# Microgrids Up and Running

*In February 2008, the first two Consortium for Electric Reliability Technology Solutions (CERTS) commercial applications were commissioned; perhaps no other technology promises to be as critical to the future of distributed energy.*

BY DAVID ENGLE

When distributed energy resources (DER) join forces on a microgrid, they can achieve much greater value as a coordinated whole, than when standing alone. Consider: Solely from a customer standpoint, the ability of multiple DER to share a point of common coupling saves thousands of dollars in fees and expenses; this alone will instantly enable more cogen projects to be financially viable. When a microgrid parallels with the utility grid, redundancies occur, which are beneficial to both the utility and the customers. For example, if a community's grid fails, the microgrid can disconnect itself, keep going, and allow customers to keep getting power. Microgrids, thus, provide "a way of riding through an outage or sag," says Chris Marnay of the Lawrence Berkeley Laboratories (LBL), in Berkeley, CA. "Sensitive loads—exit signs, phones, lighting—can be segregated onto one circuit, and then, in a power quality event, you're absolutely assured that you're going to meet those sensitive loads."

Microgrids would do the work of costly high-end uninterruptible backup power supplies (UPSs). Getting such functionality from onsite power has been keenly sought for a long time. However, this service was not really attainable for modest-sized cogeneration plants, due to prohibitively high cost of utility interconnection, says Bob Panora of Tecogen Systems LLC, of Waltham, MA. Now, Tecogen has introduced an inverter-based interconnection system, which also allows multiple DER of any kind to work together with the utility grid, through a single interconnection. Each inverter-equipped component is programmed with newly developed smart logic, which Panora's firm has licensed, enabling the units to operate in concert: in effect, working as an automated microgrid.

In February 2008, Tecogen commissioned the first two such multiple-generator commercial microgrids in the US—one using three natural gas–fueled 100-kW engines, the other with six. Although performance results are still only coming in, both onsite grids are reportedly working very well.

### Microgrids With DER: The Multiple Benefit

Of course, in positioning multiple cogen systems at any site, the key is to align them with thermal loads, the better to optimize heating and fuel efficiencies. Thanks to emerging microgrid capabilities, the siting of small generators on microgrids becomes much more flexible, says Robert Lasseter—a professor emeritus at the University of Wisconsin-Madison (UW-Madison) engineering department, who plays a leading role in pioneering the concept.

In fact, engines no longer need to be tethered to a particular constraining electrical tie, "and can be can be put anywhere" at a site or facility, he says. They don't need to be near each other for shared connections or crammed in a utility basement, for example, but can be placed instead "right where the waste heat is needed most. You can put [multiple generators] anywhere on the electrical system of the building, adjacent to where you have cooling loads or heat loads."

Considerable cost-savings in wiring and plumbing can be realized, and, by having freedom and flexibility in positioning; transmission losses or overhead and tariffs should also diminish or disappear; thermal efficiencies will rise; and net emissions to the environment may also decline. Panora adds a related point concerning a longstanding hindrance to optimally sizing cogen plants. Thanks to the microgrid model, not only can engines be more optimally positioned, but the new economies are such that multiple small engines can now be grid-paralleled and affordably connected. "There's a natural flexibility with them," he says. Energy resources can be added more incrementally. Onsite energy now becomes "much more modular," offering, "a building-block model" for power deliv-

Tecogen President Robert Panora, in a cogeneration plant

ery. "Power resources can easily be added for growth, as needed for the load."

Similarly, this smaller-sized, dispersed power will be more customizable, detachable, and configurable. Elements can be locally fine-tuned to match varying loads, moment by moment, either to optimize efficiency or to accomplish certain site-specific, power-reliability requirements. None of these capabilities were easily achievable before, or at all, with the present utility grid system.

For that matter, consider the challenge of installing power to heavily congested urban main circuits. New York City, NY, is a prime example. In most boroughs, the Con Ed utility has effectively banned or restricted putting in standalone synchronous generators to the city's choked delivery grid. Con Ed contends that the current level of electrical congestion makes this too dangerous. In contrast, a safer inverter-based microgrid architecture can be easily sited—as Tecogen did there this year with the above-noted installation of three 100-kW units in the Bronx. The resulting microgrid circuit at the Jewish Home and Hospital there is now delivering year-round heating, cooling, and power, notes JH&H site engineer Gene Holland, and the hospital is "very pleased."

