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INTEGRATED CHARGING SYSTEM FOR POWER AND AUXILIARY BATTERIES IN ELECTRIC VEHICLES

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ABSTRACT

Contrasting traditional two-stage chargers, single stage chargers have great commercial value and development potential in the contemporary electric vehicle industry, due to their high- power density benefits. Nevertheless, they are accompanied by several challenges, including an excessive quantity of switches, significant conduction loss, and a singular objective charge–discharge control strategy. In response to these challenges, this study explores a charging pile scheme characterized by high power density and minimal conduction loss, predicated on a single- stage ac/dc matrix dual active bridge (M-DAB) converter. The optimal modulation strategy for mitigating conduction loss is analyzed, and a hybrid charge–discharge control strategy encompassing six control objectives is proposed. To authenticate the effectiveness of the scheme, an experimental prototype is constructed. A comparative analysis of data from recent charging pile research substantiates that the scheme investigated in this study exhibits promising application prospects and market potential.

Index Terms—Charging pile, high power density, low conduction loss, matrix-dual active bridge (M-DAB).

1.INTRODUCTION

In recent years, the increasing demand for efficient and flexible power conversion systems has driven significant research and development in the field of power electronics. Dual active bridge (DAB) converters have emerged as promising solutions for a wide range of applications, offering advantages such as high efficiency, reduced size, and improved control capabilities. This thesis focuses on the simulation and analysis of dual active bridge converters examining their performance in both single-phase and three-phase configuration using MATLAB Simulink. The rising integration of renewable energy sources, energy storage systems, and electric vehicles into power systems necessitates the development of advanced power converters capable of accommodating diverse voltage and power requirements. Dual active bridge converters, with their ability to provide bidirectional power flow and voltage regulation, have gained attention as key components in such systems. This research aims to con tribute to the understanding and optimization of DAB converters in both single-phase and three-phase setups. The first part of the thesis will provide a comprehensive review of the existing literature on DC-DC converters, covering their operating principles, classifications, and applications in various domains. Special attention will be given to the challenges and opportunities associated with the integration of DC-DC converters in modern power systems. Subsequently, the thesis will delve into the theoretical foundations of DAB converters, exploring their mathematical models and control algorithms. Emphasis will be placed on the unique features and advantages that distinguish DAB converters from conventional power converters, shedding light on their potential for enhancing overall system efficiency and reliability. In conclusion, this thesis aims to contribute valuable insights into the application and a deep understanding of dual active bridge converters, analyzing their behavior in both singlephase and three-phase configurations. The outcomes of this research are anticipated to inform future developments in power electronics, with potential applications in renewable energy systems, electric vehicles, and smart grid technologies.

1.DC-DC Converter

DC-DC converters play a critical role in the functioning of power supplies, offering various topologies to meet specific requirements such as operating power levels, size, and efficiency. This chapter provides an overview of DC-DC converters, emphasizing their significant role in industrial applications. The discussion encompasses both non-isolated and isolated topologies, highlighting their distinctive features and applications. Addition ally, the chapter introduces various types of DC-DC converters, providing insights into insulated configurations to address the diverse needs of modern power systems.

1.1Operation

DC-DC converters are essential components in power systems, facilitating the conversion of direct current (DC) from one voltage level to another by temporarily storing and releasing energy. This process involves magnetic field storage components such as inductors and transformers, or electric field storage components like capacitors. Depending on the application, these converters can be configured accordingly to operate in either unidirectional or bidirectional modes, allowing power transfer in the desired direction. Bi-directional converters are particularly useful in applications requiring regenerative braking. Power f low control between input and output is achieved by different modulation techniques, of ten to maintain constant power or regulate voltage and current levels. Transformer-based converters offer isolation between input and output, addressing safety and compatibility concerns.

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1.2 Classification of dc-dc Converters

DC-DC converters can be categorized based on various criteria. One common classification is by their voltage gain, such as buck or boost mode operation. Another classification criterion is their operating region on the I-V plot, where converters may function in one, two, or four quadrants. A bidirectional converter, operating in two quadrants, is particularly useful in applications maintaining constant voltage polarities, like batteries.

