ASEC 2025 Conference

The 6th International Electronic Conference on Applied Sciences

09–11 December 2025 | Online

MDPI

Parameter Extraction and State-of-Charge Estimation of Li-Ion Batteries for BMS applications

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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]. At the core of EV technology lies the lithium-ion battery (LiB) system, valued for its exceptional power-to-weight ratio, environmental compatibility, prolonged operational life, and minimal energy loss during storage. However, the dynamic and complex operating conditions encountered in automotive applications necessitate sophisticated battery management systems (BMS) capable of real-time monitoring and control. Critical parameters such as state of charge (SOC) must be continuously assessed to optimize performance and ensure safety. Since the SOC parameter cannot be directly measured, accurate mathematical modeling becomes indispensable for reliable estimation [2]. The development of precise battery models directly influences the effectiveness of parameter estimation algorithms, making model selection and parameter identification crucial elements in BMS design. In battery modeling, Metaheuristic Algorithms (Mas) have played a key role in refining parameter estimation, significantly improving both accuracy and computational efficiency.

In the work of [3], the INFO algorithm—based on the Weighted Mean of Vectors—was employed to identify unknown parameters in an extended Thevenin-based ECM, focusing on dynamic behavior. However, the study did not explore SoC estimation. In contrast, [4] introduced the Improved Marine Predators Algorithm (IMPA) to address both parameter identification and SoC estimation. Nevertheless, the approach assumed fixed model parameters depending on the battery's operating mode (charging or discharging). To address this research gap, the current study presents a novel application of the INFO algorithm for comprehensive identification of both the ECM parameters and the SOC. Unlike previous works, the method dynamically adapts to changes in the battery's operating conditions, offering a more flexible and accurate modeling solution.