Project engineer Jeremy McDonald, of Genesys Engineering, notes too that the JH&H microgrid executes its the automatic islanding disconnection as intended. This enables essential electrical hospital loads to continue being supported, independent of the utility grid. After the Con Ed grid returns, reconnection and resynching of the microgrid could theoretically happen automatically, too, he says, via an integrated smart-switch; however, this particular capability has so far been nixed by Con Ed, for safety reasons. Having an operator do the reconnection is not onerous, though, given the relative infrequency of islanding events.

Another Tecogen microgrid, commissioned just days prior to the JH&H plant, is also now powering a multi-purpose resource center for the Madison-Oneida School District in upstate New York. (See "Dream Machine" project profile in Distributed Energy, November 2007.)

## More Technologies, Synergies

All of the inverters and engines on both systems are equipped with programming algorithms developed primarily at Lasseter's Wisconsin laboratory. Under his technical lead, a team consisting of Marnay and LBL colleague Joe Eto, and several national laboratories sponsored by the US Department of Energy (DOE) and California Energy Commission, produced this breakthrough. Collectively, they operate as CERTS, based in Berkeley. Equipped with the CERTS-devised logical algorithms, DE units are able to self-adjust effortlessly to ever-changing load or voltage conditions, "…all working in harmony with cumulative power—which is quite remarkable," Marnay observes.

In 2006–2007, prototype microgrids using Tecogen engines and utility inverters were field-tested at Ohio-based American Electric Power (AEP), one of the nation's large interstate utilities.

Besides offering the advantages already described, other benefits envisioned by CERTS technologies include:

*1. Easier integration of renewables*

Solar photovoltaic energy, biogas, and wind power are desirable green resources, but erratic in output. By sharing a common circuit with stable cogeneration, they will complement each other, becoming more versatile and cost-justifiable, in a microgrid array. Enhanced diversification of energy resources will also be possible, allowing for the selection or change in a primary fuel or generating resources at a particular time, determined by its spot pricing, availability, or demand.

*2. The ability to meet peak needs from off-peak storage*

In one possible power-purchase scenario, a microgrid might connect to a utility grid to buy energy and to charge-up its storage systems when the cost is lowest; then, Lasseter suggests, "during several hours of peak daytime load, you stay connected, but supplement the loads with stored power." The microgrid thus has a dual role, as a UPS for enhanced-power reliability, and for certain economic advantages.

In other scenarios, microgrid operators may also be able to arbitrate import-export tariffs to earn income during peak-rate premium times. For example, photovoltaic (PV) power might be dispatched to the utility grid, while the microgrid sustains its own attached loads from its lower-cost stored energy. In this mode, PV may be either stored, used, or exported, as the microgrid inverters and electronics enable multiple configuration options.

*3. New business models, relationships*

Landlords, industrial park managers, developers, small municipalities, investor groups, energy plant operators, niche energy retailers, aggregators, and other owners of power generation will all likely discover new electric service alternatives. Besides possessing the ability to sell local power to tenants, microgrid/DER owners will be able to offer graded power services with varied reliability levels; or, for example, give buyers the option of all-green renewables generation. Individual sites, as Marnay observes, "often have wildly different critical needs," and hold unique standards of reliability. The enhanced customizability feature of microgrids will enable entrepreneurs to meet these needs.

*4. Benefits to utilities, ISOs*

AEP's willingness to host a microgrid test site illustrates the keen interest that major utilities will likely have in this technology, for the several critical benefits to be reaped. AEP research and test engineer, David Klapp, notes: "We see definite advantages in microgrids and in getting them proven to the point where we can readily deploy them, and know how they're going to operate within our system."

On the distribution level, microgrids promise to deliver improved power reliability and will put generation in closer proximity to users...

On the distribution level, microgrids promise to deliver improved power reliability and will put generation in closer proximity to users, enhancing the prospect of combined heating and power (CHP) efficiencies at very low emissions levels—"which," he says, "are all big positives for AEP," being, currently, perhaps too dependent on coal-fueled power. Klapp was closely involved in testing Lasseter's CERTS prototype at AEP's John E. Dolan Engineering Laboratories complex in Groveport, OH.

