Energy Management and the Environment

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Energy use and environmental issues are significant factors in operating AT&T's world-wide facilities and developing products and services. AT&T is reducing energy use to protect the environment and reduce costs. This paper focuses on efforts to ensure adequate power for AT&T facilities from both conventional generating sources and on-site generation, and on using renewable energy sources where possible to power AT&T's products. Due to the increased use of microelectronics and their sensitivity to power fluctuations, both facilities and products are sensitive to power abberations and, thus, require premium power, the combination of highly reliable and environmentally beneficial sources of energy. A team has evolved at AT&T Bell Laboratories to integrate premium power with AT&T's facilities and products. AT&T also is exploring ways of assisting utility companies to better serve their customers.

An Integrated Management Approach

AT&T's daily power consumption is equivalent to the output of three large commercial power generating plants. In keeping with its goals and commitment to a better environment, AT&T in November 1993 issued a policy statement on energy management that calls for a commitment from each AT&T business unit to set an energy reduction goal by 1994, and then meet that goal within five years.

Overall, the business units have committed to reducing electric consumption on an annual basis by 384 million kilowatt-hours. Indirectly, this decrease in generated power will reduce carbon dioxide emitted into the atmosphere by a cumulative five-year total of 500,000 metric tons.

This goal is one of many steps being taken to integrally manage energy use and related environmental issues so that AT&T can efficiently develop products and services and operate its facilities on a global scale.

The importance of this integrated effort will become even more apparent as AT&T continues to expand in an increasingly competitive global economy. For example, managing energy use at facilities reduces production costs, of course, but it also decreases the need for energy generation, thereby reducing pollutants and "greenhouse gas" emissions into the atmosphere. Managing energy use in the design and operation of an AT&T product decreases the product's energy use throughout its life cycle, making it economically attractive as well as environmentally sound to use.

AT&T also can offer alternatives to traditional energy sources to power products, such as photovoltaics for wireless microcells or fuel cells for 5ESS® switches. These *renewable* alternatives can meet customer needs while also increasing their marketing appeal, which may be substantial in less developed areas of the world where the availability and reliability of power are significant issues.

For example, photovoltaics (PV), also called solar cells, offer a unique power source for products such as wireless microcell systems in remote locations. At the same time, a typical PV panel—about 13 square feet in area—produces on average 3,500 kilowatt-hours of electricity over its design life, thereby eliminating about 6,500 pounds of carbon dioxide emissions from a traditional power plant.

Panel 1. Abbreviations, Acronyms, and Terms

ac — alternating current
ASD — adjustable speed drive
CBEMA — Computer and Business Equipment Manufacturers Association
dc — direct current
DFE — design for environment
EMF — electromagnetic field
ISDN — integrated services digital network
JCP&L — Jersey Central Power & Light Co.
NOx — oxides of nitrogen
ONU — optical network unit
PA — phosphoric acid
PCS — personal communications service
PEM — proton-exchange membrane
PSE&G — Public Service Electric and Gas Co.
PURPA — Public Utility Regulatory Policies Act of 1978
PV — photovoltaic
SMES — superconducting magnetic energy storage
T&D — transmission and distribution

Demand for Quality Power

Facilities and products are more dependent on power quality due to the increased use of microprocessors and, as such, require power that is reliable and pure, that is, free of damaging voltage fluctuations. Data centers, laboratories, clean rooms, and voice and data telephony require this form of power to operate properly and to deliver the high levels of quality and reliability that customers expect and demand from AT&T.

It is estimated that 40 percent of the electrical applications in the United States today are controlled or used by electronic devices such as microprocessors. This number is expected to increase to 60 percent by the year 2000. Therefore, it is imperative that quality power be available in AT&T facilities—regardless of the country or its domestic power source—and in the choice of the power source for AT&T products, such as 5ESS switches, wireless microcell systems, and fiber-to-coaxial telecommunications systems. Integrating this need for quality power with efficient and renewable energy sources such as fuel cells and photovoltaics also will enhance the environmental benefits of the application.

This combination of high purity, high reliability, and environmentally beneficial renewable sources of energy is called *premium power*. As such, it reflects a higher value for power for which users are willing to pay to support critical applications. Premium power also reduces the amount of revenue lost from services not provided or products not manufactured due to power outages or voltage fluctuations.