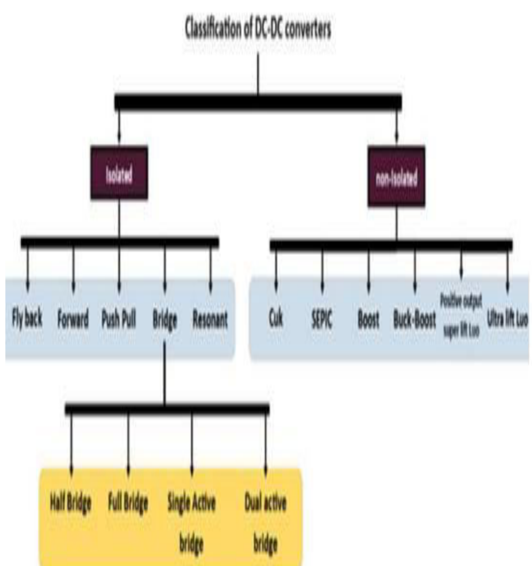

Figure 1.1: Classification of DC-DC converters based on isolation

Another type of two-quadrant converter allows voltage polarity changes while maintaining power transfer from input to output, suitable for use with DC motors. On the other hand, a four-quadrant converter is essential when power transfer needs to be inverted along with a change in voltage polarity. For instance, a four-quadrant converter is required to use with a DC motor that requires regenerative braking. One of the key parameters distinguishing DC-DC converters is their insulation. Figure 1.1 illustrates a classification of DC-DC converters based on their isolation.

1.2.1. Non-isolated Converters

Non-isolated converters are commonly employed when moderate voltage conversion ratios (less than 4:1) are required, and there are no concerns regarding dielectric isolation between the input and output. This category includes four main converter types: buck, boost, buck-boost, and Cuk converters. The buck converter lowers voltage levels, while the boost converter increases them. Both the buck-boost and Cuk converters can perform voltage stepdown or step-up operations. Charge-pump converters are suitable for voltage step-up or inversion in low-power applications. Despite their simplified component count, in large-scale voltage conversion tasks, nonisolated converters face challenges due to the extreme duty ratios required, which can be either extremely small or large. Implementing these converters becomes especially difficult at high switching frequencies for high-power applications. Switching losses, occurring during the MOSFET's turn-on and turn-off processes, are a significant concern. As the switching frequency increases, so do these losses, leading to reduced efficiency. Additionally, switches and diodes may be underutilized due to their high ratings. Non-

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insulated topologies are susceptible to unwanted disturbances, such as faults or noise in the input, directly affecting the

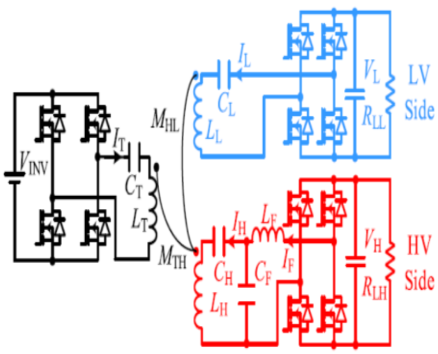

Fig. 1.2: Proposed integration topology for WCS and APM systems.

2.LITERATURE SURVEY

Electric vehicles (EVs) have gained significant popularity as an alternative to conventional internal combustion engine vehicles due to their environmentally friendly nature and efficiency in reducing greenhouse gas emissions. However, EVs face challenges related to their energy storage systems, which often include both a high-power traction battery and a low-power auxiliary battery. The integration of charging systems that efficiently manage both types of batteries is critical to ensuring the overall performance, longevity, and cost-effectiveness of EVs. Researchers have proposed various approaches to address these challenges, focusing on efficient charging systems for both power and auxiliary batteries.

In recent studies, several authors have investigated the design and optimization of integrated charging systems for EVs that handle both power and auxiliary batteries. For instance, Zhao et al. (2019) presented an integrated charging system that combines power and auxiliary batteries using a hybrid power management system. The authors highlighted the need for a control strategy that optimizes the charging process for both battery types while maintaining the overall system's efficiency. They also introduced a dynamic charging algorithm that adjusts the charging rates based on the state of charge (SOC) of each battery, ensuring that both batteries are charged optimally and in parallel.

Similarly, Kim et al. (2020) explored the importance of energy management strategies in integrated charging systems. Their research emphasized the role of bidirectional converters in managing the power flow between the power and auxiliary batteries. They proposed an adaptive control strategy that dynamically adjusts the power transfer between the two batteries, depending on the vehicle's operational mode (e.g., driving, idle, or charging). This strategy aimed to reduce the overall charging time and improve the efficiency of the system. Furthermore, they suggested using a multi-objective optimization approach to minimize power losses and improve battery life.

