The use of energy storage technologies in the USA is set to grow – particularly where applied alongside distributed generation (DG) units. Indeed, writes Richard Baxter, energy storage can allow DG units to work harder for end-use energy consumers.

Energy storage

an expanding role as a distributed resource

Energy storage technologies are beginning to find a place in the retail energy market as their capabilities are becoming better understood by both customers and energy service companies, who are beginning to see them as a useful new tool. Instead of operating only as stand-alone units, applications are being found where energy storage units can be coupled with existing assets or strategies to extend the capabilities of these assets. The focus for these 'hybrid' installations is to extend the capabilities of the existing generation or transmission assets so as to minimize, or defer, upgrades or expansions – providing enhanced or expanded service at a lower overall cost.

In general, the retail market for energy storage is focused on creating cost saving opportunities and loss-prevention for commercial and industrial clients along two related avenues – peak shaving and power quality/reliability. Whereas peak shaving reduces the purchase of peak energy and the monthly demand charge, power quality/reliability improvements protect against the estimated US$150 billion lost annually by commercial and industrial firms to poor power quality in the US.

The industrial peak shaving market is currently served by distributed generation (DG), for on-site power production, and thermal energy storage to supplement cooling loads. Emerging energy storage technology vendors look to the already-established economic rules of thumb that can be drawn from the mature market where thermal storage facilities operate. Typical payback periods for these installations vary from one to three years. By reducing demand charges and lowering peak power purchases, thermal energy storage facilities can reduce peak power costs by 50%, and can reliably produce a 30% overall reduction in cooling load cost. By spreading the cooling load to, effectively, the entire day, use of supporting equipment can also be reduced by 40–60%.

Energy storage systems can also effect a profound improvement on the quality of electricity service. Poor power quality is not a new issue for consumers. However, as industrial equipment has become more finely controlled over the last few decades, the need for improved power quality has increased along with it. Many firms looking to provide a 'total energy management solution' for their industrial and commercial customers cite this area as one in which their customers are increasingly demanding improvement.

EMERGING ROLES IN THE RETAIL ENERGY MARKET

Uninterruptible power supply

Energy storage technologies, often simply lead-acid batteries but increasingly other storage technologies, already exist in a variety of locations as an uninterruptible power supply (UPS). A UPS provides a 'ride-through' of power in the event of an interruption of service for anywhere from 9–20 seconds. A secondary role for a UPS is to power a shut-down of key systems, usually requiring 15 minutes of power. Finally, as UPS systems are becoming more developed, some advanced models are also acting as power protection devices. In total, the annual global UPS market is estimated to be $5–6 billion, with $3–4 billion in the USA.

Technology focus – flywheels

Rapidly maturing, flywheels are a promising technology and can be found in stand-alone, coupled with distributed generation (DG) assets, or in a hybrid installation with other storage media such as batteries. When coupled with other assets, the flywheel system is designed to extend the life of the other component by providing rapid injections to handle deep or cyclic responses. It is in these stressful environments that flywheel energy storage systems are most useful. Modern flywheel systems are capable of tens of thousands of cycles (rather than the 250–1000 for lead-acid batteries) and a fast recharge, often approaching a 1:1 discharge/charge rate (whereas lead acid batteries can take 2–10 times the period of discharge to recharge). Other benefits include a compact footprint and very low maintenance requirements.

Because of their flexibility, applications for flywheels range from low-power telecommunication equipment support (a few kW for hours) to high-power industrial equipment support (up to a few MW for seconds).

A flywheel energy storage system stores energy through accelerating a rotor up to a very high speed and maintaining the energy in the system as inertial energy. There are two veins of development currently: low- and high-speed rotors. Low-speed flywheels (short duration) predominate currently and are used primarily as uninterruptible power supply (UPS) devices. These generally have solid steel rotors with speeds of to 8000 rpm. In high-speed flywheels (long duration), advanced composite materials are used for the rotor to lower its weight, while allowing for the extremely high speeds, since energy is stored in the rotor not in proportion to its momentum, but to the square of the angular momentum. Speeds in high-speed units have reached upwards of 60,000 rpm, but generally operate above 10,000 rpm – see Figure 1.

