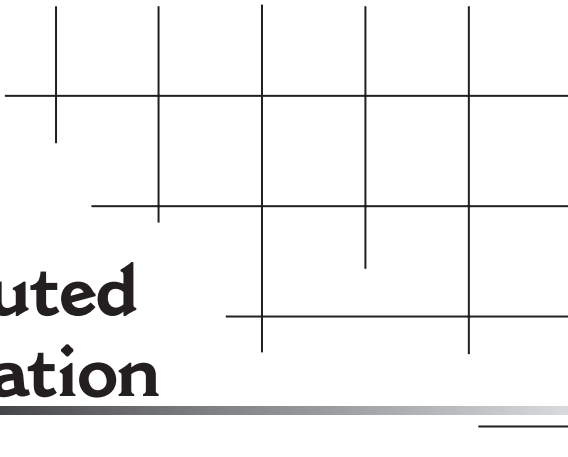


# Distributed Generation

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**Distributed Generation:  
A Nontechnical Guide**

**by Ann Chambers**  
*with Barry Schnoor*  
*and Stephanie Hamilton*

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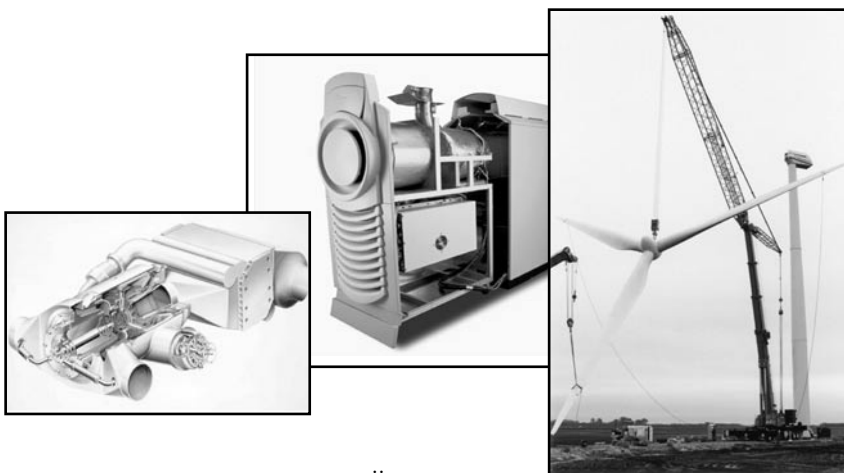
For Tony and Aaron  
*My Bubbas*

--Ann Chambers



# CONTENTS

<b>1</b>	Introduction . . . . .	1
<b>2</b>	History and Drivers . . . . .	21
<b>3</b>	Microturbines <i>by Stephanie L. Hamilton</i> . . . . .	33
<b>4</b>	Engines and Portable Power . . . . .	73
<b>5</b>	Fuel Cells <i>by Barry Schnoor</i> . . . . .	83
<b>6</b>	Renewables . . . . .	121
<b>7</b>	Technical Issues . . . . .	149
<b>8</b>	Utility Issues . . . . .	157
<b>9</b>	Case Studies . . . . .	167
<b>10</b>	Conclusion . . . . .	185
<b>Appendix A</b>	Industry Contacts . . . . .	189
<b>Appendix B</b>	Distributed Generation Glossary . . . . .	205
<b>Index</b>	. . . . .	251



# LIST OF FIGURES

1-1	JS 100 Euro Silent generation package with John Deere engine . . . . .	2
1-2	A NedWind 500 kW wind turbine generator . . . . .	3
1-3	Solar array in California . . . . .	9
1-4	The Wartsila 1,200-rpm 18V220 SG engine . . . . .	10
1-5	Gas Power System's 1.2 MW Innovator genset . . . . .	11
1-6	The Parallon 75 microturbine . . . . .	15
1-7	The Capstone Model 330 . . . . .	17
1-8	A Single Cell from a Fuel Cell . . . . .	18
3-1	A Capstone MicroTurbine . . . . .	36
3-2	A cut away of a Capstone MTG turbine and assembly package . . . . .	38
3-3	A BPS 80 kW CHP MTG . . . . .	41
3-4	A drawing of the BPS System Arrangement . . . . .	42
3-5a	The Capstone 60 kW front view . . . . .	43
3-5b	The Capstone 60 kW with panels off . . . . .	43
3-6	EES' 80 kW Turbo Alternator set . . . . .	44
3-7	Design features of the EES 80 kW Turbo Alternator set . . . . .	45
3-8	The Parallon 75 . . . . .	46
3-9	Key features and specifications for the PowerWorks . . . . .	48
3-10	The Turbec engine design . . . . .	50
3-11	The Turbec T100 . . . . .	50
3-12	The System Configuration of the Parallon 75 system illustrates a single-shaft design . . . . .	55
3-13	Ingersoll-Rand Energy Systems' PowerWorks incorporates a dual-shaft configuration . . . . .	55
3-14a	Description of the MTG testing program . . . . .	62
3-14b	Description of the MTG testing program (continued) . . . . .	63
4-1	Cummins Power offers a variety of pre-packaged diesel-powered rental units . . . . .	75
4-2	Portable diesel power generators cool the gymnasium during the summer 1999 Special Olympics . . . . .	75

