ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

E-Mail :
editor.ijasem@gmail.com
editor@ijasem.org

www.ijasem.org

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN 2454-9940

www.ijasem.org

Vol 19, Issue 1, 2025

Enhancing Wireless Charging for Electric Vehicles Using a PFC SEPIC Converter

P Stephen Raj[1], V. L. Lavanya[2], Jayshri Kumari[3], Dr. D. Ravi Kishore[4]

[1]Department of EEE, Godavari Institute of Engineering and Technology (Autonomous), stephenrajpandu45@gmail.com
[2]Department of EEE, Godavari Institute of Engineering and Technology (Autonomous),, vlavanya2757@gmail.com
[3]Department of EEE, Godavari Institute of Engineering and Technology (Autonomous),, jayashri813210@gmail.com
[4]Professor, Department of EEE, Godavari Institute of Engineering and Technology (Autonomous), hod.eee@giet.ac.in

Abstract:
The growing demand for electric vehicles (EVs) has driven advancements in wireless charging technologies, yet traditional systems often suffer from inefficiencies and poor power quality. This study proposes an integrated wireless charging system that utilizes a Power Factor Correction (PFC) Single-Ended Primary Inductor Converter (SEPIC) to enhance efficiency and improve power quality. The proposed system optimizes energy conversion, reduces harmonic distortion, and ensures stable power factor correction. Through a detailed analysis and simulation, this research demonstrates the feasibility of the system for real-world EV charging applications, contributing to the development of sustainable and efficient charging infrastructure. The findings highlight improvements in system reliability, reduced charging time, and enhanced energy transfer, making it a viable solution for widespread EV adoption. Additional aspects such as economic feasibility, environmental benefits, and potential scalability are also discussed to provide a comprehensive outlook on the proposed system's implementation.

Keywords: Power quality, Power factor correction, SEPIC converter, Electric vehicles, interleaved synchronous rectifier, SPWM

1. Introduction

Electric vehicles (EVs) are rapidly transforming the automotive industry, offering a cleaner alternative to internal combustion engines. However, efficient charging solutions remain a challenge, particularly for wireless charging systems that suffer from energy losses and power quality issues. The need for reliable, high-efficiency wireless charging has led to the exploration of advanced power electronics solutions, such as PFC SEPIC converters. This paper presents an innovative approach to wireless EV charging by integrating a PFC SEPIC converter to improve efficiency, power quality, and overall system performance. Additionally, we discuss recent trends in EV adoption, policy support for clean energy initiatives, and the necessity for scalable charging solutions. The study also evaluates the role of government policies and incentives in encouraging the widespread adoption of EVs and their impact on the charging infrastructure.

2. Literature Review

Previous studies have explored various methods to enhance wireless EV charging, focusing on inductive coupling, resonant converters, and PFC techniques. Conventional charging systems often use fixed-frequency inverters, leading to energy losses and increased harmonic distortion. Recent research highlights the benefits of PFC SEPIC converters in achieving higher efficiency and reduced power losses. Moreover, studies have indicated that integrating advanced rectification techniques, such as synchronous rectifiers and PI controllers, can further improve energy conversion and minimize losses. This study builds on these advancements by implementing an interleaved synchronous rectifier and PI controllers to further optimize energy transfer and system stability. A comparative analysis of existing and proposed charging methods is also discussed to contextualize the innovation. Furthermore, the impact of different charging environments, such as urban and rural settings, is considered to understand the broader application of wireless charging technologies.

Pandav Kiran Maroti *et al* [2022] have proposed to the role of the electric power converter in electric vehicles is described in detail. Internal combustion engines (ICEs) are gradually being replaced by electric motors, increasing efficiency and reducing greenhouse gas emissions

Khalid S. Mohammad *et al* [2022] have presented the main electric motors used in electric cars and comparison of electric car drive system needs. In order to reduce environmental pollution and replace hybrid electric vehicles (ICE) with electric vehicles (EVs), many people are working to develop these vehicles

