Carbon-Enhanced Lead-Acid Batteries

Improving the performance and reducing the cost of lead-acid batteries for large-scale energy storage

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

Energy Storage Program

Sandia National Laboratories

Lead-acid batteries are currently used in a variety of applications, ranging from automotive starting batteries to storage for renewable energy sources.

Lead-acid batteries form deposits on the negative electrodes that hinder their performance, which is a major hurdle to the wider use of lead-acid batteries for grid-scale energy storage. The formation of deposits is exacerbated under the operating conditions required by many large-scale energy storage systems, which cycle at a high electrical current while remaining in a partially charged state (high-rate, partial state of charge operation, or HRPSoC).

In 1997, researchers made two important advancements to lead-acid batteries. First, the Japan Storage Battery Company showed that adding carbon to the battery dramatically reduces the formation of deposits, thereby increasing performance and lifetime. However, the mechanism by which certain carbons enhance battery performance remains unclear. Second, the Australian Commonwealth Scientific and Industrial Research Organization developed the UltraBattery®, which combines a lead-acid battery and a capacitor into a single cell, with the capacitor acting as a buffer of the high rates of charge/discharge. The UltraBattery® allows the battery to be used for long periods in HRPSoC. This reduces the stress on the lead-acid battery, allowing a much longer life, as well as a quick charge acceptance and power discharge.

Technology Benefits

Sealed Lead-Acid Batteries

- Eliminate the threat of an acid spill or emissions and require little maintenance, due to the battery's sealed design
- Exhibit low self-discharge

Carbon-Enhanced Lead-Acid Batteries

- Improve battery cycle life dramatically
- Require minimal modification of existing industrial-scale manufacturing processes
- Offer a potential low-cost, high-performance energy storage solution for grid-scale applications

Overview

The Office of Electricity Delivery and Energy Reliability's Energy Storage Systems (ESS) Program is funding research and testing to improve the performance and reduce the cost of lead-acid batteries. Research to understand and quantify the mechanisms responsible for the beneficial effect of carbon additions will help demonstrate the near-term feasibility of grid-scale energy storage with lead-acid batteries, and may also benefit other battery chemistries.

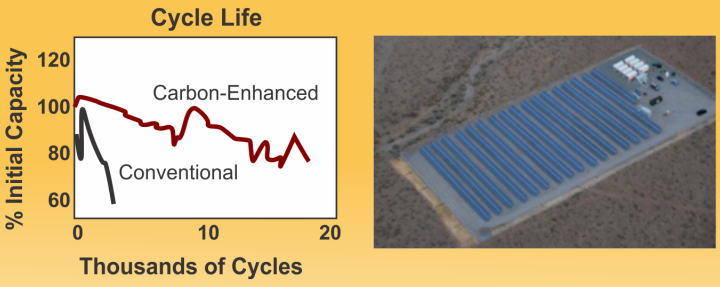
The ESS Program is also working with Ecoult on its UltraBattery® technology to characterize and measure its performance in various applications. In addition, the solar smoothing functionality of the UltraBattery® technology is being demonstrated in a 500 kWh solar energy smoothing and 1 MWh solar energy shifting demonstration project with the Public Service Company of New Mexico (PNM).

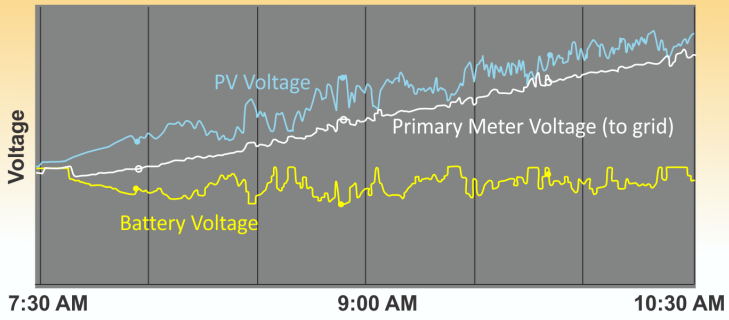
Technology Breakthrough

Above left: Adding carbon to a lead-acid battery improves its performance and lifetime compared to conventional technology.

Above right: The Public Service Company of New Mexico (PNM) grid-scale demonstration project.

Below: The PNM grid-scale demonstration project shows that the UltraBattery® can smooth the variable output of the solar panels.





Project Timeline

Ongoing research and development will reduce the costs and improve the performance of lead-acid batteries.

1997:
Research shows that adding carbon to a lead-acid battery greatly reduces the accumulation of a deposit within the battery, increasing the battery performance and lifetime.

Dr. Lam Lan develops the UltraBattery®, a lead-acid battery that uses a capacitor to buffer high rates of charge.

2002:
Different carbon forms are shown to offer very different benefits for battery performance and lifetime.

2006:
The Advanced Lead Acid Battery Consortium initiates the carbon-enhanced lead-acid battery demonstration project.

2007: East Penn Manufacturing becomes licensee of UltraBattery® for global markets outside Japan and Thailand.

2009:
East Penn Manufacturing receives several U.S. Department of Energy grants to pursue advanced lead-acid battery research.

2010:
August: Sandia National Laboratories (SNL) enters a Cooperative Research and Development Agreement (CRADA) with East Penn Manufacturing to study the effect of carbon on lead-acid batteries.

2011:
October: The PNM grid-scale demonstration is commissioned using the UltraBattery® for smoothing and advanced lead carbon for shifting. This project has already proven the solar smoothing functionality of the UltraBattery® technology.

2012:
June: The PJM grid-scale demonstration (3 MW) is commissioned using the UltraBattery®.

December: The SNL/East Penn Manufacturing CRADA project will end. Electrochemical characterization and cycling results from batteries using several types of carbon will be compared with chemical and structural analysis of the carbons and carbon-enhanced anodes. The findings will be used to evaluate the effect of cycling on the batteries.

Challenges

- Sulfate deposits accumulate on the electrode surface, limiting the capacity and cycle life of lead-acid batteries
- Researchers do not yet fully understand the characteristics of carbon that are beneficial or detrimental to lead-acid batteries
- Lead-acid batteries have a low energy-to-weight ratio compared to other battery types
- Lead-acid batteries are slower to recharge than other battery types

Project Partners

- Sandia National Laboratories
  www.sandia.gov
- East Penn Manufacturing
  www.dekabatteries.com
- Ecoult
  www.ecoult.com

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Related Reading

Sandia National Laboratories, "Energy Storage Systems Program (ESS)," http://www.sandia.gov/ess/.

Advanced Lead-Acid Battery Consortium, http://www.alabc.org/about.

Importance of Energy Storage

Large-scale, low-cost energy storage is needed to improve the reliability, resiliency, and efficiency of next-generation power grids. Energy storage can reduce power fluctuations, enhance system flexibility, and enable the storage and dispatch of electricity generated by variable renewable energy sources such as wind, solar, and water power. The Office of Electricity Delivery and Energy Reliability Energy Storage Program funds applied research, device development, bench and field testing, and analysis to help improve the performance and reduce the cost of energy storage technologies.

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