4-3	Caterpillar rental units installed outside Wallace Wade Stadium to provide electricity and cooling for the weeklong Special Olympics . . . . .	76
4-4	A 2 MW Cummins Onan PowerCommand Genset . . . . .	78
4-5	The Mirrlees Blackstone 8 MW engine bound for St. Kitts . . . . .	80
4-6	Pitt County Memorial Hospital counted on Caterpillar for the power to care for its patients . . . . .	81
4-7	New Ulm's substation with rental units installed . . . . .	82
5-1	A typical fuel cell plant . . . . .	85
5-2	MC Power's fuel cell stack . . . . .	86
5-3	Fuel cell stacks . . . . .	86
5-4	The Westinghouse SOFC . . . . .	91
5-5	The Santa Clara fuel cell installation . . . . .	105
5-6	A Siemens fuel cell plant . . . . .	110
5-7	An ONSI PAFC . . . . .	111
5-8	Northwest Power System's 5 kW unit . . . . .	113
5-9	A Ballard 250 kW fuel cell . . . . .	114
6-1	Illustration of horizontal and vertical axis wind turbines . . . . .	125
6-2	Mitsubishi 600 kW turbines in Tehachapi, California . . . . .	130
6-3	TXU's Big Spring wind project . . . . .	137
6-4	A 600 kW Tacke wind energy turbine . . . . .	138
6-5	Solar mirror tiles in an array . . . . .	140
6-6	Caterpillar diesels installed in a landfill gas-to-energy facility . . . . .	144
8-1	The first Capstone 60 MicroTurbine production unit, pictured without its side panels . . . . .	162
8-2	PowerCommand generators provide backup at Madison Gas & Electric . . . . .	164

# LIST OF TABLES

1-1	Distributed Generation Technology Statistics . . . . .	5
2-1	Overnight Capital Costs by Technology . . . . .	23
2-2	Fuel Cell Sales by Type . . . . .	31
3-1	Economic comparison of a variety of distributed generation technologies . . . . .	35
3-2	Features of the BPS 80 kW . . . . .	42
3-3	Specifications for the Parallon 75 . . . . .	47
5-1	Emissions Comparisons . . . . .	95
6-1	U.S. Electricity Net Generation Using Renewable Resources, 1990 and 2010 . . . . .	122
6-2	Renewable Power Sources . . . . .	123
6-3	Top Wind Markets . . . . .	126
6-4	Noise Comparisons . . . . .	131
6-5	Principles of Success . . . . .	133
6-6	Top 10 Permitting Issues . . . . .	133
7-1	Most Important Natural Gas Technologies . . . . .	156

# Introduction to Distributed Generation

Today's distributed generation installations are in some ways a return to the early days of electrification. Thomas Edison's first power plants were small installations that illuminated only one or two square miles. Soon, however, Edison's dc power facilities were overshadowed by George Westinghouse's ac facilities that could transmit power over great distances, leading to the utility-scale mammoths that became the mainstay of electric power generation in the United States. The large plants offered great economies of scale and transmitted power over a massive transmission grid. This is the technology that brought affordable electric power to our nation. These facilities ran primarily on fossil fuels. Our nuclear plants are generally even larger versions of this utility-scale plant, with nuclear fuel running the steam generators.

But the changing times have brought changing technologies and economics. Over the past decade or so, the uncertainty of impending deregulation caused utilities to hold off on capital intensive construction projects. This brought narrowing margins of excess capacity as our country's energy use continued to grow. These facts have given birth to the merchant power movement, powered primarily by large-scale gas turbines. But they also have led to the inclusion of smaller technologies in our power generation mix.

Over the past decades, great strides have been made by research and development groups on a great many technologies. Fuel cells first used by NASA received government funding and industry participation for several decades. This technology is now on the verge of commercialization for transportation and stationary power generation.

