Battery Charging for Electric Vehicles

ELECTRIC POWER RESEARCH INSTITUTE

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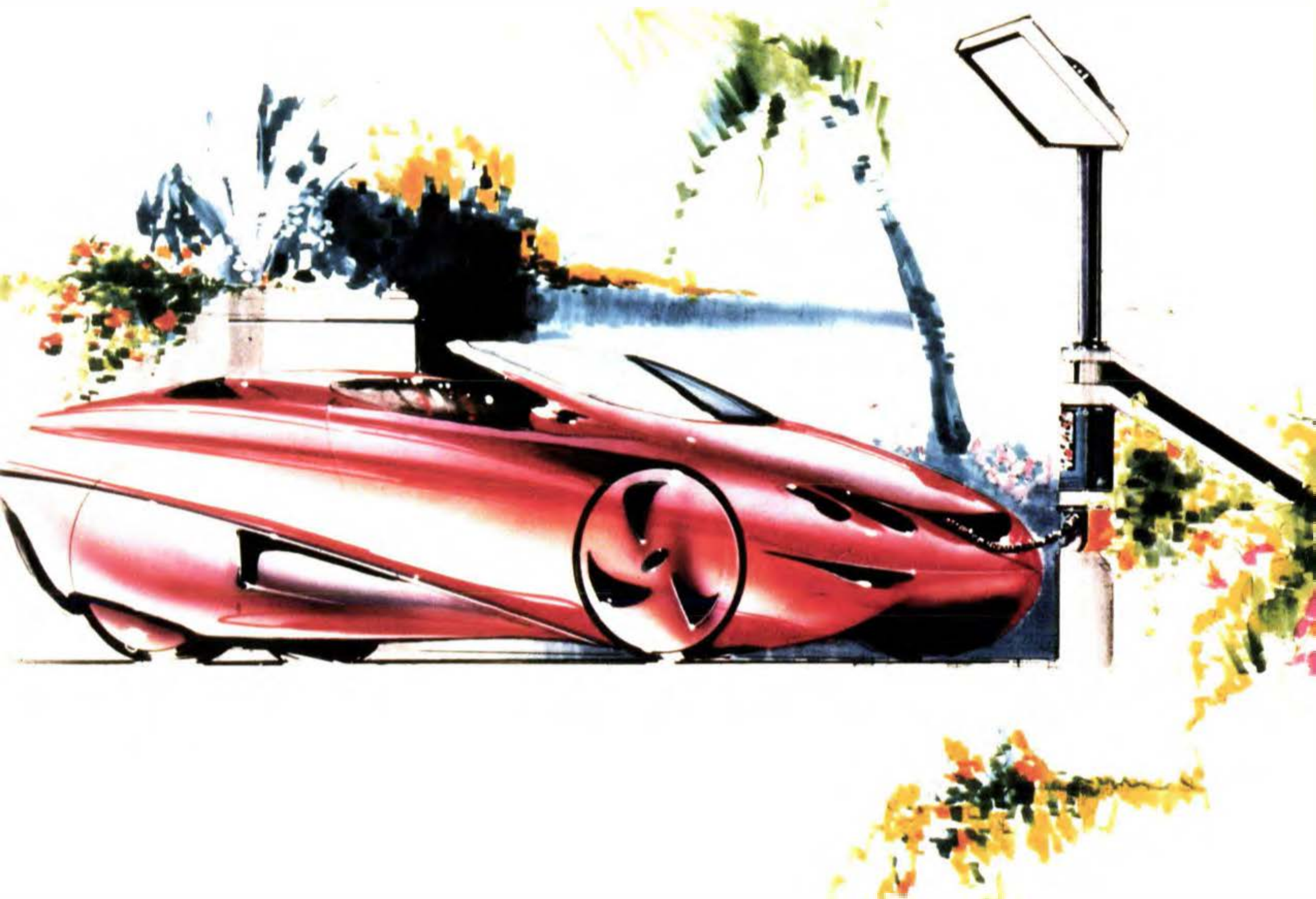

Also in this issue • R&D for Co-ops • Jack Welch on Competitiveness • Integrated Communications

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Cover: The development of simple, convenient battery-charging equipment is a key infrastructure need for an automotive future that includes electric vehicles. (Art courtesy of Mark Huetter)

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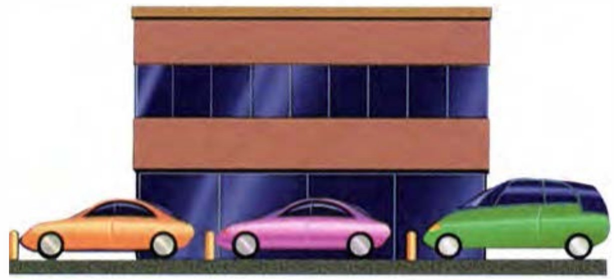

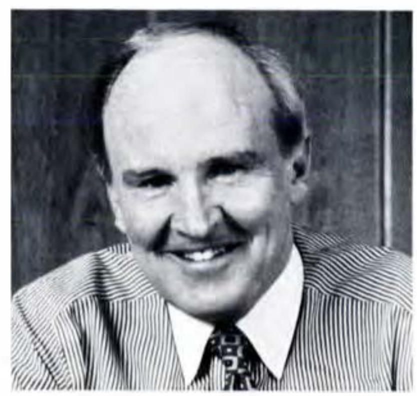

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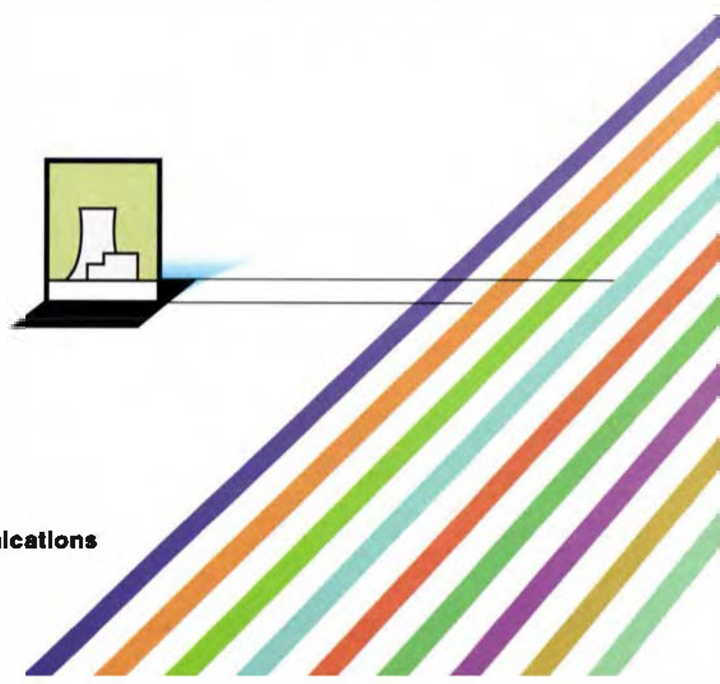


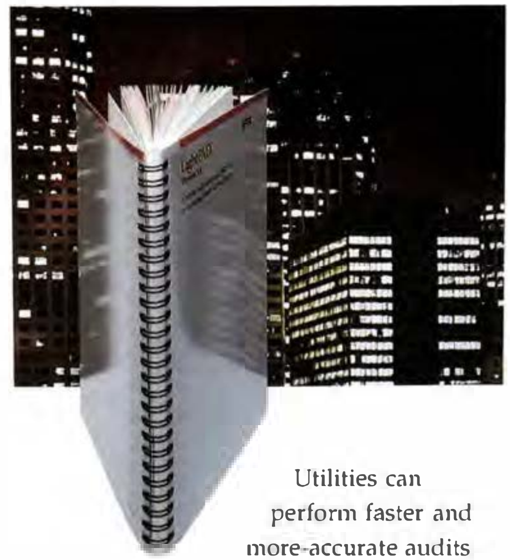
34 Integrated communications

Equipment Qualification Reference Manual

Until now, information on equipment qualification for nuclear plants has been scattered in industry standards, Nuclear Regulatory Commission regulations, and various reports and papers. This 500-page hard-cover reference manual (TR-100516) gathers all relevant material into one resource. The manual helps utilities maintain safety, even in accident or earthquake environments. A veritable road map to the world of equipment qualification, it documents the experiences of utilities and discusses such topics as artificial aging methods, materials properties, qualification testing, maintenance, and the effects of heat, radiation, and moisture on equipment. It also offers some 600 references for more-detailed information on specific areas of interest.

For more information, contact George Sliter, (415) 855-8699. To order, call the EPRI Distribution Center, (510) 934-4212.

LightPAD for Lighting Audits

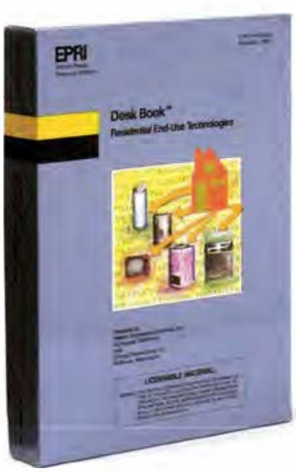


Utilities can perform faster and more-accurate audits of lighting systems for commercial and industrial customers with EPRI's new LightPAD™ software. This tool can be used either to quickly calculate the energy consumed by lighting systems or to conduct a more-detailed survey, including the evaluation of existing lighting levels. Unlike conventional auditing procedures, LightPAD allows users to input and validate data easily on-site. Room characteristics, occupancy schedules, maintenance practices, and other variables can be considered, resulting in more-accurate recommendations for retrofits that both reduce energy consumption and improve lighting quality. The results can also help prevent overestimates of energy savings from utility demand-side management programs.

For more information, contact the EPRI Lighting Information Office, (800) 525-8555. To order, call the Electric Power Software Center, (214) 655-8883.

The Desk Book of Residential Energy Use

The Desk Book™ application program—officially known as the Residential End-Use Technologies Desk Book—is EPRI's recent response to the often overwhelming proliferation of data on energy-using technologies in the residential sector. A comprehensive reference, Desk Book offers quick access to descriptive and statistical information on performance, features, markets, regulations, and R&D trends for laundry and kitchen appliances, heat pumps, water heaters, windows, insulation, lighting, and more. With this information at their fingertips, utility customer service and marketing representatives can swiftly field a wide variety of questions from consumers. Currently available as a Macintosh-based program, Desk Book is expected to be released in IBM format next year.



For more information, contact John Kesselring, (415) 855-2902. To order, call the Electric Power Software Center, (214) 655-8883.

LightCAD for Efficient Lighting Systems

Developed specifically for architects, engineers, and lighting designers, LightCAD™ 2.0 gives these professionals the tools they need to design the most cost-effective and efficient lighting systems. Used in conjunction with its host program, AutoCAD, LightCAD 2.0 automates typical drafting functions, calculates total fixture costs, and references utility lighting programs and rebate information, among other capabilities. The program can calculate lighting power by the fixture, control, room, or project. Two special features of this new version of LightCAD are the ability to perform daylighting analysis and the ability to conduct comparative economic and energy analyses for different lighting systems.

For more information, contact the EPRI Lighting Information Office, (800) 525-8555. To order, call the Electric Power Software Center, (214) 655-8883.

Terrasight: The PCB Spill Buster

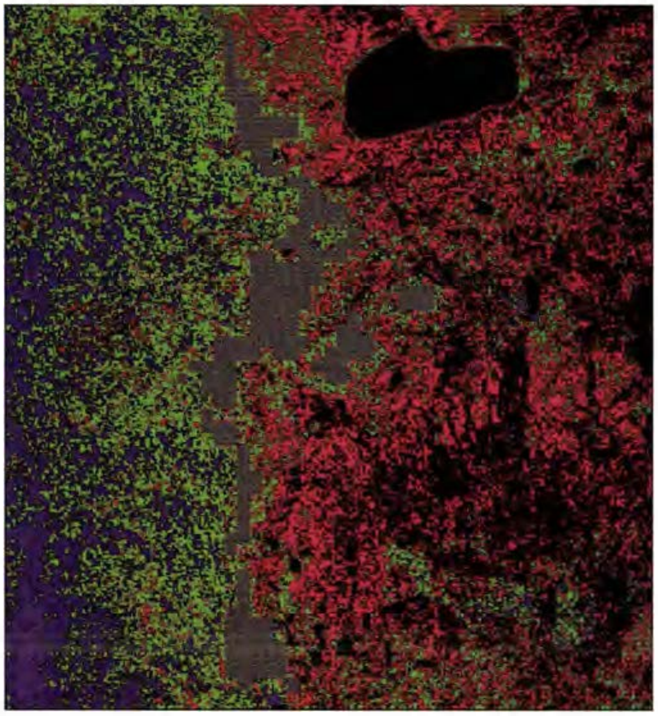
Designed to help utilities comply with Environmental Protection Agency regulations, this handheld instrument detects polychlorinated biphenyl spills and oil spills that are invisible to the naked eye. Assisted by an ultraviolet light source, Terrasight's color monitor depicts contaminated soil as fluorescent green, showing the uncontaminated areas as dark patches. Developed by Battelle Memorial Institute under contract to EPRI, the device reduces the time needed for cleanup—which normally involves extensive digging and laboratory testing to determine the scope of a spill—from hours to minutes. In lab tests, Terrasight has detected oil on nonporous surfaces at concentrations as low as 10 parts per million. In field tests, the instrument was able to clearly display a spill that was more than six years old.

For more information, contact Gilbert Addis, (415) 855-2286. To order, call Photographic Analysis Company, (800) 524-0397.

Ecotones Illuminate Environmental Change

Ecotones — the transition zones between different types of vegetation— are often quite sensitive to changing environmental conditions. A global warming trend, for example, could push the arctic-timberline ecotone farther north, extending coniferous forests into regions now covered with tundra. Monitoring of ecotones by means of satellite images is being pursued as an efficient new way to detect changing environmental conditions.

On a local scale, such monitoring may afford an early warning of environmental alteration caused by pollution or other regional effects and thus may substantially reduce the cost of control or mitigation. Study of ecotone changes could also provide a new scientific framework for detecting and evaluating the possible impacts of global climate change. EPRI research is seeking to develop better methods of identifying and analyzing ecotones from remote-sensing data.



One project, cosponsored by Empire State Electric Energy Research Corporation, is devising ways to identify so-called gradual ecotones from satellite imagery. Typically, where there is an abrupt transition between plant communities, the dominant factor is competition between species, which is only indirectly and very slowly affected by small environmental changes. A more gradual ecological transition, however, usually reflects an underlying environmental gradient, such as temperature decrease with increasing latitude. In such gradual ecotones, communities at the boundary are typically stressed to their physiological limits, so even small environmental changes may affect them dramatically.

To detect and map such environmentally sensitive ecotones, the project contractor — Applied Biomathematics, Inc., of Setauket, New York — is developing several new image analysis methods. One approach is to correlate the remotely detected color spectra of particular regions with spectra of other regions whose vegetation patterns have been described through ground study. Another approach compares images of a region taken in different seasons. The effectiveness of various detection methods will then be judged through comparison with ground surveys at the sites in question.

A second project, cofunded by the National Science Foundation, is being conducted at the University of New Mexico. In this work, fractal geometry — the mathematical representation of complex natural patterns— is being used to describe and measure the spatial patterns of ecotones at various scales. Specifically, researchers will, on the basis of high-altitude photos, mathematically characterize the geographical transition from grassland to woodland in a region of New Mexico. They will then use this information to develop a more-general computerized model for ecotone analysis. Eventually, such models could help identify regions that need to be monitored for early detection of environmental change.

■ *For further information, contact Louis Pitelka, (415) 855-2969.*

Centrifuge Used in Dam Crack Predictions

Many concrete hydroelectric dams were built decades before currently acceptable construction practices were codified. As a result, there is intense international interest in developing better computer models for analyzing dam stability — models that realistically incorporate fracture mechanics.

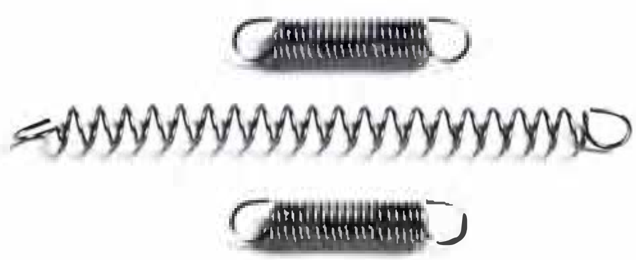
EPRI and Pacific Gas and Electric Company have been cofunding research at the University of Colorado to develop one such computer code, called Merlin, which is designed to help utilities meet Federal Energy Regulatory Commission (FERC) criteria for dam safety. The question is how to test the validity of such codes experimentally, including the realistic simulation of dam cracking, in light of the difficulty of studying this problem in the field. It is even hard to test scale models in the laboratory, because of the difficulty of simulating the large gravity and water pressure loads that dams experience.

Recently, the Colorado researchers came up with a unique approach: they used a centrifuge to accelerate 2-foot-high dam models up to 100g to simulate the gravitational forces on full-size dams. Water pressure loads were provided by flexible water bladders bonded to the back of the model, and the excessive water pressure caused by overtopping was simulated by adding compressed air over the water surface. A variety of gages were used to instrument the model, and the whole assembly was placed in a transparent container that allowed videotaping of the experiments.

Tests conducted on the dam models in the centrifuge showed that Merlin does indeed predict dam stability and crack propagation well, and EPRI members are currently evaluating the code for use in dam safety analysis. FERC is monitoring these tests for applicability to federal regulations. The centrifuge experiments also enabled researchers to examine the effects that foundation materials and conditions at the dam-foundation interface have on cracking—phenomena that have not been well understood. ■ *For further information, contact Douglas Morris, (415) 855-2924.*

Higher Temperatures for Shape-Memory Alloys

Shape-memory metal alloys have the peculiar property of returning to their original shape when heated above a critical temperature or when some mechanical constraint is removed. EPRI is looking into several potential utility applications for these unusual metals, including reactor control devices, circuit breakers, and sensors. "The advantage of these alloys for many applications will be their robustness," says project manager John Stringer. "A memory-alloy alarm switch, for example, could sit for years without the need for maintenance but then respond surely when the temperature rose above a certain point."

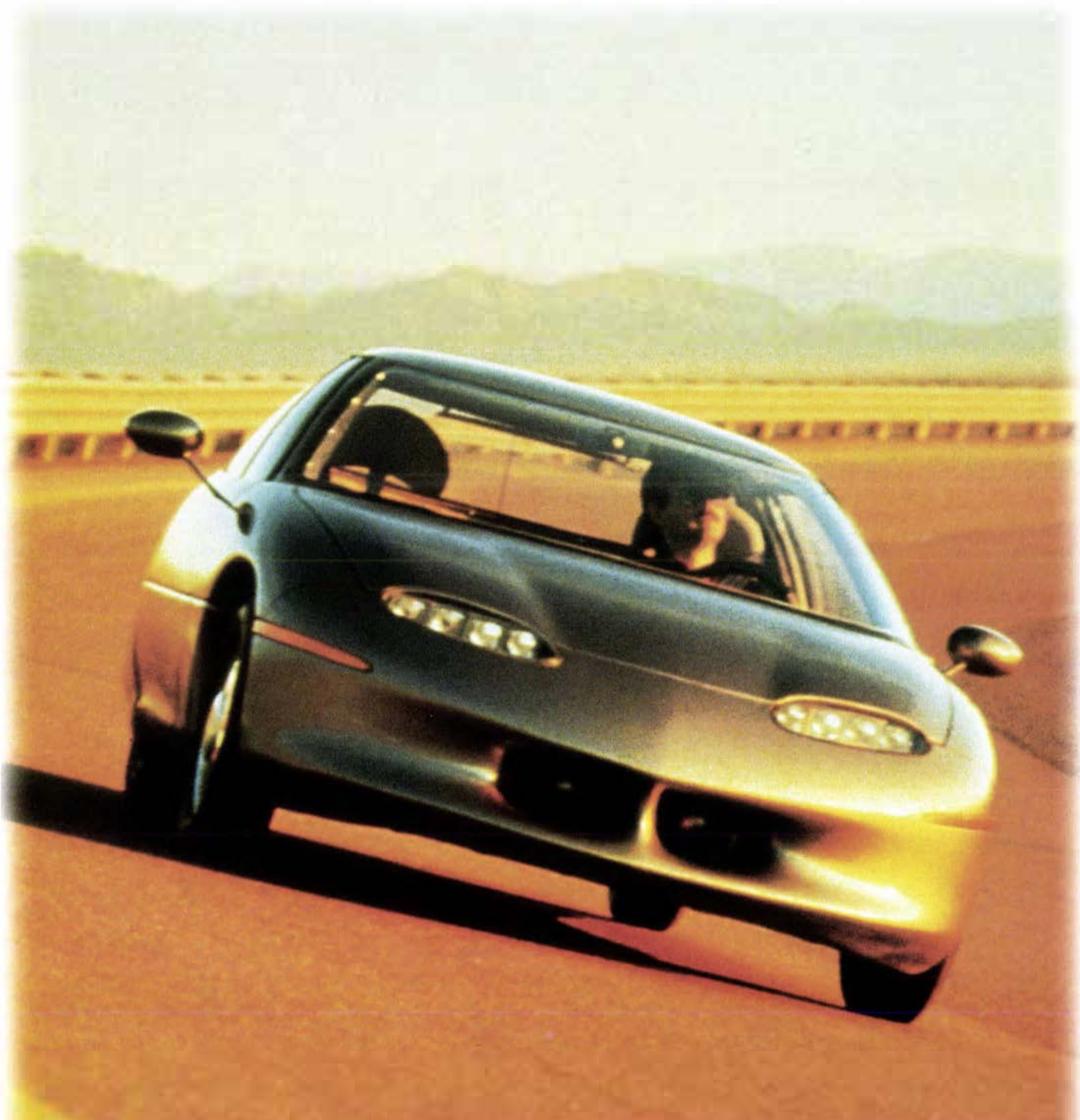


Shape-memory behavior results from the reversibility of certain changes in the crystalline structure of some alloys. After rapid cooling or mechanical stress causes a transition from a cubic lattice to a needlelike structure (known as martensite), heating the metal or releasing the stress allows it to snap back to the cubic form. Such properties have been recognized for many years, and some specialized applications have been attempted, including self-erecting satellite components that unfold in space when exposed to heat from the sun.

The problems from a utility point of view have been that the critical temperature of most shape-memory alloys is below 150°C, and that their memory characteristics tend to degrade over time. EPRI research is thus focused on characterizing the shape-memory behavior of promising alloys, with particular emphasis on creating alloys that can operate at the intermediate temperatures (290–350°C) typical of water exit conditions in nuclear reactors.

With EPRI funding, researchers at the University of Illinois are attempting to create nickel-aluminum alloys that will be suitable for shape-memory applications in the electric power industry. Already the researchers have shown that some of these alloys have critical temperatures as high as 927°C and that the onset of aging does not occur until temperatures exceed 511°C. Unfortunately, polycrystalline forms of nickel-aluminum alloys tend to be brittle. Two approaches are being explored to increase their ductility: adding small amounts of boron to change the grain boundaries and modifying the rolling and extrusion process to achieve smaller grain size.
■ *For more information, contact John Stringer, (415) 855-2472.*

Charging Up for Electric



Vehicles

by Taylor Moore

THE STORY IN BRIEF ***With significant numbers of electric vehicles expected to hit the road before the end of the decade, the push is on to develop the infrastructure—especially battery-charging systems—that will allow EVs to become a major part of the nation's transportation picture. The vision calls for simple, convenient recharging not only at home but on the road and perhaps right in your daily parking space. Smart charging systems now in development will improve on currently available plug-and-cord chargers, and a number of utilities are conducting recharge demonstration projects to gain experience before large numbers of EVs roll off the production lines. While the need for safety, common standards, and equipment compatibility is clear, load growth and the impact of charging vehicles during peak demand periods will also become issues as the EV population increases.***

UTILITY CHARGING FACILITIES ARE PROLIFERATING

A dozen or more U.S. utilities have begun installing EV charging equipment to serve demonstration vehicles in their own, other company, and municipal fleets. Some utilities, including several major ones serving California, have more ambitious programs to install dozens of charging connections at various locations over the next couple of years in preparation for the commercial introduction of EVs. Most installations feature simple metered circuits with charging cables. At some sites (often called "chargeports"), solar photovoltaic panels provide both supplemental energy for battery charging and shade for the vehicles.

The nation's electric utilities are working to get a jump start on the infrastructure necessary to support the commercial reappearance of electric vehicles (EVs), which could begin within the next five years. The utilities are part of the EV Infrastructure Working Council, a semiformal group that also includes representatives of automotive-standard setting bodies, component suppliers, EPRI, the Big Three U.S. auto manufacturers—Chrysler, Ford, and General Motors—and the overseas-based makers of Honda, Mercedes-Benz, Nissan, Peugeot, and Toyota vehicles. Near-term efforts are focused on ensuring basic compatibility and availability of battery-charging equipment for the earliest wave of demonstration and production EVs to hit the road. Many of these will be used as commercial fleet vehicles by public agencies, utilities, and other businesses.

"EPRI and the utility industry have been asked, and have agreed, to lead a cooperative, coordinated national effort to develop the infrastructure that will support the automakers' products when they come onto the market in the next few years," says Gary Purcell, an EV technology manager in EPRI's Customer Systems Division. "To be ready for them nationwide is a rather daunting task, so we are trying to marshal all the forces that we can."

