PhD Offer: Electrochemical Virtual Sensor Development for Lithium-ion Batteries[1]

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Duration: 3 years (European H2020 project INSTABAT, in final stages of signature)
Starting date: September / October 2020
Thesis grant: about 2000 €/month (gross salary, Teaching Assistant supplement negotiable)
Location: Lyon (Rhône, France)

Primary fields: Control Systems Theory, Applied Mathematics
Application fields: Electrochemistry, Electric Vehicles
Doctoral School: EEA, Université de Lyon, INSA Lyon (https://edeea.universite-lyon.fr, also available in English)

This proposed (36 month) PhD position in the Control Systems Department of Ampère Laboratory[2] at INSA Lyon is a part of the INSTABAT project[3], whose objective is to develop a **proof of concept multi-sensor platform (or "lab-on-a-cell")** capable of real-time monitoring of key electrochemical and thermal variables inside a battery cell and of predicting their impact on related physicochemical degradation phenomena taking place. An important component of this platform will be a set of **"virtual sensors"** (more commonly known in the control-systems literature as "**state observers**") that will allow the **real-time estimation** of key internal variables that cannot be directly measured. The information thus obtained should inform the Battery Management System (BMS) in order to improve the accuracy of available State of Charge, State of Health, State of Energy and State of Safety (SoX) indicators, and therefore adapt the charging and discharging strategies to improve the Quality, Reliability and Life (QRL) of the battery.

The retained candidate will have as main objective the **development of state estimation algorithms** for a class of infinite-dimensional systems (in this case, **diffusive partial differential equations**) representative of the electrochemical and thermal phenomena occurring inside the battery. In particular, the research will be oriented toward coupling thermal models and reduced **Doyle-Fuller-Newman** (or extended **Single Particle** type **models**), that are simple enough to run in real time but are able to perform adequately at high charge/discharge rates[4]. Some techniques that can be deployed include:

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[1] Funding: European Commission Horizon 2020 Research and Innovation Framework Programme call H2020-LC-BAT-2020-3, action LC-BAT-13-2020 (RIA).
[2] Ampère Laboratory is a research center regrouping researchers from the Université de Lyon, INSA Lyon, École Centrale de Lyon, Université Claude Bernard Lyon 1 and CNRS (UMR5005) http://www.ampere-lab.fr
[3] Proposal 955930: "Innovative physical/virtual sensor platform for battery cell" (INSTABAT). Participating partners: CEA (FR), BMW (DE), CNRS (FR), Faurecia (FR), Infineon (DE), INSA Lyon (FR), Universidade de Aveiro (PT), Varta (AT)
[4] Moura, S. J., F. Bribiesca Argomedo, R. Klein, A. Mirtabatabaei and M. Krstic. *Battery State Estimation for a Single Particle Model with Electrolyte Dynamics*. IEEE Transactions on Control Systems Technology. Vol. 25, Issue 2. pp. 453-468. March 2017. doi: 10.1109/TCST.2016.2571663. [Preprint] [Electrochemical Model Simulator (S. Moura)]

- Backstepping transformations for partial differential equations[5]
- Model reduction techniques (e.g. POD/Galerkin methods, finite differences, etc.)
- Extended Kalman filter techniques / nonlinear observer techniques.
- Optimization and Artificial intelligence techniques in general (e.g. convex optimization, machine learning, clustering techniques, etc.)

The candidate should exhibit a **strong mathematical and control systems foundation**, and either strong competences or capacity to rapidly acquire them in the following areas are highly desirable:

- Applied Mathematics (Analysis, PDEs, etc.)
- Optimization / AI techniques
- Numerical methods
- Programming using Matlab/Simulink

Furthermore, working knowledge or capacity to rapidly acquire it in basic electrochemistry will be required.

The successful candidate will be integrated into the Control Systems Department (AIS) of the Ampère Laboratory in Lyon and is expected to be able to evolve in a strongly inter-disciplinary team including academic and industrial partners. As a key interlocutor in the European research program, the candidate should be capable of clearly communicating and implementing (or helping, as required, with the implementation) of the developed algorithms for integration in the proof of concept platform by the end of the project.

Some useful information about doing a PhD in France for foreign students:
https://edeea.universite-lyon.fr/ed-160-eea/version-anglaise/navigation/international/foreign-phd-students
https://www.campusfrance.org/en/FAQ-Doctorate-France-questions

Application:
Candidates have to send by email the following documents:

- Curriculum Vitae
- Cover letter
- Master 1 and 2 transcripts (or latest two years of studies)
- The name and contact information of 1 or 2 references (willing and able to provide a recommendation)

[5] Krstic, M. And A. Smyshlyaev. *Boundary Control of PDEs: A course on Backstepping Designs*. SIAM, Advances on Design and Control, 2008.