ISSN 2454-9940
www.ijasem.org
Vol 19, Issue 1, 2025

Mohammad Ali Sayed *et al* [2022] have described to offer a comprehensive assessment of the EV ecosystem, from vulnerabilities to challenges and ultimately solutions. Due to its environmental benefits, the increasing need to reduce greenhouse gas emissions and the development of green cities have encouraged the use of electric vehicles

Muhammad Salman Bin Ahmad *et al* [2022] have developed Demonstrate the benefits and economic benefits of future small pure electric vehicles, including hybrid, fuel cell electric, and mixed-fuel vehicles. Transportation is widely recognized as a major contributor to global greenhouse gas (GHG) emissions

Sai Sudharshan Ravi *et al* [2022] have The presentation discusses the challenges, setbacks, and future market penetration of V2G technology. Create a bi-directional charger that allows energy to flow in and out of an electric vehicle

Yen-Chu Wu *et al* [2022] have brief that to a nonlinear integrated numerical programming architecture to optimize the allocation of financial support. Electric vehicles should reduce transportation costs. Develop and distribute rebates and infrastructure investment funds to encourage EV adoption and achieve reduction targets

Jun Chen *et al* [2022] have explained to this experience is gained using a simulated environment that includes real-world driving data, long-term vehicle control, vehicle support, and power and fuel models. Batteries often have different characteristics due to different manufacturing processes, which causes batteries to change quickly.

Nikita V. Martyushev *et al* [2023] have suggested a simulation model was developed to determine the driving behaviour of an electric vehicle from a moving place. This energy storage can be measured in many ways and the results of these measurements vary. Therefore, the design based on these circuits is a very important task for electric vehicle manufacturers

Jonna Hynynen *et al* [2023] have proposed six large-scale fire tests were conducted, including three electric cars, two electric cars inside, and one electric car with the battery pack removed. Electric vehicle fires have made headlines around the world.

Emilia M. Szumska *et al* [2023] have presented Check there are already fast charging points for electric vehicles in the EU. One of the advantages of electric and plug-in hybrid vehicles is that they can be charged quickly. Best of all, it doesn't take much longer than filling your car with gas

Masooma Nazari *et al* [2023] have described a three-stage analysis was performed by applying an integrated approach to different problems related to electric vehicles. The increasing popularity of electric cars causes many problems for electric machines, especially transmission machines, due to the introduction of unknown products

Daniel De Wolf *et al* [2023] have demonstrated to the background is the ban on fossil fuel vehicles in many European cities. First, the main benefits/limitations of the two types of transfers are compared for the users. Hydrogen cars are used for freedom and fast charging. Battery-powered cars are cheaper and the grid is widely used

Yifan Liu *et al* [2023] have developed to Use machine learning-based classification to provide insights into customer payment behaviors in reviews, including Chinese. The electric car has emerged as a global strategy to combat climate change and external emissions from transportation. Electronic payments should be used to accelerate the use of technology, but management and policymakers have limited evidence on the use of public payment facilities by clans due to poor distribution of information and regionally dispersed members

Abdulgader Alsharif *et al* [2023] have brief that Examine the Consider the implications of microgrid systems for electric vehicles. One of the biggest challenges in combating global climate change is the mobility transition. Renewable energy sources (RES), along with electric vehicles, are considered as solutions to the energy and environmental problems needed to achieve Sustainable Development Goal 7 (SDG7) and Climate Action Goal 13 (CAG13).

Wenjing Lyu *et al* [2024] have explained to the impact of battery electric vehicles (BEVs) on air quality is evaluated using real traffic data from three major cities in China

Boris V. Malozyomov *et al* [2024] have presented The mathematical model of the electric vehicle includes the battery traction module, the traction motor of the electric vehicle, and the traction force calculation system of the electric axle, which are used to determine the battery discharge depth during the operation of the electric vehicle.

Muhammad Usman Nawaz ***et al*** **[2024]** have suggested A comprehensive assessment of the environmental and economic impact of solar electric vehicles (SEVs) compared to electric vehicles

Anahita Jannesar Niri ***et al*** **[2024]** have proposed about the measures are used by governments, regulators, businesses and all other stakeholders in the battery value chain.

