Smart Battery Management System for Electric Vehicles: Self-learning Algorithms for Simultaneous State and Parameter Estimation, and Stress Detection

Design of smart battery management systems (BMS)

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$110,000

Electric vehicles (EVs) are the future of transportation systems due to their cost-effective, eco-friendly nature. The rapid growth in energy storage technologies such as lithium-ion (Li-ion) battery with high energy density has accelerated the acceptance of EVs in recent years. Efficient operation of Li-ion batteries in EVs requires an intelligent and smart battery management system (BMS) capable of learning the health degradation to accurately estimate the state-of-charge (SOC) and the state-of-health (SOH). This will add autonomy to the BMS in health-conscious decision making such as fast charging, discharging, cell balancing, and optimal power and energy management. The design of smart BMS requires the developing 1) enhanced SOC and SOH dependent parameter-varying dynamical models of Li-ion battery and 2) real-time learning algorithms to learn the parameter-varying model. The enhanced electric circuit model (ECM) of the Li-ion battery, by incorporating the SOH indicators such as capacity loss and power loss, both under normal and accelerated degradation conditions, can also detect internal faults and stress.

Problem Statement

The recent additions of Li-ion battery in the high-end plug-in EV categories offer approximately 300 miles on a single charge. It is expected that the Li-ion battery market will also reach $92 billion by 2024. However, the volatility of internal constituents, flammability, and toxicity of the electrolyte, which is the adverse side of the high energy density of Li-ion battery, make the cells thermally unstable at high temperatures and reduces life when operating at low temperatures. Further, the low tolerance to abuse (overcharging and discharging) and vulnerability to thermal runway and explosion jeopardize user safety, which is a national concern. A battery management system (BMS) is employed for the safe and efficient operation of the Li-ion battery. In addition to battery operation, the BMS also serves the purpose of estimating the state of the charge (SOC) of the battery, which is utilized to compute the range of the EV.

Objectives

Our preliminary results on the development of nonlinear parameter-varying models of Li-ion battery show the potential and the feasibility of the proposed research. The following must be completed:

- Task 1. Literature survey to explore internal and external stress-inducing factors on Li-ion batteries on-board EVs and study their effects on capacity fade, power fade, and internal parameter variation.
- Task 2. Draft an enhanced SOC and SOH dependent parameter varying ECM of Li-ion battery by including both normal and rapid aging in extreme conditions.
- Task 3. Develop self-learning algorithms using neural networks to learn the SOC and SOH dependent battery model with real-time measurements.
- Task 4. Develop faults/stress detection methods with the developed model and experimentally validate the designs in the laboratory.

Intended Implementation of Research

Workforce Development: This will be achieved directly by training graduate, undergraduate, and high school students interested in pursuing a career in STEM or Transportation Engineering career.

Education: The main motive is to engage and educate students, teachers, and working professionals with innovative multidisciplinary research and technology both on theoretical and experimental standpoints. Specially, we will work

on two aspects, i.e., course development and outreach activities. The PI is developing a graduate-level curriculum in Mechatronics and Robotics at OSU and has proposed graduate-level courses on Intelligent Systems. The research results on machine-learning and intelligent control will be used for the courses. This multidisciplinary course is expected to expose students to the developed theoretical results for battery management to prepare them to interact with both the intelligent control and electric vehicle community. To influence undergraduate education, the PI will integrate the machine learning approaches developed during the research into his Capstone design courses. The students will be learn machine learning algorithms for life cycle management and the safety of Li-ion batteries used for the design projects and the development of intelligent products.

Outreach: Technical articles, posters, and presentations will be delivered at national and local conferences and symposia such as ASCE, Transportation Research Board and, Tran-SET.

Anticipated Impacts/Benefits of Implementation

The main deliverables from this study are: (1) a bi-annual report and final report containing complete description of the problem and methodology procedures; (2) journal publications and presentations at the annual national conferences.

Figure 1: Effects of stress and operating conditions on battery internal constituents leading to health degradation

Web links

- Tran-SET's website https://transet.lsu.edu/research-in-progress/

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.