GE Energy - Creative Services

Turbine Technology

VERSATILE POWER SOLUTIONS FOR DISTRIBUTED ENERGY

BY ED RITCHIE

In the world of innovative power technology, turbines hold a unique position. They offer power solutions from as low as 250 kW, to hundreds of megawatts, and unlike reciprocal engines with hundreds of moving parts, a turbine is basically designed with one spinning shaft and a minimal parts count. Also, they're ideal for combined heat and power (CHP) applications where the thermal load allows for high fuel efficiency performance. All in all, they are an attractive choice for onsite energy applications. But is a turbine the right choice for your facility? We spoke to some experts in the industry to get their advice.

Let's start with a look at microturbines. These machines share many of the same benefits of their larger cousins, such as minimal moving parts, low noise and vibration, and great thermal output. Yet, as their name implies, they're small (close to the dimensions of a large refrigerator), and their electrical output is typically in the 250- to 400-kW range. Projects that use multiple microturbines can vary the power and heat

output by shutting down units, making them ideal for a wide variety of applications. For example, the Pennsylvania State Employees Credit Union (PSECU) has a system that's part of a Leadership in Energy and Environmental Design (LEED) Gold-certified facility and data center.

At the PSECU, a Capstone Turbine Corp. C800 Power Package provides 800 kW of electrical output for the data center, plus exhaust heat for use in a hot water and chilled water system. "The synergy works really well at the PSECU," says Jim Crouse, VP of marketing at Capstone. "We're seeing more customers that want to save money and become more energy efficient and environmentally friendly, yet they need an additional source of backup power."

In essence, the PSECU's system is actually a trigeneration installation that uses four MMBTU heat exchangers and a 250-ton flue-gas-fired absorption chiller, to provide heating and cooling of the 239,000-square-foot building. "This is what we call a dual-mode system," says Crouse. "It runs grid-parallel, or if the grid goes down we have a transfer switch that switches it from grid to island mode. The nice thing about using CHP as a backup power situation for the data center is that we're not only providing electricity in the event of a power outage, but were also providing hot water and chilled water. So, you have the electrical load on the emergency system, and that keeps the center's chillers and heaters working."

Easy maintenance is another advantage to running a group of microturbines. Says Crouse, "The whole idea of using smaller prime movers is resonating with a lot of customers. If there's a change in the 24-hour load profile, or if one is down, the other three, four, or more gives you lots of operational flexibility. Whether it's a seasonal load profile or plant shutdowns, they run when they need to. I was actually looking at that site [PSECU] because it's monitored by our distributor in Pennsylvania, and between the four units there are 73,000 hours already tallied, so it's been running 24/7 quite reliably."

The economics of running a set of microturbines under baseload was a compelling reason for the Longwood Central School District in Long Island, NY. In this case, the district chose four GT250S microturbines from New Hampshire-based FlexEnergy Inc. The FlexEnergy turbines include an integrated hot water cogeneration module to allow for a simple mechanical connection to multiple-facility hot water systems, as well as absorption chilling; reducing equipment footprint; and facilitating quiet, safe, and reliable operations.

As for the economics, the district gets significant savings in that the FlexEnergy turbines run in cogeneration mode by producing baseload power continuously throughout the year, not just when demand on the electrical grid is at a peak. According to Michael Passantino, president of MDP Energy, the project's prime contractor, Long Island has the second highest energy rates in the country, with a blended rate of $0.198 per kilowatt-hour. The Flex microturbines will bring the high school and middle school costs down to 0.09 cents per kilowatt-hour, ultimately reducing energy costs by over 50%.

Douglas Demaret, vice president of sales and marketing at Flex Energy Inc., says there are further opportunities for savings because the system uses Flex Energy Supervisory Control Master (SCM) to control the two Flex GT250S microturbines installed at the high school and an additional SCM controls two Flex GT250S turbines at the middle school. "If you have multiple units operating together, we have a master controller. It's able to offer a single point to log in to monitor performance, and it can shed a turbine in times of low load," he says. "So if your demand falls to a point where it's less than what your CHP needs, it turns a turbine off until the demand rises again. If it happens a lot, it does runtime balancing where it knows the operating hours of each individual unit and when it starts shedding turbines, it takes operating unit values into consideration to keep the hours balanced across the machines. That ties back into maintenance work, and allows us to schedule certain maintenance points. It saves the customer money if all of the units are reaching that point together, so we only need to come out once."