Global industrialization offers tremendous opportunities for the commercialization of renewable energy sources, since these markets will be driven by the demand for expanded sources of electricity, including premium power. The need for renewable energy sources also will be enhanced by the environmental consequences of coal combustion, the safety concerns and political instability associated with nuclear power, and the increasing resource/user imbalance associated with depleting world crude oil reserves. Evolving technologies also will have an impact. Telecommunications markets in many developing countries will need to use, for example, wireless telephony that will require, in turn, the premium power provided by renewable energy sources such as photovoltaics.

Power Enhancement and Loss Protection

Managers of AT&T's facilities are constantly striving to enhance the quality level of power so that critical operations are maintained without any power outages or damaging voltage aberrations. The recommendations for power quality of the Computer and Business Equipment Manufacturers Association (CBEMA) have been developed and applied at many facilities. The impact from power outages and damage caused by excessive voltage fluctuations also can be minimized by enhancing power quality and protecting against power loss by using specialized equipment and techniques.

Centralized Power Generation. Most of the world's electricity is produced and marketed essentially as a commodity by heavily regulated or state-owned *centralized* utility companies. These companies operate under the assumption that centrally generated power provides economies of scale. Thus, a natural monopoly has evolved in the production and delivery of electricity.

However, difficulties in the planning, design, and construction of these large central generating stations—due to more restrictive environmental and safety regulations and growing public opposition to the construction of new facilities—has caused energy costs from newer plants to rise considerably. At the same time, power transmission and distribution (T&D) systems have become increasingly more difficult to construct because of conflicts over where to locate such facilities, increased costs for right-of-ways, and public concerns over the effects of low electromagnetic fields (EMFs) on human health.

Rising electricity prices also have led to major innovations in the electric utility policy in the United States. The Public Utility Regulatory Policies Act (PURPA) of 1978 introduced elements of competition into the electric power generating business and led to the rapid evolvement of independent power producers.

On-Site Power Generation. In response to the above changes and challenges in power generation, and the requirement of high-quality power by certain users, *distributed* small-scale power generation on the scale of 10 kilowatts up to 1 megawatt has become a viable choice at customer sites. Utilities are now broadening their business operations from being general purveyors of electrons to also becoming sellers of high-quality energy services to select customers.

Locating a high-quality power source on site eliminates the need for costly increases in central generating and T&D capacity. While large energy-generating facilities require extensive construction in the field, where labor is costly and productivity gains are difficult to achieve, most renewable energy equipment can be constructed at customer sites, such as factories, where it is easier to apply modern manufacturing techniques that reduce costs.

The small scale of the equipment also shortens the time between initial design to operations, so that improvements can be identified by field testing and quickly incorporated into modified designs. In this way, new technologies also can be quickly introduced.

These cost savings can allow alternate energy sources such as renewables to be more economically attractive to use as distributed energy sources. Renewables also can provide significant environmental benefits due to their design and operation.

Alternate Energy for Distributed Generation

The potential role for renewable technology in distributed power generation depends on the cost of producing electricity and its value. This value, in turn, depends on the characteristics of both the renewable technology and where it operates. Several alternate energy sources that could provide distributed power for AT&T products and facilities are described below.

Fuel Cells. Fuel cells are direct energy conversion devices, converting chemical energy directly into electrical energy. Hydrogen from the fuel is chemically united with oxygen from the air to form water and electricity. Various fuels such as natural gas or propane processed through an on-board conversion device supply the hydrogen-rich gas for electrochemical conversion. Since fuel cells do not use a thermomechanical combustion process, their efficiency is not a function of the operating temperature.

Emissions of oxides of nitrogen (NOx) are very low because fuel cells are not combustion devices. Because they have a minimum of moving parts—generally fans and circulation pumps for the ancillary cooling system—fuel cells generate low noise and have low maintenance costs and a longer operating life than more traditional electromechanical devices such as diesel engines and gas turbine-driven generators.

The fuel cell process can occur using several different types of technologies and are generally classified by their electrolyte composition. Most typically the fuel cell types are proton-exchange membrane (PEM), phosphoric acid (PA), molten carbonate, and solid oxide.

Photovoltaics. Photovoltaic devices convert sunlight directly into electricity. Although the PV effect has been recognized since 1839, major material and scientific breakthroughs and developments, including those at AT&T Bell Laboratories and in the United States space program, have allowed PV systems to be commercially produced for a growing number of applications.

