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Performance Analysis of the Battery Management System in an Electric Vehicle

Snehashis Ghoshal[1], Sunil Kumar Choudhary[1], Arindam Mondal[1], M. Prakash[2]
[1]*Department of Electrical Engineering, Dr. B.C. Roy Engineering College,* Durgapur, West Bengal, India
[2]*Department of Electrical Engineering, NIT Nagaland,* Chumukedima, Nagaland, India
snehashis0007@gmail.com, sunee.world@gmail.com, arininstru@gmail.com, prakash@nitnagaland.ac.in

***Abstract*— Electric Vehicles (EVs) play a pivotal role in addressing the challenges of present-day needs related to the reduction of greenhouse gas emissions and reliance on fossil fuels. EVs contribute to clean air quality, mitigate climate change, and promote sustainability through the integration of renewable technologies. Besides, it has become economical due to its lower operating costs. Hence, EVs foster a shift towards a robust, resilient, and eco-friendly transport sector and create scopes for innovation in green technologies. The role of a Battery Management System (BMS) becomes impertinent in the case of EVs as it is the main factor for the proper operation of EVs. There is a remarkable scope for enhanced battery performance in EVs for more reliability and endurance. Hence, research and development in BMS as well as its temperature regulation are therefore major fields of concern. In the present study, a BMS was designed and simulated for efficient charging and discharging addressing different battery faults by maintaining its temperature to reasonable limits. Results showed enhanced performance of the BMS with reasonable SoC, steady voltage, and current profile. Improved battery performance leads to a more efficient driving experience as well as fast charging capability thereby reducing the cost involved and enhancing the sustainability of the system.**

Keywords*— *Electric Vehicle, Battery Management System (BMS), Temperature Control, Fault Analysis

I. Introduction

Electric Vehicles play a significant role in present days due to the acute need to solve energy and environment-related issues. Road transport is responsible for over 70% of greenhouse gas emissions and over 25% of world energy consumption, making the transportation sector the energy consumer with the biggest environmental impact [1-4]. Oil reserves are rapidly running out in the present world. Besides, oil prices have been growing steadily due to several geopolitical concerns in the last few decades [5-7]. The idea of sustainable transportation has gained popularity to address issues with oil dependency and emissions reduction. Even when compared to more efficient conventional automobiles, the widespread usage of electric vehicles (EVs) could drastically lower greenhouse gas emissions [8-10]. In addition to additional benefits such as reduced noise and vibration, EVs also attain "tank-to-wheels" efficiency, which is approximately three times greater than that of cars with internal combustion engines (ICVs) [11-12].

While EVs have numerous environmental and operational advantages, they come with several drawbacks. The higher initial cost of EVs due to expensive battery technology is the main reason that a large number of consumers are refrained from affording an electric vehicle. Besides, the lack of charging infrastructure also creates a barrier to promoting EV usage. Apart from that, longer charging periods and shorter driving ranges than conventional automobiles cause range anxiety among users. Additionally, mining of raw materials for batteries such as lithium, cobalt, etc. As well as their recycling raises sustainability concerns. Furthermore, the performance of the battery deteriorates over time, lowering the reliability and range of the vehicle. İn this regard proper design of a battery management system (BMS) plays a crucial role in EV applications. BMS ensures the safety, efficiency, and longevity of a battery pack. In this regard, BMS provides numerous scopes for research and addresses different issues related to an optimized battery operation for EVs. Challoob et al. [13] recommended advancing electric vehicle technology, equipping engineers with effective strategies for battery storage, charging, converters, controllers, and optimization methods to align with sustainable development goals. Brandl. Et al. [14] reviewed key modeling approaches for predicting battery performance and explored the requirements and standards for battery management systems. They presented a flexible architecture for implementation, techniques for state-of-charge estimation, and charge balancing by implementing an active charge equalizer. İn their study, Ananthraj & Ghosh [15] developed a Simulink-based lithium-ion battery model in Simulink. The model enables data collection and State of Charge (SOC) calculation through the coulomb counting method, instead of the traditional Open Circuit Voltage (OCV) measurement. Simulation results confirmed the effectiveness of the SOC calculation and hence the response of the battery. Sutar et al. [16] developed a BMS model for by controlling key parameters such as current, voltage, temperature, and State of Charge (SOC). The authors reported that this model enhanced power performance while contributing to greenhouse gas reduction through effective BMS implementation. Manas et al. [17] proposed a congregated battery management system (BMS) to ensure safe operating limits for parameters such as State of Charge (SoC), temperature, power management, and optimal charging. Rosen and Farsi highlighted the necessity of proper thermal management in a BMS [18]. Parameswari and Usha [19] highlighted the advantages of lithium batteries over lead-acid batteries, emphasizing their longer lifespan, lighter weight, and reduced heat emissions. Simulation analyses of 1RC and 2RC network parameters demonstrated their efficiency in minimizing chemical reaction issues. To optimize the battery performance, advanced computing techniques are being explored gradually [20, 21]. Table 1 below depicts a comparative analysis between existing and present work in literature.

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