

Parameter Extraction and State-of-Charge Estimation of Li-Ion Batteries for BMS Applications [†]

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Abstract

Lithium-ion batteries (LiBs) are fundamental to modern energy systems, particularly in electric vehicle (EV) applications, due to their high energy density, long cycle life, and low self-discharge characteristics. Accurate State-of-Charge (SoC) estimation is essential for ensuring reliable performance, efficient energy usage, and the safety of Battery Management Systems (BMSs). However, the nonlinear and time-varying characteristics of LiBs, along with the difficulty in directly measuring internal states, pose significant challenges for parameter identification and SoC estimation. This study presents an advanced approach based on the Weighted Mean of Vectors optimization algorithm to simultaneously identify the unknown parameters of an extended Thevenin Equivalent Circuit Model (ECM) and estimate the SoC. Unlike previous methods that use static parameters for specific battery modes, the proposed technique accounts for dynamic changes during both charging and discharging operations. The algorithm demonstrates superior adaptability by continuously adjusting model parameters to reflect real-time battery behavior under varying operational conditions. The algorithm also models the relationship between SoC and open-circuit voltage (Voc) using data collected from real lithium-ion cells tested under a controlled load profile in the laboratory. This experimental validation ensures the practical applicability and robustness of the proposed methodology. The simulation results confirm the effectiveness and precision of the proposed approach, showing excellent agreement between measured and estimated values, with minimal errors in both voltage and SoC prediction. The enhanced accuracy achieved through this dynamic parameter identification framework represents a significant advancement in battery state estimation technology.

Keywords: lithium-ion batteries; state of charge; optimization algorithm; parameters identification; equivalent circuit model

1. Introduction

As environmental degradation accelerates and fossil fuel resources dwindle, the automotive sector faces mounting pressure to adopt sustainable transportation solutions that contribute to global net-zero emissions targets. Electric vehicles (EVs) have emerged as a promising alternative for achieving sustainable energy goals [1], offering superior environmental credentials, enhanced energy efficiency, reduced operational costs, and improved user experience compared to conventional internal combustion engines. At the core of EV technology lies the lithium-ion battery (LiB) system, valued for its exceptional power-to-weight ratio, environmental compatibility, absence of memory degradation,



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