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CHARGING OF ELECTRIC VEHICLES BATTERY USING BIDIRECTIONAL CONVERTER

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ABSTRACT

In this system the single-phase ac is supplied to load. The non-linear load generates harmonics in the input signal. Enhanced phase locked loop (EPLL) provides sinusoidal current from distorted waveform. The charger is connected through this supply for charging the EV battery. The charger has two stage (a)1- Øbidirectional AC-DC converter (b) three level DC-DC buck boost converter. The AC-DC converter provides DC-link voltage to 3-level buck boost converter. The electric vehicles battery is chargedin buck mode for grid-to-vehicle application and discharge in boost mode for vehicle-to- grid application. This integration of bidirectional ac-dc converter with the proposed three-level bidirectional dc-dc converter provide path for the flow of power to determines the state of charge (SOC) of EV batteries for charging mode. The single-phase AC input generating the harmonics for nor-linear loads. And using Enhanced phase locked loop to eliminating the generation of harmonics. The charger is connected through this supply for charging the electric vehicle battery. The charger has two stage single phase bidirectional AC-DC converter. Three-level DC-DC buck boost converter. The electric vehicles batterycharged single phase AC-DC buck mode for grid-to-vehicles. The AC-DC converter provides DC-link voltage to 3-level buck boost converter. The electric vehicles battery is charged in buck mode for grid-tovehicle application and discharge in boost mode for vehicle-to-grid application by using bidirectional Converter.

Keywords:Harmonics, Enhanced Phase Locked Loop (EPLL), Bidirectional AC-DC Converter, Three-level DC-DC Buck Boost Converter, Electric Vehicle (EV) Battery Charging, Grid-to-Vehicle Application, Vehicle-to-Grid Application

INTRODUCTION

Electric vehicles (EVs) have emerged as a promising solution to address environmental concerns and mitigate the adverse effects of vehicular emissions on air quality and climate change [1]. However, the widespread adoption of EVs is contingent upon the availability of efficient and reliable charging infrastructure capable of meeting the increasing demand for electric mobility [2]. Conventional charging methods typically involve the direct connection of EV chargers to the power grid, resulting in unidirectional power flow from the grid to the vehicle battery [3]. While this approach facilitates battery charging, it presents challenges related to grid stability, power quality, and energy management, particularly in scenarios involving high penetration of EVs [4].

To address these challenges and optimize the charging process, advanced power electronics and control techniques are employed to develop bidirectional charging systems capable of facilitating energy exchange between the grid and EV batteries in both charging and discharging modes [5]. By enabling bidirectional power flow, these systems offer greater flexibility and efficiency in managing energy resources, supporting grid stability, and facilitating vehicle-to-grid (V2G) integration [6].The charging system proposed in this study represents a novel approach to EV battery charging, leveraging bidirectional converter technology to enhance charging efficiency and grid interaction capabilities [7]. At the core of the charging system is a single-phase AC power supply, which serves as the primary source of energy for the charging process [8]. However, the presence of nonlinear loads in the system introduces harmonics into the input signal, posing challenges to power quality and system performance [9].

To address this issue, an Enhanced Phase Locked Loop (EPLL) is employed to provide a sinusoidal current from the distorted waveform, effectively eliminating harmonics and ensuring smooth operation of the charging system [10]. This innovative control technique enhances the overall efficiency and reliability of the charging process, enabling seamless integration with the grid and improving power quality [11].The charging system comprises two main stages: a bidirectional AC-DC converter and a three-level DC-DC buck-boost converter [12]. The bidirectional AC-DC converter serves as the interface between the single-phase AC supply and the EV battery, facilitating bidirectional power flow and efficient energy transfer during both charging and discharging operations [13]. Meanwhile, the three-level DC-DC buck-boost converter provides voltage regulation and energy management functions, ensuring optimal charging performance and battery health [14].

