BATTERIES, POLICY & REGULATIONS

Integrating Energy Storage

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California may soon become the U.S. leader in energy storage spurred by the 2013 California Public Utility Commission (CPUC) mandate that the state's three largest public utilities have 1,325 MW of electricity storage in service by 2024. These projects are necessary in order for the state to meet its goal of having 50 percent of its electricity produced by renewables by 2030. The goal is ambitious and does have its risks.

"Advancing and Maximizing the Value of Energy Storage Technology: A California Roadmap," was released on Dec. 31, 2014. It is the result of the collaboration of the California Independent System Operator, the CPUC, and the California Energy Commission plus the input of over 400 stakeholders to identify those priority issues "... that need to be addressed include[ing] refining existing [energy storage] products and driving new ones to market; reducing costs of metering and connection; and creating a predictable and transparent process for commercializing and connecting storage projects."

The Roadmap includes a long list of policy and tariff structure issues that must be resolved if manufacturers and developers are to invest adequately to achieve the state's renewable goal at the scale and prices required. The time for California, as well as other ISOs, to adopt energy storage as a means for managing grid operations, particularly to mitigate the impact of intermittent renewable (solar and wind) generation resources, has arrived.

Other states, such as New York, Texas, and Washington have or are in the process of removing similar regulatory barriers, often by redefining energy storage as a qualified energy generation technology and requiring inclusion of energy storage in utility integrated resource plans. At the national level, the Federal Energy Regulatory Commission's Order No. 792 has clarified that devices "for storage for later injection of electricity" as Small Generators, and included them into its fast track interconnection procedures, which will help standardize energy storage interconnections to the grid.

In Canada, the Government of Ontario's Long Term Energy Plan calls for a total of 50 MW of storage capacity but for a slightly different reason than California. According to the National Resource Council Canada (NRC) Energy Storage for Grid Security and Modernization initiative, Canada wishes to use energy storage technologies to help defer the costs of transmission and distribution system renovation while also stabilizing the intermittent nature of renewable energy and enabling peak shaving and arbitrage.

Energy Storage Options

Energy storage technology providers can optimize the economic value of their investment by providing multiple services, supported with a suitable tariff and revenue streams. A single energy storage facility might provide and be compensated for a combination of applications including:

1. Renewables integration. Stored electricity may be dispatchable in order to offset the effects of highly intermittent renewable generation by providing ramp-rate control for "smoothing, firming, and time-shifting output, principally of wind and solar, while avoiding system level integration costs," according to a CPUS staff study (CPUC Rulemaking 10-12-007).

2. Ancillary Services. Ancillary services are required to maintain grid stability and security. They include such things as frequency control, reliability controls, and spinning reserves. Traditionally power plant generators have provided these services, but generators are often to slow to react to changes in the grid, and are less efficient when compared to a BESS.

- **Frequency Regulation.** The BESS may be used to ensure that the grid frequency stays within a specified range. The frequency provided by the electrical grid moves due to a mismatch between electricity demand and power generation. The utility will send a signal (typically every four seconds) to the BESS, asking the BESS to either charge or discharge, bringing the frequency back to its nominal value.
- **Reactive Power and Voltage Control.** Reactive power can be used to compensate for voltage drops, but must be provided closer to the load to increase the advantage of lower currents, and improved efficiencies.
- **Spinning Reserve.** This represents a reserve capacity used to help maintain output during a generator failure or unexpected transmission loss, which might otherwise cause power reductions to customers. Keeping generator capacity online but unloaded wastes fuel and causes unwanted air emissions. A BESS can be made available in microseconds, and can take the place of conventional spinning reserve generation and improve system efficiency.

3. Peak Shaving. Energy storage on the customer's side of the meter can be used to flatten demand spikes by charging during off-peak periods, and discharging during periods of peak demand lowering utility demand charges for the facility. .

4. Energy Arbitrage. A BESS may be used to purchase of electricity during low purchase cost periods and resell the stored electricity during high-cost periods, allowing the storage owner to profit from the difference in price.

