keeping CURRENT

Electric Revolution:

Think Small for a Big Change

February 1999

- A California software company installs its own $6-million substation and distribution system to improve power reliability and quality.

- The 1999 Detroit International Auto Show features a sport-utility vehicle with mini-wipers on the rearview mirrors and a hydrogen fuel-cell engine.

- A solar dealer busily installs photovoltaic systems at homes on the San Juan Islands. He's heavily booked through the summer of 2000.

These seemingly unrelated actions are all part of a looming revolution in the power industry.

They're factors leading the industry toward distributed power – locating power sources close to or at the end use, tailored to the unique needs of each consumer. It's a different way to think about providing electricity, from the bottom up instead of the top down.

Deregulation is changing the way the power industry is organized.

Distributed power will bring a new look to the power system itself.

New additions to the power system may increasingly take the form of a fuel cell here, photovoltaic windows on a super-efficient building there, and a microturbine in a substation across the way, rather than a large central plant integrated by a high-voltage transmission line.

Technological innovation is driving this revolution. Microchips, miniaturization, and improved power inverters and control technologies allow precise manipulation of power flow. Advances in materials from platinum to plastics are bringing fuel cells and other long-arcane power sources closer to the mainstream.

Many of these technologies offer environmental benefits, especially low or no air pollution.

For consumers, distributed power technologies may help reduce overall costs and improve services. For utilities, these technologies may offer new ways to serve their customers and to solve transmission and distribution problems. For everyone, they'll mean a cleaner, healthier environment.

This brochure reviews the status of some distributed power concepts and suggests how these ideas may help meet consumer and utility needs.

Rising Consumer Expectations

"I believe fuel cells or other technologies will become competitive and efficient enough for consumer consumption in the next 10 years. Utilities will be using the technologies to respond to consumers' energy and reliability needs, and we will be looking at how these small generators can help us address system planning requirements."
— John White, Snohomish County PUD

All consumers care about cost. But other aspects of electricity are playing an increasingly important role in power supply decisions, especially as deregulation gives consumers more choices.

The Reliability Market

"It doesn't do any good to add transformers in the substation when a drop of 20 percent in voltage for several cycles can cost a fabrication plant tens of millions of dollars."
— Lawrence Papay, Bechtel Inc.

Utilities have traditionally sold energy and capacity. A third market – for reliability – is emerging. Industries from silicon chip fabricators to insurance com-panies with large data bases rely on sensitive electronic equipment that requires exceptionally stable voltage. Other loads, such as hospitals, require uninterruptible power. Distributed resources can isolate loads from power quality and reliability problems.

The reliability market is not limited to commercial and industrial loads. Some utilities, such as Columbia River PUD, already sell generator sets to homeowners who want their own backup power. Avista Corporation promises that with its residential fuel cell, your kids won't know the meaning of "blackout."

Energy as a Service

"Deregulation may or may not have lowered your phone bill, but it has certainly brought you new services."
— Judi Johansen, BPA

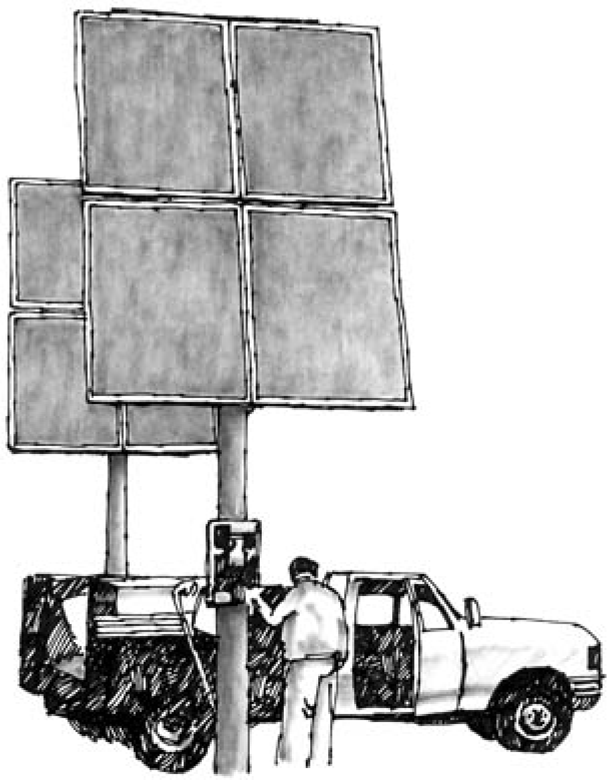
Electricity is merging with other consumer benefits, from remote appliance control to home security.