That includes enlisting the creative energies and input of designers and architects as well as private citizens, who will be among the ultimate users of mass-produced EVs. Several design competitions are under way—including two sponsored by EPRI—that aim to spark innovation in advanced infrastructure concepts for such things as public charging stations. Meanwhile, the government is stepping up its own efforts to spur the development of EV infrastructure technology through defense conversion programs that are expected to get military facilities involved with EVs.

Although many of the technical details have yet to be defined, Purcell and others are quick to dispute the oft-repeated myth that none of the infrastructure needed for EVs yet exists and that it must all be developed before such vehicles will appeal to potential users. "We already have in place 98% of the infrastructure in the electric supply and distribution system that extends to virtually every home and street in the

A Hughes inductive charger installed by Pacific Gas and Electric and the Bay Area Rapid Transit District at a BART station makes it an all-electric commute for some utility employees who rideshare in a G-Van.

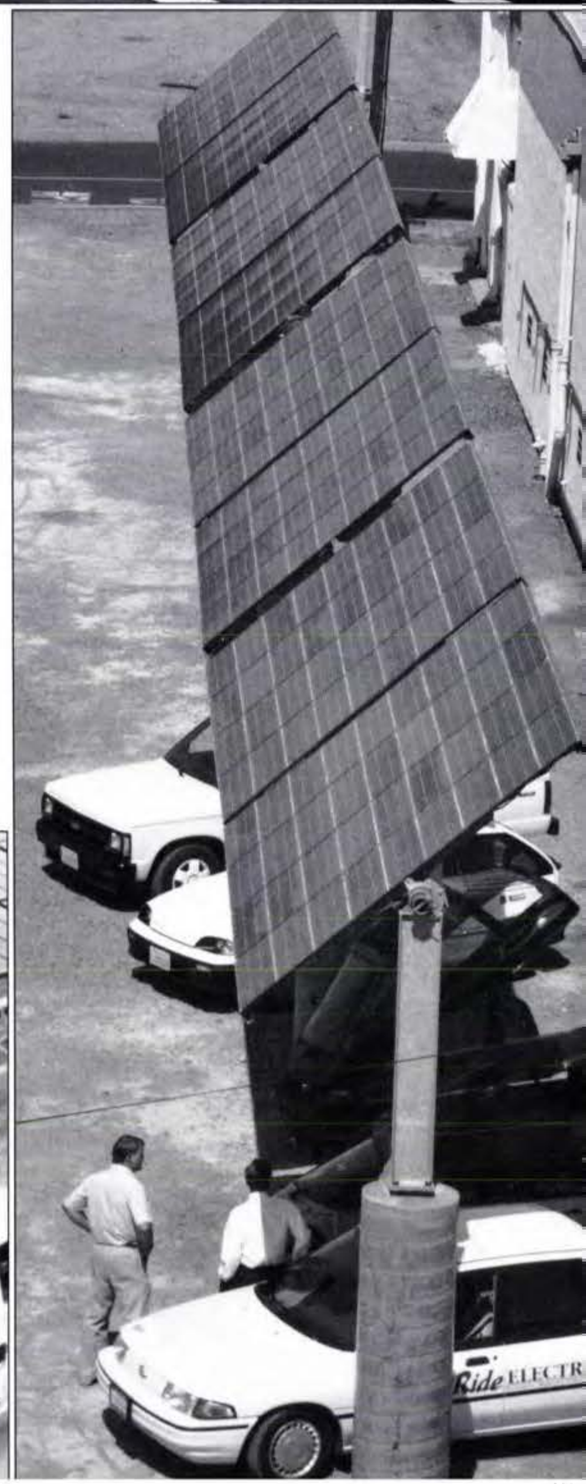
country," says Purcell. "It's the last 2%—developing the connection from the grid to the vehicle and determining how charging vehicles might affect the operation of the grid—that we're working on. This last 2% is not trivial and needs to be done smoothly to ensure the timely support of the automakers."

Chargers and vehicles before standards

Nearly every automaker that competes in the North American market has a program under way to develop and produce EVs by 1998 in order to meet the initial deadline for commercial availability set by California air quality regulators. Beginning that year, 2% of all the vehicles sold in the state are supposed to have zero emissions, which essentially limits them to electric battery power. That's about 40,000 vehicles at the recent sales rate. The zero-emission quota in California is then set to rise to 10%, or 200,000 vehicles per year, in 2003. Similar timetables are planned for adoption in several eastern states, including New York and Massachusetts, and are being seriously considered elsewhere.

It remains an open question exactly

The first public EV charging stations in Los Angeles include this one at the downtown headquarters building of the city's Department of Water & Power. LADWP plans to have 60 stations in place by the end of this year.



This solar chargeport at a Sacramento Municipal Utility District facility is only the most visible of the many public charging installations the utility has already completed or has planned.

The solar-powered chargeport at the South Coast Air Quality Management District's office was a joint effort with Southern California Edison.

how automakers will actually meet the quotas if those plans hold. Under the pressure of the 1998 California deadline, which looms very near in terms of design engineering, production planning, and machine tooling, the Big Three U.S. automakers recently revealed that they are considering a new venture to jointly develop an EV—or perhaps only key components, which each automaker would use in its own vehicle design—to compete against the well-coordinated programs in Germany and Japan.

In any event, in order to avoid any customer confusion, auto companies want to be sure that their EVs will be chargeable with the same equipment that works for other manufacturers' vehicles. As a result, much of the discussion about infrastructure among auto experts these days is centered on the need for uniform standards—standards that will apply not just in the United States but globally, and that will endure through many design generations.

Experts acknowledge that the first-generation demonstration EVs planned by automobile companies will not conform to an as-yet-unspecified universal standard incorporating all the features car companies and utilities would like to see, such as bidirectional data communications for charge control, load management, remote control and annunciation, and perhaps even vehicle diagnostics. However, it is expected that most, if not all, EVs initially offered for sale to general consumers will meet common voltage and current standards that will support 6- to 8-hour home charging, preferably during off-peak hours.

In this country, that basic initial charging standard will be a 240-V/30-A circuit such as that used by most home electric clothes dryers. The numbers will be slightly different in Japan (200 V/30 A) and in Europe (230 V/32 A), but all charging systems will be compatible with either the 50- or 60-Hz local utility ac power frequency. It's also expected that the earliest commercial EVs will have built-in electronic converters for changing the utility alternating current into direct current for the batteries; most charging cords, however, are likely to remain off-board when not in use. Some vehicles are expected to be chargeable from a regular 120-V/15-A outlet, but because of the lower rating, they will require more time to recharge.

In some respects, the desire for common standards in advance of mass-produced EVs echoes the chicken-or-egg dilemma that for so long discouraged automaker interest in EVs in advance of clear consumer demand. Although regulatory mandates have now put many development programs in motion, automakers continue to voice doubts about the strength of interest in EVs among the car-buying public. Consumers may have little attraction to EVs in the showroom, manufacturers worry, if cost premiums are too high or if charging systems are not adequate to ameliorate the inherent range limitations of lead-acid and other currently available battery technologies, such as nickel-iron and nickel-cadmium.

(In 1991 the Big Three automakers—along with the U.S. Department of Energy and EPRI, representing the utility industry—formed the precedent-setting U.S. Advanced Battery Consortium, or USABC. Its goal is to pursue R&D on advanced battery technologies for the midterm and beyond, technologies that could eventually make EVs competitive with conventional vehicles in range and performance.)

Despite the paradox of trying to set standards before there are production vehicles, "we're pushing ahead," says Craig Toepfer, a product design engineer in Ford Motor's EV program and the chairman of the Committee on EV Charging Systems of the Society of Automotive Engineers (SAE). "We must move forward, despite the fact that we do not have a century of experience, as we do with conventional vehicles, and despite the fact that the technology for EVs has not yet settled down," says Toepfer, who also heads the Infrastructure Working Council's Committee on Connections and Connecting Stations.

"Considering the many different EVs that may become available and the various power train configurations, battery technologies, power conversion strategies, and motors that may be used, the subject is obviously complicated, and there is a desire to accommodate all parties," Toepfer adds. "But I believe that this can be done and that a technical standard covering all types of charging can evolve before significant numbers of EVs reach the marketplace."

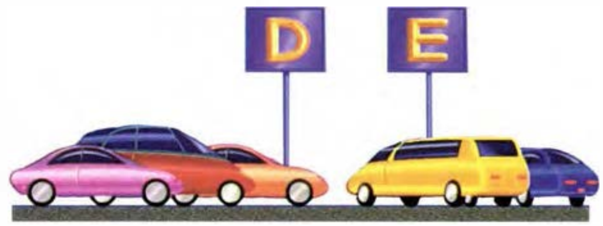
Researchers and utilities are operating on the expectation that most early EVs, whether used in commercial fleets or as commute vehicles, will be recharged mainly overnight, during off-peak hours, either with a simple charger that uses clock timing or with a smart charger that interactively communicates with the utility system and receives varying electricity price and load control signals. To help encourage off-peak charging, utilities expect to offer time-of-use or off-peak rates, which several utilities are already trying on a limited basis. These rates could apply to a separately metered circuit for EV charging at a home or business or to the customer's overall electricity use.

Technology developers and utility planners also envision the near-term need, to at least some degree, for three other types of charging facilities: curbside devices (especially in urban areas), which might be integrated with parking meters or installed like the coin-operated engine heaters popular in some northern states; EV-ready charging spaces in public parking lots; and facilities for fast charging—the electric equivalent of gasoline filling stations—where in 10 minutes or so one might boost the range of an EV by about 100 miles. Such charging capabilities would effectively eliminate the range limitation of current battery systems.

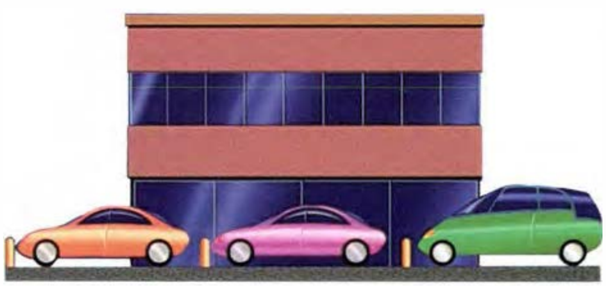
Fast charging of EVs has emerged as one of the hottest areas of interest and attention both in technology development and in standards specification. It is the area in which there is the least agreement on technical standards, despite a fairly wide consensus that the eventual availability of fast charging is

KEY TYPES OF CHARGING FACILITIES

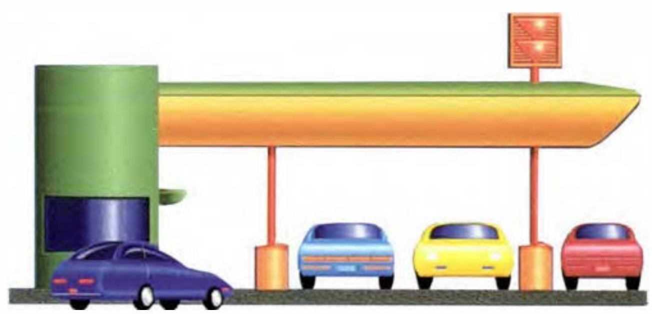
HOME/OVERNIGHT EV developers and electric utilities expect most vehicle charging to take place overnight at homes or businesses during off-peak periods of demand for electricity, partly in response to incentive utility rates that will reflect the lower cost of off-peak generation. Devices from simple clock timers to smart chargers that communicate with the utility system may be used for home charging as production EVs enter the consumer market.



PARKING LOT Specially marked spaces in public parking lots and garages (such as at malls) will help extend the range and convenience of EVs for short trips and errands. Charging spaces in company-owned employee parking lots will encourage EV commuting. Dedicated charging spaces at public transit facilities are already being demonstrated.



CURBSIDE Some utilities are providing limited numbers of public-access (in some cases, free) curbside charging connections to support early demonstration vehicles. But as the number of EVs in use grows, coin- or credit-card-operated parking-meter-type connections could again become common, as they were in cities such as Chicago and Detroit early in this century.



FAST CHARGING Systems featuring off-board, high-power electronics are under development that could provide the electric equivalent of a filling station. There, in 10 minutes, or about the time it takes to refuel a conventional vehicle, an EV could receive a booster charge that might add 70 to 100 miles of driving range. In order to minimize increases in peak period demand, researchers are exploring the possibilities for fitting these facilities with energy storage devices (such as flywheels, batteries, and superconducting magnetic coils), which could be charged at night for serving EV users throughout the day.

crucial to the competitiveness of EVs. Compared with slow, overnight charging, fast charging could involve fundamentally different technologies with quite different utility load implications. There are also key unresolved questions about the cost of providing such service, questions that will influence whether it represents a viable business opportunity in the near term for utilities or other companies.

Two developments have spurred much of the recent interest in fast charging. One is news about the possible use in some vehicles of nickel-cadmium batteries, which can be quickly recharged but must be recycled to avoid environmental release of cadmium. The other is the spreading fame of a charging system that Norvik Technologies of Ontario, Canada, invented and is jointly developing with Chrysler. A refined version of this system was recently used by Chrysler to opportunity-charge a set of thirty 6-V nickel-cadmium batteries that powered a TEVan in a nine-day, 2600-mile cross-country trek from Detroit to Los Angeles.

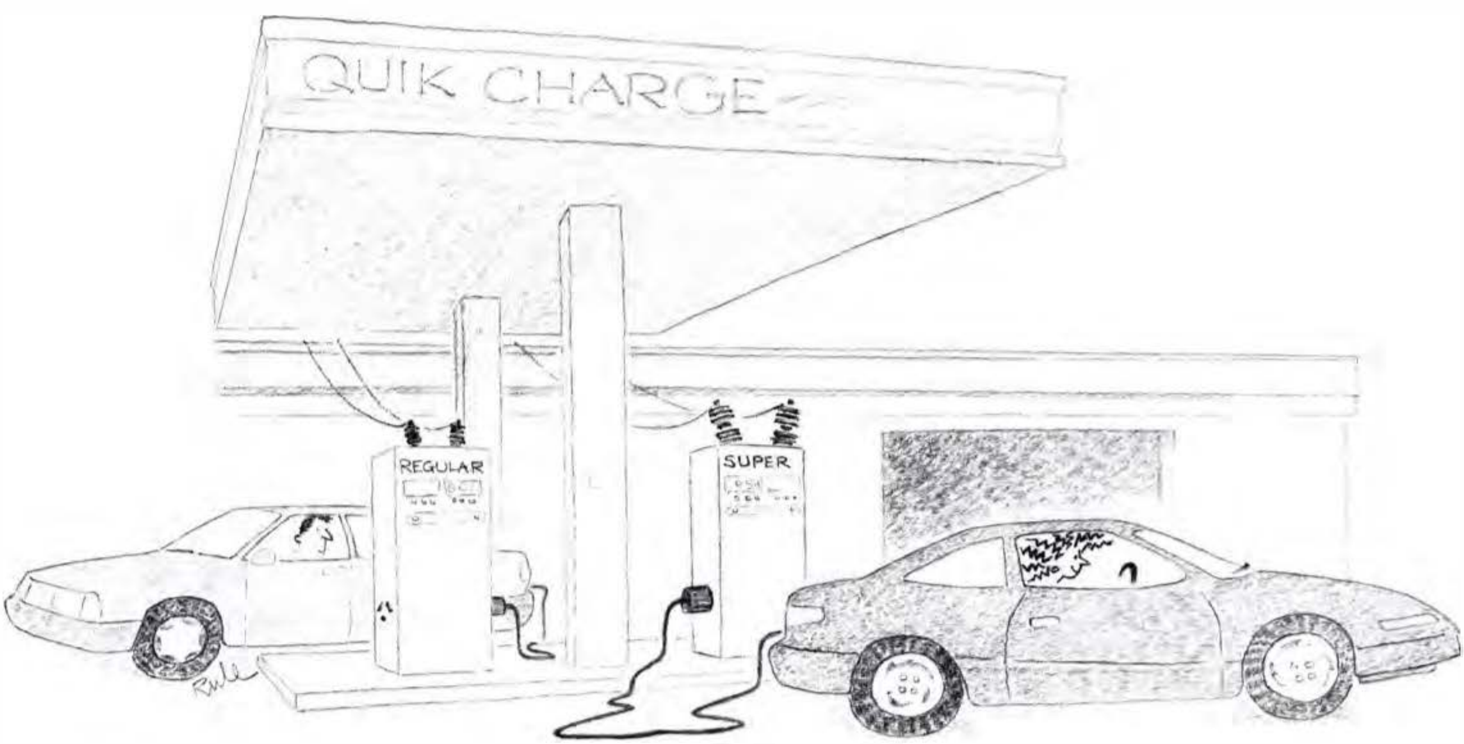
Chrysler formed a joint development venture with Norvik Technologies after its own tests convinced it that the 480-V system could successfully recharge several types of batteries in as little as 30 minutes without overheating or damaging the batteries, problems encountered in other attempts to develop fast-charging devices. The Chrysler-Norvik system applies a sensing and control algorithm to an otherwise conventional charger; the algorithm continuously monitors battery conditions and optimizes the timing of strong pulses of current to quickly restore full charge without overcharging.

A step in the right direction

Toepfer says that the Chrysler-Norvik smart charger "represents a significant step in the right direction and may provide the leadership that's needed to make real progress." He notes that the Japanese carmaker Nissan has also demonstrated a fast-charging system for its FEV (Future Electric Vehicle) concept car and that other manufacturers are evaluating the concept.

According to Toepfer, a basic dilemma facing the 12-person SAE Committee on EV Charging Systems is that "we have to try to look into the future and guess where the technology is going to settle out 20 or 30 years from now. If we set a standard today, it has to be good tomorrow and for a long time. If we say, 'Here's the way to go,' and 10 years from now it's deemed insufficient or underpowered and we have to tear it out and start over—that would not be good."

The SAE panel meets almost monthly to review technical developments and issues related to charging systems and connections. Toepfer says that the first phase of the society's standard-setting process—development of an information report for SAE members and the auto industry—could be finished by the end of this year. That would be followed by a period of dialogue and debate and then by the issuing of a Recommended Practice document, an informal guideline. Finally, the society would publish a formal Technical Standard, on which there is broad consensus. Despite the many unresolved technical questions about battery, motor, and charger types, as well as questions about the data communications protocol and media that may have to be covered under a standard, Toepfer says he thinks the SAE committee can complete its work within the 1998 time frame for commercially available EVs.



In a demonstration with Norvik Technologies of Canada, Chrysler has used a smart charging system to fast-charge nickel-cadmium batteries in a TEVan.

EHV Corporation's simple charger for public parking spaces is coin operated.

As Toepfer notes, however, the technology for EVs has not yet settled down, and this is particularly evident in the numerous approaches to charging systems that are being pursued. EPRI experts believe a charging method that employs a magnetic induction coupling between a utility power source and a vehicle's batteries is a promising approach to fast charging. It offers potentially very great ease of use as well as virtually no shock hazard.

The Institute and several utilities—including Pacific Gas and Electric Company (PG&E), the Salt River Project, and Pennsylvania Power & Light Company—continue to sponsor evaluations of several types of inductive chargers. One early system examined was the Inductran, a floor-mounted flat-plate coupler that automatically switches on when an EV fitted with a matching underplate is parked over it and the motor is switched off. Such an approach could potentially be attractive as an automatic fast-charging system in public parking facilities.

A division of the Hughes Aircraft subsidiary of General Motors has developed a flat-plate inductive coupling system that replaces the common metal plug typical of most appliances with a 5-inch round paddle covered with plastic. Connected to a charging station, the paddle is easily inserted by hand into a matching slot in an EV.

In a joint demonstration and promotion of the potential for an all-electric commute, PG&E and the Bay Area Rapid Transit District recently installed a prototype Hughes inductive charger at a dedicated EV parking space outside a BART station in Lafayette, California. The

VEHICLE CHARGING SYSTEMS EMERGE AND EVOLVE Numerous manufacturers are developing systems and equipment for charging EVs, ranging technologically from the simple to the sublime. Plug and cord equipment is already available to support home charging of EVs equipped with on-board power converters, although some additional wiring may be needed in older homes. Some public charging systems at parking spaces will feature coin- or credit-card-operated meters. Several companies are pursuing so-called smart charging systems, which incorporate microprocessor controls and electronics for communications between a vehicle and the utility distribution system.

EPRI is supporting the development at the University of Wisconsin of a coaxially wound inductive coupler that shows promise for high-power fast charging.

General Motors' Hughes Aircraft has developed a magnetic induction system with a coupler that is inserted into a vehicle's charging port.

Hughes system will recharge a PG&E-owned G-Van (developed by EPRI) used by utility employees who commute on BART, the San Francisco Bay Area's electric rail system. Meanwhile, Boston Edison Company has announced an agreement with Hughes to become the exclusive distributor of the Hughes inductive charger in nine states in the Northeast.

Hughes Power Control Systems continues to develop its charging system as part of its involvement in CALSTART, a consortium of several California defense, aerospace, and other firms, as well as the state's major utilities. CALSTART is seeking to catalyze an EV manufacturing industry and to redirect some high-technology industries into new markets. The Hughes subsidiary is also conducting an overall assessment of inductive charging technologies for EPRI. Included in this assessment is a coaxially wound coupler design developed by the University of Wisconsin at Madison that EPRI believes offers strong potential as a high-power fast-charging system.

Most fast-charging concepts would require 480-V, three-phase electric service, which is beyond the capacity of most utility transformers that serve residential areas and even some that serve commercial areas. Given enough use, however, a fast-charging station could justify the cost of the required equipment. High-power fast chargers would also operate at high frequency (20–80 kHz), which would make it possible to greatly reduce the weight of the equipment but could increase the tendency to add harmonic distortion to the utility system.

EPRI and several utilities are continuing to evaluate advanced charging concepts and technologies. Researchers hope to have a working prototype of the Wisconsin coaxially wound coupler ready for testing by the end of the year at PG&E's San Ramon Engineering Research Center. PG&E says it also hopes to test the Nissan fast-charging system this year.

Meanwhile, utilities serving cities as varied as Detroit, Houston, Los Angeles, New York, Philadelphia, and Sacramento are moving ahead with the installation of dozens of simple, nonintelligent outlets to support early demonstration vehicles. Also, EPRI is working with many utilities under a cosponsored EV research network program to establish some 14 centers for evaluating infrastructure technology.

Plans are being readied now for this network of centers, which will become the centerpiece of EPRI's EV infrastructure effort. Utilities such as Georgia Power Company, Duke Power Company, TU Electric, and the Los Angeles Department of Water & Power (LADWP) are taking leadership roles in specific focus areas of activity. For example, LADWP, which is spearheading the southern California EV infrastructure activities of the CALSTART initiative, plans to have about 60 charging stations installed by the end of this year—some located at utility and city facilities and some serving other company fleets and EVs at hospitals and universities.

Elsewhere, Sacramento Municipal Utility District (SMUD), which already has 71 charging outlets in place at 21 public locations, mainly in parking lots, plans to install 65 more over the next two years. And Detroit Edison Company is continuing its involvement with EVs, which dates from the turn of the century and includes more than 700,000 miles of on-the-road experience logged as a site operator in a Department of Energy EV conversion and demonstration program that ended in 1986. The Motor City utility estimates that it still has perhaps as many as 100 working charging locations, and it may put in another 30 to support new vehicles, including a fleet of 10 sodium-sulfur-battery-powered Ford Ecostar light vans due for delivery this fall.

EPRI, U.S. automakers, and a group of seven utilities are all sponsoring EV infrastructure technology design competitions to foster innovation in public charging and meter systems. EPRI expects to announce the first-year winners of its EV Curbside Charge Station Awards at its National EV Infrastructure Conference in December in Phoenix, Arizona.

Health, safety, and power quality issues

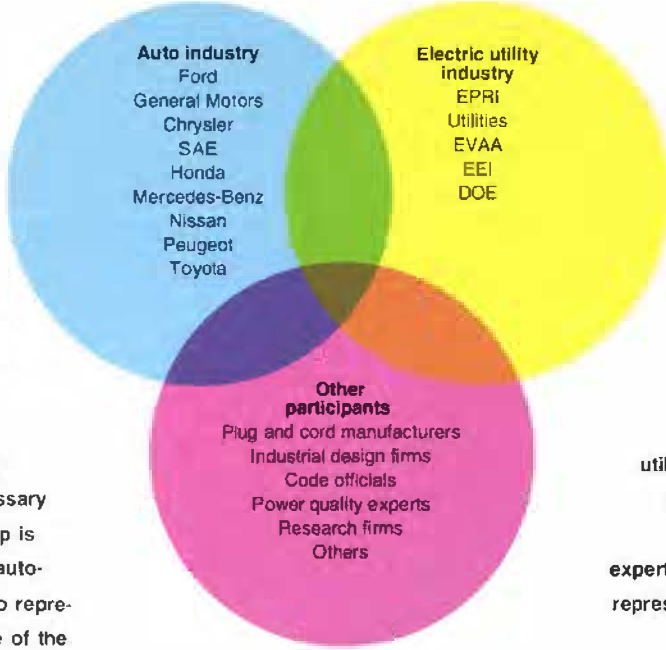
Concurrent with the testing and evaluation of the technical merits of a variety of charging systems, researchers are gathering data related to other concerns, such as health and safety issues. They are also characterizing the power quality and potential utility distribution system impacts of various charging systems.

