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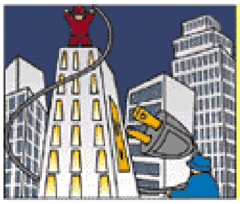


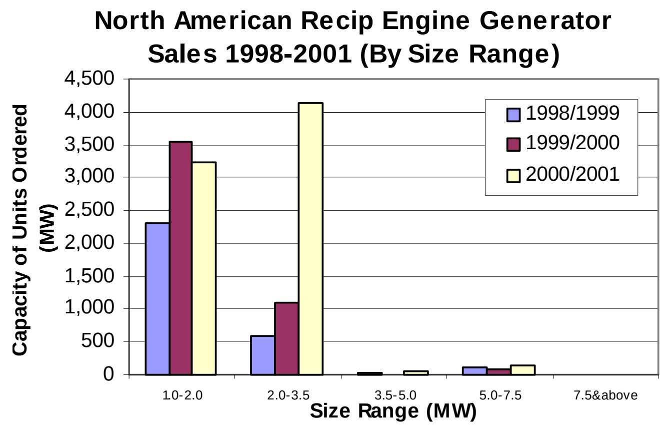
Distributed Generation MONITOR

There has been a great deal of talk recently about DG, its potential and its possibilities, but often with no real explanation of where the DG market is and where it might be heading. In this edition of the DG Monitor, we'll seek to fill this gap by providing readers with a snapshot of the DG market, its technologies, and other topics. Included are articles on the current and recent DG market, the evolving microturbine market, and fuel cell reformers. We'll follow up in the next issue of the Monitor with a look at DG's future. ***DG Monitor Staff***

A Snapshot of the DG Market

In order to understand where the DG market is going, it is important to clearly define where it is today and where is it coming from. First, we define DG as electric generation sited close to the load it serves, under 50 MW, with most of the output used by the host facility. There is a wide range of DG technologies and applications (see our Application and Technology Series). However, for all its potential and the buzz surrounding it, DG makes up just a small percentage of overall electrical generating capacity in the U.S. Though estimates vary, in the US, there are about 45-60 GW of DG, accounting for between 6-8% of capacity. Backup applications, with some Cooling, Heating, and Power (CHP) applications, also known as cogeneration, currently make up most of the DG installed base.

DG, though a small percentage of generating capacity, is a sizeable market: U.S. manufacturers ship over $3 billion in DG annually worldwide. Most of these sales are of diesel gensets to provide backup power, basically serving as an "insurance policy" in case of power failures. Fuel cells, microturbines and renewables have gotten a lot of press recently, but the reciprocating engine remains the leader in DG installations.



While overall MW declined for the 1-2 MW size range during this period, the number of units ordered actually increased, but a drop in the average size led to a decline in the capacity of orders.

In the last two years, there has been a surge in mid-sized (2-3.5 MW) reciprocating engines sales. Capacity from orders more than quadrupled from 1998-2001. Smaller 1-2 MW units grew by about 40%. These 1-3.5 MW units *(continued on page 3)*

The Microturbine Market: Recent Trends

With the 1999 through mid 2001 boom in reciprocating engine sales in mind, many are looking closely at the DG Market in hopes of identifying the 'next big thing.' Some have cast their votes for microturbines, a technology at once enormously promising and incredibly uncertain. However, though reports and expectations from this sector are often overwhelmingly optimistic in nature, there is enough uncertainty and lack of concrete data to confuse even the most seasoned market analyst.

First, just defining the microturbine market is complicated. There are many companies developing microturbines for use in DG applications, but only a handful with commercialized or near commercial products: *(continued on page 4)*

IN THIS ISSUE

Resource Dynamics Corporation

To view earlier editions of the DG Monitor or to begin receiving the publication via email please visit: www.distributed-generation.com.

About the DG Monitor The DG Monitor is a bimonthly publication of the Resource Dynamics Corporation covering the many facets of the emerging Distributed Generation marketplace. Articles both report and interpret the most important items. In addition, the Monitor includes special series on DG technologies, applications, manufacturers, and other issues, providing the reader with a complete picture of these topics over several issues.