PV power is intermittent in that electricity can be generated only while the sun is shining. But such sunny periods are often when power is most valuable, that is, when the power costs to meet peak period demands are at their highest. PV systems are inherently modular and can be located close to a customer's site where the electricity is needed. This results in reduced electricity transmission and distribution costs and increased reliability of the electric services delivered.

Distributed Energy Storage Systems

Whether serving as a combined system along with distributed energy generation, or as a stand-alone system that is connected directly to the utility grid, distributed energy storage systems have the means of storing quantities of energy that can then be distributed in times of disruptions, abnormalities, and outages of traditionally generated power. Unlike energy generation, energy storage and disbursement technologically is more challenging and costly. The current and potential uses of several different technologies in AT&T facilities and products are discussed below.

Chemical Batteries. Batteries work best in systems that require relatively short bursts of energy on an infrequent basis. However, batteries are being developed to store energy for longer periods of time and release energy as quickly as needed. Still, additional work must be done for batteries to last longer and withstand deep and frequent cycling.

Although expensive, battery power is effective in critical applications, such as backup power for a central office switch. However, to be cost effective in more general applications, battery systems must have decreased purchasing, operating, and maintainence costs. They also must provide more energy and power at less weight and volume than is presently possible. Their construction materials, manufacturing techniques, and life-cycle assessment must continue to become more in line with design for environment (DFE) goals and strategies.

Although hundreds of different battery chemistries have been developed, only about a dozen systems are attractive for use in AT&T's facilities and products. Aqueous systems, for example, include lead-acid batteries, various nickel systems, and flow batteries. Lead-acid batteries, which are inexpensive, commonly used and recycled, and can be manufactured in many forms, are the mainstay of such use. Research to enhance these batteries is focusing on increasing their life and decreasing their maintenance, weight, and cost.

Flywheels. High-speed flywheels, one of the oldest forms of human-made energy storage, are emerging as a main contender for uninterruptible power systems for facilities. Essentially, these devices take in electrical energy and convert it to kinetic energy in the form of a high-speed rotating weighted shaft that is held in place by high-efficiency, that is, low-friction, bearings. The more energy that is stored in a flywheel, the faster it rotates, with maximum speeds typically on the order of 50,000 revolutions per minute.

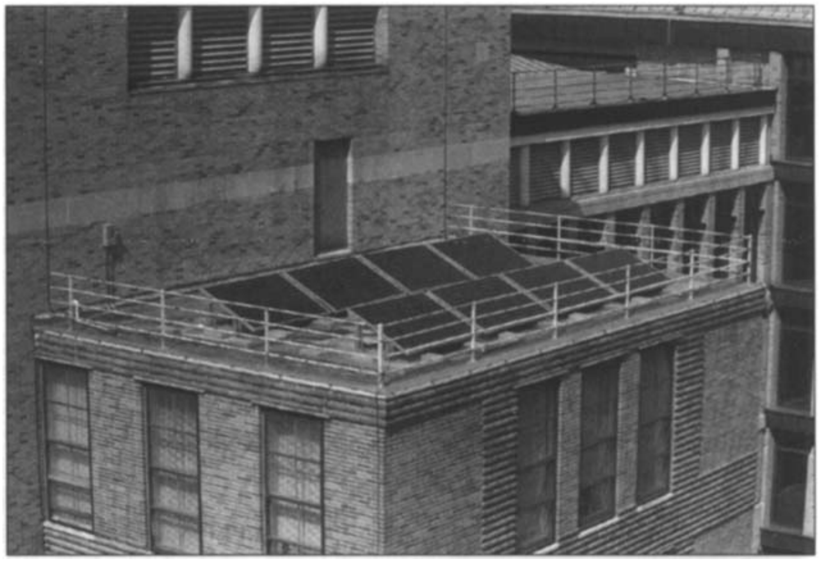
Permanent magnets mounted on the flywheel allow a "touch-free" transfer of energy into and out of the spinning flywheel. To keep friction losses to a minimum, the flywheel spins in a near perfect vacuum, down to one millionth ($1x10^{-6}$) of an atmosphere. During normal operation, electricity from a traditional source is fed to an electronic adjustable speed drive (ASD) that then powers the flywheel "motor," causing it to turn faster and faster until it reaches its maximum speed. To extract energy from the flywheel during an energy disruption, the ASD acts like a regenerative brake, taking energy out of the flywheel motor and converting it to electrical current for external applications.