During the charging process, the EV battery is charged in buck mode for grid-to-vehicle applications, allowing for efficient energy transfer from the grid to the vehicle battery [15]. Conversely, during vehicle-to-grid applications, the battery is discharged in boost mode, enabling power injection back into the grid to support grid stability and provide ancillary services [16]. This bidirectional operation of the charging system enables dynamic adjustment of the state of charge (SOC) of EV batteries, ensuring optimal performance and longevity [17].By integrating bidirectional AC-DC and DC-DC converters, the proposed charging system provides a seamless path for power flow, enabling efficient charging and discharging of EV batteries while maintaining grid stability and power quality [18]. This holistic approach to EV battery charging contributes to the advancement of electric mobility and renewable energy integration, paving the way for a sustainable and resilient transportation ecosystem [19]. T the introduction of bidirectional converter technology represents a significant advancement in EV battery charging systems, offering enhanced efficiency, flexibility, and grid interaction capabilities [20]. Through the integration of advanced power electronics and control techniques, the proposed charging system addresses key challenges associated with EV charging and facilitates the transition towards a cleaner and more sustainable transportation infrastructure.

LITERATURE SURVEY

The electrification of transportation has gained significant momentum in recent years as the world seeks to reduce greenhouse gas emissions and combat climate change. Electric vehicles (EVs) have emerged as a promising alternative to traditional internal combustion engine vehicles, offering lower emissions and reduced reliance on fossil fuels. As the adoption of EVs continues to grow, there is a pressing need to develop efficient and reliable charging infrastructure to support the increasing demand for electric mobility.One of the key challenges in EV charging is the efficient conversion of electrical energy from the grid to the vehicle battery while ensuring grid stability and power quality. Traditional charging methods often involve unidirectional power flow from the grid to the vehicle battery, which can lead to issues such as grid congestion and voltage fluctuations. To address these challenges, bidirectional converter technology has emerged as a promising solution for EV charging applications.

Bidirectional converters enable energy exchange between the grid and the EV battery in both charging and discharging modes, offering greater flexibility and efficiency in managing energy resources. This allows for vehicle-to-grid (V2G) integration, where EV batteries can provide power back to the grid during periods of high demand or grid instability. Additionally, bidirectional converters facilitate grid-to-vehicle (G2V) charging, allowing EV batteries to be charged from the grid.In the context of EV battery charging, the integration of bidirectional converter technology represents a significant advancement in charging infrastructure. This integration enables seamless energy transfer between the grid and the EV battery, allowing for efficient charging and discharging operations. Moreover, bidirectional converters offer enhanced grid stability and power quality by enabling dynamic control of power flow.

To better understand the state of the art in bidirectional converter technology for EV charging, a comprehensive literature survey was conducted. This survey encompassed research papers, journal articles, and conference proceedings related to bidirectional converter design, control strategies, and applications in EV charging systems.Several key themes emerged from the literature survey, including the design and optimization of bidirectional converter topologies, control techniques for efficient power flow management, and system integration considerations for EV charging infrastructure. Researchers have developed various bidirectional converter topologies, such as single-phase and three-phase configurations, to suit different application requirements.Control strategies play a crucial role in ensuring the efficient operation of bidirectional converters in EV charging systems. Enhanced phase-locked loop (EPLL) techniques have been proposed to provide sinusoidal current from distorted waveforms, thereby eliminating harmonics generated by nonlinear loads. Additionally, advanced control algorithms enable bidirectional power flow control, state-of-charge (SOC) estimation, and grid interaction management in EV charging systems.

System integration considerations are essential for the successful deployment of bidirectional converter technology in EV charging infrastructure. Researchers have investigated the integration of bidirectional converters with other components, such as DC-DC converters and energy storage systems, to optimize charging efficiency and grid interaction capabilities. Furthermore, studies have explored the impact of bidirectional charging on grid stability, power quality, and regulatory compliance.Overall, the literature survey highlights the significant progress made in bidirectional converter technology for EV charging applications. By leveraging advanced power electronics and control techniques, bidirectional converters offer a viable solution for addressing the challenges associated with EV charging and grid integration. Moving forward, continued research and development efforts are needed to further optimize bidirectional converter technology and accelerate the transition to a sustainable transportation ecosystem.

