Large scale batteries

Large scale batteries

In the coming decades, renewable energy sources such as solar and wind will increasingly dominate the conventional power grid. Because those sources only generate electricity when it''s sunny or windy, ensuring a reliable grid -- one that can deliver power 24/7 -- requires some means of storing electricity when supplies are abundant and delivering it later when they''re not. And because there can be hours and even days with no wind, for example, some energy storage devices must be able to store a large amount of electricity for a long time.

A flow battery contains two substances that undergo electrochemical reactions in which electrons are transferred from one to the other. When the battery is being charged, the transfer of electrons forces the two substances into a state that''s "less energetically favorable" as it stores extra energy. (Think of a ball being pushed up to the top of a hill.) When the battery is being discharged, the transfer of electrons shifts the substances into a more energetically favorable state as the stored energy is released. (The ball is set free and allowed to roll down the hill.)

When the battery is being discharged, active species on the negative side oxidize, releasing electrons that flow through an external circuit to the positive side, causing the species there to be reduced. The flow of those electrons through the external circuit can power the grid. In addition to the movement of the electrons, "supporting" ions -- other charged species in the electrolyte -- pass through the membrane to help complete the reaction and keep the system electrically neutral.

Once all the species have reacted and the battery is fully discharged, the system can be recharged. In that process, electricity from wind turbines, solar farms, and other generating sources drives the reverse reactions. The active species on the positive side oxidize to release electrons back through the wires to the negative side, where they rejoin their original active species. The battery is now reset and ready to send out more electricity when it''s needed. Brushett adds, "The battery can be cycled in this way over and over again for years on end."

Recovering capacity lost to crossover requires some sort of remediation -- for example, replacing the electrolyte in one or both tanks or finding a way to reestablish the "oxidation states" of the active species in the two tanks. (Oxidation state is a number assigned to an atom or compound to tell if it has more or fewer electrons than it has when it''s in its neutral state.) Such remediation is more easily -- and therefore more cost-effectively -- executed in a flow battery because all the components are more easily accessed than they are in a conventional battery.

A critical factor in designing flow batteries is the selected chemistry. The two electrolytes can contain different chemicals, but today the most widely used setup has vanadium in different oxidation states on the two sides. That arrangement addresses the two major challenges with flow batteries.

Large scale batteries

First, vanadium doesn''t degrade. "If you put 100 grams of vanadium into your battery and you come back in 100 years, you should be able to recover 100 grams of that vanadium -- as long as the battery doesn''t have some sort of a physical leak," says Brushett.

And second, if some of the vanadium in one tank flows through the membrane to the other side, there is no permanent cross-contamination of the electrolytes, only a shift in the oxidation states, which is easily remediated by re-balancing the electrolyte volumes and restoring the oxidation state via a minor charge step. Most of today''s commercial systems include a pipe connecting the two vanadium tanks that automatically transfers a certain amount of electrolyte from one tank to the other when the two get out of balance.

However, as the grid becomes increasingly dominated by renewables, more and more flow batteries will be needed to provide long-duration storage. Demand for vanadium will grow, and that will be a problem. "Vanadium is found around the world but in dilute amounts, and extracting it is difficult," says Rodby. "So there are limited places -- mostly in Russia, China, and South Africa -- where it''s produced, and the supply chain isn''t reliable." As a result, vanadium prices are both high and extremely volatile -- an impediment to the broad deployment of the vanadium flow battery.

Indeed, comparing the economics of different options is difficult because "there are so many dependent variables," says Brushett. "A flow battery is an electrochemical system, which means that there are multiple components working together in order for the device to function. Because of that, if you are trying to improve a system -- performance, cost, whatever -- it''s very difficult because when you touch one thing, five other things change."

So how can we compare these new and emerging chemistries -- in a meaningful way -- with today''s vanadium systems? And how do we compare them with one another, so we know which ones are more promising and what the potential pitfalls are with each one? "Addressing those questions can help us decide where to focus our research and where to invest our research and development dollars now," says Brushett.

A good way to understand and assess the economic viability of new and emerging energy technologies is using techno-economic modeling. With certain models, one can account for the capital cost of a defined system and -- based on the system''s projected performance -- the operating costs over time, generating a total cost discounted over the system''s lifetime. That result allows a potential purchaser to compare options on a "levelized cost of storage" basis.