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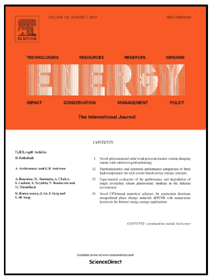

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Implementation of Reduced-Order Physics-Based Model and Multi-Parameters Identification Strategy for Lithium-Ion Battery

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Highlights:

- A strategy is proposed to extend operation point to full state of charge range.
- A criterion is employed to sort out the identifiable parameters of battery model.
- A subset with maximum nine identifiable parameters is estimated at the same time.
- The identified parameters produce small voltage errors at different current inputs.

Abstract

Physics-based models for lithium-ion battery have been regarded as a promising alternative to equivalent circuit models due to their ability to describe internal electrochemical states of battery. However, the huge computational burden and numerous parameters of these models impede their application in embedded battery management system. To deal with the above problem, a reduced-order physics-based model for lithium-ion battery with better tradeoff between the model fidelity and computational complexity is developed. A strategy is proposed to extend the operation from a fixed point to full state of charge range. As the model consists of constant, varying, identifiable and unidentifiable parameters, it is impractical to identify the full set of parameters only using the current-voltage data. To sort out the identifiable parameters, a criterion base on calculating the determinant and condition number of Fisher information matrix (*FIM*) is employed. A subset with maximum nine identifiable parameters is obtained and then identified by nonlinear least square regression algorithm with confidence region calculated by *FIM*. Compared with the outputs from commercial software, the effectiveness of the battery model and extending strategy are verified. The estimated parameters deviate from the true values slightly, and produce small voltage errors at different current profiles.

Keywords: Physics-based model; reduced-order model; extend state of charge range; parameter identification; fisher information matrix; nonlinear least squares.

1. Introduction

With the increasing pressure from fossil fuel depletion and emission pollution, the conventional vehicle with an engine as its propulsion system is gradually transforming to be hybrid or electrical driven vehicle. Lithium-ion batteries have been regarded as the preferred electrical energy storage systems for these vehicles due to their high specific energy and power. Accompanying the battery pack is a battery management system (BMS), which is intended to online monitor batteries states and extend their lifetimes.

A variety of methods have been proposed to estimate battery states, mainly including state of charge (SOC) , state of power [1], state of health [2], remaining useful life and so on. The best feasible idea is to establish a mathematical model with high fidelity and low complexity to describe the battery dynamics, and then employ the sophisticated model-based algorithms to estimate these states. Two categories battery models have been proposed and studied by many researchers, empirical equivalent circuit models (ECMs) and electrochemical models. The ECMs can efficiently model the external characteristics (current-voltage relationship) of battery, and the model parameters can be adaptively updated according to the operation condition by applying the data-driven algorithms [3, 4]. Due to the simplicity and robustness of ECMs, states estimation algorithms integrated into current BMSs rely almost exclusively on them. The electrochemical battery model originally developed by Doyle, Fuller and Newman [5, 6] is a pseudo-2D (P2D) porous electrode model, which consists of coupled partial differential equations (PDEs). Compared with the ECMs, this physics-based model can not only predict the external characteristics of battery, but also give insight into the internal electrochemical states of battery.