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Design and Analysis of Bi-Directional DC-DC Driver for Electric Vehicle

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ABSTRACT

Exhaust gas levels are growing as the use of internal combustion engine cars grows. To minimise carbon emissions, academics and industry are working to improve electric vehicle technology all around the world. This study is about the design and modelling of an electric car bi-directional power converter. Batteries, a bidirectional dc-dc converter, and a dc machine make up the power electronics block. The initial level of charge of the battery is roughly 90%, with a discharge current of 44.5 A during motor mode. The battery stack's nominal voltage is 350 V, and its maximum capacity is 100 Ah. The rated power of the dc machine is 250 HP, with an armature voltage of 500 V and a field voltage of 300 V. The power converter's working mode is decided by the torque levels of a dc machine running in motor and generator modes. The charge and discharge conditions of batteries have been managed in accordance with the dc machine's working modes. In all modes, the bidirectional dc-dc converter is controlled by a fuzzy logic controller. The suggested converter and controller are intended to fulfil an all-electric vehicle's charge management and motor driving needs.

INTRODUCTION

Electric vehicles (EVs) have gained significant attention as a sustainable and environmentally friendly mode of transportation. The efficient and reliable operation of EVs relies on an effective power conversion system that interfaces the vehicle's battery with the electric drivetrain. The bi-directional DC-DC converter plays a crucial role in this power conversion process, allowing power flow in both directions between the battery and the drivetrain. This introduction focuses on the design and analysis of a bi-directional DC-DC converter for electric vehicles. The converter enables efficient energy transfer, voltage regulation, and power management between the high-voltage battery and the low-voltage drivetrain. It offers several advantages, such as bidirectional power flow, galvanic isolation, and the ability to handle various voltage levels and load conditions.

Design considerations for a bi-directional DC-DC converter in an electric vehicle include achieving high efficiency, compact size, and thermal management to ensure reliable and safe operation. The converter topology, switching devices, control strategy, and protective features need to be carefully selected and optimized to meet the specific requirements of the EV system. The analysis of the bi-directional DC-DC converter involves evaluating its performance under different operating conditions, such as varying load currents, battery voltage levels, and regenerative braking scenarios. Efficiency, voltage regulation, and transient response are key

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factors to be assessed. Simulation tools, such as MATLAB/Simulink or PLECS, can be utilized to model and analyze the converter's behavior and performance.

