Working Together With the Smart Grid

Electric Utilities and The HVAC Industry

By Mike Oldak

The electric utility and HVAC industries have evolved over the decades to be mutually supportive and codependent. They have worked together to minimize costs to consumers, provide incentives to manage energy use wisely and help utilities avoid unnecessary capital costs for infrastructure upgrades.

As America electrified, the increasing demand for energy drove the need for larger base load power plants. These newer plants were more efficient, and for a time, incremental load growth actually helped reduce the cost of energy for ratepayers. At the same time, a new type of load—residential and commercial air conditioning—helped spur that growth.

Over the next few decades, air-conditioning use exploded, making AC units a near ubiquitous appliance. The once supportive benefits of serving air-conditioning load have turned into a cost and reliability burden, leaving utilities with the need for generation capacity sitting idle until needed to meet just a few hundred hours per year of peak demand created, in large part, by air-conditioning loads. Avoiding, eliminating or at least deferring some of these investments through demand response, peak load shifting and other Smart Grid programs has been the focus of utilities as we modernize the grid.

The once simple days of large central station power plants with a one-way network of substations and transformers to consumers is rapidly changing. The growth in electric utility telecommunications networks and associated controls are being driven by the growing need to balance large quantities of variable air conditioning and high current electric vehicle charging load against variable solar and wind generation assets widely dispersed all over the country.

The real challenge of grid modernization is providing utilities with the robust and secure ability to monitor and react to variable generation and load across their entire network. The result is that sophisticated utility telecommunications networks are becoming an integral and vital element that connects utilities with consumers and their smart HVAC systems and appliances and associated network of sensors and controls.

All this is necessary to enable utilities to optimize all of the moving pieces both reliably and cost effectively. The new codependency of HVAC in helping utilities manage the dynamic, instantaneous changes in the grid will produce huge savings that will help mitigate future electric rates increases, while providing financial incentives to consumers to purchase higher efficiency, smart HVAC systems.*

Electric utilities and their consumers can engage the HVAC industry to help develop programs to save money for

*A. Faruqui of *The Brattle Group*, indicates that based upon the studies and smart grid pilots across the United States, that savings could be as high as $7 billion a year.

About the Author

Mike Oldak is vice president strategic initiatives and general counsel at the Utilities Telecom Council in Washington, D.C.

consumers. Value for consumers is created in many ways. Historically, increased usage resulted in lower costs per kWh. Then, starting in the rising-cost era of the 1970s, value was created by providing consumers with the same benefits, but by using fewer kilowatt hours of energy. We also began providing consumers with financial incentives to substitute lower cost, off-peak energy for on-peak energy, simply by implementing time-of-day pricing.

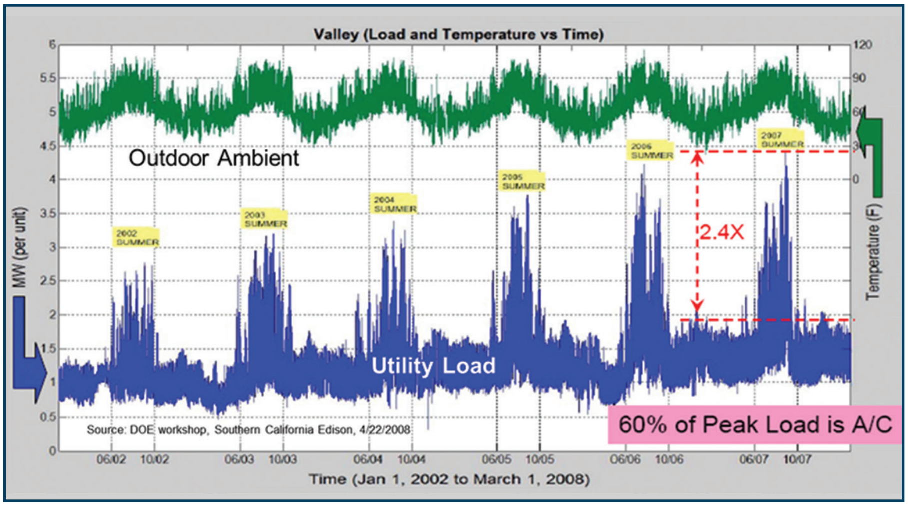

Figure 1: Typical utility load as a function of outdoor temperature.[2]

HVAC loads were once again called on to help reduce peak demands by use of utility load management programs that cycled usage among air-conditioning compressors to level total air-conditioning demand and avoid coincident peak demands. And now with modern communications capabilities, utilities are asking consumers to allow the utilities to send signals to communicating programmable thermostats to react in a specific manner during system emergencies or high cost periods.

