Distributed Energy

GENERATION | STORAGE | EFFICIENCY | TECHNOLOGY

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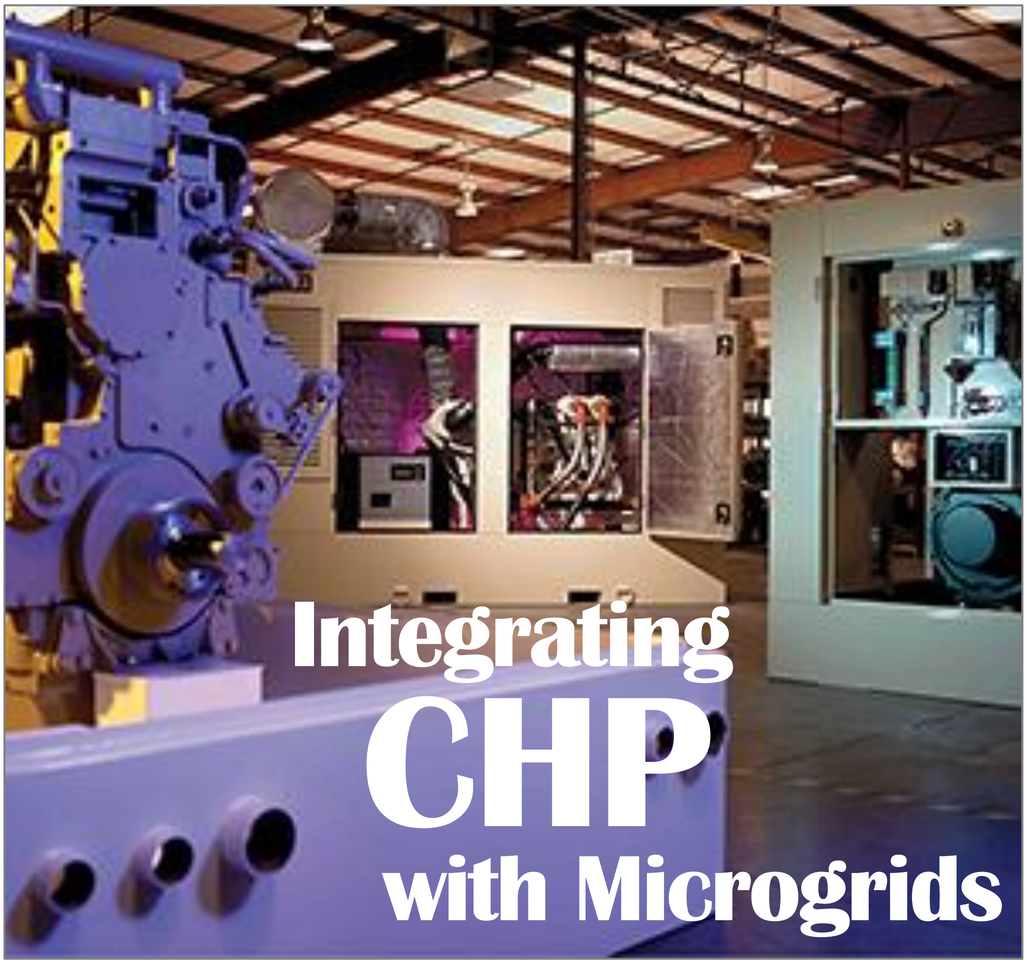

Integrating CHP with Microgrids

HIGH EFFICIENCY, ON-DEMAND POWER OFFERS STREAMLINED SUPPORT.

While combined heat & power (CHP) may not be appropriate for integration into all microgrids, it definitely does have its place in a lot of them.

CHP systems output heat (or cooling), as well as electricity, primarily as a topping cycle. “The prime mover is typically a reciprocating engine or a turbine,” says Mike de’Marsi, director of software systems engineering for Elite Energy Engineering (E3) (***www.e3nv.com***), an energy management and manufacturing company with a focus on commercial and industrial energy CHP projects.

According to de’Marsi, CHP is prized for increasing the fuel use from about 40% efficient electric operation, to up to 80% efficient electric and thermal operation from the same fuel. “As such, CHP is a baseloading technology,” he says. “These systems are not meant to start and stop to fill in momentary power shortages, as this is detrimental to the thermal collection side of the system and the maintenance regime.”