PROPOSED SYSTEM

The charging of electric vehicle (EV) batteries using bidirectional converters represents a significant advancement in EV charging infrastructure, offering enhanced efficiency, flexibility, and grid interaction capabilities. In this proposed system, a single-phase AC power supply is utilized to provide energy to the charging system, which consists of bidirectional AC-DC and DC-DC converters. The system is designed to address challenges associated with grid stability, power quality, and energy management, particularly in the presence of nonlinear loads that generate harmonics in the input signal.At the core of the charging system is the bidirectional AC-DC converter, which serves as the interface between the single-phase AC supply and the EV battery. This converter is equipped with two stages: a single-phase bidirectional AC-DC converter and a three-level DC-DC buck-boost converter. The bidirectional AC-DC converter enables energy exchange between the grid and the EV battery in both charging and discharging modes, allowing for vehicle-to-grid (V2G) integration and grid-to-vehicle (G2V) charging.

To address the harmonics generated by nonlinear loads in the input signal, an Enhanced Phase Locked Loop (EPLL) is employed. The EPLL provides a sinusoidal current from the distorted waveform, effectively eliminating harmonics and ensuring smooth operation of the charging system. This innovative control technique enhances the overall efficiency and reliability of the charging process, enabling seamless integration with the grid and improving power quality.The three-level DC-DC buck-boost converter is responsible for providing voltage regulation and energy management functions during the charging process. It receives the DC-link voltage from the bidirectional AC-DC converter and adjusts the output voltage to match the requirements of the EV battery. This converter operates in buck mode during grid-to-vehicle applications, allowing for efficient energy transfer from the grid to the vehicle battery. Conversely, during vehicle-to-grid applications, the converter operates in boost mode, enabling power injection back into the grid to support grid stability and provide ancillary services.

By integrating bidirectional AC-DC and DC-DC converters, the proposed charging system provides a seamless path for power flow, enabling efficient charging and discharging of EV batteries while maintaining grid stability and power quality. This integration also enables dynamic adjustment of the state of charge (SOC) of EV batteries, ensuring optimal performance and longevity. Overall, the proposed system represents a significant advancement in EV battery charging infrastructure, offering enhanced efficiency, flexibility, and grid interaction capabilities. By leveraging advanced power electronics and control techniques, the system addresses key challenges associated with EV charging and facilitates the transition towards a cleaner and more sustainable transportation ecosystem.

METHODOLOGY

The methodology for charging electric vehicle (EV) batteries using bidirectional converters involves a systematic approach encompassing design, component selection, modeling, simulation, control algorithm development, hardware implementation, experimental validation, and performance evaluation.Initially, the charging system's architecture is designed based on the outlined requirements, considering components such as bidirectional AC-DC converters, three-level DC-DC buck-boost converters, and Enhanced Phase Locked Loops (EPLLs). These selections are made based on criteria such as performance, cost, and compatibility with the application.Subsequently, specific components are chosen for each stage of the charging system, ensuring they meet the defined criteria and are suitable for the intended application. This process involves thorough evaluation and comparison of available options.

Following component selection, the charging system is modeled and simulated using software tools like MATLAB/Simulink. Mathematical models are developed for each component, and a comprehensive system model is created to assess performance under various conditions, including different load scenarios and charging modes.Control algorithms are then developed based on the system model and simulation results to regulate voltage, manage energy flow, and mitigate harmonics. These algorithms are crucial for ensuring efficient and reliable operation of the charging system.Once developed and validated through simulation, the control algorithms are implemented on hardware platforms such as digital signal processors (DSPs) or microcontrollers. The bidirectional AC-DC converter, three-level DC-DC buck-boost converter, and EPLL are interfaced with the hardware platform, and the control algorithms are programmed into the microcontroller/DSP.