What's different in this approach is that the pricing model changes only during those periods when the utility is experiencing a delivery problem or an extreme high cost period. While the cost of energy sold during these 50 to 100 critical hours of the year is maybe five to 10 times the normal amount, consumers benefit because these higher cost hours are more than offset by the thousands of off-peak hours that are often 30% lower, resulting in lower overall bills.

The economic value created by avoiding the purchase or generation of power during these extreme periods has been so large, that even those who don't participate in load management will receive a benefit from these savings. There are also future benefits due to the new ability to avoid or at least defer expensive infrastructure investments.

Cycling air-conditioning compressors and water heaters has been an option for utilities for decades. Cycling programs reflect the fact that if every water heater and air conditioner compressor were all operating at exactly the same time, the coincident peak from all those loads would require upgrades in infrastructure, as well as the use of higher cost energy from the incremental generation needed to meet the coincident load.

For electric storage water heaters, direct load control can remove the water heater load from the peak altogether. However, the ability to curtail *and* intelligently and incrementally control this load can help utilities reduce their cost to meet customer demand by making more efficient use of lower cost generation and/or reducing high cost wholesale market purchases. Although there is a natural diversity among all consumer uses, on the hottest days of the year, when the HVAC loads can be 60% of total demand in some regions of the country, utilities are looking for ways to ensure a maximum amount of diversity so that all the needs can be met by optimizing the use of the lowest cost generation (*Figure 1*).

Providing consumers with a seasonal financial incentive in exchange for allowing the utility to shed between 25% and 100% of the AC load, is one way utilities have attempted to reduce coincident peak demands of AC load. Although the program leans on consumers who are not home during the day, or can withstand a few degrees of temperature change, the benefits have been shown to be so large that the +90% of consumers will see the savings.

The Center for Neighborhood Technology, a non-profit group, recently reported that more than 99% of participants saved an average of 25% on the electricity portion of their bills under the Ameren Illinois Power Smart Pricing program since the program started in 2007.[1] For larger commercial and industrial consumers who are intensive energy users, the cost saving might support moving to a nighttime schedule.

It may seem strange that utilities would pay consumers to use less energy, but there are financial benefits for both the utilities and consumers. The majority of tariffs are based on the average utility costs, either over a season or a 24-hour weekday. Generally, these time-of-use rates break down into higher rates during the on-peak daylight hours and lower rates during the off-peak nighttime hours.

But on the five to 10 hottest days of the year when utilities are reaching their critical peaks, the incremental cost to generate or purchase wholesale energy can be many times the rate consumers pay. Reducing load during these hours creates substantial value. It can also provide longer term benefits, since meeting critical peaks is one of the criteria in deciding when to build new generation or sign new power purchase agreements, which in today's markets may increase costs to utilities and ultimately to consumers.

Role of Variable Speed Compressors

The new variable speed compressor motors provide new opportunities.** Slowing down variable speed compressors can better maintain the comfort level of consumers while saving money. Variable speed compressors, fans and blowers significantly reduce energy use by precisely matching the system's level of operation to that of cooling demand, which can vary throughout the day based on a building or home's individual cooling needs. They can maintain the occupant's setpoint without resorting to inefficient full-on, full-off system cycles. This on/off cycle, which is a common function of traditional fixed speed air-conditioning systems means that the system is always running at full load for the given ambient condition, whereas an air-conditioning system using variable speed technology is capable of operating under much more efficient part-load conditions.

Variable speed compressors are one example of HVAC capabilities that can be used to create value. For example, a fixed speed residential air-conditioning system with a seasonal energy efficiency rating (SEER) of 13 might achieve an energy-efficiency ratio (EER) of 11.5 at 95°F (35°C). Even if it is unloaded 25% by compressor cycling, as many utility load controlled systems are, it still performs at 11.5 EER at 95°F (35°C) while it is running.

A variable speed system, however, improves SEER by up to 30% and can also operate at a greater EER rating—up to 3.5 points higher—when unloaded by the same 25%. Reducing a fixed speed system's output, through cycling, by 25% at full-load conditions will result in an equal power reduction of 25%. Reducing a variable speed system's output by the same amount under similar conditions will result in a power reduction of approximately 43%—the result of improving efficiency.[3]

The value stream for variable speed air conditioning is robust and two-fold, providing short-term and long-term benefits to consumers (building or home owners) and electric utilities.