Similarly, the Sacramento Municipal Utility District (SMUD) is taking a look at the new opportunities. Although its rates to customers are among the lowest in California, SMUD may soon explore microgrids as a way of implementing, "much more distributed generation and combined heating and power" for SMUD customers, says Mark Rawson, the staff research project manager. Conceivably, the utility may eventually own and operate high-efficiency cogen plants, which, he adds, "would enable the utility to meet its own critical peaking power demands and realize other core values relative to climate change, customer value, and reliability."

In sum: For utilities and for private DE owners, microgrids represent a quantum leap. DE resources will be more easily interconnectable with them, and with this, utilities will also enjoy much-needed electric-generating resources and flexibility. When detached ("islanded"), microgrids will serve the customer loads as a virtual UPS. These are the key benefits; and here's more about the technologies, which will deliver them.

## Links, Smart and Logical

The key breakthrough, as noted, is the CERTS onboard algorithm. As Lasseter explains, every microgridded resource can use this to balance the power seamlessly on the islanded microgrid "using real power against frequency droop, and maintain voltage using the reactive power against voltage droop. The coordination between sources occurs through frequency, and the voltage controller provides local stability."

Each microgridded resource responds and self-adjusts, cycle by cycle, to preserve harmony—all without centralized controls or manual operators. Load shifts, imbalances, resource activation, or deactivation—even sudden voltage losses or surges—can be negotiated this way. "The several components—inverters, generators, and even power storage systems—can all be integrated," Lasseter says. "And when sources have the right information, they do the right thing."

Just as every resource is equipped with a power controller, "every resource also controls local voltage," he continues. This induces much-needed stability, and helps solve the challenge of re-synching after islanding. Ordinarily, this is tricky, because respective voltages and phase angles must fall within a narrow band; the logic-equipped resources accomplish this by inducing a frequency droop, if needed, to make up for a microgrid's power deficiency, and pulling its voltage in line with that of the utility grid. "The static switch automatically re-synchs, without any information except the voltage on each side," Lasseter notes.

Test layout of the CERTS microgrid at Dolan Laboratory on the campus of

Not only is power generation integratable this way, but, as mentioned earlier, energy storage can be factored-in, because the algorithms enable either charging or discharging. This overarching inter active capability translates into overall improved energy efficiency and project value. "Generators can … 'plug and play;' you don't have to do massive tooling of controls," Marnay says. Also, the algorithm-equipped power inverter carries "a low engineering cost … that starts to look attractive in the [relatively low hundreds] kilowatt range," he adds.

Tecogen has worked out a way to run the inverters at variable speeds, which "allows machines to run at partial loads, to have better efficiencies and accomplish close load-following," Lasseter says. Besides logic-driven automation being accomplished by the CERTS concept, other conventional onboard controls are able to adjust power on a minute-by-minute or hourly basis. For example, "As the load environment changes, you may find that the … algorithms have machines operating not at the most efficient setting. … You can redispatch them," he adds.

## Interconnection Switchgear

In addition to the smooth interactivity occurring in the microgrid, the microgrid itself interconnects, of course, with the utility grid. Here, the smart or fast switch between them does two primary jobs, as Rawson of SMUD explains.

First, "It protects the utility grid from energy which might otherwise inadvertently be exported from the microgrid," he says. "So, safety is built-in in that IEEE 1547 protection requirements that are necessary for any distributed generation [DG] connected to a utility system are met.

"The second important feature, which in my mind really is at the core of the microgrid—is its ability to sense what's happening both on the utility system and on the microgrid side, and be able to make quick decisions about whether to stay interconnected or to island," he continues.

The switch can dis- and reconnect seamlessly; from the customer's side the power-shift events are "invisible." A commercial switch with smooth and seamless two-way islanding is, of course, the ultimate goal, because when this is achieved, a customer's positive experience of DER will soar.

To appreciate the before-and-after contrast that this will deliver, Rawson explains, "Under current rather typical arrangements, if utility grid power falters, the customer's distributed generators must disconnect from the utility to protect grid safety, and the distributed generators normally do not carry the customer's load—the customer has an outage even though their generators are working fine. The distributed generators may then come back on to carry part or all of the site load. And then, when the utility comes back on, the customer has to go offline again, and go back on the utility power—unless they have expensive solutions that allow re-synching to the utility and a seamless transfer. In essence, the customer does not get the reliability value that their distributed generator could provide."

### It's Quite Laborious

Rawson continues, "But, what's so nice about this smart switch is, it allows customers to use their DG investment to meet the reliability need, for which traditional technology solutions have been, in the past, somewhat cost-prohibitive."

