Intelligent Incipient Fault Detection System for Electric Vehicle Battery: Fault Isolation Schemes and Prototype Development

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Developing an incipient fault detection system for electric vehice batteries

Lithium-ion (Li-ion) batteries are the primary power source for electric vehicles (EVs) due to their high energy and power density, and long life-cycle. The recent variants of the high-end plug-in EVs, with Li-ion battery pack, offer a range of approximately 300 miles on a single full charge close to their gasoline counterparts. Further, to bridge the gap between the fueling time of the gas-powered vehicles and the charging time of EVs, high power chargers have also been introduced, reducing the charging time to less than 30 minutes. The Li-ion battery packs operate at maximum limits to deliver the required power to achieve these optimal performances. The extreme operating conditions and abusive operations may lead to internal and external faults, such as short circuits, cell internal temperature rise, lithium plating and loss of lithium, and mechanical failure due to vibration. These internal faults have a cumulative effect on the battery's health, aggravating the vulnerability to thermal runaway. The proposed research project's overall objective is to develop, implement, and validate an intelligent fault detection scheme capable of detecting a Li-ion battery's internal faults in its incipient stage.

Problem Statement

Lithium-ion (Li-ion) batteries are the primary energy storage devices for electric vehicles (EVs) due to their high energy and power density and long life-cycle. The recent variants of the high-end plug-in EV (PEV) with Li-ion battery pack offer a range of approximately 300 miles on a single full charge, which is close to their gasoline counterparts. Further, to bridge the gap between the fueling time of the gas-powered vehicles and the charging time of EVs, high power chargers have also been introduced, reducing the charging time to less than 30 minutes. However, the volatility of internal constituents, electrolyte's flammability, and toxicity make the cells thermally unstable at high temperatures and reduce life when operating at low temperatures. Further, the low tolerance to abuse (overcharging and discharging) and vulnerability to thermal runaway jeopardize user safety, leading to an explosion, which is a national concern. Moreover, the Li-ion battery packs are operated at their maximum operating limits to deliver EVs' required power. The extreme operating conditions and abusive operations may lead to internal and external faults, such as short circuits, cell internal temperature rise, lithium plating and loss of lithium, and solid electrolyte interface (SEI) layer formation. These internal faults have a cumulative effect on the battery's health, aggravating the vulnerability to thermal runaway. Various external safety mechanisms are employed in the battery management systems (BMS) to protect the battery from external fault conditions. However, it is still challenging to detect the internal faults from the available measurements, i.e., voltage, current, and surface temperature.

Objectives

The project's overall objective is to develop, implement, and validate an intelligent fault detection scheme capable of detecting a li-ion battery's internal faults in its incipient stage. The objective will be attained by 1) developing failure mode analysis schemes identifying the root-causes, 2) developing computationally efficient fault detection algorithms using real-time machine learning, 3) developing Field Programmable Gate Array (FPGA)-based hardware architecture to implement fault detection scheme, and 4) validating the prototype experimentally.

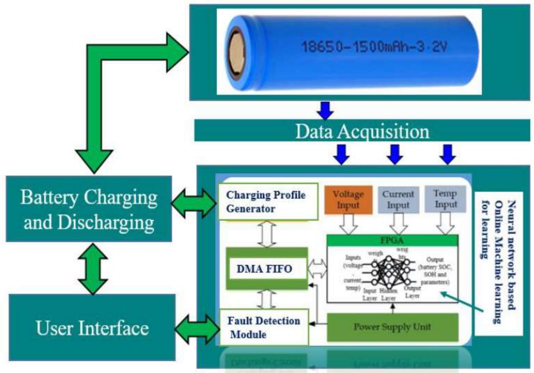

Figure 1. Hardware proposed architecture of the intelligent fault detection system

Intended Implementation of Research

The project's success will provide necessary theoretical results along with the prototype of the fault detection system for the safe operation of Li-ion battery, fostering its adoption by stakeholders. The primary motive is to engage and educate students and working professionals on this innovative multidisciplinary research and technology development. Specially, two aspects will be worked on, i.e., curriculum and course development and outreach activities. The relationship between educational and research activities will be nourished by leveraging synergistic collaborations with on- and off-campus organizations. This research will involve one graduate student. The research outcomes will be disseminated to the research community, state agencies, and transportation industries via journal publications, conference publications, and presentations. The PI will host workshops for imparting the knowledge to community college teachers and K-12 students.

Anticipated Impacts/Benefits of Implementation

The prototype and the experimental validation results obtained in this study will significantly increase the potential for implementation. The intelligent fault detection scheme will increase the battery operational safety and, in turn, electric vehicle, which is critical for its adoption. The expected benefits to the transportation community are:

1) Intelligent fault detection schemes, which can detect internal fault in an incipient stage, will provide the EV user time to carry out maintenance before safety becomes an issue.
2) The fault detection scheme will inform the EV user about the battery pack's current state, increasing the vehicle user's confidence and promoting ubiquitous acceptance.
3) Detection of internal and external faults can prevent thermal runaway and explosion.
4) The fault detection scheme can be used for determining the current state of health and the remaining useful life of the battery accurately, which will reduce the maintenance cost.
5) The experimentally validated results will minimize the barrier to the adoption of the technology by stakeholders.

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.