The system also manages the turbines for import control with dual-mode capabilities to operate uninterrupted under grid-isolated conditions when utility power is not available. Under such conditions, reliability is critical, and Demaret notes that the turbines are designed to run without complicated voltage regulating equipment. "These are synchronous generators that produce 40 volts and 60 hertz, which is a standard industrial and commercial voltage," he says. "So they match the voltage of the building and tie into the building and synchronize smoothly. Other microturbines can run at extremely high speed and produce a high-frequency, high-voltage electricity that needs to run through power electronics that change it to 480 volts and 60 hertz. Power electronics can be notoriously finicky and prone to issues in the field, so we provide a more robust connection to your electrical load that allows you to increase your reliability."

Such features make microturbines good candidates for other industries, says Demaret, "Manufacturing and data centers are big power heat and cooling users. Then hospitals, of course. Medical and pharmaceutical have been very strong for CHP right now. Health care is strong, and the primary driver is their energy cost. But they have good steady flat loads and

Photos: Capstone

Rooftop turbines at Pennsylvania Employment Credit Union

their electrical and thermal demands are stable, so you can tailor a CHP project to a hospital and optimize their savings."

With such a range of markets, it's not surprising that Navigant Research predicts that revenue from annual microturbine installations is expected to surpass $1 billion by 2020 (**http://bit.ly/1LfRC8F**).

The report analyzes the market for microturbines in terms of applications, market segments, and economics, including global forecasts for capacity and revenue, through 2024.

It also notes that applications in the oil and gas industry—plus CHP applications in the commercial, industrial, and residential high-rise markets—are growing segments of the market.

So far we've seen some good examples of the benefits of choosing microturbines, but there is a point at which the size of the thermal and electrical demands tips the scales towards larger turbines in the 3- to 6-MW range. For example, Solar Turbines Inc. in San Diego, CA, offers the Mercury 50 for applications that can use 4.6 MW of power.

"We have improved our durability, and with its extremely low NO_x [mono-nitrogen oxides] emissions, it's an efficient machine for the 4.6-megawatt range," says Uwe Schmiemann, marketing manager at Solar Turbines Inc. "It's a very good fit for hospitals or universities or landfills. Universities, due to their campus area, have a bigger heat load requirement, and we see the Mercury 50 as a better fit than reciprocating engines. On one hand, it produces more thermal energy; on the other hand, it's a small, compact unit with 4.6 megawatts, and has the lowest emissions in the industry. It's quieter, and because the turbine has a high-frequency noise, you don't have to isolate it like a typical engine with a low-vibration noise."

Turbines in the multi-megawatt-range are ideal for cogeneration or trigeneration because they have an abundance of exhaust gas that can be used to make steam and chilled water and hot air. "Here in San Diego we have a factory that's being provided with chilled water from the turbine," says Schmiemann. "Typically, the thermal energy demand is higher than the electric power demand. Yet, most of these operations are getting some power from the grid anyway and are using it as a backup. Most customers don't want to be totally independent, so they need a grid connection anyway, and equipment needs maintenance. So, the two options are to put in redundancy, or use the grid as a backup when maintenance is needed on the generator. There's also the option of selling back power onto the grid."

In a baseload situation, a turbine's ability to run in "island mode" is also an advantage. "Hurricane Sandy is a good example of why you need distributed energy," says Schmiemann. "We have several installations in New York, and they were all running through the storm. It was more stable than the electric network. So, your safety factor for backup power is much higher. Recently we did a prison in New York. They have a need for heat, and of course they have a need for safety in case there's a power outage on the grid."

For emergency situations where a location doesn't have an onsite power source, Solar Turbines offers a 5.6-MW modular mobile power unit. The company is developing a new design that packs everything into a single trailer rather than two,

Pennsylvania State Employees Credit Union

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so it's easier to relocate and connect. For larger applications, there's a 15-MW unit.

"A 15-megawatt unit still fits on a trailer, and the Titan 130 is more for utility users. We have sent these to Iraq to ensure that the oil fields keep running," says Schmiemann.

For the future, Schmiemann sees continued growth in distributed energy and decentralized power, thanks to the benefits of microgrid technology, better local resilience, and reliable natural gas resources. "Microgrids are the next opportunity after decentralization," says Schmienamm. "The benefit of a microgrid is that it allows a smooth integration of renewables and fossil fuel power generation. Whether we like it or not, we typically have fossil fuel generation as a baseload. Maybe in 20 years from now that will change, but we're not there yet. So, microgrids allow for a good combination between fossil fuels and renewables."

District heating and cooling is another area in which larger scale turbines can shine, especially steam turbine generators, such as those produced by the Elliott Group. District heating and cooling has been used worldwide for decades, but advances in technology now allow districts to produce efficient, safe electricity as a byproduct of the system's primary purpose: heating. In the past, many steam plants produced steam at a pressure that was too powerful to use to heat buildings. In these cases, a pressure-reducing valve (PRV) was used to drop the steam pressure to a desired level, but the pressure drop resulted in a waste of valuable energy.

