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Extended Abstract

Electrochemical Model Based Fault Diagnosis of Lithium Ion Battery

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Abstract

A Multiple Model Adaptive Estimation (MMAE) based approach of fault diagnosis for Li-Ion battery is illustrated in this paper. Electrochemical modeling approach is integrated with MMAE for fault diagnosis. This real physics based model of Li-ion battery (with Li-Co-O_2 cathode chemistry) with nominal model parameters is considered as the healthy battery model. Battery fault conditions such as aging overcharge and over discharge causes significant variations of parameters from nominal values and can be considered as separate models. Output error injection based Partial Differential Algebraic Equation (PDAE) observers are used to generate the residual voltage signals. These residuals are then used in MMAE algorithm to detect the ongoing fault conditions of the battery. Simulation results show that the fault conditions can be detected and identified accurately which indicates the effectiveness of the proposed battery fault detection method.

Keywords:

Electrochemical model; Lithium-ion batteries; Particle swarm optimization; Parameter identification; Battery management system

Introduction

Amongst all the secondary (alternative) energy sources available for various applications such as Plug-In Hybrid Electric Vehicle (PHEV), Hybrid Electric Vehicle (HEV), Electric Vehicle (EV) and portable electronic devices such as smartphone and laptops, lithium-ion (Li- ion) battery is considered to be the most promising. Compared to the other alternative options for energy sources (such as Nickel-metal hydride and Lithium iron phosphate etc.) lithium-ion batteries have some unique advantages including: these batteries have higher specific energy, have minimum memory effect, provide best energy- to-weight ratio, and have low self-discharge when idle. Based on these stated advantages, Li-ion batteries is the leading candidate for the upcoming generation of aerospace, automotive, and other applications.

PHEV, EV and HEV have been gaining more acceptances in recent years due to their low emissions and better fuel efficiency. Performance of these transportation options are significantly dependent on the electrochemical energy sources e.g. installed battery modules integrated with the vehicle powertrain. Depending on the user driving habit and the road conditions, battery undergoes through different operating conditions as the battery load demand changes. The safe operation of the entire battery module is always expected, as it is one of the most vital components of the stated vehicle configurations. But in reality, it is not always possible to maintain the desired safe and healthy operating conditions of the battery system for a number of reasons. For instance, battery can be overcharged during operation, can be over-discharged at different rates. Moreover, battery aging is another potential situation due to long time cycling of the battery.

Electrochemical Battery Model

The electrochemical battery model captures the spatiotemporal dynamics of li-ion concentration, electrode potential in each phase, and the Butler-Volmer kinetics which governs the intercalation reactions. A schematic of the model is provided in Figure 1.

In the provided geometry, the model considers the dynamics of Li- ion cell only in X -direction. Therefore, the model considered in this work is a 1-D spatial model where variations of the dynamics in Y and Z directions are assumed to be small. It is also assumed that Li-Ion particles are considered to be of spherical shapes with mean radius of Rp situated along X-axis.

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Multiple Models Adaptive Estimation (MMAE) Technique

This adaptive estimation technique which is a special type of fault detection method is adopted in this work with the electrochemical model of Li-ion battery .In this estimation (MMAE) technique model of Li-ion battery. In this estimation (MMAE) technique

All the models are excited by a same input signal. MMAE in our work uses PDAE observer outputs of different models (coming from due to parameter variations). If there are total "n" models, there will be outputs represent the faults or unhealthy scenarios; the remaining one is the actual plant model.

System Identification Toolbox in MATLAB was used to have matrices for all the scenarios. Using all possible residuals the conditional probabilities are evaluated. The largest conditional probability among all may be used as an indication of ongoing fault condition related to the involved specific residual

Fault Diagnosis

Among all the electrochemical model parameters of the battery dynamics, there are some parameters which depend on the battery physics and on the other hand another type of parameters exist, which depend on the chemistry of the battery. Stated two types of parameters are adopted in this fault diagnosis work. In addition to these two type of parameters, there are some parameters, which were adopted from the manufacturer provided values.

Conclusion

Fault diagnosis of Li-Ion battery was implemented for a real time operation mode for HEV. An effective fault diagnosis technique, multiple model adaptive estimation (MMAE) was implemented for some crucial operation mode of Li-Ion battery. Some possible abusive operating conditions, i.e. over-discharged, over-charged and aged mode of operation was adopted along with the healthy operation of Li-Ion battery. The obtained probability of faults was correct enough to use in real time BMS of a HEV. Obtained results of fault diagnosis is based on the electrochemical model of the battery dynamics, therefore, the obtained fault diagnosis is more reliable and it can be thought for a potential real time application for HEV battery, where the BMS would be a reliable one because of the adopted fault diagnosis technique

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