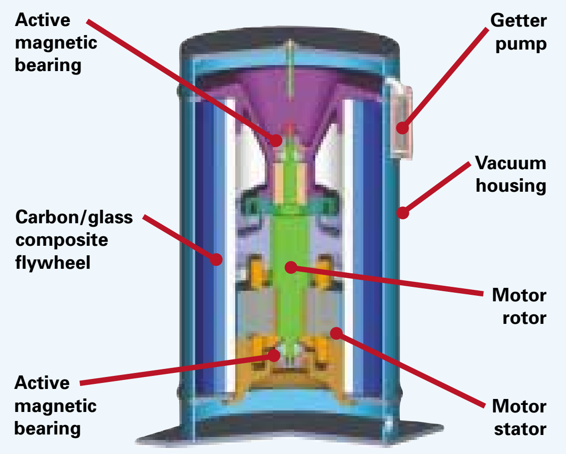

Figure 1. High-energy, high-speed flywheel assembly

The flywheel releases energy by reversing the charging process and using the motor as a generator. As the flywheel releases its stored energy, its rotor slows until it is fully discharged. Because it is mechanical rather than chemical storage, it is usually possible to fully discharge the unit without any ill effects – an ability which batteries lack. Although current flywheel technology is most developed in the auto and aerospace industries, flywheels are increasingly being targeted for electric power capabilities in the 150 kW to 1 MW range. High initial costs have slowed adoption of the high-speed units, although lifecycles costs are far lower than for battery-only systems – especially in demanding operations.

It is important to remember that the value of the UPS is not based on how much it will 'earn' for its owner, but the value of the goods and services saved from a production interruption. Some estimates put the average cost of downtime (all industries) at $1 million/h, due in large part to the often-cited anecdote of chip fabrication facilities that can lose many millions of dollars in production in just minutes of downtime, or banking/financial systems that can lose that (or more) in seconds. For that reason, UPS systems frequently pay for themselves after the first power failure.

Building on the growing capabilities of new energy storage technologies and power electronics, existing UPS systems are expanding to provide a greater level of power quality at the customer's site. As a greater level of computer electronics has invaded the workplace at every level, cost-cutting has exposed the losses from poor power quality that firms suffer as a target for management. As these losses are connected to the output of the firm, they can easily outpace the cost the firm pays for energy. For many managers, increasing revenues is difficult. Therefore, cutting embedded losses looks even more appealing, as any costs curtailed fall directly to the bottom line.

Distributed energy resource

As energy storage technologies mature, they are finding far more applications as distributed energy resources than simply as UPS units. Flywheel manufacturers in particular are expanding past the single, stand-alone unit to set-ups that provide a wider range of capabilities. One example of the growing capability of these systems is Beacon Power Corporation's 'Flywheel Energy Matrix System' – see Figure 2. By scaling the capabilities of a number of flywheel energy storage units in a semi-mobile configuration, the systems can more easily provide the high-energy storage density supporting MW output levels for tens of minutes.

As can be seen in Figure 2, individual building blocks can be combined in a standard container to assist installation on-site. This system – with a 10-year operating life – is capable of a providing a maximum output of 2.5 MW, or can provide a sustained 250 kWh at a 1 MW output. Because of the unit's modularity, many other applications besides consumer power support are possible, such as grid stabilization or load support for distribution utilities.

As retail energy market continues to evolve, the industrial and commercial markets will continue to be the focus of more integrated energy management solutions. As these strategies progress, eventually the entire $75 billion commercial and $45 billion industrial market (cost of power sold) could use energy storage assets along with distributed generation and demand response strategies for overall installation and company-wide (multi-site) integrated energy strategies.

Combination with DG assets

One of the most important new uses of storage facilities is in conjunction with DG assets to extend the capabilities of the DG unit in stressful environments. For instance, one often-praised feature of DG units – their small size – is also a limitation under some situations. Another feature is their response time to changing loads. Since storage facilities often have a much quicker reaction time, these hybrid units are able to perform over a much wider range of operating condition than just the distributed generation asset itself.

