Emerging Markets for Distributed Resources

Taylor Moore, Senior Feature Writer, EPRI Journal
Dan Rastler, Manager for Strategic Options
Doug Herman, Manager for Fuel Cell Evaluation
Electric Power Research Institute (EPRI)

FOREWORD

Producing electricity economically, efficiently, and reliably in small, geographically dispersed units, new technologies like fuel cells and micro-turbines promised to transform the landscape of power generation in a deregulated, competitive future energy services market. Distributed generators are now being coupled with advanced energy storage devices. The new concept is called Distributed Resources (DR).

Some energy companies are already laying strategic plans to use distributed resources to create customized service offerings that can meet a variety of user needs, including premium power, peak power, and cogeneration requirements.

This article describes the new opportunities posed by the advent of pint-size power plants and other distributed resources.

The topography of the U.S. electricity supply system could be about to change in a big way. Much as computer technology has evolved from centralized, mainframe systems to distributed networks of various computing platforms, the traditional paradigm of central-station utility generating plants is making room—in anticipation of a deregulated, competitive retail market for energy services—for a strategic vision of smaller, distributed resources.

Today, central-station fossil and nuclear plants supply 87% of the electricity used in the United States; most of this electricity is generated by coal-, oil-, and gas-fired plants that, on average, are 30 years old.

Despite increasing environmental constraints, these aging fossil generating plants continue to provide efficient and reliable service. It is uncertain what form of generation will replace these plants as they are retired, although most new capacity in the near term is expected to be high-efficiency, gas-fired combined-cycle units producing low-cost, commodity-priced electricity.

Beyond that, beginning around the year 2000, it appears increasingly likely that small, distributed generating units will emerge, initially in niche markets. At the same time, new manufacturing firms will begin to appear that are focused not on large boilers and turbines but on the assembly-line production of microturbines, fuel cells, photovoltaics, and other, yet to be developed, generating options. This development will signal a change in the power business as revolutionary as the microprocessor was to the computer industry.

No one is predicting the imminent demise of central-station generating plants, which—owing to engineering economies of scale—have long produced some of the lowest-cost electricity available anywhere in the world. But new technologies for smaller-scale, distributed generation promise to produce electricity as efficiently as larger plants and, in certain applications, at a cost competitive with centralized generation. Moreover, many analysts believe that the utility industry's restructuring (into regulated distribution companies, independent transmission system operators, unregulated generating companies, and integrated energy service providers) and the unbundling of prices for various components of service (in contrast to today's simpler, regulated rates) could create many new opportunities for distributed resources.

Such resources could be applied at or near customer sites to manage multiple energy needs and to meet increasingly rigorous requirements for power quality and reliability. Distributed generators could also be deployed at utility sites—for example, at substations for transmission and distribution (T&D) grid support. Some experts predict that 20% or more of all new generating capacity built in the United States over the next 10 to 12 years could be for distributed applications, representing a potential market of several tens of gigawatts.

Fueling such optimism about distributed generation is the current or imminent commercial availability of small, low-cost, low-emissions generating technologies, both conventional and advanced. In numerous niche applications, mainly in commercial and industrial markets, such technologies could offer direct competition to today's regulated retail electric rates and to tomorrow's unbundled rate structures.

Conventional technologies for distributed generation range in capacity from several tens of kilowatts to tens or hundreds of megawatts and include reciprocating gas and diesel engines as well as larger gas turbines. Emerging technologies include microturbines of 25–75 kW, fuel cells of a few kilowatts to a megawatt or more, and even renewables-based distributed generation sources—for example, photovoltaics, which may be increasingly deployed on individual rooftops at the scale of a few kilowatts as costs continue to fall.

Distributed resources (or DR) include more than just small generators, however. They also include the backup batteries and other storage technologies that, in many cases, will be coupled with distributed generators to provide ride-through capability during momentary power disturbances and to maintain critical loads during the few seconds it takes to switch from grid power to on-site sources or vice versa. Advanced energy storage systems based on flywheels and ultracapacitors are entering commercial use and could play a significant role. In addition, distributed resources are broadly defined to include customer demand and peak-load management technologies that can minimize or defer the need for additional electricity from the grid.

Power Generation Value Chain

	Centralized Bulk Power	Local Logistical Power	Customer-Based Retail Power
Market	Wholesale market at pool/interpool level	Network/hub market	Decentralized end-use market
Customers	Bulk resellers, wholesale traders	Local distribution companies, independent system operators, energy retailers, municipals, cooperatives	On-site owners, nearby end users
Customer load	Baseload and intermediate-load demand	Intermittent and peak demand	On-site load following, plus specific customer needs
Pricing and returns	Commodity pricing and returns (percentages in the low teens)	Arbitrage and risk reduction pricing and returns (percentages in the midteens)	Customer solution/bundle pricing and returns (percentages in the high teens)

A new power generation value chain is expected to evolve as utility industry restructuring creates niche opportunities for distributed resources. In contrast to commodity-priced bulk power sold on the wholesale market, logistical power will involve local transactions between retail intermediaries and specialized generation companies that may own some local as well as bulk generating capacity. At the end-user level are sales of retail power, some of it generated on-site at customer premises. Eventually, logistical generation companies may offer T&D bypass and gas-electricity arbitrage services directly to customers, using networks of distributed resources to compete with on-site generation.

