EV Charger Using SiC MOSFET

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***Abstract*—SiC MOSFETs and IGBTs are semiconductors developed for high temp and frequency applications in electrical systems. SiC MOSFETs have higher productivity, power density, and cooling capabilities, making them ideal for use in EVs. However, their adoption in the automotive industry has been limited due to challenges such as EMI, reliability issues, and cooling difficulties. The paper examines SiC MOSFET benefits in various EV applications and explores future innovations to improve their reliability and enable higher switching frequencies.**

I. Introduction

Electric vehicles are becoming more popular to address environmental issues. The power supply and battery lifespan affect their progress. To advance EV technology, charging technology is now the focus since battery material research has reached a bottleneck. Scientists have concentrated on charging technology as a reliable, fast, safe, and efficient way to improve performance.

Fast charging technology has reduced the time it takes to charge electric vehicle (EV) batteries. Direct current charging systems take less than 30 minutes, while onboard charging systems take at least four hours. Power MOSFETs using silicon carbide (SiC) are critical components of charging systems due to their high power density, efficiency, durability, and reliability. SiC MOSFETs have higher efficiency than traditional IGBT solutions, reducing power losses by up to 38

The successful implementation of this project will significantly increase the use of SiC MOSFETs as power devices due to their lower turn-on, lower switching losses and high switching speed compared to their silicon counterparts. They have been widely marketed in recent years.

II. Literature Survey

In [1], the proposed think about comes about appear that the DC quick charging framework productivity increments astoundingly on tall yield voltage levels and distinctive sorts of circuit topologies which are utilized in thev ev chargers in common.

In [2],describes about the wide band-gap semiconductors and how these semiconductors are beneficial in todays techonology and its future wide spread and use.

In [3], the author discusses about stimulation and built up of the circuit on Mathlab which is widely used paltform of making stimulation of dynamic circuits as well as smooth implementation.

In [4], the author of paper delibretley discusses the importance and construction of the EMI filter in circuits and its wide use in the circuits.

In [5], the author proposes the hypothesis of quick dc dc charging in ev vehicles and its circuitary with each briefly explaning the topologies and the parameters in detail.

ANF PID controller improves electric vehicle battery charging stability and anti-interference performance. However, its adaptive neural fuzzy controller needs complex data training, and hardware implementation is challenging.

In [7] the author emphasis is on comparing power devices made from Si, SiC and GaN. Let's see a detailed comparison of material performance based on these values. This thesis evaluates the performance of Si, SiC, and GaN-based power devices used as high-side switches of a DC-DC converter.

The paper[8] provides an overview of EV charging technologies, including converter topologies, power levels, power flow directions, and charging control strategies. It also discusses the main charging methods, with a focus on fast charging for lithium-ion batteries. The final section uses genetic algorithms to estimate optimal charging system size and evaluate future trends.

Not only will this article provide an explanation on the process of how electric cars can store and extract energy from the grid, but it will also delve into the topic of the smart grid, which is a modernized electrical grid infrastructure that aims to improve the efficiency, reliability, and sustainability of electricity delivery.

This paper[10] focuses on the commonly used SiC and GaN power supplies, detailing their advantages and disadvantages, and exploring their applications in power electronics.

III. Methodology

The aim of simulating SiC MOSFET in a PE system project is to provide quick and precise estimation of power losses and junction temperature. This will help to design and test the capabilities of SiC MOSFET in EV charger design. The simulation strategy includes three stages, as shown in Fig. 1.

First stage consist of a LISN EMC filter (Line Impedance Stabilization Network) is a specialized device used in electromagnetic compatibility (EMC) testing to ensure accurate measurements of electrical characteristics in electronic devices.

Second stage consists of AC-DC Converter which is designed to convert the AC input from grid into DC output to the third stage. This stage uses Bridgeless PFC Boost AC-DC