Muhammad Candra Saputra ***et al*** **[2024]** have demonstrated to analyze the impact of behavior, norms, behavior management, ethics, environmental awareness, financial support, and risk on the perception of brand plan for battery electric vehicle (BEV) adoption

Alejandro Jim´enez ***et al*** **[2024]** have It is suggested to Discuss the integration of renewable energy into the grid. First, the energy sector is analyzed using the smart energy concept to identify renewable energy issues. Monitor power for security. This new approach combines a holistic energy system analysis from an energy planning perspective with a detailed energy analysis where the energy balance over time is important. Surprisingly, power is not the same.

3. Methodology

The proposed wireless charging system consists of an input AC supply, a PFC SEPIC converter, a high-frequency inverter, an isolation transformer, and an interleaved synchronous rectifier. The system is designed to optimize power transfer efficiency while maintaining voltage stability. The block diagram of the proposed system is shown in Fig.1

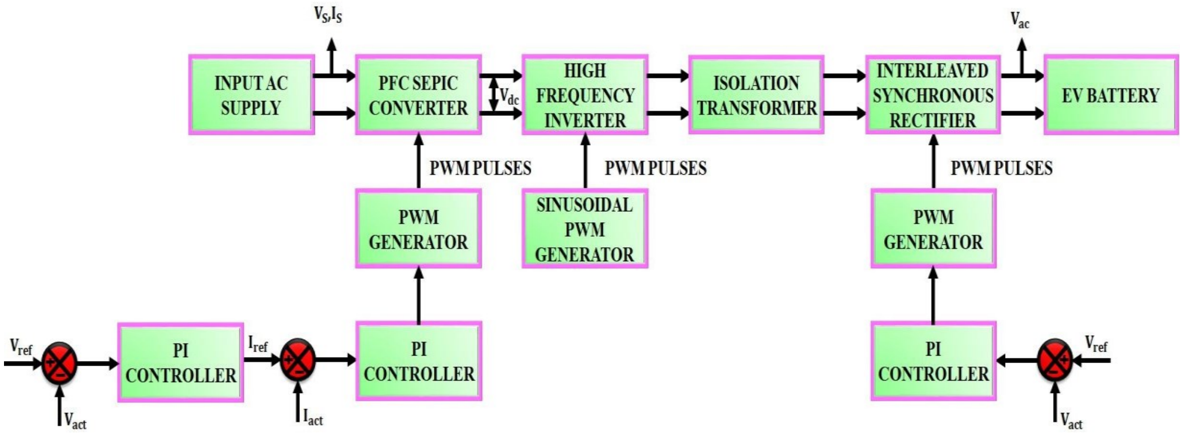

Fig.1- Block diagram of the proposed system

The major components in the proposed system are:

- **PFC SEPIC Converter**: Enhances power factor and reduces harmonic distortion, allowing for more reliable energy transmission.
- **High-Frequency Inverter**: Converts DC to high-frequency AC for efficient wireless power transfer, reducing energy dissipation.
- **Isolation Transformer**: Ensures safety and voltage regulation, preventing electrical hazards.
- **Synchronous Rectifier**: Improves conversion efficiency by minimizing rectification losses and enhancing battery charging.
- **Control Mechanism**: Utilizes PWM generators and PI controllers for precise voltage and current regulation, ensuring stability under varying load conditions.

The SEPIC converter is shown in Fig.2

ISSN 2454-9940
www.ijasem.org
Vol 19, Issue 1, 2025

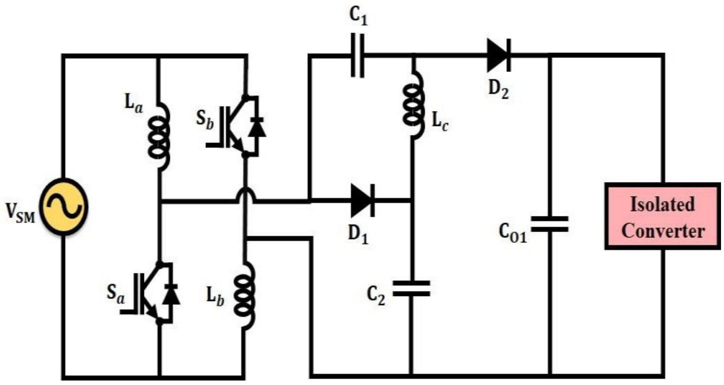

Fig.2- SEPIC converter

3.1 Operation of SEPIC converter:

The converter is operated in three modes:

