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Based on the analysis of battery management system for the range of electric vehicles

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Abstract:

With the increasingly severe global energy crisis and environmental pollution, the development of new energy vehicles has become a global consensus. As an important representative of new energy vehicles, electric vehicles have developed rapidly in recent years with their significant advantages such as zero emission and low noise. However, the range of electric vehicles has always been the key factor restricting their further popularization, and it is of great theoretical and practical significance to explore the range of electric vehicles based on battery management system. This paper briefly describes the concept and main functions of the battery management system, analyzes the problems from the aspects of battery balancing technology, battery state evaluation, reliability and safety, and proposes corresponding optimization strategies, which has certain theoretical significance and application value.

Keywords: Battery Management System (BMS), State of Charge (SOC), State of Health (SOH), Battery balancing, Battery condition assessment, Security

1. Introduction

In recent years, although great progress has been made in the research and development and industrial promotion of electric vehicles at home and abroad, the problem of battery life is still prominent. Many domestic studies focus on algorithm optimization and hardware upgrade of battery management systems to improve the accuracy and control effectiveness of battery condition monitoring. Abroad, it continues to explore the application of advanced battery management concepts and cutting-edge technologies, such as Tesla, and other companies have adopted advanced BMS technology in their products, which has improved the vehicle's endurance performance to a certain extent. Analyzing the battery life of electric vehicles based on battery management systems and exploring practical optimization solutions can promote the healthy and rapid development of the electric vehicle industry to a certain extent.

2. Overview of the battery management system

As one of the core components of electric vehicles, the battery management system (BMS) plays a vital role in solving the range problem. The main functions include battery status monitoring, charge and discharge control, battery balancing management, thermal management, etc. [1]. By monitoring the voltage, current, temperature and other parameters of the battery in real time, the BMS can accurately evaluate the state of charge (SOC) and state of health (SOH) of the battery, providing accurate range information for the driver. At the same time, the BMS optimizes the charge and discharge control strategy to avoid overcharging and overdischarging the battery, prolong the service life of the battery, and indirectly improve the cruising range. In terms of battery balancing management, BMS can balance the power of each single battery in the battery pack, prevent individual batteries from being damaged due to overcharging and discharging, and improve the overall performance and endurance of the battery pack. In addition, the thermal management function of the BMS can maintain the temperature of the battery during operation within a certain comfortable range, reducing the negative impact of temperature on battery performance and improving battery performance [2].

3. The main problems existing in battery management technology

3.1 Technical problems with battery balancing

3.1.1 Insufficient equalization accuracy

It is difficult for some balancing technologies to accurately balance the power, voltage and other parameters of each single cell in the battery pack to a consistent level. Especially when the battery pack is large and contains multiple battery cells connected in series or parallel, due to the differences in self-discharge rate and internal resistance of different cells, the balancing system may not be able to achieve the ideal balancing effect, resulting in limited overall performance of the battery pack.

3.1.2 Poor long-term equilibrium

Even if the balancing technology can achieve a good equilibrium state in the initial stage, the inconsistencies between the battery cells may reappear and gradually expand as the battery life time increases and the number of charge-discharge cycles increases. Batteries are affected by a variety of factors such as ambient temperature, charge and discharge depth during long-term use, and existing balancing technologies may not be able to respond to these changes continuously and effectively, thus affecting the long-term performance and life of the battery pack.

3.1.3 High energy loss

The process of performing cell balancing calculations consumes a portion of the energy, which reduces the overall energy utilization efficiency of the whole pack. Equalization is achieved by dissipating the energy of the battery cells with a higher charge in the form of thermal energy, which leads to a shorter range of the battery pack and reduces the energy efficiency of electric vehicles.

3.1.4 Slow and long time for equalization

Due to the large amount of energy that a high-capacity, high-voltage battery system needs to process; it takes longer to bring many battery cells to an equilibrium state. Moreover, in the process of rapid charging and discharging, the state of the battery cell changes rapidly, and it is difficult for the existing equalization technology to respond quickly and adjust in time. In fast charging mode, the energy of a partial monobloc battery will change greatly in a relatively short period of time, but the balancing system cannot complete the balancing operation during this time, resulting in a further aggravation of the imbalance between battery cells [3][4][5].

3.2 Battery condition assessment issues

3.2.1 There is a measurement error

Sensors that measure battery voltage, current, temperature, and other parameters have certain accuracy limitations. Errors in voltage measurements may lead to the deviation of the SOC estimate, and the lack of precision of the current sensor can affect the accurate calculation of the battery discharge and charge, which in turn will affect the accuracy of the state assessment. In addition, various noises such as electromagnetic interference, line noise, etc., are introduced during the measurement process. These noises can cause fluctuations and distortions in the measurement data, interfering with the evaluation algorithm's judgment of the real battery state.

