ECOLE DOCTORALE EEATS

Electronique, Electrotechnique, Automatique, Traitement du Signal

Proposal of Ph.D. thesis subject
to enter the competition for a Ph.D. public grant
starting with 2026-2027

Title: **Ageing-aware self-tuning battery state of charge estimation: towards electrochemical-model-based design of advanced Battery Management Systems**

Thesis specialty: **Automatique – Productique (Control systems)**

Research structure: **Grenoble Image Speech Signal Control Systems Laboratory – GIPSA-lab UMR 5216 / Grenoble Alpes University (UGA) – Grenoble, France**

Starting date: **01/10/2026**

Application dead-line: **31/05/2026, 23h59**

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Context and research domain:

The energy storage units are now becoming ubiquitous as key enablers of the green energy transition; thus, a lot of research effort has been lately done to trade off storage efficiency, reliability and affordable cost [1]. Storage real-time monitoring, supervising and control by means of built-in embedded algorithms – such as the Battery Management Systems (BMS) with advanced functions – are crucial. Focusing on batteries as a widely-used type of electrochemical storage, the *state of charge* (SoC) and the *state of health* (SoH) of a battery are indicators of its internal state and main function. The two states are related, as SoC estimation may become inaccurate during battery service time, because of its internal parameter variations with ageing. Thus, pertinent characterization of battery internal states is necessary by accurate, ideally real-time, on-line estimation of relevant parameters.

Among mathematical models of battery internal phenomena, the equivalent-electrical-circuit model (ECM) is one of the most used [2], whose simplest version is a voltage source described by the battery open-circuit voltage (OCV) and a series impedance accounting for the various losses; a more complex version also integrates a capacity. The ***electrochemical models*** marked the 1970s and afterwards; *e.g.*, the 1975 porous electrode model of Newman and Tiedeman [3], [4], was applied to Li-ion (LIB) batteries in the 1990s [5]. Among these models, having enabled optimization of both design and operating performance of batteries, the pseudo bidimensional model (P2D) [6] and the ***Single Particle Model*** (SPM) [7] have proven to be particularly interesting for design of accurate SoC and SoH estimators.

Precision and accuracy of electrochemical models consist of complex ***parabolic partial-differential equations*** (PDE) describing the underlying phenomena of diffusion and intercalation and electrochemical kinetics, whose parameters are notoriously difficult or impossible to measure or estimate. Hence, use of any "classical" estimator, *e.g.*, Kalman filter [8]–[10], first requires adequate model order reduction. Complexity can also be reduced by "lumping" PDE-based model parameters for estimation purposes [11]. An SPM-based adaptive observer for SoC and SoH simultaneous estimation, only based on measuring battery input current and output voltage, was for the first time proposed in 2014; however, its real-time implementation is impractical due to its computational complexity [12]. The recently proposed ***E***(enhanced)***SPM*** [13] is an SPM version improved with explicit temperature-dependent parameters and ageing-dependent expression of battery voltage.

The proposed Ph.D. thesis subject will contribute to advance research in the ***estimation of internal states of electrochemical storages at GIPSA-lab***, with broad applications in nowadays energy transition context. It will benefit from complementary advising – *i.e.*, from both control systems and electrochemical engineering viewpoints – within the collaboration initiated between thesis supervisors, Assoc. Prof. Antoneta Iuliana BRATCU and Prof. Gildas BESANÇON (with Grenoble Image Parole Signal Automatique – GIPSA-lab) and Prof. Yann BULTEL (with Laboratory of Electrochemistry and Physical-Chemistry of Materials and Interfaces – LEPMI).