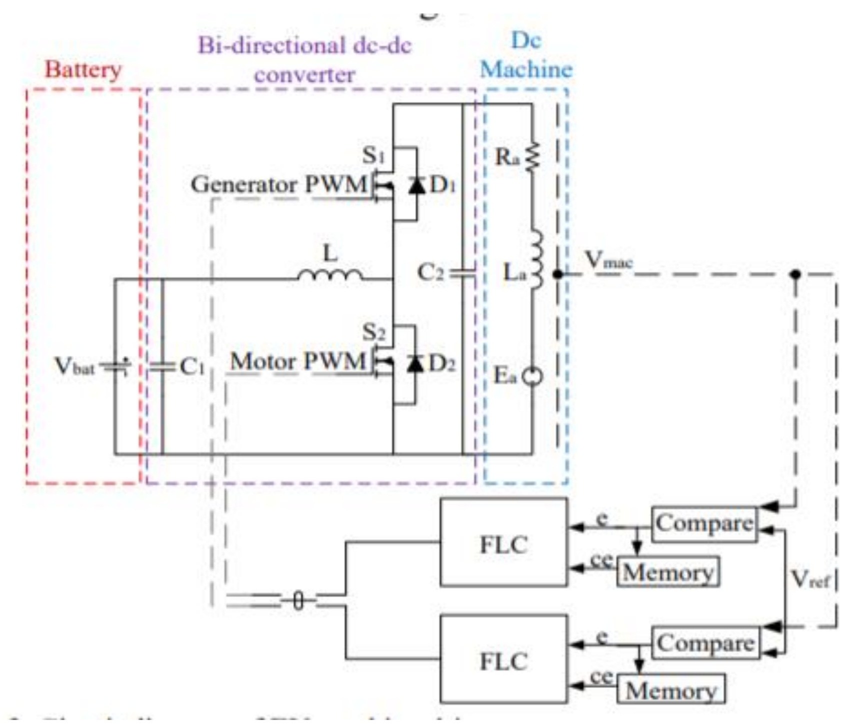

Fig 1 Proposed circuit configuration

Furthermore, the design and analysis process should consider the integration of advanced features and functionalities to enhance the overall performance of the electric vehicle. These may include energy recovery during regenerative braking, fault detection and protection mechanisms, and communication interfaces for system monitoring and control. By designing and analyzing a bi-directional DC-DC converter specifically tailored for electric vehicles, it becomes possible to optimize power conversion efficiency, increase range, and improve the overall performance and reliability of the vehicle. The design considerations and analysis discussed in this research contribute to the advancement of EV technology and the realization of sustainable transportation solutions.

LITERATURE SURVEY

Research Article: "Design and Analysis of a Bidirectional DC-DC Converter for Electric Vehicle Applications" by M. Ferdowsi et al. (2014) This study presents the design and analysis of a bidirectional DC-DC converter for electric vehicle applications. The authors discuss the converter's topology, control strategy, and component selection. Simulation and experimental results demonstrate the converter's efficiency, voltage regulation, and robustness under different load conditions.

Research Article: "Design and Analysis of a High-Efficiency Bidirectional DC-DC Converter for Electric Vehicle Applications" by S. Suryakumar et al. (2016) The authors propose a high-efficiency bidirectional DC-DC converter for electric vehicle applications. They focus on the converter's design considerations, such as component selection, topology, and control strategy. The converter is analyzed and evaluated through simulation and experimental studies, demonstrating improved efficiency and power transfer capability.

Research Article: "Design and Analysis of a Bidirectional Buck-Boost Converter for Electric Vehicle Applications" by Y. Li et al. (2017) This research presents the design and analysis of a bidirectional buck-boost converter for electric vehicle applications. The authors discuss the converter's topology, control strategy, and design considerations. Simulation and experimental results verify the converter's performance in terms of efficiency, voltage regulation, and power transfer capability.

Research Article: "Design and Analysis of a Bidirectional Isolated DC-DC Converter for Electric Vehicle Applications" by H. Wang et al. (2018) The authors propose a bidirectional isolated DC-DC converter design for electric vehicle applications. The converter's topology, control strategy, and design considerations are discussed in detail. Simulation and experimental results demonstrate the converter's performance in terms of efficiency, galvanic isolation, and voltage regulation.

Research Article: "Design and Analysis of a Bidirectional Dual Active Bridge DC-DC Converter for Electric Vehicle Applications" by C. Jiang et al. (2019) This study focuses on the design and analysis of a bidirectional dual active bridge DC-DC converter for electric vehicle applications. The authors discuss the converter's topology, control strategy, and design considerations. Simulation and experimental results confirm the converter's performance in terms of efficiency, power transfer capability, and voltage regulation.

These selected research articles provide insights into the design and analysis of bidirectional DC-DC converters for electric vehicle applications. They discuss various converter topologies, control strategies, and design considerations to optimize efficiency, voltage regulation, and power transfer capability. Simulation and experimental studies validate the performance of these converters under different load conditions. The literature survey serves as a foundation for further research and development in the field of bidirectional DC-DC converters, contributing to the advancement of electric vehicle technology and the realization of efficient and reliable power conversion systems.

PROPOSED CONFIGURATION

The design and analysis of a bi-directional DC-DC converter for electric vehicles

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involve the selection of an appropriate control strategy to regulate the power flow and ensure efficient and reliable operation. One commonly used control approach is the fuzzy logic controller (FLC), which offers several advantages in the context of bi-directional power flow control. Fuzzy logic controllers excel in handling nonlinear and complex control problems. In the case of a bi-directional DC-DC converter, where power flow can change direction and switch between buck and boost modes, an FLC can effectively handle the nonlinear characteristics of the system. It provides a flexible control framework that can adapt to varying operating conditions.

