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MODELLING OF HYBRID ELECTRIC VEHICLE CHARGER

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ABSTRACT

The Plug in Hybrid Electric Vehicles are driven by the energy stored in the battery. Through conductive AC charging method, Electric vehicle supply equipment (EVSE) is connected to Electric vehicle (EV) for charging the battery. Apart from charging it can also help in creating trustworthy equipment ground track and exchange control data among EV and EVSE. This paper discusses electrical and physical interface between EV and EVSE to facilitate conductive charging and design of an on-board charger for fast charging of the hybrid electric vehicle. The aim of this project is to design an interfacing system between EV and EVSE as per automotive industry standard and to design prototype of 3.45 kw on-board charger using MATLAB software. By modelling the charger charging of Li-ion battery can be done which is used for providing propulsion torque and through various stages of charger voltage and current level is controlled and make them desired for charging.

Keywords: Plug-in Hybrid Electric Vehicles, Battery Charging, Electric Vehicle Supply Equipment (EVSE), Conductive Charging, On-board Charger, Li-ion Battery, MATLAB Modeling

INTRODUCTION

The transition towards sustainable transportation has spurred significant advancements in electric vehicle (EV) technology [1], with plug-in hybrid electric vehicles (PHEVs) emerging as a promising solution to reduce reliance on traditional fossil fuel-powered vehicles [2]. PHEVs operate by utilizing energy stored in batteries, which can be recharged through various methods, including conductive AC charging [3]. This method involves connecting Electric Vehicle Supply Equipment (EVSE) to the EV for charging the battery [4]. Beyond the primary function of charging, EVSE plays a crucial role in establishing a reliable equipment ground track and facilitating the exchange of control data between the EV and EVSE [5].The advent of PHEVs and the increasing demand for electric vehicles necessitate a robust infrastructure to support efficient and convenient charging [6]. As such, this paper focuses on elucidating the electrical and physical interface between the EV and EVSE, with a specific emphasis on enabling conductive charging [7]. Additionally, the design and implementation of an on-board charger tailored for fast charging of hybrid electric vehicles are discussed [8].The overarching objective of this project is twofold: first, to devise an interfacing system between the EV and EVSE that adheres to automotive industry standards, ensuring compatibility and interoperability [9]; second, to develop a prototype of a 3.45 kW on-board charger utilizing

MATLAB software [10]. Through the integration of advanced modeling and simulation techniques, the charger's charging process, particularly for Li-ion batteries, can be accurately characterized and optimized [11].

In the context of PHEVs, the on-board charger plays a pivotal role in replenishing the energy stored in the battery, which serves as the primary power source for propulsion [12]. Efficient charging of the battery is essential not only for extending the vehicle's driving range but also for ensuring optimal performance and longevity of the battery system [13]. Moreover, the charger must regulate voltage and current levels at various stages of the charging process to align with the battery's specifications and charging requirements [14].The design and implementation of the on-board charger entail a comprehensive understanding of the charging dynamics, including factors such as charging rate, voltage profile, and current flow [15]. By leveraging MATLAB software, engineers can develop sophisticated models to simulate and analyze the charger's behavior under different operating conditions [16]. These models enable precise control of the charging process, allowing for real-time adjustments to optimize charging efficiency and ensure the battery's health and safety [17].

Furthermore, the interfacing system between the EV and EVSE is critical for seamless integration and operation of the charging infrastructure [18]. Standardization of the interface parameters and communication protocols is essential to enable interoperability among various EV models and charging stations [19]. By adhering to established industry standards, such as those outlined by organizations like the Society of Automotive Engineers (SAE), the interfacing system can facilitate plug-and-play compatibility and ensure reliable communication between the EV and EVSE [20].In summary, the introduction sets the stage for a comprehensive exploration of the modeling and design aspects of a hybrid electric vehicle charger. By elucidating the significance of conductive AC charging and highlighting the importance of an efficient on-board charger design, this paper aims to contribute to the advancement of electric vehicle technology and infrastructure. Through a combination of theoretical analysis, modeling, and simulation, the proposed charger system seeks to optimize charging performance, enhance battery reliability, and accelerate the adoption of electric vehicles in the automotive industry.

LITERATURE SURVEY

The emergence of Plug-in Hybrid Electric Vehicles (PHEVs) represents a significant advancement in automotive technology, offering a promising solution to reduce reliance on traditional fossil fuel-powered vehicles. PHEVs utilize energy stored in batteries as their primary propulsion source, contributing to emission reduction and promoting environmental sustainability. Central to the operation of PHEVs is the charging process, typically facilitated by conductive AC charging methods through Electric Vehicle Supply Equipment (EVSE). Beyond charging, EVSE also plays a crucial role in establishing reliable equipment ground tracks and facilitating control data exchange between the Electric Vehicle (EV) and EVSE.Conductive AC charging has become a widely adopted method for replenishing energy in PHEV batteries, providing convenience and efficiency. Understanding the intricate interface between EVs and EVSE is paramount to ensure seamless integration and optimal charging performance. Consequently, there is a growing body of literature dedicated to elucidating the electrical and physical interfaces between EVs and EVSE, particularly focusing on conductive charging methods.