Similarly, small gas turbines have benefited from the advances in large-scale turbine development, bringing this technology to recent commercial competitive standing. Diesel and gasoline-powered engines, used in transportation, are suitable for a variety of power generation uses and they have certainly made great advances in efficiencies, reliability, and emissions reduction from the transportation industry. These are becoming ever more common in the power generation world. (Fig. 1-1)

Renewable technologies such as wind power, landfill gas, solar, and geothermal are also vying for a portion of today's much needed new power generation capacity. Government assistance in research and, in some cases, tax



*Fig. 1-1 Small modular units need little space and take very little time to install. This JS 100 Euro Silent generation package is equipped with a John Deere 4045 HF 157 Powertech engine. It generates 100 kWe with relatively little noise – 70 dBA at 23 feet.*



*Fig. 1-2 Completion of a NedWind 500 kW wind turbine generator. The plant is expected to generate 2.6 million kWh annually, enough to meet the annual electricity demand of more than 800 households. Wind generation is particularly popular in rural areas, because it can allow farmers to generate additional income from grazing lands while still using the land for farming. The wind turbines use only a tiny fraction of the land they are sited on. Today's wind turbine models are far quieter than previous generations.*

credits or other incentives, help make these technologies more viable.

With the national grid showing its age, and with new transmission lines almost non-existent, distributed generation receives a great boon. These small, generally quiet facilities can be placed next to or near to the customer or customers needing their power. (Fig. 1-2)

### **Restructuring and Deregulation**

Utility restructuring, technology evolution, environmental policies, and an expanding power market are providing the impetus for distributed generation's growth into an important energy option. Utility restructuring opens energy markets, allowing the customer to choose an energy provider, method of delivery, and ancillary services. The market forces favor small, modular power technologies that can be installed quickly in response to market signals. This restructuring comes at a time when the demand for electricity is escalating both domestically and internationally. Impressive gains have been made in the cost and performance of small, modular distributed generation technologies. Regional and global environ-

mental concerns have placed a premium on efficiency and environmental performance. Concerns are growing regarding the reliability and quality of electric power.

A portfolio of small gas-fired power systems is coming onto the market with the potential to revolutionize that market. Their size and clean performance allow them to be sited at or near customer sites for distributed generation applications. These systems often allow fuel flexibility by operating on natural gas, propane, or fuel gas from any hydrocarbon. These include coal, biomass and waste from an assortment of sources including refineries, municipalities, and the forestry and agricultural industries.

Technologies such as gas turbines and reciprocating engines are already making a contribution and they have more to offer through focused development efforts. Fuel cells are entering the market, but need more research and development to see widespread deployment. Also, fuel cell/turbine hybrid systems and upcoming generation fuel cells offer even more potential. (Table 1-1)

## **Distributed Generation Defined**

Distributed generation generally applies to relatively small generating units of 30 MW or less sited at or near customer sites to meet specific customer needs, to support economic operation of the existing distribution grid, or both. Reliability of service and power quality are enhanced by the proximity to the customer, and efficiency is often boosted in on-site applications by using the heat from power generation.

While central power systems remain critical to the nation's energy supply, their flexibility is limited. Large power generation facilities are capital-intensive undertakings that require an immense transmission and distribution grid to move the power.

Distributed generation complements central power by providing a relatively low capital cost response to incremental jumps in power demand. It avoids transmission and distribution capacity upgrades by siting the power where it is most needed and by having the flexibility to send power back into the grid when needed.

	Combustion Turbines	Diesels, Internal Combustion	Fuel Cells	Microturbines	Fuel Cell Hybrids
<b>Applications</b>	On/off grid	On/off grid	On/off grid	On/off grid	On/off grid
<b>Capacity</b>	1-250 MW	50 kW-10 MW	2 kW-2 MW	25-500 kW	250 kW-3 MW
<b>Operating life</b>	40,000 hr	40,000 hr	10,000 hr	40,000 hr	40,000 hr
<b>Capital cost (\$)</b>	400-600/kW	500-800/kW	3,000/kW	550/kW	1,500/kW*
<b>O&amp;M cost</b>	5-10 mills/kWh	10-15 mills/kWh	5-15 mills/kWh	5-10 mills/kWh	5-10 mills/kWh
<b>Heat rate (Btu/kWh)</b>	8,000-10,500	9,000-11,000	9,500	12,500	6,000

Source: Edison International  
 \*projected at maturity

*Table 1-1 Distributed Generation Technology Statistics*

Technological advances through decades of research have yielded major improvements in the economic, operational, and environmental performance of small, modular power generation options.

This emerging group of distributed generation choices is changing the way energy service companies, independent power producers, and customers view energy.

## Applications

The main applications for distributed generation so far tend to fall into five main categories:

- Standby power
- Combined heat and power
- Peak shaving
- Grid support
- Stand alone

Standby power is used for customers that cannot tolerate interruption of service for either public health and safety reasons, or where outage costs are unacceptably high. Since most outages occur as a result of storm or accident related T&D system breakdown, on-site standby generators are installed at locations such as hospitals, water pumping stations, and electronic dependent manufacturing facilities.

Combined heat and power applications make use of the heat from the process of generating electricity, increasing the efficiency of the fuel use. Most

power generation technologies create a great deal of heat. If the generating facility is located at or near a customer's site, that heat can be used for combined heat and power (CHP) or cogeneration applications. CHP significantly boosts system efficiency when it is applied to mid- to high-thermal use customers such as process industries, large office buildings, and hospitals.