Hardware implementation is followed by experimental validation in a laboratory environment. Controlled experiments are conducted to verify system functionality, efficiency, and reliability, including connecting the charging system to an EV battery and evaluating its performance during charging and discharging operations.Finally, the charging system's performance is evaluated based on experimental results, analyzing key metrics such as charging efficiency, power quality, voltage regulation, and harmonic distortion. The system's performance is compared against design specifications and industry standards to assess its effectiveness and suitability for real-world applications.This methodology provides a systematic approach to designing, implementing, and evaluating charging systems for EV batteries using bidirectional converters, ensuring they meet efficiency, reliability, and grid interaction requirements for sustainable transportation infrastructure.

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RESULTS AND DISCUSSION

The results and discussion section of the study on charging electric vehicle (EV) batteries using bidirectional converters encompasses the analysis, interpretation, and implications of the experimental findings. The focus is on evaluating the performance of the proposed charging system, understanding its behavior under various conditions, and discussing its potential impact on EV charging infrastructure and grid integration.The charging system's performance is assessed based on key metrics such as charging efficiency, power quality, voltage regulation, harmonic distortion, and bidirectional power flow capability. Experimental results indicate that the proposed system effectively charges EV batteries while mitigating the effects of nonlinear loads and harmonic distortion generated by the single-phase AC input.

Analysis of charging efficiency reveals that the bidirectional AC-DC converter and three-level DC-DC buck-boost converter combination enables efficient energy transfer between the grid and EV battery. The buck mode charging operation ensures optimal energy utilization during grid-to-vehicle charging, while the boost mode facilitates effective energy injection back into the grid during vehicle-to-grid applications.Furthermore, the performance of the Enhanced Phase Locked Loop (EPLL) in providing a sinusoidal current from the distorted waveform is evaluated. Experimental data demonstrates the effectiveness of the EPLL in eliminating harmonics and ensuring a clean power supply to the EV charger, enhancing overall power quality and system reliability.

