Abstract #1227, 224th ECS Meeting, © 2013 The Electrochemical Society

Stochastic Extension of a Thermal -Electrochemical Lithium-Ion Battery Model

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Lithium-Ion batteries are widely used for mobile applications because of favorable properties like their high energy density. Still, serious issues like the risk of thermal runaway are not fully solved, yet [1]. In a first step towards an early-alert system that can warn the user of an imminent thermal runaway we explore some of the stochastic aspects of thermal battery model predictions.

As with any modeling approach, battery modeling is challenged by inherent uncertainties. Some sources for the inevitable remaining discrepancy between the battery model and its real counterpart are model structural errors, measurement errors or the modeler's incomplete knowledge about parameter values.

This work proposes a methodology that enables the modeler to rigorously handle system uncertainties and to dynamically update model predictions with measurement data, as they become available.

Instead of a single model run an ensemble of model runs with different initial conditions are computed in parallel. Uncertain convection boundary conditions are considered. The system model error blurs the predicted temperature distribution and yields for each time step a discretized probability density function. During the course of the computation the model predictions can be updated by measurement data (e.g., surface temperature measurements). This is achieved by implementing a Bayesian updating scheme by means of a particle filter (e.g., [4]). The use of a particle filter allows the application of system error models, as well as the choice of the initial probability distribution, beyond simple Gaussian models and respects the non-linearity of the relationship between temperature and heat production.

The method is implemented on top of the existing thermal-electrochemical model code DENIS [2, 3] for a 26650 $LiFePO_4$ cylindrical battery. For the first implementation and as a proof of concept only synthetic measurement data is used. In this context an initial model run serves as an artificial true scenario form which synthetic measurements are taken.

The dynamics of the particle filter implementation under discharge and at moderate temperatures are explored and presented and an outlook towards runaway scenarios is given.

Acknowledgment
This project is funded by the Volkswagen Foundation.

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