IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES
ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 8, 2022

Advanced Power Battery Management Structure for Electric Vehicles: Design and Implementation

G.Sundararajan, Y.Mohamed Batcha, M.Priya

Assistant Professor, Department of Electrical and Electronics Engineering,

J.J. College of Engineering and Technology, Trichy, Tamilnadu

Associate Professor, Department of Electrical and Electronics Engineering,

J.J. College of Engineering and Technology, Trichy, Tamilnadu

Assistant Professor, Department of Electrical and Electronics Engineering,

J.J. College of Engineering and Technology, Trichy, Tamilnadu

DOI:10.48047/IJFANS/11/8/321

Abstract

This research presents a novel power battery management structure (BMS) specifically designed for electric vehicles (EVs). The BMS consists of various modules including a central control module, measurement and control module, battery pack, motor controller, direct-current motor, vehicle-mounted charger, current and electric quantity detection module, vehicle-mounted liquid crystal display module, switching group, memory module, clock module, and temperature management module. The structure utilizes a CAN communication bus for seamless communication between the central control module, measurement and control module, vehicle-mounted charger, motor controller, and vehicle-mounted liquid crystal display module. With three operational modes (charging, discharging, and fault), the BMS enables efficient acquisition, management, and control of critical battery parameters such as voltage, temperature, current, and electric quantity. It ensures safe charging and provides early fault warnings for the battery. Compared to existing technologies, this battery management structure offers superior reliability, enhanced charging safety, stable structure operation, comprehensive functionality, and easy expandability.

Keywords: Power battery management structure, Electric vehicle, CAN communication, Battery parameters, Charging safety, Fault detection.

Introduction

The increasing demand for electric vehicles (EVs) as a sustainable transportation option has led to advancements in battery technology.[1] A crucial component of EVs is the power battery management structure, responsible for monitoring, controlling, and ensuring the safe and efficient operation of the

ISSN PRINT 2319 1775 Online 2320 7876
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battery pack.[2] The effectiveness of the battery management structure directly impacts the performance, reliability, and lifespan of the battery.[3] This research focuses on the development of a special power battery management structure designed specifically for electric vehicles.

The proposed structure incorporates various modules and components, including a central control module, measurement and control module, battery pack, motor controller, direct-current motor, vehicle-mounted charger, current and electric quantity detection module, vehicle-mounted liquid crystal display module, switching group, memory module, clock module, and temperature management module.[2] The key feature of the proposed battery management structure is its utilization of a CAN (Controller Area Network) communication bus for seamless communication between the central control module and other modules within the structure. This communication protocol enables efficient data exchange and control commands, enhancing the overall performance and reliability of the structure.

The Controller Area Network (CAN) is an internationally recognized bus standard introduced in 1993 and has since become the widely accepted norm for interconnecting Electronic Control Units (ECUs) within vehicles for the past two decades.[4] All ECUs function as interconnected nodes, linked by a conventional two-wire bus that transmits signals differentially through wired-AND technology. Within the CAN protocol, a broadcast protocol is employed based on sender ID. The CAN frames utilized for ECU communication are comprised of seven primary fields, as illustrated in **Figure 1**.

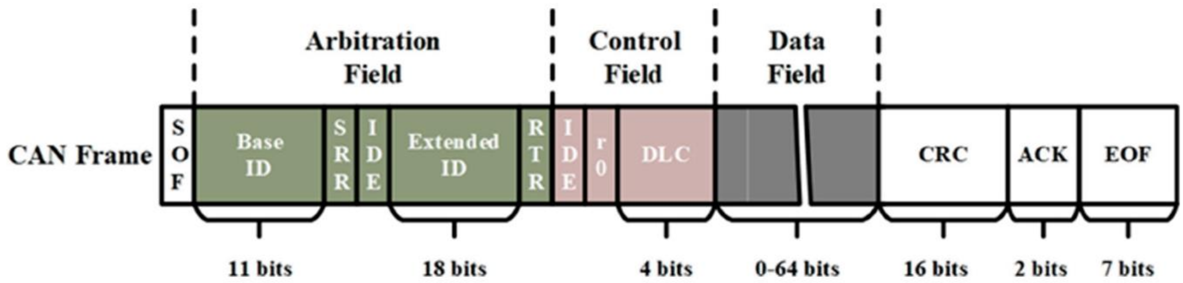

Figure 1 illustrates the format of a CAN frame

The primary objective of this research is to develop a robust and comprehensive battery management structure that addresses the specific requirements of electric vehicles. The structure aims to enable efficient acquisition, management, and control of critical battery parameters such as voltage, temperature, current, and electric quantity.[5] Additionally, the structure aims to ensure safe charging operations and provide early fault warnings for battery malfunctions.

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Currently, the energy management systems (EMSs) of hybrid electric vehicles (HEVs) can be categorized based on the depicted configuration in **Figure 2**, which can be classified into two groups: the rule-based control strategy (RCS) and the control strategy based on optimization (OCS).

