Master Thesis: Control of Heterogeneous Multi-Battery 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 function is to estimate battery internal states (state-of-charge [SoC], dynamic polarization, internal State-of-Temperature [SoT] etc.), and health 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., SoE and SoP) during driving or charging. These predictions are then used to decide maximum battery load to guarantee optimal, reliable, and safe operation (i.e., to respect voltage, current, and temperature limits). In addition, the BMS performs several other important functions like cell balancing, thermal management, and fault diagnostics etc.

Description of Thesis Work

Multi-battery ESS is a large network of multiple parallel-connected battery units, which may exhibit different dynamic behaviours, due to inevitable variations/heterogeneities in their internal parameters and operating conditions. This leads to state of charge, power, capacity, and energy (so-called SoX) imbalance among them that makes it hard to define/estimate these states on complete ESS level. A typical approach is to operate ESS based on average state estimates and constraints dictated by a weakest link in the network. However, this control approaches is quite conservative in terms of utilizing the full potential service and capacity of ESS.

To optimize utilization of this heterogeneous network of complex dynamic systems, we may need more advanced estimation and predictive control methods. In particular, the optimal fusion and mapping of individual battery states to ESS states to maximize overall utility 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:

- Develop a computationally efficient state-space model for simulating multi-battery ESS considering aforementioned heterogeneities. Validate this control-oriented model using data from lab experiments and high fidelity plant model.
- Model-based dynamic analysis of power distribution/split among heterogeneous batteries in the ESS. The main purpose is to understand the performance limits of ESS by studying the dynamic interaction among the batteries and the various internal and external factors that affect the load sharing among them. This will provide some important guidelines and considerations for robust model-based SoX estimation and control design.
- Mathematical modelling and estimation of SoX for heterogeneous ESS using state estimates of individual battery units as inputs. In this regard, the optimal number of parameters for n different batteries that need to be considered for ESS level SoX estimation with acceptable accuracy and higher computational efficiency will be investigated.

- Develop a model predictive power management scheme for heterogeneous ESS under varying operating conditions.
- Analyze and verify the performance of the proposed estimation and control methods thoroughly in comparison with existing standard methods for ESS under different load cycles and operating conditions relevant to heavy-duty electric vehicles.

Proposed Thesis Title: On Model-based Estimation and Control of Heterogeneous Multi-Battery Systems

Qualifications and Required Documents

- Must have 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 meritorious

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

Application link:

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About us

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