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A comparative study of different equivalent circuit models for estimating state-of-charge of lithium-ion batteries

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Highlights：

- Eleven equivalent circuit models compared for model/SOC accuracy, stability, robustness.
- First- and second-order RC models have best balance of accuracy and reliability.
- A higher-order RC model increased robustness.
- Accurate SOC-OCV curve and high precision sensors are essential for SOC estimation.

Abstract: An appropriate model is a prerequisite for accurate state-of-charge (SOC) estimation. The widely used equivalent circuit models (ECMs) employ a variety of forms; thus, to find the optimum ECM is a primary task for SOC estimation. In this work, we examined eleven ECMs to fulfill the following goals: (1) to compare the typical ECMs for accuracy, stability, and robustness of model and SOC estimation; (2) to compare and evaluate the robustness of the ECMs considering model and sensor errors. The results indicate that the model accuracy does not always improve by increasing the order of the RC network. Conversely, over-fitting problems appear with a certain probability. The first- and second-order RC models are the best choice owing to their balance of accuracy and reliability for LiNMC batteries. The higher-order RC model has better robustness considering the variation in model parameters and sensor errors. Independently of the ECM adopted, an accurate OCV-SOC curve and high precision sensors are essential.

Keywords: Lithium-ion battery; SOC estimation; Equivalent circuit model; Extended Kalman Filter; Comparative study.

1. Introduction

Over the past decade, energy shortage and global climate warming have provided a good opportunity for the rapid development of electric vehicles (EVs) [1-3]. Battery, motor and electric control are the three key technologies applied in EVs, and the battery represents the main factor restricting the expansion of EVs in the marketplace [4, 5]. Among all types of power batteries for