With recent concerns about possible health risks of exposure to electric and magnetic fields (EMF), EV researchers have been careful to include EMF characterization in ongoing vehicle and charging-system evaluations. As part of its broad range of studies into the potential health risks and engineering aspects of magnetic field exposure, EPRI has conducted extensive magnetic field characterization tests on two electric vans in operation at the Electric Vehicle Test Facility in Chattanooga, Tennessee. In addition, PG&E is adding to the database with field measurements for additional vehicles and for inductive charging systems, which can produce both power-frequency (60-Hz) and higher-frequency EMF. With the assistance of PG&E researchers, EPRI is leading an industry effort to define a standard protocol for EMF testing of EVs. A similar effort is under way relating to power quality characterization.

Many EV experts express concern that questions about EMF could become a cloud over an otherwise bright horizon for EVs. But most also voice confidence that there are measures—including shielding, field cancellation techniques, and simple precautions like putting distance between an operator and a charging device—that could adequately minimize EMF from EVs should that become necessary as a result of concerns over EMF exposure. For now, the priority is to develop data based on standardized EMF measurements that can be evaluated against similar measurements for common electrical equipment and appliances.

THE INFRASTRUCTURE WORKING COUNCIL

In 1991, with the cooperation of the automobile and electric utility industries, EPRI formed a committee now known as the Infrastructure Working Council. The group operates as an open forum for discussion about EV infrastructure development. Its aims are the cooperative exchange of information and the coordination of efforts to foster the development and availability of the infrastructure necessary to support EVs. Although membership is informal, each of the Big Three U.S. automobile manufacturers is committed to representing both its own views and those of the Society of Automotive Engineers (SAE). Several overseas-based automakers have also joined the council. Participation by the electric utility industry is led by EPRI, with support by individual utilities, the Electric Vehicle Association of the Americas (EVAA), the Edison Electric Institute (EEI), and the U.S. Department of Energy (DOE). The automobile and utility industry participants are permanent members of the council. Making up the third group of council participants are experts who are invited as needed, including representatives of equipment manufacturers, design firms, and code organizations.



As a possible major new type of electrical equipment, EVs present a number of issues that the Infrastructure Working Council's Health and Safety Committee is tackling head-on. In addition to coordinating the work on EMF measurements and protocol definition, the committee, headed by Dave Brown of Baltimore Gas & Electric Company, has been developing a proposed new article for the 1996 edition of the National Electrical Code (NEC) to cover EV recharging. The panel will submit a draft later this year to the National Fire Protection Association, the NEC's publisher. The article will specify safety requirements for EV equipment and systems in order to minimize shock and fire hazard. Similar work to revise the four model building codes used by the various states is also under way.

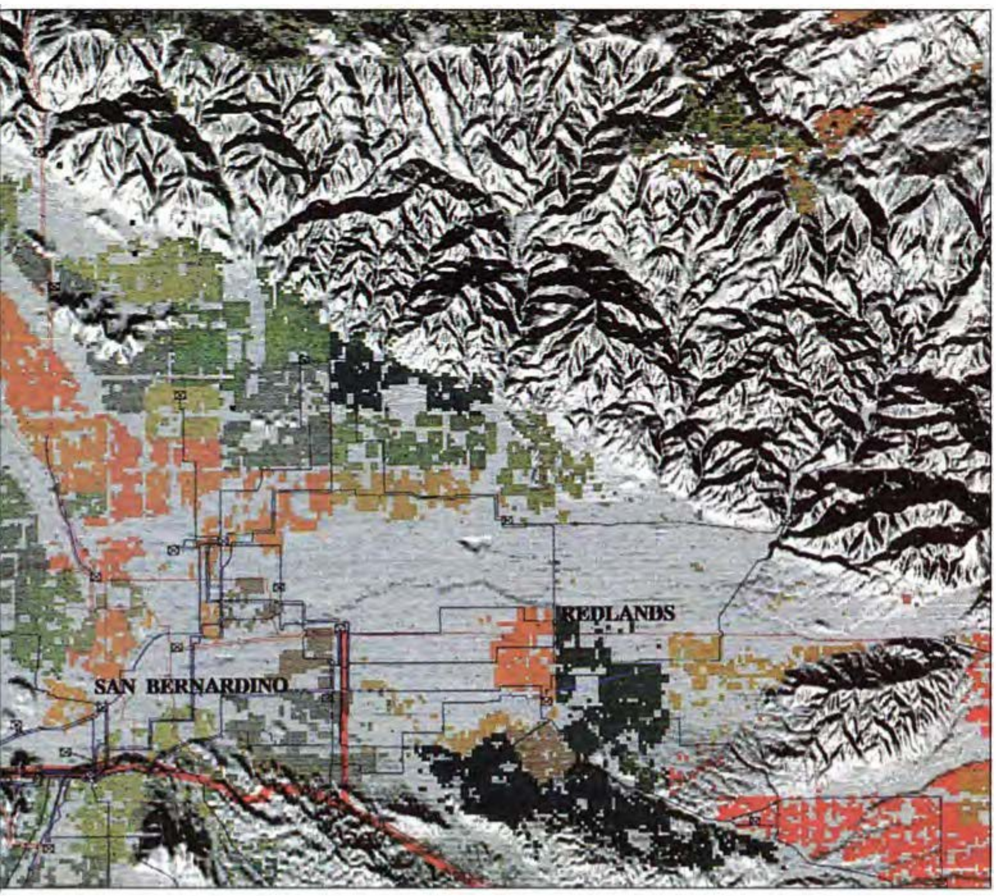
"Getting these code revisions will mean a lot to the commercialization of EVs. Wherever charging facilities are installed, they will be subject to inspection by the local code authorities, and if these authorities don't have something to use as a safety guideline, then some may approve of an installation and some may not," explains Brown, a long-time utility representative to the electrical code organization.

An example of the bumps in the road that can face EVs even in the Golden State—an example that highlights the importance of code revisions—was encountered when SMUD recently sought a local building code revision to require that future new single-family homes include a branch circuit for EV charging in the garage. Although vehicle developers and battery manufacturers have long known about the potential for producing some hydrogen gas during battery charging, the local fire marshal questioned whether the proposed amendment would require provisions for ventilation. The local code revision is on hold, pending work sponsored by SMUD to get answers that should resolve the questions. EPRI is sponsoring related work that should facilitate the adoption of EV wiring code provisions nationally.

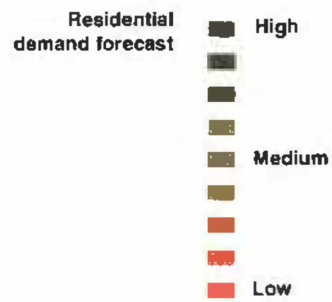
Brown says tests are under way to analyze the generation and dispersal of hydrogen from EV batteries in a garage-type enclosure and to determine what ventilation provisions, if any, may be needed. Underwriters Laboratories is under EPRI contract to certify the tests and to conduct other fact-finding to support the addition of the new article to the NEC. (Meanwhile, all the advanced batteries targeted for development by the USABC feature sealed designs that would generate no gases.)

So far the advance deadlines for revisions to future code editions have tended to set the pace on health and safety issues. But Brown points out that many other important issues have received less attention up to now because the various interested parties perceive that they will not present serious roadblocks to the commercial introduction of EVs. An example is the matter of battery recycling, which is expected to be carried out through vehicle dealers, perhaps in conjunction with battery manufacturers.

One health and safety area that has already received a full measure of attention involves fire and rescue procedures. The potential for high-voltage hazards and the release of hazardous or toxic battery materials from EVs in a crash poses special requirements for fire, rescue, and police personnel. Detroit Edison is working with the Big Three automakers to develop a comprehensive EV safety training course for such personnel. The course material, including a video, training manuals, and pocket guides, is set to be released this summer and will be widely distributed around the country. "This area is something that people often don't think of as part of the infrastructure, but it is," says John Olsen, Detroit Edison's EV program manager.



ASSESSING IMPACTS ON UTILITY SYSTEMS
Two West Coast utilities—Pacific Gas and Electric and Southern California Edison (SCE)—are conducting detailed assessments of the impacts of large numbers of EVs on their load management strategies and their distribution systems. In SCE's study, a computerized geographic information system (GIS) is being used to display the results of a University of California survey that identifies potential EV buyers in various districts. By combining the survey results and the GIS-based physical layout of SCE's distribution substations and circuits, the utility can locate vehicles within a district and evaluate the impact of EV loads on the components of its distribution system.



Planning for a unique load

EVs represent for the utility industry a unique prospective new load category, the emergence of which is being greeted eagerly and enthusiastically as well as with some trepidation. On the one hand, sufficient numbers of EVs to translate into significant electricity use and power demand would represent the first new major electrical load type to come along in many years. And to the extent that most of the vehicles would be recharged during off-peak periods, EVs could substantially improve overall utility system utilization factors, helping to lower the average cost of electricity, not to mention improving local air quality. EPRI studies suggest that there is sufficient unused off-peak utility generating capacity available in the regions of all urban areas hoping to see major growth in EV use in the next 10 to 15 years.

On the other hand, the EV is an electric appliance that—at the upper end of a typical vehicle's energy consumption—is nearly the load equivalent of an entire occupied family residence but that, unlike a house, moves around from place to place. Moreover, it is a load category that was not factored into the present capacities of the distribution systems serving most residential and commercial areas. In the absence of any load management incentives or controls and with unrestrained charging, the same EV could end up using both types of feeder for charging (commercial during the day while the vehicle is parked at work or public transit, and residential when parked at home), potentially making each's demand peak higher.

For many existing homes, it would almost certainly be necessary to install some new electrical wiring (like what is needed for an electric clothes dryer) in order to provide a 240-V/30-A charging circuit in a garage. Older, smaller homes with 60- to 100-A service might require a new panel and utility service drop to handle an EV circuit. (Many new homes have 200-A service.) Using the same transformer to serve more than a small number of EVs and charging circuits could potentially require upgrading or other system modifications.

These and related technical issues are being intently studied by a number of utilities, including PG&E and Southern California Edison Company (SCE). Each utility is taking a slightly different approach to evaluating the distribution impacts and load management ramifications of the appearance of large numbers of EVs in key parts of its service territory. Ernest Morales, a senior research engineer for SCE who heads the Infrastructure Working Council's Committee on Load Management, Distribution, and Power Quality, says that SCE is conducting a three-year study in collaboration with the California Public Utilities Commission (CPUC), the California Energy Commission, PG&E, and San

Diego Gas & Electric Company. Results from the study will help inform CPUC decisions on such equity-related questions as who should pay for distribution system upgrading if that is required—all ratepayers or just EV owners? What about stranded investment if EV owners move elsewhere?

"Most estimates of how many EVs a utility system could accommodate by the year 2010, for example, assume uniform distribution of the vehicles across the service territory, but we know that's probably not going to happen—some areas will see concentrations of EVs, while others will not," says Morales.

SCE is working to forecast the number of EVs that may turn up in each of its operating districts (as well as in LADWP's service territory). In this effort, a computerized geographic information system (GIS) that depicts the utility system in detail is being used to display the results of a large behavioral survey conducted by the University of California at Los Angeles. The survey results identify potential EV buyers in various districts under different scenarios.

On the basis of these results and the GIS-based physical layout of SCE's distribution system substations and circuits, the utility will spatially locate vehicles within a particular district. Once this capability is fully developed, SCE will be able to evaluate the total impact of EV loads on all the components of its distribution system. Some initial load forecast results could be available next year, says Morales.

Most EV chargers produced by original equipment manufacturers have a power rating of approximately 6.6 kW. In addition to residential charging, EV owners may want to charge their vehicles away from home, at convenience charging stations at such places as shopping centers and restaurants. And fast-charging stations would be located along major highways and freeways.

As a result, EVs could potentially have an impact on every part of the distribution system. "Thus a key element of our evaluation of EVs on our system is to look at ways to manage the load. Utilities are going to be ready and able to meet the demand from EVs, but it's going to take some innovative ways of managing this unique rolling load," says Morales.

Hence it may be essential that charging-connection gear be able to communicate in both directions between a vehicle and the utility system. Automakers are interested in an optical fiber data link between the vehicle and the utility connection because of that technology's imperviousness to electromagnetic interference, which could be generated by the charger. From the utility service connection back to the distribution substation, utilities are exploring the potential for a power-line-carrier-type signal on perhaps dedicated charging circuits to communicate with the substation and transmit utility load management signals—for example, signals that cycle vehicle charging or limit current draw.

PG&E is projecting the potential numbers of EVs in different parts of its service territory's 200 planning areas, across which the incremental cost of serving new load can vary significantly. The highest-cost areas to serve are likely to be those where substantial numbers of EVs are projected to come into service and that are already constrained in terms of distribution system capacity, says PG&E research engineer John Mead.

But despite the unanswered questions about the nature and impact of EV charging loads and about the psychology of consumer charging behavior, Mead says there should be plenty of time to gain experience with the limited numbers of early EVs—these will provide the answers utilities need in order to be prepared.

"I think we have more time than is generally believed to get answers to the questions about load and distribution impacts. EV technology still has a long way to go, and there are still many unknowns. But we feel that however many EVs come along, we will serve them," says Mead. "The question for us is whether there is an opportunity to do some load management and control of the nature of the load up front, before too many vehicles could become a problem. The first major projected new load in a long time will soon begin coming on-line, and we have a chance to address some of the energy demand issues in advance with the manufacturers and research organizations in order to influence the compatibility of those products with our system and alleviate potential problems. If we do our job right, no one will even notice." ■

Background information for this article was provided by Gary Purcell, Customer Systems Division.

WINNING IN THE 1990s

by Jack Welch

General Electric Chairman and CEO Jack Welch believes in managing not by the numbers but by a set of guiding values practiced by every employee every day. In this edited transcription of his keynote remarks at EPRI's recent International Symposium on Global Electrification,

Welch outlines his formula for effective enterprise and challenges utility executives to change their organizations in ways that will enable them to thrive in an increasingly complex and unforgiving marketplace.

The power business, like every other business in the world, is undergoing rapid change. Many of you have felt the influence of independent power producers in the United States, and IPPs are now in a global chase through Southeast Asia and other parts of the world as they look to electrify less-developed countries. This is a changing game; the utility business is no longer just regional, and no one knows that better than all of you in this room. The boundaries of our traditional markets are changing, and new players are increasing the ante on competitiveness.

What I'd like to talk about this morning is how one gets competitive, how one plays in this global arena. I'll start with the premise that to get there, you have to articulate a vision, clearly defining the exact thing you want to be, and then wrap around that vision a set of values, a set of behaviors that support it. When I talk about vision, values, and behavior, I'm using the terms not as annual report jargon but in a more practical sense—I see them as fundamentally the way you run a business, whether you are a utility, an IPP, or a supplier to the industry. I will be referring to General Electric a lot in this presentation, and I apologize for this. But GE is what I know best, and it offers examples I have found useful in getting my ideas across.

The vision: Our objective at GE was to be the very best in the world at everything we do or, at worst, number two in a given activity globally. If we were not, our challenge was to fix it. If we couldn't fix it, we would sell it, and if we couldn't sell it, we would close it down—get out of that aspect of the business altogether. Our objective was, and still is, to be the most productive, competitive enterprise on earth. That's the vision that we have.

What are the values one needs to fulfill that vision? I'll lay out four values that I have used effectively, although each of you can pick a set of your own, keyed to your particular vision. My set starts with *reality*; next comes an idea I'll call *boundaryless behavior*; third, *speed*; and fourth, *stretch* or *reach*.

First, reality. You, the leaders of your organizations, must see the world as it is, the situation as it exists. Not the way you wish it were, not the way it used to be, not the way you hope it will be. The way it is. For example, when I became chairman of our company in 1981, we had a vision that our nuclear business would sell one or two, maybe three, U.S. reactors a year. We were staffed up to do it, and the employees were ready to go. But we changed all that. Taking a hard look at reality, we said there would be *no* U.S. reactors ordered for the rest of the century, and there would be modest, sporadic reactor orders from outside the United States. What were the implications for GE and its nuclear business as a result of that view? Heavy R&D spending on future, safer reactors that are more acceptable to society, and a focus on fuel and services for existing reactors that would allow us to be the lowest-cost fuel and service provider for that industry.

This was an ugly process to go through. People were upset—angry—that we were forecasting the death of the business they had spent 20 years in. They resisted it. They wrestled with it. But in the end, that team came up with a new strategy: they put together the resources to develop advanced reactors and to provide service in the highquality fuel business. As a result, they had far fewer people in manufacturing but more in R&D and more in service. The outcome has been 12 years of relatively steady profits and a business much better positioned for the next century, for the time when enlightenment comes and more nuclear is required. We ended up with a business better positioned to play.

You see this kind of change coming in a variety of industries. In the airline business, in the aircraft engine business, communications advances are tipping the industry upside down. Telecommunications, videoconferencing, all kinds of electronic approaches to communication are causing a massive shift in the most attractive segment of the industry, the high-yield business traveler. Reality has been tough to come by here. Airlines have hoped that tomorrow would be like yesterday. We've been suppliers to that industry and we've seen them hope and wish, but believe me, business travel is changed forever.

And look what is happening with generics. Consider the highly publicized Marlboro Man battle, where the price of name-brand cigarettes is about twice the price of generics. The reality is that consumers want value, and brand loyalties are disintegrating. The same situation exists for drugs, home products, and foods. We are seeing rapid changes in industries that have been managing from a rocking chair—raising prices to consumers by 5% and 7% and 10% annually, while consumers are out buying unbranded products. Reality is going to hit the drug industry hard as the Clinton administration deals with new health care plans.

On reality

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This is the bottom line for reality: unless a company really gets down to seeing business the way it is, it has no place to go in formulating a strategy and no way to achieve the vision it is after.

The second value that I think is needed in an organization is boundaryless behavior. The best way to think of this big, long word *boundaryless* is to think of a house. It has walls between rooms. It has floors and ceilings between levels. It has people on the outside and people inside. Think of the house as your organization, floors being job levels, functions being defined by rooms. Now think of blowing it up, just disintegrating the house. That is what boundarylessness is all about. Get those horizontal walls down, the walls between your marketing function, your engineering function, and your manufacturing function. Get them down so people can communicate easily and fluidly.

Break down the outside of the house so suppliers and customers can participate in the entire process; take your ideas from wherever they come, and pay close attention to people from outside your organization. In new product development, the only way to bring something to market is to have one coffeepot, one room, one set of people all working together. No handoffs from engineering to manufacturing to marketing, but all team members together around one coffeepot, getting the thing done. This is how Chrysler was able to bring out its new LH cars in 24 months rather than the four to five years it used to take car companies to develop a new line.

Let me give you the story of a 100-year-old product—a GE steam turbine. We made incremental improvements in this turbine for over 100 years. Not a lot of new thinking, just a century of small changes. A year ago, a multifunctional team got together in one room around one coffeepot to figure out how to make a *big* improvement. And they did—they reduced the size of this 660-MW turbine by 20% and took a million pounds out of it, a 33% weight reduction. The point is not the great product they developed, but that within a year they were able to make massive change in a 100-year-old product by getting everyone focused on developing the answer.

I was in Cincinnati, Ohio, yesterday to review the progress on the GE-90, which is the new 100,000-pound-thrust engine to power the Boeing 777. It's an enormous engine. This product is being built under the direction of GE with three supplier partners—IHI of Japan, SNECMA of France, and Fiat of Italy—and has been in development for a year. We fired the engine up for the first time last week, and it met every specification the first time out. That's fantastic—we've never been close to doing something like that before. But the interesting thing is that, besides the partners, the other person in the room every day working with us is from British Airways, our launch customer. And he's telling us all the things a customer needs to maintain that engine. Now you have a Japanese team, an Italian team, a French team, a U.S. team, and a British customer, all designing a billion-and-a-half-dollar development project in one room—no walls and one coffeepot—getting the whole program done.

Sharing across boundaries is so important in our company that this behavior is part of how we measure our people. We take it very seriously. The first way you can get thrown out of GE is for an integrity violation—you're gone with an integrity violation. The second way, which falls just below that, is someone who doesn't behave in a boundaryless fashion—someone who holds on to turf, protects his own ideas, doesn't look to suppliers, doesn't reach out to every source for inspiration. Anyone who approaches things that way is gone.

Performance appraisals are done in the following way. We have what we call 360-degree appraisals of our people. That means the subordinates all evaluate the managers, the peers all evaluate the managers, and the superiors all evaluate the managers. So every year managers get a review from each of the people they interact with—an evaluation on boundarylessness, on reality, on the values I've been talking about. That's how we manage the business, not around the numbers but around the behavior, because the behavior will drive the numbers. If you start with the numbers, that focus will stop you from reaching them.

Boundaryless behavior, when you get it, leads to the most important competitive element: speed. That's the third value. When you compress manufacturing-cycle times, you are more responsive to your customers. You can lower inventories and get better asset utilization. We're at the point now where we can get an order for an appliance—say, a green refrigerator with the handle on the left side—on Monday in New York, and by the following Monday have it to the customer. It used to take us 12 weeks; we're down to about a week or 10 days, and we want to get to 3 days. You pick your color, you pick your features, you pick what you need, and we've got flexible factories operating without boundaries to produce it. You order on Monday, we make it on Tuesday, and you have it on Wednesday. That's the objective. You get better quality this way, because with speed you *have* to have quality. If you're set up for speed, then quality, service, all the other things fall into place.

New products, the key to growth, also come from this speed element. The Japanese auto industry got to 30% share of the U.S. market certainly by lowering costs and increasing quality, but also by always having a fresh product line with new features. Every year they would introduce something new. The U.S. companies would go for the big one—what we call the moon shot. They'd get a new product out there and then stay with it for five years, while the Japanese competition kept rolling out new products on a regular basis.

We have a pressing need in this country to take advantage of these concepts. As I mentioned, Chrysler did their last car in 24 months. It cost them about 1.7 billion dollars. They'll do their next car in less than 12 months, and it will cost them less than a billion dollars. It used to cost 4 to 5 billion dollars to do that sort of thing. Chrysler will be able to do it faster and cheaper because they've broken the walls down—they're operating in a boundaryless fashion with speed. This ability to roll out new products with new features in a timely cycle will differentiate those players that continue to go forward from those that fail.

But speed does something else to an organization that is perhaps of equal importance: it creates excitement. Speed is exhilarating—it energizes an organization and brings people to life. Speed also kills resistance to change. It blows over those well-dressed bureaucrats who hide in companies. "Slow" is a tough value to sell. It has no constituency. Who can say to the team, "Let's go slow"? Speed rallies people. It gets you better customer service, it makes you more responsive. Speed can really take an organization to a new

On boundaryless behavior

"In new product development, the only way to bring something to market is to have one coffeepot, one room, one set of people all working together. No handoffs from engineering to manufacturing to marketing, but all team members together around one coffeepot, getting the thing done."

height of energy. And it can truly differentiate you from your competitors.

This leads us to my final value, which is stretch. What we call stretch, or reach, is the thing we have learned about in our company the most recently. Stretch is raising the bar far above what you have any reason to believe one can achieve. For example, we had a company that operated at 3 to 4 inventory turns; we put the bar at 10. We had a company that had operating margins in the 7–8% range for decades; we put the bar at 15%. We didn't have the foggiest idea how to make these goals—no brilliant management technique for how to get there. But we did have a boundaryless organization built, we had speed as a value, we had reality as a value, and we had an empowered work force.

Think of all the times you've sat in a budget meeting and someone across the table comes up with some productivity measurement of 4.017, and you say, "Let's get it up to 4.217." And you debate and you wrestle all around these minute numerical changes that have nothing to do with excitement, that have nothing to do with reach, that have nothing to do with dreaming. What they do have to do with is bureaucracy. And they won't get the job done.

Our objective in this whole game is to put the bar way up on the top. Give people the challenge. Let them reach, let them stretch, let them dream. Let them come up with the ideas they need to get it done, because they're the ones who know how to do it. And when they start to make their ideas work, be sure as hell you don't punish them. Don't start to think of that 10—that stretch goal—as the kind of number you used in the old game. If your goal is 10, and someone goes from 4.017 to 6, take care of them, reward them, cheer them on, because they're on their way to something very special.

In our company we recently had our first business reach 10 inventory turns, tying up only a dollar in inventory for every 10 dollars in sales. That's an unbelievable increase; we've never been close to it before. Our company as a whole will soon be at over 6. We'll be over 8 next year and at 10 in 1995. We *know* we'll be there. None of us bureaucrats know how to get there, but people in the organization, with their hands close to the action, know how to do it and they *will* do it. We wouldn't have had a prayer under our old system of beating the budget, with us picking a number, negotiating between two finite elements to set the goal. Now let the number be as far as your eye can see, and let people go get it. They will.

I believe the winners of the competitive battles of the 1990s will set big targets, seemingly unreachable targets. They'll set numbers that are off the scale, and they'll unleash the energy, the creativity, the dreams in their organizations that can get them there.

In my view the winners, whether they be the utilities or the independent power producers, whether they be regional or global, will not be the ones that I call other-dependent. They won't depend on price or load growth or the economy. They won't be hoping for some legislative action. They'll be companies that have taken control of their own fate, companies that understand that productivity, speed, and excited and inspired people are the keys to winning. It is the people who share the dreams of that vision—the people who are inspired to reach for the seemingly impossible goals—that will lead companies of every form to greater heights and greater victories in the global competitive battle. ■

On speed

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Rural electric cooperatives—generally smaller and more remote than municipal and investor-owned utilities—are sometimes assumed to be technologically unsophisticated. But many co-ops today rely specifically on advanced technology to meet the economic and technical challenges that come with delivering high-quality electric power to sparsely inhabited but increasingly demanding service territories. In an effort to understand the challenges rural electric cooperatives now face and their use of high technology to address some of these issues, we visited three EPRI member co-ops and interviewed several others over the phone. The stories that follow illustrate what we found.