In recent years, the design and implementation of on-board chargers tailored for fast charging of hybrid electric vehicles have garnered significant attention. On-board chargers play a critical role in regulating voltage and current levels during the charging process, ensuring compatibility with battery specifications and charging requirements. Advances in charger design aim to enhance efficiency and reduce charging times, thereby improving the overall driving experience for PHEV owners.The transition towards electrification in the automotive industry emphasizes the importance of standardized interfacing systems between EVs and EVSE to ensure interoperability and compatibility. Standardization efforts, led by organizations like the Society of Automotive Engineers (SAE), seek to establish common protocols and communication standards for EV charging infrastructure. Adhering to these industry standards enables plug-and-play compatibility and streamlines the deployment of charging infrastructure.

The integration of modeling and simulation techniques has become instrumental in the design and optimization of hybrid electric vehicle chargers. Computational modeling platforms such as MATLAB enable engineers to simulate the charging process and analyze charger performance under various operating conditions. Modeling facilitates fine-tuning of charger parameters and optimization of charging algorithms to maximize efficiency and ensure compatibility with different battery chemistries.In summary, the literature survey highlights the multifaceted nature of research and development efforts in hybrid electric vehicle charging. From elucidating interface requirements between EVs and EVSE to designing and optimizing on-board chargers, researchers are actively advancing electric vehicle charging technology. By leveraging interdisciplinary approaches and emerging technologies, the automotive industry is poised to accelerate the transition towards sustainable transportation, thereby reducing environmental impact.

PROPOSED SYSTEM

The development of hybrid electric vehicle (HEV) charging systems represents a critical step towards advancing sustainable transportation solutions. HEVs, powered by energy stored in batteries, offer a promising alternative to conventional fossil fuel vehicles, contributing to reduced emissions and environmental impact. Conductive AC charging methods, facilitated by Electric Vehicle Supply Equipment (EVSE), serve as the primary means of replenishing energy in HEV batteries. Beyond their core function of charging, EVSE plays a pivotal role in establishing reliable equipment ground tracks and facilitating the exchange of control data between the Electric Vehicle (EV) and EVSE. This paper aims to address the design and implementation of a comprehensive charging system for HEVs, focusing on both the electrical and physical interfaces between EVs and EVSE to enable conductive charging. Additionally, the development of an on-board charger capable of fast charging is a key objective of this project. By adhering to automotive industry standards, the proposed system aims to ensure compatibility and interoperability with existing charging infrastructure.At the heart of the proposed system lies the design of an interfacing system between the EV and EVSE. This entails the development of standardized protocols and communication interfaces to facilitate seamless integration and operation of the charging infrastructure. By establishing common parameters and communication standards, the proposed system seeks to streamline the charging process and enhance user experience.

The design and implementation of the on-board charger represent a crucial component of the proposed system. With a targeted power output of 3.45 kW, the on-board charger is optimized for fast charging of HEVs, providing a balance between charging speed and efficiency. Utilizing MATLAB software, the charger's charging process can be accurately modeled and simulated, allowing for precise control of voltage and current levels at various stages of the charging cycle.A key feature of the proposed system is its ability to accommodate the charging requirements of lithium-ion (Li-ion) batteries commonly used in HEVs. By modeling the charging process of Li-ion batteries, the system can optimize charging parameters to maximize efficiency and ensure compatibility with battery specifications. Moreover, the system's ability to control voltage and current levels throughout the charging cycle enables it to adapt to different battery chemistries and charging conditions.

The proposed system's architecture encompasses multiple stages, each designed to regulate and optimize the charging process. From initial voltage and current control to final adjustments to meet desired charging levels, the system ensures efficient and reliable charging of HEVs. By integrating advanced control algorithms and real-time monitoring capabilities, the system can dynamically adjust charging parameters to respond to changing conditions and optimize charging performance.

The proposed system represents a comprehensive approach to modeling and designing an efficient and reliable charging system for hybrid electric vehicles. By addressing both the electrical and physical interfaces between EVs and EVSE, as well as the development of an on-board charger optimized for fast charging, the proposed system aims to advance the state-of-the-art in HEV charging technology. Through rigorous modeling, simulation, and optimization, the proposed system seeks to enhance charging efficiency, reliability, and user experience, thereby accelerating the adoption of hybrid electric vehicles and promoting sustainable transportation solutions.