Flywheel systems can provide uninterruptible power for facilities to "ride through" short-term power grid aberrations or outages, or they can provide longer-term power requirements to handle the needs of a facility or product for extended periods of time.

Superconducting Magnetic Energy. Superconducting magnetic energy storage (SMES) technology basically consists of storing electrical power in a coil of superconducting wire submerged in liquid helium. It is a strong technical contender for both utility and facility ride-throughs and energy storage applications. Storing huge amounts of energy in a SMES is technically feasible, and its ability to deliver extremely high bursts of power make it very attractive where seamless, uninterruptible power demands must be met.

SMES is the only viable energy storage technology today that directly stores electrical energy without intermediate conversions to mechanical or chemical energy. The SMES energy storage mechanism consists of a superconducting magnetic coil immersed in liquid helium (4.2° Kelvin or -55.5° Fahrenheit), causing its resistance to direct current to fall to near zero. In this state, huge amounts of electrical current can be pumped into the coil, where the current circulates with minimal losses, until it is eventually diverted when needed

Figure 1. The rooftop photovoltaic (PV) array installation at AT&T Bell Laboratories in Murray Hill, New Jersey, provides PV power to a bank of four power packs. These packs, in turn, provide direct current (dc) to a series of ISDN telephone circuits.



from the coil to the power system of the facility.

AT&T's Premium Power Design Team

The increased use of microprocessors in telecommunications manufacturing and facilities equipment requires that premium power be available in AT&T facilities. This also applies to the choice of power source for many of AT&T's products to ensure that this equipment can operate both properly and reliably.

A premium power design team was assembled by AT&T Bell Laboratories in the first quarter of 1995. Its mission is to examine the need for premium power in both AT&T's facilities and products, and to investigate commercially available technologies that would provide electric power with both enhanced quality and reliability. The team's mission also includes assessing the environmental impact of various alternate power generation technologies, and how these technologies could support AT&T's commitment to design for environment.

The team is composed of representatives from AT&T's business units involved in business communications, network systems, research, and facilities and real estate. The team also includes a representative from Jersey Central Power & Light (JCP&L), a local electric utility company serving many of the New Jersey-based Bell Laboratories' facilities. This cooperative effort illustrates how changes in the electric utility industry are requiring large industrial customers such as AT&T to view their local electric utility as a strategic partner and resource, rather than just a supplier of energy services.

Summarized below are some of the team's active and proposed projects to examine distributed power generation technologies that can provide premium power to AT&T facilities and products in an environmentally benign manner.

Photovoltaics. Three projects are designed to develop photovoltaic applications.

The Murray Hill ISDN telephony project. This project was chosen by the premium power design team to demonstrate the reliability of PV in fully powering telephony such as integrated services digital network (ISDN). The Murray Hill Bell Laboratories facility was chosen as the test site, as it will be used later to showcase this alternate energy technology and its capabilities in providing premium power to an AT&T cross-connect switching application. JCP&L provided the PV project's funding in an effort by their marketing group to develop a niche market in the premium power area for key target industries such as telecommunications.

The project consists of providing PV power to a bank of four power supplies that currently provide direct current (dc) to a series of ISDN telephone circuits. Figure 1 shows a photo of the rooftop PV array installation. The PV power was required to be inverted from its dc-generated form to 120-volt alternating current (ac) so that it was suitable for direct power supply plug-in.

The PV array charges the battery pack during daylight hours under normal operation. Power from the battery pack is continuously drawn off to feed the converter, which inverts the dc to ac at 120 volts. This power is then provided directly to the input of the existing telephony power supplies.

The PV/battery system is designed to provide continuous power to the power supplies *independent* of the JCP&L utility grid. However, in the event of a PV system equipment failure or an under-current/voltage condition, the inverter is equipped with an automatic cutover switch that will seamlessly transfer the power function back to the utility grid. The system has been performing according to design specifications since its installation in January 1995.

Whippany wireless telephony project. The premium power design team has proposed that the Network Wireless Systems Group in Whippany, New Jersey, develop a test site at the Bell Laboratories Whippany facility to power future generations of wireless telephony that are currently under development, such as personal communications services (PCS). This represents an excellent application of PV to an AT&T product with world-wide potential. Since many developing countries may not have adequate or even available electric power, an optional PV-based premium power system for wireless telephony should be very marketable throughout the world.