Mode-1: This mode initiates at time _1, when both the switches are activated simultaneously. As the switches are engaged, the inductor current starts to increase and the capacitors _1 and _2 begin discharging

Mode-2: This mode initiates at time _2, when both the switches are deactivated simultaneously. As the switches disengage, the energy stored in inductors _ and _ are delivered to the load. In this phase, the auxiliary diode _1 transfers energy to capacitor _2, while inductor _ releases its stored energy **through diode _2 during the same interval.**

Mode-3: This is the freewheeling phase, which permits the inductors to release their stored energy to the output when both switches are simultaneously switched OFF. On applying KVL, in steady-state operation, the voltages across the inductors , and are assumed to be zero due to the inductors reaching a magnetic equilibrium,

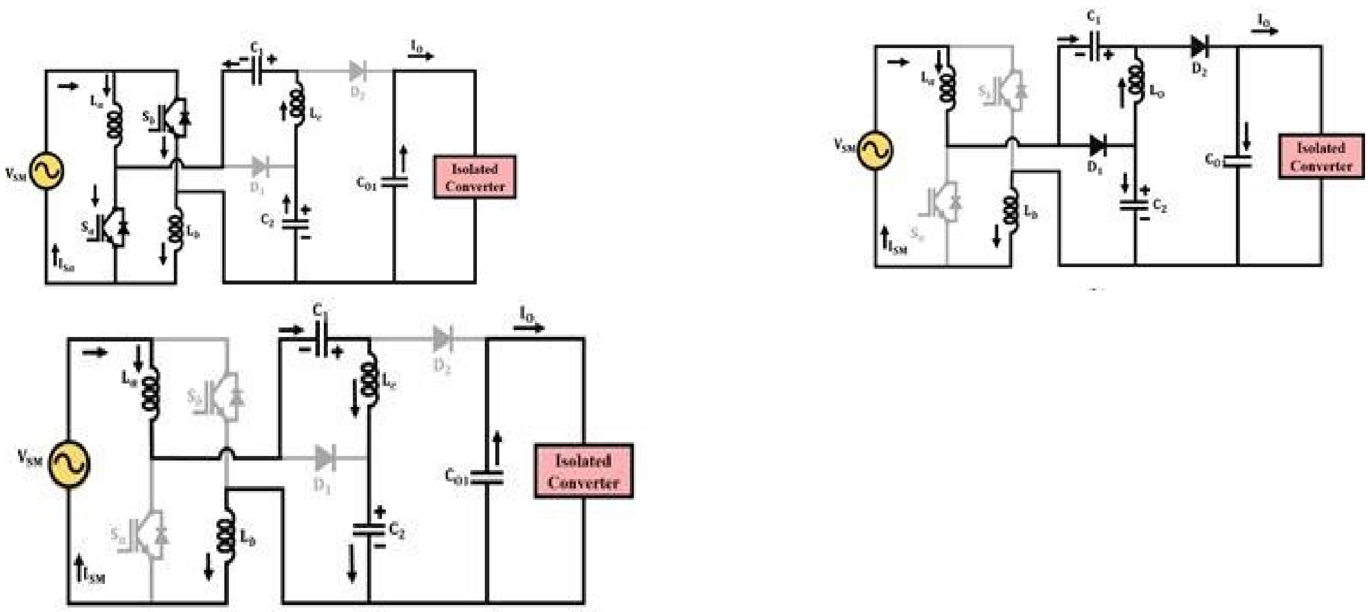

Fig-3:Operating modes of SEPIC converter (a) Mode-1 (b) Mode-2 (c) Mode-3

The PFC operation of the SEPIC converter is done by controlling the duty cycle of the converter. By adjusting the switch off and on time, the converter will optimize the input current waveform to closely match the input voltage waveform, thereby increasing the overall power

