New research on lithium titanate oxide batteries can help transit engineers design better energy storage systems

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San Jose, CA – April 6, 2015 – Electrical energy storage, rather than fuel combustion, has become a key component in transit fleets that are switching to more efficient hybrid and electric vehicles. To help engineers and technicians make that change, researchers at Penn State's Thomas D. Larson Pennsylvania Transportation Institute, funded through a grant from the Mineta National Transit Research Consortium, studied lithium titanate oxide battery chemistry for use in transit buses. Their report, *Electrical and Thermal Modeling of a Large-Format Lithium Titanate Oxide Battery System*, is available for free download from http://transweb.sjsu.edu/project/1150.html. The principal investigator was Timothy Cleary, MS, assisted by research associates Harshad Kunte, MS, and Jim Kreibick.

This research supports the work of those who are involved with battery system integration and management. The tools produced from the study are intended to help automotive engineers achieve optimal system performance and ultimately a more efficient vehicle.

The research team found, other than proprietary data/models, there was little technical information or research on electrical and thermal modeling of this advanced chemistry. So they developed a laboratory test setup of a prototype lithium titanate oxide battery pack to study their characteristic behaviors. They then produced state-of-charge estimators capable of running on the limited embedded processing power and memory of a typical battery management system.

"We also investigated the thermal performance of this chemistry in the large format, producing a physics-based empirical thermal model for use in system-level simulations," said Mr. Cleary. "This model predicts pack-level thermal behavior by reporting the minimum, maximum, and average temperatures within a system typically used for large automotive applications, as testing was concentrated on transit bus usage profiles."

Chapters in the 91-page report include: Introduction; Test Setup; Battery Management System SOC Estimation; Battery Management System Sensitivity Analysis; Equivalent Circuit Model; State-of-Charge Estimation Using Extended Kalman Filter; Thermal Testing; and Thermal Model. The publication includes 69 figures and two appendices.

For a free, no-registration download, go to http://transweb.sjsu.edu/project/1150.html

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ABOUT THE PRINCIPAL INVESTIGATORS

TIMOTHY CLEARY is director of the Battery Application Technology Testing & Energy Research Laboratory (BATTERY) at the Larson Institute at Penn State. He earned his BSc and MS degrees in mechanical engineering from Penn State. He was involved in the US DOE-sponsored Advanced Vehicle competitions for five years, culminating in his service as team leader for the 2007-2008 competition. Currently he is a faculty advisor for the Penn State EeoCAR3 team. In 2009-2010, he was a vehicle systems and simulation contracted engineer supporting US DOE research in pluggable hybrid electric vehicles. In 2010-2011 he gained Top Secret security clearance and assisted the U.S. Army's Seeker Effects Laboratory in performing infrared countermeasure testing.

HARSHAD KUNTE is a systems design architect engineer for Tesla Motors. He earned a master's degree in mechanical engineering at Penn State in 2014 with a focus on control systems engineering. His research interests are in battery systems modeling and control, primarily for electric and hybrid vehicles. At Penn State's Larson Institute, he served the BATTERY Lab as a research assistant and contributed to its extensive work in testing, modeling, and verification of large-format battery systems.

JAMES A. KREIBICK is a graduate student in electrical engineering at Penn State. His interests focus around control systems and power systems. His role in this study included testing setup and data acquisition during battery testing. He has also been actively involved in the Penn State Advanced Vehicle team, including participation in the EcoCAR 2 competition sponsored by General Motors and the Argonne National Laboratory.

ABOUT THE MINETA NATIONAL TRANSIT RESEARCH CONSORTIUM
The Mineta National Transit Research Consortium (MNTRC) is composed of nine university transportation centers led by the Mineta Transportation Institute at San Jose State University. The Consortium was organized in January 2012 after winning a competition sponsored by the US Department of Transportation (DOT) to create consortia tasked with "Delivering Solutions that Improve Public Transportation." Member universities include Bowling Green State University, Grand Valley State University, Howard University, Penn State, Rutgers University, San Jose State University, University of Detroit Mercy, University of Nevada Las Vegas, and University of Toledo. Visit transweb.sjsu.edu/mntrc

ABOUT THE MINETA TRANSPORTATION INSTITUTE
The Mineta Transportation Institute (MTI) conducts research, education, and information transfer programs regarding surface transportation policy and management issues, especially related to transit. Congress established MTI in 1991 as part of the Intermodal Surface Transportation Efficiency Act. MTI won national re-designation competitions in 2002, 2006 and 2012. The Institute is funded through the US Department of Transportation, the US Department of Homeland Security, the California Department of Transportation, and public and private grants. The internationally respected members of the MTI Board of Trustees represent all major surface transportation modes. MTI, the lead institute for the nine-university Mineta National Transit Research Consortium, is affiliated with San Jose (CA) State University's College of Business. Visit transweb.sjsu.edu

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Contact: Donna Maurillo
MTI Communications Director
831-234-4009 (24 hours)
donna.maurillo (at) sjsu.edu