Battery Management System Development for Electric Vehicles and Fast Charging Infrastructure Improvement

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Introduction

With the rising popularity of electric vehicles (EVs), the issue of range anxiety has become increasingly prevalent among EV drivers. Substandard lithium-ion batteries utilized in EVs not only diminish the rated cruise range but also pose safety hazards and exacerbate traffic congestion. Amidst these challenges, the integration of an efficient Battery Management System (BMS) emerges as a viable solution to alleviate range anxiety and extend battery lifespan without burdening customers with additional costs for battery replacement. However, despite the commercialization of numerous BMS solutions, significant limitations persist. Firstly, existing BMS solutions often rely on pre-established models of lithium-ion batteries, necessitating prior knowledge of the State-of-Charge to Open Circuit Voltage (SOC-OCV) curve, thereby restricting adaptability. Secondly, State-of-Charge (SOC) estimation methodologies predominantly rely on filter-based approaches, lacking optimality and robustness.To address these issues, this project conducts preliminary studies focusing on key BMS technologies, encompassing battery modeling, SOC estimation, and hardware implementation. Delving into these areas enables the industry to overcome existing limitations, paving the way for more advanced and effective BMS solutions in the realm of electric vehicle technology.

Study Methods

The fast-charging data for the Sanyo battery 18650 3.7V 2.6Ah is acquired under the (CC BY 4.0) license, providing a foundational dataset for our research endeavors. Leveraging this dataset, our research team embarks on constructing a robust battery model through a systematic two-step process. Initially, we develop the static component of the equivalent circuit model (ECM), comprising diverse features, and identify the parameters using the Least Absolute Shrinkage and Selection Operator (LASSO) technique. Subsequently, we tackle the dynamic aspect of the ECM, representing it as a discrete transfer function. Through iterative refinement, we minimize model error without reliance on prior knowledge of the SOC-OCV curve.

Next, we proceed to construct the moving horizon estimator (MHE), a pivotal component in real-time SOC estimation. The objective function of the MHE incorporates two critical terms. The first term aims to minimize the disparity between voltage measurements and corresponding values derived from the battery model within a pre-defined estimation window. And the second term focuses on minimizing discrepancies in SOC change, calculated via the Coulomb counting method and those derived from the battery model over the same estimation window. Solving this optimization problem facilitates real-time SOC estimation.

Finally, to bridge the gap between algorithmic development and practical application, we implement the Coulomb counting approach on an FPGA board, a crucial step in real BMS development. We utilize MATLAB SIMULINK for algorithm development, seamlessly converting it to Hardware Description Language (HDL) automatically. This HDL code can then be directly deployed onto the FPGA board, ensuring efficient and effective integration of our algorithm into real-world BMS systems.

Findings

The proposed study has the following findings:

- Enhancing the traditional ECM involves introducing additional, functional features into the static components while keeping the dynamic components as the first-order z-transfer function. Employing feature selection techniques, such as LASSO, can screen all the introduced features and improve the model accuracy.

- Despite its time-intensive nature, MHE demonstrates high accuracy in the SOC estimation, particularly when both voltage and current are integrated into the optimization process.
- MATLAB/SIMULINK emerges as a user-friendly and versatile platform for both high-level software programming and Hardware Description Language (HDL) coding, facilitating seamless development for FPGA integration.

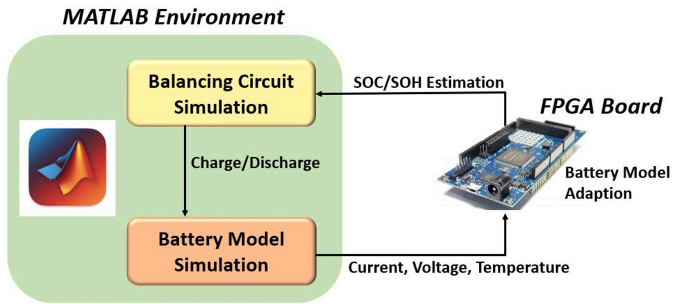
These findings collectively contribute to the advancement of battery management systems, offering insights into optimizing model accuracy and real-time SOC estimation, alongside streamlined development processes through MATLAB/SIMULINK.

The moving horizon estimator applied on an enhanced equivalent circuit model achieves high accuracy in state-of-charge estimation.

Policy Recommendations

The research findings underscore two key recommendations:

1. Exploring advanced feature extraction and selection methods in the data-driven modeling of battery energy storage systems offers a promising avenue to circumvent the need for complex electrochemical equations. By leveraging sophisticated approaches, such as machine learning algorithms, researchers can potentially enhance accuracy and efficiency in battery modeling without resorting to computationally intensive methods.
2. Integration of optimization-enabled hardware, such as Field-Programmable Gate Arrays (FPGAs), in conjunction with the MATLAB platform during Battery Management System (BMS) development, holds significant potential to bolster battery performance. This synergy between hardware and software enables streamlined execution of optimization algorithms, facilitating real-time decision-making and optimization processes, ultimately leading to improved battery efficiency and longevity.



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To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2325

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