METHODOLOGY

The methodology for modeling the hybrid electric vehicle (HEV) charger involves a systematic approach to design, simulation, and optimization, aimed at achieving efficient and reliable charging performance. The methodology encompasses several key steps, including the development of an interfacing system between the Electric Vehicle (EV) and Electric Vehicle Supply Equipment (EVSE), the design and implementation of an on-board charger, and the modeling and simulation of the charging process using MATLAB software.The first step in the methodology involves defining the requirements and specifications for the interfacing system between the EV and EVSE. This includes establishing communication protocols, interface parameters, and physical connection standards to ensure compatibility and interoperability with existing charging infrastructure. Adherence to automotive industry standards is essential to guarantee compliance and facilitate widespread adoption of the charging system.

Once the requirements are defined, the next step is the design and implementation of the interfacing system. This involves the development of hardware and software components to establish communication and control between the EV and EVSE. Hardware components may include connectors, cables, and interface modules, while software components encompass communication protocols and control algorithms. The interfacing system must be designed to handle data exchange, equipment ground tracking, and control signals reliably and efficiently.Simultaneously, the design and implementation of the on-board charger commence. The on-board charger is a critical component responsible for regulating the voltage and current levels during the charging process. The charger must be designed to deliver the required power output, ensure compatibility with different battery chemistries, and optimize charging efficiency. Using MATLAB software, the charger's design parameters, such as voltage and current profiles, are defined and optimized through simulation and analysis.

The modeling of the charger charging process involves creating mathematical models to simulate the behavior of the charging system under various operating conditions. This includes modeling the interaction between the charger, battery, and propulsion system to accurately predict charging performance and optimize charger parameters. MATLAB provides a powerful platform for developing and simulating complex mathematical models, allowing for detailed analysis of the charging process.In the modeling phase, the charging process of lithium-ion (Li-ion) batteries, commonly used in HEVs, is specifically modeled to capture the dynamics of battery charging. This includes modeling the charging current, voltage, and temperature profiles to ensure safe and efficient charging operation. By simulating the charger charging process, engineers can identify potential issues, such as overcharging or overheating, and refine charger parameters to mitigate risks and improve performance.

Furthermore, the modeling process involves simulating the various stages of charger voltage and current control to achieve the desired charging levels. This includes controlling the charger output to match the charging requirements of the battery, ensuring optimal charging efficiency and battery health. Through iterative simulation and optimization, the charger parameters are fine-tuned to meet performance targets and specifications.Throughout the methodology, rigorous testing and validation are conducted to verify the performance and reliability of the charging system. This includes testing the interfacing system for compatibility and interoperability with different EV models and charging stations, as well as validating the charger's performance through real-world testing and simulation. Any discrepancies or issues identified during testing are addressed through iterative design refinement and optimization.

The methodology for modeling the hybrid electric vehicle charger encompasses a comprehensive approach to design, simulation, and optimization. By defining requirements, designing interfaces, and modeling the charging

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process using MATLAB software, engineers can develop efficient and reliable charging systems for HEVs. Through iterative refinement and validation, the methodology ensures that the final charging system meets performance targets, regulatory requirements, and industry standards, paving the way for the widespread adoption of electric vehicles.

RESULTS AND DISCUSSION

The results and discussion section of the "Modeling of Hybrid Electric Vehicle Charger" project encapsulate the findings and insights gleaned from the comprehensive design, simulation, and optimization process outlined in the methodology. This section elucidates the outcomes of the interfacing system design, on-board charger development, and charger charging modeling, shedding light on the performance, efficiency, and implications for the broader landscape of electric vehicle (EV) charging technology.

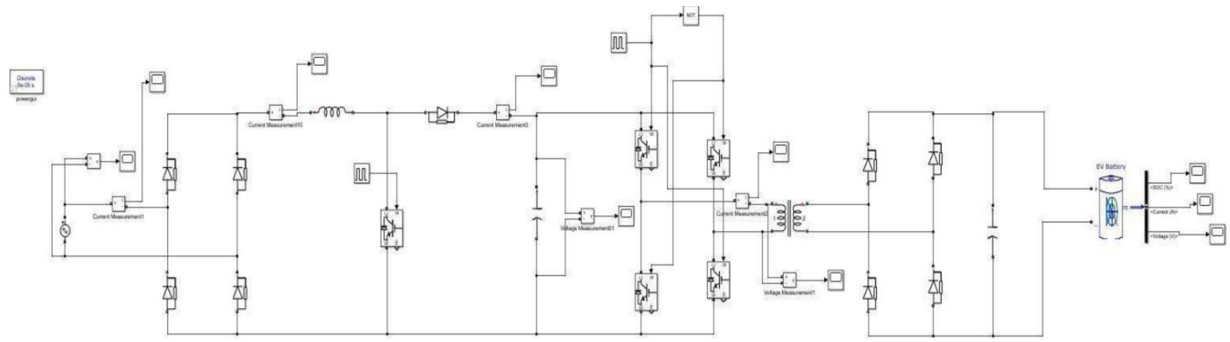

Fig 1. Proposed System

One of the primary outcomes of the project is the successful design and implementation of the interfacing system between the EV and Electric Vehicle Supply Equipment (EVSE). The interfacing system is designed to establish robust electrical and physical connections, enabling seamless communication and control during the charging process. Through adherence to automotive industry standards and meticulous design considerations, the interfacing system ensures compatibility and interoperability with existing charging infrastructure.