Power costs can fluctuate hour to hour depending on demand and generation availability. These hourly variations are converted into seasonal and daily time-of-use rate categories such as on-peak, off-peak, or shoulder rates. Customer use of distributed generation during relatively high-cost on-peak periods is called peak shaving. Peak shaving benefits the energy supplier as well, when energy costs approach energy prices.

The transmission and distribution grid is an integrated network of generation, high voltage transmission, substations, and lower-voltage local distribution. Placing distributed generation at strategic points on the grid—grid support—can assure the grid's performance and eliminate the need for expensive upgrades.

Stand-alone distributed generation serves the customer but is not connected to the grid, either by choice or by circumstance. Some of these applications are in remote areas where the cost of connecting to the grid is cost prohibitive. Such applications include users that require stringent control of the quality of their electric power, such as computer chip manufacturers.

## **Customer Benefits**

Distributed generation ensures reliability of the energy supply, which is increasingly critical to business and industry. Reliability is essential to some industries where interruption of service creates extremely expensive problems by suddenly shutting down machinery or in industries where health and safety is endangered by sudden outages.

Distributed generation is also able to provide the quality power needed in many industrial applications that are dependent on sensitive electronic instrumentation and controls that cannot withstand power dips or surges.

It can also offer efficiency gains for on-site applications by avoiding line losses and by using both the electricity and heat produced in power generation for industrial processes, heating, or air conditioning.

Customers can benefit by saving on their electricity bill by self-generating during high-cost peak power periods and by taking advantage of relatively low-cost interruptible power rates from their utility.

It allows facilities to be sited in inexpensive remote locations without the need to incur the expense of building distribution lines to connect to the main grid.

Distributed generation increasingly offers an assortment of technologies and fuels, allowing the customer to choose an application that best suits his needs. Also, with each new generation in many technologies, the amount of space needed to house the generation systems shrinks, allowing more flexibility in siting.

### **Supplier Benefits**

Distributed generation limits the capital exposure and risk because of the size, siting flexibility, and fast installation of these systems.

It avoids unnecessary capital expenditure by closely matching capacity increases to growth in demand. It also avoids major investments in transmission and distribution system upgrades by siting the generation near the customer. It also offers a relatively low-cost entry into a competitive market.

It opens the markets in remote areas that do not have an established grid and in areas that do not have power due to environmental concerns.

### **National Benefits**

National benefits of distributed generation include the reduction of greenhouse gas emissions through efficiency gains and through potential renewable resource use. Distributed generation responds to the increasing energy demands and pollutant emission concerns while providing low-cost, reliable energy industry needs to maintain competitiveness in the global marketplace.

Recent technological advances have positioned the United States to export distributed generation to a rapidly growing world energy market, much of which has no transmission and distribution grid.

It is establishing a new industry with the potential to create billions of dollars in sales and hundreds of thousands of jobs. It also enhances productivity through improved reliability and quality of delivered power.

## **The Market**

The coming importance of distributed generation can be seen in the estimated size of the market. Domestically, new demand combined with plant retirements is projected to require up to 1.7 trillion kWh of additional electric power by 2020. That is almost twice the growth of the last 20 years. Over the next decade, the domestic distributed generation market is expected to jump to 5 GW to 6 GW annually to keep up with demand.

Worldwide forecasts show electricity consumption increasing from 12 trillion kWh in 1996 to 22 trillion kWh in 2020. Much of this jump is expected to come from developing countries without national power generation grids. The projected distribution generation capacity increase associated with the global market is estimate at 20 GW annually over the coming decade.

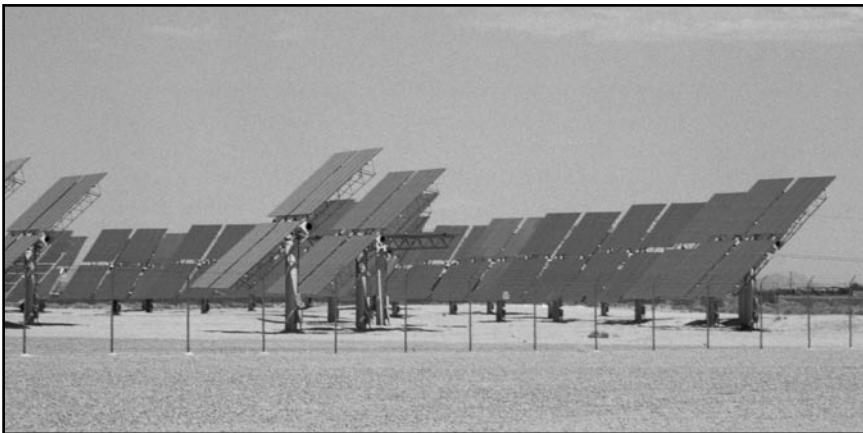
The anticipated surge in the distributed generation market can be attributed to several factors. Under utility restructuring, energy suppliers, not the customer, must shoulder the financial risk of the capital investments associated with capacity additions. This favors less capital-intensive projects and shorter construction schedules. Also, while opening the energy market, utility restructuring places pressure on reserve margins, as energy suppliers increase capacity factors on existing plants to meet growing demand rather than install new capacity. This also increases the probability of forced outages. As a result, customer concerns over reliability have escalated, particularly those in the manufacturing industry.