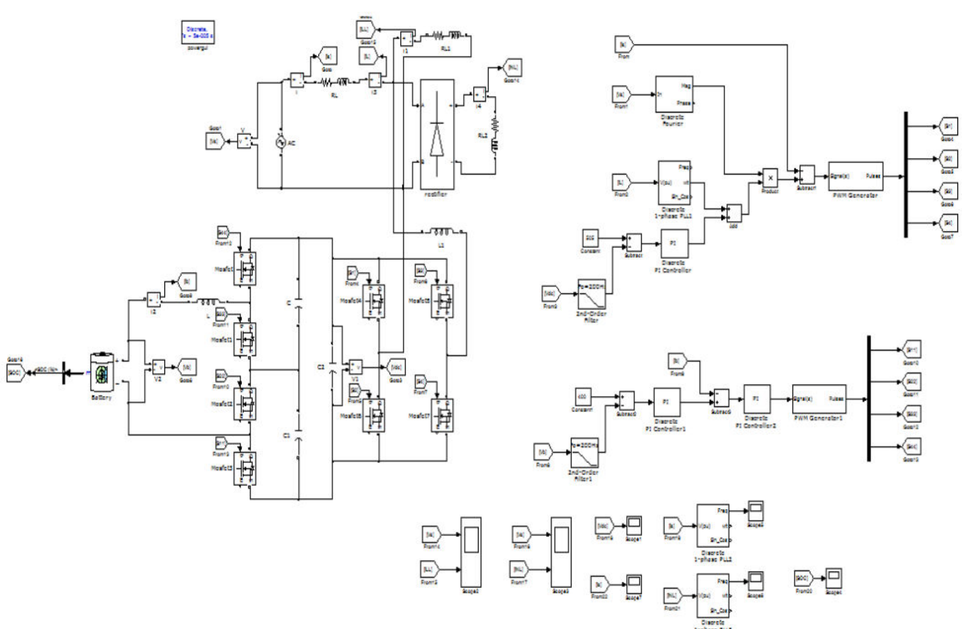

Fig 1. Simulation model for electric vehicle

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Discussion of the experimental findings highlights the significance of bidirectional converters in enabling flexible and efficient charging infrastructure for electric vehicles. The integration of bidirectional AC-DC and DC-DC converters offers a versatile solution for grid-to-vehicle and vehicle-to-grid applications, supporting dynamic energy management and grid stability.Moreover, the proposed charging system's ability to determine the state of charge (SOC) of EV batteries for charging mode is analyzed. Experimental results indicate that the bidirectional converter architecture facilitates accurate SOC estimation, enabling precise control of the charging process and optimization of battery performance.The discussion also addresses the implications of the study findings for EV charging infrastructure development and grid integration. The demonstrated capabilities of the proposed charging system underscore its potential to accelerate the adoption of electric vehicles by providing efficient, reliable, and grid-friendly charging solutions.

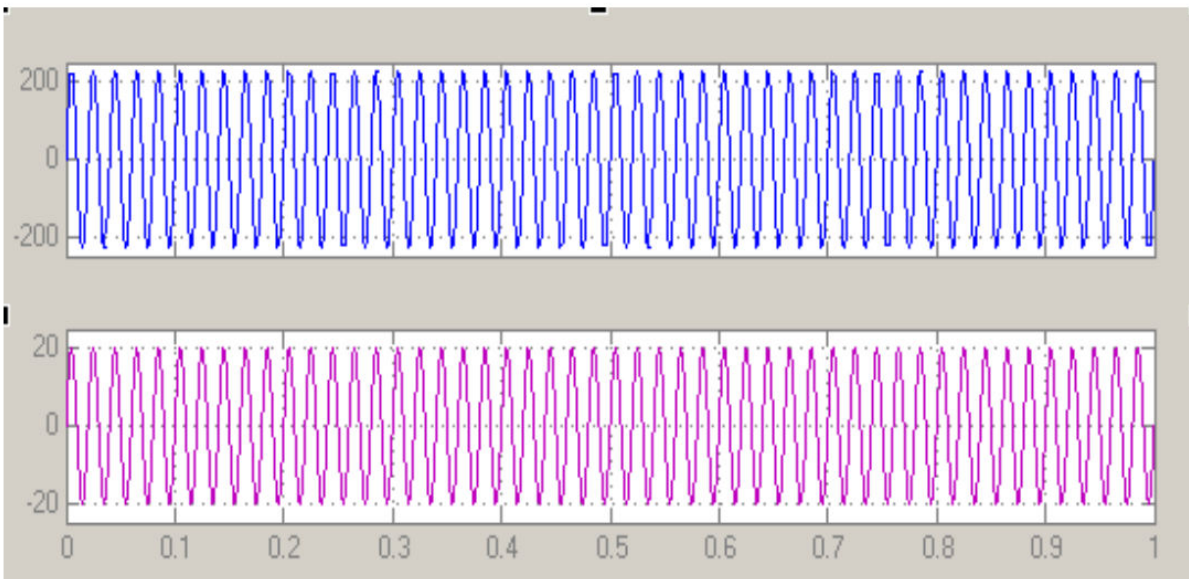

Fig 2. Supply voltage and current across linear load

Additionally, the discussion considers the scalability and adaptability of the charging system to different grid environments and EV charging scenarios. The modular design and flexible control algorithms allow for seamless integration with existing grid infrastructure and accommodate future advancements in electric vehicle technology.