According to Scott Wilshire, manager of power generation business at Elliott Group, Elliott's steam turbine generator (STG) sets allow districts to capture this wasted energy by placing the STG in parallel with an existing PRV.

"When you have a high-pressure steam source, you need low-pressure steam; typically, a pressure reducing valve is utilized, but that's all you get out of it," says Wilshire. "Steam turbines can be applied to essentially do the same thing. The high pressure comes in and work is produced, and you have steam for whatever the process need is. For industrial facilities, it can be used for preheating or different process uses that the industrial facilities have. In a district with steam systems, it's typically for heat. So for the most part, a system that's under one megawatt can go in and replace a pressure-reducing valve. So you get your low-pressure steam, plus the value of the electricity coming out of the generator. We do this with induction generators, which are rarely an economic benefit because a generator will need the grid to generate electricity, but a synchronous generator doesn't need the grid. So in that case, as long as you have steam, you can have continued electricity, even if the grid is down. If you're in a skyscraper in New York City, you're not going to keep the Empire State building lit up with one megawatt of electricity, but if there are critical loads, emergency lighting, condensate pumps, and things like that which could be powered off the generator, it's a distinct advantage."

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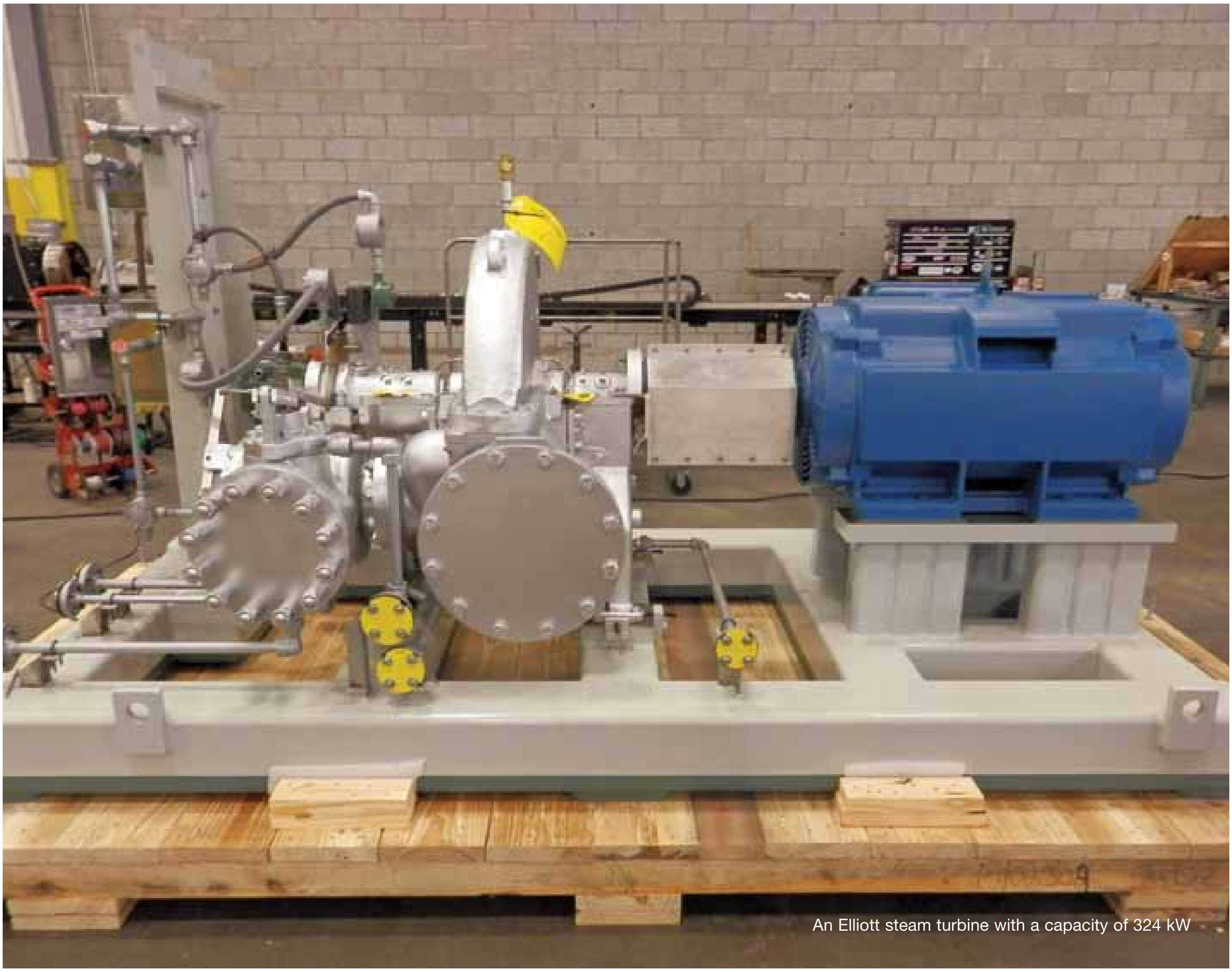
As the distributed energy trend continues to grow, the Elliot Group is focused on providing a standardized or modular design in the form of a predefined product. In the past, most steam turbine generators were custom engineered products—a customer supplied specifications and the system was custom designed for the application. But with the PRV-sized turbines the Elliot Group is doing the engineering upfront to create a defined package. "It's a modular approach," says Wilshire, "and we designed these so that they can fit through tight spaces, and we minimized the overall size and footprint. In a couple of cases we've even made them so they can be taken apart to get into a freight elevator. In the smallest cases they're about the size of a sheet of plywood."

