From the lithium-ion cell to the battery: electrochemical modeling and state estimation

Master project

Advisors

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Location

This SAFT Master project will take place at CRAN, UMR CNRS 7039 : 2 avenue de la forêt de Haye, 54516 Vandœuvre-lès-Nancy, France

Duration

5 to 6 months, starting date between February 1 and March 31 2021

Funding

924€/month gross

Keywords

Control engineering, batteries, modeling, observer, estimation, Lyapunov stability, Matlab-Simulink

Context

The global economic demand for electrochemical storage batteries is increasing today. This growth 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 related to renewable energies and power grid management on the other.

SAFT is particularly present in this context as a precursor of the deployment of lithium batteries. SAFT produces, among others, lithium-ion batteries in Poitiers, Nersac and Bordeaux. This SAFT M.Sc. project will take place at CRAN in Vandœuvre-lès-Nancy.

Topic

Electrochemical batteries are ubiquitous in our daily lives, including in our computers or our cell phones. Among the various technologies available, lithium-ion batteries offer many advantages, particularly in terms of energy mass, power mass and low self-discharge. In addition, they do not have a memory effect. On the other hand, this type of batteries requires a management system (BMS) for safety reasons, but also to prevent premature aging.

The BMS plays a key role in the performance and lifespan of the battery, and it is essential to supply the BMS with accurate data on the current state of the battery. The problem is that little information about battery variables is directly accessible through measurements, typically the current, the voltage and possibly the temperature. To access the battery states (state of charge, state of health, functioning state), a mathematical model of the battery dynamics is usually developed, based on which an observer is designed to estimate the non-measurable internal variables. Different approaches have been developed for this purpose, including some by CRAN, GREEN and SAFT, based on local electrochemical models and implementing a nonlinear observer [1,2,3].

It appears that most of these approaches are dedicated to the estimation of the state of a single lithium-ion cell. However, in practice, batteries are most often composed of several cells associated in series and/or in parallel. For reasons of implementation and computation time, single-cell approaches cannot be simply duplicated when many cells are interconnected. It is therefore necessary to develop estimation tools that are easy to implement and adapted to multi-cell batteries. Few results are available in the literature on this subject, among which [4-6].

Plan

- Literature review on the estimation of the state of batteries composed of several lithium-ion cells.
- Modeling of multi-cell batteries and simulation with Matlab-Simulink.
- Observer synthesis and simulation on Matlab-Simulink.

References

[1] P. Blondel, et al., IEEE Transactions on Control Systems Technology 27 (2) (2019) 889-897; doi: 10.1109/TCST.2017.2782787

[2] P. Blondel, et al., 20th World Congress of the International Federation of Automatic Control (IFAC 2017) 50 (1) 8127-8132, Toulouse, (2017); doi: 10.1016/j.ifacol.2017.08.1252

[3] E. Planté, et al., Submitted to IEEE Transactions on Control Systems Technology, 2021

[4] Y. Zhen, et al., Journal of Power Sources 383 (2018), https://doi.org/10.1016/j.jpowsour.2018.02.058

[5] Z. Wang, et al., Applied Energy 294 (2021), https://doi.org/10.1016/j.apenergy.2021.117022

[6] D. Zhang, et al., Submitted to IEEE Transactions on Control Systems Technology, 2021

Profile

This is a Master project for a student in control or electrical engineering. Matlab skills and good knowledge of the English language are expected.

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for more information.