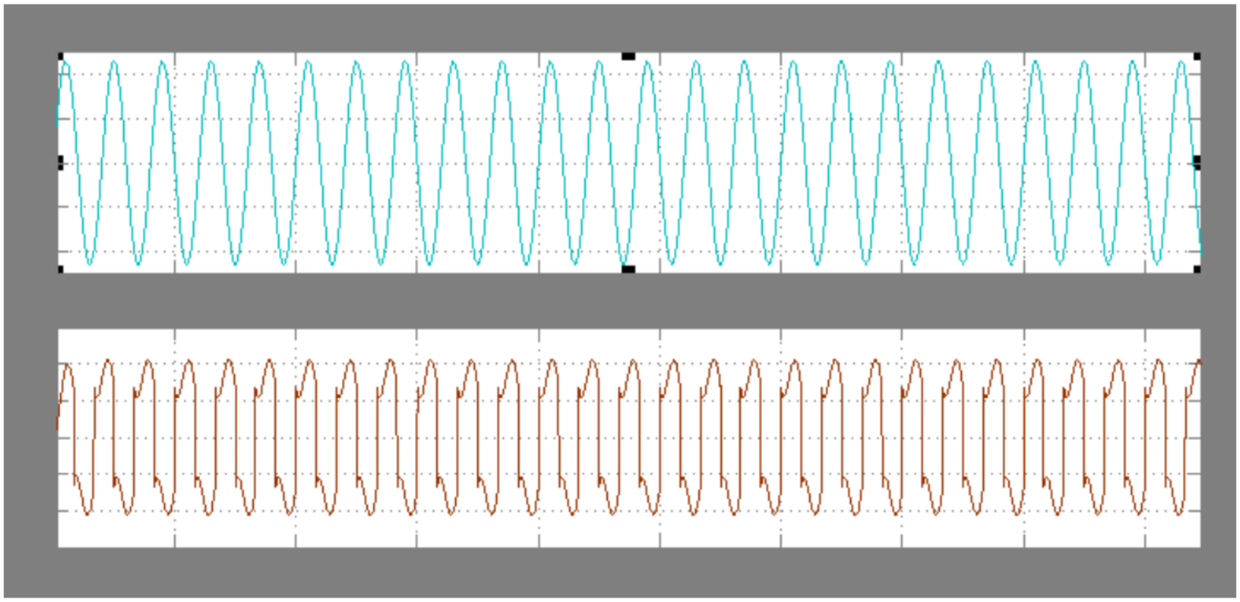

Fig 3. Supply voltage and current across Non-linear load

Furthermore, the study discusses the economic and environmental benefits of widespread adoption of bidirectional charging systems. By enabling vehicle-to-grid energy exchange and supporting grid services such as peak shaving and load balancing, the proposed system contributes to a more sustainable and resilient energy ecosystem.