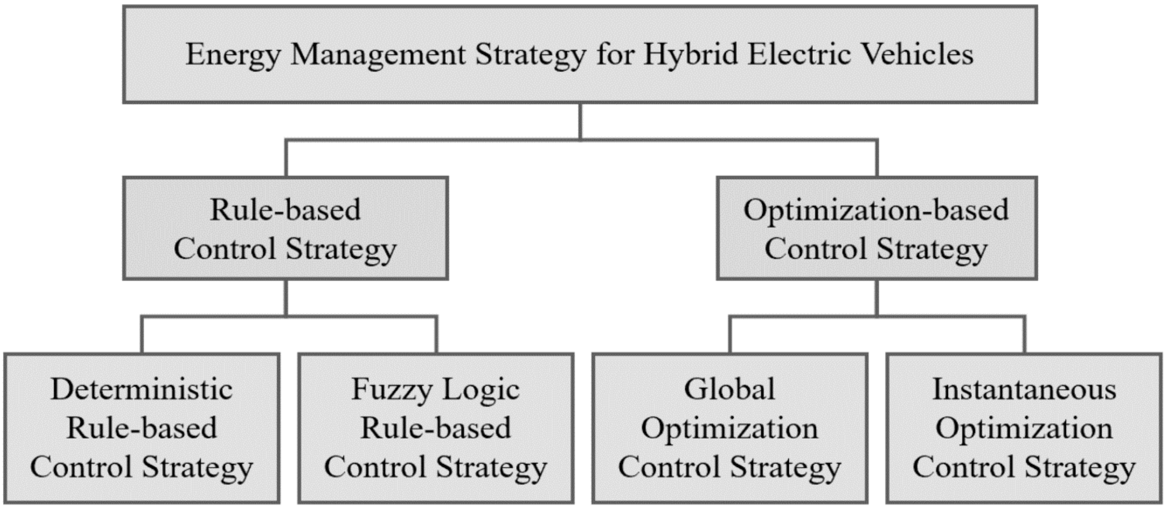

Figure 2. Categorization of energy control approaches (ECAs) for hybrid electric vehicles (HEVs)

Compared to existing battery management structures, the proposed structure offers several advantages, including higher reliability, enhanced charging safety, stable structure operation, comprehensive functionality, and convenient expansion capabilities. These improvements contribute to the overall performance and longevity of the battery, promoting the wider adoption of electric vehicles as a sustainable transportation solution.[6] In the subsequent sections of this paper, we will delve into the design, implementation, and evaluation of the proposed power battery management structure, providing a detailed analysis of its performance, functionality, and benefits for electric vehicle applications.

Related Work

With the rapid growth of the automobile industry, urban transportation is facing increasing pressure and the complexity of traffic management is rising. Furthermore, the escalating environmental concerns demand solutions that reduce pollution and minimize environmental damage. In response to these challenges, pure electric vehicles with zero emissions and no environmental contamination are progressively gaining popularity in the market.[7] Pure electric vehicles rely on rechargeable battery packs that offer high energy density, extended cycle life, and low power consumption.[8] However, a significant issue arises from the imbalances that occur among individual lithium battery cells after repeated charge and discharge cycles.

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*Within **Figure 3**, there exists the capability for the two clutches to independently disengage and engage the engine and motor. Specifically, when the motor transmits torque to initiate engine startup, the K0 clutch (where the letter "K" denotes clutch) facilitates the transmission of torque.*

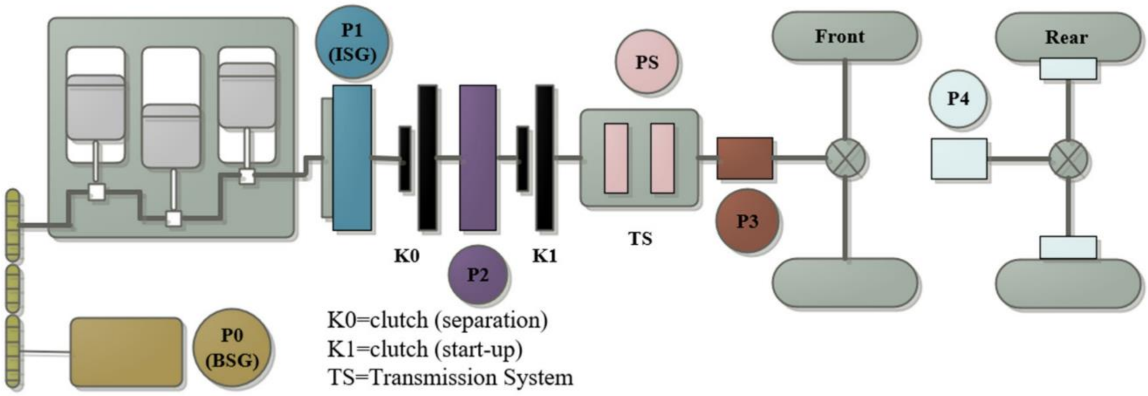

Figure 3. illustrates different schematic representations of diverse powertrain configurations