Structure of interleaved synchronous rectifier is shown in Fig. 4. In an interleaved configuration, two or more synchronous rectifiers operate out of phase with each other. This phase-shifting means that while one rectifier is conducting, the others are in a non-conducting state, effectively distributing the current load across multiple paths. This interleaving reduces the overall ripple current seen by both the input and output capacitors, which enhances the performance of the converter by minimizing voltage spikes and improving transient response

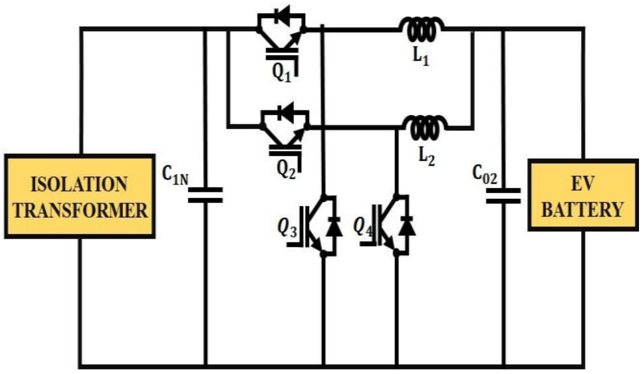

Fig.4: structure of interleaved synchronous rectifier

The generated pulses from SPWM control the inverter's switching devices

4. Results and Discussion

The proposed system was simulated in MATLAB/ SIMULINK. The input and output waveforms of SEPIC PFC are shown in Fig.5 and output DC voltage and currents are shown in Fig.6