RURAL CO-OPS BIG ON R&D

by Leslie Lamarre

The road from Palm Springs up to Anza, California, cuts seven switchback turns through the San Bernardino National Forest. The rugged journey offers a taste of the kinds of difficulties that come with bringing electricity to Anza, a community of 5000, nestled in an arid valley at 4000 feet. In the spring, violent winds whip up Anza's rocky sand, spitting it against people, cars, buildings—anything that stands in the way. Winter brings flash floods, which this year came within inches of knocking out power to half of the town.

When electricity came to Anza in 1955, the people followed. And as the area has grown, so has the demand for power. This has increased the challenges for Anza Electric Cooperative, the utility responsible for keeping the community's lights on. According to David Coyle, general manager of the 17-employee co-op, by the end of the decade demand will exceed the capacity of the only transmission line bringing power to the co-op's 500-square-mile service territory. Upgrading the line is certain to be an expensive proposition, and it wouldn't exactly be easy. The line cuts through a section of the national forest, and environmentalists are prepared to block any work along this right-of-way.

As an alternative, Anza Electric—in collaboration with its generation and transmission provider, Arizona Electric Power Cooperative, and EPRI—is exploring the possibility of installing small generation locally to meet peak demand and delay the transmission upgrade. This strategic application of modular generation, a concept called distributed generation, is new to large and small utilities alike. Anza may be among the first utilities to demonstrate it with EPRI. "Here we're seeing a rural electric cooperative taking an innovative approach to improving and lowering the cost of service," says Dan Rastler of EPRI, who oversees the study. "Anza is moving in a direction that only a few of the bigger utilities are considering at this stage."

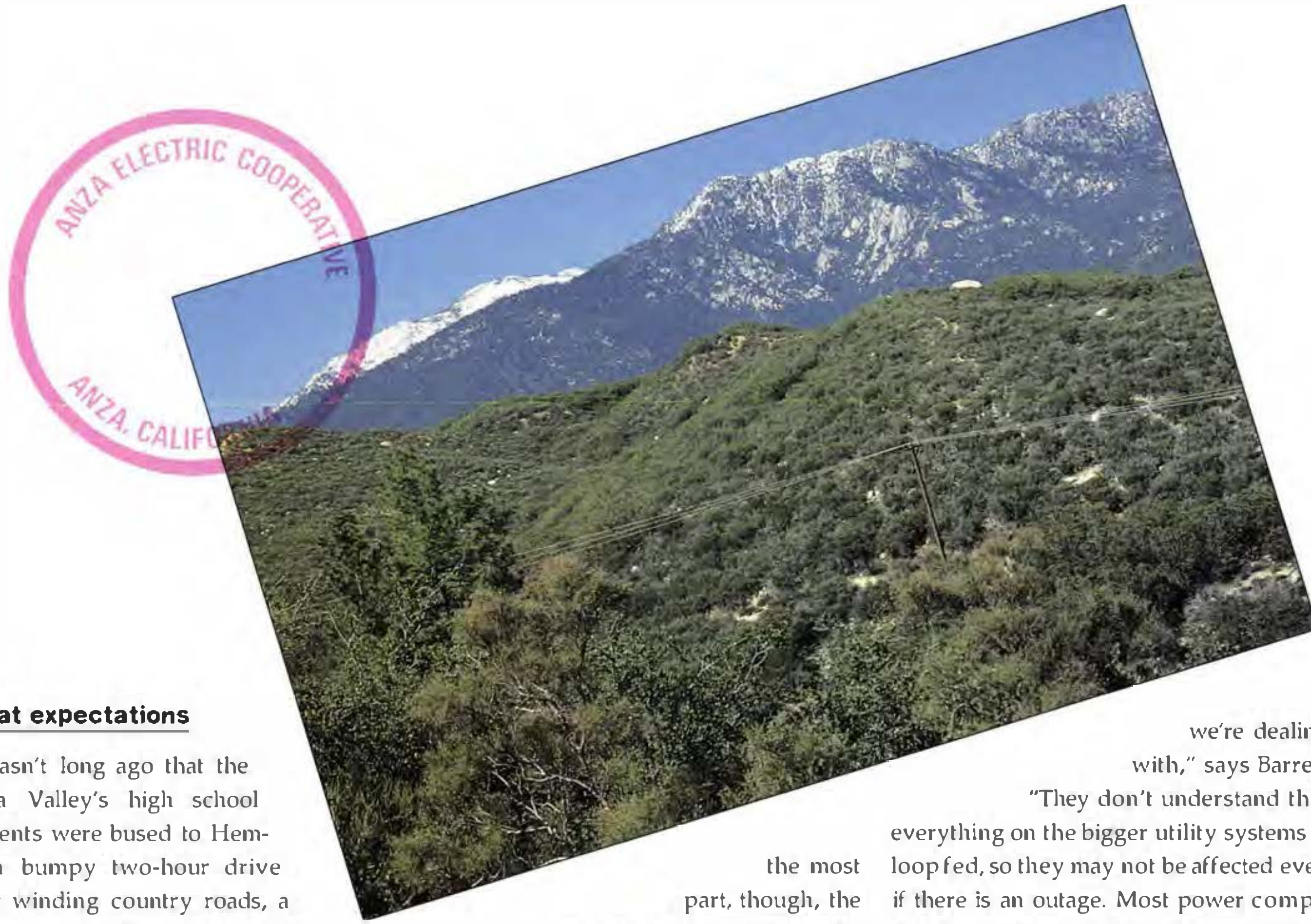
Other rural electric cooperatives across the country are similarly demonstrating and deploying advanced technologies in an effort to address the unique challenges that come with providing high-quality electric power to sparsely inhabited but increasingly sophisticated rural areas. Here are just a few examples of the dozens of big research projects that co-ops have taken on: Alabama Electric Cooperative demonstrated the nation's first compressed-air energy storage plant; Colorado Ute, now part of Tri-State Generation & Transmission Association, conducted the industry's first utility-scale demonstration of a circulating-fluidized-bed boiler; Hoosier Energy demonstrated that optimizing scrubber chemistry could capture an additional 10,000 tons of sulfur dioxide annually; and Arizona Electric is successfully employing photovoltaics to power nighttime air traffic warning beacons atop 11 transmission towers.

In the 56 years since the first of the nation's rural electric cooperatives were established, the service territories of many have changed dramatically, to the extent that those co-ops now serve semiurban areas. Other co-ops serve regions nearly as remote as they were half a century ago. But whether they are seeking to maintain a competitive edge over neighboring utilities or simply trying to keep the lights on, many rural electric cooperatives find they have an increasing need to keep up with advanced technology.

Of greatest interest are technologies that address the efficiency of distribution systems and the quality of the power delivered through them. Although today's nearly 1000 electric co-ops provide power to only 10% of the U.S. population, their service territories cover 75% of the country's landmass and they own over half the nation's miles of distribution lines. "Because there are so few consumers per mile, advanced technology R&D is crucial for the co-ops," says John Neal, administrator for energy research and development with the National Rural Electric Cooperative Association (NRECA). He notes that the co-ops average about 5 consumers per mile of distribution line, compared with 30 per mile for investor-owned utilities and over 40 for municipal utilities. "You can't keep sending a guy out 50 miles in a truck to read two meters," Neal says.

Other research interests are spurred by co-ops' challenging load profiles. Because, on average, 90% of rural electric cooperative customers are residential, the co-ops' loads tend to peak in the early evening and then to drop off significantly when residents go to sleep. "Some co-ops hardly need power plants after their customers go to bed," says Neal. Increasing end-use energy efficiency to shave peak evening loads is of great interest to co-ops, as are various load-shaping technologies and load management strategies. For instance, storage units can tap distribution, transmission, and generation capacity that would otherwise sit idle during nighttime hours. And like larger utilities today, co-ops with generating capabilities are also concerned about further reducing emissions of sulfur dioxide and nitrogen oxides. As a result, they are actively involved in demonstrating technologies and processes that accomplish this aim.

Not all co-ops are in a position to invest heavily in R&D. Some serve impoverished rural areas that continue to lose customers. But for those that are growing, research is a clear priority these days. "A lot of people ask me, 'How can you guys afford to do some of that stuff?'" says Steve Healy, general manager of Pierce-Pepin Electric Cooperative in Ellsworth, Wisconsin, which has been involved in some significant R&D projects with EPRI. "I say, 'We can't afford not to.'"



Great expectations

It wasn't long ago that the Anza Valley's high school students were bused to Hemet, a bumpy two-hour drive over winding country roads, a worse journey than many adult commuters endure. "Those poor kids were getting dressed at 5:00 in the morning and getting home after dark in the winter," recalls Chris Barrey, operations manager for Anza Electric Cooperative. But the advent of electricity has brought many newcomers to Anza, and the town's Hamilton School has expanded grade by grade. In 1991 it finally served all grades, K through 12. Today the school has 900 students and is one of the co-op's largest loads.

Roughly two-thirds of Anza's 3300 customers are residential, accounting for 67% of the co-op's electricity sales. Small and large commercial customers account for 26% of the sales, while irrigation for farming (there are 900 acres of potato fields in the area) makes up the remaining 7%. Most of Anza's residents are retired; jobs are few in these parts, and the co-op is the community's biggest employer. Many of the workers who live in Anza commute to places like Hemet and Temecula, both about 40 miles away.

Some of the community's longer-term inhabitants grew up on the two Indian reservations served by the co-op. For the most part, though, the newcomers to Anza are city folks who came seeking a more peaceful environment and affordable real estate. And although there are few paved roads, no gas service (propane fulfills most cooking needs), and no central water system (most people have their own wells), many newcomers expect the same service from the co-op as they got from their investor-owned and municipal utilities back home. "People come here from the city and expect to get as high a level of power quality as they experienced in urban areas, so we strive to keep up with the technology," Barrey says.

Over the past several years, the co-op has upgraded all substation equipment to the most advanced technology it can provide without being automated. Still, the region's rugged and environmentally sensitive terrain and its vulnerability to natural disasters, such as lightning strikes, flash floods, and high-wind dirt storms, offer the co-op some significant challenges. On top of all of this, the single transmission line that feeds the community's entire power system is a radial-fed circuit with no backup. "People just don't understand the kind of situation that we're dealing with," says Barrey. "They don't understand that everything on the bigger utility systems is loop fed, so they may not be affected even if there is an outage. Most power companies have an alternative or backup source of transmission. But when this line is down, the power's out for our entire service area."

Because parts of the line are owned and operated by a separate, investor-owned utility, Anza crews cannot directly respond to certain problems on those sections. In fact, says Coyle, "Ninety percent of the time all we can do is wait for the power to come back up." When outages do occur, they typically last about an hour, partly because—as a forest fire prevention mechanism—utility crews must physically patrol the sections that run through the national forest before power is restored. Last year the community experienced four hours of system outages. "It's getting better," says Coyle, noting that some improvements have been made to the transmission line.

Why should the co-op fret about these occasional outages? It's not that it has any competition from neighboring utilities, eager to encroach on its turf. As Barrey puts it, "Few investor-owned or municipal utilities would be interested in taking over such a sparsely populated service territory." Rather, the co-op's primary concern is in doing what it's supposed to do—provide reliable electric service to its customers. Among them are about one dozen people who rely on electrically powered life-support systems. Because Anza is a full hour's drive from the nearest hospital, the co-op and the local volunteer fire department keep small generators and portable oxygen bottles on hand to deliver to these customers in the event of an emergency.

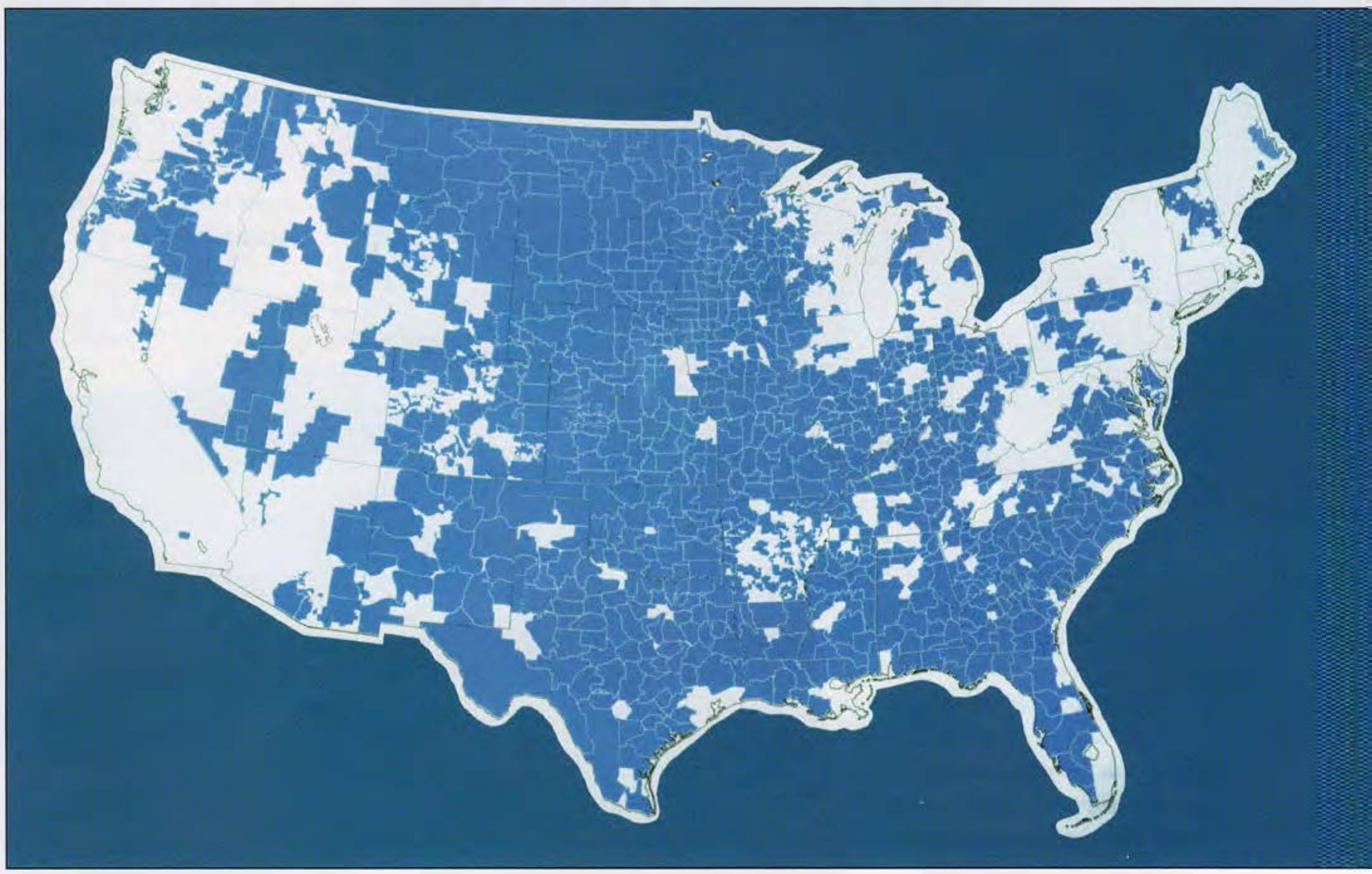
Approaching the limit

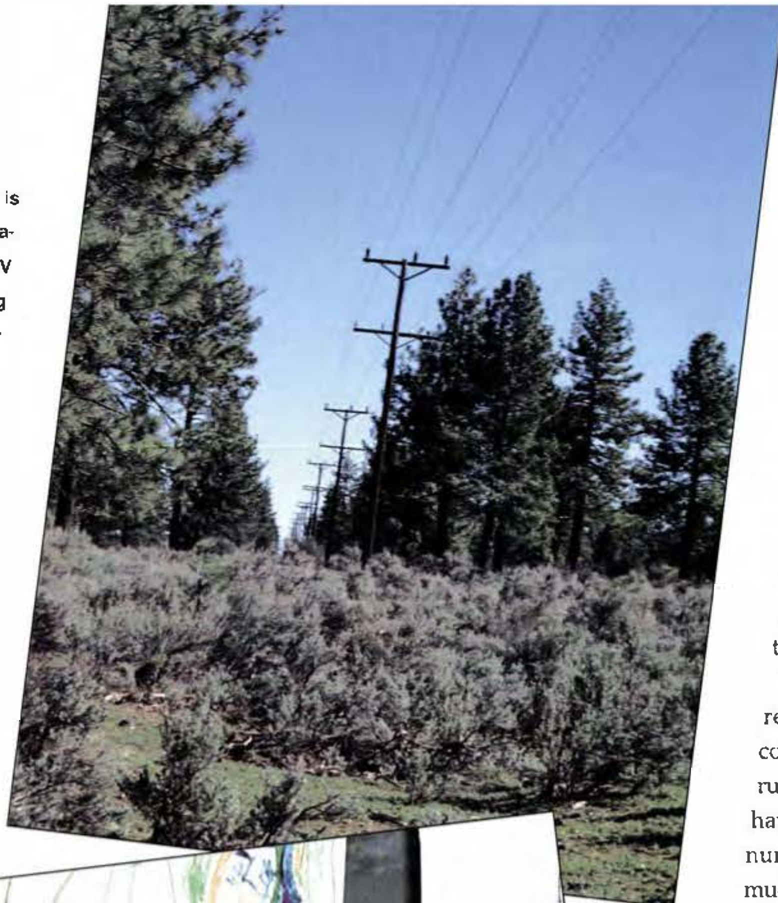
Unexpected outages on the 33-kV transmission line are not the only worry. Anza Electric is also concerned about the capacity of the line. At the rate electricity demand is growing (averaging 5% annually since the late 1980s), the line will need to be upgraded by 1999, the year demand is expected to exceed its 8.5-MW capacity. This is why Arizona Electric Power Cooperative, the generation and transmission co-op responsible for delivering power to Anza over the line, has initiated a one-year study with EPRI to explore possible alternatives to the traditional and expensive approach to this problem.

The first step of the EPRI-led study, which got under way in February, entails conducting an in-depth assessment of the problem and developing near-term solutions, including voltage support upgrades and programs intended to reduce peak demand. If such demand-side management programs are successfully implemented, they could help defer the need to upgrade the line. Because a flexible planning approach is needed, EPRI is developing a least-cost plan that takes demand-side management programs and other options into consideration, including some transmission and distribution upgrades as well as the implementation of modular generation technologies, or distributed generation (DG). According to Dan Rastler of EPRI, one near-term solution may be to employ an internal combustion or diesel engine at one of the co-op's substations. However, as Rastler notes, emissions from such a unit could prevent its implementation; because the community is in Riverside County, it must adhere to stringent emissions regulations set by the South Coast Air Quality Management District.

The cost-effectiveness of longer-term options, including photovoltaics, batteries, and fuel cells, is also being explored. "We're bringing the whole portfolio of DG technologies in to see what they are going to cost, when they will become available, and how they fit into the plan," Rastler says. By early next year, EPRI will issue its recommendations on which technologies to implement, along with a plan for their implementation. Rastler points out that

CO-OP TURF Today nearly 1000 rural electric cooperatives serve some 25 million customers in 46 states. While this amounts to only 10% of the U.S. population, the service territories of the co-ops cover 75% of the nation's landmass. Together, the co-ops own over half the miles of distribution line in the country. (Alaska, which is home to a number of rural electric co-ops, is not pictured here.)



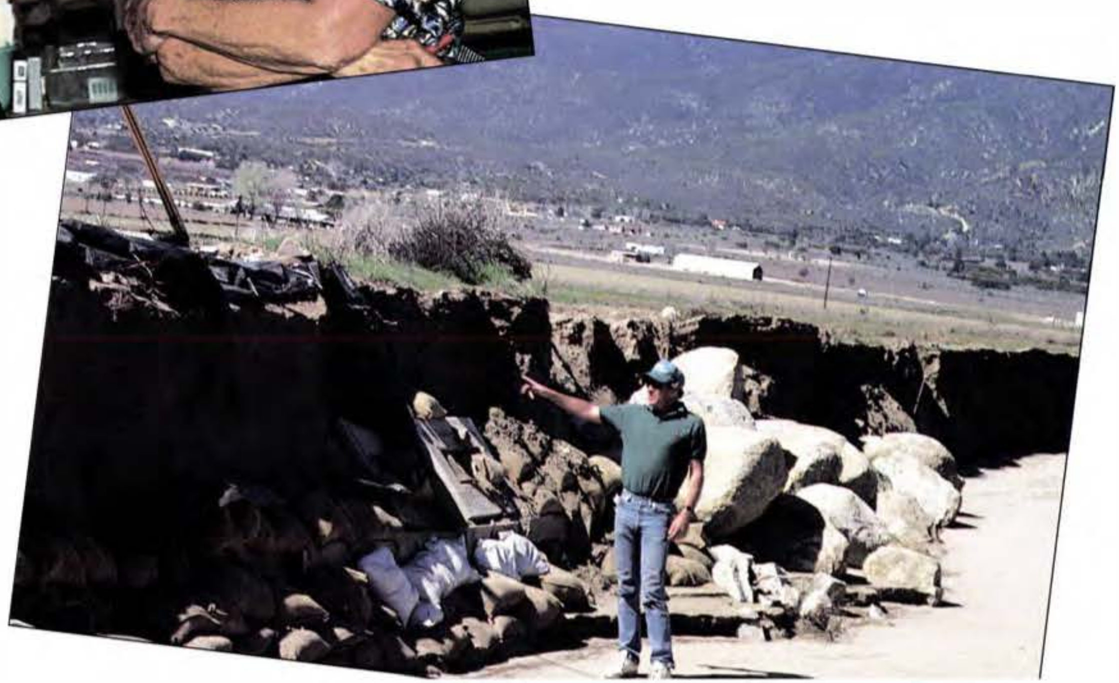


Anza Electric Cooperative is exploring innovative alternatives to upgrading this 33-kV transmission line, including the local siting of modular generation units.

this project could break new ground in the Institute's study of DG, to the benefit of all members interested in this relatively new concept. "The ability of distributed generation to defer T&D upgrades is a prevalent theory that has not yet been thoroughly demonstrated," he says. "We need data on the reliability and the life-cycle costs of DG systems that are up and running. This project may very well help us answer critical questions about the potential of this approach."

According to Rastler, EPRI's DG research is particularly valuable to co-ops. "The service territories of rural electric cooperatives tend to have a lot of area per capita, with a number of long radial feeders. And much of the future U.S. load growth is projected to occur in rural areas. This could put a strain on existing T&D feeders, which DG could relieve." Among the other co-ops studying DG options with EPRI is Oglethorpe Power Corporation.

Anza's Hamilton School is one of the co-op's largest loads.



Chris Barrey, operations manager for Anza Electric, points out a guy wire that came within inches of being swept away by a flash flood last winter.

Leveraging R&D

As consumer-owned, nonprofit business entities, individual co-ops don't have lots of money to spend on research, but many leverage the cash they do have through EPRI and the National Rural Electric Cooperative Association. NRECA administers a joint $3.4 million R&D program called Rural Electric Research, which focuses on projects of specific interest to cooperatives.

As is the case with EPRI membership, participation in the RER program is voluntary. Still, 35 of the 46 states served by co-ops are represented in either EPRI or the RER program; the participating co-ops account for 42% of the total kilowatthour sales of rural electric cooperatives nationwide.

RER participants have the option of joining EPRI on their own or through the RER program. The co-ops that join through RER usually phase into EPRI membership over a three-year period, at the end of which 80% of their dues goes to EPRI and 20% to RER. Most typically, the generation and transmission co-ops join either EPRI or RER on behalf of their distribution co-op members, but occasionally a distribution cooperative will join on its own initiative.

EPRI has many projects under way with its 363 co-op members, most of which are collectively sponsored group efforts through NRECA. The accompanying table highlights some of EPRI's current tailored collaboration projects with individual rural electric cooperatives. ■

Project	Participating Co-ops	Value to Co-ops
Solid-waste leaching study	East Kentucky Power Cooperative	This study will investigate how waste and wastewater leach from scrubber sludge ponds into the earth. The results will help co-ops with coal plants operate sludge ponds.
Application of information from EPRI's Center for Electric End-Use Data (CEED)	Hoosier Energy Rural Electric Cooperative	Documented lessons from Hoosier's experience will provide guidance for other co-ops interested in tapping into the CEED data resource.
Development of an efficient indoor heat pump for mobile homes	Alabama Electric Cooperative, East Kentucky Power Cooperative, Oglethorpe Power Corporation	Since 16% of co-op consumers live in manufactured housing (compared with 5% for other utilities), this heat pump—installed in mobile homes at the factory—could help co-ops manage peak residential loads.
Demonstration of distribution automation and the Utility Communications Architecture (UCA)	Oglethorpe Power Corporation, United Power Association	This demonstration is geared toward enhancing communication between generation and transmission co-ops and their member distribution co-ops.
Demonstration and commercialization of a 2-MW molten carbonate fuel cell	Arizona Electric Power Cooperative, Oglethorpe Power Corporation, United Power Association	Producing few emissions, fuel cells are strong candidates for serving small loads in co-op distribution regions.
Rural water and wastewater study	Arkansas Electric Cooperative Corporation, Buckeye Power, Clark County Rural Electric Membership Corporation, Dixie Electric Cooperative, Hoosier Energy Rural Electric Cooperative	The development of small-scale water and wastewater electrotechnologies promotes economic and community development, which directly affects electricity demand.

