bore through the unstable cobble that underlies much of the valley—individual stones range from the size of a fist to the size of a basketball—a drill head with an offset tungsten carbide bit was used. EPRI's manager for the project, Tom Rodenbaugh, recalls with a chuckle that "some people in the industry thought we were crazy with that drill bit. They said it would tear itself to pieces. Instead, we're going to get a valuable patent out of it."

The original drill hole was about 4 inches in diameter and had to be widened to 16 inches to accommodate the 10-inch cable conduit and some drilling mud. The widening was accomplished by pulling a two-stage back reamer through the channel in the opposite direction from the initial boring. Finally, to pull all three phases of the cable through the conduit along the entire route in a continuous length, workers used a hollow pulling rope made of steel and Kevlar, which made it possible to inject a lubricant spray at the pulling eye attached to the cable end. To monitor tensions and thus prevent damage to the cable, the rope had communications wires

BACK REAMER **This newly designed, two-stage back reamer was used to widen a 4-inch pilot hole to a final diameter of 16 inches in the Nacoochee Valley project. The initial hole was drilled using AccuNav; then the back reamer was pulled through the hole in the opposite direction to enlarge it for insertion of a 10-inch conduit.**

SAFER TRENCHING **EPRI's Soft Trencher, seen here in prototype demonstration, will not harm the buried structures it encounters, such as communications cables and plastic sewer pipes. The operator uses a remote-control panel to guide the trencher head, which has supersonic air jets to break up soil for removal by a high-volume vacuum system.**

leading to a strain gage at the pulling eye. The tension was further eased by the use of advanced cable pushers at the entry hole—the first application of this technology.

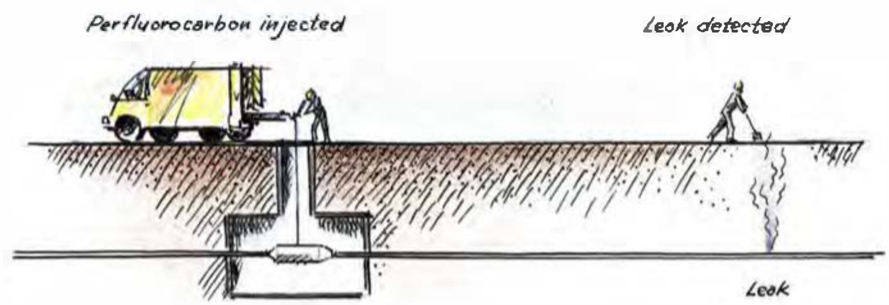
"We're very pleased with the number of firsts that were achieved in the Nacoochee Valley project," says Charles McCall, senior engineering associate at Oglethorpe. "Since we serve 39 rural electric cooperatives in Georgia, we are particularly interested in new, low-impact construction technologies that can be used to install cables in environmentally sensitive rural areas. In addition to cofunding the demonstration of this technology, we have participated in EPRI workshops on planning underground facilities."

Improved trenching

Although drilling is rapidly becoming the preferred technology for installing cable in areas where surface excavation would be particularly expensive or disruptive, trenching remains competitive in many situations where surface access is not a problem. In those cases, however, another difficulty is frequently encountered: how to avoid existing buried structures, ranging from communications cables to gas mains and sewer pipes. City utility maps are often incomplete or out-of-date, and the increasing use of plastic pipe means that ordinary metal detectors cannot be relied on to locate underground obstacles. EPRI is helping utilities respond to this challenge by developing two products that will make trenching safer and less expensive—the Soft Trencher, which won't harm existing structures, and a ground-penetrating radar system that can map both metallic and nonmetallic objects underground.

The Soft Trencher, now in prototype demonstration and scheduled for commercialization later this year, uses supersonic air jets to break up the soil without harming nonporous objects that are encountered. A high-volume vacuum lifts the soil from the excavation and transports it to a conveyor system for loading onto a truck or depositing in a windrow beside the trench. The Soft Trencher is designed to remove soil 25% faster than a backhoe while reducing the danger of damaging existing buried facilities. (Penetration of a gas pipeline by a backhoe is the suspected cause of the devastating explosion last March in Edison, New Jersey, which killed 1 person, injured 100 others, and destroyed eight apartment buildings.)

Developed by Battelle and Concept Engineering Group, Inc., the Soft Trencher can dig excavations 1 to 6 feet wide and up to 10 feet deep. In good soil, it has a nominal trenching speed of 1 foot per minute. The operator can stand in front of the Soft Trencher for a better view and use a remote control to guide its operation. The excavation head is mounted on a 22-foot telescoping boom and contains nozzles that accelerate air from a conventional compressor into highly focused jets that move at approximately twice the speed of sound. These supersonic jets penetrate the soil, building up pockets of high pressure that fracture it. The vacuum system connected to the excavation head then lifts the soil out of the trench—together with 6-inch rocks and sticks up to 18 inches long.



SNIFFING OUT LEAKS **Perfluorocarbon, a harmless fluid with a unique chemical structure, is injected into the dielectric fluid of a transmission cable system to provide a tracer for leak detection. Since the tracer can be detected in parts per quadrillion, a simple portable apparatus is all that is needed to take air samples and literally sniff out the location of a cable system leak.**

The ground-penetrating radar is being developed to locate buried utility lines, building foundations, and other underground structures that could pose a hazard to the construction process, whether excavation or earth boring. Pipes made of plastic are particularly difficult to locate with current instruments. Previous attempts to build ground-penetrating sonar or radar devices have not produced instruments that could be used routinely and cost-effectively by electric utilities.

Current efforts are focused on designing two radar-based ground penetration systems. One will use computer imaging technology to identify and map structures down to about 12 feet. The other will be a lower-cost, quick-check device that can be used specifically to detect buried plastic pipes and electrical cables. Prototypes of both devices are expected to be available for utility demonstration by 1997.

AUTOMATED FAULT LOCATION **The Fast Fault Finder can locate a fault in an underground residential distribution cable to within 2% of the circuit's length. Unlike previous methods, which required highly trained operators, the Fast Fault Finder automatically provides a digital readout of the distance to a fault by analyzing transient voltage waves created by arcing at the fault.**

Cable diagnostics and refurbishment

Major cost reductions are also possible in the maintenance and replacement of existing underground transmission and distribution systems. New diagnostic equipment can find faults in distribution cables and leaks in pipe-type cables much more quickly and cheaply than previous methods could. New techniques have also been developed to remove jammed cables from existing conduits, thus freeing up valuable channels for future use. Finally, for underground vaults in need of refurbishment, corrosion-resistant composite materials are becoming available that can extend the life of existing structures.

The Fast Fault Finder is a patented new EPRI instrument for locating faults in unbranched underground residential distribution (URD) cables up to a mile long. "Previous fault location methods generally required highly trained operators, and some risked further damaging a cable by subjecting it to repeated electrical pulses," according to EPRI's Harry Ng. "The Fast Fault Finder is fully automated and provides a simple digital readout of the distance to a fault." Based on EPRI research in voltage waveform analysis, the device works by recognizing the transient waves created by an arcing fault. It can determine the location of a fault to within 2% of the total circuit length.

Being developed for EPRI by Edison Control Corporation, the Fast Fault Finder is expected to be available in prototype units for field testing by member utilities this summer. The first test of the concept was conducted on the distribution system of Public Service Company of New Mexico and involved a test circuit 6000 feet long with 16 transformers. The instrument correctly located a fault between adjacent transformers—a critical capability for reducing the amount of time it takes repair crews to restore service to customers. Because of the Fast Fault Finder's low cost (around $800 or less), it can be permanently installed on individual URD circuits to provide real-time monitoring, in addition to being used for after-the-fact fault location. A more widely applicable device, one capable of locating faults on underground distribution circuits with Y or T branch connections, is expected to be tested in 1995. If this effort is successful, the device could become commercially available in late 1995 or early 1996.

Leaks in pipe-type transmission cables, which contain a dielectric fluid under pressure, can now be located much more quickly and accurately through the use of a perfluorocarbon tracer (PFT) system developed by Brookhaven National Laboratory with funding from EPRI, Consolidated Edison Company of New York, and the Empire State Electric Energy Research Corporation (ESEERCO). The PFT is an environmentally harmless compound with a chemical structure so rare that it can easily be detected in air at parts-per-quadrillion concentrations. A repair crew injects the PFT into the dielectric fluid of a cable and then takes atmospheric samples along the cable route to find where the tracer is leaking.

Each application of the PFT leak locator can save tens of thousands of dollars, given that conventional methods often require extensive excavation. Sometimes, for example, a leak has had to be located by using liquid nitrogen to freeze a plug of dielectric fluid so that a pressure drop could be detected on one side of the plug or the other, then making successive isolation attempts until the leak was localized. Con Edison conducted the first utility demonstrations of the leak locator, including finding and repairing a small leak in a 10,000-foot, 345-kV feeder cable between Brooklyn and Manhattan without having to remove the cable from service. Underground Systems, Inc., now provides a cable leak detection service commercially, using the PFT device under license.

TANGLE UNDERGROUND Many underground utility systems are in need of refurbishment, with old cables jammed in conduits, metal transformer tanks corroding, and some ferroconcrete vaults themselves deteriorating. New technologies are becoming available to help restore these systems more cost-effectively.

As the conduits of many urban cable systems become increasingly congested, the need for a better way of removing old cables has become apparent. Traditionally utilities have used trucks and pulleys to tug at the old cables, which often snap or simply don't budge. Now a new system has become available that uses a combination of vibration and pressurized lubricant injection in addition to pulling. Developed and commercialized for EPRI by Underground Research, the system was recently used by Seattle City Light to remove jammed cables from two banks of ducts in its downtown core area; the utility thus avoided installing new conduits at much higher cost. Future work in this area will include the development of new methods for removing both old conduit material and cables from their underground concrete encasement.

Refurbishing the underground vaults used to house transformers and other equipment has also become a critical need in many urban areas. The replacement of a vault can cost 10 times as much as initial vault installation. By using advanced composite materials to reinforce concrete-and-rebar vault structures, utilities can salvage many old vaults instead of having to totally replace them. Demonstration of reconstruction and restoration techniques is expected to begin next year.

"One of the most important things we can do to improve the economics of underground transmission and distribution is to help member utilities get the most service they can out of existing conduit and vault systems," says EPRI research manager Thomas Kendrew. "The new diagnostic equipment and refurbishment technologies developed by EPRI are creating a quiet revolution in the way utilities operate and maintain their underground systems, and can significantly extend their life expectancy."

More power, longer life

A final way to reduce the cost of undergrounding is to help utilities get higher performance out of facilities they already own. Some utilities that have used underground systems for many years are finding, in particular, that they need better ways to maximize power flow in their transmission cables and to extend the life of distribution cables. EPRI research is producing new insights into how each of these goals can be accomplished.

One of the biggest concerns to utilities with underground distribution systems has been the unexpectedly high failure rate of cables insulated with older, polyethylene-based materials. According to EPRI's Bruce Bernstein, "The Institute's research has helped us understand the factors causing these problems. Some of these factors are linked to manufacturing practices, utility test procedures, and fundamental materials behavior. But new materials have been showing improvement; solid dielectric distribution cables of the future can be expected to have lifetimes of 30 to 40 years."

The results of EPRI research on distribution cables through the early 1990s, together with practical advice on how to prevent their early failure, are now available to utilities in the two-volume *Distribution Cable Research Digest*. A future *EPRI Journal* article will discuss newer cable types.

To maximize the power that can be delivered through transmission cables, EPRI has developed the Dynamic Rating and Underground Management System, or DRUMS. A combined hardware and software system, DRUMS continuously measures the critical operating parameters of a cable and provides feedback so that the cable can be loaded closer to its thermal limit. Standard ratings of high-pressure fluid-filled transmission cables are generally based on worst-case assumptions, since real-time monitoring has been too expensive. Now, with recent improvements in sensors and microprocessors, DRUMS can offer a cost-effective way of instrumenting an underground feeder to measure key parameters—such as fluid temperature, pressure, and flow rate—and analyze them with a dedicated computer to provide real-time ratings.

FREEING STUCK CABLE **A new procedure developed by EPRI can be used to remove jammed cables from their conduits. First a lubricant is injected around the cable (top), which is then vibrated to loosen it (middle). Finally a winch at the surface pulls the cable free (bottom), leaving the conduit available for reuse at a small fraction of the cost of installing a new conduit.**

DRUMS was developed by Underground Systems with sponsorship by EPRI, Con Edison, and ESEERCO. The system is currently being demonstrated on two 345-kV Con Edison feeders that supply power to New York City. Results indicate that the normal rating of the feeders can be increased by up to 29% and that the emergency rating can be increased by up to 58%. Not only do such rating increases make more-efficient use of the feeders, but they may minimize the need to supplement power in emergencies by using expensive additional generators in the city.

"We anticipate the eventual development of a new generation of transmission and distribution cables that will make undergrounding even more attractive," concludes EPRI's Karl Stahlkopf, vice president for the Power Delivery Group. "Already, transmission cables with solid dielectrics are being used in Europe and Japan at up to 500 kV, and we are pushing for field demonstration at 345 kV in this country. We've also made a lot of progress toward improving the longevity of distribution cables. Taken together, EPRI's efforts to reduce the cost of underground systems are accelerating one of the most significant trends in the industry today—the greater use of cables in place of overhead lines for both transmission and distribution." ■

Background information for this article was provided by Ralph Samm, David Becker, Tom Rodenbaugh, Thomas Kendrew, John Shimshock, Harry Ng, and Bruce Bernstein, Power Delivery Group.