Comments or requests for additional information can be addressed to DGMonitor@rdcnet.com, through our website at www.distributed-generation.com, or by contacting Jean Connors at 703/356-1300 x 208.

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Innovative Combined Heat and Power Applications

U.S. industrial facilities utilize a wide array of thermal process equipment, including:

- hot water heaters,
- thermal liquid heaters,
- ovens,
- furnaces,
- kilns,
- dryers,
- chillers, and
- boilers.

In most industrial facilities, process heating is provided by direct or indirect heat exchange from fossil fuel-fired combustion systems. Process heating may also be provided by the direct or indirect use of steam supplied by central boiler systems. Many of these systems could be retrofit to become part of integrated distributed generation (DG) cogeneration systems.

Resource Dynamics Corporation recently completed a report for the Industrial Center's Distributed Generation Consortium and Oak Ridge National Laboratory in which leading innovative industrial cogeneration systems were identified and the overall market for these systems was assessed.

Some of the innovative systems identified included:

- Direct contact water heaters fed directly with engine/turbine exhaust,
- Indirect liquid heating using air-to-liquid heat exchangers fed with engine/turbine exhaust,
- Convection ovens used for metals fabrication preheating fed directly with engine/turbine exhaust,
- Indirect air heating using air-to-air heat exchanges fed with engine/turbine exhaust, and
- Central boiler systems using turbine exhaust gas as a combustion oxidant.

The studies showed a technical market potential of over 11 GW for these systems. For more information on RDC Technology and Market Assessments, contact Paul Sheaffer at sheaffer@rdcnet.com.

CONFERENCES

2002 On-Site Power Generation (www.egsa.org) May 6-10, 2002, Dallas, TX

Distributed Generation Technology Seminar (www.basler.com) May 14-15, 2002, Andover, MA

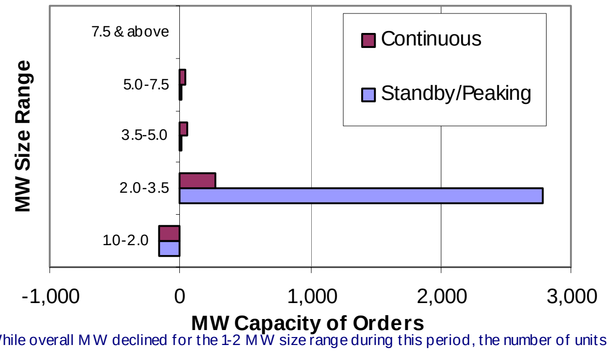
Distributed Energy Conference (www.powerin.org) May 14-17, 2002, San Diego, CA

IEEE P1547, Standard for Distributed Generation Interconnection, Working Group (www.ieee.org) June 4-7, 2002, Vail, CO

DER FEMP Workshop (www.eren.doe.gov) June 25-26, 2002, Chicago, IL

(DG Market, continued from page 1)
were mostly installed as peaking/standby units, and the largest percentage were diesel fueled. Natural gas unit capacity, perhaps surprisingly to some, did not

Change in North American Recip Engine Generator Orders 1999/2000 to 2000/2001



While overall MW declined for the 1-2 MW size range during this period, the number of units ordered actually increased, but a drop in average size led to a decline in order capacity.

grow as quickly as that of diesel engines. What may be more surprising is that although turbine sales have increased greatly these last several years, smaller, DG baseloaded turbine (mostly CHP) sales have actually declined from about 300 MW in 1999-2000 to under 50 MW in 2000-01.

These last two years have seen a great deal of growth in the DG market. This growth is due to a number of factors, many of which, such as the upswing in backup power for the dot.com boom, data centers, Y2K and the California energy crisis, are temporary. As a result, and due to the many technical and economic issues that come into play with DG market growth, there is likely to be a difference between DG market segment growth in the short and long terms.