For example, a hospital might use a fuel cell to produce absolutely reliable power, then use the hot water produced by the fuel cell to wash linens, and use a microprocessor to do the laundry at night, reducing the hospital's peak power loads.

Or, imagine walking into your new house with your arms full of groceries. "Hall lights on," you say, and the path to the kitchen lights up. BPA's NeXt House, to be featured in the 1999 Parade of Homes near Coeur'd Alene, Idaho, will demonstrate technologies that rely on "intelligent" sensors to run home operating systems efficiently and automatically.

The Green Market

There is a growing consumer demand for clean power sources. Northwest utilities such as Emerald PUD in Oregon and Snohomish County PUD in Washington are giving their customers an opportunity to choose environmentally preferred power. Tax incentives in Oregon and Washington and national programs such as the U.S. Department of Energy's Million Solar Roofs Initiative support renewable resources.



Lower Costs for Remote Sites

"I think that the fuel cell shows significant promise for customers of rural electric cooperatives. We get requests for service that would involve $150,000 to $200,000 in extension costs. As a result of deregulation, most co-ops are looking at other services we can offer our members, such as propane. A fuel cell that runs on propane would expand our approach to this new business environment."
— Werner Buehler, Salmon River Electric Co-op

Places where diesel or propane powered backup generation or battery storage are used are early candidates for newer generations of distributed resources.

Creative use of distributed resources can solve problems far from the nearest power line. For example, the Confederated Tribes of the Warm Springs Reservation recently improved salmon habitat by installing photovoltaic-powered electric pumps to draw water for cattle troughs in upland meadows. The cattle stay in the pastures, away from salmon streams. The alternative, fencing the streams, would have cost more .

Rx for Grid Strains: Take Two Fuel Cells and Call Me in the Morning

"In 10 years or so, I wouldn't be surprised to see 25-megawatt or larger generators placed in neighborhood substations as an alternative to construction of new transmission lines. It is also likely that we will see five-MW generators sited along and connected to distri-bution feeders to offset the capacity needs associated with rebuilding distribution lines."

— John White, Snohomish County PUD

Distributed resource technologies can also solve transmission and distribution problems on the utility's side of the meter. The Northwest no longer enjoys its accustomed margin of generating reserves and transmission capacity to respond reliably to demand in extremely cold weather. If the interties are fully loaded, the region could be short by as much as 700 megawatts. Maintaining voltage stability, especially west of the Cascades, could become more difficult in peak usage periods.

Distributed generation could offset the need for building new power lines, while maintaining and enhancing reliability. Building small-scale generators and managing demand for electricity supports voltage, corrects power factors, shaves peaks and levels loads.

BPA studied the use of distributed resources as part of the Puget Sound Reliability Project in 1989-90, and, in the end, met the growing power need by adding equipment to substations and beefing up energy conservation programs, rather than building a new transmission line across the Cascades.