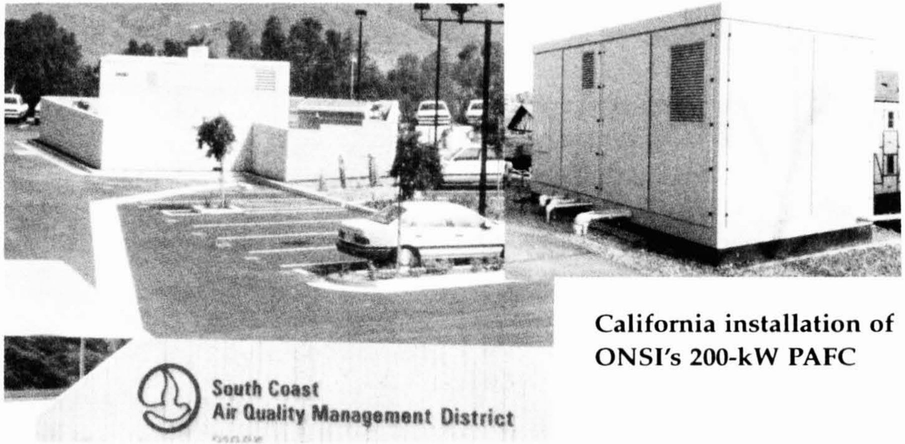
In theory, distributed resources could lead to far-flung networks of small, interconnected generators and other devices, enabling utility systems to serve growing customer energy needs while minimizing investment in and construction of new central generating and grid capacity. But before that vision becomes a reality, improved interconnection technologies are needed to link multiple small generators together into larger networks that incorporate real-time communication of market prices and centralized, or perhaps local, automated dispatch.

"Utility interest in the potential of distributed resources as a basis for new retail product and service offerings continues to grow, fueled by technical developments and by the need to find new ways of delivering value to customers," explains Dan Rastler of EPRI's Energy Conversion Division, who manages two related DR target areas. "Recent breakthroughs in microturbine and fuel cell technologies for transportation and stationary applications, coupled with the restructuring of the electric power industry, are focusing attention on distributed resources as a potential new retail-access option and a new business opportunity for electric and gas utilities."

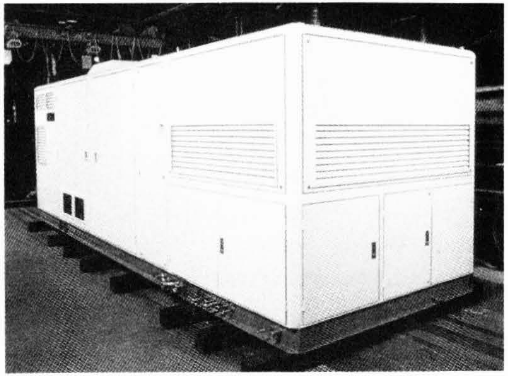
Says Christopher Maloney, vice president and general manager of Unicom Resources, a subsidiary of the Chicago-based corporation Unicom (also Commonwealth Edison's parent company), and head of Unicom's corporate development group: "We believe that, over time, distributed generation will play a critical role in shaping our industry."

Utility interest in the potential of distributed resources as a basis for new retail product and service offerings continues to grow. Unicom Resources, a subsidiary of the Chicago-based corporation Unicom, which is also Commonwealth Edison's parent company, formed an ex-

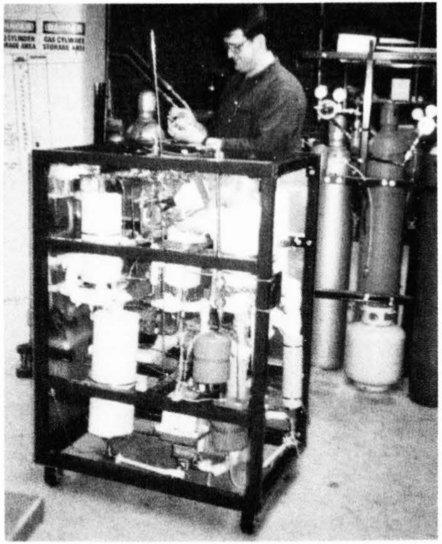
Because they offer high efficiency and low emissions, fuel cells are well suited for distributed generation applications. Already commercially available are 200-kW phosphoric acid fuel cells (PAFCs), and molten carbonate fuel cells have been demonstrated at the 2-MW scale. Solid oxide fuel cells ranging from 15 kW to 3 MW could serve as small cogenerators in commercial and multifamily residential buildings. Meanwhile, polymer electrolyte membrane (PEM) cells are under development for use in transportation vehicles and as stationary power plants at various sites. Cinergy Corporation recently placed the first commercial order for Ballard Generation System's 250-kW PEM fuel cell; a prototype is already operating on the BC Hydro grid.



