Multi-Chemistry Parameter Sensitivity Analysis of Electrochemical Battery Models

Daniel Luder[1,2], Weihan Li[1,2], Dirk Uwe Sauer[1,2,3]

[1]Chair for Electrochemical Energy Conversion and Storage Systems, Institute for Power Electronics and Electrical Drives (ISEA), RWTH Aachen University, Jägerstrasse 17-19, 52066 Aachen, Germany

[2]Juelich Aachen Research Alliance, JARA-Energy, Germany

[3]Institute for Power Generation and Storage Systems (PGS) @ E.ON ERC, RWTH Aachen University, Germany

Lithium-ion batteries have become a key element for the decarbonization of the energy and transportation sectors due to their continuously increasing energy and power density as well as decreasing manufacturing and operating costs. Battery models that precisely represent the cell internal states provide the foundation for intelligent control algorithms that accelerate the charging process and, at the same time, minimize degradation as well as optimize battery cell designs. The Doyle-Fuller-Newman model is the most popular pseudo-2-dimensional physics-based model that accurately describes the electrochemical and dynamical processes within lithium-ion batteries. The model relies on multiphase porous electrodes and concentrated solution theories and is governed by a set of coupled nonlinear partial differential equations. The high model complexity and the large number of parameters lead to a nontrivial parameter identification problem.

We propose a systematic sensitivity analysis that is performed for multiple cell chemistries in time- and frequency-domain as well as the different depth of discharges and environmental temperatures. To increase the variety of model parameters, initial states and boundary conditions, we include data from measurements conducted in the laboratory and from literature. The sensitivity matrix is created by Monte Carlo simulations that consider the relationship between the model responses to different input profiles. The sensitivity matrix is normalized by the parameter variety and subsequently the identifiability of each parameter, including its uncertainty, is given by the rank of the sensitivity index.

The results of the proposed method can be used to confidently identify physico-chemical battery model parameters from time-series and impedance data. Furthermore, the sensitivity analysis provides insights and suggestions for optimizing the cell design for existing and future batteries considering constraints such as power and energy density or impedance given by real-world applications.