Future microgrid-ready switches will ideally be scaled larger and/or smaller, Lasseter suggests. Negotiations for low-cost production units of these are now in progress. "We'd love a company that can provide a variety of breakers with the same logic on it," he says.

### Ahead: More R&D, Commercialization

As these technologies recently have matured, testing commenced in 2006-7, primarily at the Dolan Center. There, three 60-kW inverter-equipped Tecogens are programmed with the CERTS algorithms and are interacting on a 480-volt microgrid. They're subjected to a range of disparate loads and conditions, from very low to high imbalanced and harmonic loads. Tests of disconnection and automatic reconnection and resynching, (switches provided by S&C Electric Co.) have worked well, Lasseter reports. Throughout, the algorithms (programmed by Northern Power) have performed beautifully.

Grid protection tests will come next, then testing in an operational setting. Eventually, a microgrid configured for utility service, at the 12-kV distribution bus level, is envisioned, perhaps integrating "large power storage, large fuel cells, and lots of PV," he says. Test results and other pertinent tech reports will be published in a theme issue of IEEE's Energy and Power magazine, in May 2008, he notes.

Coparticipants at AEP have included Lawrence Berkeley National Laboratories; Sandia National Laboratories; the University of Wisconsin; Northern Power Systems; Tecogen; The Switch (formerly called Youtility Inc.); and the California Energy Commission's Public Interest Energy Research program.

Also coming in 2008: as many as four more microgrids are being negotiated at sites on the West Coast, although formal announcement have not been made. The prospectuses will probably emphasize integration of mixed generation, including large solar PV, energy storage systems, big diesels, a fuel cell, and the ability to island. Energy output will be significantly higher than in the Tecogen-bases systems, with generation from disparate sources having heavily staggered availability profiles, and running at the much higher voltage.

For its part, the US Department of Energy has earmarked $38 million over the next five years (complemented with cost-sharing by industry) for R&D and demonstrations, say Merrill Smith, program manager at the Office of Electricity Delivery and Energy Reliability. The DOE's aim, she adds, is "to reduce load on distribution feeders or at substations by 15%. A microgrid would be one subcomponent of this." In 2007, DOE solicited partnering proposals, which should start bearing results sometime in 2009.

General Electric (GE) has also recently completed fundamental technology development on grid controls "which will work with and complement CERTS very well," reports Juan de Bedout, manager of GE's Electric Power and Propulsion Systems Laboratory in Niskayuna, NY. GE's supervisory controls "will issue high-level commands to DE resources within the microgrid to optimize performance" of these assets, by dispatching them, drawing on stored energy "and controlling of load resources," he says.

A second tie-line control would handle the point of interconnection to regulate power exchange between the two grids. "So," he says, "from the perspective of the transmission grid, the whole microgrid can be made dispatchable and look like one entity." An operator at the utility substation level, for example, would be able to import/export power between the two grids incrementally.

A third level of controls would run the microgrid when islanded, and help solve the special challenges of managing wind and solar power, adds de Bedout. GE anticipates completing a demonstration project during a second development phase, coming imminently. Longer term, microgrid control products could be integrated into GE's existing transmission and distribution business.

Despite such advances and the seeming inevitability of microgrids eventually factoring heavily into next-generation electricity, there remains something of a challenge in proving their real immediate value, suggests Stan Blazewicz of Navigant Consulting Inc., in Boston.

Blazewicz recently coauthored a study on, "How 'Microgrids' are Poised To Alter The Power Delivery Landscape." The positive results and discoveries yielded by current and pending demonstration projects will probably steer the way to a successful business model, he suggests. Whenever the technology fully matures, electrical grids will then probably undergo a gradual, coordinated transformation, driven by the economics of reducing their energy production or power-transport costs, and by the market's desire to make energy prices more predictable.

At this point now, though, he says, "the economics for them look dramatically better as facilitators of solar pv and multiple large CHP systems," where a microgrid "does start to make a lot of sense." He adds: "A lot of the value will depend on where electricity price are heading. Throw-in energy storage and demand-response in that mix, and optimization of a local energy network—and it starts to look very interesting." DE

---

**DAVID ENGLE**, *based in La Mesa, CA, specializes in construction-related topics.* *Special thanks to* **ROBERT LASSETER, PH,D.,** *University of Wisconsin, for technical review.*