Description of the research topics:

The focus of this project is on how to render accurate on-line parameter identification easy to embed in real time. So numerical complexity and satisfactory accuracy should be traded off. To this end, investigation of ***modulating functions*** as a powerful tool of ***estimating both the states and the parameters of PDEs-described systems*** [18] is proposed. Indeed, the underpinning integral transform that maps the distributed nature of battery internal phenomena into a "lumped" representation of most determinant features is expected to facilitate embedding into a real-time numerical unit. While modulating functions are pertinent for a wide range of use cases [19], [20], to the best of our knowledge, their application to battery estimation is new and practically not investigated. Modulating functions can here be used: a) either for only parameter identification – in combination with an ODE-approximation-based estimator (see above) – or b) for a complete self-tuning SoC estimation, *i.e.*, directly relying on the governing PDEs, presumably on two dynamically-separated levels: estimation of battery internal

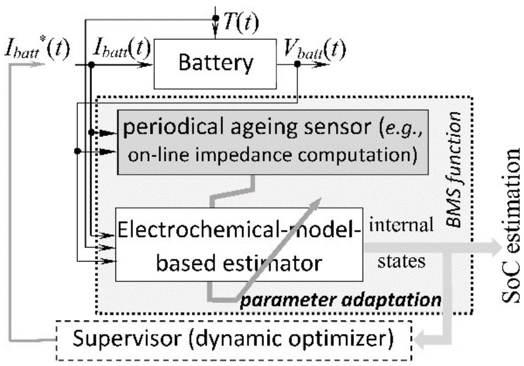

Fig. 1. Self-tuning SoC estimator block diagram.

states (*i.e.*, Li *concentrations in the positive and negative electrode*) on a faster level and parameters' update on a slower level. Fig. 1 suggests the SoC estimator's block-diagram in case a), with focus on the on-line ageing (objective) sensing (greyed block) and on parameters' adaptation law. The dynamic separation of the two levels is suggested by the much slower periodicity of ageing sensing. Case b) is the simultaneous state and parameter estimation, with intuitive need of keeping two dynamical levels. Comparative real-data validation of different methods will conclude about overall estimation performance.

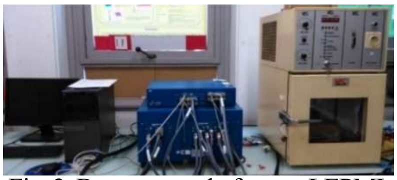
Fig. 2. Battery test platform at LEPMI.

Real data measures – input current, output voltage, residual capacity of discharge, internal resistance – will be obtained on an open platform dedicated to assembly and characterization of batteries, available at LEPMI (Fig. 2). Such data are already available in the use case of PaDESoH project: constant-temperature battery cycling specific to electric vehicle (EV) applications (*i.e.*, under current profiles associated to standard driving cycles) and characterization of two battery technologies used for EV applications.

Thesis objectives:

An incipient collaboration between GIPSA-lab and LEPMI within a one-year IRGA PaDeSoH post-doctoral project (2022-2023) allowed exploitation of SPM for SoC estimation based on current and voltage measures, by means of a novel ***two-level estimation structure*** employing a high-gain dynamic inversion on the upper level and a "classical" (*e.g.*, Luenberger) estimator on a lower level, using an ordinary-differential-equation (ODE) spatial-discretization-based approximation of PDEs [14], [15]. This estimation method relies upon previous model calibration against real measure data, *e.g.*, using the procedure we have proposed in [16] for an electromobility use case. Based on some preliminary results of a 2024 master internship [17], the two-level observer is now going to be benchmarked against some baseline SoC estimation method, *e.g.*, Kalman-filter based, within a second master internship (February-July 2025).

This Ph.D. project aims at proposing a ***real-time embedded SoC estimator which on-line takes account of parameter uncertainties, mostly due to ageing***. Thus, the advantages of the two-level SoC observer – simplicity of tuning, robustness due to the high-gain dynamic inversion and good accuracy due to the electrochemical model's use – combined with ***simultaneous slower on-line parameter identification*** are expected to ease numerical embedding and improve real-time operation within a BMS. An ***ageing-aware self-tuning SoC estimator*** will thus result, with beyond-the-state-of-the-art innovation potential.