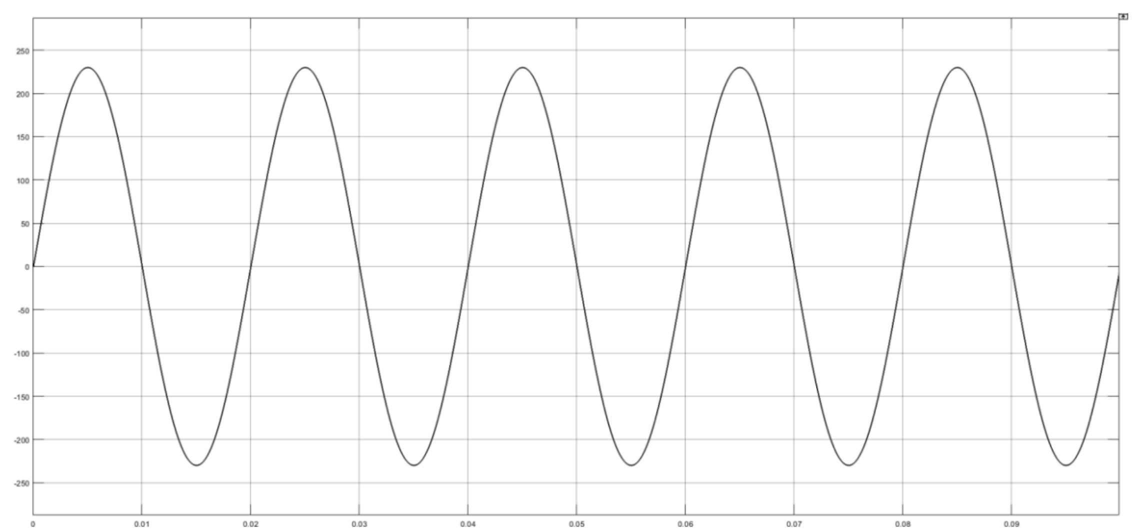

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Fig 2. Source voltage vs time

Moreover, the development of the on-board charger represents a significant milestone in the project. The charger is designed to deliver a power output of 3.45 kW, tailored for fast charging of hybrid electric vehicles (HEVs). By leveraging MATLAB software, the charger's design parameters, including voltage and current profiles, are optimized to maximize charging efficiency and battery health. The charger's performance is rigorously evaluated through simulation and testing, demonstrating its capability to meet the charging requirements of HEVs reliably.

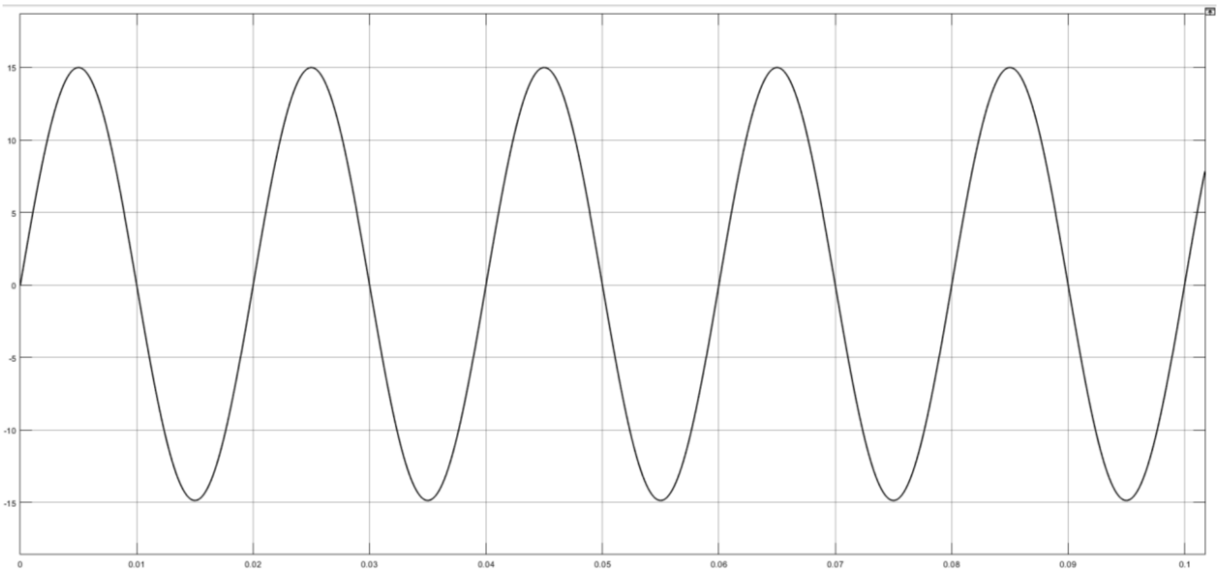

Fig 3. Source current vs time

Furthermore, the modeling of the charger charging process yields valuable insights into the dynamics of battery charging and propulsion torque generation. Through sophisticated mathematical models and simulations, the behavior of the charger, battery, and propulsion system is accurately characterized under various operating conditions. The modeling process enables engineers to fine-tune charger parameters and control algorithms to optimize charging performance and ensure safe and efficient operation.