California installation of ONSI's 200-kW PAFC



Ballard's 250-kW prototype PEM fuel cell



American Power's 3-kW prototype residential PEM fuel cell and storage system clusive alliance in 1997 with AlliedSignal's power systems unit to market—in a 12-state region and in the Canadian province of Ontario—AlliedSignal's TurboGenerator line of microturbines for distributed applications. The alliance is one of several AlliedSignal has recently formed with energy companies to market and distribute its microturbines. These pacts also include one with Public Service Enterprise Group, which covers the northeastern states, and one with New Energy Ventures of Los Angeles, which is targeting West Coast businesses as customers that could use microturbines to reduce their utility bills. Other ventures between utilities and major vendors of distributed generating equipment include Ballard Generation Systems (formed by New Jersey–based GPU and Canadian fuel cell developer Ballard Power Systems) and Plug Power (formed by Detroit Edison and fuel cell developer Mechanical Technology Inc.).

STRUCTURAL CHANGES DRIVE INTEREST IN DR

The potential and roles of distributed resources in a competitive energy market will depend heavily on the pace, extent, and geographic pattern of regulatory reform across the country. Alternative paths to industry restructuring have been identified in EPRI research and have been used to frame various market outcomes and future scenarios for the deployment of distributed resources.

This work has yielded several insights. For example, regions and states where electricity prices are above average (such as California, New York, the mid-Atlantic states, and New England) have the greatest potential for DR penetration. Competition and the freedom of retail customers to choose among energy providers may evolve more rapidly in those regions, and retail service companies and other players will enter those DR markets more aggressively.

The most promising users of DR are businesses, factories, and various other sites needing steam or hot water from cogeneration; distributed generation technologies like fuel cells and small gas turbines are well suited for such sites. These and other distributed resources can also provide economical peak shaving, high power quality, and standby and uninterruptible power.

Distribution companies are expected to represent only 10–15% of the future DR market, since they will probably be prohibited from mixing unregulated generating assets with regulated T&D assets in the same corporate entity. But distribution companies are likely to form strategic alliances with unregulated retail affiliates, energy service companies, equipment vendors, or other third parties that may own or control DR assets.

EPRI has identified three structural shifts in the electric power industry that are driving interest in distributed resources. First, the shift away from command-and-control market regulation will result in the deregulation of about 70% of the utility sector's total economic value. The generation, trading, and retailing segments of the industry will become much less regulated, while T&D functions will be more regulated.

Second, an enormous transfer of generation assets from the regulated rate base to unregulated enterprises is under way. At least 15 utilities have already announced plans to divest themselves of more than 25 GW of generating capacity. By 2001, fossil fuel plants totaling 100 GW could change hands; by 2006, some 400–450 GW of capacity could be spun off from the rate base of investor-owned utilities, most of it sold through auctions.

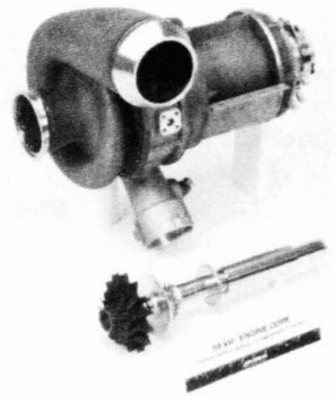
These shifts will, in turn, lead to a third major shift: the opening of a $500 billion, competitive wholesale and retail market that will bundle electricity and gas with energy services (e.g., water and cable communications) and such ancillary services as facility management and performance contracting.

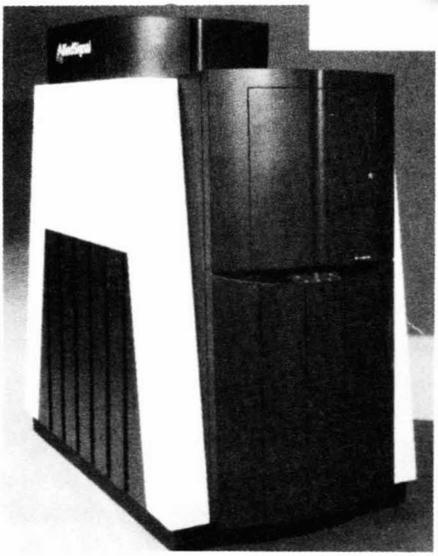
As a result of these major changes, a new value chain will form, and new business models will evolve to seize opportunities created by technology innovation and by ideas imported from industries that are already largely deregulated, such as telecommunications, natural gas, and financial services. This value chain will be much larger than the power industry alone and will aim to serve a $1 trillion customer base for all the services—energy, telecommunications, and infrastructure—needed by people and organizations to operate in buildings. There are plenty of signs that customers want to buy bundled energy and infrastructure services—witness the popularity of total customer solution marketing in many other service industries.

The new value chain is likely to have five principal segments.

<u>Generating companies</u> will focus on producing power under market conditions.