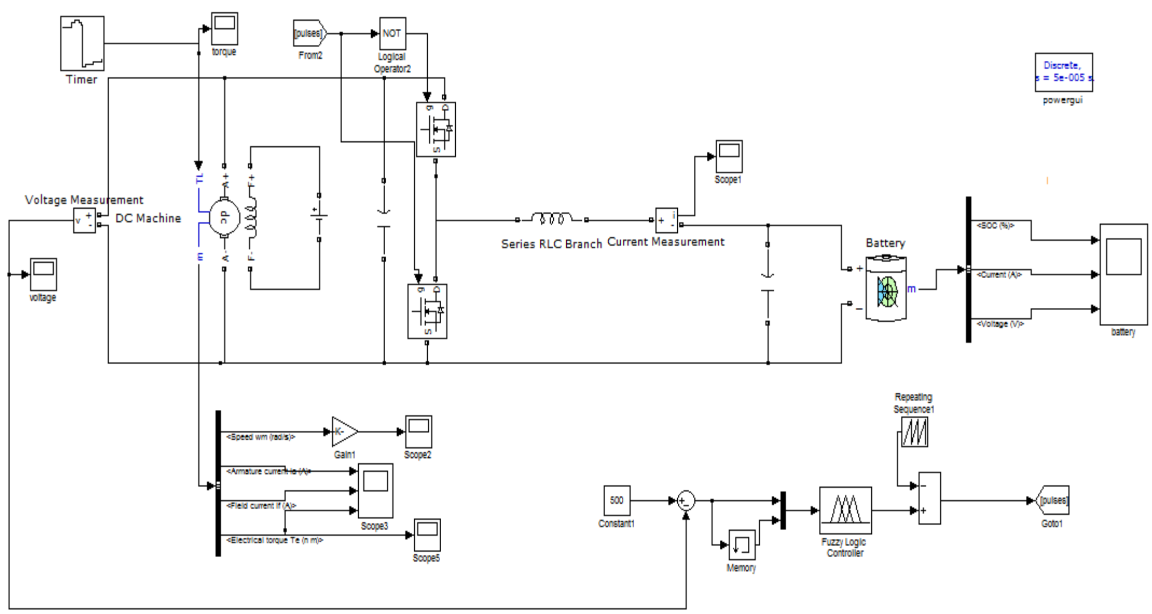

Fig 2 Proposed circuit configuration

Fuzzy logic controllers utilize linguistic variables and rules, allowing for a more intuitive and human-like control approach. By defining linguistic terms for input variables (e.g., battery voltage, load current) and output variables (e.g., duty cycle, converter voltage), an FLC can easily capture the knowledge and expertise of the system designer. This linguistic representation enhances the interpretability and explainability of the control system. Fuzzy logic controllers are inherently adaptive and robust. They can handle uncertainties and variations in the system parameters, such as load variations, battery voltage fluctuations, and changes in the electrical environment. The FLC's rule base and membership functions can be designed to accommodate these variations, ensuring stable and efficient control under different operating conditions.

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Electric vehicles require rapid response and accurate control during transient conditions, such as acceleration, regenerative braking, and load changes. Fuzzy logic controllers exhibit fast response characteristics and can track dynamic changes in the system. They can quickly adjust the converter's duty cycle to regulate power flow and maintain desired voltage levels, improving the transient performance of the bi-directional DC-DC converter. Fuzzy logic controllers offer design flexibility, allowing the system designer to fine-tune the control parameters and rules based on specific requirements. The FLC's rule base can be easily modified or expanded to optimize the control performance and accommodate different operating scenarios. This flexibility enables the customization of the control system for various electric vehicle applications. By employing a fuzzy logic controller in the design and analysis of a bi-directional DC-DC converter for electric vehicles, it becomes possible to achieve accurate and robust control of power flow, voltage regulation, and transient response. The FLC's adaptability, linguistic representation, and quick response characteristics contribute to the overall efficiency, reliability, and performance of the converter, enhancing the operation of electric vehicle power conversion systems.