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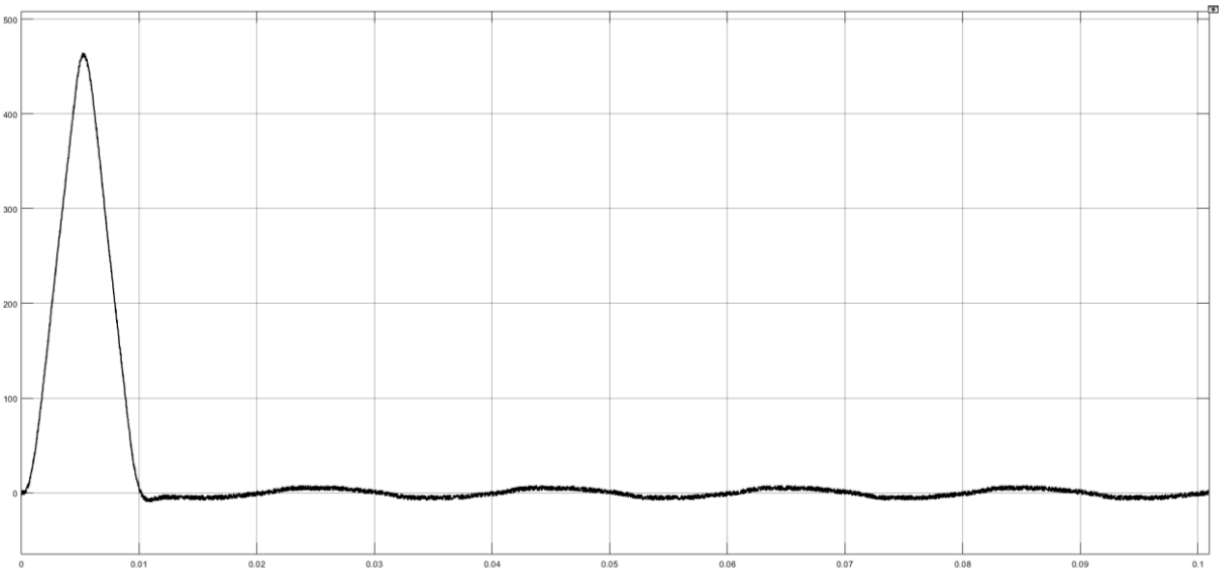

Fig 4. Variation of input current of PFC with time without inrush current solver

One of the key findings of the project is the efficacy of conductive AC charging methods facilitated by the interfacing system and on-board charger. Conductive AC charging proves to be a reliable and efficient method for replenishing the energy stored in the battery of plug-in hybrid electric vehicles (PHEVs). The interfacing system enables seamless integration with Electric Vehicle Supply Equipment (EVSE), facilitating reliable data exchange and control signals between the EV and charging infrastructure.