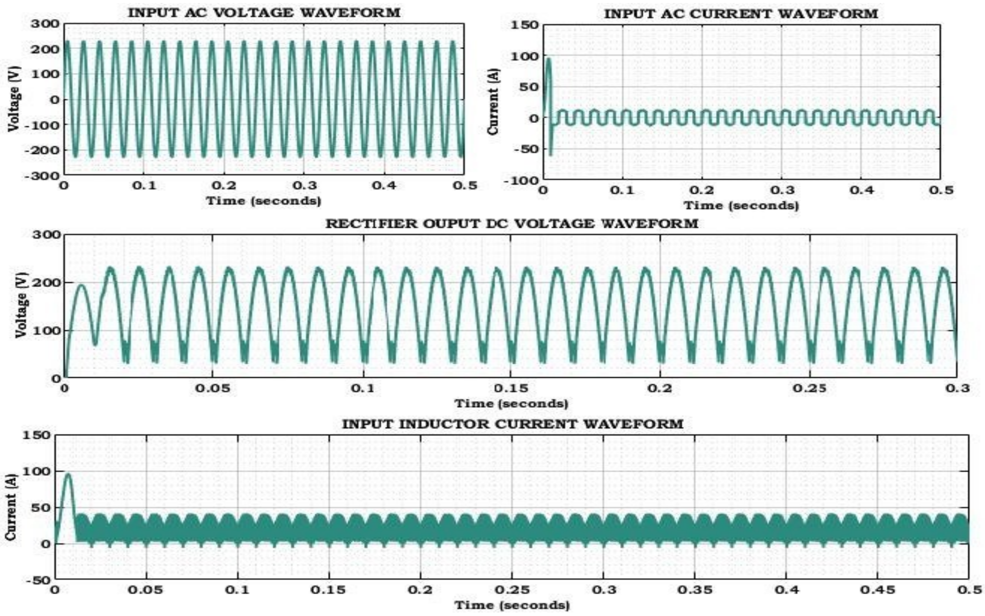

Fig.5 Input and output waveforms of SEPIC PFC

ISSN 2454-9940
www.ijasem.org
Vol 19, Issue 1, 2025

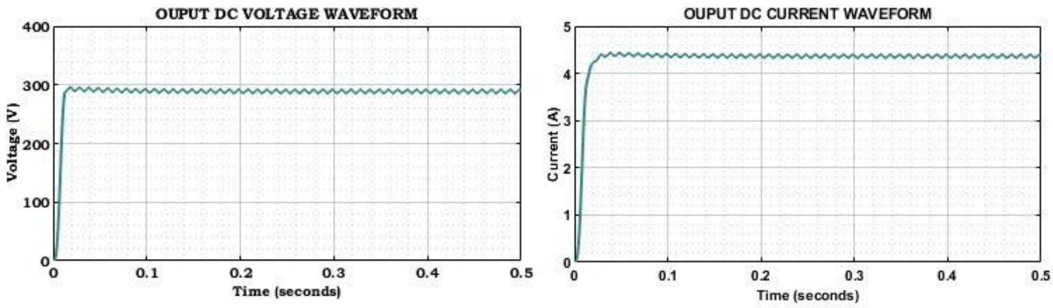

Fig.6 Output DC voltage and current stability in SEPIC PFC

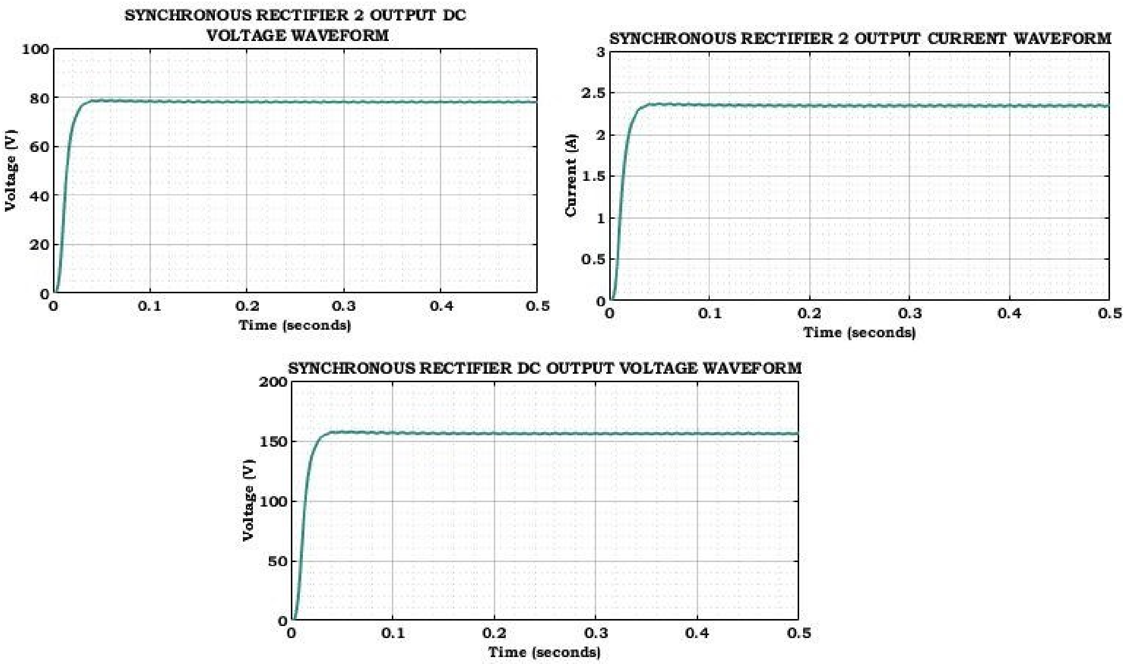

Fig.7 DC output characteristics of synchronous rectifier

The DC output characteristics of synchronous rectifier are shown in Fig.7 and the resulting power factor is shown in Fig.8