It is difficult to predict where the DG market is ultimately headed, but a few changes seem likely. In the longer term, of great interest will be the shift in the technologies that dominate the DG market. There is likely to be a corresponding shift in DG market applications. Drivers include changes in energy market structure, concerns over grid reliability, which may mean many facilities seek additional control over their power supply, technological advances, and the emergence of new DG solutions. How these drivers play out will in great part determine the evolution of the DG market.

Economics remain a barrier, and whether DG will ultimately be economically ready to meet the challenges of the market is unclear. However, with the development and improvement of DG technologies and the removal of barriers to DG implementation, the DG market can grow to be, in some estimates, as much as $5-10 billion in the US market alone, and could account for a substantial percentage of new generating capacity. Research by RDC suggests that under current conditions, 50-60 GW of untapped potential exists for the DG market in industrial and commercial facilities alone. These numbers grow with improvements in DG technologies and the lowering or removal of market and regulatory barriers to DG.

In the next issue of the *DG Monitor*, we will take an in-depth look at this untapped potential and examine DG technology cost and performance expectations and possible high growth applications. ■

Note: Information in the above graphics is based on Diesel and Gas Turbine Worldwide's annual survey of unit orders over 1 MW and RDC estimates.

(Microturbines, continued from page 1)

- Capstone Turbine Corporation offers 30-kW and 60-kW systems.
- Ingersoll Rand Energy Systems recently began taking commercial orders for its 70-kW PowerWorks™ line of microturbines.
- Elliott Energy Systems is developing and manufacturing a 80-kW microturbine.
- DTE Energy is developing a 400 kW ENT400 "mini-turbine," with commercial units expected to be available in mid-2002.
- Bowman Power Systems is a U.K. company developing 80-kW microturbines.
- Turbec AB is a Swedish company jointly owned by ABB and Volvo Aero. The company offers the Turbec T100, a 100-kW microturbine.

These and a few additional companies are playing for a share in the potentially large DG market, contending not only with each other, but with the grid and other technologies.

Compounding these challenges are the vagaries of market demand. The boom in reciprocating engine purchases was due in great part to the corresponding boom in the economy, and with the economy in retreat, microturbine manufacturers have reported a softening of demand. Honeywell withdrew its Parallon 75 from the market and sold certain microturbine related technologies to GE. Capstone Turbine has fared better, and in 2001 shipped 38 MW of power, an increase of more than 50% over 2000 figures. However, though Capstone's revenue for the full year 2001 increased, a dip in this last quarter has started to make many investors uneasy. Recently, Capstone stock hit a 52-week low, and analysts predicted the company will under perform the market over the next six months with very high risk.

Still, many remain optimistic that the slowdown in the North American economy will be short lived. Although some factors that created the DG market boom have subsided, the underlying benefits of DG remain. The percentage of the DG market that will fall to microturbines will be primarily determined by whether or not the technology can live up to expectations. Microturbines can offer many benefits: they are fuel flexible, have high availability, and have low maintenance needs. However, they have a ways to go to realize these goals and to compete with current and other developing technologies. Microturbines are currently less efficient (28 to 32%) than many competing technologies, though their overall efficiency in cogeneration applications is competitive with other technologies. Microturbines are also more costly per kW than competing established technologies. As volume increases and economies of scale fall into place, this may change.

The task of tackling technology issues and improving the economics of microturbines has been made easier through incentive and research and development programs. For example, in California, under the Self-Generation Incentive Program, gas turbines with up to 1 MW rated output, sized at or below customer's annual peak electrical demand, and using waste heat recovery, are eligible for an incentive of $1,000 per kW installed, or up to 30% of the project cost, whichever is lower. The U.S. Department of Energy's six-year Advanced Microturbine Program will invest over $60 million to aid in the design, development, and demonstration of microturbines and components. Goals of this program include 40% efficiency and lowering costs to $500/kW. Several other programs are in place that will have important consequences for microturbine development.

