Master Thesis Proposal:
State and Parameter Estimation Algorithms for Multi-Cell Systems

Thesis Background
Energy storage system (ESS) based on lithium-ion batteries is one of the most important but expensive and safety-critical components in the electrified powertrain. These batteries have complex nonlinear dynamics and need a battery management system (BMS) with advanced estimation and control algorithms to ensure their optimal performance and long lifetime. In this regard, the systems and control community have shown a lot of research interest in recent years. The overall goal is to develop a knowledgebase to design battery health-conscious BMS for optimal utilization of currently available cells to guarantee their long lifetime. One of the core BMS functions is to estimate battery internal state (state-of-charge [SOC], dynamic polarization, internal State-of-Temperature [SOT] etc.) and parameters (state-of-resistance [SOR], state-of-capacity [SOQ] etc.) using voltage, current, and temperature measurements. These estimates are used to provide critical predictions about maximum available battery energy and power (i.e., state-of-energy [SOE] and state-of-power [SOP]) during driving or charging. These predictions are then used to decide the maximum battery load to guarantee optimal, reliable, and safe operation (i.e., to respect voltage, current, and temperature limits).

Description of Thesis Work
A multi-cell system contains multiple cells connected in series or parallel. These cells may exhibit different dynamic behaviours, due to inevitable variations/imbalances in their internal parameters and operating conditions leading to state of charge, power, and energy imbalance among them. One typical approach for the estimations of SOC, SOR, SOQ, SOE, or SOP of a multi-cell system is to proceed with the typical estimations for each cell. This approach is accurate. However, computationally it has a high time and space complexity which is challenging for automotive ECUs. Another typical approach is to select certain cells from a multi-cell system and estimate the states and parameters of the selected cells. This approach is more computationally efficient but inaccurate. The inaccuracy reduces the system’s performance and shortens its lifetime. Both are not optimal and there is a trade-off between computation simplicity and estimation accuracy.

In this thesis, we will design an estimation approach considering both computational efficiency and estimation accuracy. How to achieve this optimal estimation in a cost-effective and computationally efficient manner is still an open research problem. This thesis deals with a part of this puzzle with the scope confined to the following particular research tasks:

1. **Development of computationally efficient state-space model** of this multi-cell system. The model must be scalable for any number and type of cells and for series or parallel connected cells.
2. **Select representative cells or representative groups of cells** in the multi-cell system. Analyze the dynamics of the selected cells or groups of cells.
3. **Assign SOX functions or function update frequencies** for different representative cells or groups. From this, we can get information on the states of the multi-cell system.
4. **Analyze and verify the proposed estimation scheme** thoroughly in comparison with those two typical approaches used in multi-cell systems under different load cycles and operating conditions. The main purpose is to thoroughly evaluate the potential benefits and costs associated with the operation of the proposed approach.
**Thesis Title:** State and Parameter Estimation Algorithms for Multi-Cell Systems

**Thesis Level:** Master

**Language:** English

**Starting date:** 2022-01-XX

**Number of students:** 2

**Qualifications and Required Documents**

- Must have a strong educational background in electrical engineering, engineering physics, or mechatronics with very good grades in master level courses like nonlinear filtering/estimation, linear control systems, nonlinear and adaptive control systems, model predictive control, etc.
- Must have high proficiency in Matlab and Simulink.
- You must be self-motivated and meticulous in your problem solving approach.
- Familiarity with electro-thermal dynamics of lithium-ion batteries and some experience with dSpace embedded control software development tools will be considered a merit.

Please send your application including **CV, Cover Letter**, and **Transcript of grades**.

**Contact and supervision:**

Olle Friberg  
Group head  
BMS Control  
Department of Electromobility  
CampX, Volvo GTT  
Olle.friberg@volvo.com  
+46 73 902 9923

Dr. Faisal Altaf  
Principal Research Engineer  
ESS Software and Control Design  
Department of Electromobility  
CampX, Volvo GTT  
+46 31 323 5834