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Vanadium Flow Batteries Could Become a Cost Effective Solution for Balancing Texas' Power Grid

By David Wogan | October 21, 2013 | 14

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David here. This is a post by Robert Fares, frequent guest of Plugged In. It's also cross-posted at the Cockrell School of Engineering's webpage. Robert and I engaged in a Twitter interview about his research on Friday, which you can read here.

The existing power grid has served us well for over a century. It persists as one of humankind's most impressive feats of engineering. Nevertheless, the grid has a number of key limitations that have become increasingly clear in recent years. One limitation is a lack of energy storage. Understanding exactly how new energy storage technologies might improve the electricity system is a complex operational research problem. My research, under Dr. Michael E. Webber in the Department of Mechanical Engineering, seeks to reveal the best ways to leverage new energy storage technologies on the grid. One appealing application for grid energy storage is the real-time balancing of power supply with demand. Our work recently published in the journal *Applied Energy* shows that an emerging battery technology called a vanadium redox flow battery could become a cost-effective solution for balancing Texas' grid.

Today, electric generators have to quickly ramp up and down to match electricity supply with demand at every moment in time because there is almost no storage buffer between electricity production and consumption. Even a temporary imbalance in power supply and demand could lead to a system-wide blackout. When power plants rapidly change their power output to keep the grid in balance, they deviate from their most efficient operating point, increasing fuel use and emissions.

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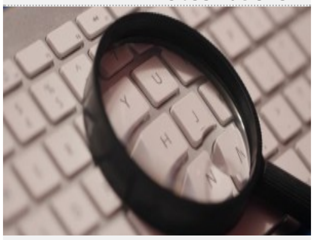

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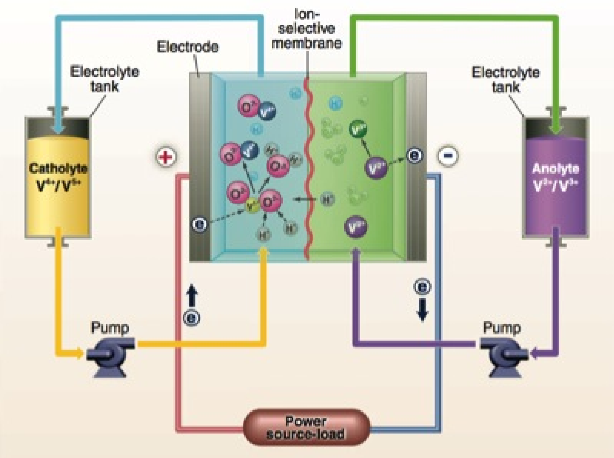
Modern battery technologies could unlock a better way to match electricity supply and demand in real time. Because batteries can alternately charge and discharge without releasing emissions or suffering major efficiency losses, using them for grid balancing could save energy, improve air quality and reduce greenhouse gas emissions. At the same time, using more batteries to balance the grid could free up power plants, allowing them to operate at peak efficiency. Because batteries use fast electrochemical reactions to store energy, they can keep electric supply and demand in tighter balance than a power plant, and reduce the number of power plants we need to balance the grid and keep the lights on. For these reasons, there are already a number of pilot projects evaluating the potential advantages of using fast-responding technologies like batteries on the grid, including in Texas.

We sought to determine when batteries used for grid balancing will become cost competitive with power plants. To answer this question, we performed a model-based economic analysis of a battery participating in Texas' wholesale electricity market, which is administered by the Electric Reliability Council of Texas (ERCOT).



A vanadium redox flow battery uses two different liquid vanadium solutions (an "anolyte" and a "catholyte") to store large quantities of electricity. Source: Dunn et al, 2011.

We modeled a megawatt-scale vanadium redox flow battery (VRFB), in other words, a flow battery large enough to power nearly 1000 typical residential homes. Unlike a traditional battery, a flow battery stores electricity in large tanks of chemical solution —making flow batteries modular and highly scalable. The flexible design reduces the cost of the battery system, and the all-liquid active materials give the battery a long operating lifetime. VRFBs last for ten or more years and can be charged and discharged over 10,000 times before they wear out. These features make VRFBs one of the most promising emerging grid energy storage technologies.

We used our VRFB model with publicly available electricity market price data to show the potential value of a battery performing "frequency regulation service," the technical term for balancing grid supply and demand. We implemented a decision-making program with the model to optimize when the battery offers frequency regulation service to the electricity market. The program shows when it's most valuable to use the battery, and calculates the maximum revenue that could be obtained from providing frequency regulation for Texas' grid with a VRFB.

Based on historic electricity prices published by ERCOT, our model shows that a

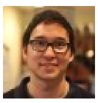
VRFB with a ten-year life could be a cost-competitive solution for grid balancing if its cost were to fall below $1,500 per kilowatt of rated battery power. The cost of a battery is typically expressed in dollars per kilowatt of rated power because the amount of materials required to build a battery scales directly with the amount of power the battery can deliver. Because VRFBs are still an emerging technology, their precise cost is uncertain right now. The most authoritative studies estimate the cost of a VRFB system designed for frequency regulation is about $1460-1613 per kilowatt of rated power. Thus, our results suggest that large-scale flow batteries are nearly a cost-competitive technology for balancing electricity supply and demand

Despite our findings, there are still a number of technical and non-technical challenges to wider use of grid energy storage. Conventional electricity markets and policies weren't designed around devices that can both produce and absorb electric energy. Furthermore, many energy storage technologies are relatively untested and still in the demonstration stage. Nevertheless, if the cost of grid energy storage falls significantly, it will almost certainly take on a larger role on the power grid.

Scientists and engineers around the world are exploring how to build large-scale batteries at costs suitable for grid applications. Along with the engineering challenges associated with building batteries, it is also important to understand the best way to utilize batteries on the grid in the future. Being a graduate student in the Cockrell School of Engineering gives me the opportunity to work with professors and other energy experts to find the answers to these difficult and prescient research questions.

In the future, I will continue my research exploring operational management of grid energy storage. As new storage technologies become more cost competitive, it will become increasingly important to understand the best ways to leverage energy storage to reduce the cost of electricity, increase the grid's reliability and integrate renewable energy.

Robert Fares is Ph.D. student in the Department of Mechanical Engineering at The University of Texas at Austin. As part of Pecan Street Inc.'s ongoing smart grid demonstration project, Robert's research looks at how energy storage models can be used with large-scale data and optimization for economic operational management of battery energy storage. Robert hopes to develop novel operational methods and business models that help to integrate distributed energy generation and energy storage technologies with restructured electricity markets and retail electric tariffs. Through his research, he hopes to demonstrate the marketability and technical compatibility of these new technologies.



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