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JUSTIFICATION OF THE IMPORTANCE OF IMPROVING THE BATTERY MANAGEMENT SYSTEM IN ELECTRIC VEHICLES

Introduction. Battery Management Systems (BMS) are vital components of electric vehicles that play a pivotal role in ensuring the efficient and safe operation of the battery packs. These sophisticated systems continuously monitor and control various critical parameters that affect battery performance. These parameters include battery voltage, temperature, state of charge, state of health, and charge/discharge rates. The BMS uses this data to make real-time decisions to optimize battery operation.

A key aspect of BMS is to safeguard the battery from harmful operating conditions. It helps prevent overcharging, which can damage the battery and reduce its lifespan, and also guards against excessive discharging, which can lead to the risk of over-discharge and even battery failure. Moreover, it monitors and balances individual cells within the battery pack, addressing imbalances and ensuring uniform cell performance.

The efficiency and overall performance of an electric vehicle heavily rely on the proper functioning of the BMS. An effective BMS not only prolongs the lifespan of the battery but also ensures stable and consistent power delivery to the vehicle's electric motor, thereby optimizing its performance.

The **goal** of this study is to analyze the role of battery management systems in electric vehicles, specifically their impact on battery performance and lifespan, with the objective of further enhancing these management systems.

As the analysis demonstrates, a significant challenge in battery operation is the occurrence of battery imbalances and a reduction in the capacity of its elements. Let's explore these issues in greater detail.

Battery imbalance - a case study. Electric vehicle batteries consist of multiple series-connected cells, each with slight variations in capacity, internal resistance, self-discharge rate, and degradation. Over time, these variations can lead to battery imbalance, causing inefficient energy utilization and accelerated degradation.

Causes of battery imbalance:

– Variations in Cell Capacity and Impedance: Increased variations in cell capacity and impedance within the battery pack can lead to differential current flows and heat generation. If not properly managed, these variations can further reduce battery life and degrade the vehicle's operation.

– Temperature and Vibration: Battery balancing performance should be evaluated under various temperature and vibration frequencies to understand its long-term effects [1].

– Driving and Recharging Behavior: Aggressive driving and recharging behavior can significantly affect battery life, contributing to imbalance [2].

– Electrical Imbalance: Imbalances in electrical properties can impact the battery pack and require thermal management systems for mitigation [3].

The effects of battery imbalance in electric vehicles are multifaceted. Variations in cell capacity and impedance can result in reduced battery life and degraded vehicle operation, as evidenced by research from [1]. Additionally, such imbalances can lead to inefficient energy utilization, affecting the operational range of the vehicle, as noted by [4]. Electrical imbalances specifically necessitate the implementation of thermal management systems to maintain optimal performance, as indicated by [3]. Beyond these primary effects, field tests have revealed economic deviations between theoretical and physical potentials of grid-balancing measures, attributed to model inaccuracies and technical characteristics, as shown by [5].

BMS functionality for battery optimization. The BMS plays a critical role in mitigating the adverse effects of battery imbalance. It ensures uniform voltage across all cells during the charging process through balancing techniques, such as shunting charged cells and redistributing energy among cells with varying voltage levels [6].

In passive balancing, cells that reach full charge are either supplied with reduced current or temporarily disconnected until all cells achieve a uniform voltage level. The BMS also monitors control signals such as high voltage per cell, start voltage balancing, low voltage shutdown, and maximum temperature of battery cells pack [7]. Additionally, BMS provides temperature control and other functionalities that contribute to battery longevity and performance [8].

The primary objectives of a Battery Management System (BMS) application are threefold. First, it aims to protect against damage to both individual cells and the entire battery assembly. Second, it seeks to extend the overall lifespan of the battery. Third, it ensures that the battery is operationally ready to complete tasks as required. To achieve these objectives, the BMS has several core functionalities. It monitors key battery parameters like voltage, temperature, and charge/discharge rates. Through intelligent computing, it assesses variables such as maximum allowable charge and discharge currents, energy throughput, internal resistance, and total work cycles. The system also supports data sharing through both wired and wireless transmission methods. Additionally, it provides protection mechanisms against overcurrent, overvoltage, undervoltage, thermal extremes, and current leakage. Lastly, it balances the charge among individual cells to maximize battery lifespan [9-11].

BMS Architecture. The architecture of BMS varies among manufacturers and may include multiple interconnected control boards, each responsible for a subset of cells. These boards feed data to a central controller for comprehensive management. Some BMS architectures are based on the concept of redundant cells, which dynamically disconnect cells for optimal balancing purposes [12]. Others use a hybrid multilevel converter and an auxiliary battery to balance voltage and state-of-charge (SOC) between batteries [6]. Reconfigurable BMS designs allow for controlled charging and discharging by monitoring various control signals such as high voltage per cell, start voltage balancing, and maximum temperature of the battery cells pack [7].

Conclusion. This work highlights the crucial role of Battery Management Systems (BMS) in optimizing electric vehicle battery performance and longevity. The study outlines how BMS mitigates challenges like battery imbalance and variations in cell capacity. By examining its core functionalities and architectures, the paper emphasizes the need for further R&D in BMS technologies to enhance battery efficiency and lifespan in electric vehicles. Improving BMS is essential for the broader success and adoption of electric vehicles.

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