These imbalances can lead to a decline in battery life and pose potential safety hazards. Consequently, higher-level requirements have been imposed on the performance and management of parameters for pure electric vehicles.[9] Although researchers are continuously exploring new technological advancements and enhancing existing battery management structures, current pure electric vehicles with battery management structures still face limitations. These limitations include inadequate reliability, limited functionality, and a lack of optimized management structure frameworks.[3] These shortcomings result in the inability to meet the requirements of large-capacity serial lithium battery groups and ensure fail-safe charging, as well as the inability to fulfill the operational needs of the vehicle.[10]

In order to address these challenges and shortcomings, there is a need for the development of an advanced power battery management structure specifically designed for pure electric vehicles. This structure should incorporate innovative technological means and provide improved reliability, expanded functionality, and optimized management structure architecture.

By meeting these requirements, the new battery management structure will ensure the fail-safe operation of the charging process, extend battery life, and satisfy the operational demands of the vehicle. In this research, we aim to propose and develop a specialized power battery management structure that overcomes the limitations of existing structures. Our objectives include enhancing the reliability of the structure, expanding its functionality, and optimizing the overall management framework. Through

ISSN PRINT 2319 1775 Online 2320 7876
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unified planning and optimization, we seek to fulfill the requirements of large-capacity serial lithium battery groups, ensure fail-safe charging, and meet the operational needs of pure electric vehicles.

By achieving these objectives, we anticipate significant advancements in the performance and effectiveness of battery management structures for pure electric vehicles. The proposed structure will offer improved reliability, comprehensive functionality, and the ability to meet the demands of large-capacity lithium battery groups.[6] This research will contribute to the wider adoption of pure electric vehicles by addressing the shortcomings of existing battery management structures and facilitating their integration into urban transportation structures, thereby reducing environmental pollution and promoting sustainable mobility.

Research Objective

The research aims to develop an advanced power battery management structure specifically designed for electric vehicles. The main objectives are to improve the structure's design, establish efficient communication protocols using the CAN bus, incorporate comprehensive monitoring and control features for various parameters, enhance the structure's charging reliability, enable early detection of faults, and ensure easy integration of future expansions to enhance its functionality. The research aims to contribute to the development of an optimized and reliable power battery management structure for electric vehicles.

Advanced Power Battery Management Structure for Electric Vehicles: Design and Implementation

The power battery management structure for pure electric vehicles consists of various components including a control module, battery pack, electric machine controller, DC motor, vehicle-mounted charger, current and electric weight detection module, vehicle-mounted LCD module, switches, memory module, clock module, and temperature treatment module. These components work together to effectively manage and control the vehicle's power battery. The control module plays a crucial role in the structure and communicates with other modules such as the electric machine controller, vehicle-mounted charger, and vehicle-mounted LCD module using a communication bus called CAN1.

The control module is composed of several sub-control modules, each connected to a corresponding sub-battery pack. The battery pack is made up of multiple sub-battery packs connected in series. It is also connected to the switches, current and electric weight detection module, and vehicle-mounted charger to form the charging circuit. Additionally, the electric machine controller is connected in parallel with the battery pack to create the discharge loop. Real-time data gathered by the control module is

ISSN PRINT 2319 1775 Online 2320 7876
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transmitted to the vehicle-mounted LCD module, where it is displayed in real-time, providing important information to the driver. The electric machine controller is responsible for driving and controlling the DC motor, which is the main component of the vehicle's propulsion structure.

The clock module, connected through the I2C bus, is used to synchronize time information with the central control module. The memory module, connected via the SPI bus, stores important data, and is specifically designed as ferroelectric memory, ensuring fast and reliable data storage. The temperature treatment module is connected to the central control module and is responsible for regulating the temperature of the battery pack. It controls the operation of multiple fans that are connected to each sub-battery pack, ensuring proper cooling and preventing overheating.

Overall, the power battery management structure for pure electric vehicles ensures efficient and safe operation of the vehicle's battery pack. It integrates various modules to monitor and control parameters such as voltage, temperature, current, and electric weight. This structure provides real-time information to the driver, guarantees charging safety, and offers comprehensive functionality. Additionally, it is designed for reliability and convenience, allowing for easy expansion and integration into future electric vehicle technologies.

Conclusion

In conclusion, this research successfully developed a state-of-the-art power battery management structure tailored for electric vehicles. The implemented structure demonstrates remarkable improvements in reliability, charging safety, and overall structure performance. By utilizing the CAN communication bus, the BMS enables seamless communication among various modules, ensuring efficient acquisition, management, and control of vital battery parameters. The structure's three working modes, comprehensive functionality, and advanced safety features contribute to its superior performance and usability. The research outcomes lay the foundation for further advancements in electric vehicle technology, fostering a sustainable and efficient transportation ecostructure.

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