Distributed Generation

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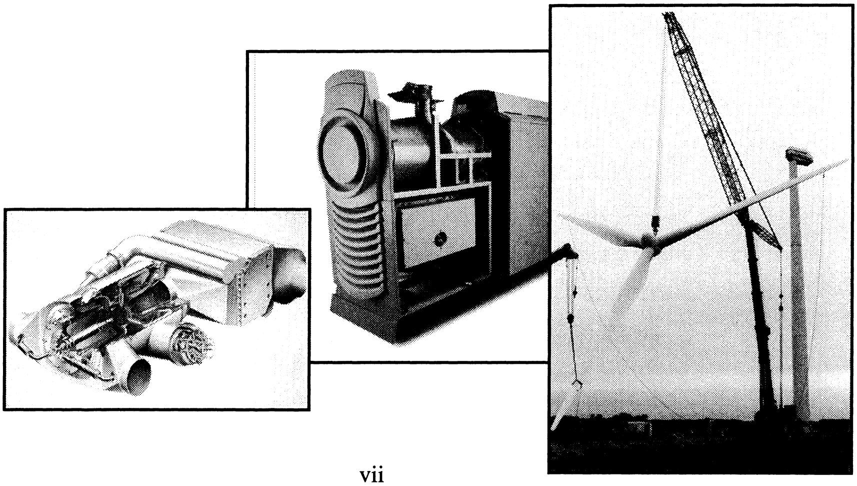

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Introduction to Distributed Generation

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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.

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 NO_x and CO, combustion turbine emissions are 50% to 70% lower than those of reciprocating engines. The NO_x and CO emissions can make it difficult to get permits for reciprocating engines in some states. For 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

The final report, issued in March 2000, lists a dozen recommendations for consideration by the Secretary of Energy, along with possible federal actions. Recommendations include the following:

Promote market-based approaches to reliable electric services. The value of reliability needs to be determined in competitive markets, and customers, as well as energy providers, need to have the opportunity to participate in markets for energy and ancillary services. Federal action recommended: support the implementation of fair, efficient, and transparent markets for electric power and ancillary services.

Enable customer participation in competitive electricity markets. To more fully participate in a competitive market, customers need to see real-time prices if they wish to have access to the communication and control technologies that will enable them to participate directly. Federal actions recommended: support development of market rules allowing customers to supply load reductions and ancillary services in competitive energy markets, and encourage development of demand management systems that support electric reliability.

Remove barriers to distributed energy resources. There is great interest in distributed generation technologies as a way for utilities to respond quickly to an increased demand for electricity where demand is already high. At the same time, utilities are working to improve power quality. Federal actions recommended: support development of interconnection standards for distributed energy resources, support state-led efforts to address regulatory disincentives for integrating customer supply and demand solutions, and study the potential for using emergency backup generators to reduce system demands to help avoid outages.

Support mandatory reliability standards for bulk-power systems. The grid is being transformed from one that was designed to serve customers of full-service utilities, each integrated across generation, transmission and distribution functions, to one that will support a competitive market. Federal action recommended: support the creation of a self-regulated reliability organization with federal oversight to develop and enforce reliability standards for bulk-power systems as part of a comprehensive plan for restructuring the industry.

Support reporting and sharing of information on best practices. Although there are many forums available for exchange of best practices

Capstone Turbine Corporation. Capstone Turbine Corporation (Capstone) is located in Woodland Hills, California. It was founded in 1988. According to Capstone, it is recognized in the industry for its research, development, and field applications of advanced turbine-driven generator technology.

Capstone's premiere product is the Capstone Microturbine. Its development began in 1993. Its technology is based on the same technology as a jet engine, except that it integrates Capstone's patented air bearings and proprietary software using state-of-the-art electronics. Capstone expects these innovations to create a versatile solution both for electric and thermal energy.

The Capstone Microturbine Model 330 is a fourth generation MTG. Many believe it reflects its maturity in terms of component arrangement, power electronics, control system, and overall packaging.

Figures 3-5a, and 3-5b show the Capstone 60kW, Capstone's newest microturbine.

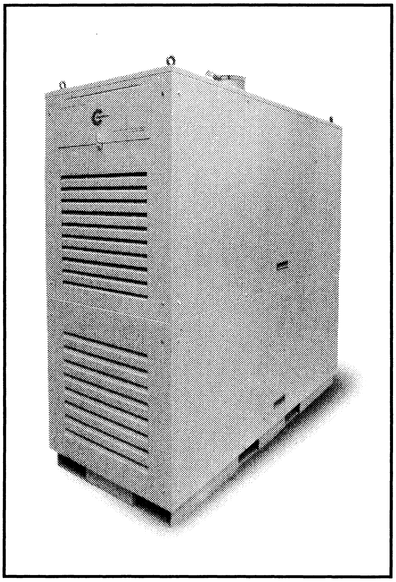

***Fig. 3-5a** Capstone 60 kW microturbine*

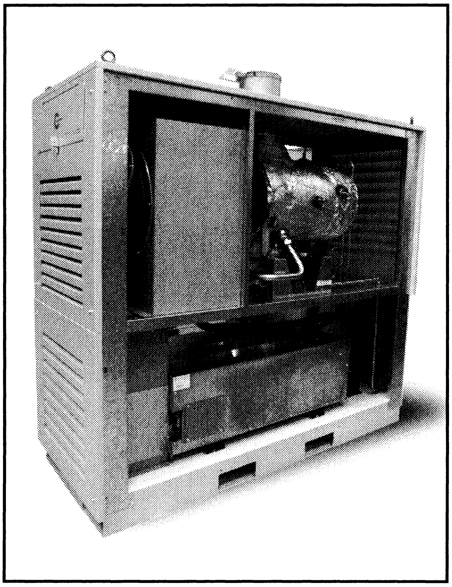

***Fig. 3-5b** Capstone 60 kW microturbine with panel removed.*

mounted unit to rotation speed necessary to support sustained combustion and export power.