Microgrids, in the generic sense, are just small power systems not fed from a larger electric utility system. “A microgrid typically includes a few buildings up to campus size," says de'Marsi. "However, microgrids—as the term has been used by New York State Energy Research & Development Authority (NYSERDA) and other financial program providers—describes an ad hoc power system typically fed from a larger electric utility distribution system, but is formed when the utility grid system is unavailable." However, the ad hoc nature of the formed system, combined with a lack of skilled personnel to oversee the operation locally, makes these systems difficult to deploy, according to de'Marsi.

An Elite Energy installation

How CHP Systems Can Be Integrated Into Microgrids and Other Renewable Energy Systems

"CHP systems, in their traditional design of operation, do not integrate well with renewable energy systems," says de'Marsi. "In order to get good service life and an acceptable return on investment, CHP systems need to operate at their full rated load at least 6,000 hours per year." Engine-based prime movers for electricity production, in particular, are recommended to produce at least 75% of their rated output by their manufacturers. This recommendation maintains efficient power production and prevents excess maintenance.

"On the whole, renewable energy systems suffer from unpredictable variable power output issues associated with how they derive their energy," says de'Marsi. "For example, birds, clouds, and airplanes

Oncor's propane-fueled 65 kW Capstone microturbine

affect the output of solar panels, while doldrums and intense storm activity negatively affect wind turbines."

As a result, significant fuel-based spinning reserves are required to back up the electricity when the renewable systems are not able to supply the instantaneous load. "This is unfortunate, as the efficiency of spinning reserve is poor, and as such, air pollution is not decreased as much as most believe through the use of large-scale renewable energy farms," says de'Marsi.

Integrating CHP into a microgrid should be planned from the outset, before the facility or campus is constructed. Examining the electric load types and creating an electrical system that can change its size quickly through the use of several electric switchgear pieces, remote-controlled breakers, static switches, and "continuous" building automation controls is essential.

"To a certain extent, the design should be modeled after a hospital system, where critical loads are served through separate electrical gear, and the user can choose the relative importance of the device," says de'Marsi. "Dividing electrical loads by importance is the first part of the design for a microgrid." For example, charging a mobile phone can occur at a normal outlet [as it is not critical], but a piece of medical equipment for a patient might be plugged into a red outlet, as the red outlets will be powered by the backup generators at the hospital site if utility power is lost.

CHP devices should be sized as to power the entire facility when four to five separate generators are running. “The temptation is to run the entire facility on one or two generators to reduce control complexity and take advantage of the lower cost of larger units, over four to five smaller ones,” says de’Marsi. “This would be a mistake. Not only do the smaller units provide more redundancy, but they allow units to be operated at higher output, more efficiently. For example, it is better to have four 250-kW units, with two operating, to support a 300-kW load, than to operate a single 1000 kW unit to operate the same load.” The incremental sizing allows the many systems to be turned off in the middle of the night, when lower electric load is present, or in the day, if more renewable sources are available. The number and size of the CHP units would be designed based on the expected normal day and night loads.

Once the base operational electrical load is known, the electric switchgear can be designed and sized for the facility.

Once the base operational electrical load is known, the electric switchgear can be designed and sized for the facility. “Having several switchgear pieces separated by stored energy breakers or static switches with the end gear being attached to a renewable generation source, allows the building to sectionalize less necessary loads when the renewable sources are not fully available,” says de’Marsi. “Facility lighting should be designed with minimal lighting on the main electrical switchgear and additional environmental lighting on the renewable switchgear.”

Further, the building automation system would be employed to help with controlling loads in a planned way to keep the microgrid powered when electricity is in shorter supply. For example, if the renewable systems are not generating their rated value, an air conditioning system might reduce the chiller loading with a variable frequency drive (VFD) as well as lowering the air distribution through a VFD fan drive, such that some cooling is still available at a lower electrical load. “Certain sections, like hallways, might have their cooling minimized to maintain desired temperatures in rooms,” says de’Marsi. The building automation system would also be able to prioritize lighting in certain areas to balance low loads.

“The greatest feature of the system would be the rapid sectionalizers,” says de’Marsi. If power is in very short supply, breakers dividing the switchgear can open, allowing the firm generation to power the building core only. This is important, as a complete blackout should be avoided, given the difficulties of restarting the system. Restarting a “dead” electrical system can be difficult, as all the electrical items need to be powered at once. If the core is powered, however, the inhabitants will have some power for critical systems, and the ability to increase the power areas as power becomes available, such as from a renewable source. “Starting from a blackout is confusing, since the facility is crippled without any power, and there is a good chance the restart will fail during the initial tries, as the system will try to pick up more load than the available generation can support,” he says.

