White paper

Energy storage: Moving toward commercialization

Energy storage will allow utilities to decouple generation from demand, increasing both grid flexibility and performance.

Evolution of the utility grid

The adoption of renewable energy and smart grid technology has rapidly altered the way we generate and deliver electricity. However, with the increase in solar, wind, and other distributed energy resources (DERs), utilities are finding it increasingly difficult to manage their systems to ensure that these variable sources of electricity are adequate to serve the constantly changing demand. As a result, grid stability and safety have become major issues.

Fortunately, the latest energy storage systems and controls can address these issues, and that makes them an important next step in the evolution of the smart grid. As the New York State Public Service Commission recently acknowledged, "A system consisting of weather variable and invariable generation will require a highly responsive demand side *and/or the ability to store electricity on a large scale."* [1] But once installed, energy storage will also allow utilities to decouple generation from demand, increasing both grid flexibility and performance.

Elements of an energy storage system

For typical electro-chemical storage devices, there are three major components: a) a storage medium; b) a power conversion system; and c) advanced controls and software. However, at present most utilities are looking at battery-based storage for the simple reason that batteries can be located almost anywhere.

For typical electro-chemical storage devices, there are two major components: a) a storage medium; and b) a power conversion system. [8] These are supplemented by balance-of-plant components including:

- Monitoring and control systems.
- A building or containers.
- Hardware, including: switchgear, transformers, medium- and low-voltage cables, and other ancillary devices.

Power converter – These are sized according to the applications. For higher power requirements, several units can be connected in parallel to provide dynamic control of active and reactive power flow in both directions.

Control system – Allows manual and automatic operation of all system components. Communication protocols support remote control and monitoring and accept load and weather forecasts.

Protection equipment – Includes AC/DC circuit breakers, protective relays, current & voltage sensors, built-in temperature monitoring devices, etc.

Switchgear – For safe and reliable grid connection and operation of the system.

Transformers – May include either liquid-filled and/or dry-type transformers that meet ANSI, IEC, and other local standards.

Batteries – Depending on the application, utilities can select from a variety of technologies such as lithium-ion (li-ion), sodium-sulfur (NaS), nickel-cadmium (NiCd), lead-acid, or flow batteries.

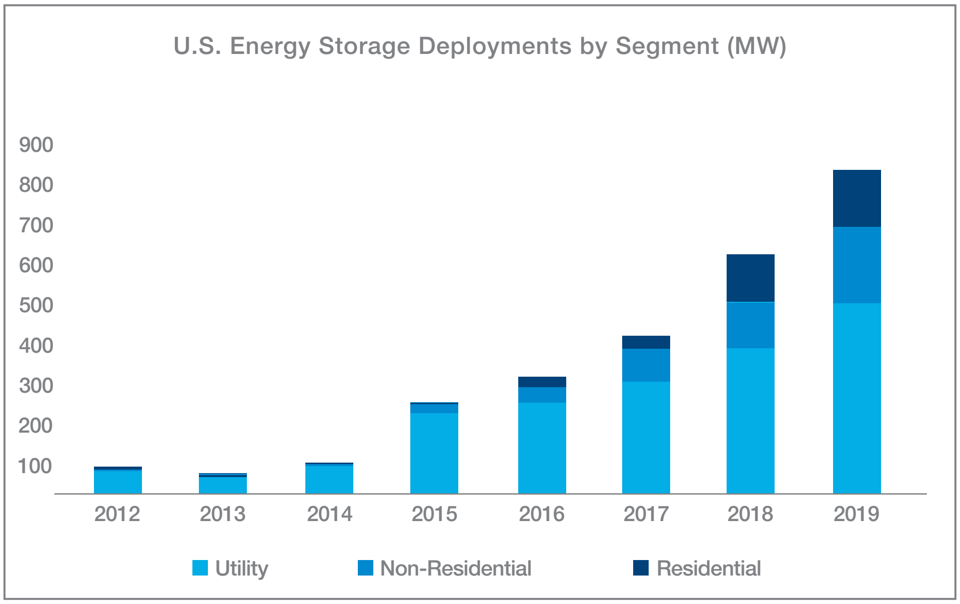

Figure 1: The U.S. energy storage market is expected to soar over the next five years. [2]

