East Penn Manufacturing Delivers New Battery Technology for Electrical Grid Support

Successes from the East Penn Smart Grid Demonstration Project

Introduction

The U.S. electric grid operates at a frequency near 60 Hz, with generation and loads adjusted to keep the frequency within a few tenths of 60 Hz. Larger deviations from this base frequency are an indicator of grid distress, i.e. over-generation or overload. Frequency regulation of the electric grid can be provided by batteries, which can respond in milliseconds, to help continuously maintain grid frequency in an optimal operation range by exchanging power with the grid.

> UltraBattery is a hybrid energy storage device that combines an asymmetric super capacitor and a lead-acid battery in one unit cell.

To solve this problem, East Penn Manufacturing Co., a battery manufacturer located in Lyon Station, PA is demonstrating battery energy storage that can be interconnected to the electric grid and provide services such as frequency regulation and peak shaving. These services support grid stability and increased renewable generation on the grid. In 2010, East Penn entered a cooperative agreement totaling $5,087,269, including $2,543,523 of funding from the U.S. Department of Energy's Smart Grid Demonstration Program (SGDP) to build an energy storage facility to support electric grid operation.

East Penn used new UltraBattery® technology from Ecoult, a subsidiary, which designed the Battery Energy Storage System (BESS). This advanced lead-acid technology is one of the candidate battery chemistries to support the development of a smart grid featuring abundant distributed generation.

The BESS consists of an array of UltraBattery® modules (see Fig. 1), which combines the advantages of an asymmetric super capacitor and a lead-acid battery in one cell. This battery chemistry makes the battery particularly capable to provide ancillary services and peak shaving services to the grid. A key objective of this project was to facilitate replication of this design for other sites as a pre-engineered package. The ancillary services consist of 3 MW provided to PPL EnergyPlus for up to 22 minutes and 1 MWh peak shaving services to Metropolitan Edison delivered over 1-4 hours.

Figure 1. Operational battery bank for frequency regulation. Courtesy of East Penn.

The Battery Advances Energy Storage Technology

East Penn packaged and tested its advanced lead-acid technology featuring integrated super capacitor into lead-acid battery chemistry (see Fig. 2). This technology exceeds the metrics met by conventional lead-acid technology for cycle life (longevity), partial state of charge (pSoC)[1] operation (durability) and efficiency. It is also just as safe as traditional lead-acid technology. This performance has been established by rigorous testing by multiple organizations. The project tested its technical and market potential while connected to the electric grid.

Testing showed that cycle life (number of cycles) is up to 5 times that of a conventional valve regulated lead acid (VRLA) battery, confirming earlier experiences with the technology. This longevity makes the technology cost effective for electrical grid applications and also for hybrid electric vehicle[2] (HEV) automotive applications that operate at a partial state-of-charge.

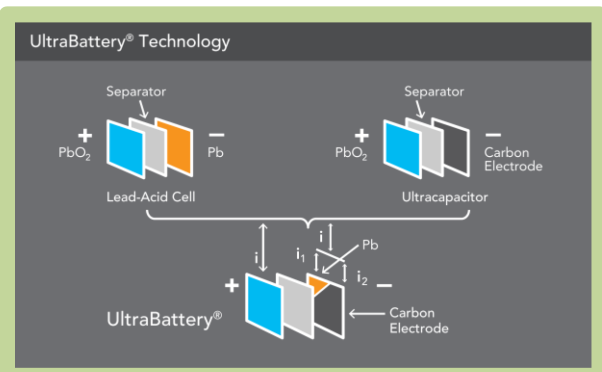

Figure 3. Lead-acid cell (top left), ultracapacitor (top right), UltraBattery® (bottom). Courtesy of East Penn.

Applications across multiple industries can lower the per-unit cost, increasing the chances for sustainable commercial success.

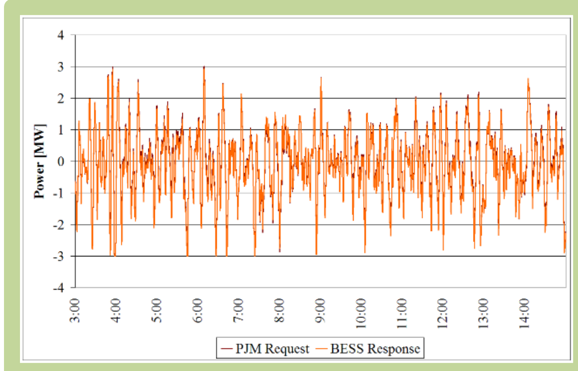

Figure 2. BESS response to 3 MW PJM Regulation Signal

Lead-acid batteries are not fully charged or discharged during normal operation in order to avoid known failure modes. Together with even smaller variations in charge during operation (see Fig. 3), this is referred to as partial state-of-charge (pSoC) operation. In this regime, performing variability management applications, such as regulation services or renewable ramp rate smoothing, UltraBattery® technology has exceptional recharge rate capability.