Power quality

When the Kellstone Quarry on Kelleys Island in Lake Erie cranks up its motors for stone crushing, its neighbors know it—not by the sound, but by the flicker of their lights. The quarry is the biggest single load on the island, located 4 miles off the coast of Sandusky, Ohio, and about a mile from the Canadian border. "When they start those motors, there's a little dimming," says John Cheney, president and general manager of Hancock-Wood Electric Cooperative, which serves the island. "The lights come right back up. But it's not the kind of service we like to give."

With 1500 inhabitants in the summer, dwindling to 125 during the frigid winter months, the island represents only 7% of Hancock-Wood's customers and an even smaller percentage of the co-op's total electricity sales. But its power quality problem offers an ideal opportunity for the demonstration of an emerging technology—a static VAR compensator (SVC) for the distribution system—that could benefit many utilities, including cooperatives. SVCs employ solid-state technology, which allows them to compensate for sudden changes in voltage, responding instantly to fluctuations that may occur during a given electrical cycle.

SVC technology is already commercially available for utility transmission systems. But according to Harshad Mehta of EPRI, who manages projects pertaining to this technology, no practical SVC has been developed for the distribution system; the existing technology is too expensive and bulky. To address these problems, EPRI and NRECA have developed a prototype distribution SVC. It is significantly more compact than transmission SVCs, and when it becomes commercially available (as anticipated in 1995), it will sell at a much lower cost, Mehta says.

Hancock-Wood is one of four EPRI members that will demonstrate the prototype SVC technology for one year starting this August. The co-op hopes that the SVC not only will regulate voltage, offering a solution to the light-flickering problem, but will also effectively increase the power delivery capacity of the two 20-year-old submarine cables delivering electricity to

the island. The other alternative the cooperative has explored is adding a new cable to provide greater power delivery capacity, a project that would cost $1.4 million. "That's a big expense relative to the island's population," says Cheney. And according to Mehta, while this approach might help alleviate the flicker problem, it wouldn't resolve it.

During the 12-month demonstration of the prototype SVC on Hancock-Wood's system, the co-op will monitor the unit's performance closely. The results will help Hancock-Wood determine whether the technology might offer a good permanent solution and will help EPRI improve the product for the market. Mehta expects other co-ops to show a strong interest in this technology once it is fully developed. According to Martin Gordon, NRECA's program manager for energy R&D, "Rural electric cooperatives have many potential applications for this technology. They tend to have long distribution lines, and since voltage fluctuations may occur during the delivery of electricity along those lines, static VAR compensators could be employed to maintain the voltage."

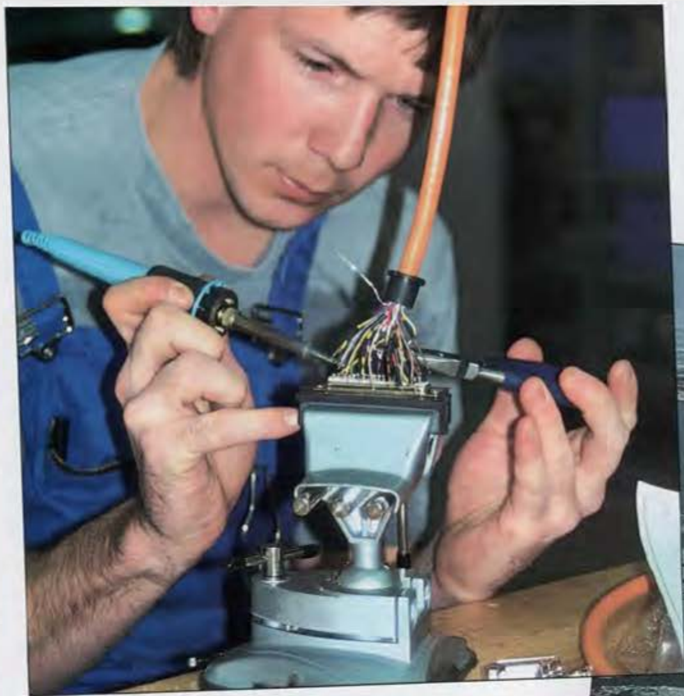
Sophisticated customers

Fifty-three years ago, when Hancock-Wood was established, the fertile plains of northern Ohio drew hundreds of farmers to the region. While grain farms are still prevalent in the area these days—yielding mostly corn, soybeans, and wheat—the emphasis is on high-volume production; farmers who once made a living off of 100 acres now need 500. Today residential and farming customers together account for only 35% of the co-op's sales. But the growth of Hancock-Wood's commercial and industrial customer base has been good for the co-op and the local economy. Cheney credits Interstate 75—which provides a direct link to Toledo, 36 miles north of the co-op's North Baltimore headquarters, and to Detroit, an additional 45 miles north on I-75—for luring much of the business growth the co-op has experienced over the years.

"We're selling power to firms that are larger and more sophisticated than those of the past," says Cheney. "Their need for our technical expertise is increasing." One of these firms, a German-owned company called Grob, designs state-of-the-art robotics for automobile assembly lines. Proximity to the automobile industry in Detroit was a critical factor in the company's decision on the location of its plant. The 50,000-square-foot facility, which houses apprenticeship workstations, drafting facilities for engineers, welding stations, sophisticated diagnostic machinery, and testing quarters for the prototypes produced, is one of only three such Grob plants worldwide. It began operating in October 1991 with fewer than 30 people and now employs 110.

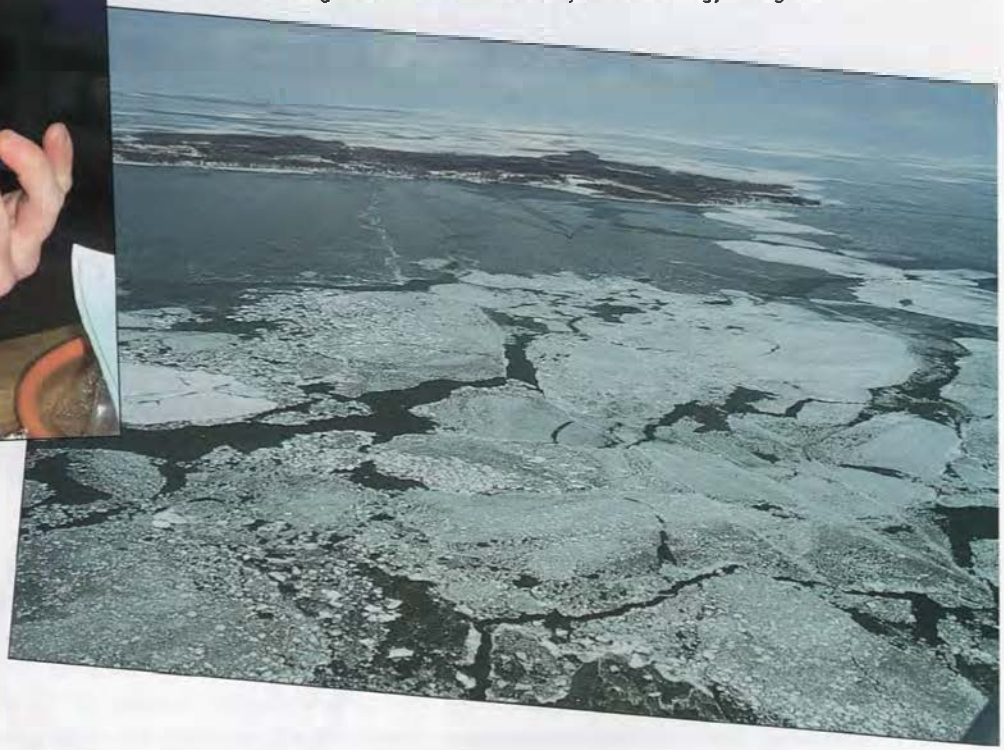
Another industrial customer, Air Products and Chemicals, employs only nine people but represents 40% of the co-op's business. Located across the street from the co-op, the company's plant manufactures such air products as liquid nitrogen, liquid oxygen, and liquid argon. It is also one of the biggest industrial loads on the system of Buckeye Power, the generation and transmission cooperative that serves Ohio's 27 distribution cooperatives, including Hancock-Wood. "Our only raw materials are electricity and air," explains Bob Miller, who manages the plant. The firm's five motors, which total 23,500 horsepower, run every day around the clock except when units are taken down for maintenance or when the company shuts the plant down during peak demand periods.

The Air Products plant gets a significantly reduced rate for decreasing its power use during peak demand. The com-



An employee of Grob, a German-owned company that designs robotics for automobile assembly lines, completes some intricate work. Grob is one of several high-tech customers in Hancock-Wood's service territory.

Hancock-Wood Electric Cooperative's service territory includes Kelleys Island in Lake Erie. A stone quarry on the island will begin testing an advanced distribution system technology in August.



pany bases such decisions on information relayed through Buckeye Power's two-way satellite communications system. Linking Buckeye's load management center to the Air Products plant, the system relays load management data to the company every 5 minutes. The satellite system is also used to communicate load management information for the direct load control of water- and space-heating systems in the service territories of all of Ohio's co-ops. According to Herb Caldwell, a manager at Buckeye who oversees load control, the data communicated by the satellite are delayed by approximately 1 second. Although there was no delay with the previous system, which relied on 2600 miles of dedicated telephone lines leased by Buckeye, the satellite system's monthly operating costs are 40% lower. In the four years since its installation, the satellite system has paid for itself.

The use of satellite technology for load control is relatively new to the utility industry. In fact, because of Buckeye's experience in this area, it was one of three utilities selected to participate in a current EPRI project on bidirectional satellite communications technology. The aim of this project is to significantly reduce the size and expense of satellite dishes. "The co-ops really got the ball rolling on this one," says William Blair, the EPRI manager overseeing the project. "The big dishes usually cost $20,000–$50,000 installed, and rural electric cooperatives generally don't have that kind of money. Our goal is to produce a much smaller dish that utilities can buy and install for under $10,000." As Blair points out, the bigger utilities stand to benefit from this project just as much as the co-ops. For them, Blair says, the issue is not only money but also the space limitations of compact urban substations.

The EPRI contractor for the project, Nova-Net, has selected and modified an existing GTE technology to meet a number of utility requirements. By July, the new prototype satellite dish is expected to be ready for demonstration on the systems of Buckeye Power, United Power Association, and Public Service Company of Colorado.

This section of East Findlay has traded farmland for shopping centers in recent years, contributing new business to the co-op.

PIERCE-PEPIN ELECTRIC COOPERATIVE
ELLSWORTH, WI

Holsteins and high technology

Forty miles east of St. Paul, Minnesota, in the rolling hills of Wisconsin, lies a land seemingly removed from the bustle of urban life. This is big farm country; red barns, white barns, and gray barns with clusters of towering silos dot the open fields along Route 10, the road that leads to Pierce-Pepin Electric Cooperative in Ellsworth (population 2800). But first impressions can be deceiving. If the trends projected by demographic experts are accurate, the area is gradually becoming a bedroom community for the Minneapolis–St. Paul region. Farmers today represent only 6% of the co-op's accounts, compared with 100% when the co-op was established in 1937. Residential service—primarily to commuters who work elsewhere—represents 90% of the co-op's accounts. The remaining 4% of its customers are commercial and industrial.

Experts have projected that this area is ripe for further development, since the land within reasonable commuting distance to the west of the Twin Cities is already almost fully developed. This year, for the first time, the federal Office of Management and Budget included Pierce County, the home of Ellsworth, in the official Twin Cities metropolitan area (now a 13-county region). And with the completion of two major highway projects expected by the mid-1990s, additional commuters are poised to settle here.

Regardless of the forecasted changes, however, farming remains an important element of Pierce-Pepin's makeup today. Of the co-op's 5300 customers, 300 are farmers—mainly in the dairy business. And all but six of the co-op's 30 employees have some sort of farming background. Still, just because this co-op knows its Holsteins from its Guernseys doesn't mean that it isn't sophisticated in its approach to the electric power business.

Step into the lobby of Pierce-Pepin and you feel as if you've mistakenly walked into an appliance dealership. The space is chock-full of the latest-model refrigerators, ovens, washing machines, and dryers. You may even see a salesman assisting customers. In fact, the lobby of Pierce-Pepin *is* an appliance dealership. And while this kind of diversification is rela-

Vernon Carlson still remembers the day back in 1946 when electricity came to his 960-acre cattle farm in Glenburn, North Dakota. "We were milking about 12 cows back then, and the first thing we got was an electric cream separator," says Carlson, now 73. "We all hated that job of turning the handle on the cream separator" Carlson, who now raises buffalo on the same farm, recalls the other drudgeries of rural life before electricity. "We used a gas engine to pump water for the cattle, and if that broke down, we pumped by hand," he says. "I remember my dad saying he'd pump 1000 strokes, and then he would rest for a while."

Carlson is one of 25 million consumers in 46 states served by rural electric cooperatives today. First established by the Roosevelt administration through the creation of the Rural Electrification Administration (REA) in 1935, consumer-owned rural electric cooperatives were intended to bring electricity to rural areas, offering a better way of life for farmers, 90% of whom were without electricity back then. Through the REA the co-ops received loans with below-market interest rates. This money allowed them to establish distribution systems and obtain the other equipment required to deliver power.

The early co-ops were distribution cooperatives, which purchased electricity from the large power companies that serviced urban areas. But by the late 1960s, cooperatives began joining forces to establish what are now known as generation and transmission cooperatives, or G&Ts. The idea behind the G&Ts, which are owned and operated by the distribution co-ops, is to help ensure a reliable source of power at a reasonable cost.

The nearly 1000 rural electric cooperatives that exist today electrify virtually all inhabited rural areas in the country. Fifty-eight of them are G&T co-ops. Together, the G&Ts produce about 44% of the electricity sold by the distribution cooperatives. Federal power sources like the Bonneville

CO-OPS—Then and Now

Power Administration and the Tennessee Valley Authority supply an additional 33% of the co-ops' power. The remainder is purchased from investor-owned utilities.

Rural electric cooperatives are nonprofit businesses, incorporated under the laws of the states in which they operate. For the most part the co-ops are regulated by their members, or consumers, who set their rates. Co-ops in 17 states are subject to state regulation, which ranges from territorial protection to rate setting. The co-ops are also subject to other regulations at the local, state, and federal levels, such as emissions reduction requirements.

Co-ops today

Rural electric cooperatives are as varied as the people they serve. For instance, Alaska Village Electric Cooperative's 5500 members live in 50 isolated communities sprinkled across northern central Alaska. The co-op's service territory reaches into the Arctic Circle, where inland winter temperatures of −65°F are common. Because there are such large expanses of land between the tiny villages, getting electricity to them is expensive. The REA considers this co-op's situation a hardship, which means it qualifies for reduced interest rates. Still, the village residents—30% of whom have incomes below the poverty level—pay five and a half times the national average for their electricity (42¢/kWh).

A few thousand miles to the southeast is the vastly different world of Wright-Hennepin Cooperative Electric Association. Located within comfortable commuting distance of Minneapolis—about 30 miles northwest of the metropolis—the co-op has grown with the city. In Wright-Hennepin's 56-year history, its customer base has evolved from a makeup of 85% farming and 15% residential and commercial to one of 15% farming and 85% residential, commercial, and industrial. The co-op has also suffered from the competition of utilities eager to encroach on its turf. In fact, a nearby municipality recently annexed some of the co-op's commercial customers to its system.

While Wright-Hennepin struggles with the challenges of capturing new business opportunities, Alaska Village Electric Cooperative grapples with the types of issues facing social service agencies. Many co-ops play both roles. Take Dixie Electric Cooperative of Union Springs, Alabama—a growing co-op serving 12,000 customers, including thriving businesses in the city of Montgomery as well as inhabitants of the most impoverished rural areas in the state. Dixie Electric has overseen the installation of a central water system to provide running water to rural residents of Bullock County, some of whom relied on wells and even rivers and streams for their drinking water. Now the co-op is exploring the possibility of installing a central sewer system for the same region.

The contrasting natures of co-ops today are at the crux of a simmering debate in the U.S. Congress about the future of the REA. Those pushing for a change in the system of low-interest loans—which are available to both electric and phone company cooperatives—argue that the time has come for prospering co-ops to stand on their own two feet. Their opponents point to the still-significant need of co-ops that, like Alaska Village, serve poor areas.

Given the strong and influential supporters on both sides of this argument, the debate over the proposed REA changes is likely to continue for some time before an outcome is determined. But in the mind of rural dwellers like Vernon Carlson, who remember well the days before electricity, one thing is certain. As Carlson puts it, "It's reassuring to look across the countryside and see the neighbor's yard lights." □

Solid irons, heated on a wood-burning stove, were a regular part of life in rural America before electricity.

The arrival of electricity was a milestone for rural communities.

Customers of rural electric cooperatives today are as sophisticated as those of the bigger utilities.

An appliance salesman for Pierce-Pepin Electric Cooperative assists customers with a decision in the co-op's showroom.

tively new to even the most progressive of the bigger utilities in the country, Pierce-Pepin has been involved in it since the very beginning.

"With only 5.7 customers per mile of distribution line, we need to pull in any extra revenue we can find to keep our rates down," says Steve Healy, general manager of the co-op. "In fact, in the old days we used to do wiring and plumbing and even installed barn cleaners." Now 45 years old, Pierce-Pepin's appliance dealership is the largest in Pierce County. And the co-op has offered appliance repair service for 43 years. Last year, appliance sales and repairs pulled in $700,000, representing 10% of Pierce-Pepin's total sales.

The co-op has been just as assertive about advanced technology as it has been about business opportunities. In a current project with EPRI and Sandia National Laboratories, Pierce-Pepin is demonstrating the use of photovoltaic (PV) technology for watering a farmer's cattle and horses in a remote area. Up until last July, when the PV panels were installed, the pump was powered by a distribution feeder that cuts across one of the farmer's cornfields. This feeder makes planting and harvesting difficult, since its poles interfere with the farmer's machinery. Now the electricity generated by the PV panels runs the pump, delivering the water to a trough 150 feet away. (A wire fence prevents the animals from getting close enough to damage the panels.)

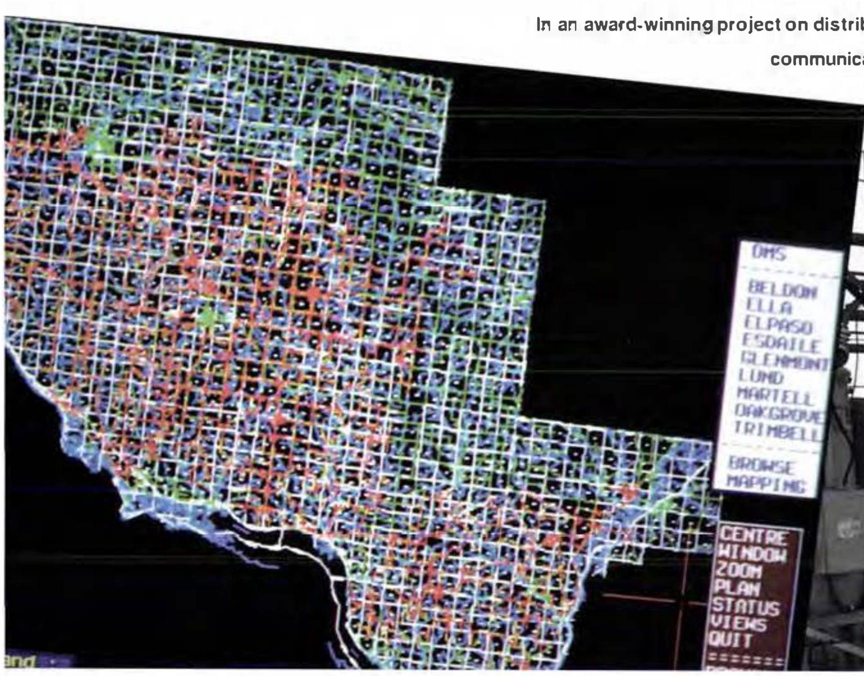
"So far it's worked out great," says Marvin Nielson, who owns and operates the farm. He says he would like to keep the PV panels permanently and dismantle the feeder. But before that happens, Pierce-Pepin intends to address a few problems that have arisen, such as the tendency for water in the pipe to freeze on cold winter days.

Nielson's PV unit is part of a broad EPRI effort involving 18 utilities that have applied photovoltaics to serve isolated water-pumping loads. "The application of photovoltaics to serve isolated loads is of growing interest to rural electric cooperatives, since they have a number of long radial feeders serving relatively small loads," says John Bigger, an EPRI manager who oversaw this coordinated effort with Sandia. Many water-pumping installations are employed only in the summer, he points out, and maintaining the distribution feeders that power them can become costly. "In many cases photovoltaics offers the co-ops an opportunity to reduce costs."

Smashing success

One of Pierce-Pepin's most recent advanced technology endeavors is also among its most significant. Completed

In an award-winning project on distribution automation, real-time data from this substation were communicated to a computerized map of the co-op's service territory.



early this year, the nine-month project resulted in the integration of real-time data from one of the co-op's substations into a computerized map of its service territory. As Jeff Olson, Pierce-Pepin's engineer for the project, explains, the creation of the computer interface displaying the map was a project in itself. "You practically needed a PhD in computer science to figure out what was going on with the old computer interface," he says, noting that users had to travel through several different data screens to locate the information they needed.

The new interface indicates, in color, the location of the co-op's substations and other critical equipment. The intent is to relay a variety of real-time information—data on current, voltage, and power transformer temperature—in a user-friendly format. For instance, if a transformer is running hot, a light will flash on the screen, allowing the co-op to investigate and correct the problem before it threatens to disrupt electric service. Because the interface is linked with Pierce-Pepin's mainframe computer system, users can also call up a wealth of useful data on individual co-op customers.

With cofunding from NRECA and EPRI, Pierce-Pepin integrated a demonstration of the Utility Communications Architecture (UCA) into this distribution automation project. Developed by EPRI, UCA offers the industry a standard set of open protocols that will enable electronic systems produced by different manufacturers to communicate with one another. (The article on page 34 of this issue provides more details on UCA.) Currently, utilities employ technologies that usually rely on separate, proprietary communications protocols. This means that if a utility wants two systems (a mainframe computer and a mapping system, for instance) to communicate with one another, it has to develop an electronic interpreter—either through a contractor or in-house—that will allow information to flow between the two systems. The expense of such projects keeps them far beyond the reach of most rural electric cooperatives (and, for that matter, many of the country's bigger utilities).

"If we were a large investor-owned utility, we might have the money to develop special communications gateways," says Olson. Indeed, as he points out, Pacific Gas and Electric Company even developed its own proprietary protocol to allow communication between its central computer system and the data-gathering technologies in its service territory. "The UCA protocol will give us the flexibility of being able to go to a number of different vendors to get the best price," he says. "That's why UCA is of such interest to co-ops. It has the potential to save us a lot of money while making our operations much more efficient."

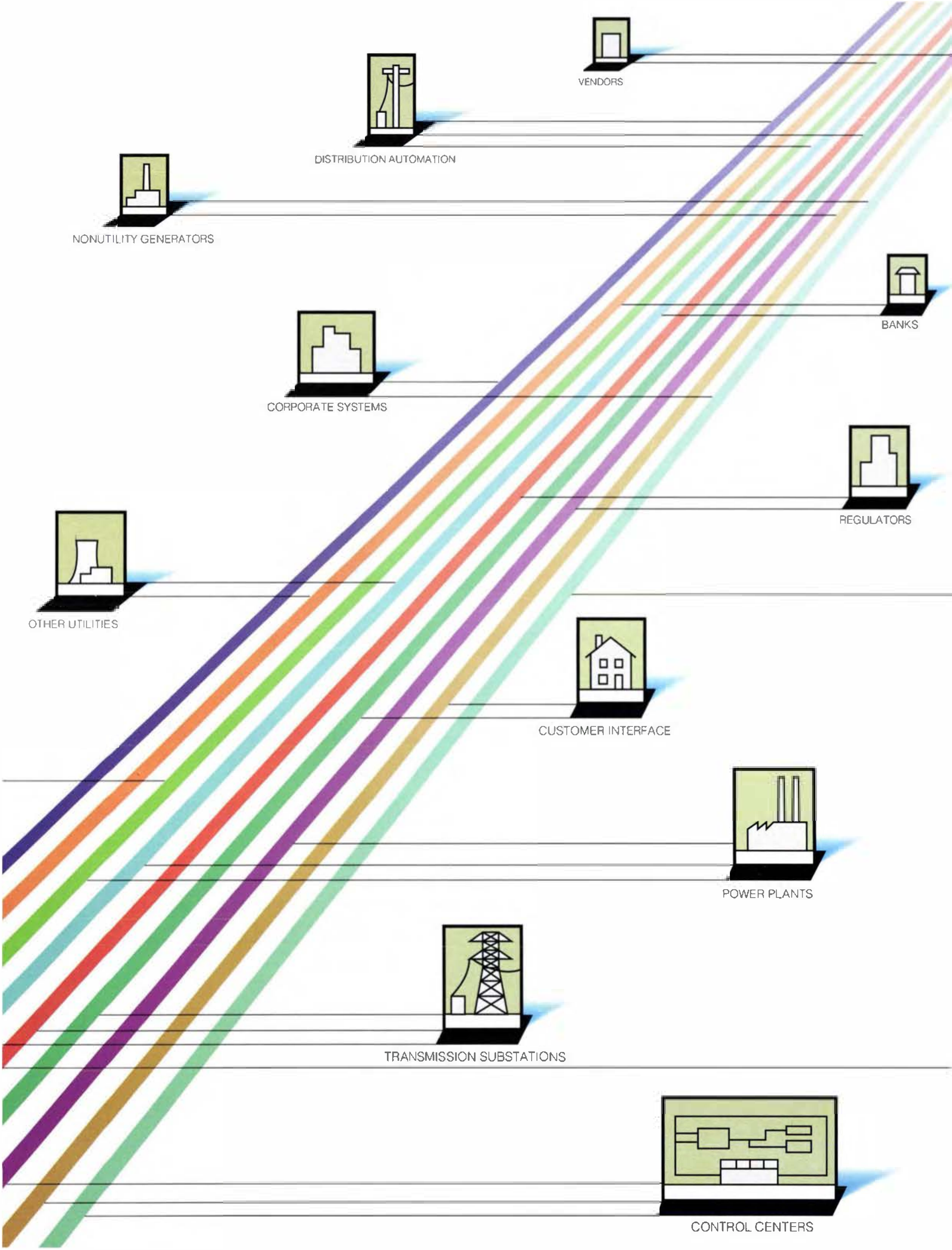
According to William Blair of EPRI, the Pierce-Pepin project, managed by Power Systems Engineering, represents the most advanced implementation of UCA in a distribution automation system. "The project was a smashing success," says Blair, who oversaw the UCA aspects of the effort. He notes that the project recently won an award for the best utility project on distribution automation in 1992, an honor announced at an international industry symposium in January.