Energy storage assets could have a role to play as DG assets become more widespread, as DG does not always have only positive results. Whereas most view the continued introduction of DG assets as improving the operation of the grid, expanding numbers of DG systems can exacerbate the supply balance for utilities. According to a recent Lawrence Berkeley Laboratory report (LBNL-47896), customers that implement DG often self-provide over 90% of their energy needs, but provide only about 50–70% of their peak load. In other words: 'on-site generation tends to fill a baseload role, and the customers buy power at their peaks rather than installing their own generation. The resulting residual load, as seen by the grid, therefore, tends to be much smaller than without DG in place, but has a much lower load factor.'

Storage assets can provide support to the DG unit in both on-grid and off-grid situations. In enabling off-grid operations of a facility, the energy storage asset can:

- enable the seamless transition to an off-grid environment (and back again)
- provide load-following and voltage stability of the off-grid environment while it is separated from the dampening capability of the larger grid.

On-grid uses of energy storage (coupled with a DG unit) are generally more beneficial in an isolated environment where the dampening effects (voltage and energy supply) of the grid are minimized. Here, energy storage facilities provide load-following and voltage stability support to the DG unit – allowing the generation component to operate in a more reliable and cost-effective manner. In one 1997 study, conducted by the US National Renewable Energy Laboratory, a storage facility (charged by a wind turbine) was used to provide power to the grid to prevent the peaking diesel generator from starting. In this test, a 10-minute storage capability reduced the fuel use by 18%, the diesel running time by 19%, and the number of diesel starts by 44%. Another storage installation in Metlakatla reduced direct annual fuel costs by $400,000 per year, plus associated annualized costs of almost $100,000 and had a three-year payback period.

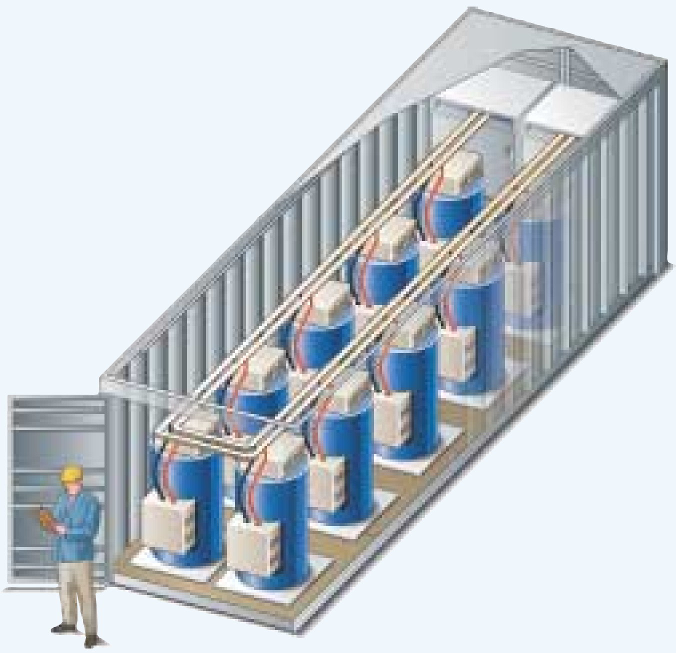

Figure 2. Beacon power container

GOING FORWARD

As the market looks to distributed generation resources to shoulder a greater burden of end-use and system demand, energy storage technologies stand to play a key role in extending the capability of these assets at a lower cost – enhancing their competitiveness and effectiveness. By providing a cache of ready power, energy storage assets can support distributed generation units and provide more reliable and secure power while operating in a more efficient manner.

As commercial and industrial clients demand enhanced power quality protection and a means to lower their energy bills, energy storage assets stand as a component of the solution. By acting as both a dynamic sink and a source for power, energy storage facilities can act a 'shock-absorber,' providing support to existing DG resources to operate in a wider range of capabilities for their customers.

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