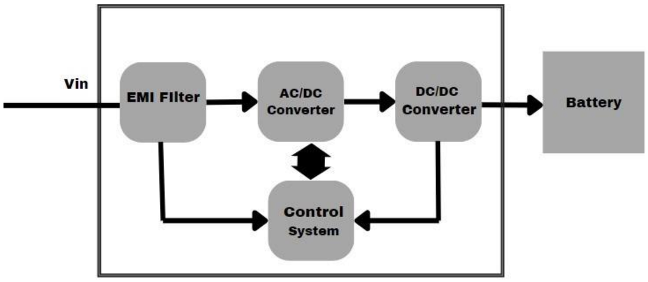

Fig. 1: Block Diagram

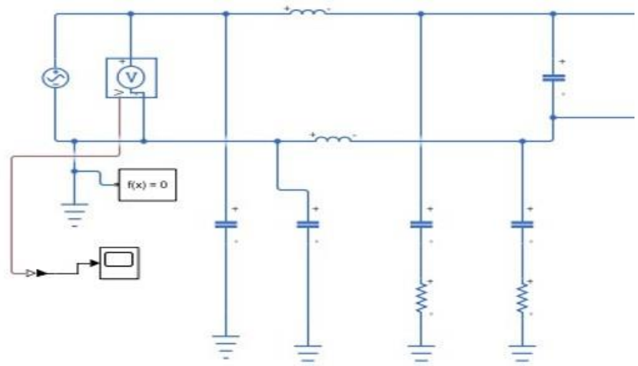

Fig. 2: Mathlab Stimulation Circuit

Converter topology, which has more benefits than traditional Bridge Rectifier.

In the third step of the process, a transformer is used to change the voltage level of the DC source. This transducer can be an electronic circuit or an electromechanical device. . This circuit is often used in electric car battery chargers. A full-bridge DC-DC converter with phase shift control is a good choice for high efficiency at high operating frequencies. It reduces switching losses and minimizes electromagnetic interference, making it a favorite in many applications.

IV. LISN Filter

In the field of electromagnetic compatibility (EMC) testing, a LISN EMC filter (Line Impedance Stabilization Network) is an essential device used to ensure precise measurement of electrical characteristics in electronic devices. The primary goal of this specialized device is to stabilize the impedance of the power line and reduce any interference caused by the device under test. A LISN EMC filter consists of a network of inductors, capacitors, and resistors that prevent unwanted noise and harmonics from polluting the power source and interfering with the accuracy of the EMC test results. With a well-designed LISN EMC filter, engineers can obtain reliable and repeatable EMC test results that comply with industry standards and regulations.

V. AC-DC Converter

Plug-in hybrid electric vehicles (EVs) require an onboard charger (OBC) to connect the mains and the vehicle’s high-voltage battery. To maximize power flow, a power factor correction converter (PFC) is required for efficient AC/DC power conversion. Traditional PFCs have limitations that affect performance, especially in EVs with space and weight constraints. To address this, a bridgeless PFC boost converter topology has been developed, utilizing SiC MOSFET for improved performance. The bridgeless PFC amplifier consists of an inductor, two high-frequency amplifier SiC switches (SiC1 and SiC2), and two components to control the current at line frequency. The line frequency components can be two diodes or two SiC switches (SiC3 and SiC4).

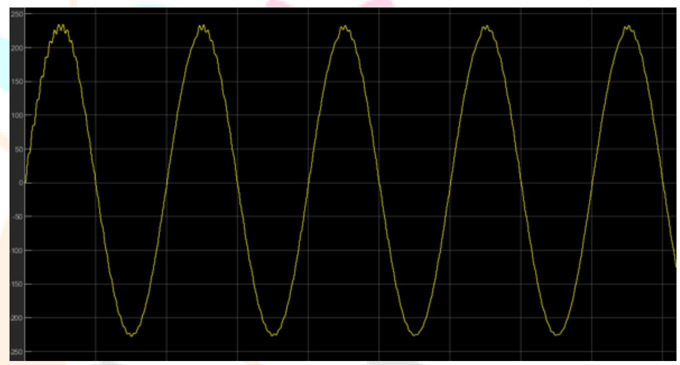

Fig. 3: LISN Mathlab Stimulation Output

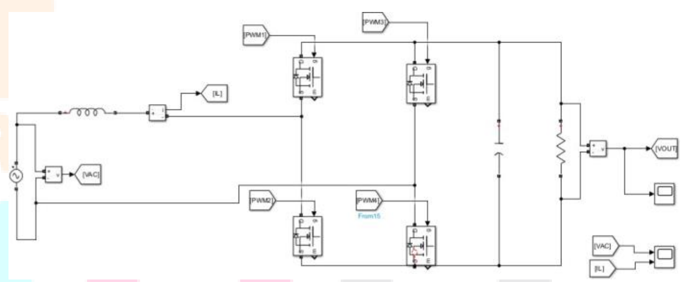

Fig. 4: Bridgeless PFC Boost AC-DC Converter

Bridgeless boost converters offer several advantages over traditional converters. They reduce diode count, increase power density, and improve efficiency. They also minimize common mode noise, AC ripple, reverse recovery, and require fewer components. The low reverse charge of the SiC body diode and the low on-resistance of the SiC MOSFET make the converter an efficient and cost-effective solution for bidirectional internal chargers.

