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Computationally Efficient Electrochemical-Thermal Li-Ion Cell Model for Battery Management System

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Abstract : Vehicle electrification is gaining momentum, and many car manufacturers promise to deliver more electric vehicle (EV) models to consumers in the coming years. In controlling the battery pack, the battery management system (BMS) must maintain optimal battery performance while ensuring the safety of a battery pack. Tasks related to battery performance include determining state-of-charge (SOC), state-of-power (SOP), state-of-health (SOH), cell balancing, and battery charging. Safety related functions include making sure cells operate within specified, static and dynamic voltage window and temperature range, derating power, detecting faulty cells, and warning the user if necessary. The BMS often utilizes an RC circuit model to model a Li-ion cell because of its robustness and low computation cost among other benefits. Because an equivalent circuit model such as the RC model is not a physics-based model, it can never be a prognostic model to predict battery state-of-health and avoid any safety risk even before it occurs. A physics-based Li-ion cell model, on the other hand, is more capable at the expense of computation cost. To avoid the high computation cost associated with a full-order model, many researchers have demonstrated the use of a single particle model (SPM) for BMS applications. One drawback associated with the single particle modeling approach is that it forces to use the average current density in the calculation. The SPM would be appropriate for simulating drive cycles where there is insufficient time to develop a significant current distribution within an electrode. However, under a continuous or high-pulse electrical load, the model may fail to predict cell voltage or Li^+ plating potential. To overcome this issue, a multi-particle reduced-order model is proposed here. The use of multiple particles combined with either linear or nonlinear charge-transfer reaction kinetics enables to capture current density distribution within an electrode under any type of electrical load. To maintain computational complexity like that of an SPM, governing equations are solved sequentially to minimize iterative solving processes. Furthermore, the model is validated against a full-order model implemented in COMSOL Multiphysics.

Keywords : battery management system, physics-based li-ion cell model, reduced-order model, single-particle and multi-particle model
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