# Real Time State Estimation of Reformulated Lithium-ion Battery Model for Advanced Battery Management Systems (BMS)

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Battery Management Systems (BMS) monitor and control the energy flow of a battery in such a way that the energy is used optimally, while preventing damage and, ensuring overall safety (1). For the BMS to function efficiently it is necessary to have the knowledge of internal states of the battery, which can be described by: the State-of-Charge (SoC), the State-of-Health (SoH) and the remaining runtime ($t_r$). The accurate determination of these above mentioned parameters holds the key for the optimal use of batteries and helps avoid over engineered batteries.

Physics-based models (2, 3) that incorporate most of the transport and kinetic phenomena affecting the internal states of a lithium ion battery are in the form of coupled nonlinear Partial Differential Equations (PDEs). While these models are accurate in terms of prediction capability, they cannot be employed for on-line (real time) control and monitoring purposes due to their huge computational expense. The reformulated model (4) is capable of predicting the internal states of battery with simulation times on the order of milliseconds without compromising on accuracy for an entire discharge. This talk will focus on demonstrating the feasibility of the reformulated model's use for control-relevant real-time applications. Two approaches in the field of nonlinear and constrained state estimation that have received great attention recently are Moving Horizon Estimation (MHE) and Particle Filtering (5, 6). Results of a comparative study on performances of both the methods for computational time, robustness and accuracy will be presented. The talk will also focus on the issues and challenges in state estimation in moving from a powerful workstation to a microcontroller platform which imposes serious constraints on available computational recourses (e.g. memory, speed and precision).

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