

## PARAMETERISATION OF THE SINGLE PARTICLE MODEL FOR LITHIUM-ION CELLS

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Lithium-ion batteries are becoming a technology of choice in automotive as well as grid and off-grid energy storage applications. Large-scale battery systems require advanced and more accurate diagnostics and prognostics tools to maximize the battery performance over lifetime. Increasingly, researchers are investigating the use of electrochemical models to enhance the state estimation and prediction capabilities of battery management systems (BMSs), for example by allowing fast charging while minimizing degradation [1-3]. Recently [4-5], we have shown that such models, including the Newman pseudo two-dimensional (P2D) model [6], can be used for lithium-ion battery state estimation. However, an important challenge remains as whether the model parameters can be estimated from available measurements of voltage, current and temperature. Previous studies attempting the parameter estimation, such as [7-8], have revealed the challenging nature of this identification problem.

We present here and in a recent paper [9] a structural and practical identifiability analysis of an electrochemical model for lithium-ion batteries, namely the single particle model (SPM) [10]. The SPM is a simplification of the P2D model, which neglects electrolyte dynamics and assumes uniform reaction rate across each electrode. The structural identifiability approach involves grouping the parameters and partially non-dimensionalizing the SPM to reveal that there are only a small number of unique grouped parameters required to fully parameterize the SPM. We show that these parameters can be identified from experimental data provided that the electrode open-circuit potential functions have a known and non-zero gradient, the electrode parameters are ordered and the parameters describing kinetics in both electrodes are combined into a single charge-transfer resistance term.

We then investigate the practical identifiability of the SPM by performing parameter estimation against experimental frequency-domain electrochemical impedance spectroscopy (EIS) data at various depth-of-discharge (DoD). This confirms the crucial role played by the electrode OCP dependency on DoD for the parameter estimation of lithium-ion battery electrochemical models. If the gradient of an electrode open-circuit potential is zero, the parameters associated with this electrode cannot be identified. We show that EIS data at several DoDs may be combined to obtain confident parameter estimates for both electrodes. Finally, as a separate validation, the parametrized model is also shown to provide good predictive capabilities in the time domain, exhibiting a maximum voltage error of 20 mV, and RMS error of 10 mV, between model and experiment over a 10 minute highly dynamic discharge.

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