1. Batteries

The 98MW Laurel Mountain Wind Farm uses battery energy storage to optimize energy sold into PJM and to provide regulation services.

Source: AES Energy Storage LLC

5. Black Start. A BESS can provide balance of plant power needed for a plant restart.

Technology suppliers and system developers view the ability to provide multiple services from a single plant as a huge benefit and an economic opportunity. For example, a BESS might supply ancillary services to the wholesale market at other times providing reliability services to the local grid or peak shaving services for a large end user. The challenge for the market is to define the true economic benefit, and if possible, get paid for it.

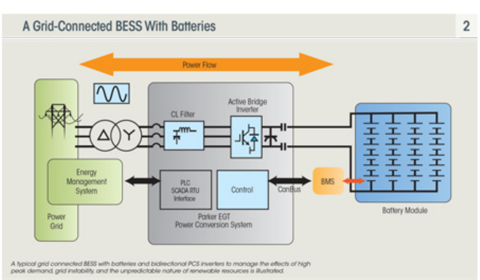
The technology is available but electric utilities don't have the modeling tools that fully value the contribution that energy storage systems offer to the wholesale market, nor do they know how to price the true benefits of these services to the rest of the system. It's difficult to participate in an energy market when the market rules haven't been fully understood or established or written, but this is changing and now a focus.

Writing tariffs that address the multi-use potential of BESS and how the operation of a BESS might be economically optimized is complicated. Each project must address site-specific needs as well as conform to the requirements of the local energy markets so conflict in priorities is to be expected. For example, a BESS may earn a higher economic return with energy arbitrage during periods of extremely high demand instead of providing desperately needed ancillary services. Proper tariff design and interconnection constraints are perhaps the only real impediment remaining to the rapid expansion of BESS installations

Energy Storage in Action

The 98MW Laurel Mountain Wind Farm, owned by AES Energy Storage LLC and located on a mountain top, near Belington, West Virginia, is an example of a multi-use BESS. The 32MW/8MWh grid-connected BESS and AES uses its Storage Operating System (sOS) to optimize electricity sales into the market. The plant also supplies frequency regulation and grid stability services to the PJM market, which adds an important second revenue stream to the owners. The plant can also moderate the ramp rate of the plant electricity production.

Laurel Mountain thus far has operated with over 95 percent availability and has been consistently the low cost provider of regulation service in the region. The project is a collaboration of AES Wind Generation, AES Energy Storage, battery manufacturer A123 Systems, and power conversion system (PCS) supplier Parker Hannifin Energy Grid Tie Division (Parker). Power generated by the facility is sold to PJM. When commissioned in Oct. 2011, it was the largest lithium-ion BESS in the world (Figure 1 on page 25).



A Grid-Connected BESS With Batteries 2

A typical grid connected BESS with batteries and bidirectional PCS inverters to manage the effects of high peak demand, grid instability, and the unpredictable nature of renewable resources is illustrated.

Source: Parker Hannifin, Energy Grid Tie Division

Prior to this installation, Parker supplied AES Energy Storage with a PCS for a 12 MW BESS installation at AES Gener's Norgener plant, the Los Andes Substation that provides critical backup services to the electric grid in northern Chile. The backup service was installed to provide grid stability services to the mining operations in the region. Grid operator CDEC-SING has recognized Los Andes as one of the best performing spinning reserve units in the region. The plant is used both as a generation and a grid stability resource.

"As one of the largest power generators in Chile, we're consistently looking for ways to unlock [the] value of our existing plants while maintaining grid reliability and flexibility," said Felipe Ceron, CEO of AES Gener. "Since 2009, we've been working with AES Energy Storage to free up generating capacity at our Norgener plant by employing a battery-based installation to meet the power system's obligations for spinning reserve." Los Andes has been in commercial operation for nearly three years.

The Brain of BESS

The battery energy storage system consists of two main parts: battery modules and the accompanying Battery Management System (BMS), and a PCS used to enable the interface of the batteries to the grid. Individual battery cells are connected in a series/parallel arrangement in order to obtain the desired nominal voltage for highest efficiency and required storage capacity. The PCS is a bidirectional power conversion device (inverter), enabling AC power from the grid to be converted to DC to charge the batteries in a controlled manner, and discharge DC battery power to feed AC power onto the grid (Figure 2).

