Estimation of Lithium-Ion Battery Ageing Using Electrochemical Models

Master's Thesis or Engineering School Final-Year Internship

Supervisor

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Location

This internship will take place at CRAN, CNRS Joint Research Unit 7039: 2 avenue de la forêt de Haye, 54516 Vandœuvre-lès-Nancy, France.

Duration

5 to 6 months, with a planned start date between February 1 and April 15, 2027.

Funding

Approximately €924/month gross (2023 data).

Mots-clefs

Control engineering, lithium-ion battery, observer design, Matlab-Simulink

Context

Worldwide demand for electrochemical batteries is growing all the time. This is mainly due to the emergence of hybrid and electric vehicles ("Hybrid Electric Vehicle", "Plug-in Hybrid Electric Vehicle" and "Battery Electric Vehicle") on the one hand, and the energy storage market linked to renewable energies and power grid management on the other.

SAFT is particularly active in this context, as a pioneer in the deployment of lithium batteries. SAFT produces lithium-ion batteries in Poitiers, Nersac and Bordeaux, France. This internship, financed by SAFT, will take place at CRAN in Vandœuvre-lès-Nancy, France

Topic

Electrochemical batteries are ubiquitous in our daily lives, whether in computers or mobile phones. Among the available technologies, lithium-ion batteries offer numerous advantages, including high energy density, high power density, and low self-discharge. They also do not suffer from the memory effect. In return, these batteries require a Battery Management System (BMS) for safety reasons, as well as to prevent premature ageing.

The BMS plays a key role in battery performance and lifespan, and it is essential to provide it with accurate data on the current state of the battery. The challenge is that only a few battery variables are directly accessible through measurements, typically current, voltage, and sometimes temperature. To access the battery's internal states (state of charge, state of health, functional states), a mathematical model of the battery dynamics is usually developed, based on which an estimator is designed to infer the unmeasurable internal variables. Various approaches have been developed for this purpose, notably by CRAN, GREEN, and SAFT, which rely on local electrochemical models and implement nonlinear observers [1,2,3,4].

The objective of this internship is to design and numerically validate estimation algorithms (observers) for the lithium quantity, a parameter closely related to battery ageing. To achieve this, we plan to use electrochemical models formulated as finite-dimensional nonlinear ordinary differential equations. These models are often reduced: a variable is removed by exploiting the commonly accepted assumption that the total lithium quantity remains constant. The challenge here will be to lift this assumption, which is no longer valid over long-time horizons, and to explicitly estimate this so-called slow variable.

Plan

1. Literature review and selection of one or more estimation methods.
2. Study of the estimation methods using Matlab-Simulink, based on a given model.
3. Validation in Matlab-Simulink using experimental data.

References

[1] P. Blondel, R. Postoyan, S. Raël, S. Benjamin, P. Desprez. Nonlinear circle-criterion observer design for an electrochemical battery model. *IEEE Transactions on Control Systems Technology*, *27*(2), 889-897, 2018.

[2] P. Blondel, R. Postoyan, S. Raël, S. Benjamin, P. Desprez. Observer design for an electrochemical model of lithium-ion batteries based on a polytopic approach. *20th IFAC World Congress*, 50 (1) 8127-8132, Toulouse, 2017.

[3] E. Planté, R. Postoyan, S. Raël, Y. Jebroun, S. Benjamin, D. Monier-Reyes. Multiple active material Lithium-ion batteries: finite-dimensional modeling and constrained state estimation. *IEEE Transactions on Control Systems Technology*, 2022.

[4] M. Khalil, R. Postoyan, S. Raël. Systematic observer design with robust global convergence guarantees for a large class of lithium-ion battery models. IEEE Control Systems Letters, 9, 649-654, 2025.

Profile

We are looking for students with a background in in control engineering, electrical engineering or applied mathematics. Proficiency in Matlab is desirable, and a good command of English is expected.

Please contact Romain Postoyan (romain.postoyan@univ-lorraine.fr) and Stéphane Raël (stephane.rael@univ-lorraine.fr) for more information.