Finally, according to de’Marsi, many developers try to install battery systems to balance renewable power or provide electricity for times when renewables are wavering in their output. While electricity storage is good in concept, battery storage systems (currently the easiest-to-deploy storage technology) suffer from battery failures. “The current level of battery development is expensive and requires too much maintenance to be used in a combined CHP, solar, and wind facility for more than a backup to a localized computer room,” he says.


Two Capstone microturbines provide power for the Black & Veatch microgrid.

According to John Glassmire, director of energy engineering for HOMER Energy (***www.homerenergy.com***), there are three ways CHP can be integrated into microgrids and other renewable generation sources. “The typical CHP system for a microgrid involves harvesting waste heat from an electrical generator, providing heat in addition to the electricity from the generator,” he says. “With the right type of generator, this type of CHP can provide ‘black-start’ capability, as well as a significant portion of onsite energy for a microgrid.” In many instances, if there are onsite thermal demands, such as steam or hot water loops, CHP simultaneously provides increased resiliency to utility grid outages and other major events, while reducing overall energy costs. Because of its potential to reduce costs, most microgrids deployed next to utility grids today include CHP.

In addition, according to Glassmire, CHP can be integrated with distributed renewables such as solar PV. “Most PV systems that are deployed stop operating when the utility grid has an outage,” he says. “However, if properly designed, CHP can provide a way for PV to continue to produce energy and reduce the fuel required during an outage.”

There is another type of CHP that creates electricity from excess and waste heat, typically in industrial processes. “This can also be used to increase efficiency and reduce the fuel required to provide energy,” says Glassmire. Typically, this kind of CHP will not operate unless the utility grid is up. Similar to the situation with most PV, this type of CHP can operate when the utility grid is down, only if there is both the right kind of switchgear and another generation source to provide the grid.

As Jim Crouse, executive vice president, sales and marketing for Capstone Turbine Corporation (***www.capstoneturbine.com***) sees it, depending on what the customer is trying to accomplish, CHP can be the cornerstone of a microgrid system, being a baseload system that provides hot water, chilled water, and electricity. “It is a dispatchable and controllable generation asset that differs from wind or solar, which tend to make up a lot of microgrid solutions,” he says. “In other words, it provides a piece of the puzzle that is independent of weather and time of day.”

A 2015 installation of a Capstone microturbine at Black & Veatch’s Rodman Innovation Pavilion.

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Benefits of Using CHP in These Applications

According to Crouse, most microgrids are targeted at providing electricity. “By adding CHP, the buildings connected to the microgrid can also take advantage of the thermal energy and make chilled water or hot water within the microgrid solution, without the need for additional electrical input from an electric utility,” he says. “We have a few disaster recovery facility projects where the microturbines run grid-connected. However, if there is an outage, they disconnect from the grid, usually proactively, and then provide the electricity for the facility, as well as the hot water and chilled water, so these facilities can provide showers, laundry, kitchen, work, et cetera.”

“There are two benefits to combining CHP units with renewable resources,” says de’Marsi. “The first is that CHP provides high-efficiency power on demand. When there is no wind and it is night, the CHP system will provide both heat and electricity to maintain the facility.” The second benefit is that hot water and chilled water (through the use of absorption chillers) can be made by the CHP. Having heating and cooling from the thermal side of the CHP lowers potential electric load, versus if these systems were electrically driven.

According to Glassmire, the primary benefits of these applications are economic and as well as resiliency during grid outages. “By harvesting heat from an onsite power generation unit, customers can also improve efficiency and reduce the fuel required to serve energy needs,” he says. “There are also CHP systems that can generate electricity from a waste heat stream.”

How CHP Can Address Intermittency and Demand Response

“Since CHP is a fuel-based system, it is not subject to the more unpredictable nature of renewable resources,” says de’Marsi. “As such, the equipment can continue to provide baseload power for a facility. In order to maintain power stability within the facility, load curtailment in the form of a stand-alone, computer-controlled demand response system would be necessary, as described earlier.”

“In terms of intermittency, we are working on some solutions that will allow customers to move

Two Capstone microturbines at Black & Veatch’s world headquarters.

The microgrid at Black & Veatch’s world headquarters includes Capstone microtubines, solar PV, geothermal technology, battery energy storage, and custom controls architecture.

seamlessly from being connected to the grid to being islanded,” says Crouse. “Because we provide inverter-based generation, we can respond quickly to load changes and thus, address intermittency more quickly than an internal combustion engine synchronous generator solution could.”

Gaining Perspective

Before integrating CHP with microgrids and other renewable generation, it makes sense to understand the economics and opportunities.