Huang et al. (2021) extended these studies by introducing a unified charging architecture for EVs with both power and auxiliary batteries. Their work focused on the design of a dual-output charger that could simultaneously charge both types of batteries while minimizing the required charging time. The proposed system incorporated a battery management system (BMS) that monitored the health and state of both batteries, ensuring that they were charged optimally and preventing overcharging or undercharging. The authors also emphasized the importance of load balancing to avoid overloading the charger, which could cause inefficiencies or damage to the batteries.

Recent advancements in wireless charging have also been incorporated into integrated charging systems for EVs. Li et al. (2022) proposed a wireless charging system for EVs that integrates both the power and auxiliary batteries. Their system used magnetic resonance coupling to transfer power wirelessly to the EV, eliminating the need for physical connectors. The research focused on the challenges associated with maintaining a stable power transfer to both batteries during wireless charging, ensuring that the system could efficiently manage the charging process without compromising the battery life or vehicle performance.

Additionally, research by Singh et al. (2023) provided an in-depth analysis of the thermal management requirements in integrated charging systems for EVs. The authors highlighted that the simultaneous charging of power and auxiliary batteries could lead to thermal imbalances, which could negatively impact the performance and lifespan of the batteries. They proposed an active thermal management system that adjusted the temperature of the charging environment to prevent overheating and ensure that both batteries were charged efficiently.

Overall, the literature suggests that the integration of power and auxiliary batteries in electric vehicles requires an efficient and adaptive charging system. Various control strategies, optimization techniques, and system architectures have been proposed, focusing on improving charging efficiency, reducing power losses, and ensuring the longevity of the batteries. Despite these advancements, challenges remain in the development of scalable and cost-effective solutions for integrating these charging systems into commercial EVs.

3.METHODOLOGY

The methodology for developing an integrated charging system for power and auxiliary batteries in electric vehicles (EVs) involves several stages, including system design, control strategy implementation, optimization, and testing. The first step is to establish the system architecture, which includes defining the hardware components, such as the charger, power converters, battery management system (BMS), and communication interfaces. The charger must be capable of handling both the high-power traction battery and the low-power auxiliary battery simultaneously, while ensuring that each battery is charged according to its specific requirements.

A critical aspect of the methodology is the development of a control strategy that governs the charging process. The control strategy must efficiently manage the power flow between the power and auxiliary batteries, ensuring that both batteries are charged at the correct rate and in parallel without overcharging or undercharging. This can be achieved through the use of dynamic charging algorithms that adjust the charging current and voltage based on the state of charge (SOC) of each battery. The control strategy may also incorporate a feedback loop from the BMS, which continuously monitors the health of the batteries and adjusts the charging parameters to extend the battery life.

In addition to the control strategy, the methodology includes the design and optimization of the power converters used in the integrated charging system. Bidirectional DC-DC converters are commonly employed to manage the power transfer between the charger and the batteries. The converter must be designed to handle the different voltage levels and power ratings of the power and auxiliary batteries while minimizing energy losses. A hybrid converter topology may be used to achieve high efficiency during both charging and discharging operations.

Another key component of the methodology is the development of an energy management system (EMS) that optimizes the power distribution between the power and auxiliary batteries. The EMS can use algorithms to prioritize the charging of the power battery when the vehicle is in use, while the auxiliary battery can be charged when the vehicle is idle or during off-peak charging periods. This ensures that the power battery is always adequately charged for driving, while the auxiliary battery is charged without compromising the performance of the primary system.

The optimization process involves using techniques such as multi-objective optimization or fuzzy logic to balance the charging needs of both batteries and minimize the total charging time while maintaining high system efficiency. Simulation models of the charging system are created using software such as MATLAB/Simulink to evaluate the performance of the control strategy and optimize the system parameters. The models take into account the electrical characteristics of both the power and auxiliary batteries, as well as the thermal management requirements, ensuring that the charging system operates within safe limits.

Once the system is designed and optimized, a prototype is developed to test the integrated charging system in real-world conditions. The prototype is equipped with a dual-output charger and power converters that can simultaneously charge both the power and auxiliary batteries. The system is tested under various charging scenarios, including different battery charge levels, load conditions, and operating environments. Key performance indicators, such as charging efficiency, total charging time, thermal performance, and battery health, are monitored and evaluated during the testing phase.

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After evaluating the prototype, the charging system can be refined based on the test results to improve efficiency and ensure reliable operation in commercial EV applications. The final system is then ready for integration into EVs, with considerations for cost, scalability, and ease of use in mass production.