The PV system-level performance issues are of principal concern to AT&T, and it will be of paramount importance for the system design and operation to be reliable and "survivable" in a remote environment so that it can provide service on a stand-alone basis. One key concern is fluctuations in the solar resource, that is, fluctuations due to cloudy weather.

Effective system-sizing tools need to be developed and existing tools need to be proven to enhance the level and predictability of system reliability. Furthermore, AT&T needs to address the issue of the *value* of reliability, that is, determining the point where the cost of adding PV panels and batteries exceeds the value of the increased reliability. Another design issue to be investigated is the control of charging a battery to attain maximum battery capacity and service life.

The premium power design team also plans on testing and evaluating other means of energy storage devices for a microcell installation, such as flywheel devices. "Smart" systems also can be evaluated, such as self-diagnostic systems that will monitor the PV power and energy storage systems and transmit key data to a central office. Special alarm conditions also can be transmitted so that the central office can then evaluate the data and dispatch the appropriate repair team.

Building-integrated PV. The premium power design team is examining projects where there is significant potential for integrating PV into the design of a building. These projects will showcase the capability of designing the PV system into the fabric and structure of a building's exterior walls or roof so that it is aesthetically pleasing, functional, and cost-efficient.

Building-integrated PV also would reduce the facility's peak electric demand on the local utility, thereby reducing both the electric consumption and demand charges, as well as enhancing AT&T's image of being committed to environmentally sound power applications.

At AT&T's EasyLink business unit, a PV-powered building lighting system has been installed at an existing data center in Middletown, Virginia. Other opportunities to use building-integrated PV will be forthcoming as existing AT&T facilities are renovated and new facilities are constructed world-wide.

Fuel Cells. This section discusses two projects that will evaluate the application of fuel cells to support premium power.

Crawford Hill fuel cell/premium power bus. Working in conjunction with the AT&T Bell Laboratories Holmdel Property Management Group, JCP&L has installed a commercial fuel cell for premium power generation at the AT&T Bell Laboratories Crawford Hill facility. This facility is serviced at the end of an electric feeder line for residential service. The line has been subject to numerous voltage aberrations and power outages that have caused significant problems with the sensitive lab and computer equipment at the facility.

The fuel cell, manufactured by the ONSI Corporation, is an on-site power plant that is about the size of a small tractor-trailer container. When supplied with natural gas, the unit generates electricity and hot water through an electrochemical process. Figure 2 shows a schematic illustrating the operation of the Crawford Hill fuel cell.

The fuel cell operates continuously, providing

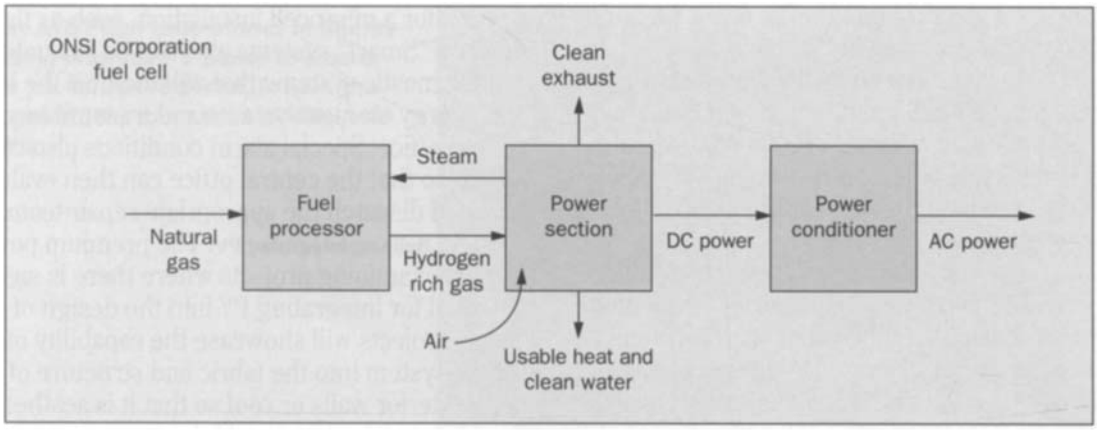


Figure 2. The Crawford Hill fuel cell test involves natural gas being processed by the ONSI Corporation's fuel cell to create hydrogen-rich gas. The fuel cell's power section electrochemically reacts the gas to generate electricity, which is converted from direct current (dc) to alternating current (ac) to provide 200 kilowatts of baseload power.