CONTRIBUTORS

Technical sources for Journal feature articles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KENDREW

Buying and Selling Power in the Age of Competition (page 6) was written by science writer John Douglas, with background information provided by **Riaz Siddiqi** of EPRI's Power Delivery Group. Siddiqi has managed research on utility planning and power market management since joining the Institute in 1989. Previously he was with Georgia Power Company's bulk power markets organization, where he was involved in the development of joint ventures, innovative financing proposals, and nontraditional power sales. Siddiqi has also held positions at San Diego Gas & Electric Company and Southern Company Services. He holds a BS degree in electrical engineering from Pakistan University of Engineering and Technology and an MBA from Mississippi State University. ■

Power Rx for the Health Care Industry (page 14) was written by Leslie Lamarre, *Journal* senior feature writer, with assistance from **Myron Jones**, manager for environment and energy management in the Customer Systems Group. Before joining EPRI in 1990, Jones was vice president of a subsidiary of Pacific Gas and Electric Company, where he was responsible for natural gas sales and corporate planning. He has also worked for Bechtel, Shell Development Corporation, United Technologies, and Rust Engineering. Jones holds an MS degree in chemical engineering from the University of Maine. ■

Costs Coming Down for Underground (page 22) was written by science writer John Douglas, with background information from members of the Power Delivery Group.

Tom Rodenbaugh, a manager of underground transmission research, joined EPRI in 1974 after two years as a physics instructor for graduate and undergraduate students at San Jose State University. He received a BS in physics from the University of California at Berkeley and an MS in solid-state physics from San Jose State.

Ralph Samm, program manager for underground transmission, came to EPRI in 1974. Earlier he spent 17 years with I-T-E Imperial Corporation, where he managed R&D projects in several areas, including work on gas-insulated cables and substation equipment and on current-limiting-fuse design and application. Samm holds a BS in electrical engineering from Johns Hopkins University and an MBA from the University of Pittsburgh.

David Becker, program manager for distribution systems, joined the Institute in 1993 after more than 25 years with Pacific Gas and Electric Company, where he most recently served as energy management system manager. Becker received a BS in electrical engineering from Lafayette College and an MS in engineering management from the University of Santa Clara.

Thomas Kendrew, who manages distribution research, joined EPRI in 1977. Previously he worked with public and private utilities for 18 years. Kendrew holds a BS in electrical engineering from Heald Engineering College and an MS in the same field from the University of California. ■

EPRI Announces New Executive Leadership Team

As EPRI moves into its new Progressive Flexibility program, the Institute has announced some changes in its upper management structure to more effectively implement and manage the new program. The Board-approved changes, which went into effect on May 1, will help keep the Institute's operations in step with the concurrent restructuring and downsizing in the industry as a whole. EPRI anticipates that the restructuring of its staff and business processes will allow the Institute to respond with greater efficiency and agility to member and industry needs in the coming years.

"The new EPRI organization emphasizes a flatter, smaller, and more consolidated executive team," says President and CEO Richard Balzhiser. "The primary goal in making these changes is to more closely align our organization with the evolving structure of the electricity industry."

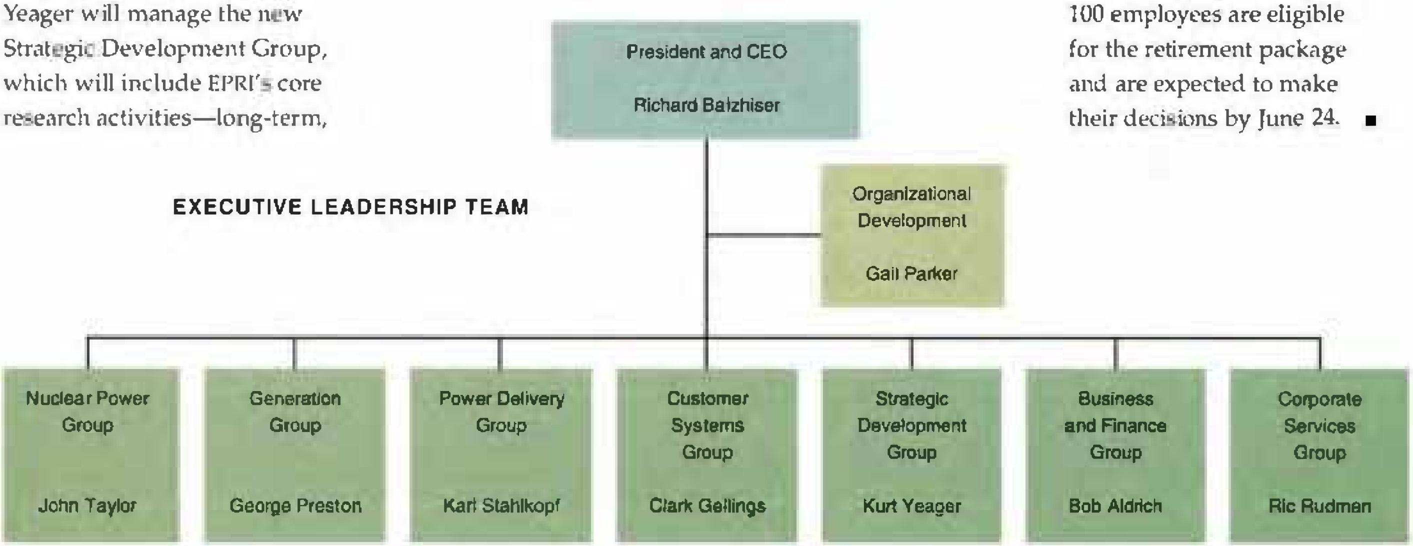
EPRI has reduced the number of its vice presidents by a third and has redistributed responsibilities under a new executive leadership team. Four vice presidents will manage business areas similar to the organizational units within most utilities: Clark Gellings in Customer Systems, George Preston in Generation, Karl Stahlkopf in Power Delivery, and John Taylor in Nuclear Power. The 14 elective business units offered in EPRI's Progressive Flexibility program will be organized under these four groups.

Senior Vice President Kurt Yeager will manage the new Strategic Development Group, which will include EPRI's core research activities—long-term, public interest, and environmental science—along with client relations and strategic planning. Senior Vice President Ric Rudman will oversee Corporate Services, including information technology services, human resources, administrative services, corporate legal, and corporate communications.

The Business and Finance Group will be headed by Vice President Bob Aldrich, who will have responsibility for contracts, finance, and commercialization. The creation of this group reflects the increased emphasis on partnering with our R&D contractors and others who commercialize or deliver EPRI products worldwide. The group's creation also recognizes the added financial complexity entailed by the Progressive Flexibility program's menu-based R&D offerings.

Gail Parker, Vice President for Organizational Development, will work closely with Dick Balzhiser in planning and executing the organizational and process changes involved in EPRI's continuing evolution to a leaner, more efficient organization. Her primary responsibilities will shift over the next four months as she begins a development assignment in the Customer Systems Group.

In another effort to streamline its operations, EPRI announced a voluntary retirement incentive program on May 5 to provide an opportunity for eligible EPRI staff to retire with additional transition and retirement benefits. About 100 employees are eligible for the retirement package and are expected to make their decisions by June 24. ■



Geographic Information Systems

Smart Maps Can Offer Utilities Advice

A utility needs to site a transmission line through a scenic area and wants to get a sense of the visual impact. It also needs to know about environmental constraints in the region, as well as any political or physical boundaries. In the past, the utility would have assembled a multidisciplinary team to gather data, visit the site, and pore over a plethora of hand-drawn maps, legal documents, and data charts. Today, the same siting process can be conducted by one person with a computer.

The technology that enables this kind of synthesis is called a geographic information system (GIS). Already extensively used by federal agencies and the automotive industry, GISs feature software products that boil all relevant data down to a multilayer computerized map that can perform sophisticated analyses on cue. In the case of a transmission line siting, a GIS could assign environmental, visual, and cost values to the various options and display the best route on the computer screen, showing how it would cut through the landscape.

At this time the electric utility industry does not have much experience with GIS technology. According to Pat Wilkey, an engineer with Argonne National Laboratory, cost has been a big hurdle. "The high initial cost of entering hand-drawn maps and data into a computer has caused a lot of people to shy away from GIS," he says. "But within the last two years scanning technologies have come along that make this transition a lot easier. The computing time and costs of GIS programs have also come down."

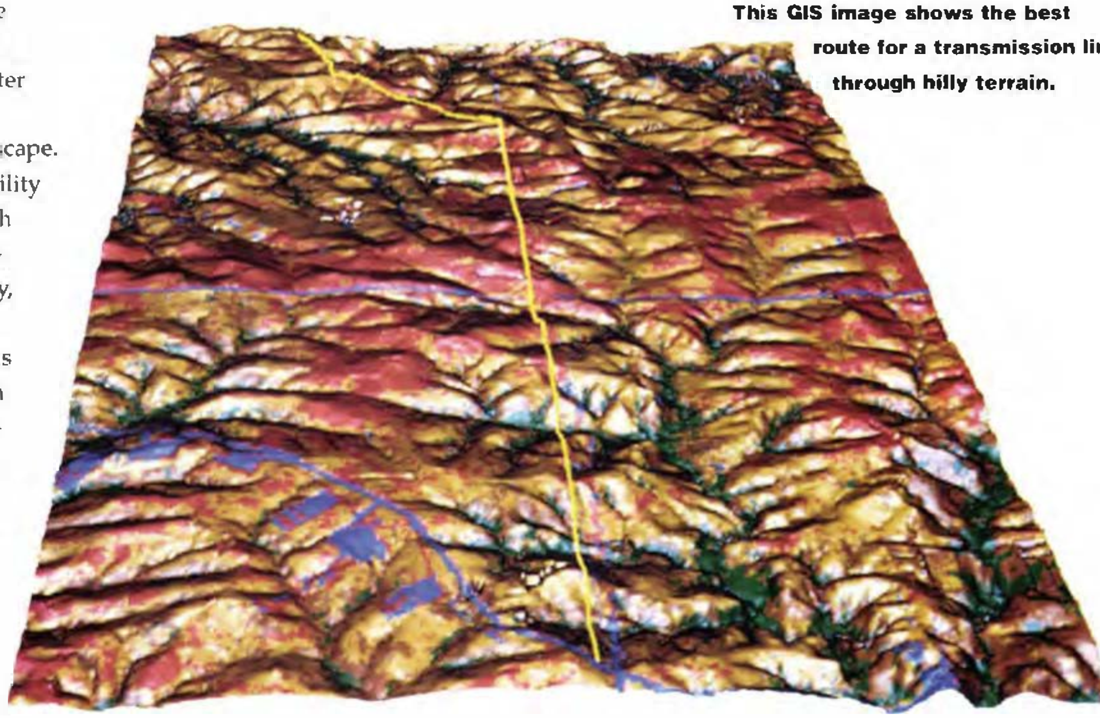
In a first step toward exploring the opportunities to exploit GIS technology in the electric utility industry, EPRI has launched a scoping study to assess the status of the technology among utilities. The study, being conducted by Argonne National Laboratory, will identify potential applications for GISs in the industry. It is expected to be completed by mid-1995.

In the meantime, Argonne researchers are working with individual EPRI member utilities—including New York State Electric & Gas Corporation and Pacific Gas and Electric Company—on GIS projects that have been undertaken with EPRI as tailored collaboration ventures. The researchers expect to develop methodologies for addressing specific issues at these utilities. The methodologies, which could also be useful in addressing similar issues at other utilities, will be made available to other EPRI members.

"Transmission line siting is just one of the many potential applications for this technology," Wilkey says. "GIS programs can be applied to functions ranging from marketing to demand-side management." Much of the information input into the programs is available at no cost through federal and state agencies, Wilkey says. In fact, Duke Power Company has tapped into North Carolina's clearinghouse for statewide information on topics that include hydrology and political boundaries.

Wilkey expects that more utilities will take steps toward applying GIS technology as competition in the industry increases. "Utilities are looking to expand their market share and to use their existing resources more efficiently," he says. "GIS can help them make timely decisions and establish a stable database for making future decisions. Many utilities are jumping into it with both feet."

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



This GIS image shows the best route for a transmission line through hilly terrain.

Artificial Intelligence

Advanced Neural Networks for Optimizing Power Plant Performance

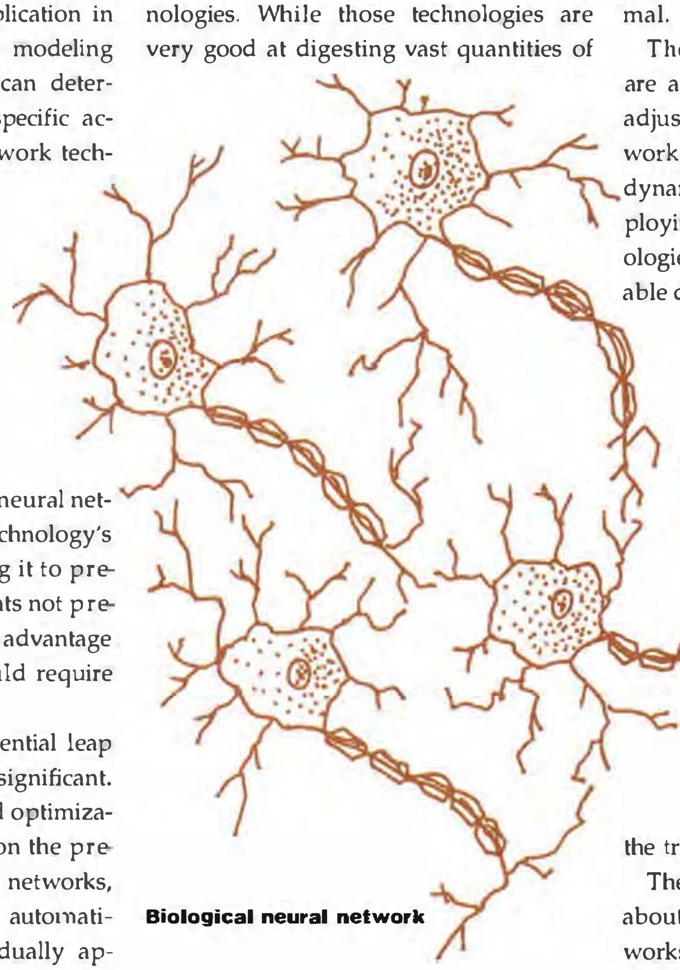
Artificial neural networks are typically used to analyze massive quantities of historical data. One practical application in the electric utility industry is modeling generators so that operators can determine the likely outcome of specific actions. With existing neural network technology, however, a generator model can offer guidance only on situations the generator has already experienced. EPRI researchers are working to change that.