<u>Transmission companies</u> or network operators will run the high-voltage systems for long-distance power transfers. Trading companies



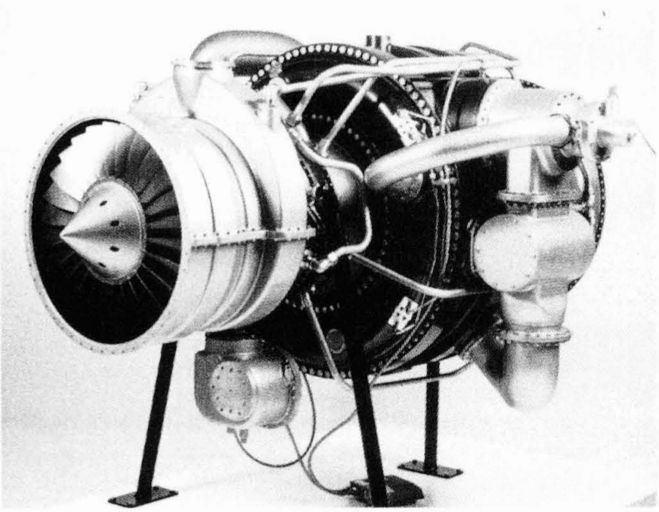


Microturbines of 25 to 100 kW that can be mass produced at low cost are entering commercial markets for distributed generation. They are designed to combine the reliability of auxiliary power systems used on board commercial aircraft with the design and manufacturing economies of automotive turbochargers. The reliability and durability of microturbines for distributed applications remain to be demonstrated. Shown here are Allied-Signal's 75-kW Turbo-Generator (below) and a 50-kW micro-turbine core originally developed for use in hybrid electric vehicles.

will buy power from generating companies and serve as intermediaries to sell power to downstream customers.

Local distribution companies for electricity, gas, telecommunications, cable service, and the like will be the platforms for delivering electrons, Btus, and other services.

Meanwhile, retail merchant companies will sell the services to customers, buying wholesale energy from traders and getting it to customers through the distribution companies.



AlliedSignal's 10-MW ASE120 aeroderivatiave gas turbine

Compact combustion turbines based on jet aircraft engine designs and heavy-frame industrial turbines are commercially available in unit sizes of 1-100 MW. Simple-cycle units can provide peak power or T&D grid support. Advanced high-efficiency designs incorporating waste heat recuperation are ideal for industrial cogeneration (combined heat and power) applications.

NEW OPPORTUNITIES IN THE VALUE CHAIN

The emergence of such a value chain will coincide with three other major trends. First, there will be both consolidation and fragmentation in the power industry. The ownership of large, centralized generating plants will be consolidated in order to cut production costs. At the same time, new opportunities will appear for localized and distributed generation in medium unit sizes to complement this bulk supply system and to serve as a hedging asset to balance supply and demand portfolios.

Second, there will be an outpouring of new service offerings to meet the needs of new wholesale and retail customers. Wholesale market offerings will tend to be structured; in the retail market, some customers will want customized solutions while most may prefer stan-

Your Utility May Be Able To Help You

EPRI Tools for DR Analysis

EPRI's distributed resource data files include comprehensive portfolios of information, technologies, and analytical tools for developing and executing new DR strategies. Drawing on expertise in three areas—user systems, energy conversion, and power delivery—this balanced program is creating and delivering products to help utilities help their customers understand and implement cost-effective distributed resources.

The targets cover the spectrum of R&D from strategic business assessments, information resources, and distribution system investment planning tools to the definition and development of new DR technology products for retail users. DR applications are being developed that can migrate from niche markets to mass markets. The EPRI targets offer numerous tailored collaboration opportunities for direct user participation in pilot tests and demonstrations of emerging distributed technologies that promise significant benefits in critical applications.

TAG (EPRI's DR Technical Assessment Guide) software provides generic cost and performance information on distributed generation and storage technologies, end-use technologies, and distributed system upgrade equipment. TAG-DR is designed to serve as a one-stop information source and analytical tool for preliminary planning for DR-related implementation. Your utility will have access to this software.

To successfully implement distributed resources, energy service providers can help users with packaged, turnkey solutions. EPRI's Distributed Resources Workstation enables users to identify custom solution packages that are best suited for their individual applications. It can evaluate DR options for such key energy services as cogeneration, standby power, peak shaving, premium power, and uninterruptible power. Recent enhancements to the software have added capabilities for modeling complex load shapes as well as rate structures for purchased energy.

The DR Workstation enables user-specific analysis that can quickly identify the optimum solution for combining services and equipment to meet individual user needs. It provides an analytical platform that can evaluate all of a user's options, from buying power to installing on-site generation, installing load-control devices, and improving energy efficiency.

On the basis of load and rate modeling and the evaluation of various technology and service scenarios, the DR Workstation can generate a report that details the economics of an optimum user solution. Because the information is so highly customized in terms of both local utility rates and user needs, such reports can have great strategic value in assessing DR.

Correct analysis of which DR options make the most sense for each individual user can spell the difference between a successful project and an unsuccessful one. The DR Workstation greatly simplifies and streamlines the process.

dardized, one-rate service plans.

Third, new technologies, both for generation and for trading and transaction processing, will be used to help serve these new customers. Technology will profoundly affect the way electricity is generated and brought to the competitive market.

On the generating side, there will be plant upgrades and the reengineering of operation and maintenance activities; enhanced real-time diagnosis and control; advanced gas turbines and more-flexible operating cycles; and improvements in distributed generation, including more types of prime movers, better controls, lower costs, and increased reliability.

On the trading and transaction side, faster trading systems and bargain-hunting expert systems will play a role, as will advanced customer knowledge systems and the growing sophistication of service offerings.

The new value chain envisioned will involve three forms of power.