METHOD

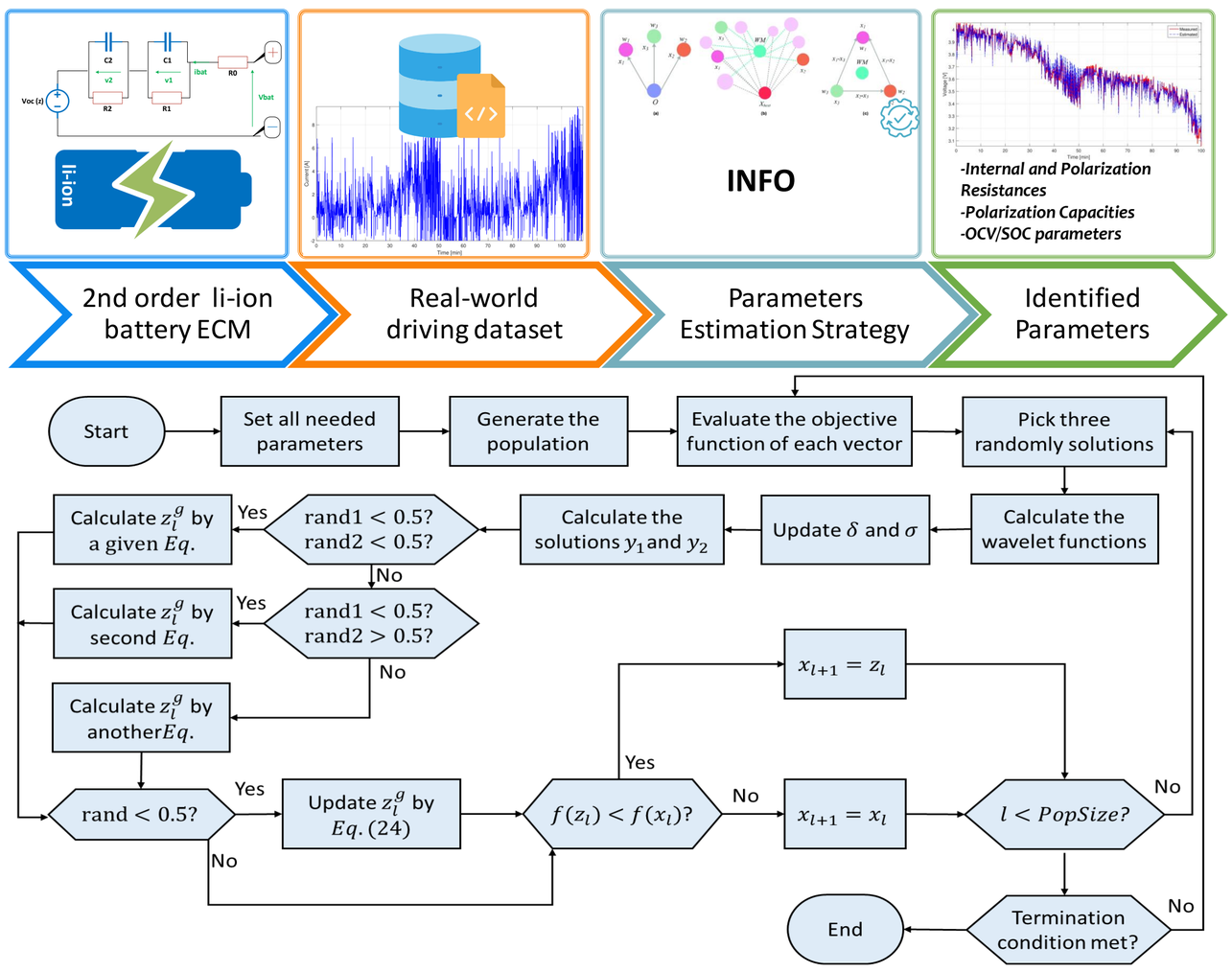
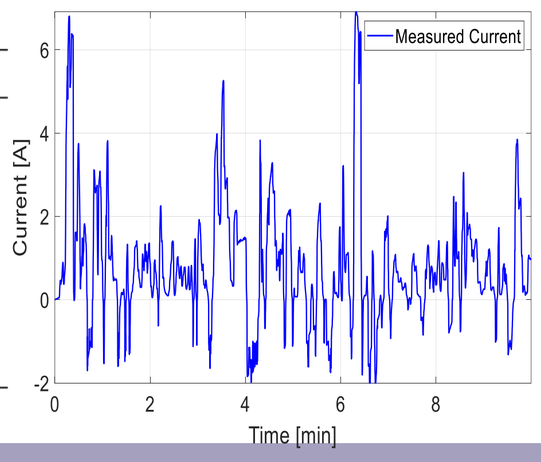


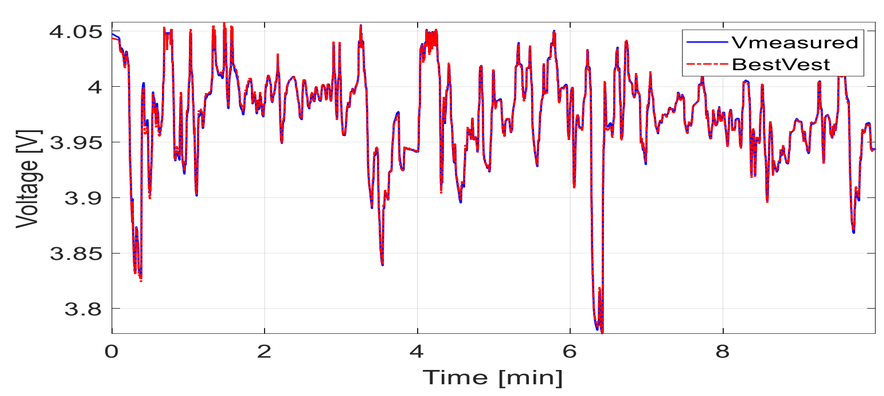
Table 1

Main specification of the tested LiB.

