ABSTRACT

Nowadays, lithium-ion batteries are the most preferred power sources used in consumer electronics, automotive and bio-medical applications due to their high energy density, smaller size, high power density, low self-discharge, longer cycle life, no memory effect etc. as compared to other types of batteries available in market. The usage pattern of a lithium-ion battery largely affects its overall life and reliability. In order to improve the battery safety, efficiency and reliability, a battery health monitoring system (BHMS) is very much essential, especially for electronic gadgets and electric vehicles. In order to design a BHMS, an accurate battery model representing the real battery is essential for efficient monitoring of the state of charge (SoC) and state of health (SoH) of batteries. As many of these states are not directly measurable, they are usually estimated based on model-based algorithms. Based on the literature, significant amounts of research have been carried out to develop electrical equivalent and degradation models for lithium-ion batteries for this purpose.

This thesis considers the existing battery models and proposes an approach for estimation of the electrochemical impedance spectrum (EIS) of lithium-ion batteries based on a fractional order equivalent circuit model (FOECM) which can be implemented online. The parameters of the FOECM are determined using recursive least squares (RLS) technique in conjunction with a fractional order state variable filter (FOSVF) based on current and voltage measurements. Regarding SoH monitoring, a method for the estimation of remaining useful life (RUL) of lithium-ion batteries has been presented based on a combination of its capacity degradation and internal resistance growth models. Further the aforesaid models were fused together to obtain a new degradation model for RUL estimation, which improved the uncertainty in prediction as compared to the individual models by maintaining satisfactory prediction accuracy. Finally, the internal resistance degradation model obtained based on the estimated EIS spectrum is used in the prognostics framework to predict the RUL of the battery quite satisfactorily as compared to the RUL obtained based on EIS measurements. The advantage of the proposed online EIS estimation approach can be continuous monitoring of the battery health at regular cycle intervals based on estimated battery model parameters without the use of expensive EIS equipment.

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Keywords:

Lithium-ion batteries, equivalent circuit model, parameter estimation, electrochemical impedance spectrum, state of charge, state of health, remaining useful life.