In a recently initiated project at the University of Missouri, EPRI-sponsored researchers are developing a new approach to neural networks that will expand the technology's range of extrapolation, enabling it to predict the likely outcomes of events not previously experienced. Another advantage is that the new approach would require less data to make predictions.

The implications of this potential leap in neural network science are significant. With the help of a computerized optimization system, which would act on the predictions generated by neural networks, operations could be adjusted automatically so that they would gradually approach optimal performance, even under conditions not yet experienced. Practical applications in the industry include boilers capable of self-tuning for emissions control and heat rate improvement.

"In order to accomplish these kinds of tasks, there has to be an intelligent means of predicting or extrapolating from current knowledge," says Stan Yunker, EPRI's manager for the two-year project at the University of Missouri. "Neural networks have never been used this way before."

Artificial neural networks are named after their biological counterpart, the interacting group of information-processing neurons in the brain that are responsible for capacities like image recognition and situation assessment—the kinds of skills not found in most other computer technologies. While those technologies are very good at digesting vast quantities of information and spitting out split-second computations, they are not known for their ability to make predictions that represent the complexities of real life.



Biological neural network

Artificial neural networks depend on strings of parallel processing units that analyze problems independently and relay the outcomes to other processing units until a final prediction is reached. One drawback of today's neural networks is that they require such large quantities of data; some of these data may not be available, while other pieces of data may become invalid as system components change. Another deficiency of existing neural network technology is that it can be misled by an unusual event and offer an unsound prediction that assumes the event is normal.

The University of Missouri researchers are addressing these two deficiencies by adjusting the architecture of neural networks so that the networks' geometry is dynamic rather than constant, and by employing sophisticated statistical methodologies to better extrapolate from available data. Once the networks are adjusted so that they are not misled by aberrant behavior, they will be able to generate more-reliable models from which to extrapolate. Through a continual sequential process of generating data from the operation of utility machinery and updating the neural networks with these data, utility engineers will be able to use the more-advanced models to move further and further beyond the range of previous experience toward the true optimal running conditions.

The Missouri project addresses one of about a dozen applications for neural networks that EPRI is currently investigating. The other applications range from recognizing hand-lettered text and maps to performing diagnostic work on check valves without having to take them apart. Most of these projects are included in the Institute's Artificial Intelligence Initiative, a joint effort with the National Science Foundation aimed at advancing the science of artificial intelligence and improving utility operations.

■ *For more information, contact Stan Yunker, (214) 556-6533.*

Utilities Hosting Field Demos of Microwave Clothes Dryers

In preparation for six-month field tests beginning later this year, 10 utilities are hosting supervised demonstrations of prototype microwave clothes dryers under development by EPRI for home and commercial use. The new dryers promise to shorten drying time substantially and to reduce energy use. And thanks to a lower drying temperature, they won't harm even delicate fabrics. Two major appliance manufacturers that are members of an industrial advisory committee for the project will be watching the field tests with an eye to possible commercialization of microwave dryers within a few years.

To familiarize utility marketing staffs with the dryers' potential, two early prototype units (one for residential use and one for commercial use) are making one-week appearances at the participating utilities before prototypes for field testing arrive later this year. The week-long demonstrations began in March, when Niagara Mohawk Power Corporation hosted the residential unit's first display—at the Buffalo, New York, Home and Garden Show.

Because the early prototypes operate at a higher microwave frequency than will production models, their operation must be supervised to ensure that certain foreign metallic objects—objects that could pose a scorching hazard—are not placed in the units. (These include bobby pins, although zippers are okay.) The utility demonstrations are being supervised by Thermo Energy Corporation of Palo Alto, which along with JG Microwave of Twain Harte, California, has been developing the microwave dryer for EPRI since 1990.

In addition to Niagara Mohawk Power, the utilities scheduled to host demonstrations of the residential dryer this spring are Buckeye Power, Duke Power Company, Northern States Power Company, TU Electric, and Wisconsin Electric Power Company. Meanwhile, a similar-sized prototype commercial model will be demonstrated at Alabama Power Company, Hawaiian Electric Company, New England Power Service Company, and Oklahoma Gas and Electric Company. Initially, both residential and commercial models are being designed for a capacity of 7–12 pounds, but researchers say a larger, 110-pound-capacity commercial unit is feasible.

In the third quarter of this year, researchers plan to deliver to each participating utility a refined residential or commercial prototype (depending on the utility's preference in the initial demonstration) for use in various internal, customer, and demonstration settings. These units will be

Niagara Mohawk's display at the Buffalo Home and Garden Show

manufactured by Thermo Energy and Astex/Gerling Laboratories of Modesto, California. They will feature a lower operating microwave frequency, which is expected to eliminate most metal-object hazards, and a safety sensor that will shut off microwave power at the earliest indication of fabric overheating.

After six months of use in the field, the dryers will be recalled to the manufacturer for close examination and evaluation. A second six-month round of field testing is scheduled to follow. A decision by either of the major manufacturers to pursue commercial production of microwave dryers would involve a significant financial commitment and require some time for manufacturing development and tooling.

Microwave dryers are expected to be able to dry clothes as much as 65% faster than conventional dryers and at cooler temperatures (as low as 110°F) because their energy is directed specifically to evaporating water molecules rather than to heating the fabric, in fundamental contrast to today's dryers. Microwave dryers are the most energy-efficient when waste heat from the magnetron generators is used to heat the air blown through the clothes tumbler; the fastest drying speed is obtained when microwave power is supplemented by magnetron waste heat and resistance-heated air.

The residential prototype is equipped with one 2.5-kW magnetron—roughly equivalent to the power of three average microwave ovens—while the commercial prototype features three times that power to achieve faster drying. Models designed for home use are expected to dry clothes about 10–15% faster than conventional dryers. "The residential units are limited by the current-carrying capacity of the typical 220-volt, 30-ampere outlet," says Richard Smith, president of Thermo Energy. "Commercial units can draw more power and thus use more magnetrons. But we expect that the residential unit should come close to keeping up with a conventional clothes-washing machine."

Among the parameters that will be closely evaluated in the field tests are those relating to energy efficiency. EPRI researchers plan to perform standardized Department of Energy efficiency tests on the units before field testing and to compare their operating efficiencies with those measured in the laboratory. They will also assess the effects of microwave drying on various fabrics.

■ *For more information, contact John Kesselring, (415) 855-2902.*

EPRI Helps PEPCO Clear the Air Over Washington, D.C.

Air quality in the nation's capital will benefit from reduced emissions of nitrogen oxides from fossil power plants in the years ahead, thanks to the use of EPRI-developed control strategies and combustion optimization techniques. These approaches will enable Potomac Electric Power Company to cut NO_x while maintaining plant performance—without the installation of costly new low-NO_x burners.

PEPCO recently estimated that, by using EPRI techniques and computer tools to optimize plant operating conditions and modify control strategies, it could save over $36 million at its five-unit, 480-MW Potomac River station, compared with the cost of installing low-NO_x burners to achieve a target emission rate for compliance with provisions of the 1990 Clean Air Act Amendments (CAAA). The utility is also investigating applications at other generating plants that serve the capital. The methods are applicable to all corner-fired pulverized-coal boilers—with or without new burners—that operate near the regulatory limits for NO_x.

PEPCO's Potomac River station, which is within sight of the Washington Monument and the U.S. Capitol and is situated in an ozone nonattainment area classified as serious, is a coal-fired station covered under Phase 2 of the CAAA acid rain (Title IV) provisions. The 1950s-era plant is dispatched daily, operating at a high load factor during the day and at low load at night. Anticipating the NO_x reduction requirements of both the ozone and acid rain sections of the CAAA, PEPCO and EPRI have been evaluating combustion optimization as a way to improve the plant's thermal performance while also reducing NO_x.

In tests on Unit 4 at the station, engineers from PEPCO and Lehigh University used techniques and computer tools developed in previous EPRI research that identified the key parameters affecting NO_x and heat rate. EPRI's HEATRT code was used to analyze the effects of various plant operating conditions, while the EPRI-developed Plant Monitoring Workstation was used to continuously monitor and record operating performance and conditions.

Test results indicated that the economizer oxygen level was the most significant factor affecting the unit's NO_x emissions level, followed by air damper settings and burner tilt position. Fuel bias and primary air modulation also affected the NO_x level at reduced load. Researchers found that careful control of these parameters kept NO_x emissions below the target of 63% of the unit's baseline emissions level.

These results were validated by reprogramming the plant's distributed control system with the new strategy and monitoring emissions and performance under normal dispatching. In automated operation, the unit successfully maintained thermal performance and NO_x emissions at desired levels. PEPCO intends to use this method for NO_x control at all five Potomac River units (the basis for the estimated $36 million in savings) and is investigating its use at two additional plants, including one that will have low-NO_x burners.

■ *For more information, contact Ellen Petrill, (415) 855-8939.*

Exploratory Research

Stability and Nonlinear Dynamics in Power Systems

by Martin Wildberger, Exploratory & Applied Research

In recent years the expectation of dramatic increases in the interconnection and complexity of power systems has raised concerns about the performance, security, and control of transmission and distribution networks. These increases are expected to result primarily from two developments: new legal requirements allowing greatly expanded wheeling of power over existing networks, and the widespread application of power-electronics-based active switching and control devices to raise the real power capacity of existing lines via local control of voltage, impedance, or phase angle.

As a result of these trends, power systems are already becoming increasingly stressed. And unexpected behavior has been observed in many networks under unusual stress—behavior suggesting that some important system dynamics are not yet well understood and hence are not accounted for in simulations conducted for control and security purposes. Enhanced fundamental knowledge about system stability and nonlinear dynamics may be necessary in order to control existing and future power systems reliably and continuously under all contingencies. In addition to ensuring power network security under normal and exceptional stress, such improved understanding could yield substantial economic benefits by allowing secure operation closer to performance margins than is currently considered safe.

Power system simulation and nonlinear dynamics

Modern interconnected power networks can be described as stressed, highly nonlinear, noncontinuous systems. Systems of this type are extremely difficult to accurately model, either mathematically or conceptually. Thus current power system simulations generally aim to model the slow, quasi-continuous dynamics most significant to system dispatchers, such as excessive voltage and apparent-power variation with respect to changing demand. The details of transient behavior, with which most computational complexity is associated, are for the most part neglected.

Typical network simulations are considerably simplified (although they still incorporate hundreds of complex equations). In addition, even the most comprehensive models include fundamental approximations to account for anticipated behavioral nonlinearity or noncontinuity and depend on critical assumptions about performance because we lack a complete understanding of the physical behavior of complex power systems. For example, to facilitate computation for conventional simulations, parameters like load values are held constant, even though these parameters are known to vary slightly. And the modeling of systems that incorporate active control devices requires the use of assumptions because complete descriptions of device behavior are not yet available.

Since all models do not use the same approximations and assumptions, their predictions of system behavior may differ strikingly, especially for conditions of stress. Utility experts thus find it difficult to assess the validity of a given model's results. Nonetheless, as long as predictions indicate that control measures will maintain generation-load imbalances within a normal operating range, dispatchers assume that the system will remain stable—and they are almost always correct in doing so.

ABSTRACT *Power systems are characterized by nonlinear dynamics, and unusual and unexpected behavior has been observed in both simple and complex networks. System behavior is expected to become increasingly complicated because of such factors as greater interconnection, the implementation of high-speed electronic power control devices, and wheeling requirements. Because other nonlinear systems are known to exhibit chaotic behavior, exploratory research is being conducted to determine if the potential for chaos exists in power networks and, if so, how to avoid or control such behavior. By increasing our fundamental understanding of power system dynamics, these investigations could lead to substantial economic benefits: they could reduce the potential for catastrophic failure as well as allow secure network operation closer to performance margins.*

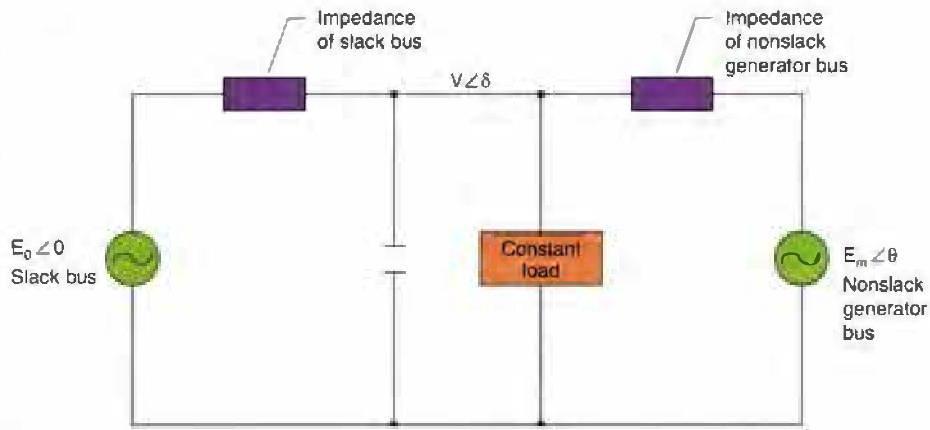
However, recent studies of historical voltage collapse events suggest that traditional load simulations—such as those assuming constant load angle, constant impedance, and constant current—may not capture important voltage dynamics. For example, a voltage collapse may be initiated by the oscillatory behavior of generator exciters, but models that consider only the slow dynamics of the system ignore exciter dynamics and other transient behaviors. As a result, unsteady system states may be incorrectly assessed as stable, with continued operation possibly leading to local or systemwide failure.

Chaos theory, the study of nonlinear dynamics, may provide new approaches for understanding the transient behavior of complex power systems and for ensuring network stability. (Chaos theory and its potential utility applications were discussed in the *EPRI Journal*, June 1992.) Mathematical research during the past 20 years indicates that any system involving feedback can exhibit chaos. While chaotic behavior may be desirable in some processes—for example, in fuel-air mixing—chaos in transmission and distribution networks could lead to problems.

In a recent exploratory study, EPRI-sponsored researchers at the University of California at Berkeley and Cornell University concluded that chaos is present in simple power system models over a range of loading conditions. Their results suggest that events such as voltage collapse, low-frequency electromechanical oscillations, and transient stability may be linked to chaotic behavior. For example, for the simple three-bus ac power system shown in Figure 1, the researchers established a fundamental relationship between voltage collapse and chaos-related bifurcations in voltage–reactive power solutions.