3.2.2 Environmental factors

Temperature has a significant impact on battery performance. In the low temperature environment, the chemical reaction rate of the battery slows down, the internal resistance increases, the usable capacity decreases, and the rate of change of SOC will also change. High temperatures may accelerate battery aging, causing SOH to drop faster. The high humidity environment may also cause moisture in the battery housing, electrodes, and other components, affecting the performance and internal chemical reactions of the battery, which in turn may affect the battery state [5][6][7].

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3.3 Reliability and Security Issues

3.3.1 Hardware level

In the complex vehicle operation environment, harsh conditions such as high temperature, vibration, and electromagnetic interference are unavoidable. High temperature may lead to the degradation of the performance of electronic components, the computing speed of the chip is reduced, and the internal capacitance value changes, which affects the accurate monitoring and control of the battery status of the battery management system. Vibration can loosen solder joints on the board, causing poor contact and signal transmission interruptions or errors. Electromagnetic interference may affect the measurement accuracy of the sensor and the stability of signal transmission, resulting in deviations in the current value measured by the current sensor.

3.3.2 Software Layer

Due to the complexity of the software algorithm and control logic of the battery management system, problems such as software vulnerabilities and program crashes are prone to occur in the actual operation process. During the fast charging of the battery, the software failed to adjust the charging strategy in time, resulting in overcharging of the battery. In addition, there are risks associated with software updates and maintenance, and errors in the update process can also compromise the security of the battery management system [8].

4. Optimized strategies

4.1 Battery balancing technology

Exploring the transformer-based active equalization circuit can make use of the electromagnetic coupling characteristics of the transformer to realize the efficient energy transfer between battery cells. This kind of circuit can flexibly adjust the direction and size of energy transmission according to the actual needs of each cell in the battery pack, and improve the equalization efficiency. At the same time, the multi-winding inductance equalization circuit is studied, and the balancing time of multiple battery cells is realized through the cooperative work of multiple inductors. A multi-factor equilibrium decision-making model was established, which not only considered SOC, SOH, temperature, and internal resistance, but also included factors such as the discharging and charging history and self-discharge rate of the battery. The fuzzy logic control algorithm is used to judge the balancing demand of the battery according to the comprehensive weight of multiple factors, and a reasonable balancing strategy is formulated. High-precision sensors are used to monitor the state parameters of each single battery in the battery pack in real time, analyze the monitoring data in real time through intelligent algorithms, and adjust the balancing strategy and balancing parameters in time according to the dynamic changes of the battery state to ensure the stability and sustainability of the balancing effect.

4.2 Accuracy of battery state evaluation

The ampere-hour integral method can be combined with the Kalman filter method, and the particle filter algorithm can also be introduced to further improve the SOC estimation accuracy of the battery state of charge by taking advantage of its good processing ability for nonlinear systems. At the same time, multi-source data such as battery voltage, current, temperature and internal impedance of the battery are fused, and the potential connection between the data is mined through the data fusion algorithm, which provides more comprehensive and accurate information for state estimation. In addition, neural networks are used for in-depth analysis and learning of the battery's historical data [9]. These models can capture the trend of battery state over time, effectively deal with the influence of complex factors such as battery aging and self-discharge on state estimation, and optimize the SOH evaluation model of state of health.

4.3 Security aspect

In terms of hardware selection, electronic components with high reliability, wide operating temperature range, strong anti-vibration and anti-electromagnetic interference capabilities are selected. Measures such as dual power supply and multiple protection circuits can be used to ensure that the system can still work normally when a hardware component fails. For the reinforcement of software, the correctness and security of the software are proved through mathematical models to avoid the occurrence of software vulnerabilities. Real-time fault detection technology is introduced, and intelligent algorithms are used to monitor the running status of the software. Strengthen the security protection of software, adopt encryption technology, access control technology, etc., to prevent software from being maliciously attacked and tampered with, and ensure the security of system operation.

5. Summary

Battery management systems have broad prospects in improving battery life. Through the in-depth mining and analysis of a large amount of battery data, combined with real-time road conditions, driving habits and other information, the battery management system can achieve more accurate battery status prediction and charging and discharging strategy optimization. With the continuous development of artificial intelligence, machine learning and other technologies, battery management systems will move towards a more intelligent direction.

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