Microturbine marketing and distribution frameworks are still in the formation stage, and the establishment of strategic relationships between manufacturers and other market players has been much in the news of late. To highlight an interesting market position strategy trend, several manufacturers announced their planned production of larger microturbine units. Both Capstone and Ingersoll-Rand have developed or are working on models in larger size ranges. Capstone now makes a 60 kW unit, and has plans for a 200 kW class machine. Ingersoll-Rand's 70 kW microturbines will be supplemented with a 250 kW unit, targeted for industrial plants and slated for delivery in mid to late 2002. Elliott Energy Systems plans to add a 500 kW unit to its 45-200 kW Turbo Alternator® series.

These manufacturers are charting new territory, hoping to be the first units in these size ranges. Their strategies, as well as the results of recent rounds of commercialization, product breakthroughs and economic fluctuation, will take time to unfold. Until then, the microturbine market remains an uncertain one. However, one thing is clear- decisions made now by both manufacturers and financiers will in great part determine whether microturbines are to be an enormous success or not. ■

DG TECHNOLOGY SERIES: FUEL CELL REFORMERS

Fuel cells use hydrogen as a fuel source. There are a number of ways to obtain hydrogen, but most fuel cell systems use hydrogen-rich fossil and waste fuels. Fossil fuels include methanol, ethanol, natural gas, propane, gasified coal, and waste fuels including anaerobic digester gas and landfill gas. Hydrogen is produced from these fuels by a process known as reforming, with the most common type being endothermic steam reforming. This type of reforming takes fuel and water and vaporizes them at high temperatures. Hydrogen is then separated out. Steam reforming is an endothermic process - energy is consumed - which reduces the overall efficiency of a fuel cell system that has an integrated reformer.

CO_2 is emitted during the reforming process. For every Btu of fossil or waste fuel going into a fuel cell system, the fuel cell system emits as much CO_2 as an engine or combustion turbine that uses the same amount of fuel. If the fuel cell system is more efficient than a traditional generator, it will produce less CO_2 per kWh generated. Emissions of NO_X and SO_X are close to zero with fuel cells using integrated reformers, although fuel cell hybrid vehicles do not count as zero-emission vehicles because they do produce some of these smog-producing pollutants.

For stationary fuel cell power generation, fuels like natural gas or propane are generally used. Many facilities already have natural gas service, and other facilities can be supplied by propane delivered by truck and stored in tanks. For reformers that are part of transportation applications, the main issue is energy storage. In order to avoid heavy pressure tanks associated with gaseous fuels, most reformers use liquid fuels like gasoline and methanol.

Methanol and natural gas are likely to be the most common fuels converted to hydrogen in a steam reformer. The process for each is described below.

Methanol

The molecular formula for methanol is $\mathbf{CH_3OH}$. During the reforming process, hydrogen (**H**) is removed while carbon monoxide (**CO**) emissions are minimized. The process begins with the vaporization of liquid methanol and water. Heat produced at a later stage in the reforming process or from the reactions in the fuel cell is used to accomplish this. The vaporized methanol and steam are passed through a heated catalytic chamber.

The catalyst causes the methanol to split into carbon monoxide (**CO**) and hydrogen gas ($\mathbf{H_2}$):

$$\mathbf{CH_3OH \Rightarrow CO + 2H_2}$$

and the water vapor to split into hydrogen and oxygen; this oxygen combines with the CO to make CO_2.

$$\mathbf{H_2O + CO \Rightarrow CO_2 + H_2}$$

Natural Gas

Natural gas, which is mostly made up of methane ($\mathbf{CH_4}$), is reformed using a similar reaction. The methane reacts with water vapor in the catalytic chamber to form carbon monoxide and hydrogen:

$$\mathbf{CH_4 + H_2O \Rightarrow CO + 3H_2}$$

and the water vapor splits into hydrogen and oxygen. The oxygen combines with the CO to form CO_2.

$$\mathbf{H_2O + CO \Rightarrow CO_2 + H_2}$$

Some methanol/natural gas and carbon monoxide make it through the process without reacting. These are then burned in the presence of a catalyst. In this way, most of the remaining CO is converted to CO_2, and the remaining methanol/natural gas oxidizes to CO_2 and water. This exothermic reaction can supply heat to the first stage of the reformer. Other technologies are also used to clean up any other pollutants, such as small concentrations of NO_X and SO_X.