For the home or building owner, a variable speed system provides significant energy savings by improving the system's SEER rating. By avoiding full-on, full-off cycles, space comfort is also improved, including tighter temperature control, enhanced dehumidification, lower noise levels and smoother heating ability. In heat pump applications, variable speed systems provide another benefit: more heat. With a higher heating seasonal performance factor (HSPF) index, variable speed heat pumps enable effective heat pump use in more northern climates.

For the electric utility, variable speed not only improves system energy use, but is smart grid-ready—better able to facilitate peak load reductions through demand response or price response capabilities. By providing a continuously adjustable output, the local utility would be able to adjust the system's speed to better accommodate periods of peak load. Therefore, demand is reduced without much noticeable impact on the occupant's level of comfort. The use of variable frequency drives (VFDs) to achieve variable speed also improves the utility's distribution power factor. Power quality is improved by virtually eliminating compressor in-rush current, which in part creates conspicuous light flickers, and limits load control deployment on utility distribution circuits.

Role of Thermal Energy Storage

Thermal energy storage systems for both heat (bricks) and cold (ice) deliver significant savings to utilities and their consumers. For the utility, these systems reduce coincident peak demand and shift costly on-peak energy consumption to the lowest cost off-peak period. Similarly for consumers, the use of ice storage reduces the peak demand charge and shifts energy consumption to lower cost off peak rates. In extreme hot and dry climate zones where diurnal temperature differentials average 25°F (14°C), ice storage can improve overall building cooling energy efficiency.

The electrical system efficiency gains associated with peak load shifting are dramatic; meaning a 50% improvement in generator source fuel efficiency associated with cooling buildings is typical (*Figure 2*). These gains are achieved because each asset in the electricity supply chain operates more efficiently at night. Central generation plant efficiency is better at night; this is expressed as average heat rate (Btu/kWh), which is the amount of fuel burned to produce a kWh. Electrical transmission and distribution system line losses are relatively lower at night, so fewer kilowatt hours are lost between the generator and the HVAC unit. Finally, HVAC system efficiencies improve as evening temperatures drop. Conversely, the amount of generator source fuel consumed to cool buildings increases as heat rates, congestion, and temperatures rise.

The overall electrical system efficiency, from the burning of generator source fuel through the production of building cooling during the day or the production of ice at night, is the product of the efficiencies along the path. Using the example below, during the day, roughly 18% of generation source fuel is delivered into the building as cold air (82% losses or $0.28 \times 0.95 \times 0.92 \times 0.72 = 18\%$) (*Figure 2*). However, at night, due to higher efficiencies along the path, 27% of the source fuel is delivered into the building and stored as ice for use the next day (73% losses). This equates to roughly a 50% improvement in generator source fuel efficiency ($18\% \times 1.5 = 27\%$).

Role of HVAC in Regulation Service

Another benefit of integrating utilities and thermal energy storage is the ability of thermal energy storage to keep up with the requirements of utility and other grid operators. For example, the Midwest Independent System Operator (MISO) is charged with keeping supply and demand in balance over an 11 state region in the Midwest. The grid operators dispatch generation for each hour based upon the locational marginal pricing (LMP) in real time. Those power plants that bid the lowest price are dispatched first.

**This variable speed technology is also being built into other appliances that can be controlled by utilities such as pool pumps.

However, MISO must also provide regulation service to ensure grid system stability and proper and safe operations, which requires holding some reserves to "balance" the system (*Figure 3*).

Traditionally, regulation means that generation responds to a system operator's automatic generation control (AGC) signal that is sent about every four seconds. Regulation is the most expensive ancillary service because up and down generation capacity must be held back from the energy market to provide that regulation. As can be seen in *Figure 4*, that traditional resource response cannot meet the speed or volatility of the AGC command signal, and that is why fast responding (non-traditional) assets such as batteries or grid-interactive thermal batteries offer great value. The response of electric resistive load thermal energy storage—water and space heating—is a huge benefit for utilities since the response is virtually instantaneous.