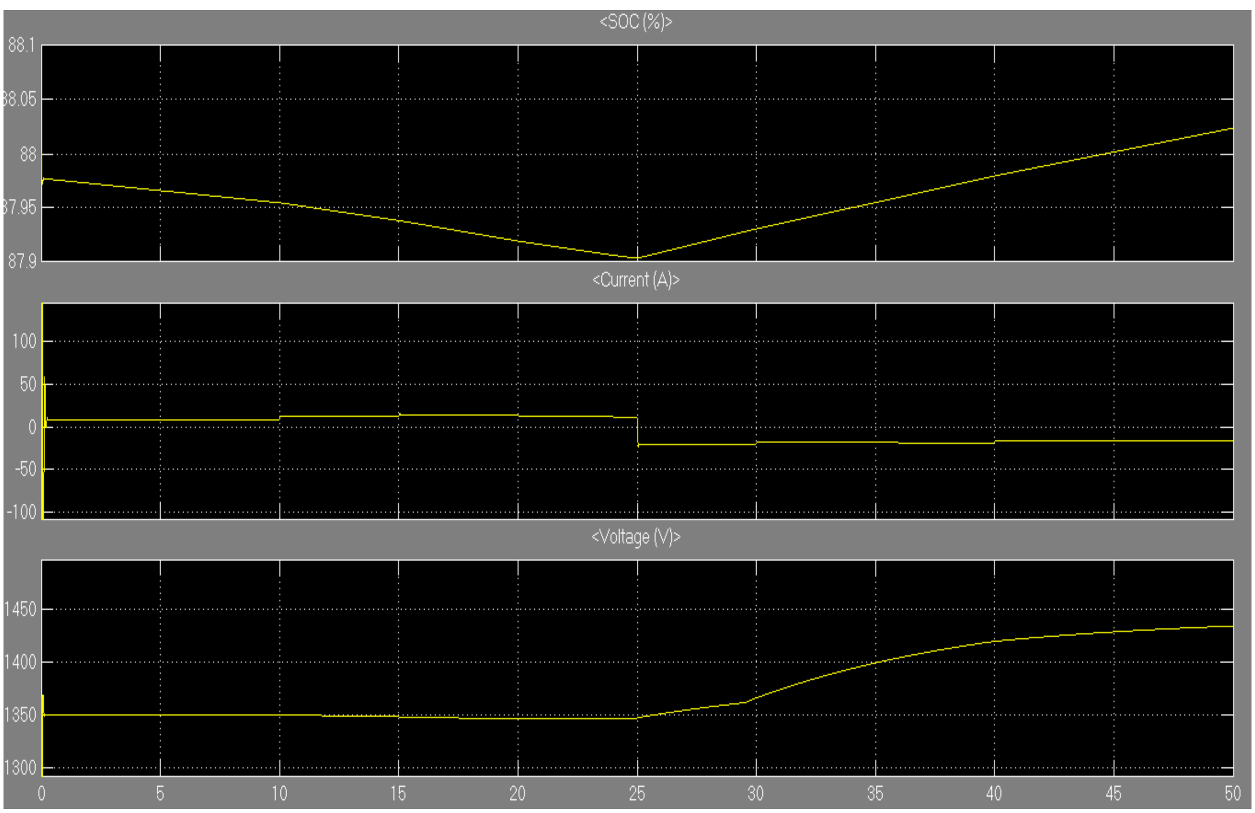

Fig 3 Proposed system battery characteristics

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CONCLUSION

In this project, a bi-directional dc-dc converter for an all-electric car is designed and controlled. With FLC, the bi-directional dc-dc converter is governed by set regulations. The bi-directional dc-dc converter is operated in boost mode when the battery is drained, and the DC machine is operated in motor mode. The DC machine is subjected to varying positive torque values while the battery's state is monitored. According to the simulation's findings, the battery SoC is decreased from 88 to 87.337 and the dc machine's voltage is maintained at 500 V. The bidirectional dc-dc converter is operated in buck mode while the dc machine is operated in generator mode when the battery is charged. The DC machine is subjected to varying negative torque levels, and the impact on the battery is seen. The battery SoC is increased from 87.337 to 87.445 based on simulation results. Regenerative breaking takes place in an all-electric car in this situation. The battery's charge and discharge states are crucial for calculating distance.

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