NEW IRON BATTERY DESIGN FOR FLOW BATTERIES

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PROJECT TITLE: 10kW 80kWh Energy Storage System Based on All-Iron Hybrid Flow Battery
PROGRAM: GRIDS SBIR
AWARD: $2.25 million
PROJECT TEAM: Energy Storage Systems (ESS Tech, Inc.)
PROJECT TERM: October 2012 – December 2016

TECHNICAL CHALLENGE

Advanced energy storage promises to play a key role in the modernization of our nation's electricity grid. While relatively little storage is deployed on today's grid, future grid development will likely require energy storage that not only enables the integration of increasing amounts of renewables, but also improves the grid's operating capabilities, enhances reliability, allows deferral of infrastructure investments and provides backup power during emergencies. To expand the benefits of energy storage for the grid, storage systems are required that can match both the power and energy scale of the electrical grid while minimizing impact on the cost of electric power delivery. Electrochemical energy storage (e.g. batteries) provides significant opportunities to address these needs, if lowered cost and increased lifetime can be delivered.

TECHNICAL OPPORTUNITY

Redox flow batteries are attractive for grid storage because the amount of stored energy can be scaled independently of the battery's power level. This is because the energy is stored in liquid electrolytes that are pumped from storage tanks through a cell stack (the active part of the battery, including the electrodes) during charging and discharging. Historically, flow cells have been limited in power delivery because energy was not efficiently transferred from the liquids to the battery electrodes. Issues of stability in cycling the electrolytes have also limited the choice of the chemical used in fuel cells, resulting in high costs. Improved understanding of fluid dynamics and new approaches to managing electrolytes offer new opportunities to dramatically increase the performance of flow batteries, as well as bring down their cost.

Figure 1: Photo of ESS battery stacks

INNOVATION DEMONSTRATION

Energy Storage Systems (ESS) initially focused on improving energy density by adapting the understanding of chemical flow to the electrodes from their experience with fuel cells. The company developed a high-power cell and a compact stack design based on vanadium chemistry. ESS then evaluated other chemistries to address the high cost of the vanadium-carrying electrolytes, which was a large fraction of overall system cost. Early academic literature on the iron flow battery (IFB) indicated a potential low-cost approach using abundant iron as the active material, but state-of-the-art power densities were low (50mW/cm^2), so there was a clear opportunity to leverage ESS's high-power cell design in conjunction with the iron chemistry.

ESS adapted its cell and stack design to use iron chloride ($FeCl_2$) electrolytes that cost less than 1/10 of the vanadium-carrying electrolytes. The resulting high-power cell design has demonstrated a four-fold power density increase over existing iron flow battery technologies.

In addition to the low power density of traditional IFBs, ESS also had to address the problem of cycle life. When ESS began its project, state-of-the-art IFBs exhibited round trip efficiency of roughly 50% and life of less than 100 cycles. Chemical side reactions limited the cycle life by altering the pH of the electrolyte and causing precipitation of active species. The ESS team developed an effective chemical rebalancing system that ensures the IFB can cycle over extended periods. After incorporation of its rebalancing system, ESS demonstrated single-cell cycle life of more than 2500 cycles without measurable degradation, and AC energy efficiency of 70% in a scaled-up 10kW/75kWh IFB.

PATHWAY TO ECONOMIC IMPACT

ESS has delivered a package targeted to be very competitive with incumbent battery systems and continues to focus on further lowering its system costs with an emphasis on low-cost cell components, including membrane and electrodes.

ESS's first markets for the product are customer-owned systems (less than 100kW in size) coupled with renewables for firming and load management. To increase customer benefits, ESS has developed a battery management system in which end-users have a way to harness their local electricity rate structures to their economic advantage. ESS's first customers include the U.S. Army Corps of Engineers and Stone Edge Farms, a winery in Napa, CA. In addition, ESS has approximately $1 million in firm orders for delivery in the first half of 2016. As ESS moves into higher-volume production, the company is also seeking to drive cost out of its system through manufacturing improvements.

ESS announced in October of 2015 that the company had closed a $3.2 million Series A round that was led by Pangaea Ventures. This funding will be used for working capital and to scale up manufacturing to meet initial system orders.

LONG-TERM IMPACTS

The successful application of high-power flow cell designs, and the development of approaches to address chemical imbalances and incorporate lower-cost materials, remove the two most serious barriers to commercial applications of flow batteries for grid storage. ESS's results help to position flow cells to move into the larger applications in the grid needed to create significantly expanded integration of intermittent renewable power sources.

With increasing production scale, continuing development of lower-cost cell components and the potential for significant increases in cycle life, ESS is positioned to be very competitive in the rapidly developing grid storage market, with the potential to deliver storage costs that minimize the impact on the levelized cost of electricity.

INTELLECTUAL PROPERTY

As of February 2016, the ESS project has resulted in seven subject invention disclosures and six U.S. Patent and Trademark Office patent applications.