“Our HOMER Pro software is the only major commercial tool focused on microgrid design optimization,” says Glassmire. “This includes CHP microgrids and microgrids that include a mixture of CHP, renewables, and storage.”

An example: HOMER Energy evaluated the potential for clean energy generation at over 40 different potential microgrids, across 27 different communities in Massachusetts, as part of the Massachusetts Department of Energy Resources “Community Clean Energy Resiliency Initiative” in 2014. The project goal was to enhance comprehensive climate change preparedness and improve municipal resilience to protect communities from interruptions in energy service due to severe climate events.

HOMER modeled the benefits and costs of using clean energy microgrid technologies at strategic critical facilities, including hospitals, shelter facilities (including schools, town halls, and senior centers), communication centers, and public safety buildings (fire, police, and emergency response).

Each study included consideration of the costs and benefits of using renewable energy technologies (solar PV and wind energy) with battery storage, load management, and CHP generation to harden critical facilities to energy service outages.

The grid-tied system consists of nine different distributed generation resources, including the 65 kW Capstone microturbine, two solar photovoltaic arrays, two energy storage units, and four generators.

"Outcomes of our analysis were used to disperse over $40 million in state funding to implement clean energy microgrids across Massachusetts," says Glassmire.

CHP in Action: A Case Study

Operating the largest distribution and transmission system in Texas, Oncor Electric Delivery System is a regulated electric delivery business that provides power to more than three million homes and business, and operates approximately 119,000 miles of transmission and distribution lines statewide. Oncor also works with distributed generation customers to ensure safe and reliable interconnection with the state's power grid.

As an advocate for clean energy technologies, Oncor wanted to establish a resilient and innovative microgrid at its facility in Lancaster, TX. The system would be designed to promote the adoption of alternative power generation capabilities within a microgrid application. Oncor also wanted to implement a technology that could easily parallel with its existing generators as well as future technologies.

With a plant design in place, Oncor turned to Horizon Power Systems, the Capstone distributor for the state of Texas, for a propane-fueled, 65 kW Capstone microturbine that would be able to parallel-load with all other technologies onsite, including solar, wind, and other renewable power sources.

"Oncor selected a propane-fueled Capstone microturbine as one of the primary sources for our advanced microgrid project," says Lance Spross, Oncor's director of engineering standards & maintenance strategy. "The microturbine integrated easily into the microgrid and has performed beyond our expectations."

Commissioned in December 2014, the grid-tied system consists of nine different distributed generation resources, including the 65 kW Capstone microturbine, two solar photovoltaic arrays, two energy storage units and four generators. The microgrid has a total peak capacity of 900 kW. However, it is scalable to meet any load requirements.

The system can operate at its peak capacity for two hours before dropping to a baseload of 550 kW, as solar generation falls off at night and the batteries deplete.

"Of all the components included in Oncor's advanced microgrid, the Capstone microturbine was the simplest to integrate and has consistently operated as designed," says Spross. "The advanced controls and technologies have enabled demonstration of important capabilities like peak saving and load shifting with very low emissions."

Along with commissioning the microgrid, Oncor completed its Technology Demonstration and Education Center at the company's onsite System Operations and Services Facility. This facility showcases the role that distributed energy resources will play in the electric grid of the near future by providing reliable power to homes, businesses, and schools. These technologies are integrated into a larger system of four interconnected microgrids that allow for continuous site operation during extended storm outages and other critical events.

Oncor now offers public facility tours to showcase its clean energy generation sources, including the Capstone microturbine. "The selection of a Capstone turbine as an example of reliable onsite power generation, by an entity of Oncor's reach, will open new conversations concerning distributed generation and fault-tolerant grid improvement for years," says Bryan Hensley, vice president of sales and marketing for Horizon Power Systems. **DE**

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SIDEBAR

Today's improved CHP technology can increase the value of CHP within microgrid configurations. Dexterous integration with renewable energy assets and better software mean that CHP can be used effectively for demand management applications, while adding greater reliability to emergency power systems.

In some cases interoperability with renewable energy assets can be achieved through integration with the CHP unit itself. The Tecogen InVerde e+ CHP unit, for example, is unique in that it houses a built-in DC inverter, enabling connectivity with both energy storage and solar power assets. This drastically increase the possible configurations, and in certain scenarios eliminates the need for stand-alone inverters. Combined, the system offers a 25% power boost for demand-side response.

The InVerde e+ is also configured with unique CHPInsight software, powered by GE. The technology delivers cloud-based monitoring for optimized performance and increased insight into unit performance. Similar advanced software and analytics platforms continue to drive the optimization of CHP in microgrid configurations.