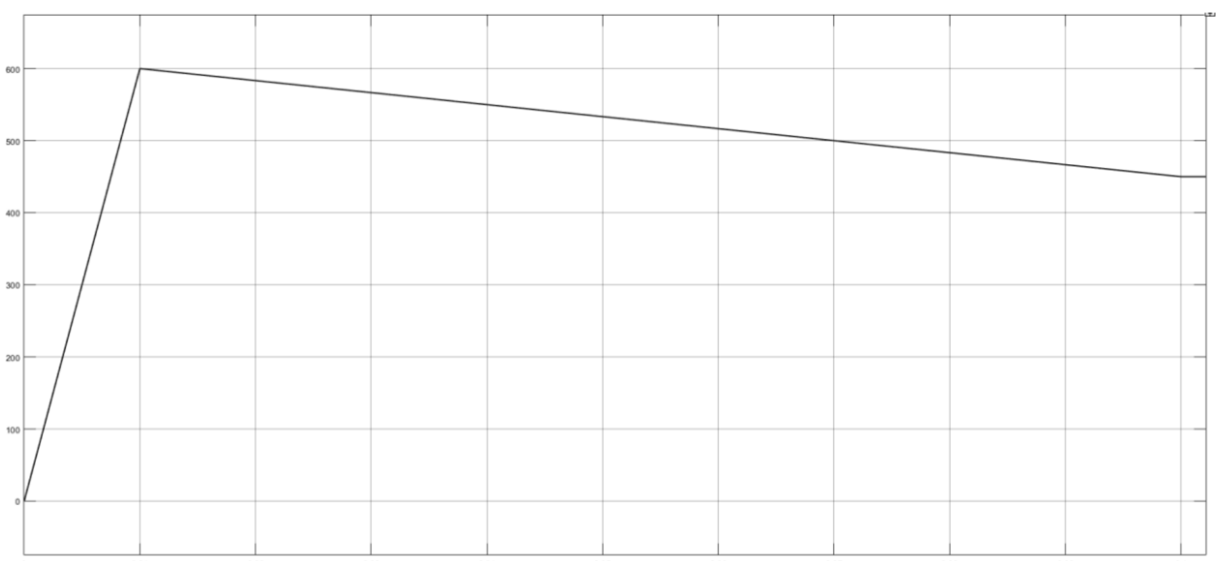

Fig 5. Output voltage of the boost converter

Moreover, the design and optimization of the on-board charger demonstrate the feasibility of fast charging for hybrid electric vehicles. The charger's ability to regulate voltage and current levels at various stages of the charging process ensures compatibility with different battery chemistries and charging requirements. Through iterative

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refinement and optimization, the charger achieves high efficiency and reliability, enhancing the overall driving experience for PHEV owners.

