SOLAR WIRELESS CHARGING OF BATTERY IN ELECTRICAL VEHICLE

By

SHRADDHA KAUSHIK *

SHRADDHA MISHRA **

SAURABH SONI ***

SAURABH JAISWAL ****

*-**** *Department of Electrical Engineering, Bhilai Institute of Technology, Durg, Chhattisgarh, India.*

https://doi.org/10.26634/jee.17.4.20886

Date Received: 12/06/2024 *Date Revised: 25/06/2024* *Date Accepted: 09/07/2024*

ABSTRACT

Energy comes from a variety of natural sources, including the sun, nuclear power plants, and the chemical energy found in fuels. This study explores innovative solar-powered wireless charging methods for electric vehicles, aiming to enhance both efficiency and environmental sustainability. Traditional gasoline-powered vehicles contribute significantly to air pollution, noise pollution, and environmental degradation. In contrast, wireless charging technology, particularly through wireless power transmission (WPT), offers a cleaner alternative by eliminating the need for physical connections and reducing the associated emissions. The study highlights that WPT is not only reliable and effective but also operates silently, further contributing to a reduction in urban noise pollution. By integrating solar power, this method not only supports sustainable energy practices but also advances the push towards a cleaner and quieter future for transportation.

Keywords: WPT -Wireless Power Transmission, EV - Electrical Vehicle, IPT -Inductive Power Transfer.

INTRODUCTION

Today, the world's most significant challenge is energy demand. Electrical energy is generated from natural sources such as the sun, water, wind, and nuclear energy. Solar energy is currently the most frequently utilized source of electrical energy. In the last two to three years, wireless power transmission (WPT) has become one of the fastest-developing technologies for power transfer without the need for wires. This newly enhanced technology is both dependable and efficient. Wireless power transfer is increasingly important in today's world as it allows electric cars to operate more effectively.

This paper describes how to charge a battery using solar energy, which can support several devices, making it more advantageous. Power transfer via cables results in energy loss and has led to many accidents. In contrast, WPT is completely safe for humans. Consequently, it is now more environmentally and climate-friendly than traditional methods. Modern wireless power transfer solutions are more dependable and efficient.

Wireless power transmission has advanced significantly over the last 2-5 years. The advantages of wireless charging methods are listed below. Wireless charging technology has revolutionized the way we power our devices, increasing convenience and eliminating the need for cables. Traditional wireless charging methods typically require the charging source and device to be in close proximity. However, our work aims to improve this technology by using magnetic coils to achieve efficient power transmission over longer distances.

The key advantage of the approach is its ability to transmit significant power even when the coils are located at a significant distance from each other. This capability opens the door to practical applications where devices can be charged without the need for direct physical contact with a charging station (Tummapudi et al., 2023). Using the principles of electromagnetic induction, this wireless charging system not only provides convenience but also offers flexibility and security in a variety of environments.

Comparison with Existing Systems

Existing systems are often focused on wireless charging solutions that work effectively over short distances, generally ranging from a few centimeters to a few inches. These systems are suitable for smartphones, portable devices, and similar gadgets placed near the charger. In contrast, this approach investigates the feasibility of wireless charging over long distances, making it suitable for scenarios where devices are not in close proximity to the charging source. This capability is particularly beneficial in industrial environments, smart infrastructure, and applications involving vehicles and equipment at high altitudes or in large spaces (Sun et al., 2018). By pushing the limits of wireless charging technology, this work aims to redefine the convenience and efficiency of wirelessly powered devices and pave the way for future innovations in power transmission and device autonomy.

1. Literature Review

In 1890, Nikola Tesla was the first person to create Wireless Power Transmission or WPT. He developed the inductive and capacitive coupling system for WPT because he intended to build a supply system without the need for wires (Okasili et al., 2022). The Tesla Coil is a coil that he invented. The concept for the electrical vehicle [EV] charging system was provided by Erhuvwu Ayisire (Joseph et al., 2019). In addition to providing information regarding battery charging, using solar energy analyzed the main and secondary sides (Tazay, 2021). The most challenging and crucial aspect of creating a wireless charging system is creating the coil design. This paper provides information about wireless charging in electrical vehicles through the use of solar energy.

