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Tutorial Title

Battery States Monitoring and Estimation Using Impedance Identification Techniques

Instructor Team

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Abstract

Accurate state of charge (SOC) estimation, state of health (SOH) estimation and temperature monitoring are required in order to ensure a safe, reliable, and degradation-aware battery operation. Nowadays, the algorithms developed for these purposes heavily rely on complete or partial battery capacity measurements, which are both costly and impractical during daily battery operation. The AC impedance of batteries can be a viable alternative as the measurement times are shorter than for capacity measurements. Furthermore, the impedance offers plentiful information about the battery's physico-chemical properties at any moment. Thus, in this tutorial, after introducing the status of the lithium-ion battery technology, we will focus on presenting different battery impedance identification techniques (both AC and DC techniques). Since, traditional impedance identification techniques, such as DC pulses or electrochemical impedance spectroscopy, face technical and economic challenges when they need to be performed on-board, impedance identification techniques using broadband signals have emerged as a viable solution. In this tutorial, we will introduce various broadband signals that can be used to identify impedance. We will discuss in detail the procedures for designing the signals and exemplify their hardware implementation. Finally, in the last part of the tutorial, we will provide examples and illustrate the performance of broadband signals for measuring the impedance and subsequently estimating and monitoring the battery states', including SOC, SOH, and temperature; lastly, we will discuss and prove the usefulness of these impedance identification techniques for clustering and sorting batteries for use in second-life applications.

Instructor Team Biographies

Daniel-Ioan Stroe - received the Dipl.-Ing. degree in automatics from "Transilvania" University of Brasov, Romania, in 2008, and M.Sc. degree in wind power systems from Aalborg University, Aalborg, Denmark, in 2010. He has been with AAU Energy, Aalborg University since 2010, from where he obtained his Ph.D. degree in lifetime modeling of Lithium-ion batteries in 2014. He is currently an Associate Professor with AAU Energy and the leader of the Batteries research group. He was a Visiting Researcher with RWTH Aachen, Germany, in 2013, and since 2022, he has been a visiting professor at Czech Technical University in Prague, Czechia. He has co-authored over 250 scientific peer-reviewed publications, most of them on topics related to Lithium-ion battery performance and lifetime modeling and battery state estimation. Furthermore, he is serving as an associate editor for various journals. Daniel's

current research interests are in the area of energy storage systems for grid and e-mobility, Lithium-based battery testing and modeling, and lifetime estimation and diagnostics of Lithium-ion batteries. He has organized and lectured more than 10 tutorials at IEEE conferences, including ECCE 2015, ECCE 2018, and ECCE 2022.

Tomi Roinila - received the M.Sc. (Tech.) and Dr.Tech. degrees in automation and control engineering from the Tampere University of Technology, Tampere, Finland, in 2006 and 2010, respectively. He is currently an Associate Professor with Tampere University, Tampere. His main research interests include modeling and control of grid-connected power-electronics systems, analysis of energy-storage systems, modeling of multi-converter systems, and impedance identification techniques for battery systems and grid-connected power converters.

Jussi Sihvo - received his M.Sc. degree in power electronics in 2018, and Ph.D. degree in battery modeling and system identification in 2021 from Tampere University, Tampere. Currently, he works as an MSCA post-doctoral research fellow at the Department of Energy at Aalborg University. His research interests include modeling, diagnostics, and analysis of battery storage systems. He has 10 years of experience from both academia and industry with impedance-based identification techniques for the diagnostics of battery cells and systems. He is also an established researcher in system identification and control system design.