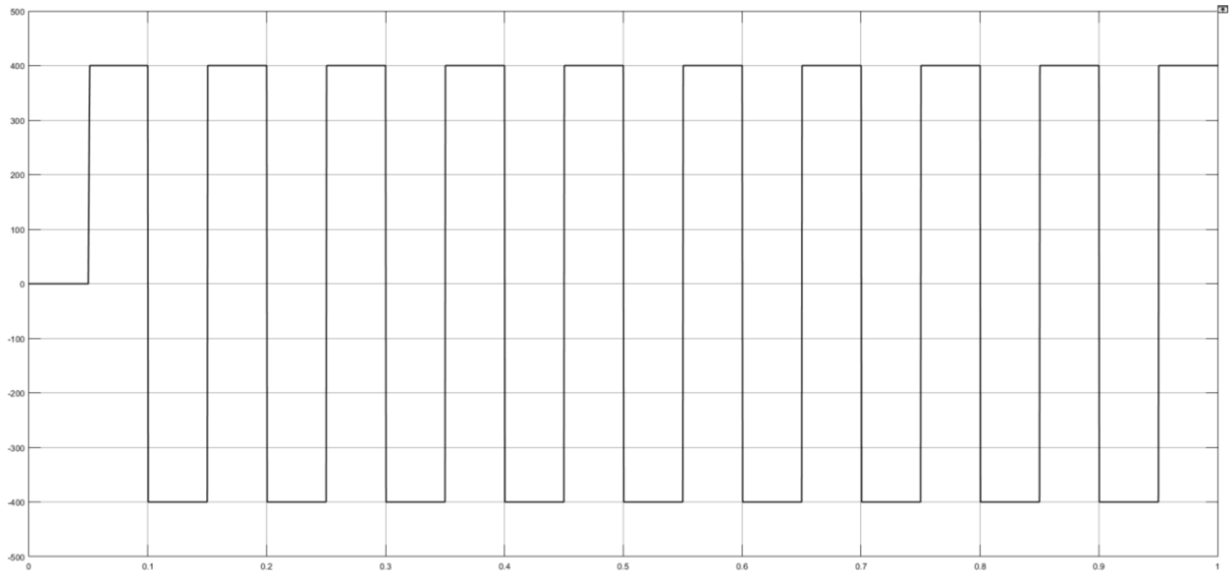

Fig 6. Primary voltage vs time

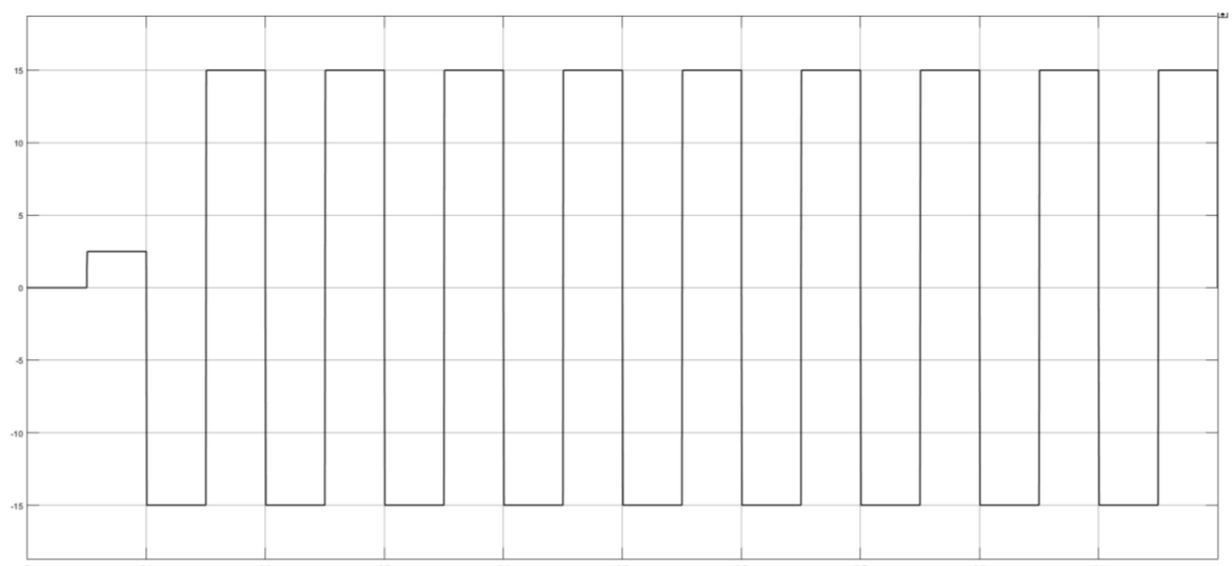

Fig 7. Primary winding current vstime

Additionally, the modeling of the charger charging process elucidates the intricate interplay between the charger, battery, and propulsion system. By accurately capturing the charging dynamics, engineers can identify potential issues and optimize charger parameters to mitigate risks and improve performance. The modeling process provides valuable insights into the charging behavior of lithium-ion (Li-ion) batteries, enabling precise control of charger voltage and current levels to align with battery specifications.

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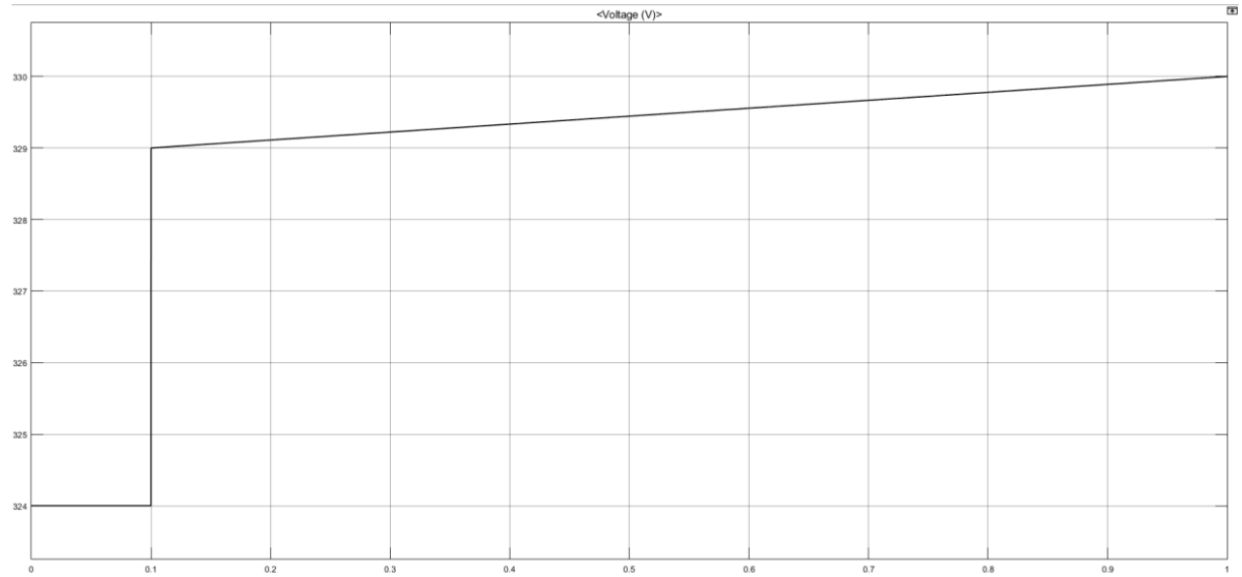

Fig 8. Battery Current vs time

Furthermore, the results underscore the importance of standardized interfacing systems and communication protocols in promoting interoperability and compatibility across different EV models and charging stations. By adhering to automotive industry standards, the interfacing system ensures plug-and-play compatibility and reliable communication between the EV and EVSE, streamlining the deployment of charging infrastructure.

