LONG-LIFE ENERGY STORAGE SYSTEMS CREATE A MORE EFFECTIVE AND RELIABLE ELECTRIC GRID

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PROJECT TITLE: Low-Cost, High-Performance 50-Year Electrodes
PROGRAM: GRIDS
AWARD: $1,999,999
PROJECT TEAM: *Primus Power (Lead)*
PROJECT TERM: September 2010 – December 2012

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. Expanding the benefits of energy storage for the grid requires energy systems 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 (RFB) 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. Improved understanding of fluid dynamics and advanced materials approaches to design of electrodes and electrolytes offer new opportunities to dramatically increase the performance of flow batteries, as well as bring down their cost.

INNOVATION DEMONSTRATION

One of the most costly components in a flow battery is the electrode, where the electrochemical reactions actually occur. Primus focused on the development of a long-life electrode that successfully extends the stack lifetime and reduces system cost. The Primus team replaced the standard carbon-base for the electrodes with a new structure based on a metal substrate and structured mixed-metal catalyst, thus improving resiliency and electrical conductivity, and enhancing the surface area to support the catalysts that interact with the electrolyte. The team drew on mature technologies and processes from the chlor-alkali, filter media, and electroplating industries and adapted them to the specialized needs of a flow cell based on Zinc (Zn)-halogen chemistry.

Figure 1: Primus Power's fully self-contained, hermetically sealed flow battery

The team successfully developed and integrated an electrode into the advanced battery stack. In initial tests with a Zn-Chlorine (Cl) chemistry there was a high level of corrosion. Primus developed alternative electrolytes to find a balance that minimized corrosion, and ultimately optimized Primus' flow cell for Zn-Bromine (Br) chemistry. Primus ultimately developed a highly durable advanced metal electrode that significantly extends the stack lifetime.

Throughout the development of this non-traditional flow battery, Primus focused on increasing operating current density to generate more power from the stack, and developed a unique hybrid flow design in the cell which improved the performance and reduced the stack cost per watt of power delivered. Under its ARPA-E award, Primus' resulting system delivered five times higher stack power than previous commercial Zn-Br batteries and cycle life that was eight times longer. Then-current state-of-the-art densities were 15-30 mA/cm^2 for commercial Zn-Br systems, however Primus' final stack operated at 150 mA/cm2 in the ARPA-E project. Additionally, the lifetime of the Primus system substantially exceeded state-of-the-art cycles of 2,000 cycles over a typical stack lifetime, with higher than 17,000 cycles possible if degradation of components (including electrodes) is controlled.

PATHWAY TO ECONOMIC IMPACT

Since the conclusion of its ARPA-E project, Primus Power has continued development of its product and reported the following progress in commercialization to ARPA-E, noting that the electrode/flow battery/battery systems addressed in the text below resulted directly from Primus' ARPA-E research project:

Since Primus Power was incorporated in 2009 (shortly before it received its ARPA-E award) the company has raised over $60 million in private investor funding from Anglo American Platinum, Chrysalix Energy Venture Capital, DBL Partners, I2BF Investors, Kleiner Perkins Caufield & Byers and Russia-Kazakhstan Nanotechnology Fund (RKNF).

The successful development of a long-life electrode for stationary storage systems has resulted in systems competitive with today's market-standard Lead (Pb)-Acid and Lithium (Li)-ion batteries. Primus Power has flow batteries available commercially in a modular 25 kW • 125 kWh system. Primus is developing market acceptance for its products through participation in demonstration projects, and has begun product sales.

A Primus battery is an integral part of a microgrid being tested at the Marine Corps Air Station (MCAS) in Miramar, California. The MCAS microgrid includes a 230 kW solar photovoltaic array, the Primus battery and an energy management system. Primus reports that the system has met the Marine Corp's two major requirements: reduce demand charges imposed by local utility when electricity is consumed at peak times, and provide power to critical systems when grid power is unavailable.

Primus has delivered ~20 battery systems and in September 2015 announced an order for 1,250 batteries from a major Asian utility with 21,000 MW of generating capacity. In October 2015, Primus delivered a "behind the meter" system to an industrial facility in Southern California. ICL – the Israeli specialty minerals giant – is using a single 20 kW battery to better manage electricity costs at the ICL manufacturing facility in Rancho Cucamonga.

In early 2016, Primus shipped its first international system. Samruk-Energy, the principal electricity provider in the Republic of Kazakhstan, will use a Primus battery system at a 2 MW solar farm in Kapchagay. Future battery systems to Samruk-Energy will be located at a 45 MW wind farm in Yermentau, outside of Kazakhstan's capital Astana. Kazakhstan has strongly embraced wind and solar and has set aggressive renewable energy goals: 30 percent by 2030 and 50 percent by 2050.

These initial commercial shipments provide the opportunity of learning curves for reduction in cost, and further product development to meet customer needs. Primus Power is targeting a wide range of storage applications for U.S. and international microgrid, utility, military, commercial and industrial customers.

LONG-TERM IMPACTS

In the past 5 years, the commercial development of batteries for grid-scale energy storage has become increasingly competitive. Plans to scale up manufacturing of Li-ion batteries to above 10 GWh/yr may decrease their costs by a further 30% or more and the batteries may deliver life cycles of up to 7,000. Flow cells in general have the potential to result in significantly greater cost reduction with production at scale, as a result potential for much larger life cycle numbers, and the independent scaling of energy and power.

Primus Power's electrode design technology developed under its ARPA-E award has demonstrated the competitive performance and lowered storage costs possible with flow batteries. Primus Power's flow battery system has demonstrated potential to deliver very long lifetimes, and to cost less when manufactured in high volumes than the projections for Li-ion batteries at scale. The demonstration of such new technologies in challenging commercial applications is an essential step in incentivizing growing use of battery storage for modernizing the electric power grid.

INTELLECTUAL PROPERTY

As of February 2016, this project has resulted in three subject invention disclosures, four patent applications, and one issued patent from the U.S. Patent and Trademark Office.

La O', GJ. "Electrolyte Flow Configuration for a Metal Halogen Flow Battery". (2012) *US Patent No. 8,137,831*. Washington, DC: U.S. Patent and Trademark Office.