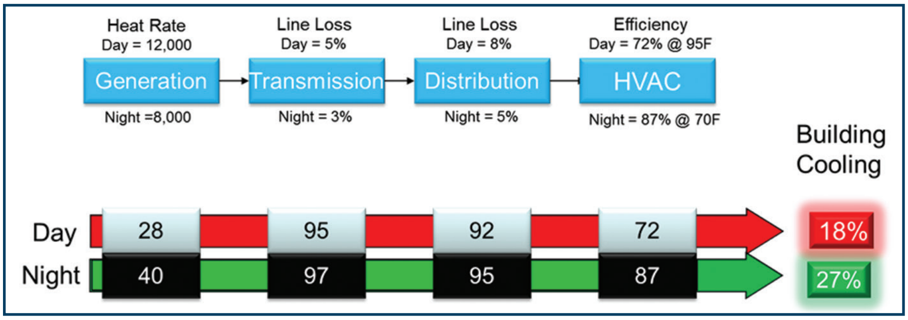

Figure 2: Relative generation source fuel efficiency, day and night.[4]

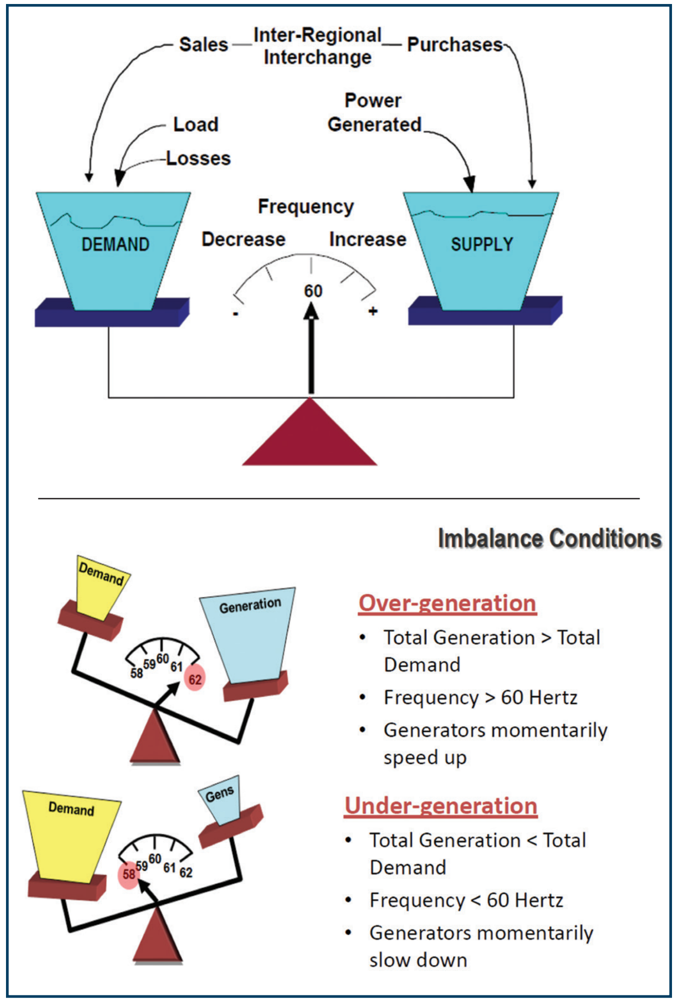

Figure 3a (top): Supply and demand factors impacting grid balance. **Figure 3b (bottom):** The impact of grid imbalance on frequency.[5]

Role of HVAC in Renewable Integration

As renewable energy sources become larger parts of generation resources, variable speed compressors and thermal energy storage will increase in value. Their flexibility will enable the agile and timely regulation of loads to match the fluctuating outputs of renewables generation. This will help offset the requirement for high-cost "spinning reserves"—generators operating with no load just to be available instantaneously—at times when solar or wind power outputs decrease due to naturally occurring lulls in production. And, by diminishing some of the variability associated with renewable energy sources, these technologies could in fact help facilitate the penetration and deployment of renewables as a more viable and reliable energy source in the United States.

Grid-interactive electric-thermal storage (GETS)[6] is the integration of intelligent and real-time control signals with enhanced electric thermal storage space and water heaters. GETS space and water heaters interface with signals from the local utility or grid operator to quickly respond by either shedding load or increasing demand. Because space and water heating are the largest energy loads in consumer homes and many businesses, this combination of electric thermal storage space and water heating along with grid-interactive, smart control provides utilities with a great tool for managing and regulating sources of power supply, transmission and distribution while optimizing both economic and environmental benefits for utilities and consumers.