1. Commodity-priced bulk power for wholesale transactions at the power pool or interpool level will be generated by large baseload and intermediate-size plants. (The price of such baseload-generated electricity could fall in a competitive market because most U.S. regions currently have a capacity surplus.)

2. The second type of power—for local (generally intrapool) purchase by distribution and retail merchant companies—is called logistical power and will be generated in smaller amounts and for shorter periods to help balance wholesale supply and retail demand. It will be produced by specialized generation companies operating within regional electricity networks. In each region, half a dozen such specialized logistical producers may emerge, each supplying 40–50 energy companies. These producers will offer backup reliability services, peak-management contracts, and price risk containment insurance.

3. The third type of power, retail power, will be sold at the end-user level as part of a broader offering (bundled with other commodities and combined with facility services). Some of that power will be generated at customer sites. Eventually, the regional logistical companies mentioned above could offer T&D bypass and arbitrage

services, using networked and other interconnected forms of distributed generation to compete with on-site distributed generation.

Industry restructuring and the emergence of a new value-added chain in the production and delivery of electricity is likely to lead to an explosion in electricity product innovation. Distributed generation will offer the means for providing more-profitable, value-added custom service offerings in the intermediate wholesale and retail markets.

FOCUS ON CUSTOMERS

One upshot of industry restructuring along a new value-added chain is the emergence of an entirely new set of potential DR customers.

Merchant retail companies may develop local networks of distributed generation to support their service business.

Distribution companies could become customers for distributed generators in the 1–2-MW range for operations support.

Energy demand aggregators may want to own interests in similar-size units to help firm up loads for better prices.

Logistical companies may own some cogeneration or small, dispersed power units to balance asset portfolios and provide flexibility to power contract transactions.

Given the anticipated involvement of these types of players, end users are expected to account for no more than 15–25% of the total amount of distributed generation that is installed. But even that percentage range could translate into very large numbers of installations in various types of buildings. EPRI has analyzed a significant number of key market segments in detail and has identified a potential of 1.6 million existing establishments—representing an aggregate load of 288 GW and annual revenues of some $66 billion—where distributed resources conceivably could be economical.

DR penetration of these markets is likely to occur gradually. But by the time that retail electricity markets are fully deregulated (around 2002–2003), the equivalent of 25–30 GW of load may be accessible to distributed generating units in the 200-kW to 1-MW capacity range. During the transition to full retail competition, some dozen or more utilities may invest in on-site generating facilities in applications of 1–2 MW as part of a strategy to retain larger customers, creating a near-term market for distributed generation of as much as 2 GW.

Regulators may limit such investments, however, to pilot programs or franchises to unregulated subsidiaries, which are expected to take the lead in developing distributed resources.

Throughout the transition to competitive energy markets, the pace of DR deployment will be strongly affected by regulatory treatment of utilities' stranded costs. These include not only costs for noncompetitive central-station power plants built in a regulated environment—plants based on demand projections that turned out to be too high—but also wires charges for maintaining and operating newly independent transmission networks.

Whether energy service companies and customers can avoid or bypass these wires charges and capture the full benefit of distributed generation is an issue. A vertically integrated utility can identify economic benefits all the way through its system, from lower generating costs to reduced T&D requirements. But for a restructured, disaggregated utility, how those benefits can be captured through market mechanisms is still an open question.

Pollutant emissions with a potential impact on local air quality could be another wild card for certain distributed generating technologies. Most states are expected to follow the example of such states as California and Massachusetts, which offer legal waivers to potentially lengthy permitting requirements for fuel cell generators because of their intrinsically low pollution and quiet operation. State agencies, however, may continue to strictly apply low-emissions standards for reciprocating engines and gas turbines.

OPTIONING USER'S GENERATORS

Some utilities already see on their systems a significant installed base of user-owned distributed generation that may be ripe for very low cost conversion to dispatchable, firm peaking capacity. Utilities see this potential when they look at user sites that have emergency backup generators, most of which are rarely called into service or even started.

PacifiCorp of Portland, Oregon, is pursuing the development of customer-owned backup generators as distributed peaking capacity. Following pilot tests last year, the company is recruiting user and negotiating commercial arrangements to pay to take over the operation and maintenance of backup generators at user sites.

PacifiCorp will retrofit the machines with closed-transition switchgear and a software-based control system to make them remotely dispatchable and aggregate them as a significant block of peaking capacity. Users will collect a fee for the conversion and will be paid for electricity their generator supplies to the grid.