Tech Specs

Nanotechnology Sparks the Revolution

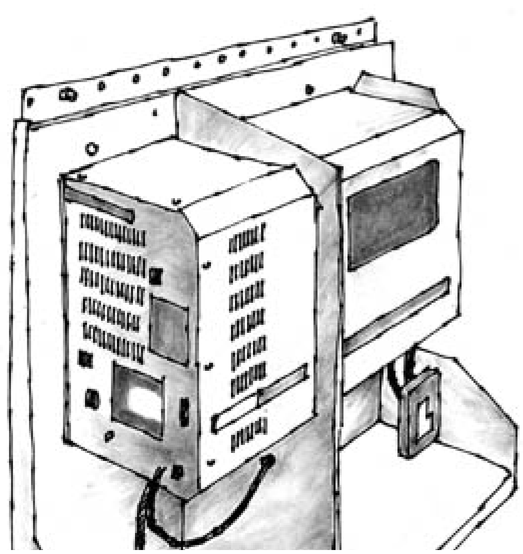
"The digital microprocessor is providing a quantum leap in electricity's advantages."
— Kurt Yeager, Electric Power Research Institute

They're not sexy. They're not noticeable or often even visible. But without them, the power revolution wouldn't be happening. They're the tiny chips, little wires, subtle sensors and obscure metal boxes that connect, invert and control power, run it in the right directions, and let humans know what's going on.

Super-capacitors, thyristors and other advanced solid-state power electronics have created whole new ways to manipulate electricity flow. New micro-processor sensors in automated building and industrial systems collect data on every crucial aspect of operations. Submetering end-use power consumption allows for smart houses and businesses, individual control and more effective energy saving.

Inversion and Integration

"Control and integration are just as important as power source."
— Joseph Iannucci, Distributed Utility Associates



Fuel cells, photovoltaics and other small-scale power plants produce direct current. Direct current now can be inverted to alternating current and integrated with the grid at reasonable cost thanks to advances in inverters and power conditioning equipment. Conditioning equipment synchronizes small generators such as fuel cells, photovoltaic arrays or microturbines with the power distribution system.

With recent improvements in integration and control technology, consumers who install their own back-up generation can connect their on-site generation to local distribution lines in synchrony with the alternating-current grid. New integration equipment automatically isolates the native load if the grid goes out. These advancements have two benefits — the grid remains reliable, and utility workers can work safely. Reduced inversion and control costs are a major factor in reducing costs for distributed resources.

Toward an Omni-Directional Grid

"Local resources radically impact how the distribution system works."
— Kurt Yeager, EPRI

The power grid has generally been seen as a one-way street – from central plants to end users. As industries, commercial loads and homes begin to add more distributed resources and hook them up to their local network, the power system will become more of an omni-directional web.

In recent years, the high-voltage grid has seen an exponential rise in transactions with opening of the wholesale power market. This has spurred the development of wide-area networks to control the ricocheting power flows, and has led to plans for mandatory reliability standards. As power flows into the grid from many more small sources, these control mechanisms will become even more important. The benefit, in the end, may be a more efficient and reliable network, as more of the demand is provided close to the load.

Much Ado about Fuel Cells

"No matter what kind of fuel we use, we'll have less than half the pollutants, plus twice the efficiency on the electric side."
— Mark Jackson, BPA

This winter, utilities from Salmon River, Idaho, to Eugene, Ore., have seen a five-kilowatt fuel cell system power a house. BPA commissioned Northwest Power Systems to develop the prototype, which runs on methanol and water. BPA plans to offer the next generation of the fuel cell system to customer utilities for use in remote locations.

Fuel cells use a chemical reaction to produce electricity and heat from hydrogen. Advantages include low to no air pollution, silent operation and flexible sizing. Some larger fuel cells maintain their efficiency over a wide range of loads and can be used for load following.

When natural gas, methanol or another hydrogen-rich fuel is used to run a fuel cell, the hydrogen first must be separated from other elements in a fuel reformer. Waste elements such as carbon dioxide are vented. The net emissions depend on the fuel, but are lower than thermal power production. Fuel reformers take time to come up to temperature before they can work. Fuel cells convert energy into electricity at about 40 percent efficiency, including fuel reformation. Fuel reformation produces waste heat. When heat from fuel processing and the fuel cell heat is used to produce hot water for domestic or commercial use, the combined electric and thermal fuel use efficiency can exceed 90 percent.