Power Electronics—key component. MTG manufacturers use different power electronics. Some manufacturers use highly integrated power electronics that are proprietary to the manufacturer. Single-shaft machines require power electronics to convert high frequency generated power to a standard of 50 or 60 Hz power.

Control Systems—essential to success. MTGs rely on microprocessor based control systems. Similar to inverters and other power electronics, these systems are expected to improve in quality and decline in price.

Recuperators—important for efficiency. Unrecuperated MTGs are rated at about one-half the efficiency of recuperated MTGs. Recuperators are necessary for MTGs. MTGs generally exhibit efficiency that at best are still below 30%, even with a recuperator.

COMPARISON OF DESIGN CONFIGURATIONS

Single Shaft vs. Dual Shaft

Of the six manufacturers cited in this chapter, all but one use a single-shaft design. Ingersoll-Rand alone uses a dual-shaft design. Each design has certain capabilities and limitations. Customers will determine which design best suits their requirements. Only one shaft means no gearbox reduction is necessary. It also eliminates numerous moving parts associated with the gearbox and greatly simplifies the overall turbine design.

However, an offset to the gearbox is the addition of an inverter for the single-shaft design. An inverter adds to the cost, complication, and complexity of sophisticated power electronics.

A single-shaft design offers simplicity whereas a dual-shaft design offers ability to run additional processes such as air compressors and chillers. Running additional processes will be important to certain customers who can make use of an additional shaft. Other customers may not have a requirement for additional processes and will want the simplicity of a single shaft for electricity only or CHP.

The economics and service benefits are key selling points for Sussex to promote its flexibility in designing custom plans for members of the cooperative.

Chicago's Commonwealth Edison (ComEd) has also turned to diesels for peaking needs. The summer of 1998 brought an acute power shortage that adversely affected the upper Midwest. ComEd contracted Aggreko to provide 20 MW of temporary diesel generation to supplement the utility's capacity. That project was deemed such a success that Aggreko was contracted to supply 60 MW of temporary diesel power the following summer.

Two Chicago substations were supplied with 1,250 kW generators totaling 30 MW each for the summer of 1999. The sites were manned by Aggreko technicians for the duration of the project.

When needed, each generator synchronizes with the grade and is base loaded to 1,000 kW. The Aggreko GreenPower generators ran six to eight hours daily, based on area grid demands.

The generators were set up in pairs and connected to one 2,500 kWA transformer. A 2,300-gallon EnviroTank fuel tank allows approximately 15 hours of continuous run time if needed. More than 24,000 feel of low voltage cable was used to set up the peaking diesels which ran as a distributed generation peaking power solution from April to September.

Utility Expansion

Diesel-powered gensets are a modular option for utilities that need to add capacity, but not enough to merit the construction of a large facility. Since they have a small footprint, these units can often be added to existing generation sites for a capacity boost. For example, when the island of St. Kitts needed a turnkey expansion to its Needsmust power station, it selected two Mirrlees Blackstone base load gensets – an 8 MW and a 6 MW, boosting the facilities capacity by 14 MW. (Fig. 4-5)

Mirrlees Blackstone was also selected to expand the Corito Power Station on Anquilla, supplying a 16-cylinder, 2.5 MW genset. The diesels are seen as the latest technology for continuous operation in remote locations. Both of the installations discussed here included supervisory control

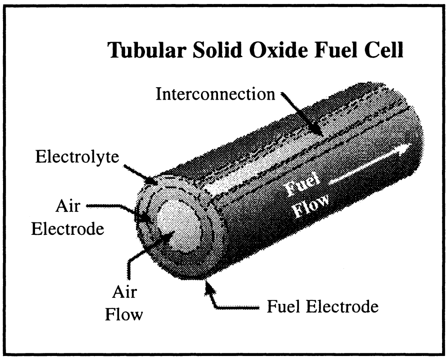

Fig. 5-4 *The Westinghouse SOFC.*

SOFCs promise efficiencies of 60% in large, high-power applications such as mid-sized power generating stations and large industrial plants. (See SOFC field study later in this chapter) This type of fuel cell uses a ceramic material, rather than a liquid electrolyte. This material lends itself well to the high operating temperatures (1,000 C) and fuel flexibility expected in an SOFC.

The SOFC was under development in the 1950s, even before NASA developed the alkaline fuel cell.

Similar to the MCFC, carbon monoxide is a usable fuel for an SOFC. Unlike an MCFC, however, CO_2 is not required at the cathode.

The high operating temperature allows for internal fuel reforming with the addition of reforming catalysts. Again, the high temperatures make this fuel cell plant an ideal candidate for cogeneration applications.

Future applications and renditions of the SOFC power plant will likely be linked to a gas turbine in a combined-cycle application that could achieve efficiencies as high as 75%, or even 85% when waste heat from the process is used.

The high operating temperature has some drawbacks, however. Thermal expansion mismatches among materials and seals between cells is difficult in flat-plate configurations.[10] Design changes, such as casting the cell into different shapes, may help alleviate this problem.

A 100 kW SOFC test has been ongoing in Europe and two smaller, 25 kW SOFCs are online in Japan.[11]

Polymer Electrolyte Fuel Cells (PEFC), or Proton Exchange Membranes, (PEM) function without the addition of an electrolyte, other than the membrane itself.[12] The cell consists of a proton-conducting membrane sandwiched between two platinum porous electrodes. The electrochemical reaction is similar to that of the PAFC.

Because of the characteristics of this type of cell, a low operating temperature of about 80 C is possible. The PEM is also able to sustain opera-