Distributed Generation Options

Type	Size	Efficiency (%)*	Market
Diesel engines	50 kW-6 MW	33-36	Standby power for commercial and small industrial customers; T&D support
Internal combustion engines	5 kW-2 MW	33-35	Primary power; commercial generation
Combustion turbines	1-100 MW	33-45	Industrial cogeneration; T&D support
Microturbines	25-100 MW	26-30	Standby power; remote power; commercial cogeneration
Phosphoric acid fuel cells	200 kW-1 MW	40	Commercial cogeneration; premium power
Solid oxide fuel cells	25 kW-3 MW	45-65	Commercial cogeneration; primary power
Molten carbonate fuel cells	3-5 MW	55	Primary power
PEM fuel cells	<1-250 kW	40	Residential customers; premium power; remote power
Battery storage	500-5000 kWh	70-75	Power quality; voltage regulation; premium power
Photovoltaic arrays	<1-1000 kW	10-20	Remote power;peak shaving; power quality; green pricing
Flywheels	2-20 kWh	70-80	Telecommunications, cable TV, premium power
Stirling engines	1-25 kW	20	Residential customers; remote power

David Engberg, technology business development director at PacifiCorp Energy Ventures, says the company is pursuing this form of distributed generation not only because it promises to be low in cost but also because PacifiCorp has a business interest in the dispatch and control technology being used. This technology, called the Virtual Power Plant, is a computer-based system developed by Encorp of Fort Collins, Colorado, for the remote monitoring, control, and grid paralleling of dispersed generators.

For utilities, converting installed backup generators to dispatchable, firm peaking capacity can be a very low cost alternative for adding capacity, on the order of $100/kW. Correctly determining the value of such a call option on distributed generating capacity so that it can be properly compared with alternative options is perhaps the biggest hurdle to using the approach.

This type of distributed generation tends to get overlooked, but it can be valuable to a utility and to generator owners because it gives them some return on investment for what is otherwise a dead asset. It is one of the resources to help manage peak demand. Closed-transition switchgear is neither standardized nor commodity priced. Its cost—higher than that of the simpler switchgear commonly used for backup generators—can make conversion uneconomical for units of less than a few hundred kilowatts.

INTEGRATION WITH THE GRID

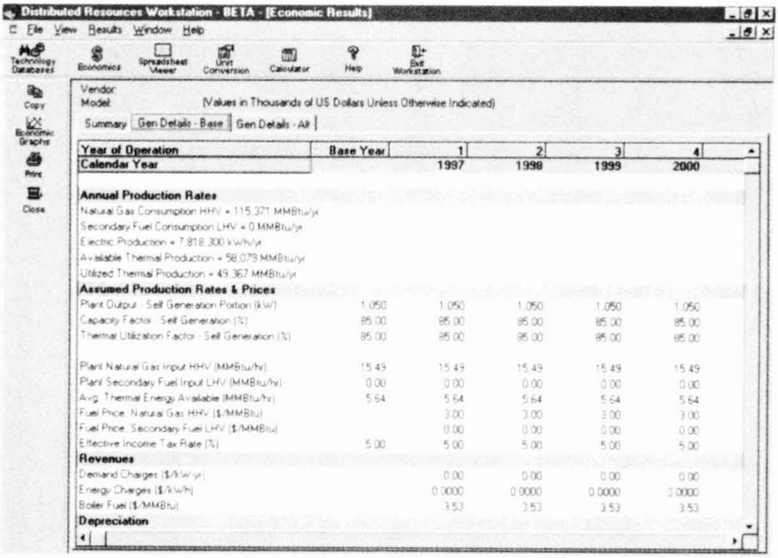
The need for less-expensive, standardized switchgear is only one of several issues to be addressed regarding the interface between distributed generation and utility distribution systems—issues that are likely to become more prominent as DR penetration increases. Another is the need for broadly accepted interconnection standards that ensure personnel safety and the protection of customer-owned equipment from distribution system operations or anomalies.

Although some IEEE standards and guidelines for connecting distributed resources with the grid have been developed, particularly for photovoltaics, compliance is voluntary and often inconsistent. Few utilities have established generic procedures for communicating interconnection requirements for on-site generation by customers.

In addition, to enable higher levels of grid-connected distributed generation in the future, it will be necessary to improve power conversion and inversion technology through the use of thyristors or other power electronic devices. Some distributed power sources, including fuel cells, need inverters to convert DC output to grid-quality AC, while other technologies—such as various turbogenerators—require AC-DC-AC converters.

New, lower-cost, programmable power electronic packages are needed that can flexibly serve the conversion and inversion requirements for most or all distributed power technologies. The next generation of inverter or programmable operating devices for interconnection could have many functions besides DC-AC conversion, such as protective functions and the capability for communications with central control systems. It will be able to serve as an adaptable interface for integrating distributed resources at high penetration levels.

If modularity and programmable logic are built into these devices, and if inductive components can be eliminated, and if the devices can be made compatible with many applications (to increase manufacturing



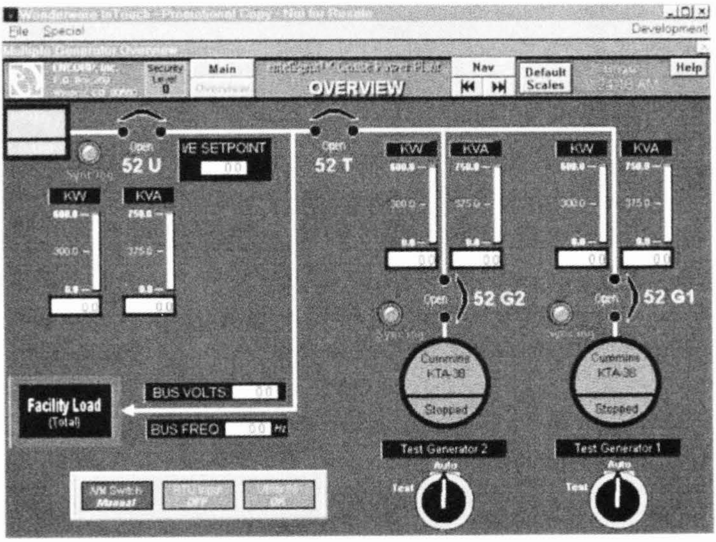
EPRI's Distributed Resources Workstation, which draws on detailed vendor- and model-specific data on the performance and economics of various DR technologies, can be used to analyze and compare alternatives options for individual customer applications.

volumes), it should be able to drive costs down and improve reliability. Eventually, inverters and other electronics that are smarter and significantly cheaper, and that can be applied with nearly all types of distributed resources, will be developed.