The challenge of following changes in renewable outputs can occur at any hour of the day. GETS space and water heater loads can adjust their charge as fast as the rate of wind and other renewable generation changes. This ability to quickly follow changes in supply with changes in demand can significantly increase the value and ability to fully use renewable energy. The improvement in renewable integration brings a new dimension of system conservation and efficiency and helps keep electric rates low. This ability to track and use real-time renewable generation and monitor and react to other critical needs of the grid can significantly decrease the space and water heating carbon footprint and lower the cost of operation for consumers.

Advanced communicating water heaters can also provide significant consumer savings. Currently, utilities have more than 5 million electric water heaters under "direct load control" (one-way communication) and pass a portion of the benefits to the end consumer. By incorporating two-way communication, the GETS water heater provides consumers with the ability to choose and heat water during the hours of lowest prices, and/or quickly and accurately absorb excess renewable wind and solar energy, all while providing continuous and uninterrupted hot water to the customer. This feature is being seen as increasingly critical to cost-effectively maintaining grid reliability while at the same time accommodating renewable integration and reducing dependence on fossil fuels leading to greater penetration and optimization of renewable generation.

Importantly for building systems, the "intelligent efficiency" and flexibility of re-tasking existing devices coming from information and communication technology-enabled electric water heaters can be replicated with electric space heating, too. Also, thermal storage is cited by the Department of Energy's Sandia National Lab as the lowest cost of any energy storage, the only current cost-effective storage, and the only one with payback for residential and small commercial customers (*Figure 5*).

Regulatory Bottom Line

In many cases, state commissions have authorized utilities to provide financial incentives to consumers to accomplish a desired result. All with an understanding that the ultimate value to consumers will exceed the costs of the financial incentive, or have some other social or policy rationale. Examples include incentives for renewable resources, compact fluorescent lights, and other energy-efficiency programs. Some of these programs may cost a little today, but provide much greater long-term benefits. Regulators and legislators understand that today's small incentives may be needed to motivate building owners and accelerate the uptake of needed

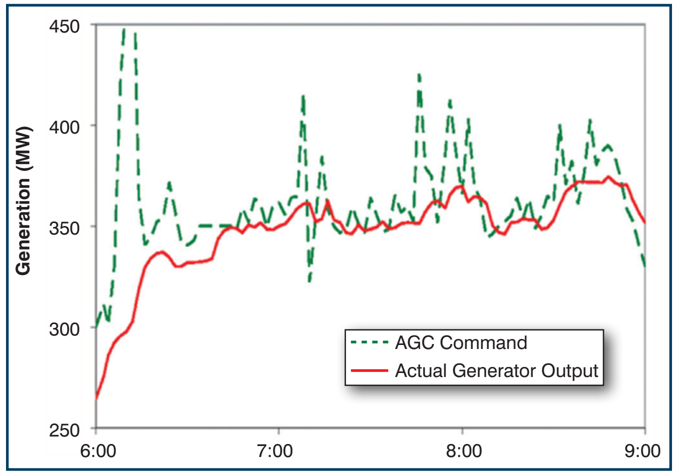

Figure 4: A fossil power plant following a regulation command signal.[5]

new technology. These incentives may come in the form of Federal or state tax incentives, but the on-and-off nature of tax incentives hasn't been enough to stimulate the long-term transition to variable speed.

Utility incentive programs can also provide a boost, especially when combined with tax incentives. Many utilities have regulatory mandates to provide energy-efficiency incentives, free energy audits, subsidies for energy efficient appliances or CFLs, or other policy motivated incentives. Many also provide incentives for peak load reduction technologies, called demand response incentives. To provide the appropriate incentives, utilities, consumer advocates, regulators and legislators all need to understand the value that can be created by new technologies. Advocates for regulatory incentives need to show the ability of the technology to impact the bottom line of utilities and con-