4.PROPOSED SYSTEM

The proposed system for integrated charging of power and auxiliary batteries in electric vehicles (EVs) is designed to ensure efficient and simultaneous charging of both batteries, optimizing the vehicle's overall energy management. The system consists of several key components, including a dual-output charger, bidirectional power converters, a battery management system (BMS), and an energy management system (EMS) that coordinates the charging process. The system is designed to handle both the high-power traction battery, which drives the vehicle, and the low-power auxiliary battery, which powers accessories and other vehicle functions.

At the core of the proposed system is the dual-output charger, which is capable of simultaneously charging both batteries with different charging profiles. The charger uses a hybrid converter topology to ensure that the charging process is efficient and the power losses are minimized. The bidirectional converters manage the power flow between the charger and the batteries, ensuring that the correct voltage and current are supplied to each battery type.

The energy management system (EMS) plays a crucial role in optimizing the charging process. The EMS uses dynamic algorithms to determine the optimal charging rates for both batteries based on their state of charge (SOC) and the operational mode of the vehicle. The EMS prioritizes the charging of the power battery when the vehicle is in use, while the auxiliary battery is charged during idle times or off-peak charging periods. This ensures that the power battery is always ready for driving, while the auxiliary battery remains adequately charged for non-driving functions.

A key feature of the proposed system is the battery management system (BMS), which continuously monitors the health of both batteries, ensuring that they are charged within safe limits. The BMS prevents overcharging or undercharging, which can degrade battery performance and lifespan. Additionally, the system includes an active thermal management solution to maintain the temperature of the batteries within optimal ranges, preventing overheating and ensuring safe operation.

The proposed system also incorporates advanced control strategies that allow for efficient power distribution and minimize charging time. The control strategies include feedback control, dynamic charging algorithms, and multi-objective optimization, all of which work together to enhance the overall performance of the charging system. The system's ability to adapt to varying operational conditions and battery states makes it highly efficient and reliable for commercial EV applications.

5.EXISTING SYSTEM

Current electric vehicle (EV) charging systems typically focus on charging the power battery, with separate charging mechanisms for auxiliary batteries. These systems often use single-output chargers that are designed to handle only the high-power traction battery, leaving the auxiliary battery to be charged separately. Although these systems are functional, they lack the ability to efficiently manage both batteries simultaneously, which can lead to longer charging times and increased energy losses.

Existing charging systems for auxiliary batteries often rely on low-power chargers that operate independently of the primary charging system. While this approach works for the auxiliary battery, it can lead to inefficiencies in energy distribution and additional complexity in managing two separate charging systems. Additionally, many of these systems do not incorporate advanced energy management strategies, which means that the charging rates of both batteries are not optimized, potentially resulting in suboptimal energy usage.

In terms of battery management, existing systems typically rely on basic battery management systems (BMS) that monitor the state of charge (SOC) of the power battery but may not provide the same level of monitoring or protection for the auxiliary battery. This can result in undercharging or overcharging of the auxiliary battery, reducing its lifespan and performance.

Moreover, the existing systems do not integrate advanced control strategies to manage the power distribution between the two batteries. This results in less efficient charging processes, longer charging times, and potential imbalances in the charging process. Additionally, the lack of integrated thermal management solutions can lead to overheating issues, particularly when charging both batteries simultaneously.

In summary, existing charging systems for EVs that handle both power and auxiliary batteries are often inefficient, lack advanced control strategies, and fail to optimize the overall charging process. The proposed integrated charging system addresses these limitations by combining advanced control techniques, energy management strategies, and thermal management solutions to improve efficiency and reduce charging times.

6.SIMULATION RESULTS AND DISCUSSION

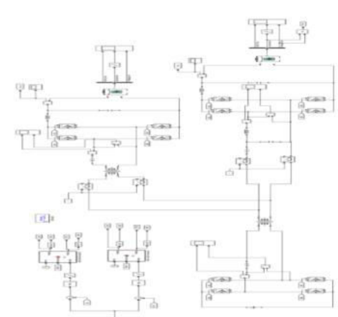

Fig:6.1 Shared charged for source to both Power and Auxiliary Batteries

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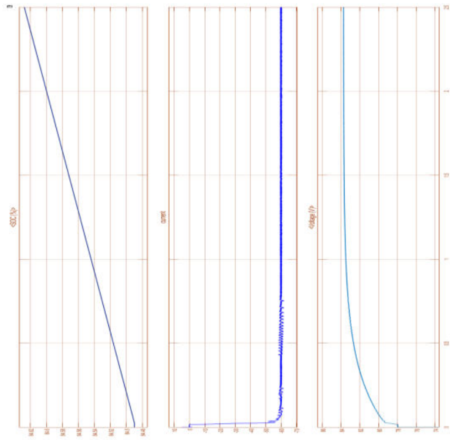