Fuel cell development is now driven by automotive industry efforts to develop cars to meet air pollution standards. Several organizations plan to offer or demonstrate residential-sized fuel cells in

1999, including Avista, General Electric and Plug Power.

"Eventually, you could build a house, buy an HVAC fuel cell at Home Depot, and buy only natural gas from your utility."
— Kim Zentz, Avista

Types of Fuel Cells

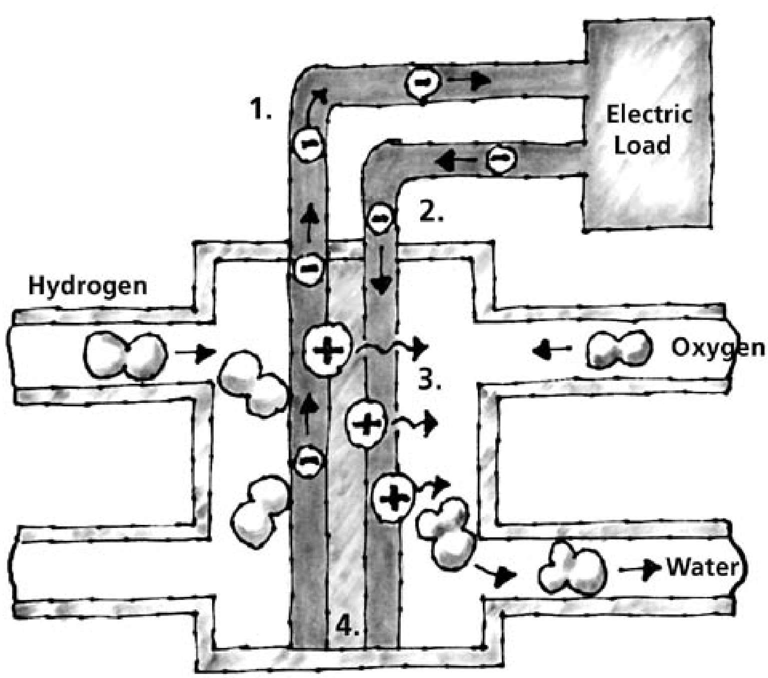
The type of fuel cell that's getting press for its potential use in cars and homes is the **proton exchange membrane (PEM)**. It feeds hydrogen to a thin membrane coated with a catalyst that induces the hydrogen protons to travel through it. The PEM runs at about 180 degrees F and starts up quickly (excluding warm-up time for a fuel reformer).

Solid oxide fuel cells (SOFC) run at about 1,800 degrees F. At that temperature, internal fuel reforming is possible. When excess heat is used to run conventional turbines, overall efficiencies of about 85 percent are possible.

A U.S. Department of Defense fuel cell demonstration program is placing 30 **phosphoric acid fuel cells** at DOD sites in 17 states. Applications include central power plants, hospitals, dorms and barracks, swimming pools, office buildings, laundries, kitchens and control centers.

Molten carbonate fuel cells run at high temperatures. **Alkaline fuel cells**, a low temperature, older technology, require careful pressure balance between air and fuel electrode.

How Fuel Cells Work



1. Electrons from the hydrogen molecule are conducted by the electrode to the electric load.
2. Electrons return to the fuel cell.
3. Protons, electrons and oxygen combine to form water molecules.
4. The membrane electrolyte assembly separates hydrogen molecules into electrons and protons and allows the protons to move through the membrane.

