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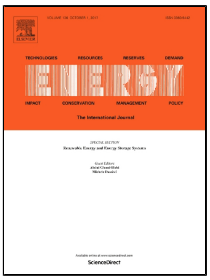

Polynomial approximation pseudo-two-dimensional battery model for online application in embedded battery management system

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Polynomial approximation pseudo-two-dimensional battery model for online application in embedded battery management system

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Highlights:

- The distribution of reaction flux is approximated by polynomial functions.
- The electrolyte potential is derived directly according to the governing equation.
- The accuracy of overpotential is improved compared with single particle model.
- The proposed model retains very high fidelity and lower computing burden.

Abstract

Physics-based model has been regarded as a promising alternative to equivalent circuit model due to its ability to describe internal electrochemical states of battery. However, the rigorous physics-based model, namely pseudo-two-dimensional (P2D) model, is too complicated for online application in embedded battery management system. In this paper, to simplify the P2D model, a series of polynomial functions are employed to approximate the electrolyte phase concentration profile, solid phase concentration profile, and non-uniform reaction flux profile, respectively. Especially, the accuracy of 2nd-order and 3rd-order polynomial approximations for reaction flux is compared, and the higher-order is validated with more strength. Benefit from the acquisition of above variables, the electrolyte potential is derived directly according to the conservation of charge at electrolyte phase; the accuracy of activation overpotential is also improved by using the non-uniform reaction flux rather than assuming the uniform current density in single particle (SP) model. Finally, the developed model is simulated by different constant current rates, hybrid pulse and driving cycles, and its outputs are compared with P2D model and original SP model. The results demonstrate that the model proposed in this paper could capture the battery characteristics efficiently, and also significantly reduce the computation complexity.

Keywords: Lithium-ion battery; physics-based model; pseudo-two-dimensional model; simplified model; polynomial approximation; reaction flux.

1. Introduction

Nowadays, under the pressure of fossil fuel depletion and emission pollution, many governments of different regions and countries among the world have turned to develop the electric vehicles (EVs) and hybrid electric vehicles (HEVs). With the superiority of high specific energy and power, long life, low self-discharge rate, non-memory effect, lithium-ion batteries have been regarded as the preferred candidate for these vehicles [1]. To guarantee safe and reliable battery operations, and prolong the battery life, a battery management system (BMS) is indispensable to online monitor the battery states and regulate the charge or discharge behaviors.

Since most mature and sophisticated algorithms for state estimation are model-based, it is prerequisite to construct a battery model with high fidelity and easy to application. Two categories battery models have been proposed and researched in the literature, namely empirical equivalent circuit models (ECMs) and physics-based electrochemical models [2, 3]. Although comprised of circuit components, the ECMs can efficiently model the external characteristics (current-voltage relationship) of battery. And by applying the data-driven algorithms [4], the model parameters of ECMs can be online identified to adapt the operation condition. However, the parameters of ECMs cannot embody electrochemical meanings and ensure high model accuracy at whole operation ranges, especially at low state of charge (SOC) or low temperature [5]. The rigorous physics-based battery model originally developed by Doyle, Fuller and Newman [6, 7] is a pseudo-two-dimensional (P2D) porous electrode model, which consists of four coupled partial differential equations (PDEs) and one algebraic equation. Compared with the ECMs, this physics-based model can not only predict the external characteristics of battery, but also give insight into