Indeed, in California, where solar is king, the state has mandated investor-owned utilities install 1.3 GW of storage by 2020. "Storage is also gaining interest in the Northeast, but for different reasons," said Pat Hayes, Energy Storage Business Development Manager, ABB. "There, states are seeking protection from future mega-storms like Hurricane Sandy, which ravaged power systems in 2012, and they're doing that in part with microgrids, which rely on energy storage for emergency support."

Overall, the U.S. installed nearly 62 MW of energy storage in 2014, up 40% from 2013, and completed 180 individual installations – representing an investment of $128 million. During the next five years the U.S. energy storage market is expected to grow even faster, resulting in an 858 MW annual market in 2019. This would be 13 times the size of the 2014 market and four times the size of the 2015 market. (See Figure 1).

In 2014, the PJM region, which includes most of the mid-Atlantic states, was the largest utility-scale market, with 40.3 MW of energy storage deployed, followed by California. While storage systems installed in PJM were largely for frequency regulation, the majority of California projects were utility-owned, transmission- and distribution-connected storage systems. (See Sidebar: The California and PJM experiences)

But there's more driving interest in energy storage besides the California and the PJM markets. According to a recent industry survey, more than half of the

The California and PJM experiences

"California's mandate, which requires utilities in that state to adopt 1.3 GW of energy storage by 2020, is compelling those same utilities to undertake a massive program of acquisition and testing," said Michelle Meyer, Senior Product Manager for Energy Storage, ABB. "Their goal is to encourage the development and integration of cost-effective energy storage systems." In developing that mandate, the state's PUC had three guiding principles:

- Optimization of the grid, including peak reduction, contribution to reliability needs, or deferment of transmission and distribution upgrade investments
- Integration of renewable energy
- An 80% reduction in 1990 greenhouse gas emission levels by 2050

"PJM took a different approach," said Meyer, "and the way it changed its compensation mechanisms for regulation services – basing them on speed and accuracy – was a game changer for energy storage. Its ability to respond in milliseconds resulted in higher payments, making storage for a single application a lucrative investment."

Consequently, two-thirds of the 62 MW of energy storage deployed in the U.S. in 2014 was located in PJM's service territory to provide frequency regulation, i.e., to balance energy load and supply in real time. This need arose because of the strain that the addition of intermittent renewable generation and complex loads – such as large electric motors at manufacturing plants – placed on the grid.

In the past PJM utilities typically would either start up or shut down coal or natural gas generators to balance load. However, the large rotating masses of these assets take tens of seconds to ramp up and as a result cannot follow a fast-moving electrical signal. In contrast, battery or flywheel energy storage, for example, can respond instantly (in milliseconds) to correct deviations in frequency levels.

"To date, PJM is the only system operator to fully adopt and implement FERC Order 755, which requires ISOs to pay for performance," added Meyer. "And as a result, energy storage systems in that area receive much higher revenues per MW for regulation."

nation's utility executives ranked energy storage as the top emerging technology in which they believe their companies should invest. [3]

"As regulators and policy makers develop the rules, the standards, and the incentives for energy storage, utilities are just beginning to scratch the surface of its true potential," said Hayes. "They have begun to look at how energy storage can be integrated across their fleets to optimize their entire systems." For these and other reasons, Hayes noted, "utilities are coming to realize that energy storage – done right – not only offers strategic advantages in creating a more flexible grid, it also has the potential to strengthen the bottom line."

Identifying the benefits

Recent advances in energy storage technology and power electronics are a major reason for the increased interest in energy storage. In fact, they enable energy storage facilities to provide utilities at least 17 readily identifiable benefits that fall into roughly five categories: [4]

- Electric supply
- Ancillary services
- Grid system enhancements
- End user/utility customer benefits
- Renewables integration

Depending on a utility's specific needs, energy storage systems can be employed on either distribution or transmission systems and for single-purpose or multiple-purpose operations, often with varying discharge times. (See Figure 2.)

