A phenomenological force model of Li-ion battery packs for enhanced performance and health management

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ABSTRACT

A 1-D phenomenological force model of a Li-ion battery pack is proposed to enhance the control performance of Li-ion battery cells in pack conditions for efficient performance and health management. The force model accounts for multiple swelling sources under the operational environment of electric vehicles to predict swelling-induced forces in pack conditions, i.e. mechanically constrained. The proposed force model not only incorporates structural nonlinearities due to Li-ion intercalation swelling, but also separates the overall range of states of charge into three ranges to account for phase transitions. Moreover, an approach to study cell-to-cell variations in pack conditions is proposed with serial and parallel combinations of linear and nonlinear stiffness, which account for battery cells and other components in the battery pack. The model is shown not only to accurately estimate the reaction force caused by swelling as a function of the state of charge, battery temperature and environmental temperature, but also to account for cell-to-cell variations due to temperature variations, SOC differences, and local degradation in a wide range of operational conditions of electric vehicles. Considering that the force model of Li-ion battery packs can account for many possible situations in actual operation, the proposed approach and model offer potential utility for the enhancement of current battery management systems and power management strategies.