200 kilowatts of baseload power for the facility's 600-kilowatt daily load. The fuel cell's power feeds a dedicated premium power bus that distributes this power to users operating sensitive laboratory and computer equipment. The remaining, less-sensitive power needs at Crawford Hill are supplied via the utility's power grid.

In the event of a fuel cell outage, an automatic transfer switch activates to feed utility grid power to the dedicated bus. This is, in effect, the reverse of an emergency power generation scheme, in that the fuel cell is normally *on-line* providing baseload power, while the utility grid provides *backup* power to the fuel cell. Emissions from the fuel cell are negligible—essentially minute traces of contaminants from the natural gas. The unit has been functional since January 1995.

Testbed for AT&T equipment. As part of the fuel cell demonstration project at Crawford Hill, the premium power design team working in coordination with AT&T Network Systems Power Group is planning to test a mobile telephone switch on the electric bus powered from the fuel cell. The team plans in late 1995 to have a mobile switch operating off the fuel cell's power bus to monitor the performance of the switch running on the fuel cell's premium power. Following this initial test, a fuel cell could be brought to a new or existing telephone switch site for further demonstration and evaluation.

Product-integrated micro-fuel cells. The applications described above involve fuel cells that produce power in the hundreds of kilowatts range. However, a very promising line of micro-fuel cells that produce power in the hundreds of watts range—for very specific low-powered, local applications—are being developed in the United States.

These micro-fuel cells can be powered from the direct feed of hydrogen gas, liquid methanol (alcohol-based fuels), or from chemical hydrides. Their potential applications are myriad, including longer-term power sources for personal laptop computers, handheld mobile telephony, microcells for personal communications services, and optical network units (ONU) for broadband interactive telecommunications systems.

It is the premium power design team's goal to assist in integrating technologies such as fuel cells with these and other potential applications in AT&T's products and facilities.

The New Power Market

We have discussed, so far, ways of improving, yet reducing, energy consumption in the development, manufacture, and operations of AT&T products and services. Now let us consider how AT&T can aid the power utilities in managing their service offerings.

Throughout the world the utility industry is

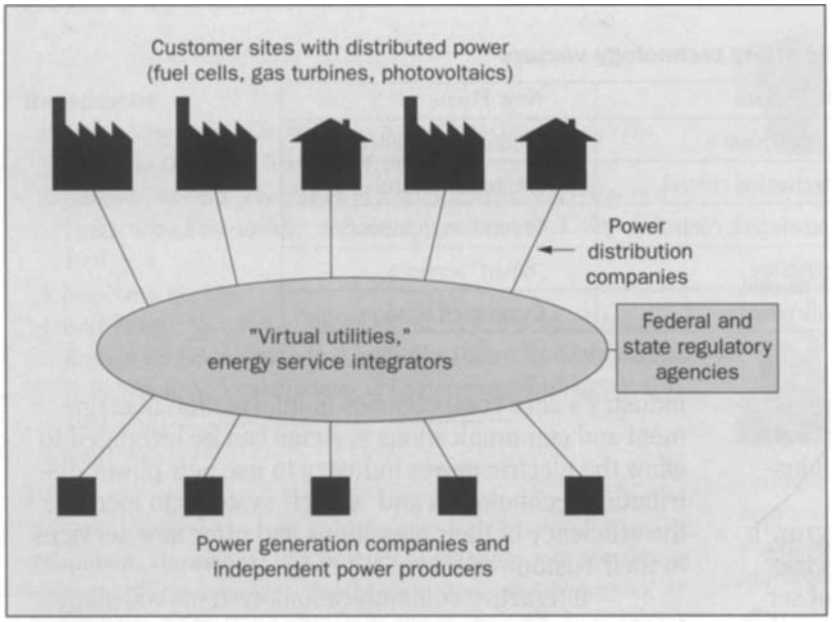


Figure 3. This illustration shows the concept of "virtual utilities," in which energy integrators contract with generation, transmission, and local distribution companies to deliver power to residential and business customers.

undergoing rapid change. The traditional characteristics of the utility industry—monopoly status, government owned, and government regulated—are giving way to competition, privatization, and deregulation. Customers will be able to choose their utility supplier and their terms of supply, rather than the utility alone determining the service it will provide.