The PCS must produce electricity that can be synchronized with the grid frequency and have a stable output, in effect disguising itself to the grid as a stable synchronous generator. It must also be capable of performing a smooth transition when used as a power backup system. Other components within the PCS are responsible for physically connecting to the grid and battery system, as well as for protection, detection, power quality, safety, and interfacing with the (SCADA) signaling to and from the utility. Integral harmonic filters are used to deliver pure sine wave power well within IEEE519 guidelines for total harmonic distortion. The PCS provides automated sequenced shutdown and disconnection under power loss in compliance with IEEE 1547 guidelines or can be configured to function in island mode, providing backup power for an isolated microgrid plant.

In addition to simply charging and discharging batteries, many systems provide an important extra benefit–providing both real and reactive power (VAR support). This capability provides the ability for the BESS to grid support and voltage regulation. Firmware and programmability in the PCS allows for flexibility of control and operating autonomy. If PCS contains the algorithms for real and reactive power management, it can eliminate or reduce the responsibility of external site management by the utility. A well-designed PCS will also include robust LVRT (low voltage ride-through), HVRT (high voltage ride-through), and FRT (frequency ride-through) support over a wide range of operating conditions during critical events.

3. Power Conversion System

The Parker 890GTS/GTB is used on solar as well as BESS energy storage systems. The enclosure houses the PCS and thermal management systems for a BESS size up to 2 MW.

Source: Parker Hannifin, Energy Grid Tie Division

BESS Design Features

A BESS is often installed outdoor in remote and environmentally hostile regions, like those installed in the deserts of Chile or in the salt spray of a coastal area. In these environments, thermal protection and modular designs are important considerations. An energy storage system only produces revenue for its user when it is on line and providing its intended services, whether that is frequency regulation, VAR support, power backup, arbitrage, or used as a Microgrid.

Heat is the enemy of electronics. The key to a reliable installation is good thermal management in order to protect inverters, batteries, and ancillary components. Cooling system design in grid-tie inverters traditionally has relied on air or liquid water-glycol cooling. Air-cooling has low heat exchange efficiency and can consume a lot of energy. Chilled water-glycol requires a substantial volume of liquid to be pumped through the system, which consumes significant space and power, and raises concerns about corrosion and other maintenance issues.

A better option is closed-loop evaporative cooling. In this type of system a refrigerant such as R134a is circulated at low pressure through the thermally critical components inside the PCS. As heat from the components transfers to the refrigerant, it partially evaporates, with the resulting vapor sent to a condenser. Using outside air, the vapor then condenses to a liquid form and returns to the holding reservoir, where it is again pumped through the components. This method of cooling has proven to be very efficient, requiring much less liquid flow than in a water/glycol system. This allows for a higher power density, and lower auxiliary power requirements, and longer system life. Real-time temperature monitoring at crucial points throughout the PCS provides preemptive notification of thermal issues. This form of system cooling has a tremendous advantage over more traditional air or liquid cooling systems. Using this design, Parker has reduced the enclosure size to two thirds compared to its competition (Figure 3).

The modular design approach chosen by Parker includes other benefits; the two most valuable are scalability and system redundancy. Scalability allows for the expansion of a base system for future state conditions. In some cases, a small trial system has been installed, which is easily expanded once the concept is demonstrated and proven. In others, availability of funding has dictated building in stages. Also, additional systems can be added to respond to the need for additional grid stability and VAR support. Another advantage is when tariffs are established in the future for new services, additional modules could add new revenue streams at existing plants.

Modular design on the inside of the PCS also offers the benefit of maximum up-time by virtue of low MTTR (mean time to repair). Interchangeable spare phase modules containing power semiconductors and all related circuitry can be stocked on site, where plant technicians can quickly diagnose a failure and replace a module without requiring a service call from the factory. Redundant fan motors and cooling pumps mean one component can fail, while allowing the system to continue to function.

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