Modelling Panel Abstract & Speaker Biography

Embeddable state-estimation algorithms for lithium-sulfur battery management

D. J. Auger, A. Fotouhi, K. Propp and S. Longo

Advanced Vehicle Engineering Centre, School of Aerospace, Transport and Manufacturing (SATM), Cranfield University, Bedfordshire MK43 0AL, UK

This presentation will introduce work done as part of the Revolutionary Electric Vehicle Battery (REVB) project to develop practical battery management algorithms for lithium-sulfur. The presentation builds on early-stage work presented at the 2016 conference. This work has now been taken to completion, and the results presented show the results of application in a mature, realistic experimental con-text, and much of it has now been accepted by peer-reviewed academic journals.

From a battery management perspective, lithium-ion batteries are easy to work with. The remaining capacity can be reliably estimated from measurements of the current and integration over time; it is also possible to get reliable estimates of battery state of charge from measurements of the quiescent terminal voltage - the 'open-circuit voltage' - since there is a strongly monotonic relationship between the two quantities. Compared to lithium-ion batteries, lithium-sulfur is hard to work with: due to the complexities of lithium-sulfur's electrochemical reactions, remaining usable capacity can vary according to the way in which a cell is used, so the current integral method is unreliable. Direct voltage measurement methods do not work either, since the relationship between open-circuit voltage is not monotonic.

One method of determining state-of-charge (SOC) is the use of a rapid real-time equivalent-circuit modeller together with a pre-trained Adaptive Neuro-Fuzzy Inference System (ANFIS). The practicalities of using ANFIS are discussed, in particular the selection of model structure, the selection of parameters to use as ANFIS inputs, and the selection of an appropriate parameterization algorithm. This has been found to work well, giving a remaining useful capacity estimate that is accurate to approximately 7% on average for a representative automotive duty cycle based on the Urban Dynamometer Driving Schedule (UDDS) test, which is a fair representation of real-world driving demands.

A second method of determining state-of-charge is the use of recursive Bayesian estimators such as the Extended Kalman Filter (EKF), the Unscented Kalman Filter (UKF) and the Particle Filter (PF). To use these, a nonlinear equivalent-circuit model is first assembled from measured discharge data. This model is then used as the basis for the filter implementations. It has been found that the all estimators work well when the initial state of charge is well-known, but that the Unscented Kalman Filter has clear advantages over the others when the initial state of charge is uncertain.

The presentation concludes by discussing on-going work to develop estimators based on a new class of models, namely the 'zero-dimensional' electrochemical models developed by Imperial College London. At the time of writing, this work is ongoing, and the presentation will discuss the latest results and identify directions for further work.

Speaker Biography:

Dr Daniel Auger studied at the University of Cambridge, receiving the MEng Honours in Electrical and Information Sciences and a PhD in Control Engineering. He then moved to BAE Systems as a senior engineer, then MathWorks as a Senior Consultant. He took up his present post in early 2013.

Daniel has considerable experience of industry-based simulation, modelling and control projects. He has worked with marine, aerospace and automotive transport applications and indeed many other sectors. He has particular expertise in advanced control techniques, formal model validation and state estimation for battery systems.

Daniel is a chartered engineer. In 2015 he was elected as an IEEE Senior Member, and in 2016 he was elected as an IET Fellow. He is also volunteer chair of the IEEE UK and Ireland Control Systems Society Chapter.

Current Activities

Teaching in Automotive Engineering, Automotive Mechatronics and Intelligent Mobility Engineering

Daniel is module convenor for two MSc modules within Cranfield's automotive programme: Automotive Control and Simulation, and Advanced Control and Optimisation. These modules cover classical control, including PID and more advanced 'loop-shaping' methods; state-space control and state estimator/observer design; advanced robust and optimal control techniques, including H-infinity design (mixed-sensitivity methods and McFarlane/Glover H-infinity loop-shaping) and model-predictive control; and use of industry standard modelling, simulation and analysis software.

Daniel is also leading the development of a course proposal for a new MSc in Intelligent Mobility Engineering, aimed at creating graduates who can excel in the emerging cross-disciplinary transport systems sector.

Modelling and battery management for advanced battery chemistries

Daniel leads the development of BMS management algorithms for lightweight lithium-sulfur batteries within the £4 million project 'Revolutionary Electric Vehicle Battery' (REVB). This work is delivering bespoke system identification techniques well-suited to lithium-sulfur cells and online battery state estimators, suitable for direct use in embedded controllers

The Cranfield team includes Dr Stefano Longo (co-investigator), Dr Abbas Fotouhi (research fellow) and Karsten Propp (researcher). Our collaborators are OXIS Energy, Ricardo, and Dr Greg Offer's team at Imperial College London.

Driverless cars / connected and autonomous vehicles
Daniel is a co-investigator on the £1.6 million 'CogShift' project, which is part of the EPSRC-Jaguar Land Rover 'TASCC' programme. This project is developing advanced 'take-over' control systems to help users of highly-automated but not fully autonomous cars take back control when required.

The Cranfield team is led by Dr Dongpu Cao (principal investigator), also supported by Dr Mark Sullman and Dr Yifan Zhao (co-investigators). Details of the project and our collaborators are available on the EPSRC web site.

Other activities
Daniel has several smaller research projects: (i) optimization of electric vehicle powertrain configurations, and control of battery/supercapacitor hybrids; (ii) development of energy management strategies for hybrid through-the-road vehicles; and (iii) development of advanced engine control diagnostics using a mix of real-world data and hardware-in-loop testing.