With the increasing use of sensitive electronic components, the need for reliable, high-quality power supplies is ever more important in most industries. The cost of power outages or poor quality power can be disastrous in industries with continuous processing and pinpoint quality specifications. Studies indicate that nationwide, power fluctuations cause annual losses of \$12 billion to \$26 billion.

As the electric power market opens up, the pressure for improved environmental performance increases. In many regions of the country, there is near-zero tolerance for additional pollutant emissions as the regions strive to gain compliance. Public policy, reflecting concerns over global climate change, is providing incentives for capacity additions that offer high efficiency and use of renewable energy sources. (Fig. 1-3)

Overseas, the utility industry is undergoing change as well, with market forces displacing government controls and public pressure forcing more stringent environmental standards. There is an increasing effort to bring commercial power to an estimated two billion people in rural areas throughout the globe who are currently without access to a power grid.

Distributed generation is becoming an increasingly popular solution for the future power needs of the United States, primarily because of continuing deregulation of electric power. Tying the merchant power trend to distributed generation allows developers to take advantage of opportunities where traditional utility plants are not the best solution. Large utility plants may sometimes be at a disadvantage in a competitive environment. Big



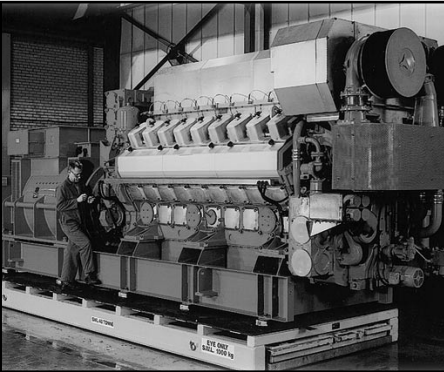
***Fig. 1-3** Solar arrays such as this one in California are well suited to sunny locales. While the installation cost is relatively high, there is no following fuel cost. A great benefit in areas with air quality concerns, renewable generation from solar or wind power, create no objectionable emissions.*

plants can generate a large amount of electricity at a moderate price, but there are often problems with running these plants at low loads.

Transmission infrastructure construction is becoming more and more of an expense and problem for utilities as well. Distributed generation plants can avoid both problems by installing capacity where it is needed. With distributed generation, a small power generation unit can be placed on-site, or very close, to the facility or facilities that need the power. This eliminates costly overbuilding of capacity and expensive transmission line construction.

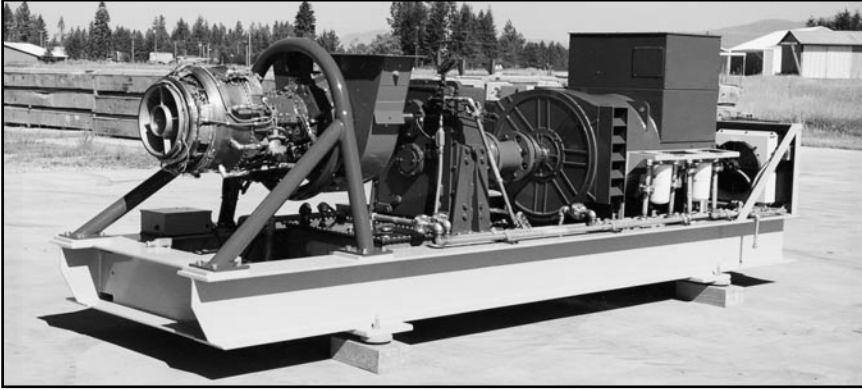
The mini-merchant for distributed generation is a new concept, referring to a distributed generation facility that seeks to match its generating portfolio to a local or regional electricity demand profile in the most efficient and economic way. These plants are typically cogeneration facilities, with overall thermal efficiencies as high as 88%. When compared directly to the separate production of electricity and thermal energy, these plant can reduce the CO<sub>2</sub> emission by 50% for the same amount of useful energy. They may also reduce the amount of fuel used by up to 50%.