No matter the size, turbine owners can look forward to reliability and long run times with minimal maintenance, according to Allen Thornton, vice president sales, North America Rotating Equipment Services, Sulzer Turbo Services. "These machines are quite common in refineries and chemical plants, and people appreciate the requirements for maintenance because there are a lot of safety precautions needed," says Thornton. "So there's annual maintenance required and testing, but these machines run four to five years before there's any need for internal cleaning when they run at lower



Elliott

An Elliott steam turbine with a capacity of 324 kW speeds and pressures. But, steam turbines at 15 to 35,000 horsepower can go five to seven years before they need any internal cleaning."

With such high performance, it's not surprising that we've found some great examples of just how reliable turbines can be. For instance, the fleet of Siemens H-class gas turbines has exceeded 200,000 operating hours. At Fortuna, a new landmark on Düsseldorf Harbor, the Fortuna combined-cycle gas turbine (CCGT) power plant at the Lausward location in the port of Düsseldorf, has broken three world records: a maximum electrical net output of 603.8 MW was achieved with a net energy conversion efficiency of 61.5%. In addition, Fortuna also provides 300 MW for the Dusseldorf's district heating system, thus achieving a peak value for a power plant equipped with only one gas and steam turbine. The overall efficiency for natural gas as a fuel reaches up to 85%.

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Turbines are also finding their way into many interesting alternative fuel applications. For example, GE recently announced that it has been selected by Mechelen-based Belgian Eco Energy (BEE), to build the largest greenfield, 100% biomass-fired power plant in the world. The plant will be powered by wood chips and agro residues, and generate approximately 215 MW of clean energy for the area's industry and households. The biomass fuel allows the facility to reach over 60% efficiency when operating in cogeneration mode. A circulating fluidized bed boiler, steam turbine, generator, as well as air quality control systems make up the critical components for the project. BEE's new plant also includes a district heating system of approximately 110 MW of thermal energy to supply heating to industries and households in the city of Ghent, Belgium.

Another example of innovation in the area of alternative fuels comes from Kawasaki Heavy Industries, Ltd. The company recently announced that it has developed and tested a hydrogen-fueled Dry Low Emission (DLE) combustion technology that achieves low-NO_x combustion without using water or steam, which used to be indispensable with conventional technology. This new combustion technology has been confirmed to deliver low-NO_x performance in a verification test conducted in Germany.

It's a breakthrough because hydrogen combustion in gas turbines can be unstable due to the fast combustion speed of hydrogen. In past applications, when combined with high-flame temperatures, this resulted in NO_x emissions that were nearly double the amount emitted when combusting natural gas. Kawasaki found a solution that minimizes flashback and other instances of unstable combustion, by using small hydrogen flames, and it also achieves low-NO_x combustion.

Last fiscal year Kawasaki also launched a new development project for an industrial gas turbine combustor that uses small hydrogen flames. This project was commissioned by the Japan Science and Technology Agency, which oversees one of the Cross-ministerial Strategic Innovation Promotion Programs that deals with energy carriers, as part of an initiative pursued by the Cabinet Office's Council for Science, Technology, and Innovation.

Large turbines aren't the only source of innovation in alternative fuels. Flex Energy microturbines have a surprising range of fuel alternatives. "Natural gas is a primary fuel source," says Demaret, "but we can run on any gaseous fuel, such as propane, biogas, butane, methane, and all the other alternative fuels that are more or less considered waste gases. Typically, with microturbines it's hard to control the flame speed in the combustor, but we don't have issues with that, so we're able to burn all those fuels. Also, these machines can be running on one fuel and switch to another without having to make any modifications to the equipment, such as shutting down and changing valves. It can be done automatically and the equipment will continue to run on the different fuel source."

With so many fuel options, size ranges, and innovations, it's not surprising that the market is seeing healthy growth in the turbine industry. Whether your business or facility needs process heat from just one 250-kW microturbine, or a 300-MW behemoth, there's a turbine to fit nearly every application. **BE**

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