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Identification of Lithium-Ion Physics-Based Model Parameter Values

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Due to their computational simplicity and robustness, equivalent-circuit-type cell models are widely used as the basis for control algorithms in battery-management systems. These models execute quickly and have relatively few parameter values to optimize to make the model calculations fit laboratory test data. However, equivalent-circuit models lack the predictive capability of physics-based cell models. For example, while equivalent-circuit models can predict a cell's current–voltage behaviors well, they cannot predict internal cell electrochemical variables such as lithium concentration or electric potential at different spatial locations internal to the cell. Knowledge of these internal variables is critical to being able to predict and control the instigators of premature aging or unsafe operating conditions.

While physics-based models have much greater predictive capabilities, they also have many more parameter values that must be measured or inferred to make the model match the behaviors of a real cell. This "system identification" problem is significant, and in the past has relied on cell teardown and complex and costly electrochemical experiments to determine the required parameter values.

In this paper, we propose a methodology that minimizes the need for laborious cell teardown and electrochemical experimentation. Instead, the model equations are reformulated, and specific cell-level laboratory tests are crafted such that the current–voltage response isolates certain sets of parameter values in the model. These tests are executed on standard cell cycling equipment. A simple and fast optimization procedure then computes the physics-based model parameter values directly from the specialized lab-test data.

We present results based on a virtual (simulated) cell, where "truth" values for the electrochemical parameters are known for comparison purposes. The virtual cell's coupled partial-differential-equation model is simulated using COMSOL and the same designed experiments as would be used in a laboratory. The current–voltage data from the simulation are used to identify the cell's parameter values: these identified values are compared to the known "truth" values. In most cases, the identified parameters have error less than 1% when compared to the truth values.

Keywords: physics-based model; lithium-ion model; measuring lithium-ion model parameters; system identification