The UltraBattery® cell achieves typical DC–DC efficiency of 93–95% when performing variability management applications such as regulation services or renewable ramp rate smoothing in a pSoC regime.

The UltraBattery® also achieves typical DC–DC efficiency of between 86% and 95% (rate dependent) when performing energy-shifting applications in pSoC. This high efficiency compares favorably with the typical efficiency of

[1] White Paper, UltraBattery®: High Efficiency and Long Life in Partial State of Charge Applications, http://www.ecoult.com/landing/whitepaper/index.php, accessed 5/19/15

[2] White Paper, "Public-Domain Test Data Showing Key Benefits and Applications of the UltraBattery", published Jan. 2014, http://energystoragealliance.com.au/public-domain-test-data-showing-key-benefits-applications-ultrabattery

less than 75% when standard valve regulated lead acid (VRLA) batteries are applied to energy shifting using the typical top-of-charge regime.

Compared to conventional lead-acid technology, the UltraBattery® requires fewer refresh cycles, and due to its operation in the pSoC, increased round trip efficiency. For frequency regulation the average round-trip AC-AC efficiency is 81.5%, which includes the AC-DC/DC-AC conversation necessary for interconnection to the grid.

East Penn battery technology is "highly beneficial since a mismatch between frequency regulation request and response causes feedback loops due to generator overshoot."

Operation Proves Performance in Real World Setting

East Penn constructed a 3 MW, 1 MWh facility at their site in Lyon Station, PA, with battery monitoring and power conditioning subsystems, and began providing frequency regulation services to the grid in 2012 (see Fig. 4). As of March 31, 2015, the demonstration BESS has achieved 6,272 MWh of charge/discharge throughput in supplying ancillary services to PJM. With battery regulation, the battery bank provides an essentially instantaneous response, whereas traditional generators respond more slowly and tend to overshoot the regulation goal, thereby being inefficient and sometimes causing reliability problems.

Commercialization: Filling the Energy Storage Space

The project showed that there is a strong *technical* case for new generation lead-acid batteries in frequency regulation applications, as described above.

The project showed that there is a strong *economic* case for new generation lead-acid batteries in frequency regulation applications. Even performing frequency regulation alone the economic case is impressive for this technology. However in dual purposing – where UltraBattery® is utilized to provide more than one service – the economic case improves further, especially when the services are complementary such as the case with frequency regulation and data center backup.

The project showed that there is a strong *environmental* case for new generation lead-acid batteries in frequency regulation applications. In situations where rapid response is needed, batteries outperform fossil fuel generators in dynamic frequency regulation services, because they are more efficient in reaching the frequency set-point than using fossil generation directly. This can reduce the carbon output of the traditional electricity grid per unit of energy delivered. Furthermore, while many energy storage solutions have no economically viable recovery and recycling paths (e.g. end up in land-fill or are ground into sludge for construction materials) UltraBattery® has a fully closed-loop and profitable recovery chain – essentially every old battery is recovered and 96% of each battery is used to make new batteries. Furthermore the remaining 4% is almost entirely used in industrial and agricultural processes.

Figure 4 Battery containers. Courtesy of East Penn.

Next Steps

The East Penn system continues to supply ancillary services to PJM, and will be demonstrating a new format UltraBattery® in the frequency regulation application. Also, as current data center backup solutions age, East Penn technology can be used for upgrades. Their UltraBattery® offers the possibility of incrementally swapping out these batteries with an "active" cycling battery. As that happens, the entire grid becomes "smarter" – more flexible and more able to cope with innovative functions like frequency regulation, peak shaving, demand management, solar cycles, wind smoothing, and diesel offset. UltraBattery® cells are every bit as safe, powerful and recyclable as traditional lead-acid cells (already one of the world's most perfectly recycled products) and they can be utilized without major adjustment in distribution paths or shipping regimes.

Further Reading

For more information about the East Penn smart grid demonstration project, read its technology performance report, published on the SmartGrid.gov website. A more detailed description of SGDP can also be found at SmartGrid.gov.

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $1.5 billion in 32 cost-shared Smart Grid Demonstration Program projects to modernize the electric grid, strengthen cybersecurity, demonstrate energy storage, improve interoperability, and collect an unprecedented level of data on smart transmission, distribution operations, and customer behavior.