Researchers seek longer battery life for electric locomotive

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Norfolk Southern operates 21,000 route-miles in 22 states. Credit: Michael Bezilla

(Phys.org)—Norfolk Southern Railway No. 999 is the first all-electric, battery-powered locomotive in the United States. But when one of the thousand lead-acid batteries that power it dies, the locomotive shuts down. To combat this problem, a team of Penn State researchers is developing more cost-effective ways to prolong battery life.

The experimental locomotive's batteries, just like automotive batteries, are rechargeable until they eventually die. A leading cause of damage and death in lead-acid batteries is sulfation, a degradation of the battery caused by frequent charging and discharging that creates an accumulation of lead sulfate.

In a recent study, the researchers looked for ways to improve regular battery management practices. The methods had to be nondestructive, simple and cheap—using as few sensors, electronics and supporting hardware as possible while still remaining effective at identifying and decreasing sulfation.

"We wanted to reverse the sulfation to rejuvenate the battery and bring it back to life," said Christopher Rahn, professor of mechanical engineering.

Rahn, along with mechanical engineering research assistants Ying Shi and Christopher Ferone, cycled a lead-acid battery for three months in the same way it would be used in a locomotive. They used a process called electroimpedance spectroscopy and full charge/discharge to identify the main aging mechanisms. Through this, the researchers identified sulfation in one of the six battery cells. They then designed a charging algorithm that could charge the battery and reduce sulfation, but was also able to stop charging before other forms of degradation occurred. The algorithm successfully revived the dead cell and increased the overall capacity. The researchers, who report their results in the current issue of the Journal of Power Sources, then compared the battery to a new battery.

"We desulfated it, and we increased its capacity," said Rahn. "We didn't increase it all the way to brand new. We weren't able to do that, but we did get a big boost."

The researchers increased the cell capacity by 41 percent and the overall battery capacity by 30 percent. Even better results might have occurred if sulfation were the only aging mechanism at play, but the researchers found other factors reduced capacity, as well.

"Some of the other cells we identified may have had a water loss issue," said Rahn. "And for these types of batteries, there's nothing you can do about it."

Other mechanisms that can damage lead-acid batteries include positive electrode corrosion, irreversible hard sulfation, positive electrode softening or shedding, electrolyte stratification, internal short-circuiting and mechanical damage.

The researchers are now developing alternative models to replace the electroimpedance spectroscopy model that would allow charging right up to, but not past, sulfation in batteries where sulfation is not yet present, hoping to prevent it from occurring in the first place.

"You would charge as fast as you can and right when you see gassing starting to happen, you ramp down and reduce the current charging," said Rahn. "It's still related to degradation, but it's not really a rejuvenation project anymore."

Penn State and Norfolk Southern, which operates 21,000 route-miles in 22 states, began developing locomotive No. 999 in 2008 to evaluate the application of battery technologies for railroad motive power, with particular interest in energy savings and emissions reduction.

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