Competition, particularly in power generation, will replace government regulation as the means of setting prices. The private sector will assume a greater role in owning and operating decentralized power plants, as well as transmission facilities. Customers of utilities will benefit from these dramatic changes through lower prices, but will have to deal with complex new choices in both products and services.[1]

Competitive Restructuring. Leaders of previously regulated industries have survived and prospered from deregulation by developing new re-integration strategies to provide enhanced customer value.[2] The development of integrated energy service packages also will become the strategy of the power utilities that want to prosper in their deregulated market, as they will be able to deliver superior value to those customers who require it. Being a low-cost producer will be a necessary, but not the only element, for utilities to survive in a deregulated environment.

Changing Rules. The history of regulatory and court decisions in the deregulation of the telecommunications and natural gas industries would indicate that the deregulation of the electric utility industry will ultimately result in open access to all customers, and markets will develop in the buying and reselling of bulk power over transmission systems.

The development of secondary markets in transmission rights will create independent energy *integrators* operating in wholesale and, potentially, retail markets. These companies will be considered to be "virtual utilities," packaging contracts with generation, transmission, and local distribution companies to deliver power to residential, commercial, and industrial customers.[3] Figure 3 conceptually illustrates this virtual utility.

Technology in Electric Power. Deregulation, the development of virtual utilities, new power generation and energy storage technologies, the need for premium power, increased focus on the customer, and the need to reduce costs will all drive the electric utilities to change their focus and associated technology as summarized in Table I.[4]

Strategic Alliances with Utilities. The concurrent evolution of both the telecommunications and electric power industries and their complementary core competencies will result in the two industries creating strategic

Table I. Changing electric utility technology vectors

Function	Old Focus	New Focus
Generation	Central plant	Modular distributed
Transmission	Mechanical control	Electronic control
Environmental	End-of-stack controls	Prevention/remediation
Distribution	Reliability	"Smart" services
Customer	Bulk power	Customzed services

partnerships to leverage their strengths and provide packages of integrated services to their respective customers.

The reasons and benefits for these two industries to align together are as follows:

Interactive communications. The key to the growth strategy within the increasingly deregulated electric utility industry—which is expanding the scope of services to customers, developed from experiences in the deregulated telecommunications and natural gas industries—is the need for information and information technologies.[5] AT&T and Public Service Electric and Gas Co. (PSE&G), another New Jersey power utility, have entered a joint venture with five other companies to create a broadband interactive communications system for use between PSE&G and its customers. This system will enhance the information flow throughout the utility system, permit the integration of various technologies, and improve the efficiency of the utility's power generation and transmission systems.

Complementary core competencies. There is an increasing interdependence between the electric power and telecommunications industries. The deployment of new communications technologies will increasingly affect the electric power industry, just as changes in the power supply industry will impact the telecommunications industry. The electric power industry can leverage its core competency in power generation and distribution to meet the telecommunications industry's needs for distributed power generation at both telecommunications facilities and remote locations along the network, and for premium power where required by microprocessor-based telecommunications equipment and systems.

The business of providing energy-efficient services is information intensive. The telecommunications industry's core competencies in information management and communications systems can be leveraged to allow the electric power industry to use new power distribution technologies and "smart" systems to increase the efficiency of their operations and offer new services to their customers.

Interactive communications systems will allow for power grid optimization, that is, "smart" distribution substations capable of connecting into power generation and energy storage systems when needed to satisfy power demands, and demand-side management of customer loads in response to pricing information on the real-time cost of the electricity.

Summary

This paper focused on the need to reduce energy use for economical and environmental reasons, while ensuring that AT&T facilities are provided premium power for critical activities. AT&T also is looking at using renewable alternative sources of energy to power some of its products, including on-site sources, and has formed the premium power design team to study possible applications.

AT&T also is looking at strategic partnering with energy service industries to create a new or "missing" industry that will provide fully integrated energy services to the utilities' customers, providing them with more choices by using advanced power generation and energy storage technologies at lower costs.

The evolution of the power industry will have a positive impact on the environment as cleaner, environmentally benign power generation and energy storage technologies will become the technologies of choice to meet customer demands and improve the utility's productivity and use of assets.

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