Microgrids and Demand Response

How software controls can bridge the gap between wholesale market prices and consumer behavior.

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As ideas go, a microgrid is nothing new. Think of steam pipes for district heating in older urban cores. But add a few software controls, and the possibilities grow.

A microgrid—in our case a simple aggregation of electrical loads and generation—can take many forms: a shopping center, an industrial park, or a college campus. Within the system, you may find fuel cells, microturbines, or reciprocating engines. Typically, the generators within the microgrid also supply heat for local needs, such as space heating or dehumidification.

From a utility's viewpoint, the microgrid looks just like a single electric load. But seen from the opposite side—from behind the meter where the consumer resides—a microgrid can function as a distributed energy resource (DER). It can produce value both by (1) maximizing energy and thermal efficiencies to reduce electric demand, and (2) selling useful product back to the integrated utility grid in the form of ancillary services, like voltage control or regulation.

Microgrids might even help the industry achieve the elusive goal of demand response—a feature now missing from electric industry restructuring models, which lack retail tariffs that expose consumers to the real market consequences of their decisions about power usage.

In fact, a study has shown that using microgrids for load management not only benefits those consumers who use the technologies, but also lowers the wholesale market prices paid by all consumers. *(See Richard Cowart, "Efficient Reliability, The Critical Role of Demand Side Resources in Power Systems and Markets," The Regulatory Assistance Project, June, 2001, http://www.rapmaine.org/efficiency.html.)*

All that is needed to start the revolution is a system of software controls called an EMS (energy management system). The EMS is the system that dispatches the power output of the generators (*e.g.*, microturbines, reciprocating engines, fuel cells, and photovoltaic cells) and controls the heating and cooling equipment (*e.g.*, boilers, chillers, fans, desiccant removal, dampers, etc.).

In the simple case, EMS can optimize generator performance. But beyond that, an EMS can integrate various decisions on energy production, consumption and storage within the microgrid—and then coordinate them with such other factors as thermal energy conservation, emissions limits and credits, and wholesale market attributes such as transmission congestion and locational marginal energy prices. These decisions will be based on the heat requirements of the local equipment, the weather, the price of electric power, the cost of fuel, and other considerations.

Of course, real-time price data is first required. But with that information, microgrids could provide a highly elastic demand curve for wholesale energy markets. That would be of significant value in a day-ahead market, where the EMS could bid in "capacity" based on anticipated weather and process plans.

Other technical problems remain as well. A primary example would be conventional protection schemes that are designed chiefly for one-way power flow from the source of supply—the substation—to the load points. With two-way power flow, conventional protective relaying and fusing based on fault current levels will not work properly because the fault current levels will vary greatly depending on the number of connected generators, system configuration, etc. Getting around this problem will require development of fault detection systems that can operate on a totally different paradigm than conventional relaying.

No fully developed EMS exists today. Yet manufacturers already are introducing products into the market that can serve as building blocks for a highly versatile EMS (*see sidebar, p. 58*). Soon that may open the door to physical energy systems more attuned to market realities.

A Bare-Bones Concept

Under the concept of a microgrid as developed by the Consortium for Electric Reliability Technical Solutions (CERTS), the microgrid never exports power to the grid but is operated only as a controllable load. The generators thus need a minimum of overview control. Each is programmed with control characteristics that allow them to function together to provide a high-quality source of power under a range of operating conditions. The generators are given only basic dispatch commands by the EMS. Other functions the EMS can perform include:

- Intelligent energy storage, based on special weather-related or process needs;
- Full optimization of combined heating and power (CHP);
- DER functionality without a dedicated generator control system, because the EMS will dispatch only voltage and power;
- Microgrid operation based on the energy market predictions for both gas and electricity;
- Optimization of heating, ventilation and air conditioning (HVAC) through advanced control strategies;
- Minimized pollution based on sophisticated algorithms that consider CHP and displaced emissions;
- Enhanced power quality where, for example, a loss of grid power causes a seamless transfer to standalone power involving only a loss of non-critical loads within the microgrid;
- Support of the future grid through an array of ancillary services, such as voltage regulation and reserve power.

Even without supplying power to the utility, the microgrid still can supply significant services to the utility. The ability to control load is extremely important to a utility during times of system stress. Reducing 5 MW of load in an overloaded feeder can do more to restore local voltage than supplying 10 MW of generation from a distant generator. The ability to control load enables a powerful control of voltage. Also, the ability to control power factor enables voltage control.

Thermal Energy and Storage

Microgrids that feature CHP can provide a 30 percent improvement over conventional power plant efficiency. That can produce a total system efficiency of 80 percent, by using thermal energy that otherwise would be wasted. Any additional thermal energy contributions to commercial and industrial (C&I) processes would only improve cost savings further. The thermal energy produced by reciprocating engines, gas turbines, microturbines, fuel cells, and stirling engines, etc., all can be used for systems and appliances that rely on thermal energy (*e.g.*, air and water heaters and handlers, chillers, steam turbines and heat recovery boilers and generators).