A FLEXIBLE ENERGY OPTION

Although opinions vary widely about how rapidly and how extensively distributed resources will be developed and deployed in the United States during this period of power industry transition, there is little disagreement about their virtually infinite potential in developing countries that have little or no existing power delivery infrastructure.

Moreover, in Europe, rapidly growing customer markets for cogeneration (combined heat and power) are providing opportunities for



Encorp's Virtual Power Plant software is designed to let users monitor and control multiple remote standby (emergency) generators at various locations via phone lines or other means of communication. PacifiCorp Energy Ventures plans to use the Virtual Power Plant network to dispatch small generators at customer sites as peaking capacity.

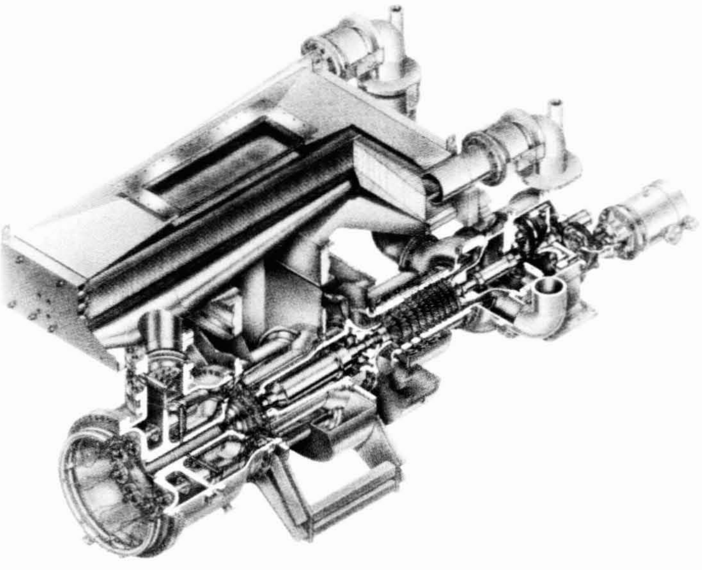
distributed generation. The deployment of distributed resources abroad is expected to help reduce costs, which in turn will make the technologies more competitive in U.S. markets.

PacifiCorp and Unicom are among the utility companies actively pursuing DR projects overseas. Many of the manufacturers of distributed generating equipment are getting a lot of interest from governments and agencies around the world that don't have the billions of dollars needed to build central-station power plants and transmission infrastructure. Global market forces are creating a need for these technologies.

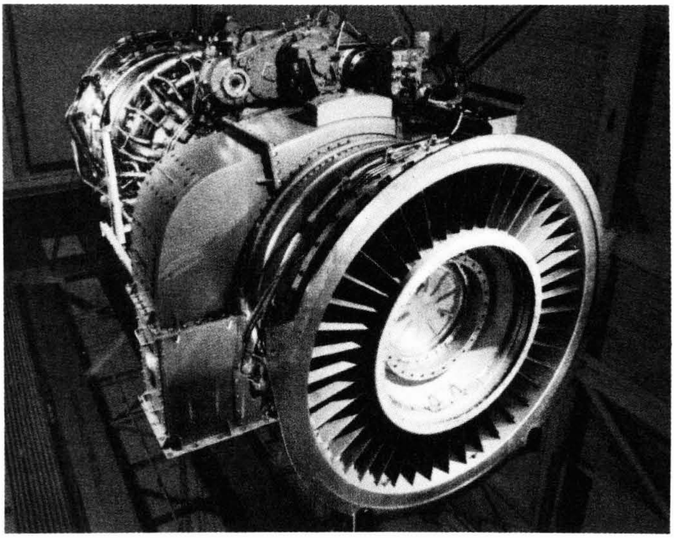
Indeed, worldwide, the convergence of market competition, customer choice, and the undeniable benefits of electrification are making future prospects for distributed generation brighter than ever.

Some utilities clearly see a potentially substantial competitive threat. Those which are engaged in the energy services business, however, now see a product or series of products on the horizon that can be bundled with natural gas, O&M, and such financial services as leasing.

In addition, for the tens of thousands of users that have cogeneration requirements, the distributed resources concept is a very attractive solution.

