Shaping the Future

Renaissance in Batteries for Utility-Scale Storage

By Brent Barker

For more than 200 years, battery technology has advanced in waves. In 1800, Alessandro Volta invented the first battery providing continuous current. In 1859, Gaston Planté invented the lead acid battery, establishing a chemistry that dominated the commercial and industrial battery market for 150 years. In the 1960s and 1970s, NASA-funded research unleashed a new wave of electrochemical innovation. In 1991, Sony introduced the first commercial lithium ion battery, and the technology's costs and performance have improved over the past 25 years as commercial giants LG, Samsung, Sony, Panasonic, and Tesla scaled up manufacturing.

Lithium ion dominates consumer electronics and electric vehicles, and Navigant Research reports that these batteries remain the leading form of energy storage for new projects worldwide—accounting for 83% of newly announced systems through the third quarter of 2016.

The growing need for grid storage to support solar and wind is providing energy to create a new wave of battery innovation.

"With more technologies such as sodium ion and flow batteries entering the picture, the big question for researchers and the electricity industry is, will the next generation include technologies other than lithium ion?" said Brittany Westlake, energy scientist in EPRI's Energy Storage and Distributed Generation program. "The answer will vary depending on the application."

In mobile battery applications such as electric vehicles, high energy density is critical. For stationary applications such as substations, cost, cycle life, and duration are paramount.

Sodium Ion Technologies

Sodium ion batteries are similar to their lithium ion counterparts, but sodium ions replace the transport charge. In the battery's discharge mode, electrons stripped from sodium atoms move through an external circuit to produce energy, while positive sodium ions are shuttled from the anode to the cathode, where they are intercalated (lodged) in the lattice structure.

"Think of intercalation as stuffing ping pong balls into spaced layers of chicken wire," said Westlake.

The key advantages of sodium ion: Sodium is more naturally abundant, and the aqueous electrolyte (such as salt water) is safer. Because lithium is highly reactive with water, organic electrolytes must be used, and the batteries must be carefully packaged to prevent electrolyte evaporation and possible short circuit.

The disadvantage: Sodium ion batteries are 25% larger and much heavier, which can result in longer charge and discharge times, as well as a lower energy and power density. "Sodium ion batteries may not be the best choice to replace lithium ion in electric vehicles," said Westlake. "But it could be competitive in stationary applications such as substations and remote grid-scale storage where weight and battery footprint are less important."

Several sodium ion start-up companies have entered the race for stationary battery markets. One of them, Alveo, emerged from Stanford University a few years ago. "There are a number of competitive cell chemistries in the stationary battery market," said Alveo Chief Executive Officer Colin Wessells. "Lead-acid, the current workhorse, is the cheapest but has a relatively short cycle life. Lithium ion has a good cycle life and costs are falling, but total costs for installed systems are still about $600 per kilowatt-hour."

Alveo and others are targeting markets in which they have a performance or economic advantage. They focus technology development on creating a battery with high power and long cycle life at a lower cost. Alveo is about a year away from sending out demonstration packages to interested parties.

Aquion, a sodium-ion startup out of Carnegie Mellon University, is focusing its products on long-duration storage for solar applications, providing cycles of 4 to more than 20 hours.

Flow Batteries

Flow batteries operate much like fuel cells: Two different electrolytes are pumped from separate tanks through a stack of electrochemical reaction cells to generate electricity. Enlarging the tanks prolongs the duration of the battery's *energy* output (kilowatt-hours) while enlarging the reaction cells increases the *power* output (kilowatts).

"One of the strengths of flow batteries is that they enable independent adjustments to energy and power, so that you can tailor the system design to your needs," said Westlake.

A 2015 EPRI survey of 20 commercial flow battery companies provides a snapshot of the market, including information on chemistry and products. According to the study, all-vanadium and zinc bromide chemistries account for the most commercially available products, with system power averaging 763 kilowatts and 1507 kilowatts, respectively. The most economic application of flow batteries is for daily discharging of 4 or more hours.

Pacific Northwest National Laboratories (PNNL) has pioneered flow battery technology, and three companies have licensed its vanadium battery design, which increased storage capacity by 70%. PNNL is developing an organic-aqueous flow battery with the potential to produce energy at $180 per kilowatt-hour, 60% less than the cost for vanadium flow batteries.

"We're in a battery chemistry renaissance," said Wessells. "There are many more new technologies being commercialized than you would have imagined 10 years ago. Most are not going to work out, but it is good for the industry that so many things are being attempted."

Key EPRI Technical Experts

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