Olson says that the project gave Pierce-Pepin employees valuable experience with distribution automation. Over the next decade, the co-op plans to phase in distribution automation systemwide. The hope is to integrate UCA-based technologies into this system. "Distribution automation will allow us to diagnose problems even before customers are aware of them," Olson says. "Co-ops can really benefit from this technology. Because they have to travel such long distances of line, the process of locating and isolating an outage takes them a lot longer than it usually takes on an urban system."

Certainly, such grand achievements on the part of any utility are laudable. But to what extent should the little co-ops leave the grand innovations to the big guys? Steve Healy, general manager of Pierce-Pepin, offers this response: "Customer service is not a function of size. The advantages we gain through R&D help us provide excellent customer service." Pointing to increasing competition, more-stringent environmental regulations, and advances in technology, Healy says he expects the electric power industry to change significantly within the next decade. "If we're not part of the process and up to speed on what's going on, we're going to get left behind," he says. "Besides," he adds with a grin, "maybe the big guys can learn something from us." ■

Photos by Leslie Lamarre

Farmer Marvin Nielson discusses his photovoltaic panels with Jeff Olson, Pierce-Pepin's engineer.


VENDORS
DISTRIBUTION AUTOMATION
NONUTILITY GENERATORS
BANKS
CORPORATE SYSTEMS
REGULATORS
OTHER UTILITIES
CUSTOMER INTERFACE
POWER PLANTS
TRANSMISSION SUBSTATIONS
CONTROL CENTERS

Framework for Utility Data Highways

by Taylor Moore

***THE STORY IN BRIEF* Someday, all the computer systems used by a utility will share data almost seamlessly through powerful companywide networks. Such networks would not only increase the efficiency and reduce the cost of data communications but also enhance the synergy between a company's related functional areas. Because the networks envisioned will use open-systems communications protocols, which permit the linking of hardware and software from different vendors, systems can often be integrated progressively, a section at a time, without having to replace existing equipment. The utility industry is now a major step closer to the vision of integrated communications with EPRI's completion of the Utility Communications Architecture (UCA), which specifies applicable open-systems protocols and standards. EPRI is working with several utilities to demonstrate the implementation of UCA-compliant networks across functional areas and in focused applications of particular strategic value.**

Along with the current talk about rebuilding America's infrastructure of bridges and roads, there are proposals for another kind of infrastructure—a futuristic, fiber-optic infrastructure of high-speed, electronic data highways that could link vast networks of computers of all kinds for increased economic productivity. While the development of such a vision awaits policy and budget commitments, the vision itself mirrors in key respects the communications and information management future that the electric utility industry has already charted for itself.

In the industry's vision of the future, all of a utility's myriad computer systems will be accessible to each other and will interact as needed—from corporate mainframes and control center energy management systems to substation computers, power plant monitoring and control systems, distribution-level control devices and data systems, office computers, and even computers on the customers' side of the meter. The computers and, in turn, their data and programs will be linked in local- and wide-area networks that employ a variety of high-capacity data communications media, such as satellite, fiber-optic, and radio-based technologies, as well as copper wire. The interlinked pools of data (ranging from the specifics of customers' varying demand for energy to details on the technical performance of production and delivery facilities) will be updated continuously and interactively—in real time, as events happen.

Even as this vision of integrated utility communications is taking form, the ongoing revolution in the cost, size, and capabilities of microprocessor-based computer systems is causing the migration of data and applications from mainframes and other large systems to decentralized networks of specialized workstations and file servers. Ever more microprocessing power is available in remote programmable devices and in smart sensors and switches in power plants and on transmission and distribution systems. These trends are reflected in the fall from dominance of mainframe and other large system vendors offering total-system solutions based on proprietary operating software and protocols. Such systems are increasingly being replaced by multivendor networks of interoperable hardware and compatible software, a growing share of which is based on Open Systems Interconnection (OSI) standards.

Utilities are among several large users of computing power (others include government agencies and major manufacturers) who have used the OSI Reference Model as the basis for defining specification standards that meet their anticipated future requirements for computer-based telecommunications. Much of the activity to develop OSI standards and protocols originated in Europe with the International Organization for Standardization. Earlier related developments included activities of the Paris-based Consultative Committee for International Telephony and Telegraphy and efforts revolving around the U.S. government's ARPANET computer network. The open-systems banner has most recently been carried in this country by such companies as General Motors and Boeing, who defined and developed OSI-based protocols that would allow them to economically integrate the flow of data between, say, the automation control systems on the factory floor and the design engineering departments.

On behalf of its members, EPRI is some six years into a long-term initiative to help the electric utility industry realize the benefits of open-systems computing and data communications. The key goals are to define a framework of applicable OSI protocols and develop the tools to demonstrate and implement the integration of data flows between various utility computer systems and between utilities and individual customers. Research managers say good progress is being made. Several major steps in what is expected to be a slow march toward the ultimate vision of integrated utility communications have recently been completed or initiated. Moreover, the counterpart research arms of the gas and water utilities are becoming increasingly involved with EPRI in pursuing integrated communications.

The electric utility industry's plan for the move to open systems is taking shape in the Utility Communications Architecture (UCA), EPRI's comprehensive framework for utility information management in the future (see sidebar on page 40). The progress in UCA development has already prompted a stream of vendor endorsements and announcements of compliant products. The completion of related specifications for managing data between differently structured databases—called Database Access Integration Services (DAIS)—clears the path for utility software vendors to develop new applications for linking dissimilar databases or to enhance existing products. Meanwhile, four EPRI technical divisions are involved in an array of projects to demonstrate the integration of data communications across functional areas in various realms of utility operations. The projects include several major demonstrations expected to get under way this year and a number of tailored collaboration projects already under way.

Improving the bottom line

More than just a futuristic vision motivates utility industry interest in integrated data communications. Utilities spend an ever-increasing amount—estimated at $2 billion to $5 billion a year and growing 25% or more every year—for voice and data telecommunications. There are already strong pressures to find ways of reducing operating costs to improve utility earnings. As utilities install more data and control automation systems in the future, the cost of communications for and between these systems, if not contained, could undermine the value of the productivity gains promised by automation in the first place. But beyond reducing costs, utilities are acutely aware that more substantial gains in efficiency and productivity would be possible across the spectrum of business operations if more of their various computer systems could share data and programs on a real-time basis, seamlessly and transparently to users.

Utilities have long known that the data-intensive and geographically widespread nature of their business makes them one of the largest industrial users of telecommunications. But recent EPRI projects to develop a foundation for integrated communications have revealed just how significant a role telecommunications plays in the business, says Michael Moran, vice president for engineering and production at West Texas Utilities Company and chairman of EPRI's Integrated Communications Advisory Committee. "Our industry is *the* largest user of real-time data communications, and in the use of all telecommunications we are second only to the telephone industry itself. So telecommunications represents a significant portion of our infrastructure and our ability to do our job. And it turns out that utilities are the largest driving force in the development of real-time protocols," Moran says.

"Integrated utility communications is a next-generation concept, a vision of where we need to be—taking today's telecommunications networks and automated systems and integrating those with an ability to communicate from computer to computer," Moran adds. "Utilities have done a good job installing various computer and automation systems—including distribution automation, supervisory control and data acquisition, energy management, and demand-side management systems—but like our own traditional industry structure, these systems have been only vertically integrated. We have lacked any real horizontal integration, or communication, between our engineering, operations, and financial systems."

Moran says that integrated communications is the product of "an industry focus that is much broader than communications. All utilities are looking at organizational changes to reduce operating costs as a way of increasing earnings. What's happening with integrated communications is just one aspect of that. Utilities are looking closely at all of our independent automation systems and realizing we need to get more out of them by tying them together and making them work as a team."

At the corporate level, open communications will help improve productivity by enabling the elimination of duplicate data and redundant systems, including systems for financial and customer information, work management, engineering, and executive information. The integration of communication between corporate systems and utilitywide energy management systems (EMSs) will enable a company to

How Integrated Communications Can Benefit Utility Operations

Networks employing an open-systems architecture like EPRI's Utility Communications Architecture, or UCA, promise benefits that extend across the spectrum of utility operations. Integrating the flow of data between the computer systems that utilities use to monitor, control, and analyze operations in each of the six major functional areas is expected to improve efficiency and reduce the costs of telecommunications. But experts say that many of the productivity gains may come in unanticipated ways as dissimilar hardware and software systems are made to interoperate, with the flow of data between them becoming increasingly automated.

Corporate systems
Redundant data in separate financial, customer information, work management, engineering, and executive information systems could be eliminated. Utility executives and planners could access real-time and historical system operations data, for example, or call up for analysis the cost and performance data from a power plant's local-area network.

Power plants
Local-area, in-plant computer networks for the monitoring, control, and diagnostics of key components and major subsystems can help power plants operate more efficiently and respond with greater flexibility to changing customer demands for energy. The real-time integration of plant performance data with systems at utility control centers will lead to more-effective dispatching of generating capacity.

Control centers
Expert systems applications being developed for energy management systems could be made available in other areas of utility operations for up-to-the-minute assessment of system conditions and problems. New challenges, such as monitoring power flows over individual circuits and managing complex wheeling transactions, will require even greater integration of energy management system data with information from supervisory control and data acquisition (SCADA) systems for transmission substations. Such integration will, in turn, permit operation of the interconnected power system closer to its physical limits while maintaining high reliability.

Transmission substations
More-powerful SCADA systems and microprocessor-based protective relays are being used to automate and optimize transmission system operation. They require increasingly large flows, at very high speeds, of extremely accurate real-time data on system conditions between substations and utility system control centers, as well as similar data exchanges with neighboring utilities.

Distribution automation
Utilities are already automating many of the electromechanical relays and switches that are used to operate the distribution system. As the degree of automation increases, so does the utilities' ability to monitor and automatically respond to service problems, in some cases before the customer is even aware of them. Integrated communications and open-systems architecture will make it easier for utilities to install equipment and systems from various vendors as the technology continues to evolve.

Customer interface
Real-time data communication between utilities and their customers will add a new dimension to the relationship. This communications capability will allow utilities to implement, for example, electronic billing and customer payment, as well as various demand-side management services, including variable, time-of-use pricing of electricity. Customers could tie such utility data into their own programmable systems, such as smart systems for home energy management. Measures like these could help reduce utility system peak demand and lower customers' electric bills.

optimize its operations by better coordinating all its functions.

At power plants, the integration of in-plant control systems with the supervisory control and data acquisition (SCADA) systems and the EMSs used in transmission and distribution operations will enable more-efficient scheduling for the economic dispatch of generating capacity based on actual heat rate. Already, computer systems are increasingly being used to monitor power plant equipment and subsystems and predict when maintenance will be required. Connecting these networks to overall plant control systems promises to automate routine operation to an unprecedented degree as well as reduce operation and maintenance costs.

At control centers, EMSs continue to increase in cost and complexity even as utilities strive to make greater use of these powerful computing and information system assets. Utilities are on the verge of needing to monitor and quantify in real time the power flows over individual circuits and to attribute such flows to specific uses. Expert systems are being applied to EMSs to diagnose power system problems, analyze malfunctions, and suggest preventive or corrective actions. UCA and DAIS support the integration of EMSs with other systems in a utility and with the EMSs of adjoining utilities, enabling the interconnected power system to be operated closer to its full capacity while maintaining high reliability.

And as transmission systems are operated closer to their limits, they are becoming more automated through the implementation of more-powerful transmission SCADA systems and such devices as microprocessor-based relays. Open communications and data access like the kind provided by UCA and DAIS are essential to this increased automation and will help make it easier to communicate large amounts of real-time system data between interconnected utilities in support of increased power wheeling.

Automation of much of the electromechanical switching and relaying on the distribution system that directly serves customers is another way that utilities hope to achieve maximum use of their facilities and provide competitive, high-quality service. Such distribution automation (DA) promises to help utilities optimize the day-to-day operation of the system and respond efficiently when trouble develops. But little currently exists in the way of an installed base of DA equipment and systems, although it's expected that such automation will eventually involve extensive electronic networks. Thus the cost of communications for DA will be high unless systems are based on interoperable components and protocols. Interoperability will preserve the long-term stability of a DA system and should create a competitive environment among vendors.

Having a data communications link to their customers through DA systems will allow utilities to implement electronic billing as well as various demand-side management (DSM) services, such as real-time pricing of electricity. Programmable systems on the customers' side of the meter are already beginning to use such real-time pricing data to control deferrable loads. Utility benefits could include lower on-peak demand and possibly increased off-peak use of electricity, while customers could realize lower electric bills and increased control over their environment and safety. UCA provides the open architecture necessary for communications between the utility and intelligent customer systems or devices.

Migration strategy—a key to conversion

Utilities are being encouraged to view UCA not as a set of products to be purchased but as a technological concept that could change a utility's fundamental approach to the way it operates. Because a concept is adopted and implemented over time, opting for UCA requires a company to make a strategic business decision that such a fundamental change can help it manage some of its biggest challenges.

Besides unrelenting pressure to control costs, major issues facing utilities include competition, corporate restructuring, mergers and acquisitions, new business opportunities, and increasing federal and state environmental regulation. It's expected that the open-systems communications environment provided by UCA will make it easier for vendors and users to develop new systems and technology applications, both for solving today's problems and for addressing future challenges as they arise. Integrated systems will make greater, more effective use of information that already resides in a computer system somewhere on one of the islands of automation that today support a utility's overall business.

An entire volume of the UCA user's guide is devoted to strategies for migrating to open, UCA-based systems and highlights the various factors and issues that utilities should consider in planning such a migration. Technical migration alternatives like multiple-protocol support, application gateways, and hybrid protocols are explored. Examples of migration alternatives for a variety of non-OSI architecture environments (including SNA, DECnet, CDCNet, Foxboro DCS, TCP/IP, WSCC, and tDEC) are provided. A starting assumption is that the need to convert a specific system to UCA specifications is the result of an identified business need to upgrade, improve, or expand the system.

Wade Malcolm, program manager for power electronics and controls in EPRI's Customer Systems Division, says that many utilities who have analyzed the UCA study and specifications in terms of their own business planning—some at considerable depth and expense—are forging ahead in adopting the specifications as the basis for near-term solutions and in developing longer-term migration strategies for implementing UCA-compliant networks. "We're recommending that utilities incorporate UCA-DAIS specifications in hardware and software orders as systems are replaced, so we expect a gradual migration to integrated communications. Given that different utilities are implementing networks in different functional areas on different schedules, it's difficult to say that one area is or will be predominant for UCA implementation. The corporate area has the largest base of existing, installed systems and the greatest array of emerging UCA-compliant products. But a large existing base of installed systems can be as much of a barrier to UCA implementation as not having available products."

With the growing acceptance of UCA and DAIS as the utility protocols for future data communications, the increasing involvement of vendors offering UCA-compliant systems and applications will help foster the industry's eventual migration to integrated data communications. But according to two utility engineers involved in telecommunications, that migration could come slowly if the focus is not on implementing those networks in ways that offer real solutions to real business problems.

August Nevolo, chief telecommunications engineer at Pacific Gas and Electric Company, serves on EPRI's Integrated Communications Advisory Committee and coordinated the UCA project's study of PG&E's operations and communications requirements. He says that many of the important business benefits likely to result from implementing UCA networks are as yet unknown and unanticipated. "Rather than seeing UCA from the perspective of a corporate data processing or office environment, I see it as a vehicle for bringing about key applications of advanced communications technology in a utility operations environment."

Nevolo goes on, "Initially, the big benefits will come in helping people on the business and operations sides of PG&E do their jobs better with consistent, integrated data. But the solutions that UCA will offer for problems we do not yet perceive will probably be its greatest benefits over time. The real benefits will accrue in the applications, not in the technology. Networks cost money; they don't save money. But how you use a network, and how the end users derive benefit, is where the payback comes in."

PG&E's top telecommunications expert says that utilities should be thinking about UCA and integrated communications as a long-term solution. They should not expect to have the technology all in place in four or five years and then immediately begin to realize incredible benefits. "We've got to be more patient and install UCA networks where they make sense. As the benefits appear, so will the budget for solving the problems of implementing this technology."

Another knowledgeable observer, Jerry Whooley, manager of emerging technology at Public Service Electric & Gas Company (PSE&G) in New Jersey, says UCA has achieved tremendous name recognition and is a major advance for utility communications. However, it is still perceived as a set of technical specifications rather than as a pathway to strategic business advantage, adds Whooley, who also serves on EPRI's Integrated Communications Advisory Committee. (This high-level panel, which guides the Institute's program, includes representatives of the Edison Electric Institute, the North American Electric Reliability Council, and General Motors' Technical Center, as well as representatives of individual utilities.)

"We feel confident that the technology for integrated communications is here and that the software for exchanging the data will be here shortly. There's no question that we can buy it, install it, and make it work. As a result, our focus has been on the company's business needs, because if integrated communications isn't tied to real business needs, it isn't worth doing," he explains.

Whooley says that PSE&G analyzed EPRI's six-volume UCA report in order to align its recommendations with the utility's business needs and applied a technique called the Information Engineering Methodology to develop an overall business plan, using data models developed for individual business units. "We now have the framework for a UCA-compliant information network that will make all our computers interoperable. Next, we will drill down into each business area and produce data models that will be the basis for future, DAIS-compliant data exchange." Whooley concludes, "If you're really serious about integrated communications, you have to plan for it."

Projects and demonstrations moving ahead

The emergence of UCA and DAIS as the preferred industry models for future data communications has triggered a stream of announcements from hardware and software vendors over the past two and a half years—announcements either of outright endorsement or of plans to provide compliant products or related services. One notable endorsement has come from Digital Equipment Corporation (DEC), which launched a new program dubbed DECunity for linking utility functions and implementing data sharing by using UCA and DAIS. Some dozen independent vendors of SCADA systems, graphic information systems, and customer information systems are working with DEC and have committed to implement UCA protocols in their systems. This, in turn, makes it practical for utilities to begin implementing UCA protocols for many functions.

Indeed, the array of compliant products that has followed the arrival of UCA and DAIS has prompted many utilities to proceed with implementation projects for specific functions—applications that fit with their particular corporate strategies—in advance of the kind of full-blown utility demonstration typical of traditional EPRI projects. "We've come a long way in the last couple of years. In that time, the opportunities in several areas of system automation within the industry have grown significantly, so we have a lot more applications of UCA-compliant networks than we thought we would by now," says Vasu Tahiliani, senior program manager for distribution in EPRI's Electrical Systems Division.

Distribution automation Tahiliani says that many utilities are placing high priority on DA and DSM and are willing to spend heavily for automation systems at the distribution level and at the customer's meter. "But even if a utility installs these systems as fast as it can afford to, the systems will take years to fully implement," he explains. "Utility executives want to have some assurance that the equipment they will be installing in five years—which they know will be improved over what they are installing today—will at least interoperate and communicate with today's automation equipment. So establishing common specifications and protocols now for vendors to use in designing and planning products could be a real catalyst to the deployment of distribution automation."

According to EPRI's William Blair, who manages UCA-related projects in DA, the dilemma facing many utilities in this area reflects the larger dilemma posed by integrated communications: "Utilities want to buy communications equipment from one vendor, remote terminal units from another vendor, and electronic meters from a third vendor. And they want them to 'plug and play' together, now and in the future." EPRI's Electrical Systems and Customer Systems divisions are working with a number of utilities who are moving aggressively in the DA and customer interface areas to achieve that interoperability. The Institute is involved in more than half a dozen cost-shared projects with utilities in which the UCA and DAIS specifications are a fundamental element of implementation.

Customer interface A working prototype of EPRI's concept of integrated communications was featured among the many vendor exhibits of DA and DSM products at last year's Second International Symposium on Distribution Automation and Demand-Side Management. In this EPRI-sponsored demonstration of interoperability, UCA and DAIS were used in a network for communicating real-time load data from conventional field sources to various demand-side automation systems for price-based load control. "We used some EPRI software, some off-the-shelf products, and prototype products from vendors. With UCA and DAIS we showed how to tie them all together and integrate systems for SCADA functions, remote meter-reading, real-time variable pricing with customer communication, and electronic customer billing," reports Larry Carmichael, manager of customer interface and controls projects in the Customer Systems Division.

In addition to numerous tailored collaboration projects involving selected applications of UCA-compliant data communications, EPRI recently selected four utility proposals for major UCA-DAIS demonstration projects over the next two years. The demonstrations, to be conducted at Kansas City Power & Light Company,

UCA-DAIS Framework: A First Step

With the publication of the six-volume report *Utility Communications Architecture* (EL-7547), prepared for EPRI by Andersen Consulting, the utility industry took a big step toward defining a telecommunications future based on Open Systems Interconnection (OSI) standards. UCA provides a comprehensive set of technical specifications of communications requirements in all functional areas of utility operations, based on detailed evaluations of two large utilities, and describes applicable existing OSI protocols and standards.

Pacific Gas and Electric Company and Houston Lighting & Power Company served as the utility prototypes for Andersen's assessment of functional and communications requirements. Technical focus teams of experts at each utility (representing each of the six defined functional areas of power plants, control centers, corporate systems, transmission, distribution automation, and customer interface) provided perspective and feedback to the UCA project on a day-to-day basis. That information was supplemented and broadened to represent an industry perspective by the participation of some 40 other utilities. Some 220 specific uses of computers in utility operations were identified.

Project participants and managers conducted both a top-down definition of key specific functions and a bottom-up technical assessment of the communications requirements in each of the six major areas of utility operations. They then evaluated the ability of existing OSI and other protocols and standards to meet utility needs, identified areas of unmet requirements, and pinpointed needs for additional development.

UCA Version 1.0, the result of this assessment, is a utility industry specification based on the hierarchical, seven-layer OSI Reference Model. The model and its related suite of open, standard communications protocols are designed to enable different computer systems to interoperate without the end users of one system having to know specific characteristics of another system. Each of the seven layers of the OSI model addresses specific functions involved either in machine-to-machine communication, in data transport, or in the interface with end users. And each layer electronically converses with its corresponding layer on another machine.

By identifying a suite of applicable, available protocols, as well as gaps in the existing standards' coverage of key requirements, and by providing a detailed technical specification of communications requirements across all functional areas of utility operations, UCA has taken its place among other government- and industry-specific OSI profiles. These include General Motors' Manufacturing Automation Protocol, Boeing's Technical Office Protocol, and the Government OSI Profiles (GOSIP), versions of which have been adopted here and in Britain and Canada. Adherence to U.S. GOSIP specifications has been required of computer systems procured by the federal government in this country since 1990. Similar profile development efforts are ongoing in other industries as well.

Version 1.0 of UCA identifies four key areas of unmet needs for communications protocols in the utility industry, areas that will be important to the ultimate realization of integrated communications. They are protocols to support communications with simple field control and monitoring devices in both power plants and substations; true simultaneous data broadcast/multicast capabilities to support emerging distribution automation functions; very high speed communications to support stringent monitoring and control requirements in transmission and distribution substations; and urgently needed protocols to support graphic displays of CAD files, system maps, and energy management system diagrams across utility wide-area networks and even between utility systems.

The UCA project identified a subsidiary, simpler three-layer communications model that may suffice for local-area networks, such as in power plants, where most of the data remain within the network. Hardware devices and software designed to communicate under this simpler model could be less expensive. Subsequent versions of UCA are expected to more fully develop the three-layer architecture on the basis of new empirical data.

The major companion to UCA in EPRI's multielement strategy for integrated communications has also recently been demonstrated. Honeywell led a team of EPRI contractors and participants that included IBM, Sun Microsystems, UNISYS, and DEC. They surveyed some 100 utilities and worked closely with Northern States Power Company to develop specifications and software that provide universal access to data stored in distributed systems that make up a utility's diverse overall database. Just as UCA is focused on hardware interoperability and communication, the Database Access Integration Services (DAIS) product is a specification for software interfaces between dissimilar databases that imposes a common interface for data on a network.

EPRI's DAIS is now available for vendors to use in developing their own database access software for UCA networks. Northern States Power hosted a small-scale demonstration of DAIS, using software developed by Honeywell to link five databases on three computer systems (including those involving customer information and distribution system monitoring) for information exchange. ■

Northern States Power Company, PG&E, and PSE&G, reflect a spectrum of efforts to integrate data communications between multiple systems and applications.