Power for a Bottom-Up System

"Distributed generation may change the energy landscape like PCs changed computing."
— Jack Robertson, BPA

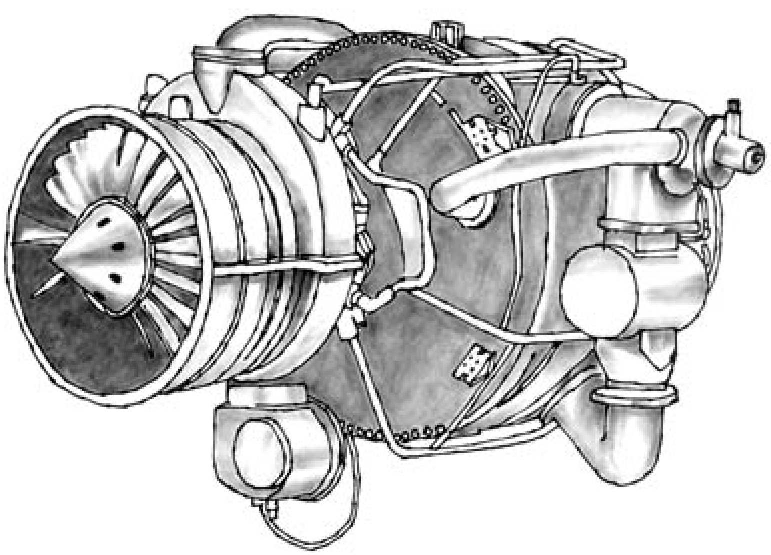
A number of different power sources and concepts are competing for distributed resource markets. All have their niche. Here are some of the options. The least known near-term contender, fuel cells, is described in some detail in the box on page 5.

Efficiency and Demand-Side Management

There is a strong synergy between distributed generation and energy efficiency. Energy-efficient building design, industrial processes and controls, especially those that reduce peak power loads, can allow for siting a smaller on-site resource, and make distributed generation more economic.

Microturbines

Microturbines are miniature combustion turbines ranging from 30 kilowatts on up. They're essentially jet engines and can run on natural gas or other fuels. Costs are expected to be six to 10 cents per kilowatt-hour, assuming 8,000 hours of use a year, for models introduced this year and next. Microturbines require an uninterruptible air supply, exhaust venting and in some settings, noise abatement. Fuel to electricity conversion efficiency is about 17 percent, or 30 to 32 percent efficiency combined with heat recovery.



Reciprocating Engines

Diesel engines command about 80 percent of the world's small generation market. Diesel, propane, gas and other reciprocating engines are widely available, competitively priced and well-understood by consumers. Energy conversion efficiency can be up to about 30 percent. These generators are supported by mature distribution and service networks. The net cost to consumers depends on the frequency of use and the local cost of fuel.

Photovoltaic Solar

New solar cell technology has lowered the price of photovoltaic systems from about $8 per watt five years ago to under $5 per watt. Customers range from upscale U.S. vacation homes to remote Third World villages to BP gas stations. New solar products are coming to market, such as a photovoltaic thin-film substitute for glass in windows and skylights.

Thermal Solar

Various thermal solar generators are in development. Most use focused sunlight to drive a Stirling cycle. The Stirling cycle uses a fixed volume of fluid that flows back and forth within a closed cylinder. Like an internal combustion engine, the working fluid in the cylinder is compressed at a low temperature, heated rapidly, then allowed to expand. But the heat source is external rather than fuel burned in the cylinder. When concentrated sunlight provides the heat, the result is power produced without air pollutants.

Other Familiar Renewables

Windmills, geothermal, biomass and other familiar renewable technologies are also benefiting from improved inversion and control technologies, and continue to develop. The Northwest has just seen the addition of two grid-scale windfarms, one in eastern Oregon and the other in Wyoming. Two geothermal projects are nearing completion of environmental review at Glass Mountain, Calif.