EPRI is currently supporting a variety of exploratory research efforts aimed at increasing our understanding of chaos and transient stability in power systems. In two fundamental studies, researchers at UC Berkeley and the University of Illinois at Urbana-Champaign are examining in detail certain unusual, possibly chaotic behaviors observed in small power systems and are developing tools for evaluating system stability under parametric or structural variations.

Figure 1 Researchers have identified chaotic behavior in simple ac power system models, including this three-bus model.



Characterizing bifurcations and analyzing instability

The UC Berkeley project (RP8050-9) is a continuation of earlier EPRI-funded work on the existence and nature of chaos in model power systems. The current efforts focus on improving the characterization of bifurcations in simple and complex power systems. Bifurcations, which represent qualitative transformations in a system's operational behavior (changes from stable to unstable states, for example, or the onset of multiple allowable solutions), can lead to chaos. Because fundamental power flow equations have multiple solutions (swing dynamics), bifurcations in power system behavior are always possible.

In recent analyses, the three-bus model shown in Figure 1 was enhanced to include generator dynamics, revealing several additional bifurcations, some of which lead to chaotic oscillation through period-doubling cascades (Figure 2). For these cases, an infinite number of power flow solutions occur in response to only a small change in reactive load, causing rapid fluctuations in voltage and load angle that could produce power flow oscillations exceeding the thermal limits of transmission lines and lead to system collapse.

Simulations focusing on these dynamic-generator-case bifurcations also indicate that voltage collapse may take place before the reactive power demand is increased to the system's steady-state operating limit—the point at which the static-case saddle-node bifurcation occurs. Thus the model system, and probably actual power systems as well, may be less stable under fluctuating real-world conditions than under the steady-state cases assumed in conventional stability calculations.

University of Illinois scientists are working to develop a general theory of structural stability, since power system structural stability limits are not well understood (RP8010-21). The goal is to provide dispatchers with a better understanding of the limits of all significant structural parameters—such as load angle, current, impedance, and reactive power demand—so that power systems can be operated to maximize cost-effectiveness without initiating harmful chaotic behavior.

Structural stability is important for power system security because key parameters are known to fluctuate slightly. For a system to be assessed as structurally stable, its behavior must return to its previous steady state if perturbed. For example, a power network is considered structurally stable if slight changes in current or load angle do not appreciably affect the interactions between voltage and other system variables. (This differs from the more common notion of Lyapunov stability, which assesses stability on the basis of the initial values of system variables.) Structural stability defines the parameter ranges within which system behavior is qualitatively similar; multiple ranges may exist for a given parameter. Little work has been done in this area for nonlinear models of power systems.

Research has revealed that for systems characterized by more than two parameters, no complete description of structural stability is possible. But parametric limits of structural stability can be related conceptually and mathematically to bifurcations. Both indicate qualitative changes in system behavior and can be seen in phase portraits of a system. Thus bifurcation analysis of system behavior can partially characterize structural stability ranges.

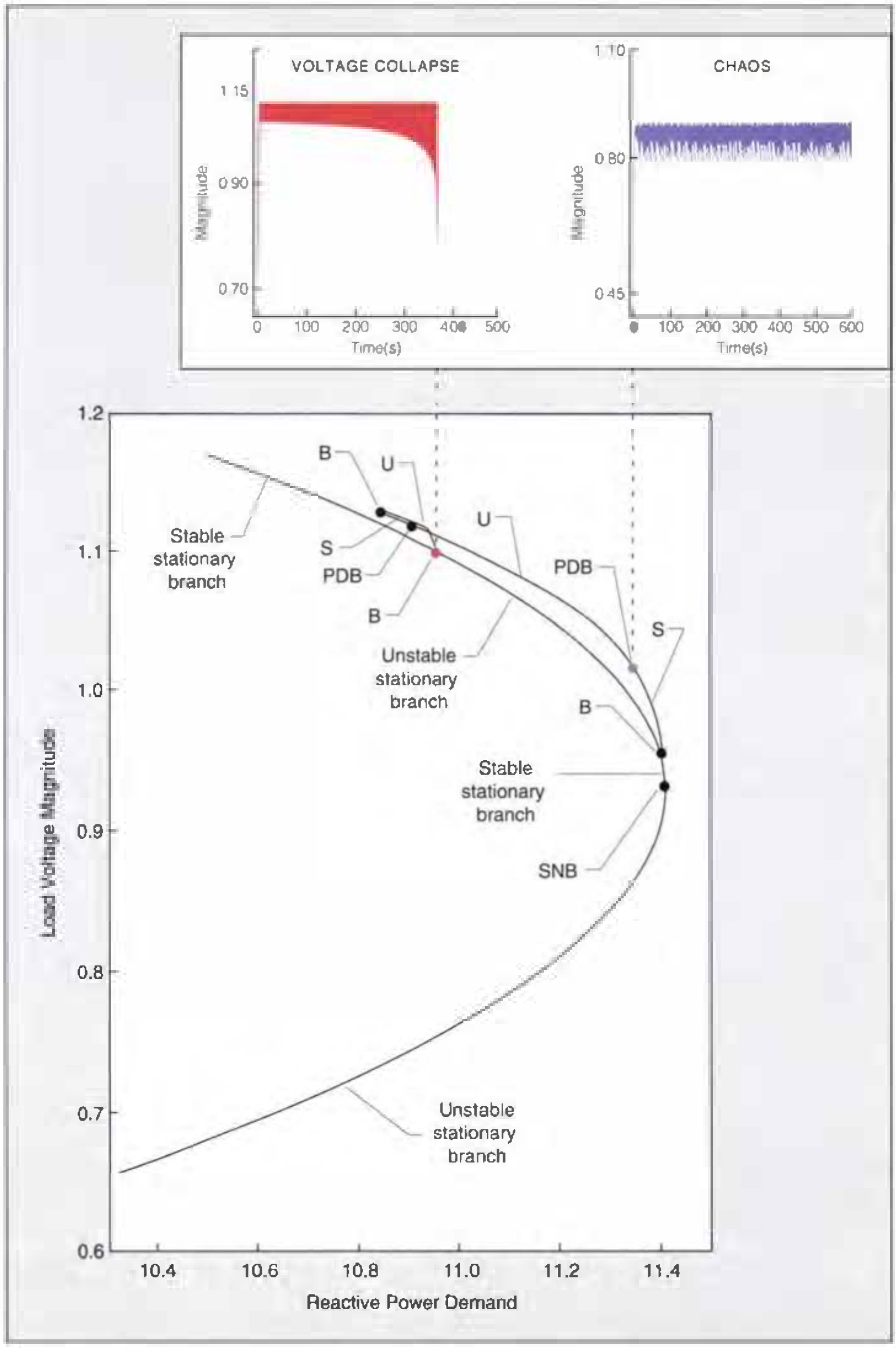


Figure 2 Bifurcations indicate qualitative changes in system behavior that can sometimes lead to chaos. This bifurcation diagram shows the branching of steady-state solutions for the three-bus model power system with transient generator dynamics; system behavior settles on the stable segments. When perturbed, as by increased reactive power demand, the system state may be driven through a chaos-causing bifurcation; the smaller graphs show the behaviors associated with two typical bifurcations. (The abbreviations are as follows: *S*, stable solution branch; *U*, unstable solution branch; *PDB*, period-doubling bifurcation; *SNB*, saddle-node bifurcation associated with voltage collapse in conventional models; *B*, other bifurcations induced by generator dynamics.)

Like the UC Berkeley researchers, the Illinois scientists have observed that if control actions are taken into account, the critical values of parameters that influence voltage collapse may be lower than those predicted by static criteria. They postulate that the range over which a dynamic system is structurally stable is always smaller than the range for the same system considered under static conditions only. Thus parameter margins identified by conventional, static-case power system models to ensure safe system behavior may be overly permissive for dynamic, real-world networks.

The results of both the Berkeley and Illinois investigations suggest that knowledge of dynamic system stability limits is key for reliable control of modern power systems. These margins must be satisfactory at all system buses for the varying load demands typical over a 24-hour period. To identify the margins, an enhanced understanding of active power networks is required. Particularly important are physical and mathematical descriptions of the behavior of active control devices that fully account for their fast-switching dynamics.

The development of more-complete power system simulations will also facilitate efforts to determine if the various chaotic behaviors observed in simplified nonlinear models occur near the ordinary operating conditions of real networks or only under extreme conditions that are of little practical concern. Of related interest is whether the large number of interlocking subsystems that compose actual networks will allow incipient chaotic fluctuation to develop into large-scale excursions or whether independent safety cutoffs will shut down critical subsystems before the onset of systemwide chaotic behavior.

Related investigations

EPRI is also supporting other exploratory investigations into nonlinear behavior in power and control systems.

Researchers at Cornell University are continuing to explore the existence of chaos in power systems (RP8050-6). Their attention is currently focused on more-complicated transitions to chaos than the period-doubling bifurcation route initially discovered in the Cornell collaboration with UC Berkeley. The researchers hope to document the load states leading to various complex behaviors and determine whether those conditions occur in actual power systems.

Scientists at the University of Maryland are exploring the nonlinear control of power system models that exhibit bifurcation-induced instability, such as voltage collapse (RP8050-5). Their efforts are aimed at extending the concept of participation factors to include nonlinear systems and demonstrating that feedback of measured signals could be used to significantly increase the margin of stability of power networks operating near a point of bifurcation.

Researchers at Iowa State University are investigating the interarea-mode behavior of interconnected power networks under stress, a type of behavior in which generators geographically remote from a disturbance are affected by it (RP8050-8). Several systems in the North American interconnection have exhibited this behavior when subjected to large local instability. The researchers aim to develop a basic understanding of the phenomenon and evaluate the effects of various controls on dynamic system behavior.

And at the University of Wisconsin two research teams are working to understand, model, and ultimately avoid bifurcations and harmonic instabilities in power systems, in particular those related to the use of active control devices (RP8050-3, -4). As part of this effort, the scientists are characterizing the behavior and interactions of general fast-switching circuits, such as thyristor-controlled reactors/capacitors in power systems.

Utility Planning

Area- and Time-Specific Marginal Capacity Costs

by Grayson Heffner, Customer Systems

Past research on marginal costs for electric utilities has focused primarily on generation systems and has shown that the costs of producing electricity vary by time of use. As local transmission and distribution costs become larger and larger percentages of utilities' construction budgets, however, attention is turning to these expenditures, and several recent studies demonstrate significant variations across areas and over time in the cost of providing T&D capacity. This situation—combined with increased competition, the ever growing need to control rates, and the departure from rate-of-return regulation—has prompted many utilities to begin focusing on previously overlooked local transmission and distribution costs.

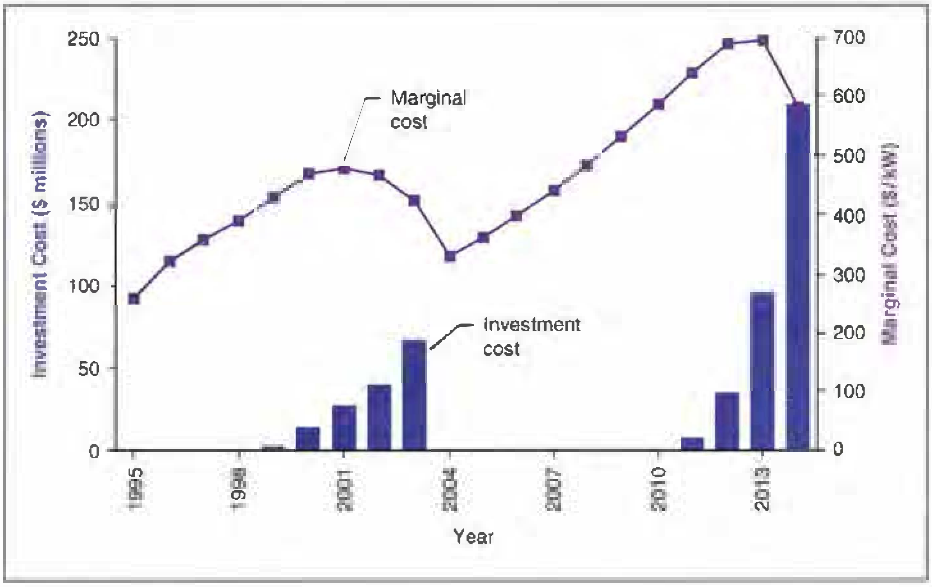
EPRI is cofunding many studies to help utilities quantify their local T&D marginal capacity costs. The studies are estimating the marginal costs in each particular planning area by year and are allocating these costs to hours within each year. Because these costs vary by area and time, they are called area- and time-specific marginal capacity costs (ATSMC). As the EPRI studies show, the uses of ATSMC data are wide and varied, ranging from resource planning to pricing and marketing. EPRI is developing a costing model that will enable utilities to calculate ATSMC either at highly disaggregated levels or at less-detailed, screening levels.

ABSTRACT *Estimates of local-area transmission and distribution marginal capacity costs are playing an increasingly important role in electric utilities' pricing, resource planning, and marketing decisions. EPRI is sponsoring several major studies to identify and evaluate methods of determining these T&D costs, which vary by time and location, and is developing software to help utilities estimate the costs for their planning areas. The method used in the software allows a utility to examine T&D investments area by area within its service territory and to see which hours of the year are most costly to serve.*

ATSMC method

The method used to calculate ATSMC is the one adopted by the California Public Utilities Commission for use by Pacific Gas and Electric Company in its 1993 general rate case. Described in detail in EPRI report TR-100487—*Targeting Demand-Side Management (DSM) for Transmission and Distribution Benefits*—the ATSMC method is also re-

Figure 1 A typical local transmission expansion plan. Planned investments (bars) occur in discrete blocks of unequal size, and changes in the marginal cost of transmission capacity (curve) from year to year reflect the varying value of deferring expansion. The marginal cost is usually high before a large capacity addition but declines significantly after the addition, reflecting the new excess capacity.



ferred to as the deferral, or present worth, method. It enables utility planners to estimate the value of deferring a local expansion plan for a specified period of time. The value of a one-year deferral, for example, equals the difference between the present value of the expansion plan and the present value of the expansion plan deferred for one year, adjusted for inflation and technical progress. Dividing the deferral value by the load reduction needed to obtain the one-year deferral yields the marginal capacity cost for the area. Next the capacity cost is allocated among the hours of the year, according to the area's peak load pattern.