As Malcolm and Tahiliani note, the DA and DSM areas have the most immediate potential for implementing UCA networks and integrating applications, largely because there is little current market penetration of DA or customer interface data systems and most of the anticipated products in these areas do not yet exist. "So these will likely be the areas of the greatest near-term growth in UCA implementation, although you can't fully implement such networks today because not all of the necessary products are available," says Malcolm.

An interim option was pursued by Pierce-Pepin Electric Cooperative in Wisconsin, with funding from the National Rural Electric Cooperative Association and EPRI. Pierce-Pepin took a hybrid approach, modifying some currently available products to demonstrate certain aspects of UCA-compliant communications in a limited way. The results indicate the great value that UCA can have, even to small utilities.

In the furthest-developed UCA implementation to date in the DA area, the Pierce-Pepin cooperative identified barriers and solutions to integrating disparate data systems, focusing on the integration of SCADA information with data from its automated mapping and facilities management system on one substation feeder in northwestern Wisconsin. Project managers worked with over a dozen vendors of DA products to implement UCA specifications. "This was an area where there wasn't much in the way of existing products, but the utility used what was available and built on that to create something better than the current system," says project manager William Blair.

The Pierce-Pepin project involved both DA functions and systems related to the customer interface. The close relationship between DA and the customer interface is reflected in the joint sponsorship by EPRI's Customer Systems and Electrical Systems divisions of over a dozen other projects involving UCA protocols under the Customer Interface Initiative.

In one of the projects under this initiative, the Customer Systems Division is working with Consolidated Edison Company of New York in demonstrations of real-time pricing with two large customers — demonstrations that will eventually involve migration to UCA-compliant communications. Other work in progress is producing a UCA-compliant version of the Customer Communications Gateway, which is expected to become the standardized interface between a utility's DA system and a variety of customer automation systems, including Smart House systems and commercial building EMSs. The Customer Systems Division also sponsors the UCA Exchange (which can be reached toll-free at 800-UCA-EXCH) and the MMS Forum. These bring together hardware and software vendors and utility users to pursue interoperability agreements based on the Manufacturing Message Specification, the application layer specified in UCA for real-time control and data acquisition, as in communicating with meters or remote terminals at a customer interface or in a power plant.

Control centers For power control centers, with their massive energy management systems, some UCA-compliant open protocols are beginning to become available from vendors of EMSs and related systems. Three or four vendors, for example, are committed to using the UCA-compliant DECunity platform. Upgrades and initial UCA-compliant offerings from other major vendors are anticipated in the near future.

Another significant development related to control centers is the announced plan for upgrading to UCA compliance the two major utility industry protocols for interutility EMS data exchange. Currently, utilities associated with the Western Systems Coordinating Council use one set of protocols, while many utilities in the East use a protocol associated with the Interutility Data Exchange Committee. As a result of interaction between EPRI staff and the utilities connected with these groups, the protocols are in the process of being merged in a single UCA-compliant protocol to be called UCStandard.

Power plants and transmission substations Power plants (both nuclear and fossil) and transmission substations are areas that have seen less development and implementation of UCA-compliant networks or products, but both areas could see significant development in the near future. At least two of the half dozen major vendors of fossil plant distributed control systems have begun to offer UCA-compliant versions of some products. And EPRI is working with all of the vendors to pursue utility-hosted demonstrations of UCA-compliant communications in plant monitoring and control applications.

These projects include work at the Eddystone station of Philadelphia Electric Company, where EPRI's Monitoring & Diagnostic Center is using a fiber-optic data highway to tie together numerous plant and equipment monitoring and control systems in a predictive maintenance network. EPRI has also worked with vendor Asea Brown Boveri to integrate data communication between seven plant monitoring systems at Carolina Power & Light Company's multiunit Roxboro station. In addition, the Institute is working with smaller vendors of equipment diagnostic systems to incorporate UCA-compliant specifications in place of costly proprietary interfaces that can drive up the cost of their products.

As noted in EPRI's UCA project report, currently available OSI architectures have a limited ability to meet the communications requirements for simple field devices that can support a number of functions. EPRI is participating in the Instrument Society of America's field bus development effort to ensure that such requirements are ultimately reflected in ISA-adopted standards. Standards that result from this and certain other ongoing technical efforts are likely to be incorporated into a future version of UCA.

EPRI also considers UCA and DAIS fundamental elements in a long-term strategy for integrating the many pieces of EPRI software available for power plants today into some type of overall plant monitoring workstation.

Meanwhile, an instrumentation and control upgrade initiative in EPRI's Nuclear Power Division includes open-systems specifications as part of its strategy for nuclear power plants. But stringent regulatory requirements for data communications involving nuclear plant systems, especially safety-grade systems, could be a barrier to early progress in implementing open plant systems. The division plans to publish, by the end of this year, a methodology manual and workbook that will help nuclear utilities plan open-systems migration strategies and to determine the appropriate network configuration of various information, monitoring, control, and safety systems in an integrated plant data communications network.

As for transmission substations, EPRI hopes to build on its pioneering work on automated control systems at PSE&G's Deans substation. "The Deans automation system is already very close to meeting the UCA requirements," reports Stig Nilsson, program manager. "Work has been initiated to make the system fully UCA-compatible while meeting the industry's exacting performance requirements."

Corporate systems Corporate data systems are at the other end of the spectrum from DA and the customer interface in that there is a large installed base of mainly proprietary systems and communications protocols in this area, as well as a rapidly growing availability of systems and solutions based on OSI specifications. Some large system vendors have recently made OSI-based protocols available in lieu of their proprietary protocols at no extra cost — a milestone in itself.

But because utilities do have a large base of installed systems for business and accounting functions, the upgrade and migration to UCA protocols in the corporate area could lag behind that in other areas, such as DA and customer information, where utilities see an immediate advantage to installing new equipment and systems. Still, greater access to and use of, say, the inventory data found in corporate accounting databases could translate into major cost savings companywide.

At the corporate level are wide-area networks that ultimately will link all of a company's local-area networks with a high-speed, high-capacity data highway. The most tangible example of a wide-area network may well be EPRINET, the electronic communications gateway to EPRI information and services that in effect links every EPRI member in an interactive, real-time network. According to Marina Mann, EPRI's vice president for information technology, the architectural infrastructure that underlies EPRINET is already UCA-compliant. Meanwhile, UCA-compliant applications and services are being made available as part of the latest generation of EPRINET, which began its rollout this June. Adds Mann, "One of the most immediate benefits of putting UCA into practice will be the ability of EPRINET participants to use the electronic mail system of their choice for the exchange of messages and electronic documents. This will open the floodgates of communication between EPRI and our members."

Also at the corporate level (more as a result of organizational than functional relationships) are efforts to involve gas and water utilities more closely in pursuing and implementing UCA as an all-utility communications protocol. EPRI last year began a project that is jointly funded by the American Water Works Association Research Foundation to extend UCA specifications to meet the communications needs of water companies. Water utilities anticipate many of the same advantages that electric utilities do from being able to integrate data from monitoring, metering, and computer systems. EPRI has already gained the involvement of the Gas Research Institute in exploring opportunities for funding research to extend UCA to the gas industry.

EPRI is also cooperating with the National Institute of Standards and Technology and with other industries that have defined OSI profiles to combine these as a generic industry-government open-systems specification. Broad acceptance of such a specification could be expected to foster even wider availability and use of such OSI-based architectures as UCA.

A foundation on which to build

According to Narain Hingorani, EPRI's vice president for electrical systems, "UCA and DAIS together provide the foundation on which utilities can build cost-effective and efficient integrated information systems for every major functional area of their business. If quick and ready access to information has real economic value to a company, then UCA-DAIS is absolutely essential.

"With UCA and DAIS, utilities can expand automation systems without depending on the same vendor and without fear of obsolescence of existing equipment. Such systems can use any existing media — twisted pair, microwave, optical fibers, or radio waves, for example. A utility would not have to use the proprietary interfaces and consoles that are presently needed to interconnect systems. Much of the automation will be achievable through the integration of off-the-shelf components in workstations, personal computers, processors, and controllers, leading to tremendous cost savings and, in the years to come, to the full automation of utility information systems. The adoption of UCA-DAIS is a major corporate decision and will be a must in the industry's more competitive future." ■

Further reading

Database Access Integration Services. Final report for RP2949-5, prepared by Honeywell, Inc. Forthcoming. EPRI TR-101706.

UCA Workshop Report. Final report for RP2568-24, prepared by Plexus Research, Inc. Forthcoming. EPRI TR-101263.

Plant Communications and Computing Architecture Plan Methodology Manual and Workbook, Vols. 1 and 2. Final report for RP3405-1, prepared by Queue Systems, Inc. Forthcoming. EPRI TR-102306.

"Advanced Metering: Benefits on Both Sides of the Meter." *EPRI Journal*, Vol. 17, No. 3 (April/May 1992), pp. 18–25.

Utility Communications Architecture, Vols. 1–6. Final report for RP2949-1, prepared by Andersen Consulting. December 1991. EPRI EL-7547.

"Reaching Out With Two-Way Communications." *EPRI Journal*, Vol. 15, No. 6 (September 1990), pp. 4–13.

"Building a Framework for Integrated Communications." *EPRI Journal*, Vol. 13, No. 5 (July/August 1988), pp. 28–35.

Integration of Utility Communication Systems. Final report for RP2473-14, prepared by Energy and Control Consultants. August 1987. EPRI EL-5242.

Background information for this article was provided by Wade Malcolm, Customer Systems Division, and Robert Iveson and Vasu Tahiliani, Electrical Systems Division.

CONTRIBUTORS

Technical sources for Journal feature articles

PURCELL

WELCH

TAHILIANI

MALCOLM

Charging Up for Electric Vehicles (page 6) was written by Taylor Moore, *Journal* senior feature writer, with assistance from **Gary Purcell** of EPRI's Customer Systems Division.

Purcell, manager for electric vehicle systems technology, joined EPRI in 1977 after 15 years with Lockheed Missiles & Space Company. A mechanical engineering graduate of Oklahoma State University, Purcell earned an MBA at Pepperdine University. ■

Winning in the 1990s (page 18) is based on a speech delivered by General Electric Company's **Jack Welch** as the keynote address at EPRI's recent International Symposium on Global Electrification. Welch, who joined General Electric in 1960, was elected vice president in 1972 and vice chairman in 1979. In 1981 he became the eighth chairman and CEO in GE's 114-year history. Welch holds three degrees in chemical engineering—a BS from the University of Massachusetts and MS and PhD degrees from the University of Illinois. ■

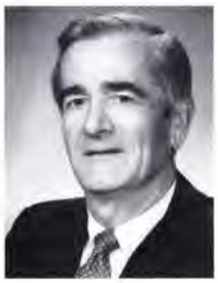
Framework for Utility Data Highways (page 34) was written by Taylor Moore, *Journal* senior feature writer, with principal guidance from two EPRI program managers.

Vasu Tahiliani, who heads the Custom Power Distribution Program in the Electrical Systems Division, joined EPRI in 1977 as a senior project manager for transmission substations. He became the division's technology transfer administrator in 1984 and program manager for technology transfer the following year. He assumed his present position in 1991. Before coming to EPRI, Tahiliani was with ITE Imperial Corporation for five years, managing gas-insulated-substation projects. Earlier he spent five years with McGraw Edison Company's Power Systems Division and served as a design engineer with Jyoti Electrical, Ltd., of Baroda, India. Tahiliani holds two electrical engineering degrees—a BS from the University of Baroda and an MS from West Virginia University.

Wade Malcolm has been manager of the Power Electronics & Controls Program of the Customer Systems Division since July 1991. Earlier he was a project manager in the Electrical Systems Division's Distribution Program, on loan from Philadelphia Electric Company. At Philadelphia Electric, Malcolm was an engineer in the Research Division and the Electric Transmission and Distribution Department. He has BS and MS degrees in electrical engineering from Drexel University. ■

New Members and Vice Chairman of Board Elected

John W. Ellis, chairman of Puget Sound Power & Light Company, was reelected chairman of EPRI's Board of Directors at a meeting that followed the Institute's annual meeting of members in March. EPRI's member utilities earlier had returned Ellis to another two-year term on the Board. A. Drue Jennings, chairman of the board and president of Kansas City Power & Light Company, was elected vice chairman.



Ellis

Jennings

The member utilities elected five new members to the Board of Directors. Elected to a one-year term was William S. Crawford, president and CEO of Memphis Light, Gas & Water Division. Elected to four-year terms were James L. Broadhead, chairman and CEO of Florida Power & Light Company; Richard K. Byrne, president and CEO of Buckeye Power, Inc.; Erroll B. Davis, Jr., president and CEO, Wisconsin Power & Light Company; and Eugene R. McGrath, chairman and president of Consolidated Edison Company of New York, Inc. ■

Board Names Four New EPRI Officers

Three vice presidents and a controller were elected for EPRI by the Board of Directors at its meeting in March. The new vice presidents are Richard G. Claeys, vice president for corporate communications; Marina M. Mann, vice president for information technology; and Gail E. Parker, vice president for human and administrative resources. John D. Bateman was named EPRI controller.

"These elections reflect increased recognition by the Board of Directors of the importance of communications, information technology, and EPRI's staff in supporting the Institute's overall mission of delivering value to utilities in the form of new science and technology," says Richard L. Rudman, senior vice president for business operations.

Claeys joined the Institute in 1985 as director of the Corporate Communications Division. In addition to managing EPRI's internal and external communications programs, he is responsible for the Institute's publishing, conference, and exhibit functions; audiovisual services; executive presentations; and liaison with industry groups and trade associations on communications issues. Before coming to EPRI, Claeys was vice president of corporate communications for Metropolitan Life Insurance Company in New York. He is a member of the Public Relations Society of America and was inducted into the society's College of Fellows in 1991.

Mann has served as director of the Information Technology Division since she joined EPRI in 1984. Development and refinement of the EPRINET electronic information network and the introduction of global videoconferencing services to connect utilities and EPRI are among the major innovations implemented under her leadership. Before coming to the Institute, Mann was vice president of central systems for Wells Fargo Bank. In January 1993, Mann was named EPRI's representative to the advisory committee for the Twenty-first Century Information Infrastructure Project of the Washington, D.C.–based Council on Competitiveness. She is also a member of the Society for Information Management.

Claeys

Mann

Parker

Bateman

Parker has been director of the Human Resources Division since 1983; her responsibilities were expanded in 1992 to include most of EPRI's administrative services. She joined the Institute in 1974 as a personnel administrator, rising to manager of employment and employee relations and, later, to assistant division director. Before coming to EPRI, Parker worked for six years for the University of Michigan in employee compensation and affirmative action. Parker is chair-elect of the Board of Directors of the Society of Human Resource Management, the largest organization of human resource professionals in the country. She is also a member of the Bay Area Human Resource Executive Council.

Bateman joined EPRI in 1985 as director of administration in the Nuclear Power Division. Before that, he had spent 20 years in personnel and audit management with the DOE in Richland, Washington. He became director of EPRI's Finance Division in February 1993. ■

EPRI's Advisory Council Expanded

Among the actions taken at its meeting in March, the Board of Directors amended EPRI's bylaws to increase the size of the Advisory Council from 25 to 30 members.

"The Advisory Council is EPRI's window to the world. Given all the changes occurring in the electric power industry, the Board felt that expanding the Council would broaden the spectrum of views on the industry and EPRI's role as its collaborative research arm," explains Marvin Lieberman, director of regulatory relations.

Among recent vacancies was one created by the appointment of John Gibbons, former director of the congressional Office of Technology Assessment, to be President Clinton's science advisor (as head of the White House Office of Science and Technology Policy).

The amendment also increased the number of Council members appointed by the National Association of Regulatory Utility Commissioners (NARUC) to a maximum of 10, up from 7. Three vacancies remain to be filled by NARUC. "The increased number of regulators on the Council reflects the growing importance of state regulation in shaping the electric power industry," adds Lieberman.

NARUC's new appointees to the Advisory Council are James M. Byrne, Utah Public Service Commission; Richard H. Cowart, Vermont Public Service Board; Allan G. Mueller, Missouri Public Service Commission; and Ronald E. Russell, Michigan Public Service Commission. ■

White House Sends Congratulations

President Clinton recently extended his congratulations to EPRI on its twentieth anniversary and expressed his belief that advanced technology development will play a major part in building America's future. In an April letter to EPRI President and CEO Richard E. Balzhiser, Clinton wrote that EPRI "can be proud of its contribution to America's tradition of technological innovation and discovery."

He continued, "The future holds exciting possibilities for more efficient energy systems and environmentally friendly technology. Research and development efforts can yield benefits for our people, our society, and our quality of life." Applauding EPRI's "interest in promoting environmentally responsible energy," Clinton concluded, "With your help, we can set America on a new course." ■

Global Electrification Symposium Commemorates EPRI's 20th Anniversary

Prominent energy leaders—including senior executives of member electric utilities, government and regulatory officials, and academic experts—shared their insights on global sustainability, the role of electrification, and implications for the industry at a one-day international symposium hosted by EPRI in the nation's capital. The gathering, titled "Global Electrification: Promise for the Future," was held in honor of the pioneering spirit that led to the creation of EPRI 20 years ago.

EPRI President and CEO Richard E. Balzhiser and Board of Directors Chairman John W. Ellis, chairman of Puget Sound Power & Light Company, welcomed approximately 200 guests to the May 13 symposium. John F. Welch, Jr., chairman and CEO of General Electric Company, delivered the keynote address. Among the other symposium speakers were Dr. Zbigniew Brzezinski, national security advisor in the Carter administration and now a member of the President's Foreign Intelligence Advisory Board; Dr. Jan Beyea, chief scientist and vice president of the National Audubon Society; Dr. Hisham Khatib, chairman of the World Energy Council's Committee on Energy Issues in Developing Countries; Dr. Harold L. Hodgkinson, director of the Center for Demographic Policy, Institute for Educational Leadership; and Dr. William Nordhaus, professor of economics at Yale University.

The morning sessions focused on the challenge of sustainable global development, highlighting as key concerns population growth, environmental impacts, disparity in the global distribution of wealth, and barriers to economic development. The afternoon panel discussions focused on the role of electrification and advanced electrotechnologies in addressing these concerns and the implications for electric utility leadership worldwide. Participating on the technology panel were Dr. Craig S. Tedmon, Jr., executive vice president of Asea Brown Boveri, Ltd., and Yoshihiko Sasaki, director of electric power technology, MITI. The utility panel included H. Allen Franklin, president and CEO of Southern Company Services; Joseph H. Paquette, Jr., chairman and CEO of Philadelphia Electric Company; and Jean Bergougnoux, president of Electricité de France.

Welch's keynote address appears in this issue of the *Journal*. Other symposium presentations will be featured in subsequent issues. ■

Recycling Fly Ash

Turning Ash Into Cash

Fly ash was used in restoring and revegetating this site.

In an effort to transform an increasingly burdensome waste disposal expense into a revenue producer, EPRI recently joined forces with two of its members. Their goal: to find a productive use for the millions of tons of fly ash and flue gas desulfurization (FGD) sludge that coal-fired power plants produce every year.

In 1989, U.S. utilities generated 72 million tons of coal ash alone. "As a result of recent clean air legislation, wastes from coal burning are expected to increase, while available disposal sites are becoming more and more scarce," according to EPRI project manager John W. Goodrich-Mahoney.

In response to this dilemma, the Southern Company, the Tennessee Valley Authority (TVA), and EPRI are exploring the potential for creating ash- and sludge-based products to sell as soil amendments for agricultural use and land restoration. This research project, which is scheduled to begin later this year, will consider what mixtures of coal combustion by-products and organic matter provide the best material for agricultural soil enrichment and land reclamation use. The environmental effect of each mixture also will be assessed.

Field studies will be conducted by the University of Georgia, TVA, the University of Kentucky, and the University of Tennessee. This work is being undertaken as a result of a 1991 EPRI study showing that the southeastern and southwestern United States have the largest tracts of agricultural land near coal-fired plants—tracts that could provide excellent markets for fly ash fertilizer. The study also found that the regulatory environment in these areas is conducive to the research. Initial results from the new studies are expected in 1994, with a final report by 1996. EPRI encourages other interested utilities to get involved.

■ *For more information, contact John W. Goodrich-Mahoney, (202) 293-7516.*

50% More Power

Researchers Developing Near-Term Battery for EVs

As auto manufacturers scramble to bring electric vehicles (EVs) to market, a key question that remains unresolved is how to give zero-emission cars the range and power of their gas-guzzling counterparts. To supply first-generation EVs with enough zip to appeal to power-hungry drivers, EPRI researchers are developing an advanced lead-acid battery they say will offer substantial advantages over existing lead-acid models at no increase in cost.

In 1998, mandates for zero-emission vehicles go into effect in California, Maine, Massachusetts, and New York. As a result of these and similar measures being considered in other states, experts estimate that at least 70,000 electric vehicles will be on the road by the end of 1998. Robert Swaroop of EPRI, battery systems manager, expects that many of these vehicles will use EPRI's new battery.

Slated for availability by 1995, EPRI's advanced battery is expected to provide 50% more power than today's sealed lead-acid models, which can propel cars for about 50 miles before recharging is required. In addition to giving electric cars a range of 75–80 miles, the new batteries offer three to four times better acceleration and hill-climbing ability. "While EVs with today's lead-acid batteries are sluggish in acceleration, vehicles using our new model should be competitive with gasoline-powered cars," Swaroop says.

The advanced battery is being designed and manufactured by Electrosource, Inc., an Austin, Texas, R&D and manufacturing company. Tests of battery performance and cycle life—the number of times that the battery can be recharged—are currently under way at Argonne National Laboratory near Chicago. When full production is reached—as is expected by 1995—the batteries will cost less than \$120/kWh, according to Swaroop. A small car would need a 15- to 20-kWh battery, while a van might require a 40-kWh model, he says.

A predecessor of Electrosource began the project in the early 1980s. "EPRI got involved in 1992 because we believe that for meeting near-term requirements, the battery offers tremendous advantages over existing lead-acid, nickel-iron, and nickel-cadmium batteries," says Jack Guy, commercialization manager in EPRI's Customer Systems Division. This work complements the U.S. Advanced Battery Consortium's efforts to develop, by 1995, midterm technologies that offer a vehicle range of up to 170 miles and, by 2002, long-term technologies that can power cars for 300 miles.

■ *For more information, contact Jack Guy, (415) 855-2803.*

Materials Research

Composites Considered for Corrosion-Resistant Equipment

Since the earliest days of commercial power generation, the corrosion of power system components has caused major headaches for electric utilities. Thanks to plastics with the strength of steel, however, such problems may one day be no more.

Composites—long a mainstay of high technology and advanced-aircraft manufacturing—are gradually finding their way into everything from car body panels to oil rigs. Tom Kendrew, EPRI's manager for underground construction, would like to add electric power transmission and distribution equipment to the growing list of products that benefit from the space-age materials.

"The utility industry loses millions of dollars in equipment maintenance and replacement costs each year because of corrosion," Kendrew says. "Corrosion also is one of the principal causes of service disruption from underground transformer failure." Kendrew sees composites as having the potential to reduce both problems.

EPRI has retained Foster-Miller, Inc., of Waltham, Massachusetts—a leading developer of advanced materials for the Department of Defense and other government agencies—to investigate the feasibility of substituting lightweight, high-strength, corrosion-resistant composites for the steel and aluminum used in transformers, switches, and other power industry hardware.


Some parts of advanced aircraft are made from composites.

Composites commonly used today include carbon, glass, or boron fibers in some type of organic resin, such as polyester or epoxy. "Previously, composites weren't used heavily in general manufacturing and industry because of their relatively high cost," Kendrew says. "Now prices are coming down, and we feel it's time to look at these materials for more general applications."

Initially, Foster-Miller will identify the most promising composites for underground transformer casings. Kendrew expects to have prototypes of the casing materials available for laboratory testing later this year. Then researchers will analyze each composite to determine corrosion resistance, repairability, fire resistance, and resistance to insulating oils. By 1994, Kendrew anticipates having a prototype transformer ready for field testing.