"Many of these benefits can be combined to develop attractive value propositions," said Hayes. For instance, storage that reduces an end-user's time of use (TOU) energy charges could also reduce demand charges, provide dispatchable load control, or even reduce T&D congestion. "That," noted Hayes, "could defer both T&D expansion and the investment that would require." (See Sidebar: "Energy storage applications and benefits")

Taking a strategic approach

Recognition of these benefits has generated dynamic growth in the energy storage market. However, to ensure the cost-effective deployment of storage systems, it has to be done right. This means storage has to become an integral part of utility networks, not something bolted on to meet an immediate local need. "Adding energy storage is more complicated than simply buying the hardware, connecting it to the grid, and normalizing the voltage," said Clinton Davis, VP Renewable Solutions, Enterprise

Energy storage applications and benefits

These may be combined into attractive value propositions. [4]

Electric supply

1. Electric energy time-shift
2. Electric supply capacity

Ancillary services

3. Load following
4. Area regulation
5. Electric supply reserve capacity
6. Voltage support

Grid system enhancements

7. Transmission support
8. Transmission congestion relief
9. Transmission & distribution (T&D) Upgrade deferral
10. Substation on-site power

End user/utility customer benefits

11. Time-of-use (TOU) energy cost Management
12. Demand charge management
13. Electric service reliability
14. Electric service power quality