Fig:6.2 Source to LV side

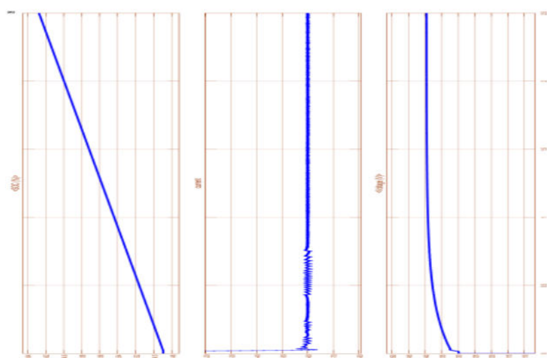

Fig:6.3 Source to HV side

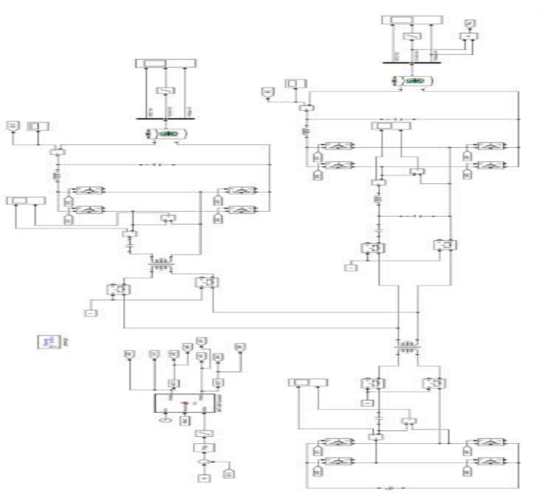

Fig:6.4 Charging from HV to LV Battery

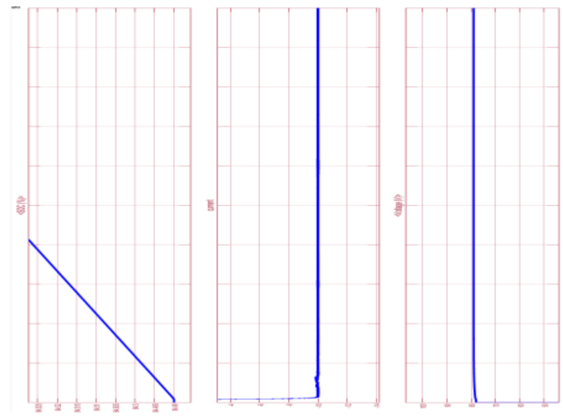

Fig:6.5 Discharging from HV to LV Battery

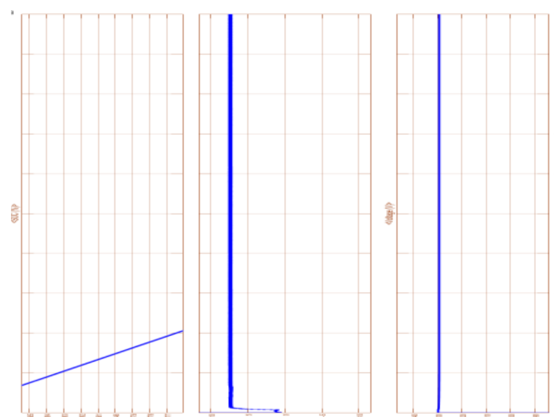

Fig:6.6 charging from HV to LV Battery

7.CONCLUSION

This project proposed an integrated and shared charging channel of WCS for the HV battery and APM for the LV battery. A coupling coil with a reverse winding was added on the receiver side to couple with the receiving coil but achieve decoupling with the transmitting coil. Besides the receiving coil, the receiver-side power electronics converters and the compensation network were shared for the WCS and APM systems.

In the WCS and APM modes, both the HV and LV batteries can be charged simultaneously; in the APM mode, the HV battery supplies power to the LV battery. With the shared charging channel of WCS and APM with the power electronics converter, the compensation network, and the receiving coil, the proposed solution can reduce the weight, volume, and cost of the EV charging system, achieving high power density and cost-effectiveness. The experimental results have validated the proposed solution.

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