As regards valorisation, potential of technological transfer towards industry and patenting will be considered in a first place, with subsequent publication in high-level conferences (*e.g.*, *European Control Conference* (*ECC*), *IEEE CCTA* (*Conference on Ctrl. Technology and Appl.*), *IFAC CPES* (*Control of Power and Energy Systems*) *Symposium*, *etc.*) and journals, including, if not patented, open-access ones (*IEEE Trans. on Ctrl. Syst. Technology*, *IEEE Open Journal of Ctrl. Syst.*, *Journal of Energy Storage*, *Journal of Power Sources*, *Ctrl. Eng. Practice*, *etc.*). The articles will also be uploaded in the open-access HAL repository.

Scientific, material and financial conditions:

The future Ph.D. student will be enrolled with both research labs (GIPSA-lab and LEPMI).

Material conditions at GIPSA-lab: laptop computer with MATLAB®/Simulink® software licenses. Manipulation of these resources do not involve special security requirements.

Material conditions at LEPMI: The future Ph.D. student will possibly be required to carry out battery cycling experiments using the *battery characterization equipment* at LEPMI (Fig. 2), for estimator validation under specific use cases. She/he will previously undergo specific protection and security training and will benefit from support of technical staff at LEPMI; if relevant, she/he will wear individual protection equipment.

This subject enters the EEATS Doctoral School competition for public Ph.D. grants (approx. 2100 Euros per month gross salary). The Ph.D. student will also benefit from budget of GIPSA-lab MODUS team (depending on global team needs), *e.g.*, for participation to national and international scientific events.

A Ph.D. student is allowed to dedicate 1/6 of her/his annual worktime to another remunerated activity, *e.g.*, teaching hours or technical/scientific expertise.

Partial reimbursement of transport expenses (home – workplace) is ensured.

International collaborations:

The newly initiated GIPSA-lab–LEPMI collaboration recently gained international interest in the context of the research visit of Prof. Martin DÉSILETS of University of Sherbrooke in Québec, Canada, at LEPMI in 2024. Prof. DÉSILETS's research interest is on ageing prediction modelling for batteries. He renewed his visit at LEPMI in 2025. Funding of a jointly supervised Ph.D. thesis was obtained in response to the 2025 UGA IDEX RI call for proposals.

At the same international level, Prof. Besançon and Assoc. Prof. A.I. Bratcu received in 2025 a Ph.D. student supervised by Prof. Daniel COUTINHO from Universidade Federal de Santa Catarina in Brazil, for a ten-month research visit at GIPSA-lab. The visiting student is interested in developing estimators of battery SoC and SoH and he benefited of relevant measure data available at GIPSA-lab and LEPMI. This collaboration has already issued two joint publications: an article accepted in *Control Engineering Practice* journal and a paper submitted to the *IEEE 12th International Conference on Control, Decision and Information Technologies* (CoDIT 2026).

In this context, funding of the proposed Ph.D. project will allow effectively supporting this emergent collaboration dynamic and reinforce project proposal submissions pertaining to a major research topic of the green energy transition, at both national and international levels.

In this framework, the future Ph.D. student may be required to leave on international mobility; applications for funding such mobility are susceptible to be made at the level of UGA.

Profile and required skills:

Ideally, a person holding a master degree in **control systems engineering** and having a strong background in mathematical modelling, estimation and identification of dynamical systems, with interest and skills in **applications of electrochemical energy storage**, is sought for. Good knowledge of partial differential equations is highly appreciated.

Proficiency in **MATLAB®/Simulink®** is indispensable.

Proficiency in technical English is highly expected.

Good skills in scientific writing and text processing software tools (*e.g.*, Microsoft Word and LaTex) are necessary.

Proven high academic performance (excellent transcripts and ranking) is expected and must be provided. A record of publications in high-level journals and/or scientific conferences is a plus (but not mandatory).

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Contact:

Applications should be done following the link below:

https://www.adum.fr/script/candidature/index.pl?site=edeeats

Any additional question should be addressed to:

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