Renewables integration

15. Renewables energy time-shift
16. Renewables capacity firming
17. Renewables integration

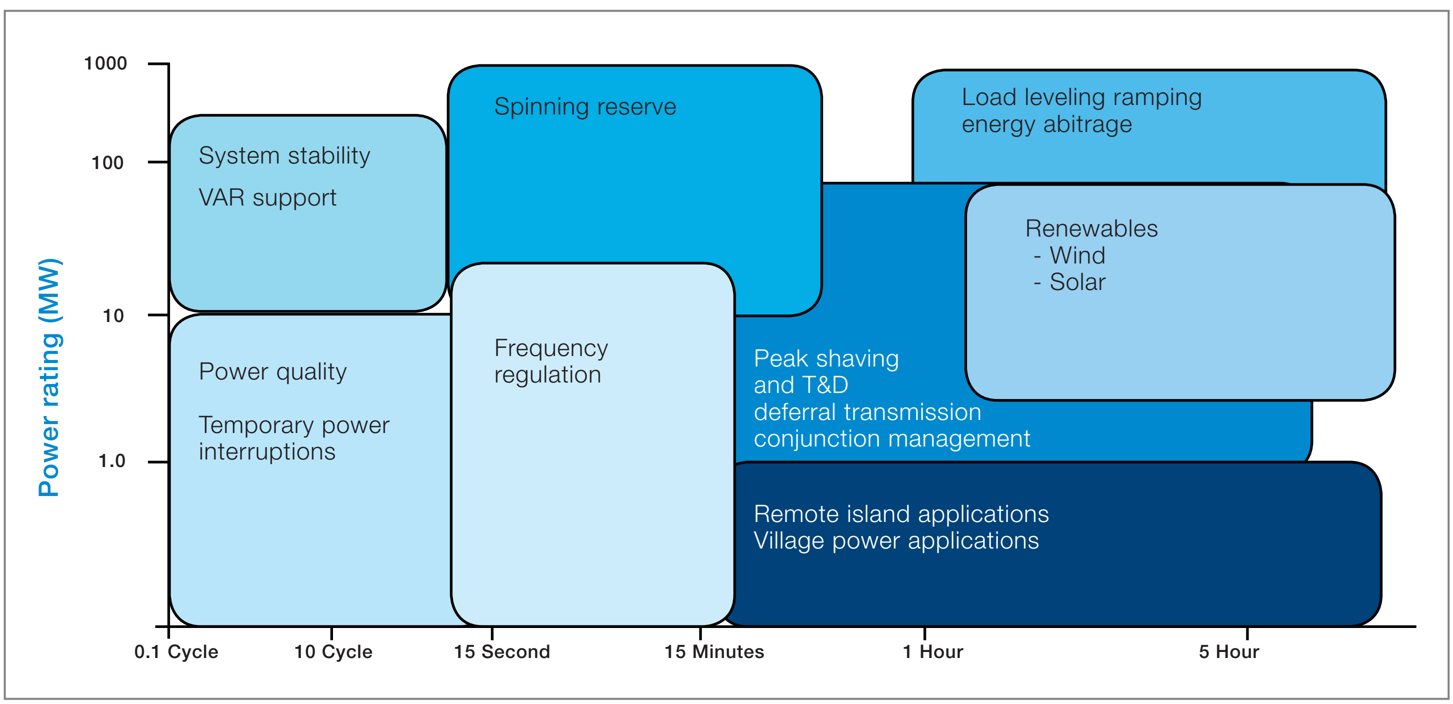

Figure 2: Energy discharge time (axis not to scale) [5]

Software, ABB. "Utilities need to look beyond the tactical or local level and take a holistic – or strategic – view of both the physical and financial components of energy storage – and that must be step one in the planning process."

Davis recommends that when developing long-term resource plans to meet their portfolio goals, utilities not concern themselves initially with a particular energy storage technology. "They first have to determine how best to dispatch stored energy based on energy-price forecasts and, critically, the least-cost way to provide electricity." (See "Southern California Edison's Approach" below.)

On the physical side, "utilities first need to identify the weak points on their networks where energy storage can help and determine the optimal point of common connection for it," Davis noted. "Then they can determine what it's going to take to integrate the storage facility and make it available in real time."

Fortunately, neither communications systems nor technology should be an issue when assessing energy storage integration needs, according to Doug Voda, Medium Voltage Smart Grid Segment Leader, ABB. "The communication architecture required for energy storage is basically the same for all distribution automation systems," he said. "Most energy storage systems are connected to SCADA, which not only enables utilities to employ communication and automation algorithms to set the times for both energy storage and the release of stored energy but also to change them day-to-day as required."

On the financial side, utilities have to ask what products and services they want to provide and how profitable they will be. "That means predicting electricity prices, then using those prices to forecast how often their energy storage facilities will run and how profitable they will be – say, over a 10-year period," Davis adds. "This involves forecasts based on weather, industry knowledge, economics, the expected charging/discharging schedule, and both system lifetime and lifecycle costs."

Maximizing performance

Once this strategic analysis is complete, utilities will be in a position to determine both the optimal technology and size for each energy storage application. "To get the maximum benefit from their investment in energy storage," Davis said, "utilities have to employ it as efficiently as possible – and for the greatest return at any given time." That requires software capable of monitoring and controlling more than just a single energy storage facility; it requires enterprise software that enables grid operators to visualize their entire network.

"Enterprise software really is the glue between the energy storage system and the consumer," said Davis. "It can map DERs on the distribution grid while also employing advanced algorithms to analyze weather forecasts and projected load profiles to help utilities optimize an energy storage system's charging and discharging schedules. This not only enhances operational efficiency but also provides immediate access to those who need to use energy storage resources."

As noted earlier, California utilities are under a mandate to integrate 1.3 GW of energy storage by 2020, but Southern California Edison (SCE) is way ahead of schedule. In fact, the utility has already signed a total of more than 260 MW of energy storage contracts, far exceeding its mandated 2014 target of 50 MW.

In addition, to aid the full adoption and commercialization of energy storage, SCE is pushing the industry to move away from today's highly customized and highly engineered systems toward standardized, "pre-engineered" battery energy storage units. The utility is confident that – if adopted industry-wide – this approach would stimulate mass production, greater economies of scale, and ultimately price reductions throughout the supply chain.

In addition to requesting more pre-packaged energy storage systems, SCE has also introduced a procurement framework designed to encourage an economic evaluation of energy storage systems based on location, technology, cost, and application. SCE's energy

Southern California Edison's approach

Figure 3: Southern California Edison's proposal evaluation process. [6]

storage Request for Offers (RFO) evolution emulates its normal RFO process and involves four major steps. (See Figure 3: Southern California Edison's proposal evaluation process.)