The PFC system is all about making sure that the current consumption is just right. It uses both positive and negative cycles of the AC supply and high-frequency SiC MOSFETs to figure out how much power is needed. If you want to fix

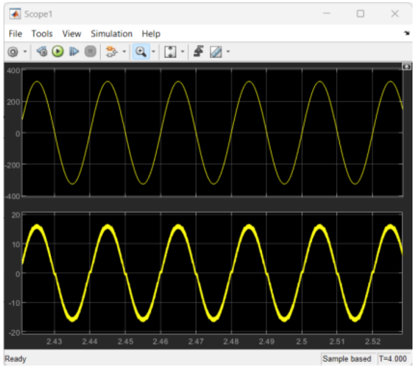

Fig. 5: Input Voltage and Current Waveforms

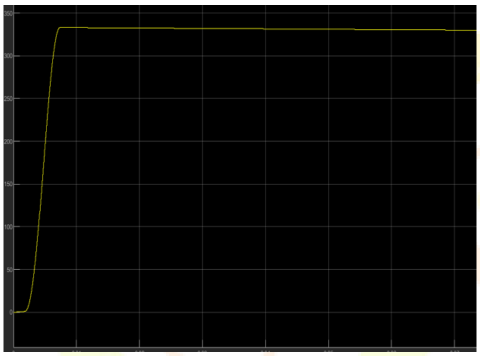

Fig. 6: AC-DC Output

the problems with harmonic input currents, you can use a PFC bridgeless transformer. That'll make sure everything's in sync with the input voltage. To get a synchronous mode boost converter working, you'll need high-frequency SiC MOSFETs and a coil. If you want to generate a PWM signal, you'll need to find an appropriate control system.

Figure 6. shows the output of an AC-DC converter, which is a DC output at a constant value of 400V. The controller ensures that the expected output and the resulting output are the same. PWM singal to match both values.

VI. DC-DC Converter

In a study, authors developed a mathematical model of the phase-shifted full-bridge zero-voltage switch circuit in electric vehicle battery chargers. They used adaptive neural fuzzy PID control to create a closed-loop system, which performed the best in experiments and simulations in terms of stability, overshoot, and response speed, meeting the expectations of optimization design.

Phase Shift Full Bridge Converter The PSFB converter is the go-to choice for battery charging applications due to its exceptional efficiency and reliability. The output side of the PSFB converter offers significant advantages such as low output current ripple and a lower current rating for the transformer secondary winding. These benefits make the battery charging system highly efficient and cost-effective, making it the preferred choice for many industries.

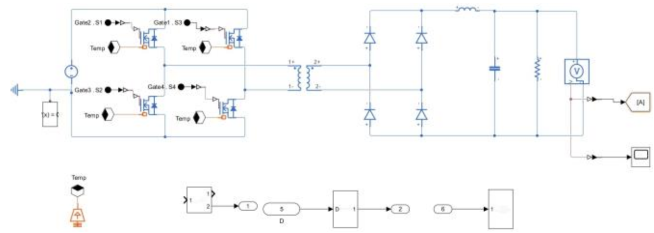

Fig. 7: Mathlab Stimulated PSFB DC DC Convert

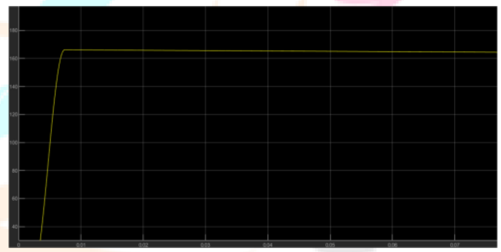

Fig. 8: Matlab Simulated PSFB Output

PI Controller A Proportional and Integral (PI) controller is a commonly used control system technique that is particularly useful in reducing harmonics and facilitating energy storage in the charging unit of Electric Vehicles (EVs). The PI controller is designed to correct the error between the commanded setpoint and the actual value, based on some type of feedback. This feedback can come from several sources, such as sensors or other monitoring devices.

The PI controller contains two components: a proportional term and an integral term. The proportional term is responsible for controlling the system's response to the error signal, while the integral term is responsible for eliminating any steady-state error. The PI controller's ability to combine the proportional and integral terms provides a faster response time than I-only control, which only uses the integral action.