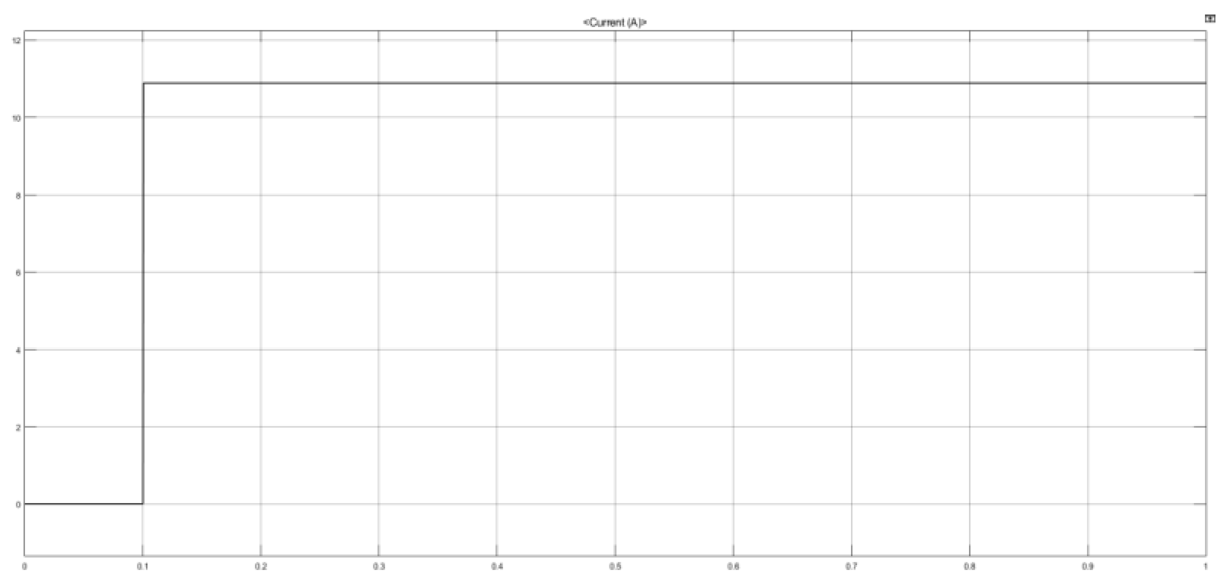

Fig 9. Battery Current vs time

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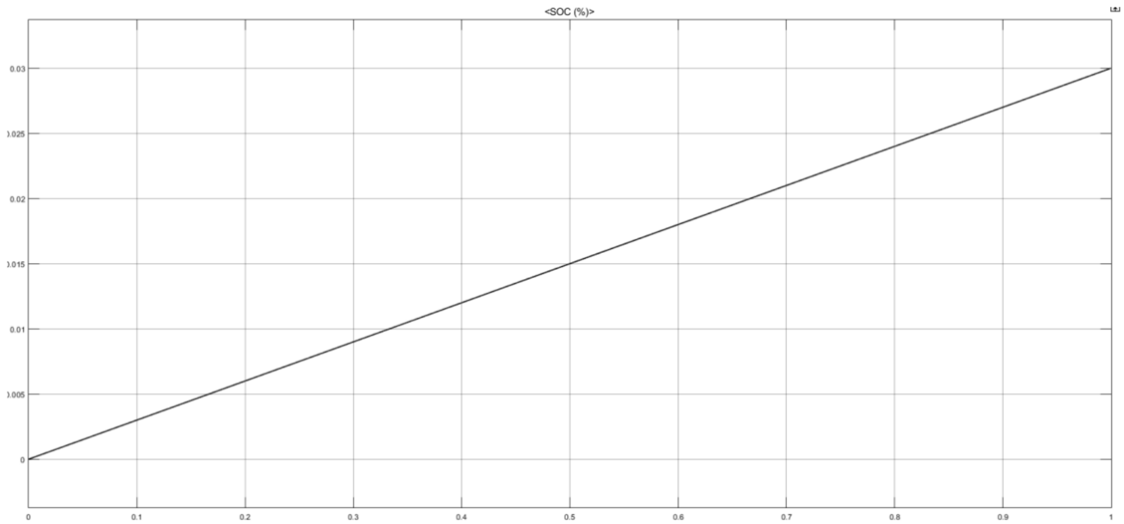

Fig 10. Battery SOC vs time

In summary, the results and discussion section of the "Modeling of Hybrid Electric Vehicle Charger" project highlights the successful design, implementation, and optimization of an interfacing system and on-board charger for plug-in hybrid electric vehicles. Through rigorous testing and simulation, the project demonstrates the efficacy of conductive AC charging methods and the importance of standardized interfacing systems in advancing electric vehicle charging technology. The findings pave the way for the widespread adoption of electric vehicles and the continued evolution of sustainable transportation solutions.

CONCLUSION

Asthe use of electrical vehiclesisincreasing day by day their charging system must be robust and reliable so that one can use electric vehicles without any problem. It presents conductive AC charging for charging plug-in hybrid electric vehicles. This project conductive of charging is investigated and complete analysis of the on-board charger is done due to which one should be able to verify the valid states for the start of charging and the range of maximum current limit is determined by the duty cycle. This project shows how one can design conductive charging systems as per automotive industry Standards.

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