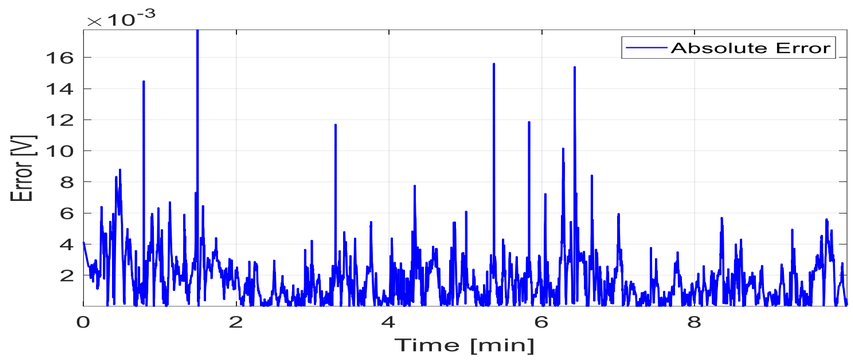
Specification	Value
Cell	Samsung INR18650-35e
Type	lithium-ion
Chemistry (An/Cath)	Graphite/NCA
Nominal capacity [Ah]	3.40
Nominal voltage [V]	3.60
Voltage range [V]	2.65–4.20
Weight [g]	50
Cell dimension [mm]	65.25 x 18.55



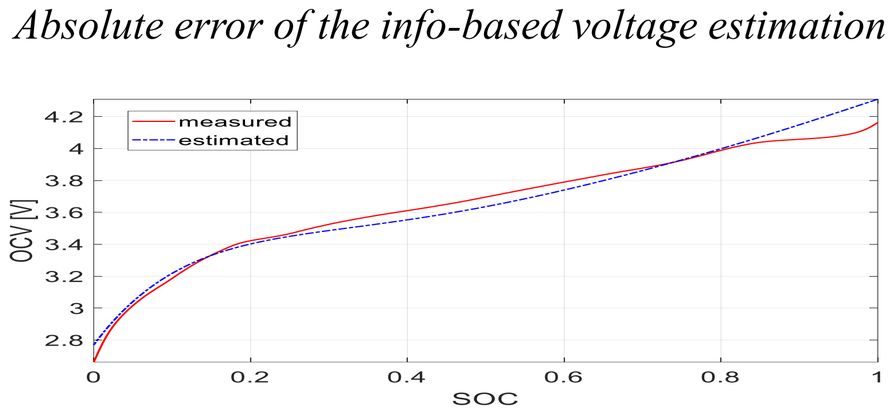
RESULTS



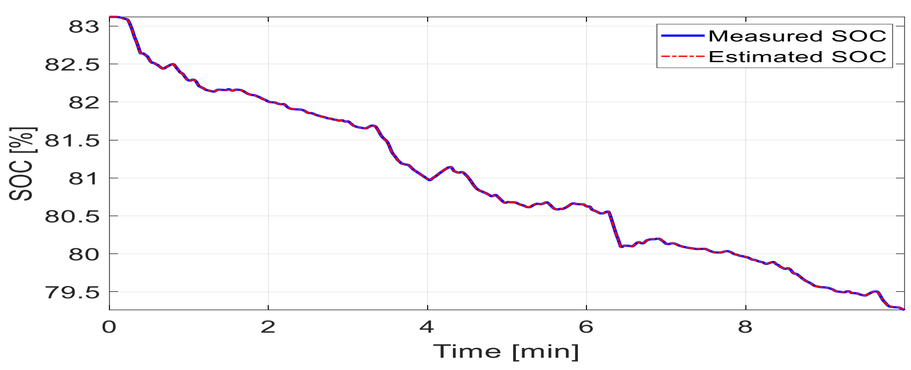
Measured and estimated LIB voltage via the INFO algorithm



Absolute error of the info-based voltage estimation



Estimated vs. measured OCV using the INFO algorithm



Measured and estimated SOC

CONCLUSION

This study introduced a novel application of the INFO optimization algorithm for the dual task of parameter identification and SoC estimation in lithium-ion batteries using an extended Thevenin ECM. By dynamically accounting for real-time changes in operating conditions. Simulation results showed strong agreement between measured and estimated values, with very low error margins in both voltage prediction and SoC tracking.

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