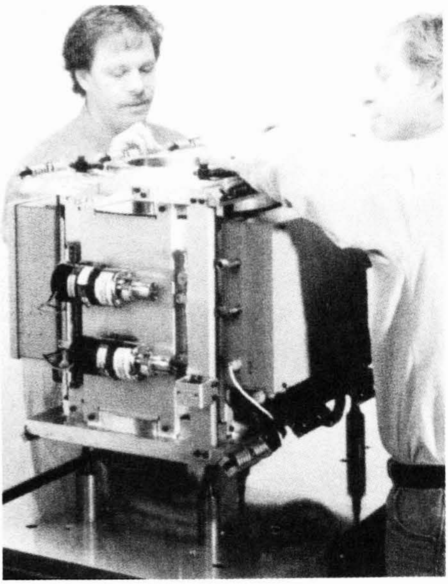


Solar Turbines' 4.2-MW Mercury 50 recuperated turbine

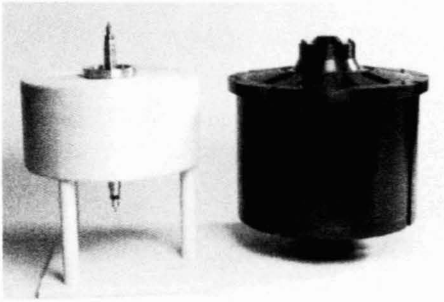


General Electric's 45-MW LM6000 aeroderivative turbine

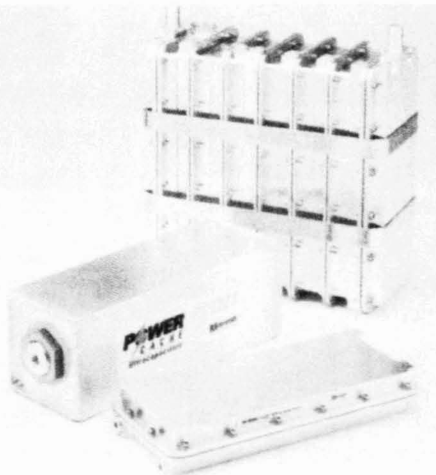
Energy storage devices, including batteries and advanced technologies like flywheels and ultracapacitors, can be integrated with distributed generators to provide peak power or ride-through power during transitions between grid supply and local generation. For example, Trinity Flywheel Power's 700-kW system, which features twin flywheel motor-generators, can deliver electricity on demand for 5 seconds. And Maxwell Energy Products' PowerCache ultracapacitor cells can be configured in series or parallel arrays to meet a range of storage requirements. A 28-cell module can provide up to 12.5 kW of power for a few seconds, and several modules together can provide ride-through capability for a 75-kW micro-turbine.



Trinity Flywheel's 700-kW system



Beacon Power's 1-kW/2-kWh flywheel system for use in cable TV and standby power applications



Maxwell's PowerCache ultra-capacitor cells and modules

There are still many challenges ahead, but distributed resources will give energy companies and energy users a flexible energy solution that can complement electricity straight from the grid.

ABOUT THE AUTHORS

Taylor Moore, *EPRI Journal* senior feature writer, has been with EPRI since 1982. Previously, he was a reporter for the Associated Press. Mr. Moore has a BA in energy and resources, University of California at Berkeley. He received principal assistance from two members of EPRI's Energy Conversion Division.

Dan Rastler, manager for strategic options, came to EPRI in 1981 as a project manager for fuel cell systems. Previously he spent five years with General Electric Company's Nuclear Energy Division, four years in the U.S. Air Force, and one year with Toscopetro Corporation. Rastler received a BS in chemical engineering from the University of California at Davis and an MS in mechanical engineering from UC Berkeley.

Doug Herman, manager for fuel cell evaluation, joined EPRI in 1993. Previously he spent 10 years with Pacific Gas and Electric Company in San Francisco, where he managed various engineering projects. Herman received a BS in mechanical engineering from the University of Santa Clara and an MS in energy and resources from the University of California at Berkeley.

Background information for this article was provided by EPRI's Dan Rastler, Doug Herman, and Tony Armor, Energy Conversion Division; Howard Mueller, Corporate Development; and Frank Goodman and Gopalachary Ramachandran, Energy Delivery and Utilization Division.

Electric Power Research Institute, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303; 650-855-2000

EPRI's considerable work in the area of distributed resources includes the strategic business and technology assessments documented in these reports, which are available to funders of the distributed resources targets. Check your utility for further information.

Selected EPRI DR Reports

Distributed Resources Strategic Review: Market Drivers Impacting Future Business Prospects (TR-110245; forthcoming)

Understanding Customer Needs and Markets for Distributed Resources (TR-109234-V 1)

Markets for Distributed Resources: Business Cases for DR Applications (TR-109234-V2)

Assessment of Micro-Generation Technologies for Distributed Generation Applications (TR-107634)

State of the Art of Fuel Cell Technologies for Distributed Power: Technical and Strategic Assessment of Products, Markets, and Retail Competitiveness (TR-106620-R1)

State-of-the-Art Assessment of Advanced Combustion Turbines for Distributed Generation (TR-108862)

State-of-the-Art Assessment of Polymer Electrolyte Membrane Fuel Cells for Distributed Power Applications (TR-107064)

Commercial-Sector Solid Oxide Fuel Cell Business Assessment (TR-106645)

Santa Clara 2-MW Fuel Cell Demonstration: Power Plant Test Report (TR-108252)

Internal Combustion Engine Advances for Distributed Generation Markets (TR-108861)