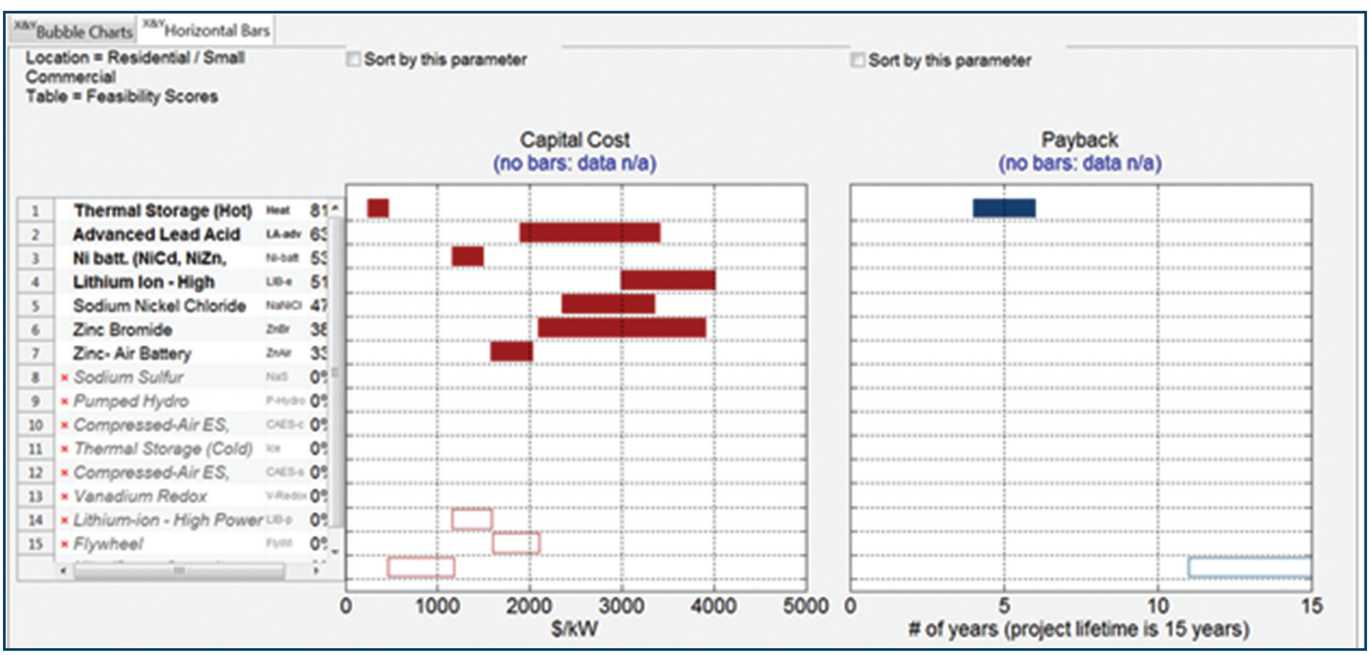

Figure 5: Thermal storage is cited by the DOE's Sandia National Lab as the lowest cost of any energy storage.[7]

sumers. To gather regulatory support the case must be made that the technology can:

- Be more energy efficient (higher SEER);
- Consume off-peak energy for use during peak periods (thermal energy storage);
- Shift usage to off-peak periods (time delay dishwashers);
- Significantly reduce or eliminate normal use during critical peak periods in response to either a price or demand response signal (smart thermostats);
- Provide utility ancillary services (quick regulation service);
- Improve the efficient use of fuel (off-peak energy storage); and
- Limit the total coincident demand by cycling use among various consumer appliances (compressors, high current electric vehicle chargers, pool pumps).

The good news is that the HVAC industry is well positioned to meet virtually every criterion identified, and the incentive pool for these types of on-peak efficiency and demand limiting measures is increasing. Utilities are installing the necessary sophisticated communications networks required to ensure the full and beneficial coordination of utility needs with HVAC capabilities. The value created by these opportunities can be shared among the utility, the consumers and the HVAC industry through utility credits for the installation of HVAC and other home appliances that are both highly efficient and importantly, capable of smart decisions based upon utility signals and consumer engagement. The new codependency of utilities and the HVAC industry will provide improved service for consumers and help keep electric rates in line.

References

1. Center for Neighborhood Technology. 2008. "How Can I Save?" www.powersmartpricing.org/how-it-works/how-can-i-save/.
2. U.S. Department of Energy. 2008. Workshop at Southern California Edison.
3. Wilkins, R. 2011. "Exploiting Technologies with Parallel Energy Efficiency and Demand Response Benefits." EPRI Demand Response Ready Technology Workshop.
4. Nemtzow, G. 2011. "Dispatchable Utility-Scale Distributed Energy Storage."
5. PJM. 2012. PJM Regulation Performance Senior Task Force—PBR Training Phase 1 presentation.
6. Steffes, P. 2012. Personal communication.
7. Sandia National Laboratories. 2012. ES-Select Tool. www.sandia.gov/ess/esselect.html. ■

Advertisement formerly in this space.