The mini-merchant plant model hinges on overall economics and how cogeneration and distributed generation fit together. For distributed generation merchant facilities to work well, several characteristics must exist—flexible dispatch, load following, duty cycle, cogeneration, power production, and service territory. These plants can be run on internal combustion engines or gas turbines. (Figs. 1-4 and 1-5)



**Fig. 1-4** *The Wartsila 1,200-rpm 18V220 SG engine provides intermediate load power. It is rated at 2.5 MW.*

The electricity production capacity must be capable of being dispatched, cycling on and off based on the price of alternative sources of electricity. To facilitate dispatch, the mini-merchant relies on three classes of generators, responding to base load, intermediate load, and peak load demand requirements. Effective dispatch requires that all engines be capable of starting and synchronizing in less than 30 seconds. In most



*Fig. 1-5 Gas Power System's 1.2 MW Innovator genset can use liquid or gaseous fuels.*

cases, this capability will be unnecessary, but it could be required. Rapid load changes must also be accommodated without tripping off the load and maintenance should not be affected by repeated starting and stopping of the units. These abilities make these small plants far more flexible than standard utility-scale units.

For distributed generation applications, load following capabilities are essential. Reciprocating engine efficiency is reasonably flat between 40% and 100% load for individual generators. By having several engines, it is possible to load follow a local area from base to peak with little effect on efficiency. Large-scale utility plants do not enjoy this luxury. They generally have limited load range for top efficiency.

The difference between baseload and peak averages 100%. For instance, electricity load in the summer months is low at night, when many industrial customers are closed and air conditioners are running very little. But during the day when the industrial customers are operating and air conditioners are cycling, the power demand jumps 100% or more.

To minimize the capital cost for a distributed generation plant, it is important to match the generating equipment type to the expected duty. Peaking requirements are met through peaking generating equipment, intermediate generation is used for intermediate needs and baseload equipment provides for baseload needs.

Thermal energy production, called cogeneration, helps optimize efficiency for distributed generation facilities. Thermal energy production must be reliable with or without electricity production for this ability to truly be an asset. Natural gas engines have a fairly high exhaust temperature of more than 770 degrees Fahrenheit, corresponding to a plant thermal capacity of more than 24 MWth. Heat is recovered from exhaust gases and used for thermal needs in the facility.

The amount of electricity produced at a cogeneration distributed generation plant or mini-merchant is determined by the size of the thermal host. This ensures that the production efficiency is maintained at an optimum level. When there is little thermal need, all of the generation costs are absorbed by the electricity cost, with none going to a thermal power cost. If electricity is needed at a time when thermal needs are low, the decision to produce electricity versus buying it from outside will depend on a comparison of the incremental cost of production and purchase. Normally the cost of purchasing outside electricity is lowest when weather is moderate. Extremes in climate in both summer and winter increase the electrical demands.

In the open market, there are times when low electricity load conditions on the grid force “must run” facilities belonging to utilities to discount their energy to near zero pricing. When this happens, on-site generating facilities need to have the flexibility to purchase that low cost outside power. The goal of distributed generation, however, is to minimize reliance on the transmission grid for peaking and intermediate generation, and to produce baseload generation when it is economically practical.

Using distributed generation resources sited close to loads allows utilities and other energy service providers to

- provide peak shaving in high load growth areas,
- avoid difficulties in permitting or gaining approval for transmission line rights-of-way,
- reduce transmission line costs and associated electrical losses, and
- provide inside-the-fence cogeneration at customers’ industrial or commercial sites.

## Homeowner Demand

One million homeowners a year are purchasing backup power systems for their homes, according to figures compiled by Briggs & Stratton. In recent years, Y2K fears, weather patterns such as El Niño and La Niña and their ensuing ice storms, tornadoes, blizzards, hurricanes and heat waves are creating nervous customers looking to ensure their reliability.

The summer outages of 1999 prompted the Department of Energy (DOE) to commission a Power Outage Study Team to evaluate electric reliability. The team's interim report was released earlier this year, predicting that sections of the country will continue to experience serious outages until operations, regulations, and technology can catch up with demand.

There are a multitude of issues that can drive homeowners to backup power systems, including loss of heat, flooded basements when sump pumps lose power, freezer and refrigerator contents spoiling, family members on life-sustaining home medical equipment, and telecommuters who need electronic equipment for their employment.

"I think it is a trend. People want to be protected, particularly those people who are working at home, where going without power for 30 to 36 hours would be a real problem," says Walt Steoppelwerth, known as the "Remodeling Guru." "A lot of builders are now offering entire electrical packages to support all the needs in a home."

Using a permanent transfer system makes a portable generator safer and more convenient for homeowners. The most critical circuits are connected to the generator via the transfer system. Then, if the power goes out, those circuits can be turned on at the transfer switch.

Backup power systems, including a transfer switch and either a 5,000 W or 7,500 W generator and emergency power transfer system, can be purchased for \$1,000 to \$1,500. They are available at many home improvement, hardware or outdoor power equipment retailers.