This process of removing the remaining carbon monoxide from the exhaust stream is important for two reasons: first, if the CO passes through the some types of fuel cells, the performance and life of the fuel cell are reduced; second, CO is a regulated pollutant.

The Downside of Reformers

Many articles in the popular press state that fuel cells only produce electricity and water. This is true, but if your source of hydrogen is from a steam reformer, the overall system produces CO_2 and trace amounts of pollutants. In addition, when you calculate the electric or overall efficiency of a fuel cell system, you need to take into account the reforming process. ■

DG NOTES

Apr 18, 2002 - As a new partners in **Waukesha Engine's** Power Energy Partner Program, **DTE Energy Technologies** will provide a value-added marketing channel in Waukesha Engine's efforts to grow its engine business within the power generation market.

Apr 17, 2002 - **FuelCell Energy** and partner **PPL Energy Plus** will provide two Direct FuelCell® power plants for installation at New Jersey hotels owned by Starwood Hotels & Resorts Worldwide, Inc. The New Jersey Clean Energy Program will be provide approximately $1.7 million in funding. On April 3, 2002, **FuelCell Energy** received U.S. patent, #6,365,290,``High Efficiency Fuel Cell System," for its combined cycle Direct FuelCell/Turbine power plant.

Apr 2002 - The world's first fuel cell-gas turbine hybrid power plant, combining a **Siemens Westinghouse** solid oxide fuel cell with an **Ingersoll Rand** microturbine, is now generating electricity, being tested at the National Fuel Cell Research Center on the campus of the University of California-Irvine.

Mar 20, 2002 - Seven 200 kW **UTC Fuel Cell** PC25 Systems will provide primary power for the world's largest fuel cell installation at a Verizon critical call-routing center on Long Island, New York. Verizon will install four natural gas powered generators to operate in parallel with the fuel cells as a hybrid system.

Mar 14, 2002 - **Ztek Corp.** was selected as a finalist by the Connecticut Clean Energy Fund to team with **The Renewable Resources Group, LLC** to receive funding for a demonstration of Ztek's 25 kW SOFC system for the DEP's facility at Dinosaur State Park in Rocky Hill, Connecticut.

Mar 7, 2002 - Under **Clarus Energy's** Alternative program, Clarus develops power generation on-site tailored for California businesses that purchase from an energy service provider and are at risk of having their contracts voided because of the suspension of direct access by the California Public Utilities Commission. Clarus Energy acquires the power generation equipment, negotiates gas contracts, performs installation, implements co-generation, operates and maintains the equipment, and obtains permits and siting approvals. Customers are only responsible for a monthly energy bill.

Mar 6, 2002 - **Trigen-Boston Energy Corporation** will own, operate, install, and maintain a 6 MW CHP plant at the New England Confectionery Company's new site in Revere, Massachusetts. The agreement is for 20 years, and construction is to begin immediately. Necco expects to save over $15 million in energy costs from the two gas engines, heat recovery steam and hot water generation system, selective catalytic reduction system, and oxidation catalyst for emissions control.

RDC DG NEWS

Presentations

"Fuel Cell Hybrid Market Assessment and Early Adopter Study."- Paul L. Lemar, Jr., at Second DOE/UN International Conference and Workshop on Hybrid Power Systems, Charlotte, NC, April 16-17, 2002.

"DG Interconnection: Will the 'Black Box' Technology Help or Hurt the Business Deal?" - N. Richard Friedman, at MicroPower "Get Connected" Workshop, Toronto, Canada, April 8, 2002.

"Siting of DR Units: Rules of the Game." - Paul Lemar, Jr. and E.J. Honton, and "DR Cost Impacts on T&D Systems." - N. Richard Friedman and E.J. Honton, at EPRI's VIIth Distributed Resources Conference and Exhibition, Dallas, TX, March 20-21, 2002.

Reports

The National Rural Electric Cooperative Association (NRECA) - Customer Backup Power Generation, March, 2002.

The National Rural Electric Cooperative Association (NRECA) - Business and Contract Guide for Distributed Generation Interconnection, March, 2002.