Step 1: Develop price forecasts and scenarios

SCE will prepare and evaluate forecasts for day-ahead energy prices, resource adequacy (RA) prices, ancillary services (AS) prices, and real-time energy prices over the expected project lifetime.

Step 2: Determine revenue streams

SCE carefully assesses both the benefits and the costs of each storage system. With front-of-the-meter systems qualifying as eligible supply-side capacity and resources, SCE evaluates potential revenue streams based on RA value, ancillary services pricing, and money saved by deferring upgrades. Of course, this cost-benefit analysis will also need to include both the operating profile and locational attributes of the energy storage system.

Step 3: Present value and sum all revenue streams

All revenue streams based on a cost-benefit analysis include a 10% discount rate to yield a single net present value (NPV) of the investment.

Step 4: Consider qualitative factors

After the quantitative evaluation is complete, SCE assesses the less tangible qualities and characteristics of the proposed energy storage system, such as project viability and project diversity in "leading to the market transformation." Finally, after thoroughly vetting the cost-benefit ratio of each project, SCE ranks each RFO to determine which projects will be most beneficial to its grid.

"Without a doubt," noted Hayes, "as more and more utilities follow SCE's lead and adopt formal processes to define their energy storage needs, system providers will be better able to standardize their solutions to meet the demands of the marketplace, both increasing deployments and lowering prices."

Moving toward standardization

In 2013 the Cowessess First Nation installed an 800-kW Enercon wind turbine along with a 400-kW, 744 kWh lithium-ion battery storage system and an ABB power conversion system (PCS) on tribal land in Saskatchewan, Canada. (See Figure 4.) Along with smoothing out variations in wind turbine power output, the storage system instantly dispatches power at times of peak demand.

To reduce installation time and cost, and to simplify the project layout, ABB

Figure 4: The battery energy storage system on Cowessess First Nation land in Saskatchewan, Canada.

and SAFT designed a fully integrated battery energy storage system (BESS) that could be packaged in one container. (See Figure 5.) ABB's PCS also came equipped with advanced controls and software designed to integrate with the utility's network management system and properly respond to periods of peak demand, voltage variability, and deviations in frequency levels.

On a day with strong winds the Cowessess system could theoretically dispatch 1.2 MW of electricity for a full hour – 800 kW from the wind turbine and 400 kW from the batteries – but at present the load is not that large. However, the system can be employed to firm the turbine's output for extended periods. [7]

Storage in the age of commercialization

The surge in growth of both renewables and microgrids is clear evidence that the U.S. is in the early stage of an energy revolution. And further, as more and more regulators, utilities, and consumers embrace energy storage, additional revenue streams will be identified, and opportunities for project profitability will occur more often – and at a faster pace.

"Energy storage has the potential to transform how the California electric system is conceived, designed, and operated," the California PUC declared in its order mandating the installation of 1.3 GW of storage by 2020. [9] And they aren't the only ones thinking this way. With PJM, Texas, and other regions joining California in adjusting market rules and pushing both energy storage installations and R&D, it's no surprise that U.S. energy storage installations are predicted to jump 13 times the 2014 market by 2019. Unquestionably, this is just the beginning.

"Stored energy – regardless of the technology employed to store it – is absolutely essential for grid stability and reliability as electrical loads and generation become increasingly more dynamic," said Hayes. Further, as the market moves toward standard applications and uses, utilities will become better able to plan for, justify, and incorporate energy storage in their systems, giving them a strategic advantage in how they operate their networks.

To gain that strategic advantage, however, utilities have to do energy storage right. As Davis noted earlier, that's more complicated than simply buying and installing the hardware. Fortunately, many utilities are beginning to take a holistic approach when evaluating energy storage, one that considers how renewables, microgrids, and communication protocols can work together with storage devices.

Figure 5: Standard ABB Power Conversion Systems can be integrated into a larger container or e-house.

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