Figure 1, which shows a typical local transmission expansion plan, illustrates the first step of the ATSMC process. The bars represent planned investments, while the curve shows the marginal cost of transmission capacity in dollars per kilowatt for each year of the plan. The marginal capacity cost reflects the varying value, over time, of deferring expansion. For example, in the years before the planned investments, the marginal cost is relatively high. After the investments are made, it declines.

Once a utility has calculated the marginal capacity cost from year to year for each of its local T&D planning areas, the second step is to identify which peaking hours in each area are necessitating the expansion investments. The marginal capacity cost for a given year can then be allocated to each of these local peak hours to develop estimates of the capacity cost by hour. Figure 2 is a three-dimensional graph of capacity costs per kilowatthour for a single year in one T&D planning area. Presented in this disaggregated form, the data can be easily used for a variety of utility planning, ratemaking, and marketing functions.

Regardless of the size of a utility's service territory, T&D marginal costs vary from area to area and are driven by load growth and the timing of capital investments to meet that growth. For a midwestern utility studied, the planning-area costs vary from less than $200/kW to nearly $1200/kW. Because the ATSMC method calculates the value of deferring real, area-specific expansion plans, it helps utilities identify real savings that can be achieved through load reduction.

There are several key differences between the ATSMC method and earlier marginal-cost methods:

□ In the ATSMC method, T&D expenditures in a planning area are assumed to be independent of expenditures in any other area. Adding capacity in one area, for example, does not change the load-carrying capability in another area. Nor does a load change in one area affect the T&D investment requirements in another area.

□ In the ATSMC method, local T&D investments are considered to be "lumpy"—that is, to occur in discrete blocks of unequal size. The T&D marginal capacity cost should be high before a large capacity addition and should decline significantly right after the addition takes place, reflecting the new excess capacity.

□ Traditional marginal-cost methods average marginal capacity costs across local areas and over time, suggesting that these costs do not vary substantially by time-of-use (TOU) period and are relatively flat over time. As a result, traditional methods do not recognize that certain hours of the year are much more costly to serve than others. In contrast, the ATSMC method shows that costs vary greatly according to the hour and the time of year.

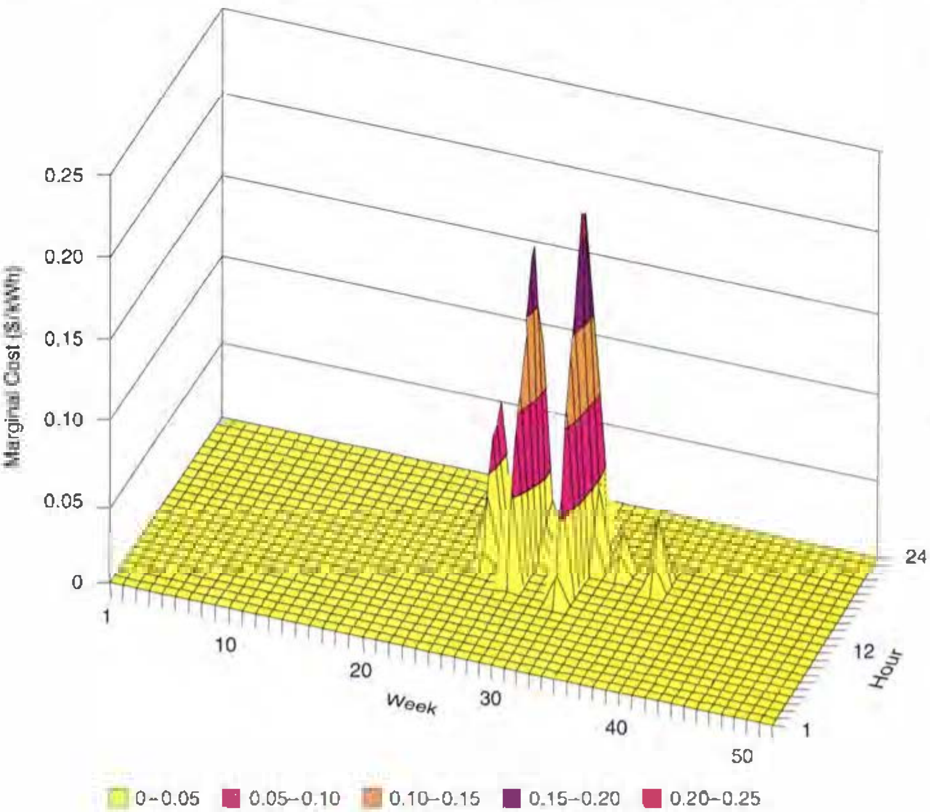
□ Traditional marginal-cost-pricing methods tend to show more-uniform marginal costs and rates by TOU period. For example, using traditional methods, one East Coast utility calculated differences in the range of $0.07/kWh between the costs of serving summer peak and off-peak periods. Using the ATSMC method, the utility found that the costs ranged from over $3.50/kWh in the highest-cost hours of August to well below $0.07/kWh for the majority of hours in the rest of the year.

Uses of ATSMC data

By far the most common use of the ATSMC method has been in T&D resource planning. Utilities are using the new method to screen existing resource options, target options for high-cost areas, and design options to better match the needs of local areas. The options include DSM, distributed generation and storage (DG&S) devices, and alternative T&D designs.

The value of using the ATSMC method to assess alternatives is illustrated in the following example. Let's say a utility has just increased its capacity in an inner-city area. Because of this sufficient capacity, the T&D expansion plan for the area does not call for any capacity upgrades. The utility would

Figure 2 Marginal capacity costs per kilowatthour in one T&D planning area for a year. The peak period encompasses the year's 100 highest hourly loads. By enabling utilities to break down capacity costs by hour of the year, the ASTMC method provides valuable data for T&D resource planning.



therefore save little, if any, capacity-related costs in the area by reducing air conditioning demand through a load control program. In contrast, such a program could be highly cost-effective in a suburban area that is characterized by large air conditioning loads during the area peak and, as a result, is scheduled for a T&D expansion project in the near future.

This example shows how targeting DSM and DG&S programs for high-cost areas can significantly increase the programs' cost-effectiveness. The T&D marginal cost for an area, however, is only part of the cost-effectiveness equation. The other part is a program's ability to match the peak load pattern in the area. For example, an air conditioning load control program would be of little value in a winter-peaking area. The ATSMC method, by disaggregating costs down to the hourly level, allows utilities to compare even subtle differences in value—for example, between a direct load control program that lasts for 2 hours and one that lasts for 4 hours.

In addition, the ATSMC method can be used by both transmission planners and distribution planners to evaluate the profitability of investments to serve new loads. For example, suppose a distribution planner is considering a $20 million investment in new facilities to serve a fast-growing area that will raise the revenue requirement by $40 million. Is this a prudent investment? The investment is prudent if the incremental profit from the increase in sales is greater than the incremental investment. If the investment is not profitable, the ATSMC framework can be used to analyze modifications. By computing the present value of deferring T&D upgrades for a specific length of time, the method can help identify changes that reduce the cost of the investment plan. The resulting integrated local T&D expansion plan can specify the least-cost mix of DSM programs and the optimal timing of program implementation.

Finally, the ATSMC method can help utilities cope with increased competition from cogeneration, self-generation, and neighboring utilities in that the method can be used to calculate whether incremental sales are likely to increase earnings, reduce rates, or both. This issue is especially crucial after the addition of a large baseload unit whose construction costs must be recovered to protect the utility's financial viability.

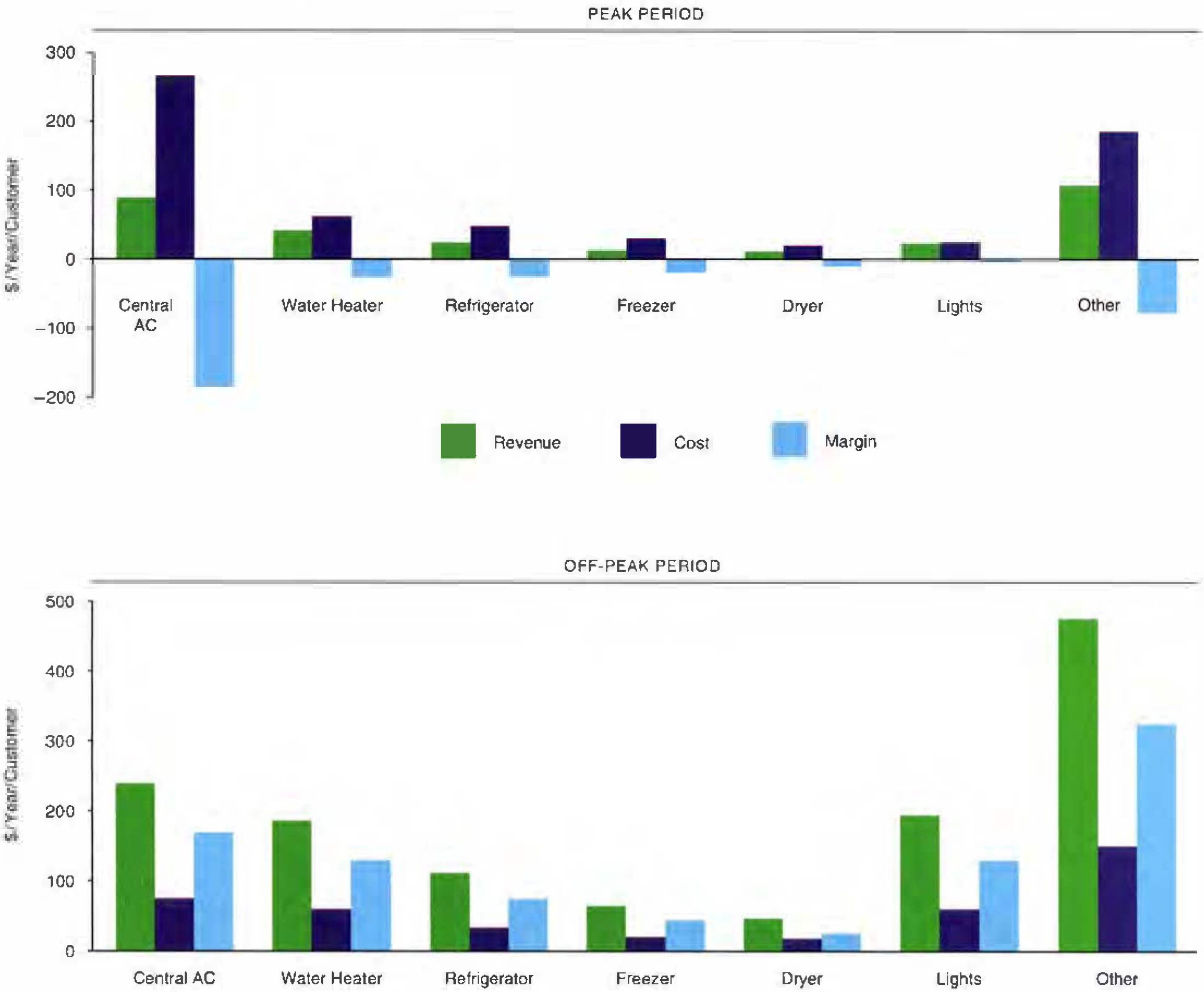
For example, after completing nuclear units, two West Coast utilities offered rate incentives to stimulate incremental off-peak sales. The ATSMC method had allowed the utilities to estimate how increased off-peak sales could contribute to margin (which is the difference between the revenues generated by a load and the costs of serving the load). The method had shown that margin could be increased over time by decreasing the costs of providing service. Such a decrease is achieved by reducing the load during the hours with the highest production costs. Though offering off-peak rate incentives does decrease overall revenues, the loss in revenues is more than offset by the decreased costs of service, even after taking into account the costs of the rate incentive program.

By decomposing margin estimates into peak and off-peak shares, the ATSMC method can demonstrate which end uses contribute to margin during the off-peak period. Figure 3, for example, shows margin by TOU period for a number of residential end uses for a utility in the Southwest. The data indicate that, for every residential air conditioner added in a particular area in its system, the utility loses nearly $185 in margin during the peak period of a year. Because the off-peak use of residential air conditioning is not high, the utility recovers only $166 in margin during the off-peak period. Belying the belief that additional sales always increase earnings, this utility loses margin on sales for some end uses that have a disproportionate responsibility for local T&D investments.

Flexible planning tool

Contrary to popular opinion, rapid load growth and major capital investments do not automatically indicate high-marginal-cost areas. Rather, high-marginal-cost areas are typically those with average invest-

Figure 3 Estimates of margin (the difference between generated revenues and service costs) by end use and time of use for an average residence in one area served by a southwestern utility. (The residence uses 1500–3000 kWh of electricity a month.) The data show that, contrary to popular belief, additional sales do not always increase earnings; for every residential air conditioner added in this area, for example, the utility loses nearly $20 a year in margin.



ment costs but slow load growth. In such areas, a modest amount of load reduction can provide a lot of deferred capacity at great value to a utility.

The ATSMC method is indispensable to any utility attempting to use DSM and DG&S in its local planning areas to reduce its T&D investments. Following current utility planning practices, the method mirrors how planning engineers think about T&D upgrades and is consistent with the utility industry's T&D replacement policy. The method considers the timing of T&D investments, includes only investments that are potentially deferrable, and is extremely useful in calculating avoided costs that would result from the deferral of investments projected for each planning area. It offers a solid basis for estimating the cost-effectiveness of both DSM programs and DG&S devices by local planning area.