Several manufacturers of CHP systems now package systems starting as small as 25 to 30 kilowatts. However, the small size of these systems will present unique challenges in making efficient use of thermal energy, compared with the use of steam from larger, 50-MW combined-cycle plants, which are used often to supply steam for larger local uses, such as heating of dormitories, heating petroleum in a refining operation, or cooking in a food processing industry. In small CHP or microgrid applications, it may often be attractive to customers to have the heat loads designed into the system at the time of project conception.

Thermal storage is also readily adaptable to HVAC systems—especially commercial cooling systems and their central chilled water plants. One conventional method is to use HVAC chillers with a thermal energy storage tank to shift peak loads. *(See Jim Heller, "Load Shifting with Thermal Energy Storage," Navy ENews 95b, Naval Facilities Engineering Service Center, http://www.nfesc.navy.mil/)* Even so, the analysis required to optimize HVAC operation is not trivial. Each of the key components of the HVAC system has its own energy efficiency value, which will depend on a variety of factors, such as load or humidity. Thus, an EMS offers the only practical method to achieve higher efficiencies and coordination with markets.

Overall, the optimal use of storage will require long-term contract arrangements and planning for DER operation. And a modular or pre-packaged CHP system may provide the key to successful integration of CHP in small-scale, microgrid applications.

For example, the packaged systems may contain a microturbine packaged with a desiccant-type dehumidifier and an absorption chiller. The advantage of using DER in air-conditioning applications is that the peak demand for the air conditioning typically coincides with the utility peak demand for power. A test of such a system is being performed at the University of Maryland for the Department of Energy. *(See Douglas Hinrichs et. al., "Integrated CHP Offers Efficiency Gains to Buildings Market," Energy User News, 9/27/01, http://www.energyusernews.com.)*

Ancillary Services

One of the most exciting prospects of the microgrid controlled by the EMS is its ability to provide ancillary services, or reliability services. Microgrids located near urban centers could provide these services much more efficiently than distant generating stations because they would operate near the loads. Voltage regulation is one of the services under consideration in certain trial programs.

For many ancillary services, the EMS would make a decision in a day-ahead market as to whether it would be profitable to supply the service, and at what price. The EMS would then bid into the market and find out if the bid was successful. If successful, the EMS would plan to supply the service the next day.

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most significant services, spinning reserve, is sold like insurance. The microgrid would be paid for supplying the service regardless of whether it is called for, and it should be called for only infrequently (though a rapid, automatic response is required when called upon). The bidding and dispatching could be done automatically with only periodic operator oversight.

Reactive supply and voltage control are both required to regulate distribution voltage and to maintain bulk power system reliability, but whether microgrids can sell this service will depend on their size and the availability of a market.

SAMPLE VENDORS: SMALL-SCALE SYSTEMS

Some already offer an EMS. Others offer flexible packages.

1. **Tridium, Inc.** (www.tridium.com)
   (Offering Vykon System; Jace-NP®—Java Application Control Engine.)
2. **Engage Network Solutions** (www.engagenet.com)
   (Active Energy Management System; Dgen)
3. **Sutron** (www.sutron.com)
   (GenCom)
4. **Encorp** (www.encorp.com)
   (Virtual Power PlantTM)
5. **Invensys Energy Solutions** (www.ies.invensys.com)
   (Barber-Colman DYNA Products; Premier Power Solutions)
6. **Wonderware** (www.wonderware.com/home.htm)
   (InTouchTM, InControlTM)
7. **Capstone**
   (CRMS—Capstone Remote Monitoring System; Power SERVER CPS 100)

For more, see, http://www.ornl.gov/ORNL/BTC/Restructuring/pub.htm, Appendix A, pp. 66-78.

Emissions Limits and Credits

When used in CHP applications, DER will both reduce and displace emissions from central electric power generation and from local heat generation. The EMS will make operational decisions that result in the lowest net emission production. These decisions will be directed by the net impact of the DER/CHP use, including displaced emissions and not just the local DER emissions production.

Nevertheless, to achieve this level of coordinated operation, a reasonable and fair emissions tariff must be integrated into the market system so that the electric power supplied from the DER will be valued appropriately considering the net emissions reduction. This tariff could even be a function of time, season, and location, so the tariff would be most attractive at the worst pollution times and locations. It would provide a stimulus to the EMS to dispatch the DER at the optimum power level for minimizing net emissions, and at times which are the most favorable for minimizing the impact from emissions.

Microturbines generally achieve their lowest emissions release levels at operating levels at or near 100 percent of rated power output. That means, fortunately, that the EMS can dispatch the microturbine to supply heat to a process system at its full rating, and the electric power can be supplied with minimum emissions.

Yet minimizing emissions will require rapid and precise control of the combustion process. This rapid, expert control is best provided by the manufacturer's own control system, and not by the EMS. Factors the EMS may consider are emission production versus power level, and displaced emissions for both the heat output and electric power output.

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