The End of the Rainbow: Hydrogen

Hydrogen has long been seen as a potentially inexhaustible, clean power supply. When hydrogen is burned as a fuel, the only byproduct is water. The water can be used to make more hydrogen, completing a renewable cycle. On earth, most hydrogen is found in compounds and must be separated for use as a fuel – from water by electrolysis, from natural gas or other hydrocarbons by reaction with steam or by burning, and from acids by reaction with active metals. Direct hydrogen production and storage techniques that would eliminate carbon byproducts and compete in cost are still in research and development. BPA has sponsored studies of the economics of producing hydrogen as a fuel from Columbia River water, which proved feasible but is not now cost-effective.

Off-Grid Influences

Much of the impetus toward distributed power sources is coming from outside the United States, and outside the power industry.

Shopping the Auto Show

A dozen of the world's major automakers are exploring fuel cell, electric and hybrid vehicles as ways to meet drastically reduced emissions

standards with cars and trucks people
will buy. The list includes DaimlerChrysler, Ford, General Motors, Honda, Mazda, Mitsubishi, Nissan, Peugeot, Renault, Toyota, Volkswagen and Volvo. The auto industry has invested well over $1 billion in the effort. The U.S. Government supports the work with its Partnership for a New Generation of Vehicles.

Fuel cell and hybrid electric-internal combustion vehicles are appearing at auto shows worldwide. DaimlerChrysler has committed to commercial launch of a fuel-cell vehicle by 2004-5. Toyota says it will be first to market with a fuel-cell car.

The stringent cost, space and output requirements needed to make fuel cells work in cars are expected to drive costs way down for applications in stationary power plants.

International Issues

There are 1.8 billion people in the world today who do not have electricity. Some countries may go straight to distributed power, and add a grid later if it proves beneficial. This happened in the telecommunications industry in China. There are more cell-phones in China today than regular phones, because there is only a limited traditional telephone network. Countries which do not have a strong integrated power grid are primary clients for distributed resource companies, including many firms in the Pacific Northwest.

Japan and Europe, which are aggressively pursuing greenhouse gas reduction and reduced dependence on oil, are in the forefront of developing distributed power technologies. Most of these technologies are more efficient in energy conversion than traditional thermal plants and thus help reduce greenhouse gasses.

Barriers to Distributed Resources

"This is great, if they can get the cost down."
— Utility executive reaction to a BPA fuel cell demonstration

There are significant barriers to distributed resources.

The first is technical maturity and product cost. Government initiatives such as the Partnership for a New Generation of Vehicles, Million Solar Roofs and the Department of Defense fuel cell demonstrations are designed to help bring new technologies to market.

These new technologies do not have established customer service and support networks. Most are still working out the fundamental technologies and are just developing business alliances.

Siting and permitting procedures for distributed generation sources will be needed.

Standards and procedures are needed for safety certification. A 1970s fuel cell demonstration project in New York City was held up for two years by the fire department for fear of the potential volatility of hydrogen stored on the site.

Standards are needed to integrate distributed generation with the power grid. The Institute of Electrical and Electronic Engineers is working on model standards for distributed resource network integration.

Tax structures now work against some distributed resources, particularly systems efficiencies in buildings.

For More Information

For more information about distributed power technologies, contact:

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E-mail: Comment@BPA.gov
BPA home page: *http://www.bpa.gov*

Or try any of the following Web documents or sites. Most link to more sites.

Documents

- Electric Power Research Institute: *http://www.epri.com/gg/newgen/disgen/links.html*
- California Energy Commission: *http://www.energy.ca.gov/CADER/minutes_97-04-10.html*

Sites

- American Solar Energy Society: *http://www.ases.org*
- California Alliance for Distributed Energy Resources: *http://www.energy.ca.gov/cader/*
- Distributed Power Colalition of America: *http://www.dpc.org/*
- Energy Efficiency & Renewable Energy Network, U.S. DOE: *http://www.eren.doe.gov/*
- HyWeb Hydrogen Fuel Cell Energy Information: *http://www.hyweb.de/index-e.html*
- National Fuel Cell Research Center: *http://www.nfcrc.uci.edu*
- National Hydrogen Association: *http://www.ttcorp.com/nha/index.htm*

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