New Contracts

Project	Funding/ Duration	Contractor/EPRI Project Manager
Customer Systems		
Electric Hybrid Bus Project (RP3025-7)	$300,000 24 months	Metropolitan Transportation Authority/*P. Symons*
Application of Superconducting Storage Device Technology at Selected Carolina Power & Light Customers (RP3597-1)	$1,400,500 48 months	Electrotek Concepts/ *M. Samotyj*
Gas Pipeline Compressor Study: Feedstock for Microwave Reactors (RP3633-2)	$83,200 5 months	Canyon Road Corp./ *A. Amarnath*
Field Test of Microwave Clothes Dryer (RP3666-1)	$633,100 17 months	Thermo Energy Corp./ *J. Kesselring*
Short-Term Forecasting With the Hourly Electric Load Model, or HELM (RP3741-1)	$80,000 7 months	ICF Resources/ *P. Meagher*
Electric Adjustable-Speed Drives and Controls for Specific End-Use Applications (RP3812-1)	$395,000 39 months	CRS Sirrine Engineers/ *M. Samotyj*
Area-Specific Targeting of Demand-Side Management Programs and Distributed Generation Technologies (RP3817-4)	$220,000 18 months	Energy and Environmental Economics/*G. Heffner*
Application of Quality Function Deployment to Marketing Program Design at Kansas City Power & Light (RP3825-6)	$135,000 6 months	Putnam, Hayes, & Bartlett/ *T. Henneberger*
Metals, Glass, and Minerals Production (RP3827-1)	$95,000 35 months	Carnegie Mellon University/ *E. Eckhart*
Computer-Aided Lighting Design (RP3863-4)	$750,300 24 months	Hart, McMurphy & Parks/ *K. Johnson*
Machinery, Transportation, and Equipment Fabrication (RP3878-1)	$357,000 36 months	Battelle Memorial Institute/ *E. Eckhart*
Industrial Efficiency Optimization Using Pinch Analysis (RP3879-1)	$87,000 14 months	TENSA Services/ *A. Amarnath*
Environment		
Zimmer Magnesium Hydroxide Slipstream Recovery Project (RP1031-22)	$200,000 36 months	Cincinnati Gas & Electric Co./*R. Moser*
Cellular Responses to Low-Frequency Electromagnetic Fields: Resonant Effects on Calcium Binding to Proteins (RP2965-29)	$126,900 18 months	University of Utah/ *C. Rafferty*
Effect of 60-Hz Magnetic Field on Copromotion of Chemically Induced Carcinogenesis in Skin of Mice (RP2965-30)	$1,483,100 35 months	Battelle Pacific Northwest Laboratories/*R. Kavet*
Effect of 60-Hz Magnetic Field on Copromotion of Chemically Induced Carcinogenesis in Skin of Mice (RP3349-7)	$272,400 24 months	University of Texas/ *R. Kavet*
Advanced Low-NO_x Digital Control System (RP3545-1)	$700,000 54 months	Southern Company Services/*R. Squires*
Analytical Methods Qualification: Graphite Furnace Atomic Absorption Spectroscopy for Cadmium, Arsenic, and Chromium (RP3569-1)	$391,400 29 months	TRW/*B. Nott*
PISCES Field Chemical Emissions Monitoring at Arapahoe Clean Coal Technology Project (RP9018-1)	$467,000 13 months	Public Service Co. of Colorado/*B. Toole-O'Neil*
Dallas–Ft. Worth Winter Haze Project (RP9019-1)	$1,600,000 36 months	ENSR Consulting and Engineering/*P. Halpern*
Development of Small-Statured, Stress-Tolerant Trees for Landscape Use (RP9022-1)	$380,000 51 months	University of Minnesota/ *L. Pitelka*
Environmental Distribution of Organic Substances at Utility Sites (RP9024-3)	$495,600 12 months	Atlantic Environmental Services/*I. Murarka*
PISCES Air Toxics Testing at a Subbituminous-Coal-Fired Plant (RP9028-12)	$255,500 10 months	Radian Corp./ *P. Chu*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Determination of Leachate Characteristics at a Power Plant Dry-Ash Landfill Site (RP9032-2)	$145,000 15 months	Battelle, Pacific Northwest Laboratories/*J. Goodrich-Mahoney*
Improved Performance of Postcombustion NO_x Systems via Temperature and Ammonia Measurement and Control (RP9037-3)	$105,400 11 months	PSI Environmental Instruments Corp./*J. Stallings*
Development of Therapeutic Approaches for Electrical Injuries (RP9038-3)	$1,280,000 36 months	University of Chicago/ *R. Wyzga*
New Strategy for Coal Tar Remediation (RP9039-3)	$189,700 25 months	U.S. Department of Energy/ *R. Wyzga*
Influence of Autoclaved Cellular Concrete Feedstocks on Physical and Environmental Properties (RP9040-1)	$80,000 13 months	University of Pittsburgh/ *D. Golden*
Evaluation of Coal-Switching Option for Cyclone-Fired Boiler (RP9043-5)	$408,400 26 months	Southern Research Institute/*R. Altman*
Evaluation of Electrodynamics Venturi for Fine-Particulate Control (RP9043-6)	$207,000 7 months	Southern Research Institute/*R. Altman*
Mist Elimination Field Studies (RP9044-3)	$627,000 48 months	Radian Corp./*R. Rhudy*
Demonstration of Coal Reburning for Cyclone Boiler NO_x Control (RP9045-15)	$700,000 15 months	Babcock & Wilcox Co./ *A. Facchiano*
Compensatory Mechanisms of Fish Populations: Key Species Program (RP9046-2)	$200,000 27 months	Martin Marietta Energy Systems/*J. Mattice*
Compensatory Mechanisms of Fish Populations: Key Species Program (RP9046-3)	$200,000 27 months	Sport Fishing Institute/ *J. Mattice*
Solidification Processing of Ashalloy Metal Matrix–Fly Ash Composites (RP9047-1)	$400,000 57 months	University of Wisconsin, Milwaukee/*D. Golden*
TRUE Case Study at Florida Power & Light (RP9051-2)	$99,500 5 months	ENSR Consulting and Engineering/*L. Levin*
Exploratory & Applied Research		
Intelligent Supervisory Control Through Discrete-Event Identification (RP8030-6)	$100,000 25 months	University of Notre Dame/ *J. Weiss*
Aerosol Transport and Deposition Mechanisms (RP8034-3)	$134,000 36 months	University of Notre Dame/ *R. Oehlberg*
Damage Modeling: Seam-Welded Piping (RP8046-1)	$79,900 11 months	University of Pennsylvania/ *R. Viswanathan*
Nonlinear Power System Behavior Using Normal Forms: Extension of Linear System Analysis via Higher-Order Correction (RP8050-8)	$171,600 29 months	Iowa State University/ *D. Sobajic*
Electrochemical Enzymatic Synthesis of Amino Acids (RP8060-3)	$224,000 25 months	Wesleyan University/ *R. Weaver*
Electroreductive Coupling Reactions (RP8060-5)	$173,000 22 months	University of California, Santa Barbara/*R. Weaver*
A Novel Moderate-Temperature Solid Oxide Fuel Cell (RP8062-3)	$103,000 13 months	Jet Propulsion Laboratory/ *R. Goldstein*
Structure and Chemistry of $CuInSe_2$ and Its Alloys for Solar Cell Technology (RP8063-3)	$157,600 36 months	University of Delaware/ *T. Peterson*
Generation		
Solid Oxide Fuel Cells With $BaCeO_3$ Electrolytes (RP1676-19)	$187,500 60 months	Georgia Tech Research Corp./*R. Goldstein*
Theoretical Calculations Relevant to the Staebler-Wronski Effect (RP2702-5)	$120,700 30 months	Iowa State University/ *T. Peterson*
Guidelines for Large-Screen Display Technology, Consolidated Edison Energy Control Center (RP3152-25)	$223,800 17 months	Mitre Corp./ *R. Fray*
Filter Element Failure Investigations and Dust-Sintering Studies (RP3161-12)	$103,200 12 months	British Coal Corp./ *R. Brown*

Project	Funding/ Duration	Contractor/EPRI Project Manager
Enhanced GENCAT Software (RP3220-38)	$79,900 7 months	Decision Focus/ *G. Lamb*
Diesel Generator NO_x Control Performance Enhancement (RP3486-1)	$520,600 65 months	Hawaiian Electric Co./ *H. Schreiber*
Combustion Viewing System Monitoring and Maintenance at Jersey Central Power & Light (RP3488-3)	$67,000 11 months	Joseph Technology Corp./ *W. Piulle*
Demonstration of Low-Tech Coal-Water Slurry at Pennsylvania Electric's Seward Station (RP3600-1)	$800,000 24 months	GPU Service Corp./ *D. O'Connor*
Development of Guidelines and Tools for Control System Retrofits at Meramec Station (RP3606-1)	$1,505,000 39 months	Union Electric Co./ *J. Weiss*
Intelligent Tutoring System (RP3606-2)	$295,000 23 months	Babcock & Wilcox Co./ *R. Fray*
Header Feedwater Heater Retrofit (RP3652-3)	$1,550,000 20 months	Union Electric Co./ *S. Pace*
Water Management Benefits of Hydro Plants (RP3713-1)	$289,000 12 months	Kearns & West/ *C. McGowin*
Microbial Composting Process for Manufactured-Town-Gas Wastes (RP3734-1)	$250,000 36 months	Environmental Biotechnologies/*S. Yunker*
Effects of Cycling Operation and Operating Limits on Fossil Plant Production Costs and Availability (RP3746-1)	$2,270,100 38 months	Aptech Engineering Services/*D. Broske*
Evaluation of Cascaded Advanced Turbine (CAT) Power Plant Options With the Tennessee Valley Authority (RP3816-1)	$630,000 27 months	Energy Storage & Power Consultants/*A. Cohn*
Application of EPRI R&D Products to the Kingston Control and Diagnostics Project, Phase 1 (RP3876-2)	$1,200,000 31 months	Tennessee Valley Authority/ *J. Weiss*
Advanced Aeroderivative Gas Turbines (RPCAGG/RPCAGT-2)	$464,400 4 months	General Electric Co./ *C. Dohner*
Collaborative Advanced Gas Turbine Project (RPCAGG/RPCAGT-4)	$80,200 27 months	Turbo Power and Marine Systems/*C. Dohner*
Advanced Energy Systems Projects (RPCAGG/RPCAGT-5)	$125,300 27 months	Energy Options/ *C. Dohner*

Integrated Energy Systems

Project	Funding/ Duration	Contractor/EPRI Project Manager
Multiarea Analysis in Resource and Strategic Planning (RP3605-3)	$65,000 11 months	Case Western Reserve University/*J. Bloom*
Estimating Damages From Climate Change (RP3676-6)	$675,100 21 months	Industrial Economics/ *T. Wilson*
Climate Change Valuation Research Design Support and Synthesis (RP3676-7)	$140,000 18 months	RCG/Hagler, Bailly/ *T. Wilson*
Nonuse Valuation Experiment (RP3676-8)	$50,000 5 months	Research Triangle Institute/*T. Wilson*
Analysis of Current Forecasts of U.S. Energy Supply and Demand (RP3680-1)	$198,800 14 months	Charles River Associates/*R. Hill*
Comprehensive Electrical Systems Planning (RP3838-1)	$298,500 26 months	University of Texas, Austin/*J. Bloom*
Strategic Asset Management Case Study (RP7678-2)	$118,000 5 months	Strategic Decisions Group/*L. Rubin*
Framework for Strategic Asset Management (RP7678-3)	$127,500 5 months	Strategic Decisions Group/*L. Rubin*

Nuclear Power

Project	Funding/ Duration	Contractor/EPRI Project Manager
Eddy-Current Characterization of Hydriding in Fuel Cladding (RP1250-28)	$137,700 13 months	Babcock & Wilcox Co./ *S. Yagnik*
New Hafnium Alloys (RP1628-10)	$88,600 16 months	Teledyne Wah Chang Albany/*B. Cheng*
Electromagnetic Interference/Radio-Frequency Interference Measurements at Perry Nuclear Power Plant (RP2409-28)	$77,900 3 months	National Technical Systems/*R. James*
Electromagnetic Interference/Radio-Frequency Interference Measurements at Peach Bottom Nuclear Power Plant (RP2409-29)	$69,000 2 months	National Technical Systems/*R. James*
Resin- and Sludge-Handling Study and Desk Reference Input (RP2414-63)	$89,500 23 months	Sargent & Lundy/ *C. Hornibrook*
Advanced LWR Program Technical and Licensing Support (RP3260-37)	$149,600 16 months	PoleStar Applied Technology/*S. Gray*
Air Oxidation of UO_2 Fuels (RP3290-8)	$87,000 22 months	Atomic Energy of Canada/ *R. Lambert*
Generic Framework for Probabilistic Safety Assessment Applications (RP3333-15)	$52,900 11 months	Science Applications International Corp./ *J. Sursock*
PWR Shutdown Risk Assessment and Management Guidelines (RP3342-2)	$381,700 19 months	Westinghouse Electric Corp./*P. Kalra*
Comparison of On-Line Corrosion Analyzers (RP3388-9)	$62,800 6 months	General Electric Co./ *P. Millett*
National Demonstration of Full Reactor Coolant System Chemical Decontamination (RP3396-1)	$13,180,000 59 months	Pacific Nuclear Fuel Services/*C. Wood*
Cable Diagnostics Matrix (RP3427-3)	$50,000 4 months	Altran Materials Engineering/*J. Carey*
Dynamic Safety System (RP3500-25)	$158,100 9 months	AEA Technology/ *C. Wilkinson*
Dynamic Safety System (RP3500-26)	$169,300 9 months	Ohio State University Research Foundation/ *C. Wilkinson*
Postirradiation Evaluation of BWR Fuel From Hope Creek (RP3609-1)	$586,000 40 months	General Electric Co./ *S. Yagnik*
Motor-Operated-Valve Actuator Lubrication Performance Program (RP3660-1)	$133,000 9 months	MPR Associates/ *L. Dorfman*
Analysis of Corrosion Products on Alloy 600 (RPS413-11)	$84,500 4 months	Rockwell International Corp./*A. McIlree*
Inhibition of Intergranular Attack/Stress Corrosion Cracking on Alloy 600 (RPS510-7)	$292,100 13 months	Commissariat à l'Energie Atomique/*P. Paine*
Development of Molar Ratio Control Guidelines (RPS520-11)	$185,400 23 months	Dominion Engineering/ *P. Millett*
Development of Molar Ratio Control Guidelines (RPS520-15)	$76,100 12 months	B&W Nuclear Technologies/ *P. Millett*