## Combustion Turbines

Two types of combustion turbines are available for 1 MW to 25 MW distributed generation. Heavy-frame models are relatively rugged with mas-

sive casings and rotors. Aeroderivative designs, based on aircraft turbofan engines, are much lighter than the heavy-frame models and operate at higher temperature ratios. They also have higher compression ratios, so aeroderivative units have better simple-cycle efficiencies and lower exhaust gas temperatures than heavy-frame models.

Combustion turbine designs typically have dual-fuel operation capability, with natural gas as the primary fuel and a high quality distillate, such as No. 2 oil, as a back-up fuel. Because gas turbines have relatively high fuel gas pressure requirements, a natural gas compressor is usually needed unless the plant happens to be sited near a high-pressure cross-country natural gas pipeline. Combustion turbines typically require a minimum natural gas pressure of about 260 psi, while aeroderivative engines require a minimum natural gas pressure as high as 400 psi. A gas compressor can increase total plant cost by 5 to 10 per cent.

Maintenance costs for heavy-frame units can be about one-half that of aeroderivative units. Major maintenance of heavy-frame units may occur on-site, with an outage of about one week for a major overhaul. With aeroderivative units, the gas generator can be replaced with a leased engine, minimizing the power replacement costs associated with the maintenance outage. Aeroderivative engines can be replaced in two or three shifts, and the removed engine can be overhauled off-site.

## **Microturbines**

The market for microturbine products will be a significant niche, totaling \$2.4 billion to \$8 billion by 2010, and more than 50 percent of that market will be international. That's one of the conclusions reached by microturbine stakeholders, according to a market forecast from GRI.

Microturbines are of growing interest for distributed power generation because they can deliver combined heat and power, onsite generation, and be the prime mover for refrigeration and air compression. (Fig. 1-6)

Chicago-based GRI used the Delphi approach to conduct its "Microturbine Market and Industry Study." The project is intended to give an expert-based perspective of the market by separating hype from



*Fig. 1-6 Unicom Distributed Energy and Honeywell/Allied Signal Power Systems have demonstrated the Parallon 75 microturbine at an energy efficient McDonald's in Bensenville, IL.*

economic reality. Thirty-seven experts, representing microturbine manufacturers, utilities, venture capital firms, energy service companies, government entities and other stakeholder organizations were surveyed.

The study concludes that, while initial sales of microturbines will occur primarily in North America, more than half of sales will be international by 2010. Many stakeholders feel microturbines can provide eight percent of the estimated one million megawatts (MW) of new power capacity that will be needed by 2010.

Manufacturers, experts, and utilities believe that the growth rate and market acceptance will be greater internationally, in the long run, because

- fewer barriers are likely to be imposed by existing utilities, power providers or regulators;
- fewer interconnection issues will arise because many applications will be for “prime” power without grid interconnection, and
- shorter value chains will exist, which reduces cost premiums.

## Reciprocating Engines

Reciprocating engines vary greatly and have different designs depending on the fuel they burn. Natural gas-fired engines are known as spark ignition

or SI engines. Diesel oil-fired engines are known as compression ignition or CI engines. Compression ignition engines can also burn natural gas and a small amount of diesel fuel used as an ignition source. These are known as dual fuel engines.

Distributed generation facilities using reciprocating engines often have several units, rating from 1 to 15 MW each. Medium-speed and high-speed engines derived from train, marine, and truck engines are best suited for distributed generation because of their proven reliability, high efficiency, and low installed cost. High speed engines are generally favored for standby applications, whereas medium-speed engines are generally best suited for peaking and baseload duty.

Reciprocating engines have long been used for energy generators in the United States. However, overseas their ruggedness and versatility have made them popular choices for remote power needs.

Reciprocating engines have a higher efficiency than combustion turbines, although efficiency falls as unit size decreases. Aeroderivative turbines have higher efficiency than heavy-frame combustion turbines in this small size range.

Reliability and availability are important cost-related issues for distributed generation facilities. A 1993 survey found that 56 medium-speed engines at 18 different plants had an average availability of more than 91%. Combustion turbine plants demonstrate availabilities exceeding 95%.

Environmental performance of these technologies depends on what emission is being considered. For  $\text{NO}_x$  and CO, combustion turbine emissions are 50% to 70% lower than those of reciprocating engines. The  $\text{NO}_x$  and CO emissions can make it difficult to get permits for reciprocating engines in some states. For  $\text{CO}_2$  emissions, reciprocating engines have lower emissions than combustion turbines because of their higher simple-cycle efficiency.

## **Potential**

The worldwide market for distributed generation-size combustion turbines and reciprocating engines has grown in recent years. (Fig. 1-7)

Combustion turbines saw 250 orders in the 1 to 5 MW range in 1997, down from 280 orders in 1996. There were 187 orders in the 5 to 7.5 MW

range in 1997, up from 135 orders in 1996. There were 240 orders in the 5 to 15 MW range, up from 49 the previous year.