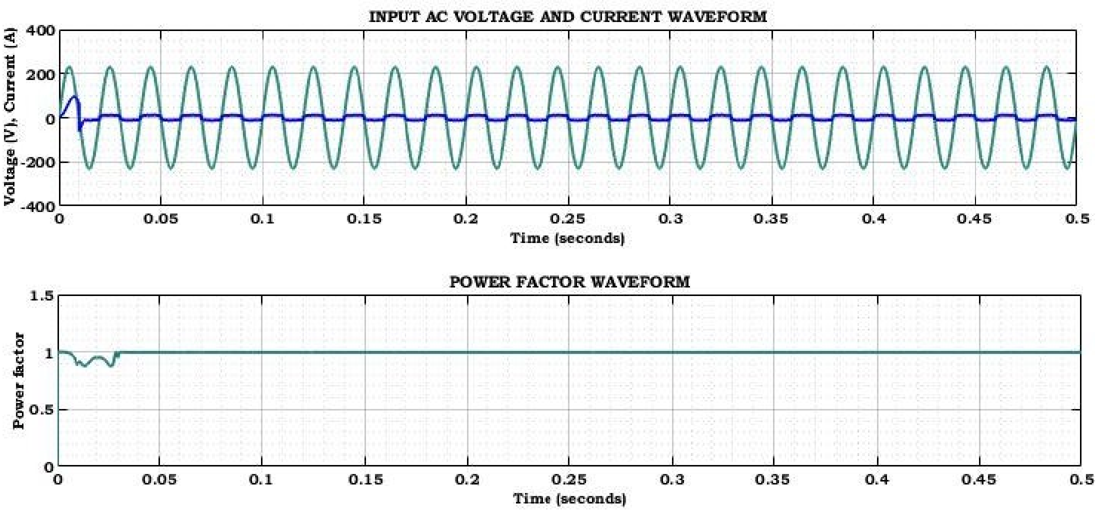

Fig.8 Waveforms of input voltage, current and resulting PF

ISSN 2454-9940
www.ijasem.org
Vol 19, Issue 1, 2025

Simulation results demonstrate that the proposed system achieves significant improvements in power factor correction, energy transfer efficiency, and voltage stability. Key findings include:

- Near unity power factor, ensuring efficient power utilization with minimal energy losses.
- Reduction in harmonic distortion, improving power quality and reducing interference with other electronic components.
- Enhanced energy transfer efficiency, minimizing losses in the charging process and enabling faster battery charging.
- Stability analysis indicates that the PI controllers effectively regulate voltage and current, preventing fluctuations and ensuring smooth operation.
- Comparative assessment with conventional wireless charging methods shows a marked improvement in efficiency and cost-effectiveness.

The integration of PI controllers contributed to maintaining stable voltage and current outputs, validating the effectiveness of the proposed approach in real-world applications. The impact on EV battery longevity and potential benefits for smart grid integration are also discussed. Additional parameters such as temperature variation effects, electromagnetic interference (EMI), and charging station scalability are analyzed to provide deeper insights into system performance under various conditions.

5. Conclusion

This study presents a novel integrated wireless charging system for EVs that enhances efficiency and power quality using a PFC SEPIC converter. The proposed system addresses key limitations of traditional wireless charging by improving power factor correction, minimizing harmonic distortion, and optimizing energy transfer. Additionally, it presents a feasible solution for large-scale EV adoption by ensuring reliable, efficient, and fast charging. Future research will focus on integrating renewable energy sources, smart grid compatibility, and further improving system robustness through advanced control strategies. The potential for AI-driven adaptive charging, real-time load balancing, and automated fault detection is also discussed, providing a roadmap for future innovations in EV charging infrastructure. Further studies on the economic implications of widespread adoption, lifecycle cost analysis, and user adoption patterns will also be conducted to support industry-wide implementation.

References:

