Berichte aus der Energietechnik

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A Novel Electrochemical Battery Model For State Of Charge And State Of Health Estimation

Shaker Verlag
Aachen 2010

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Zugl.: Zurich, ETH, Diss., 2010

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Cover: Lithium-ion cells
by
Roland Sigwart Photographie
Hauptstrasse 16
78183 Huefingen, Germany
www.sigwart-photo.de

Printed in Germany.

ISBN 978-3-8322-9588-2
ISSN 0945-0726

Shaker Verlag GmbH • P.O. BOX 101818 • D-52018 Aachen
Phone: 0049/2407/9596-0 • Telefax: 0049/2407/9596-9
Internet: www.shaker.de • e-mail: info@shaker.de

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ISBN: 978-3-8322-9588-2 (Diss. ETH No. 19100)

Key words: Battery management system, Combined parameter analysis and identification, Electrochemical battery modelling, Electrolyte dissociation, Fisher-information matrix, Lumped parameter system, Online parameter estimation, Sensitivity analysis, SOC & SOH estimation, Solid–electrolyte interface, Unscented Kalman Filter.

Currently, there is a strong demand in the automobile industry for replacing internal combustion engines by electrical drivetrains. This requires the development of powerful battery systems on the basis of rechargeable lithium-ion cells. In order to operate them in an optimal way, it is essential to accurately detect the state of charge (SOC) and the state of health (SOH) of the energy storage system. For this purpose, the thesis at hand presents a novel electrochemical model of a lithium-ion cell. By the abdication of parameter maps the model can be parameterized for a particular cell by using some few characteristic measurements. The compact model structure only consists of 6 states and also includes the thermal behaviour of the cell. Thus, it is well suited for the implementation in battery control units.

Based on classical single-particle approaches, a lumped-parameter nonlinear model is developed. It is able to predict accurately the terminal voltages for arbitrary loads, and even for potentiostatic operation. The key points are: (1) an incorporation of the electrolyte potential, (2) a modal decomposition of the partial differential equation of the liquid phase lithium-ion concentration, (3) a correct handling of the SOC-dependent diffusivity in the insertion materials of both electrodes, and (4) a consideration of temperature-dependent kinetic processes. A combined parameter analysis and identification is successfully applied for the parameterization of the model. Using a Fisher-information matrix approach in combination with a sensitivity analysis, the identifiability of each parameter is estimated in dependence on the measurement information. Using this information, it is possible to choose a small number of relevant experiments, which are sufficient to fully parameterize the model.

In order to determine the internal model states that account for the actual stored amount of charge (SOC) the so-called unscented Kalman Filter (UKF) is employed. It allows for the distinction of electrode individual state of charges. This inherently discrete-time state estimation approach provides a decoupling of the model and the filter correction update and is therefore well suited for stiff differential equations. Besides, no Jacobians of the nonlinear state space battery model have to be computed. The UKF shows an extraordinary tolerance against parameter errors. This property makes it a promising candidate for the monitoring of cell aging effects.

In a last step, the estimated states of the UKF are used to track cell degradation effects (SOH). By means of the cell model parameters that account for the capacity of the cathode and the overall conductivity of the electrolyte, the currently available maximum charge and power can be predicted. For this reason, the estimated states are compared for congeneric load profiles but different stages of age. Deviations are then addressed to shifts in the respective model parameters. This approach provides the distinction of capacity fade due to active material losses and due to rate capability fade as well.