Reciprocating engines in the 1 to 3.5 MW range saw 4,400 orders in 1997, up from only 1,200 in 1990. There were about 2,100 continuous duty engines sold in 1997, up from 1,300 in 1996. About 370 peaking-duty engines were sold in 1997, down from 870 sold in 1996.

Distributed power systems account for less than 2 GW of electric power, but they are expected to provide as much as 50 GW by 2015.

## Fuel Cells

Fuel cells are poised to make significant contributions to the growing distributed generation trend. After more than 150 years of research and development, the basic science has been developed and necessary materials improvements have been made to make fuel cells a commercial reality. Phosphoric acid fuel cells, the technology with the earliest promise for large-scale generation, the phosphoric acid fuel cell, is now being offered commercially, with more than 100 200-kW units installed worldwide. More advanced designs, such as carbonate fuel cells and solid-oxide fuel cells, are the focus of major electric utility efforts to bring the technology to commercial viability.

Fuel cells can be described as continuously operating batteries or an electrochemical engine. Like batteries, fuel cells produce power without combustion or rotating machinery. Fuel cells make electricity by combining hydrogen ions, drawn from a hydrogen-containing fuel, with oxygen atoms. Batteries provide the fuel and oxidant internally, which is why they must be recharged periodically. Fuel cells, on the other hand, use a supply of these

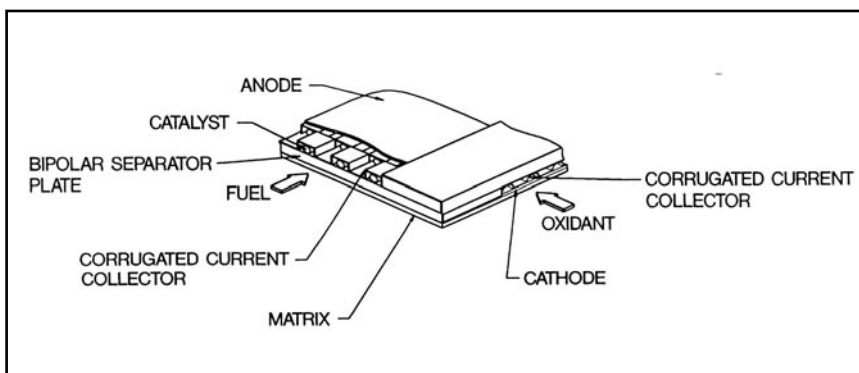


*Fig. 1-7 The Capstone Model 330 can be grid connected or stand-alone and it can run on natural gas, propane, or sour gas. They are used for load management, back-up power or peak shaving.*

key ingredients from outside the system and produce power continuously, as long as the fuel and oxidant supplies are maintained. (Fig. 1-8)

The fuel cell uses these ingredients to create chemical reactions that produce either hydrogen- or oxygen-bearing ions at one of the cell's two electrodes. These ions then pass through an electrolyte (which conducts electricity), such as phosphoric acid or carbonate, and react with oxygen atoms. The result is an electric current at both electrodes, plus waste heat and water vapor as exhaust products. The current is proportional to the size of the electrodes. The voltage is limited electrochemically to about 1.23 volts per electrode pair, or cells. These cells then can be stacked until the desired power level is reached. Several stacks can be combined into a "module," for site installation. The waste heat from fuel cells is well-suited for cogeneration or process heat applications.

Fuel cells offer great potential in the distributed generation field for several reasons. Because they are installed in small modules, an industrial customer or utility can install only the amount of power really needed, eliminating extra up-front costs for power that will not be needed for several years. If more power is needed later, more fuel cell modules can be added quickly and easily, with low overhead. The cogeneration and process heat functions of fuel cells are of great appeal to industrial customers, which are currently the great majority of distributed generation providers. Fuel cells also offer very short lead times from order placement to installed power generation capacity.



*Fig. 1-8 A Single Cell from a Fuel Cell*

Fuel cell costs have been falling rapidly in recent years, and they should soon become competitive economically with other technologies, especially where strict environmental compliance is required. Operating costs are competitive, particularly when operators consider the fuel cell plant's high efficiency and reliability when operating at partial loads. Siting and operating flexibilities add to their attractiveness, and can translate into site-specific dollar savings.

### **Internal Combustion**

Internal combustion engines can be the prime mover for small power plants, especially for distributed generation or industrial loads. Many of today's installed distributed generation facilities run on these tried-and-true technologies. These engines are basically similar to the gasoline- or diesel-fired engines predominant in today's transportation vehicles. The parts and fuel are readily available, and because there is large commercial demand for these, they are also relatively inexpensive.