Power Delivery

Project	Funding/ Duration	Contractor/EPRI Project Manager
Microfracture Mechanisms in Glass-Polymer Insulator Materials (RP2472-13)	$80,000 17 months	Bonneville Power Administration/*J. Hall*
UCA/DAIS Demonstration (RP2949-21)	$379,500 26 months	Kansas City Power & Light Co./*W. Blair*
Analysis of Control Interactions on FACTS-Assisted Power Systems (RP3022-34)	$344,800 30 months	CEPEL/*A. Edris*
Functional Specifications for On-Line Dynamic Security Assessment (RP3103-5)	$314,500 12 months	Macro Corp./*G. Cauley*
Extremely Low Frequency Field Exposure Reduction Supply Curves (RP3335-12)	$88,900 12 months	Carnegie Mellon University/*R. Lordan*
Development of Control Center Application Program Interface Guidelines (RP3654-1)	$1,199,500 37 months	Macro Corp./*G. Cauley*
Advanced Distribution Power Line Communication Project (RP3674-9)	$1,288,000 47 months	Allegheny Power Service Corp./*R. Bernstein*
Exercising Load Management Options From the Energy Control Center: Software Documentation and System Demonstration (RP3708-4)	$120,000 5 months	Analytic Sciences Corp./ *R. Adapa*
Development and Integration of CRAFT in Distributed Energy Management System Environment (RP3708-5)	$92,700 12 months	Utility Information Systems Consulting Services/ *D. Sobajic*
Integration of CRAFT in Distributed Energy Management System Environment (RP3708-6)	$61,000 9 months	National Systems & Research Co./*D. Sobajic*
Inter-Control Center Communications Protocol: ERCOT Data Link (RP3830-4)	$1,961,100 26 months	Houston Lighting & Power Co./*A. Vojdani*
Dispersed-Energy-System Impacts on Distribution Systems (RP4524-1)	$269,700 11 months	Electrotek Concepts/ *A. Sundaram*

New Technical Reports

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CUSTOMER SYSTEMS

Modeled and Measured Infiltration, Phase II: A Detailed Case Study of Three Homes
TR-102511 Final Report (RP2034-40); $200
Contractor: Ecotope, Inc.
EPRI Project Manager: J. Kesselring

Residential Ventilation Control
TR-102767 Final Report (RP2034-44); $200
Contractor: Honeywell, Inc., Sensor and System Development Center
EPRI Project Manager: J. Kesselring

Comparative Global Warming Impacts of Electric Vapor-Compression and Direct-Fired Absorption Equipment
TR-103297 Final Report (RP3138-11); $200
Contractor: James M. Calm, P.E.
EPRI Project Manager: M. Blatt

Environmental Justification for Railroad Electrification
TR-103379 Final Report (RP3025); $200
Contractor: Bevilacqua-Knight, Inc
EPRI Project Manager: P. Symons

Proceedings: EPRI Urban Rail Issues Workshop
TR-103380 Proceedings (RP3025); $200
Contractor: Bevilacqua-Knight, Inc.
EPRI Project Manager: P. Symons

Travel and Electricity Demand Analysis of Potential U.S. High-Speed Rail and Maglev Corridors
TR-103444 Final Report (RP3025-3); $200
Contractors: Argonne National Laboratory; Bevilacqua-Knight, Inc.
EPRI Project Manager: P. Symons

Overcoming Barriers to the Diffusion of Efficient Technologies
TR-103527 Final Report (RP3249-1); $200
Contractor: Macro Consulting, Inc.
EPRI Project Manager: M. Evans

Testing and Evaluation of Line-Voltage Thermostats
TR-103805 Final Report (RP3512-5); $200
Contractor: Geomet Technologies, Inc.
EPRI Project Manager: J. Kesselring

ENVIRONMENT

Analysis of Markets for Coal Combustion By-Products Use in Agriculture and Land Reclamation
TR-102575 Final Report (RP3207-1); $200
Contractor: Environmental Management Services
EPRI Project Manager: J. Goodrich-Mahoney

Options for Handling Noncombustion Waste, Second Edition
TR-103010 Final Report (RP3006-2); $200
Contractors: Mittelhauser Corp.; Roy F. Weston, Inc.; Precor Corp.
EPRI Project Manager: M. McLearn

User's Guide for MANAGES™: Personal Computer Software for the Management and Evaluation of Groundwater Monitoring Data
TR-103153 Final Report (RP2485-23); $200
Contractor: Southern Company Services, Inc.
EPRI Project Manager: I. Murarka

Proceedings: Avian Interactions With Utility Structures (International Workshop)
TR-103268 Proceedings (RP3041); $200
EPRI Project Manager: J. Huckabee

Volume Estimation Methods for Contaminated Soils at Manufactured Gas Plant Sites
TR-103301 Interim Report (RP2879-12); $200
Contractors: Atlantic Environmental Services, Inc.; Meta Environmental, Inc.
EPRI Project Managers: I. Murarka, A. Quinn

Use of Halophytes to Remove Carbon From the Atmosphere: Results of a Demonstration Experiment
TR-103310 Final Report (RP8011-3); $200
Contractor: University of Arizona, Environmental Research Laboratory
EPRI Project Manager: L. Pitelka

Uptake and Translocation of Selected Polycyclic Aromatic Hydrocarbons by White Sweetclover Under Laboratory Conditions
TR-103313 Final Report (RP2879-10); $200
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: J. Goodrich-Mahoney

Electrokinetic Removal of Coal Tar Constituents From Contaminated Soils
TR-103320 Final Report (RP2879-21); $200
Contractor: Lehigh University
EPRI Project Manager: I. Murarka

The Fossil Fuel Combustion Waste Leaching Code (Including the GMIN Chemical Equilibrium Model and the HELP Water Balance Model), Vols. 1 and 2
TR-103343-V1, TR-103343-V2 (RP2485-8); $200 each volume
Contractor: Battelle Pacific Northwest Laboratories
EPRI Project Manager: I. Murarka

Residential Transient Magnetic Field Research
TR-103470 Interim Report (RP2966-7); $200
Contractor: Enertech Consultants
EPRI Project Managers: R. Kavet, S. Sussman

Chemical Attenuation Reactions of Selenium
TR-103535 Final Report (RP2485-3); $200
Contractor: Battelle Pacific Northwest Laboratories
EPRI Project Managers: D. McIntosh, I. Murarka

The Gypsum Industry and Flue Gas Desulfurization (FGD) Gypsum Utilization: A Utility Guide
TR-103652 Final Report (RP3571-1); $200
Contractors: New York State Electric & Gas Corp.; ORTECH
EPRI Project Manager: D. Golden

Dry Calcium Hydroxide Injection at 1000°F for SO_2 Control
TR-103666 Final Report (RP2533-7); $1500
Contractor: RC-Environmental Services & Technologies
EPRI Project Manager: B. Toole-O'Neil

EXPLORATORY & APPLIED RESEARCH

Corrosion Fatigue Boiler Tube Failures in Waterwalls and Economizers, Vol. 4: Summary Report and Guidelines for Corrosion Fatigue Evaluation
TR-100455 Final Report (RP1890-5); Vol. 4, $200
Contractor: Ontario Hydro
EPRI Project Manager: B. Dooley

Evaluation of Pressure-Sensing Concepts: A Technology Assessment
TR-102177 Final Report (RP8004-14); $200
Contractor: Oak Ridge National Laboratory
EPRI Project Manager: J. Weiss

Guidelines for the Control and Prevention of Fly Ash Erosion in Fossil-Fired Power Plants
TR-102432 Final Report (RP2711-2); $200
Contractor: ABB Combustion Engineering, Inc.
EPRI Project Manager: B. Dooley

Smart Temperature Sensor Research
TR-103043 Final Report (RP8004-4); $200
Contractor: University of Tennessee
EPRI Project Manager: J. Weiss

Preliminary Study of Inertial-Electrostatic Fusion (IEF) for Electric Utility Power Plants
TR-103394 Final Report (RP8012-16); $200
Contractor: Energy/Matter Conversion Corp.
EPRI Project Manager: R. Hirsch

Fiber-Optic Electric Field Micro Sensor
TR-103395 Final Report (RP8004-5); $200
Contractor: Brown University
EPRI Project Manager: J. Stein

Development of Oxygen and pH Sensors for Aqueous Systems
TR-103400 Final Report (RP9000-9); $200
Contractor: University of Notre Dame
EPRI Project Managers: B. Dooley, B. Syrett

Application of Neural Networks, Part 1 (To Determine the Operability of Check Valves) and Part 2 (To Improve the Operation of Nuclear Power Plants)
TR-103443-P1 and -P2 Final Report (RP8010-12); $200
Contractor: University of Tennessee
EPRI Project Manager: J. Naser

In Situ Measurement of Particulates by Acoustic Detection
TR-103627 Final Report (RP8004-10); $200
Contractor: Monitek Technologies, Inc.
EPRI Project Manager: B. Dooley

Structural Stability in Power Systems
TR-103870 Final Report (RP8010-21); $200
Contractor: University of Illinois, Urbana-Champaign
EPRI Project Manager: R. Adapa

GENERATION

Fluidized-Bed Combustion of Alternate Fuels
TR-100547 Final Report (RP2190-6); $200
Contractor: Combustion Systems, Inc.
EPRI Project Manager: C. McGowin

Coal Gasification Guidebook: Status, Applications, and Technologies
TR-102034 Final Report (RP2221-39); $200
Contractor: SFA Pacific, Inc.
EPRI Project Manager: N. Holt

Guidelines for the Selection and Application of Power Plant Control Valves, Revision 1
TR-102051-R1 Final Report (RP2922-3); $200
Contractor: ENCOR-America, Inc.
EPRI Project Manager: J. Weiss

Extreme Rainfall Probability
TR-102727 Final Report (RP2917-33); $100
Contractor: Yankee Atomic Electric Co.
EPRI Project Manager: D. Morris

Proceedings: Combustion Turbine Controls Upgrade Workshop
TR-102768 Proceedings (RP2101-78); $200
Contractor: Scofield Communications
EPRI Project Manager: G. Quentin

Display Specification for Fossil Power Plant Digital Control System Operator Interfaces
TR-102845 Final Report (RP2710-20); $200
Contractors: General Physics Corp., Science Applications International Corp.
EPRI Project Manager: R. Fray

Cycle Chemistry Corrosion and Deposition: Correction, Prevention, and Control
TR-103038 (RP2712-11); $200
Contractor: GPS Technologies, Inc.
EPRI Project Manager: B. Dooley

Wedge Tightness Detector for Turbogenerators
TR-103092 Final Report (RP2820-3); $200
Contractor: VinTek, Inc.
EPRI Project Manager: J. Stein

Engineering and Economic Evaluation of Ahlstrom Pyropower's Circulating Pressurized Fluidized-Bed Combustion Power Plant Design
TR-103206 Final Report (RP3167-1); $200
Contractor: Bechtel Group, Inc.
EPRI Project Manager: J. Wheeldon

Guide to the Data Applications Center (DAC): 1993 Summary
TR-103359 Final Report (RP2952-7); $200
Contractor: Strategic Power Systems, Inc.
EPRI Project Manager: R. Frischmuth

Life Assessment of Boiler Pressure Parts, Vol. 1: Executive Summary
TR-103377-V1 Final Report (RP2253-10); $10,000
Contractor: General Atomics
EPRI Project Manager: R. Viswanathan

Life Assessment of Boiler Pressure Parts, Vol. 2: Materials Properties
TR-103377-V2 Final Report (RP2253-10); $10,000
Contractor: General Atomics
EPRI Project Manager: R. Viswanathan

Life Assessment of Boiler Pressure Parts, Vol. 3: Heavy Section Crack Initiation and Propagation
TR-103377-V3 Final Report (RP2253-10); $10,000
Contractor: General Atomics
EPRI Project Manager: R. Viswanathan

Life Assessment of Boiler Pressure Parts, Vol. 5: European Replica Database Evaluation
TR-103377-V5 Final Report (RP2253-10); $200
Contractors: General Atomics; Failure Analysis Associates
EPRI Project Manager: R. Viswanathan

Life Assessment of Boiler Pressure Parts, Vol. 6: Guidelines for NDE of Heavy Section Components
TR-103377-V6 Final Report (RP2253-10); $10,000
Contractors: General Atomics; Babcock & Wilcox Co.
EPRI Project Manager: R. Viswanathan

Life Assessment of Boiler Pressure Parts, Vol. 7: Life Assessment Technology for Superheater/Reheater Tubes
TR-103377-V7 Final Report (RP2253-10); $200
Contractors: General Atomics; Babcock & Wilcox Co.
EPRI Project Manager: R. Viswanathan

Gas Turbine Inlet Air Cooling
TR-103464 Final Report (RP3032-4); $200
Contractors: Lincoln Electric Systems; Burns & McDonnell; Encotech, Inc.; Mackie Associates
EPRI Project Managers: H. Schreiber, R. Wendland

Engineering Development of Selective Agglomeration: Trace Element Removal Study
TR-103479 Final Report (RP3118-1); $200
Contractors: Praxis Engineers, Inc.; Southern Electric International, Inc.; CQ Inc., Southern Company Services, Inc.
EPRI Project Manager: W. Weber

Production and Properties of a Superclean 2.5% Ni-CrMoV HP/LP Rotor Shaft
TR-103689 Final Report (RP1403-55); $200
Contractors: Japan Steel Works, Ltd.; Toshiba Corp.; General Electric Co.
EPRI Project Manager: R. Viswanathan

Premium Fuels From Coal Refuse
TR-103709 Final Report (RP1895-35); $200
Contractor: CQ Inc.
EPRI Project Manager: C. Kulik

INTEGRATED ENERGY SYSTEMS

Strategic Asset Management: Helping Electric Utilities Translate Vision Into Value
TR-102730 Final Report (RP3678-1); $5000
Contractor: Strategic Decisions Group
EPRI Project Manager: L. Rubin

