Chapter 4
Comparative Analysis of State-of-Health Estimation Techniques: A Comprehensive Survey

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ABSTRACT

The advancement and transformation in batteries have given rise to high-power applications such as electric vehicles. Electric vehicles are widely accepted in the automobile industries assessing the most feasible alternatives for lowering carbon emissions and addressing the various global sustainable environmental challenges. Lithium-ion (Li-ion) batteries are the prominent component in the energy storage system. Monitoring the battery condition is a prominent task of the battery management system (BMS). Many parameters affect the battery's health and could lead to degradation of the battery leading to underperformance of the system. This chapter discusses the various methods of computing the state of health (SOH) and presents an analysis of the SOH errors, estimation model, benefits, drawbacks, and challenges and provides recommendations for battery management system development.

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1. INTRODUCTION

The growing technology and consumption of non-renewable resources have led to a dearth of natural resources. Various issues such as global warming, smog, emissions of carbon, and climatic change are affecting the ecological imbalance. The transportation sector contributed an average annual rise of 1.7% of emissions from 1990 up to recent until 2022, which is higher than any other sector (IEA, 2023). The gradual depletion of non-renewable resources has led to the importance of electric vehicles in the market. The growing demand for electric vehicles is scaling tremendously, hence the development of a proper battery management system claims for the need. In any Electric Vehicle (EV), the Battery Management System (BMS) comprises sensors, actuators, and controllers etc., the function of a BMS is to monitor the battery parameters and control the monitored parameters to ensure that the energy stored in the battery is safely utilised and efficiently.

The selection of the battery plays a vital role in the EV application. There are numerous chemistries of the battery available to be used for various applications. To name a few lead acid (Pb-acid), nickel metal hydride (Ni-MH), lithium-ion (Li-ion), nickel-cadmium (Ni-Cd) etc (Itagi et al., 2024; Monolithic Power Systems, 2024). The Pb-acid-based batteries have lower energy density and are heavier in weight. These batteries are majorly used in automobiles where the vehicle weight factor is not important. When compared with Pb-acid batteries, Ni-MH-based batteries have a higher energy density, are cost-effective and have a great balance within their parameters. In many cases, Ni-MH is considered to be more secure than Li-ion. However, due to its lower energy density when compared to Li-ion batteries, Ni-MH is less approached in EVs but can be seen in many hybrid vehicles. Similarly in the case of Ni-Cd, even though they have a longer shelf life, due to the precarious Cd element and the memory effect the industries look for a more ecologically pleasant resort.

Hence when compared with all the above-mentioned chemistries, Li-ion comes with high energy density, greatly recyclable with low self-discharge. The possession of high energy density in Li-ion batteries helps in reducing the cell count in the pack and also boosting the driving range of the vehicle (Khan et al., 2023). Amidst all the mentioned, the lithium-ion is compatible with EVs owing to the fact of its incredible features. The prime task of the BMS is to monitor, control and assess various parameters of batteries, like State of Charge (SOC) (Kallimani et al., 2022), State of Energy (SOE) (Hou et al., 2023), State of Health (SOH) (Y. Liu et al., 2023), and State of Power (SOP) (Wu et al., 2022) using various algorithmic procedures. The procedures are carried out with regard to current, voltage and temperature within the battery (K. Liu, Li, et al., 2019).

1.1. Motivation

The SOH of a battery specifies degradation levels (Mingant et al., 2019). The major reason for the ageing of batteries is due to mechanical, chemical, thermal, and also electrode composition. The conventional estimation methods of SOH comprise model-based, direct, and indirect measurement methods, adaptive filtering and data-driven methods. In the direct measurement approach, however, to estimate SOH static-cycling conditions are considered under robust presumptions. The already stated conditions are unsuitable for real-time EV batteries as they necessarily involve real-time SOH calculation. The charging/discharging occurs dynamically because of SOH of a battery is a critical principal parameter for estimating SOC. This regulates the EV's driving mileage and is critical to computing SOH in real time. However, most methods are sufficiently substantiated in the plenteous experimentally acquired data, and

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