Data-Driven Parameter Identification of an Electrochemical Model for Lithium-ion Batteries with Artificial Intelligence

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Abstract / Oral presentation topic:

Electrochemical models are more and more widely applied in battery diagnostics, prognostics and fast charging control, considering their high fidelity, high extrapolability and physical interpretability. However, parameter identification of electrochemical models is challenging due to the complicated model structure and a large number of physical parameters with different identifiability. The scope of this work is the development of a data-driven parameter identification framework for electrochemical models for lithium-ion batteries in real-world operations with artificial intelligence, i.e., the cuckoo search algorithm. Only current and voltage data are used as input for the multi-objective global optimization of the parameters considering both voltage error between the model and the battery and the relative capacity error between two electrodes. The multi-step identification process based on sensitivity analysis increases the identification accuracy of the parameters with low sensitivity. Moreover, the novel identification process inspired by the training process in machine learning further overcomes the overfitting problem using limited battery data. The data-driven approach achieves a maximum root mean square error of 9 mV and 12.7 mV for the full cell voltage under constant current discharging and real-world driving cycles, respectively, which is only 17.9% and 42.9% of that of the experimental identification approach.

This work aims to develop a parameter identification framework that is suitable for fast and accurate identification of physical parameters of electrochemical models under real-world operation. The proposed data-driven parameter identification framework not only shows significant performance improvement compared with the other data-driven methods but also shows a higher identification accuracy compared with the state-of-the-art experimental identification method. Several highlights of the framework are given below.

- Identifies 26 parameters of an electrochemical model only based on voltage and current measurement and overcomes the overfitting problem by a novel identification process inspired by the training process in machine learning.
- Multi-objective fitness functions are considered, improving the identification accuracy of capacity-related parameters significantly, which is essential for a low voltage error between the model and the cell.
- Multi-step identification procedure reduces the negative influences of the identification of the high-sensitivity parameters on the identification of the low-sensitivity parameters, therefore, increases the identifiability and reduces the identification errors.
- Cuckoo search algorithm identifies the parameters more accurately and with a faster convergence speed compared with other metaheuristic algorithms, e.g., particle swarm optimization.
- Compared with the experimental identification method, the proposed data-driven approach reduces 82.0% and 59.6% of the voltage error under low and high load dynamics, respectively, and reduces 95.4% capacity error between two electrodes.

At the time of review for this work, no comparable work was found in the same domain, which implements a cuckoo search algorithm under a multi-objective multi-step framework for the identification of parameters for lithium-ion electrochemical models. The validation of the identification framework not only with a virtual cell numerically and with a commercial cell experimentally are conducted to show the viability of acceptance of data-driven methods in future battery research.

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