Integrated Standardized Database/ Model Management System: Study Management Concepts and Requirements
TR-103544 Interim Report (RP3443-1); $200
Contractor: Abacus Programming
EPRI Project Manager: L. Rubin

NUCLEAR POWER

Protective Relay Maintenance and Application Guide
NP-7216 Final Report (RP2814-89); $8900
Contractor: Edan Engineering Corp.
EPRI Project Manager: W. Johnson

The Knowledge-Based Technology Applications Center (KBTAC) Seminar Series, Vol. 3: Introductory Knowledge-Based System Development Seminar
TR-101740-V3 Final Report (RP3109-1); $200
Contractors: Kaman Sciences Corp.; Syracuse University
EPRI Project Manager: C. Lin

The Knowledge-Based Technology Applications Center (KBTAC) Seminar Series, Vol. 4: Introduction to Neural Networks and Fuzzy Logic
TR-101740-V4 Final Report (RP3109-1); $200
Contractors: Kaman Sciences Corp.; Syracuse University
EPRI Project Manager: C. Lin

Reactor Vessel Embrittlement Management Handbook
TR-101975-T1 Final Report (RP2975); $200
TR-101975-T2 Final Report; license required
Contractors: Sartrex Corp.; Failure Analysis Associates; ATI Consulting, Inc.; Southern Technical Services; Decision Focus Inc.
EPRI Project Manager: R. Carter

Maintenance and Application Guide for Control Relays and Timers
TR-102067 Final Report (RP2814-86); $8900
Contractor: MOS, Inc.
EPRI Project Manager: W. Johnson

Functional Specification Requirements for a Microprocessor-Based Annunciator System
TR-102872 Final Report (RP3136-1); license required
Contractor: MPR Associates, Inc.
EPRI Project Manager: J. Ketchel

Contingency Strategies for Diablo Canyon During Potential Shutdown Operation Events: ORAM Technology
TR-102969 Final Report (RP3342-2, RP3333-11, RP3114-68); license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: P. Kalra

Generic Outage Risk Management Guidelines for BWRs: ORAM Technology
TR-102971 Final Report (RP3333-10, RP3114-66); license required
Contractor: ERIN Engineering and Research, Inc.
EPRI Project Manager: P. Kalra

Reflux Cooling: Application to Decay Heat Removal During Shutdown Operations—ORAM Technology

TR-102972 Final Report (RP3114-68, RP3333-11, RP3342-2): license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: P. Kalra

Contingency Strategies for BWRs During Potential Shutdown Operation Events: ORAM Technology

TR-102973 Final Report (RP3333-10, RP3114-66); license required
Contractor: ERIN Engineering and Research, Inc.
EPRI Project Manager: P. Kalra

Outage Risk Management Guidelines for Diablo Canyon During Shutdown Operations: ORAM Technology

TR-102981 Final Report (RP3342-2, RP3333-11, RP3114-68); license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: P. Kalra

Systems Aspects of Reactor Pressure Vessel Integrity

TR-103084-T1 Final Report (RP2975-5), $200
TR-103084-T2 Final Report; license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: R. Carter

Qualification Testing of Three Advanced Amines for Secondary-System pH Control in Once-Through Steam Generator Plants

TR-103098 Final Report (RPS520-5); $200
Contractors: B&W Nuclear Technologies, Inc.; Toledo Edison Co.
EPRI Project Managers: P. Millett, T. Passell

Guide for Determining Preventive Maintenance Task Intervals

TR-103147 Interim Report (RP2970-2); $15,000
Contractor: ERIN Engineering and Research, Inc.
EPRI Project Manager: D. Worledge

Containment Iodine Behavior Experiments: Advanced Containment Experiments (ACE) Project (Summary Report)

TR-103212 Final Report (RP2802); $200
Contractors: Oak Ridge National Laboratory; Battelle Pacific Northwest Laboratories; Westinghouse Hanford Co.; Whiteshell Nuclear Research Establishment
EPRI Project Manager: M. Merilo

Water Level Measurement Uncertainties During BWR Instability: Tests and Analysis

TR-103292 Final Report (RP3114-95, RP4144-17); $10,000
Contractors: The Research Partnership; S. Levy, Inc.
EPRI Project Manager: R. Torok

Duke Power Compact PHOCUS Boresonic System Evaluation

TR-103342 Application Report (RP3232-1); $200
EPRI Project Manager: J. Lance

Temperbead Welding Repair of Low-Alloy Pressure Vessel Steels: Guidelines

TR-103354 Final Report (RPC104-2); $200
Contractor: EPRI Repair and Replacement Applications Center
EPRI Project Manager: W. Childs

Proceedings: Third EPRI Turbine and Generator NDE, Life Assessment, and Maintenance Workshop

TR-103392 Proceedings (RP3232-1): call (704) 547-6100 for price
EPRI Project Managers: J. Lance, T. McCloskey

Service Water System Corrosion and Deposition Sourcebook

TR-103403 Final Report (RP3052-6); $750
Contractor: Puckorius & Associates
EPRI Project Manager: R. Edwards

A Decision Analysis Approach to Prioritizing Decommissioning Alternatives With Illustrative Application to the Trojan Nuclear Power Plant

TR-103423 Interim Report (RP3171-4); $200
Contractor: Decision Focus, Inc.
EPRI Project Manager: C. Wood

PWR Full Reactor Coolant System Decontamination Engineering Evaluations and Reactor System Operating Procedures

TR-103431 Final Report (RP3307-1); $200
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: C. Wood

Non-Process Instrumentation Surveillance and Test Reduction

TR-103457 Final Report (RP2409-13); $1000
Contractor: ABB Impell Corp.
EPRI Project Manager: R. James

Review of Steam Generator Girth Weld Cracking

TR-103498 Final Report (RPS407-52); $500
Contractor: Dominion Engineering, Inc.
EPRI Project Manager: A. McIlree

Maintenance Effectiveness Evaluation Software Tools: MEET Software

TR-103513 Final Report (RP3323-1, -2); $1000
Contractor: Science Applications International Corp.
EPRI Project Manager: B. Chu

Maintenance Effectiveness Evaluation Database Tools: MEET Databases

TR-103514 Final Report (RP3323-1, -2); $1000
Contractor: Science Applications International Corp.
EPRI Project Manager: B. Chu

BWR Primary System Activity Transients During Plant Shutdowns

TR-103536 Interim Report (RP2758-2); $200
Contractor: Radiological & Chemical Technology, Inc.
EPRI Project Manager: H. Ocken

Natural Convection Phenomena in a Prototypic PWR During a Postulated Degraded-Core Accident

TR-103574 Final Report (RP2177-6), $200
Contractor: Argonne National Laboratory
EPRI Project Manager: R. Sehgal

Thermal Stratification, Cycling, and Striping (TASCS)

TR-103581 Final Report (RP3153-2); license required
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: J. Kim

Burnup Verification Measurements on Spent-Fuel Assemblies at Oconee Nuclear Station

TR-103591 Final Report (RP3290-7); $200
Contractors: Sandia National Laboratories; Los Alamos National Laboratory
EPRI Project Manager: R. Williams

Liquid-Liquid Mixing by Gas Injection in a Pool Configuration

TR-103628 Final Report (RP1933); $200
Contractor: University of Wisconsin, Madison
EPRI Project Manager: R. Sehgal

Stress Relief Treatment of Alloy 600 Steam Generator Tubing

TR-103645 Final Report (RPS303-1); $200
Contractor: Brookhaven National Laboratory
EPRI Project Manager: A. McIlree

Evaluation of High Off-Gas Failures in Barrier and Non-Barrier BWR Fuel

TR-103655 Interim Report (RP2229-11); license required
Contractor: S. M. Stoller Corp.
EPRI Project Manager: O. Ozer

Testing and Evaluation of a Moisture Separator Drain Demineralizer at Davis-Besse Nuclear Station

TR-103833 Final Report (RP2977-6); $200
Contractors: Toledo Edison Co.; B&W Nuclear Service Co.
EPRI Project Manager: T. Passell

POWER DELIVERY

On-Line Expert System for Customer Restoration and Fault Testing, Vol. 6: CRAFT for Operation and Automatic Switching Design in User-Friendly Environment

EL-6680-V6 Final Report (RP2944-1, RP3708-3); $5000
Contractor: University of Washington
EPRI Project Managers: G. Cauley, D. Sobajic

Flexible AC Transmission System (FACTS): System Studies to Assess FACTS Device Requirements on the Southern Electric System

TR-103168 Final Report (RP3022-14); $5000
Contractor: Southern Company Services, Inc.
EPRI Project Manager: R. Adapa

Power System Backup Control Center Requirements

TR-103605 Final Report (RP2473-68); $5000
Contractor: Macro Corp.
EPRI Project Manager: G. Cauley

Power System Dynamic Security Analysis Using Artificial Intelligence Systems, Phase 1: Feasibility Evaluation

TR-103607 Final Report (RP3103-2); $5000
Contractor: ABB Systems Control Co., Inc.
EPRI Project Manager: G. Cauley

Handbook of Shielding Principles for Power System Magnetic Fields, Vols. 1 and 2

TR-103630-V1, TR-103630-V2 Final Report (RP3335-2); $200 each volume
Contractor: General Electric Co.
EPRI Project Manager: R. Lordan

EPRI Events

JULY

10–14
Mercury as a Global Pollutant
Whistler, British Columbia
Contact: Pam Turner, (415) 855-2010

11–13
PWR Secondary Water Chemistry Training and Optimization Workshop
San Antonio, Texas
Contact: Barbara James or Gary Brobst, (707) 823-5237

12–13
Needs-Driven Program Design
Dallas, Texas
Contact: Lynn Stone, (214) 556-6529

25–27
International Conference on Low-Level Waste
Norfolk, Virginia
Contact: Linda Nelson, (415) 855-2127

27–29
ASME/EPRI Radwaste Workshop
Norfolk, Virginia
Contact: Linda Nelson, (415) 855-2127

AUGUST

2–4
Direct DSM Marketing
Dallas, Texas
Contact: Lynn Stone, (214) 556-6529

3–4
Nuclear Plant Performance Improvement Seminar
Charleston, South Carolina
Contact: Susan Otto, (704) 547-6072

9–12
Nondestructive Evaluation of Fossil Plants
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

16–18
Workshop: Distributed Digital Systems, Plant Process Computers, and Networks
Charlotte, North Carolina
Contact: Denise O'Toole, (415) 855-2259

17–19
Effects of Coal Quality on Power Plants
Charleston, South Carolina
Contact: Susan Bisetti, (415) 855-7919

18–19
1994 EPRI Fatigue Seminar
Park City, Utah
Contact: Pam Turner, (415) 855-2010

24–26
4th International Symposium on Magnetic Bearings
Zurich, Switzerland
Contact: Tom McCloskey, (415) 855-2655

30–September 1
Cooling Towers and Advanced Cooling Systems
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

SEPTEMBER

7–9
4th Conference on Cycle Chemistry in Fossil Plants
Atlanta, Georgia
Contact: Linda Nelson, (415) 855-2127

7–9
4th International Conference on Rotor Dynamics
Chicago, Illinois
Contact: Tom McCloskey, (415) 855-2655

8–9
Decision Analysis for Environmental Risk Management
Palo Alto, California
Contact: Katrina Rolfes, (415) 926-9227

12–16
International Symposium: Resolution of Material Problems for PWRs
Fontevraud, France
Contact: Peter Paine, (415) 855-2076

13–15
7th International Workshop on Main Coolant Pumps
Marina del Rey, California
Contact: Susan Otto, (704) 547-6072

14–15
11th Annual Operational Reactor Safety Engineering and Review Groups Workshop
Dallas, Texas
Contact: Susan Bisetti, (415) 855-7919

14–16
Fossil Plant Cycling
New Orleans, Louisiana
Contact: Lori Adams, (415) 855-8763

21–23
Healthcare Initiative Project Meeting and Conference
Location to be announced
Contact: Myron Jones, (415) 855-2993

25–30
Aerosols and Atmospheric Optics
Snowbird, Utah
Contact: Peter Mueller, (415) 855-2586

28–30
Magnetic Field Management Seminar
Lenox, Massachusetts
Contact: Rich Lordan, (214) 556-6520

OCTOBER

4–6
Pollution Prevention Seminar
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

5–7
Flexible AC Transmission Systems (FACTS) Conference
Baltimore, Maryland
Contact: Lori Adams, (415) 855-8763

12–13
Fuel Oil Utilization Workshop
Tampa, Florida
Contact: Stephanie Drees, (714) 259-9520

17–19
Energy-Efficient Office Technology
New York, New York
Contact: Lori Adams, (415) 855-8763

19–21
13th Conference on Coal Gasification Power Plants
San Francisco, California
Contact: Linda Nelson, (415) 855-2127

19–21
Fuel Supply Seminar
Chicago, Illinois
Contact: Susan Bisetti, (415) 855-7919

24–27
Power Quality Applications, 1994
Amsterdam, Netherlands
Contact: Carrie Koeturius, (510) 525-1205

28
Municipal Wastewater and Energy Conference
New York, New York
Contact: Keith Carns, (314) 935-8598

NOVEMBER

1–3
Substation Equipment Diagnostics Conference
New Orleans, Louisiana
Contact: Kathleen Lyons, (415) 855-2656

15–17
Primary Water Stress Corrosion Cracking in Alloy 600 PWRs
Tampa, Florida
Contact: Linda Nelson, (415) 855-2127

15–18
Market Research Symposium
Marina del Rey, California
Contact: Susan Bisetti, (415) 855-7919

28–December 1
Fuel Cell Seminar
San Diego, California
Contact: Ed Gillis, (415) 855-2542

DECEMBER

5–7
12th International Electric Vehicle Symposium
Anaheim, California
Contact: Pam Turner, (415) 855-2010

FEBRUARY 1995

22–24
1995 Foodservice Symposium
New Orleans, Louisiana
Contact: Susan Bisetti, (415) 855-7919

MARCH

28–31
1995 SO_2 Control Symposium
Miami, Florida
Contact: Pam Turner, (415) 855-2010

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