1. Maroti, P.K., Padmanaban, S., Bhaskar, M.S., Ramachandaramurthy, V.K. and Blaabjerg, F., 2022. The state-of-the-art of power electronics converters configurations in electric vehicle technologies. Power Electronic Devices and Components, 1, p.100001.
2. Mohammad, K.S. and Jaber, A.S., 2022. Comparison of electric motors used in electric vehicle propulsion system. Indonesian Journal of Electrical Engineering and Computer Science, 27(1), pp.11-19.
3. Sayed, M.A., Atallah, R., Assi, C. and Debbabi, M., 2022. Electric vehicle attack impact on power grid operation. International Journal of Electrical Power & Energy Systems, 137, p.107784.
4. Bin Ahmad, M.S., Pesyridis, A., Sphicas, P., Mahmoudzadeh Andwari, A., Gharehghani, A. and Vaglieco, B.M., 2022. Electric vehicle modelling for future technology and market penetration analysis. Frontiers in Mechanical Engineering, 8, p.896547.
5. Ravi, S.S. and Aziz, M., 2022. Utilization of electric vehicles for vehicle-to- grid services: Progress and perspectives. Energies, 15(2), p.589.
6. Wu, Y.C. and Kontou, E., 2022. Designing electric vehicle incentives to meet emission reduction targets. Transportation Research Part D: Transport and Environment, 107, p.103320.
7. Chen, J., Zhou, Z., Zhou, Z., Wang, X. and Liaw, B., 2022. Impact of battery cell imbalance on electric vehicle range. Green Energy and Intelligent Transportation, 1(3), p.100025.
8. Martyushev, N.V., Malozyomov, B.V., Sorokova, S.N., Efremenkov, E.A. and Qi, M., 2023. Mathematical modeling the performance of an electric vehicle considering various driving cycles. *Mathematics*, *11*(11), p.2586.
9. Hynynen, J., Willstrand, O., Blomqvist, P. and Andersson, P., 2023. Analysis of combustion gases from large-scale

electric vehicle fire tests. Fire Safety Journal, 139, p.103829.

10. Szumska, E.M., 2023. Electric vehicle charging infrastructure along highways in the EU. Energies, 16(2), p.895.
11. Nazari, M., Hussain, A. and Musilek, P., 2023. Applications of clustering methods for different aspects of electric vehicles. Electronics, 12(4), p.790.
12. De Wolf, D. and Smeers, Y., 2023. Comparison of battery electric vehicles and fuel cell vehicles. World Electric Vehicle Journal, 14(9), p.262.
13. Liu, Y., Francis, A., Hollauer, C., Lawson, M.C., Shaikh, O., Cotsman, A., Bhardwaj, K., Banboukian, A., Li, M., Webb, A. and Asensio, O.I., 2023. Reliability of electric vehicle charging infrastructure: A cross-lingual deep learning approach. Communications in Transportation Research, 3, p.100095.
14. Alsharif, A., Tan, C.W., Ayop, R., Al Smin, A., Ali Ahmed, A., Kuwil, F.H. and Khaleel, M.M., 2023. Impact of electric Vehicle on residential power distribution considering energy management strategy and stochastic Monte Carlo algorithm. Energies, 16(3), p.1358.
15. Lyu, W., Hu, Y., Liu, J., Chen, K., Liu, P., Deng, J. and Zhang, S., 2024. Impact of battery electric vehicle usage on air quality in three Chinese first- tier cities. Scientific Reports, 14(1), p.21.
16. Malozyomov, B.V., Martyushev, N.V., Kukartsev, V.V., Konyukhov, V.Y., Oparina, T.A., Sevryugina, N.S., Gozbenko, V.E. and Kondratiev, V.V., 2024. Determination of the Performance Characteristics of a Traction Battery in an Electric Vehicle. World Electric Vehicle Journal, 15(2), p.64.
17. Nawaz, M.U., Umar, S. and Qureshi, M.S., 2024. Life Cycle Analysis of Solar-Powered Electric Vehicles: Environmental and Economic Perspectives. International Journal of Advanced Engineering Technologies and Innovations, 1(3), pp.96-115.
18. Niri, A.J., Poelzer, G.A., Zhang, S.E., Rosenkranz, J., Pettersson, M. and Ghorbani, Y., 2024. Sustainability challenges throughout the electric vehicle battery value chain. Renewable and Sustainable Energy Reviews, 191, p.114176.
19. Saputra, M.C. and Andajani, E., 2024. Analysis of factors influencing intention to adopt battery electric vehicle in indonesia. ADI Journal on Recent Innovation, 5(2), pp.100-109.\
20. Jiménez, A., Cabrera, P., Medina, J.F., Østergaard, P.A. and Lund, H., 2024. Smart energy system approach validated by electrical analysis for electric vehicle integration in islands. Energy Conversion and Management, 302, p.118121.