■ *For more information, contact Tom Kendrew, (415) 855-2317.*

New Contracts

Project	Funding/Duration	Contractor/EPRI Project Manager
Customer Systems		
Demonstration of Industrial Heat Pump Technology Using Low-Temperature Effluent From a Wastewater Treatment Plant (RP2662-44)	$65,000 6 months	City of Topeka / *M. Jones*
Heat Pump Installation Guide: Closed-Loop Ground-Source Manual (RP3024-10)	$103,900 13 months	NRECA / *C. Hiller*
End-Use Emissions Database and Software Development, Phase 2 (RP3121-8)	$179,700 9 months	Science Applications International Corp. / *P. Sioshansi*
Opportunities in Advanced Materials Processing (RP3243-15)	$59,900 5 months	Arthur D. Little / *E. Eckhart*
Scoping Study: Magnetic Fields Management Related to Industrial Electrotechnologies (RP3254-4)	$52,500 16 months	IIT Research Institute / *M. Samotyj*
Market Potential Assessment for Optimized Industrial Refrigeration Systems for Food Processing (RP3324-8)	$70,900 6 months	Tecogen / *A. Amarnath*
Ultrasound Applications in Textile Dyeing and Washing (RP3329-3)	$150,000 12 months	North Carolina State University / *A. Amarnath*
Zero-Ozone-Depletion-Potential Refrigerant for Centrifugal Chillers (RP3412-11)	$348,700 22 months	Allied Signal / *W. Krill*
Alternative Refrigerants Evaluation Program: Evaporator Outside Tube and Condenser Outside Tube (RP3412-53)	$104,900 12 months	Lehigh University / *S. Kondepudi*
High-Efficiency Laundry Project (RP3417-2)	$2,824,300 60 months	Maytag Corp. / *J. Kesselring*
Commercial Building Performance Evaluation (RP3509-1)	$546,800 29 months	Architectural Energy Corp. / *K. Johnson*
ESPRE Program Enhancements and User Support (RP3512-10)	$71,900 10 months	Arthur D. Little / *J. Kesselring*
Building Performance and Diagnostics (RP3553-1)	$175,000 12 months	Carnegie Mellon University / *K. Johnson*
Electrical Systems		
Universal Database for Operator Training Simulator (RP1915-13)	$79,900 7 months	Unified Information / *J. Gralow*
Field Trials: TOMCAT 2000 (RP2472-11)	$50,000 6 months	Wisconsin Power & Light Co. / *H. Mehta*
Guidelines for Substation Life Extension (RP2747-9)	$619,700 22 months	Sargent & Lundy / *J. Porter*
Handbook on Distribution Grounding Methods (RP3066-1)	$450,100 19 months	Southern Electric International / *T. Kendrew*
Production-Grade Program for Evaluating Simultaneous-Power-Transfer Capability (RP3140-4)	$1,093,500 24 months	ABB Systems Control Co. / *P. Hirsch*
State Estimation Issues: External System Modeling Enhancements (RP3355-1)	$482,600 21 months	Macro Corp. / *J. Gralow*
Dispersed System Impacts: Survey and Requirements Study (RP3357-1)	$295,400 8 months	EPIC Engineering / *D. Maratukulam*
Dynamic Voltage Restorer (RP3389-1)	$1,496,500 32 months	Westinghouse Electric Corp. / *H. Mehta*
System Studies for Custom Power Application (RP3389-5)	$59,600 10 months	Auburn University / *H. Mehta*
Prototype Expert System for Power Quality Advisement (RP3389-6)	$191,700 38 months	Tennessee Technological University / *H. Mehta*
Biological Control of Wood Decay in Utility Poles (RP3420-1)	$220,000 36 months	Michigan Technological University / *H. Ng*
Computing the Magnetic Fields of High-Pressure Fluid-Filled Cables (RP7898-41)	$54,600 9 months	Clemson University / *F. Garcia*
Improvement of Cable Connector Reliability (RP7910-20)	$97,200 9 months	Foster-Miller / *T. Kendrew*
Evaluation of Gases Generated by Heating and Burning of Cables (RP7910-22)	$594,700 37 months	Underwriters Laboratories / *T. Kendrew*
Environment		
Evaluation of Electrodynamic Venturi for Fine-Particulate Control (RP1835-20)	$325,400 11 months	Florida Power & Light Co. / *R. Altman*
Cyclone Boiler Test Program at Central Illinois Public Service Company's Coffeen Plant (RP1835-31)	$93,000 14 months	Systems Applications / *R. Altman*
Industrial Ecology: Technological Trajectories, Technological Transitions, and Habitability (RP2030-47)	$172,800 12 months	Rockefeller University / *S. Peck*
Ash Structural Fill for Site Demonstration (RP2422-22)	$774,300 119 months	JTM Industries / *D. Golden*
Moist Duct Injection/Advanced Silicate Pilot Plant Project (RP2826-3)	$180,000 18 months	Tennessee Valley Authority / *B. Toole-O'Neil*
Full-scale Evaluation of Low-NO_x Burner for Oil-Fired Boilers (RP2869-16)	$75,000 12 months	New England Power Service / *A. Kokkinos*
Feasibility of Ground-Penetrating Radar for Use at Manufactured Gas Plant Sites (RP2879-27)	$86,100 18 months	University of Kansas Center for Research / *I. Murarka*
Reporting of Manufactured Gas Plant Technology Demonstrations at Niagara Mohawk Power Corp. (RP3072-4)	$564,100 39 months	Remediation Technologies / *B. Nott*
Installation of COHPAC (Compact Hybrid Particulate Collector) at Plant Miller (RP3083-34)	$166,100 23 months	LeCorp / *R. Chang*
PISCES Air Toxics Testing at B&W's SNRB Project and Ohio Edison's R. E. Burger Plant (RP3177-14)	$340,000 8 months	Babcock & Wilcox Co. / *P. Chu*
Mercury Speciation in Flue Gas: Methods Development (RP3177-18)	$91,600 14 months	Frontier Geosciences / *P. Chu*
Statistical Analyses of Risk Factors for Sporadically Occurring Legionellosis (RP3266-2)	$124,200 12 months	U.S. Centers for Disease Control / *J. Yager*
Florida Atmospheric Mercury Study (RP3297-1)	$1,127,700 60 months	KBN Engineering & Applied Sciences / *D. Porcella*
Bruner Island Ash Disposal, Consolidation Analysis and Monitoring (RP3346-1)	$247,800 3 months	Pennsylvania Power & Light Co. / *D. Golden*
Exploratory & Applied Research		
AC/AC Switchmode Regulator: Proof of Principle (RP8001-13)	$83,900 15 months	San Jose State University Foundation / *H. Mehta*
Electroorganic Syntheses in Supercritical Electrolytes (RP8002-45)	$140,000 28 months	Johns Hopkins University / *R. Weaver*
Electroreductive Coupling Reactions (RP8002-46)	$255,000 38 months	University of California, Santa Barbara / *R. Weaver*
Chemical Applications of Electrohydraulic Cavitation for Hazardous Waste Control (RP8003-36)	$438,800 33 months	California Institute of Technology / *M. Jones*
Spurious Solutions in Two-Phase Flow Codes and Methods of Neutralizing Them (RP8006-30)	$337,500 25 months	Brown University / *J. Kim*
Marine Biotechnology: Research Opportunities and Policy Issues (RP8011-21)	$100,000 11 months	National Academy of Sciences / *D. Spencer*
Automated Recognition of Hand-Lettered Text (RP8014-1)	$431,600 18 months	Kaman Sciences Corp. / *J. Naser*
Novel Methods for Sequential Optimization (RP8016-2)	$107,500 23 months	Ultramax Corp. / *S. Yunker*
Polymeric Ultrathin Films as Bonded Lubricants, Coatings, and Membranes (RP8019-1)	$117,700 36 months	Oregon Graduate Institute of Science and Technology / *B. Bernstein*

Project	Funding/Duration	Contractor/EPRI Project Manager
Exploratory & Applied Research (cont.)		
Electrocoagulation Applied to Wastewater for the Recovery of Soluble Metals (RP8020-1)	$118,000 12 months	Rutgers University/*M. Jones*
Avoiding Bifurcation Instabilities in Electric Power Systems (RP8050-3)	$171,300 49 months	University of Wisconsin, Madison/*A. Wildberger*
Effects of Coal Chlorine Levels on Fireside Corrosion in Coal-Fired Boilers (RP9002-8)	$61,700 7 months	Battelle Memorial Institute/*A. Mehta*
Distribution Cable Replacement Decision Analysis (RP9002-10)	$91,600 6 months	Decision Focus/*H. Ng*
Generation & Storage		
Design Data on P-91 Castings and Refractalloy-26 Bolting (RP1403-23)	$205,500 31 months	MAN Energie GmbH/*W. Bakker*
Battery Evaluation Methodology (RP2123-1)	$185,200 13 months	Energy and Environmental Economics/*S. Chapel*
Strategic Modeling in Distributed Utility and Battery Evaluation (RP2123-5)	$155,600 11 months	Applied Decision Analysis/*S. Chapel*
Novel Methods for Sequential Optimization (RP2147-24)	$107,500 23 months	Ultramax Corp./*S. Yunker*
Nondestructive Evaluation for Life Prediction of Gas Turbine Blade Coatings (RP2465-3)	$56,700 11 months	Failure Analysis Associates/*R. Viswanathan*
On-line Demonstration of Automation Design Concepts (RP2710-24)	$137,500 25 months	Leeds & Northrup Co./*D. Broske*
Combustion Turbine Materials Evaluation and Life Management (RP3064-3)	$113,000 12 months	Power Tech Associates/*G. Touchton*
Strategic Investment Evaluation for Central Station Storage Technologies (RP3116-6)	$105,000 11 months	Applied Decision Analysis/*S. Chapel*
Compact Simulator Technology Development and Demonstration (RP3152-16)	$154,600 12 months	Trax Corp./*R. Fray*
Compact Simulator Technology Development and Demonstration (RP3152-19)	$185,100 24 months	Automation Technology/*R. Fray*
Indirect Coal-Fired Combined Cycle: State-of-the-Art Plant (RP3222-4)	$112,900 12 months	Power Tech Associates/*J. Bartz*
Decision Support Methods for Fossil Plant Assets Management (RP3288-2)	$1,162,000 19 months	Strategic Decisions Group/*M. Blanco*
Hard-Panel Emulation Technology for Compact Simulators (RP3384-9)	$607,800 14 months	ESSCOR/*R. Fray*
Combined-Cycle Control System Evaluation and Optimization (RP3384-10)	$660,000 17 months	Florida Power & Light Co./*R. Fray*
Reservoir Model and Flammability Tests for Storage of Compressed Air in Depleted Natural Gas Fields (RP3389-1)	$88,100 11 months	University of Calgary/*B. Mehta*
Development of EPRIWorks Object-Oriented Developers Modules (RP3402-1)	$628,500 18 months	Automation Technology/*G. Pflasterer*
Improvements on Fossil Plant Operation and Maintenance Practices (RP3432-1)	$2,075,100 16 months	Tampa Electric Co./*D. O'Connor*
Advanced Leak Location—Research Evaluation Demonstration (ALL-RED) (RP3438-1)	$300,300 16 months	Bogan/*R. Colsher*
Computerized Logging System for Combustion Turbine Overhaul Maintenance (RPCTAG-5)	$464,100 31 months	Operational Services/*R. Frischmuth*
Integrated Energy Systems		
Emissions Allowance Inventory Management (RP3344-3)	$69,300 16 months	Applied Decision Analysis/*C. Clark*
Battelle Northwest Integrated Climate Change Analysis Model (RP3441-2)	$591,600 15 months	Battelle Memorial Institute/*L. Williams*
Impact of Global Climate Change on Electric Utilities, Phase 2 (RP3441-3)	$701,000 19 months	ICF Resources/*C. Clark*
Greenhouse Gas Risk Analysis (RP3441-6)	$372,000 30 months	Barakat & Chamberlin/*L. Williams*
Climate Research: Analysis of Alternatives and Technology Transfer Support (RP3441-10)	$342,100 15 months	Science & Technology Management/*J. Davis*
POWERCOACH Software Development (RP3581-1)	$210,000 3 months	Strategic Decisions Group/*R. Siddiqi*
Nuclear Power		
Tests of NOREM Hardfacing Alloy in Feedwater Gate Valves (RP1935-25)	$136,900 68 months	Boston Edison Co./*W. Childs*
Evaluation of High Off-Gas Failures in Barrier and Nonbarrier LWR Fuel (RP2229-11)	$177,400 14 months	S. M. Stoller Corp./*O. Ozer*
Instrumentation Surveillance and Test Reduction (RP2409-13)	$183,900 20 months	ABB Impell Corp./*R. James*
Safety and Relief Valves: Testing and Maintenance Guide (RP2814-82)	$116,500 16 months	Quadrex Corp./*V. Varma*
General Electric Medium-Voltage Circuit Breaker Guide (RP2814-83)	$65,100 12 months	BCP Technical Services/*J. Sharkey*
Westinghouse Medium-Voltage Circuit Breaker Guide (RP2814-84)	$65,100 12 months	BCP Technical Services/*J. Sharkey*
Protective Relay Maintenance and Application Guide (RP2814-89)	$64,900 9 months	Edan Engineering Corp./*W. Johnson*
ICRP Software Commercialization Program (RP2906-4)	$224,800 17 months	Science Applications International Corp./*R. Colley*
Comanche Peak Service Water System Specimen Examination (RP2939-12)	$63,900 4 months	Stone & Webster Engineering Corp./*D. Cubicciotti*
Development of Licensing PWR LOCA Analysis Method Based on Best-Estimate Approach (RP2956-4)	$180,000 21 months	Yankee Atomic Electric Co./*J. Kim*
Severe-Accident Evaluation Technical Support (RP3012-3)	$193,300 11 months	Science Applications International Corp./*J. Haugh*
License Renewal: Integrated Plan Assessment (RP3075-6)	$431,100 9 months	Multiple Dynamics Corp./*J. Byron*
Procedures Software Tool (RP3111-3)	$279,900 18 months	Battelle Human Affairs Research Centers/*J. Yasutake*
Primary Water Stress Corrosion Cracking Testing of Alloy 600 Penetrations (RP3223-3)	$202,600 7 months	Babcock & Wilcox Co./*R. Pathania*
Individual Plant Examination and Fire Probabilistic Risk Assessment Studies (RP3234-5)	$132,000 24 months	Science Applications International Corp./*R. Oehlberg*
Advanced LWR Program Support (RP3260-32)	$447,700 7 months	PoleStar Applied Technology/*T. Marston*
Burnup Credit Verification Measurement Study (RP3290-7)	$130,000 19 months	Sandia National Laboratory/*R. Williams*
Operating Plant Fatigue Management Program, Phase I (RP3321-1)	$254,000 13 months	Structural Integrity Associates/*Y. Tang*
BWR Shutdown Risk Assessment and Management Guidelines (RP3333-10)	$667,800 14 months	Erin Engineering & Research/*P. Kalra*
PWR Shutdown Risk Assessment and Management Guidelines (RP3333-11)	$652,500 15 months	Westinghouse Electric Corp./*P. Kalra*
Advanced Control-System Design Base Documents and Task Force Support (RP3338-6)	$83,700 19 months	Duke Power Co./*S. Bhatt*
Integrated Instrumentation and Control Project Evaluation Method (RP3373-5)	$91,600 12 months	Decision Focus/*C. Lin*

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TAG™ Technical Assessment Guide, Vol. 2, Part 2: Commercial Electricity End Use (1992 Edition)
CU-7222 Final Report (RP3138-8), Vol. 2, Part 2, $200
Contractor: J. A. Pietsch
EPRI Project Managers: M. Blatt, W. Krill

Commercial Water Heating Applications Handbook
TR-100212 Final Report (RP3169-1); $200
Contractor: D. W. Abrams, P.E., & Associates, P.C.
EPRI Project Manager: K. Johnson

Field Testing of High-Efficiency Supermarket Refrigeration
TR-100351 Final Report (RP2569-6); $200
Contractor: Foster-Miller, Inc.
EPRI Project Managers: M. Khattar, M. Blatt

Low-Airflow Drying of Fungicide-Treated Shelled Corn
TR-100969 Final Report (RP2782-4); $200
Contractors: University of Illinois; National Food and Energy Council
EPRI Project Managers: A. Amarnath, O. Zimmerman

Desk Book™: Residential End-Use Technologies
TR-101005 Final Report (RP2034-45, RP2892-25); license required
Contractors: Aptech Engineering Services, Inc.; Energy International, Inc.
EPRI Project Managers: J. Kesselring, B. Emehiser

Water-Loop Heat Pump Systems, Vols. 1 and 2
TR-101134 Final Report (RP2480-13); Vols. 1 and 2, $200 each volume
Contractor: Eley Associates
EPRI Project Manager: M. Khattar

Pinch Technology/Process Optimization, Vol. 5: Case Study—Champion International Corporation Pulp and Paper Mill in Sheldon, Texas
TR-101147 Final Report (RP2783-17); Vol. 5, $200
Contractor: TENSA Services, Inc.
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Assessment of Industrial-Sector Load Shapes
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Electric Vehicle Battery Testing and Development at Argonne National Laboratory: 1991 Annual Report
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EL-6420 Final Report (RP3187); Vol. 1, Rev. 1, $200
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EPRI Project Manager: M. McCafferty

Effect of DC Testing on Extruded Cross-Linked Polyethylene Insulated Cables
TR-101245 Interim Report (RP2436-1); $200
Contractor: Detroit Edison Co.
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Proceedings: FACTS Conference 2
TR-101784 Proceedings (RP3022); $1000
EPRI Project Manager: B. Damsky

Scoping Study: Substation Design Workstation
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Small Signal Stability Analysis Program Package Version 3.0, Vols. 1–5
TR-101850 Final Report (RP2447-1); Vol. 1, $200; Vols. 2–5, license required
Contractor: Ontario Hydro
EPRI Project Managers: M. Lauby, P. Hirsch

ENVIRONMENT

Guidelines for FGD Materials Selection and Corrosion Protection, Vols. 1 and 2
TR-100680 Final Report (RP1871-23); Vols. 1 and 2, $10,000 for set
Contractor: Battelle
EPRI Project Managers: P. Radcliffe, B. Syrett

Prototype Evaluation of Limestone Injection Multistage Burner (LIMB) Technology on a Pulverized-Coal-Fired Boiler, Vols. 1–5
TR-101072 Final Report (RP2786-2); Vols. 1–5, $200 each volume
Contractor: Energy and Environmental Research Corp.
EPRI Project Manager: B. Toole-O'Neil

Guidelines for the Use of Fiberglass-Reinforced Plastic in Utility Flue Gas Desulfurization Systems
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Leukemia in Telephone Linemen
TR-101813 Final Report (RP2964-4); $200
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EPRI Project Manager: R. Black

Controlling Corrosion in SO_2 Wet Scrubbers Using Impressed Currents, Vol. 1: Installation Procedures
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Contractor: Harco Technologies Corp
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Controlling Corrosion in SO_2 Wet Scrubbers Using Impressed Currents, Vol. 2: Monitoring of Phase 4 Field Demonstration
TR-101917 Final Report (RP1871-15); Vol. 2, $75,000
Contractor: Battelle Memorial Institute
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EPRI Project Managers: G. Cook, P. Symons

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EPRI Project Manager: R. Leyse

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EPRI Project Manager: R. Siddiqi

Priority Services Design and Forecasting Project: Priority Service Methods at Commonwealth Edison
TR-101431 Final Report (RP2801); $200
Contractors: Applied Decision Analysis, Inc.; Laurits R. Christensen Associates
EPRI Project Manager: R. Siddiqi

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EPRI Project Manager: T. Passell

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Contractors: Asea Brown Boveri; Halliburton NUS Environmental Corp.
EPRI Project Managers: J. Christie, J. Sharkey

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EPRI Project Manager: T. Griesbach

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EPRI Project Manager: R. Pathania

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EPRI Project Manager: C. Hornibrook

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TR-101257 Proceedings (RP3294-1); $200
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EPRI Project Manager: R. Williams

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EPRI Project Manager: J. Lance

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TR-101711 Final Report (RP3206-1, -2, -3, -4); Tier 1, $200; Tier 2, $25,000
Contractors: PLG, Inc.; Halliburton NUS Environmental Corp.; Science Applications International Corp.; Accident Prevention Group
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The Knowledge-Based Technology Applications Center (KBTAC) Seminar Series, Vol. 1: Introduction to Knowledge-Based Systems
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Contractors: Karman Sciences Corp.; Syracuse University
EPRI Project Manager: C. Lin

Cation Adsorption on Manganese Dioxide–Impregnated Fibers
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EPRI Project Manager: C. Hornibrook

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EPRI Project Managers: J. O'Brien, R. Viswanathan

Replacement of Pins and Rollers in Irradiated BWR Control Blades, Vol. 1
TR-101837 Final Report (RP3435-1); Vol. 1, $200
Contractor: ABB Combustion Engineering
EPRI Project Manager: H. Ocken

Proceedings: Utility Material Condition Monitoring Workshop
TR-101844 Proceedings (RP5365-1); $200
Contractor: Karta Technology
EPRI Project Manager: M. Lapides

Proceedings: Second EPRI Balance-of-Plant Heat Exchanger Nondestructive Evaluation Workshop
TR-101846 Application Report (RP3232-1); call for price
Contractor: EPRI Nondestructive Evaluation Center
EPRI Project Manager: J. Lance

Endurance Tests of Valves With Cobalt-Free Hardfacing Alloys: BWR Phase Final Report
TR-101847 Final Report (RP1935-14); $10,000
Contractor: Atomic Energy of Canada, Ltd.
EPRI Project Manager: H. Ocken

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TR-101867 Final Report (RP2407-5); $1000
Contractor: Molterus Engineering Corp.
EPRI Project Manager: R. Edwards

Severe Accident Management Guidance Technical Basis Report, Vols. 1 and 2
TR-101869 Final Report (RP3051-2); Vols. 1 and 2, license required
Contractor: Fauske & Associates, Inc.
EPRI Project Managers: R. Oehlberg, S. Oh

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Risk-Based Technical Specification Program
TR-101894 Final Report (RP3184-1); $200
Contractor: Westinghouse Electric Corp.
EPRI Project Manager: J. Sursock

EPRI Events

SEPTEMBER

8–10
EPRI's 9th Electric Utility Forecasting Symposium: Forecasting and DSM
San Diego, California
Contact: Lori Adams, (415) 855-8763

13–14
Measurement of Power System Magnetic Fields
Lenox, Massachusetts
Contact: Mary Fitzgerald, (413) 494-4359

14
Impact of Global Climate Change on Electric Utilities
St. Louis, Missouri
Contact: Susan Marsland, (415) 855-2946

14–17
PCB Seminar
New Orleans, Louisiana
Contact: Linda Nelson, (415) 855-2127

16–17
Operational Reactor Safety Engineering and Review Group Workshop
Baltimore, Maryland
Contact: Susan Bisetti, (415) 855-7919

19–24
In Situ Monitoring of Corrosion and Water Chemistry
Houston, Texas
Contact: Barry Syrett, (415) 855-2956

21–23
4th International Symposium on Biological Processing of Fossil Fuels
Sardinia, Italy
Contact: Stan Yunker, (415) 855-2815

27–29
AMP–EEI Fall Conference (focus on electrotechnology case studies)
West Palm Beach, Florida
Contact: Leslie Niday, (614) 846-7322

27–October 1
4th International Conference on Batteries for Energy Storage
Berlin, Germany
Contact: Steve Eckroad, (415) 855-1066

29–October 1
Condenser Technology
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

OCTOBER

7–8
Repowering With Gas Turbines
Danvers, Massachusetts
Contact: Barry McDonald, (714) 259-9520

13–15
Fuel Supply Seminar
Tampa, Florida
Contact: Susan Bisetti, (415) 855-7919

19–21
Fossil Plant NDE
Eddystone, Pennsylvania
Contact: John Niemkiewicz, (215) 595-8871

20–22
Meeting Customer Needs With Heat Pumps
New Orleans, Louisiana
Contact: Pam Turner, (415) 855-2010

26
Air Toxics R&D Results
Cleveland, Ohio
Contact: Denise O'Toole, (415) 855-2259

26–28
Fossil Plant Construction
Palm Beach, Florida
Contact: Lori Adams, (415) 855-8763

27
Air Toxics R&D Results
Atlanta, Georgia
Contact: Denise O'Toole, (415) 855-2259

27–28
Annual Fuel Oil Utilization Workshop
Baltimore, Maryland
Contact: Stephanie Drees, (714) 259-9520

27–29
12th Coal Gasification Power Plants Conference
San Francisco, California
Contact: Linda Nelson, (415) 855-2127

28
Air Toxics R&D Results
Denver, Colorado
Contact: Denise O'Toole, (415) 855-2259

NOVEMBER

5
Municipal Water and Wastewater Conference
Seattle, Washington
Contact: Keith Carns, (510) 262-9506

7–12
International Conference on Photochemical Measurement and Modeling Studies
San Diego, California
Contact: Pam McCalla, (412) 232-3444

8–11
4th Annual Seminar on Decision Analysis for Utility Planning
San Diego, California
Contact: Katrina Rolfes, (415) 854-7101

9
Low-Level-Waste Training Courses
Monterey, California
Contact: Linda Nelson, (415) 855-2127

10–12
International Low-Level-Waste Conference
Monterey, California
Contact: Linda Nelson, (415) 855-2127

15–18
International Conference on Fossil Plant Simulators, Modeling, and Training
New Orleans, Louisiana
Contact: Susan Bisetti, (415) 855-7919

16–19
1993 Power Quality Applications/ Power Electronics Conference and Exhibit
San Diego, California
Contact: Carrie Koeturius, (510) 525-1205

19
2d International Seminar on Subchannel Analysis
Palo Alto, California
Contact: Lance Agee, (415) 855-2106

DECEMBER

1–3
2d National Electric Vehicle Infrastructure Conference
Scottsdale, Arizona
Contact: Pam Turner, (415) 855-2010

6–9
4th International Conference on Cold Fusion
Maui, Hawaii
Contact: Linda Nelson, (415) 855-2127

7–9
Utility Motor and Generator Predictive Maintenance Workshop
San Francisco, California
Contact: Susan Bisetti, (415) 855-7919

8–9
6th Annual Conference on Utility Strategic Asset Management
St. Petersburg, Florida
Contact: Lori Adams, (415) 855-8763

8–10
Efficient Lighting Symposium
Scottsdale, Arizona
Contact: David Ross, (703) 742-8402

8–10
Expert Systems Applications for the Electric Power Industry
Phoenix, Arizona
Contact: Jouni Keronen, (415) 855-2020

JANUARY 1994

18–20
Fossil Plant Inspections
San Antonio, Texas
Contact: Lori Adams, (415) 855-8763

FEBRUARY

9–11
Innovative Electricity Pricing
Tampa, Florida
Contact: Pam Turner, (415) 855-2010

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