In addition to reducing harmonics, the PI controller can also maintain the stability and accuracy of the system. It is able to stop the system from fluctuating and can bring the system back to its set point. This makes it an effective technique for controlling systems in various applications, including EVs.

Overall, the PI controller is a powerful tool that is widely used in control systems. By using the proportional and integral terms, it is able to correct system errors and maintain stability in a variety of applications, making it an essential component of modern control systems.

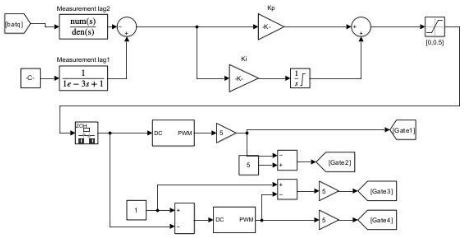

Fig. 9: Pi Controller

VII. Summary

Silicon carbide (SiC) devices are known for their ability to deliver high-voltage, high-current, and high-temperature components, making them an ideal choice for creating more energy-efficient systems, such as those used in electric cars. These devices can withstand high power density and operate at high temperatures, which is essential for creating electric cars with maximum driving range. By using silicon carbide devices in electric vehicle systems, manufacturers can create more efficient, longer lasting and more reliable vehicles. The use of silicon carbide in battery systems can lead to significant savings because over time the losses in energy recovery are smaller. In addition, it allows higher frequencies and densities and better thermal management. These benefits can have a positive impact on overall system efficiency and effectiveness. Silicon Carbide has the highest levels of hours and reliability in the industry, making it an excellent material for power conversion.

VIII. Future Scope

The future range of electric vehicle chargers using silicon carbide (SiC) MOSFET technology offers several significant advantages and potential advances:

Efficiency: SiC MOSFETs offer significantly lower switching losses and lower conduction losses than conventional silicon-based MOSFETs -s. This higher efficiency reduces energy loss during charging, which speeds up charging time and lowers operating costs for EV owners.

Fast charging: SiC MOSFETs enable faster switching speeds and higher operating frequencies, enabling the development of ultra-fast EVs -chargers. loading speeds. This is particularly important as EV manufacturers strive to reduce charging times and increase vehicle range, ultimately improving the overall user experience. Power density: SiC MOSFETs have a higher power density than silicon-based devices, which means they can handle higher levels. power in a smaller form. This leads to more compact and lighter electric vehicle chargers, which are essential for applications such as public charging stations and on-board electric vehicle chargers.

Thermal performance: SiC MOSFETs have better thermal conductivity and higher temperature tolerance compared to silicon devices . This enables the development of EV chargers that operate efficiently in harsh environments and high temperatures without compromising performance or reliability.

Integration with renewable energy: As renewable vitality sources such as sun oriented and wind ended up more common, the require increments. coordinated electric vehicle charging framework with these economical vitality sources. SiC MOSFET-based electric car chargers can successfully interface renewable vitality frameworks, empowering naturally inviting charging arrangements that diminish reliance on fossil fills.

Network integration and smart charging: SiC MOSFET technology allows electric car chargers to charge vehicles and supply excess energy back to the grid. Advanced control algorithms and communication protocols enable smart charging functions and optimize charging schedules based on grid conditions, energy prices, and user preferences.

Cost reduction: Although silicon carbide MOSFETs have traditionally been more expensive than silicon. equipment, continued improvements in manufacturing processes and economies of scale reduce the cost of silicon carbide-based components. As production volumes increase and technology advances, the prices of electric car chargers using SiC MOSFET technology are expected to become more competitive, which will further accelerate their market adoption.

In general, the future scope of electric car chargers using SiC MOSFET technology. is characterized by better efficiency, faster charging speed, better reliability and better integration with renewable energy sources and smart grid infrastructure. These advances will play a critical role in supporting the widespread adoption of electric vehicles and moving toward a more sustainable transportation ecosystem.

IX. Conclusion

SiC is superior to silicon devices for cars, providing better efficiency, lower emissions, and enhanced safety. This includes higher power density, better system efficiency, extended operating life, lower system costs and long-term reliability. Although silicon carbide is already used in some automotive parts, there is still a lot of untapped potential. The efficiency of the power source and energy management system of an electric car directly affects its autonomy. In addition, the necessary infrastructure, such as efficient fast charging systems, must be compact and efficient. Silicon carbide, due to its unique physical properties, is a unique solution to meet the demands of this new market.

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