Making 'renewable' viable: Engineers develop new technology for grid-level electrical energy storage

July 11 2012

In the aftermath of the recent United Nations Rio+20 Conference on Sustainable Development, the focus of many industrialized nations is beginning to shift toward planning for a sustainable future. One of the foremost challenges for sustainability is efficient use of renewable energy resources, a goal that hinges on the ability to store this energy when it is produced and disburse it when it is needed.

A team of researchers from Drexel University's College of Engineering have taken up this challenge and has developed a new method for quickly and efficiently storing large amounts of electrical energy.

The Challenge of Renewable Energy

Electrical energy storage is the obstacle preventing more widespread use of renewable energy sources such as wind and solar power. Due to the unpredictable nature of wind and solar energy, the ability to store this energy when it is produced is essential for turning these resources into reliable sources of energy. The current U.S. energy grid system is used predominantly for distributing energy and allows little flexibility for storage of excess or a rapid dispersal on short notice.

The Drexel's team of researchers is putting forward a plan to integrate into the grid an electrochemical storage system that combines principles behind the flow batteries and supercapacitors that power our daily technology.

Existing Technology

Batteries store a large amount of energy, but are relatively slow in discharging it and they have a limited lifespan, or cycle-life, than their counterparts – electrochemical capacitors, which are commonly called "supercapacitors" or "ultracapacitors."

Conventional supercapacitors provide a high power output with minimal degradation in performance for as many as 1,000,000 charge-discharge cycles. The capacitor can rapidly store and discharge energy, but only in small amounts compared to the battery.

The obstacle in the way of using either a battery or a supercapacitor to store energy in the grid is that energy storage ability is inextricably tied to the size of the battery or the supercapacitor being used. Supercapacitors, similar to lithium-ion batteries, are manufactured in fairly small cells ranging in size from a coin to a soda can. Large amounts of expensive material, such as metal current collectors, polymer separators and packaging, would be required to construct a battery or supercapacitor of the size necessary to function effectively in the energy grid.

"Packing together thousands of conventional small devices to build a system for large-scale stationary energy storage is too expensive," said Dr. Yury Gogotsi, director of the A.J. Drexel Nanotechnology Institute and the lead researcher on the project. "A liquid storage system, the capacity of which is limited only by the tank size, can be cost-effective and scalable."

A Grid Energy Storage Solution

The team's research yielded a novel solution that combines the strengths of batteries and supercapacitors while also negating the scalability problem. The "electrochemical flow capacitor" (EFC) consists of an electrochemical cell connected to two external electrolyte reservoirs - a design similar to existing redox flow batteries which are used in electrical vehicles.

This technology is unique because it uses small carbon particles suspended in the electrolyte liquid to create a slurry of particles that can carry an electric charge.

Uncharged slurry is pumped from its tanks through a flow cell, where energy stored in the cell is then transferred to the carbon particles. The charged slurry can then be stored in reservoirs until the energy is needed, at which time the entire process is reversed in order to discharge the EFC.

The main advantage of the EFC is that its design allows it to be constructed on a scale large enough to store large amounts of energy, while also allowing for rapid disbursal of the energy when the demand dictates it.

"By using a slurry of carbon particles as the active material of supercapacitors, we are able to adopt the system architecture from redox flow batteries and address issues of cost and scalability," Gogotsi said

In flow battery systems, as well as the EFC, the energy storage capacity is determined by the size of the reservoirs, which store the charged material. If a larger capacity is desired, the tanks can simply be scaled up in size. Similarly, the power output of the system is controlled by the size of the electrochemical cell, with larger cells producing more power.

"Flow battery architecture is very attractive for grid-scale applications because it allows for scalable energy storage by decoupling the power and energy density," said Dr. E.C. Kumbur, director of Drexel's Electrochemical Energy Systems Laboratory. "Slow response rate is a common problem for most energy storage systems. Incorporating the rapid charging and discharging ability of supercapacitors into this architecture is a major step toward effectively storing energy from fluctuating renewable sources and being able to quickly deliver the energy, as it is needed."

This design also gives the EFC a relatively long usage life compared to currently used flow batteries. According to the researchers, the EFC can potentially be operated in stationary applications for hundreds of thousands of charge-discharge cycles.

"This technology can potentially address cost and lifespan issues that we face with the current electrochemical energy storage technologies," Kumbur said.

"We believe that this new technology has important applications in [the renewable energy] field," said Dr. Volker Presser, who was an assistant research professor in the Department of Materials Science and Engineering at the time the initial work was done. "Moreover, these technologies can also be used to enhance the efficiency of existing power sources, and improve the stability of the grid."

This concept for energy storage was recently published in a special issue of *Advanced Energy Materials* focused on next-generation batteries. The team's ongoing work is focused on developing new slurry compositions based on different carbon nanomaterials and electrolytes, as well as optimizing their flow capacitor design. The group is also designing a small demonstration prototype to illustrate the fundamental operation of the system.

"We have observed very promising performance so far, being close to that of conventional packaged supercapacitor cells," Gogotsi said. "However, we will need to increase the energy density per unit of slurry volume by an order of magnitude, and achieve it using very inexpensive carbon and salt solutions to make the technology practical."

Provided by Drexel University

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https://phys.org/news/2012-07-renewable-viable-technology-grid-level-electrical.html