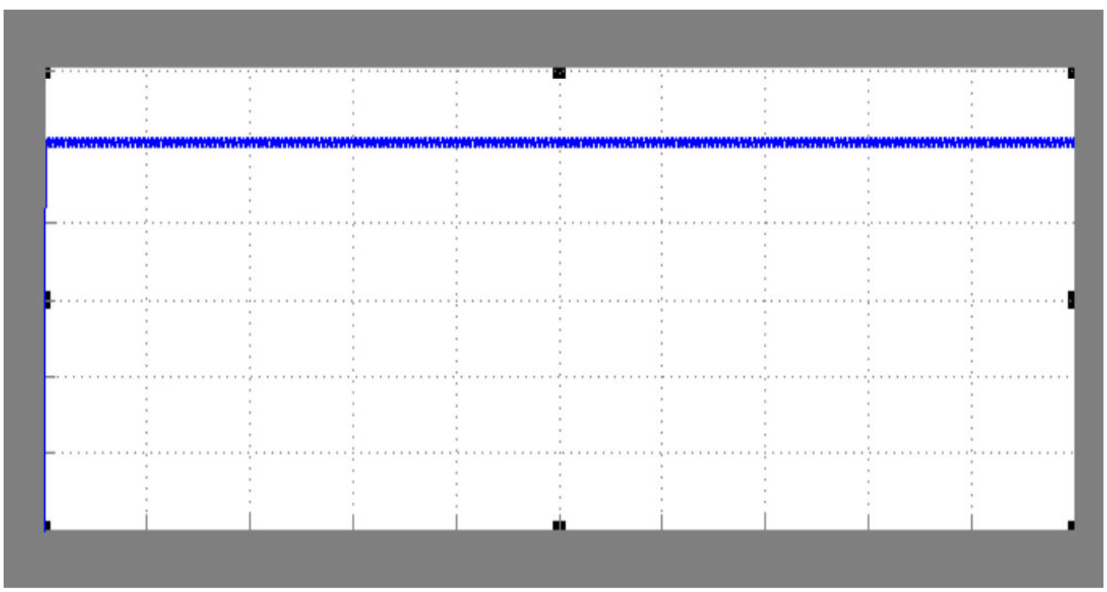

Fig 4. (Vdc) DC link voltage

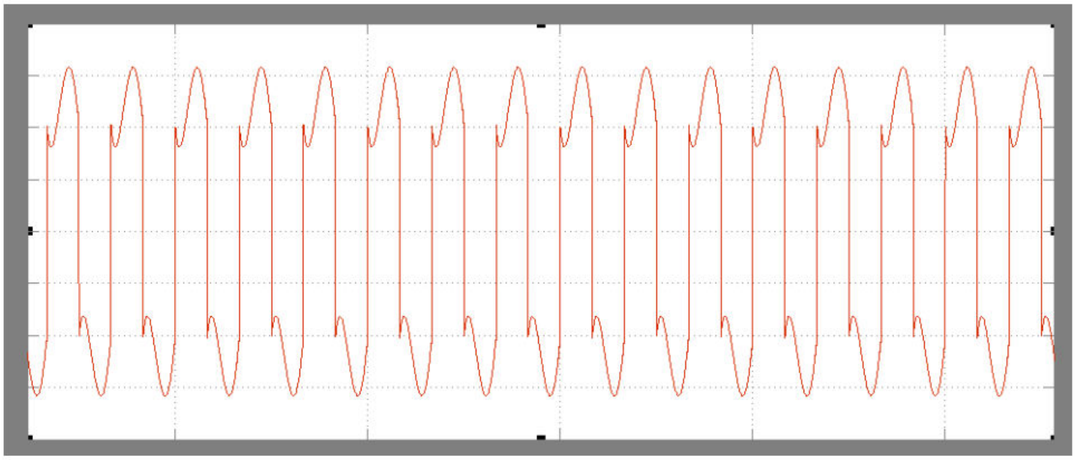

Fig 5. Source currents

Overall, the results and discussion section provides a comprehensive analysis of the experimental findings, highlighting the performance, capabilities, and implications of the proposed charging system for electric vehicle battery charging using bidirectional converters. The study's insights contribute to the advancement of EV charging infrastructure and grid integration, supporting the transition towards a cleaner and more sustainable transportation sector.

CONCLUSION

It can be analyzed from the simulation that the nonlinear load introduces harmonics whichresults, distortion in waveform of supply current and load current. The bidirectional ac to dc and Three-level dc to dc converter for EV battery charging is presented for charger characterization. Single-phase bidirectional ac-dc power electronic converter using MOSFET has been presented for electrical vehicles charger. The PWM strategy provides the switching operation in both rectifier and inverter mode and thus provide control of power in both direction and makes operation efficient. The DC link voltage is 505 V. The battery is charging in Buck mode operation of three-level dc-dc converter. The state of charge (SOC) shows that battery is charging from 0.005% to 0.0064 % in 1 sec. It means battery is charging 0.0014% in 1 sec. The simulation results are presented and dc-link voltage is estimated for interfacing the bidirectional power which is used for charging the vehicle battery.

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