2. Methodology

Power Sources for Wireless Power Transmission

Rayan et al. (2023) conducted a study in which wireless power transfer was performed using two different power sources to investigate the feasibility and efficiency of power delivery. The sources used are:

Solar Panel Setup

Absorption and Conversion: The solar panel absorbs solar energy and converts it into electrical energy.

Electrical Output: The solar panel has two terminals, positive and negative. Figure 1 shows the solar panel.

Zener Diode Application:

A zener diode is connected across the terminals to regulate the voltage output, ensuring a consistent voltage level suitable for charging purposes.

Diode for Current Regulation:

A diode is placed in such a way that it prevents reverse current flow from the battery back to the solar panel, ensuring energy flows efficiently in one direction.

Capacitor Integration:

A capacitor is connected in parallel across the solar panel terminals to reduce ripple in the output, stabilizing the voltage and current supply.

Battery Management System (BMS) Functionality: A BMS battery management system is employed to manage the batteries efficiently.

Battery Charging:

It controls the charging process of the batteries, ensuring they receive the appropriate voltage and current from the solar panel.

Battery Discharge: Simultaneously, the BMS manages the discharge of the batteries, ensuring power is delivered as needed for wireless charging.

To achieve the desired low-voltage DC supply from a high- voltage AC source, a step-down transformer, rectifier, and filter capacitor are utilized in the following steps.

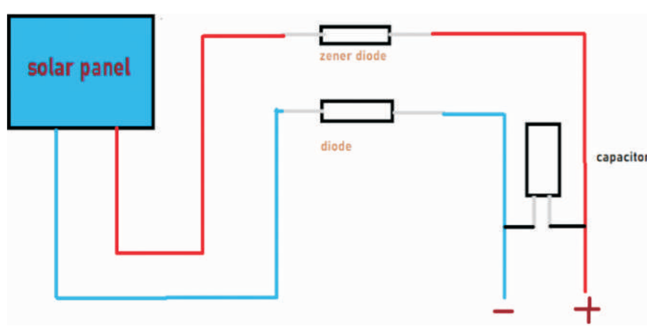

Figure 1. AC Supply with help of Transformer

Step-Down Transformer:

A step-down transformer is employed to reduce high input AC voltage to a lower AC voltage. The primary winding of the transformer is connected to the high-voltage AC supply, while the secondary winding provides a lower voltage output suitable for subsequent rectification. The selection of the transformer is crucial, as it must provide the required voltage level and handle the power demand of the circuit.

Rectification:

The AC output from the secondary winding of the transformer is then fed into a rectifier circuit. The rectifier's role is to convert the AC voltage to a pulsating DC voltage. This is typically achieved using a bridge rectifier configuration, which employs four diodes arranged in a bridge formation to ensure that both halves of the AC waveform are utilized, resulting in a full-wave rectified output. The rectifier effectively converts the AC voltage to a unidirectional DC voltage, although it still contains significant ripple.

Filtering:

To smooth the pulsating DC voltage and reduce the ripple factor, a capacitor is connected in parallel with the output of the rectifier. The choice of capacitor value is important: higher capacitance values usually provide better smoothing, less voltage ripple, and a more stable DC output.

To manage power from different sources (such as a solar panel or a step-down transformer) and facilitate its transfer, the following steps are undertaken:

Terminal Configuration:

The setup initially provides four terminals: two positive and two negative. The negative terminals are combined into a single terminal, resulting in three terminals: one common negative and two positive terminals.

Three-Way Switch

A three-way switch is used to connect these terminals. This switch allows us to select the power source, either the solar panel or the step-down transformer. By switching between the sources, we can choose the desired power input.

Magnetic Coil for Power Transfer

Once the source is selected, a magnetic coil is used to transfer the power efficiently. This ensures that the power is delivered to the load with minimal loss.

3. Ease of Use

The worldwide shift towards sustainable transportation solutions has spurred the exploration of innovative technologies that combine renewable energy sources with the rapidly growing Electric Vehicle (EV) industry. Among these groundbreaking technologies, solar wireless EV charging systems have emerged as a beacon of promise. These systems represent a symbiotic fusion of solar power harnessing and wireless charging capabilities, offering a glimpse into the future of eco-friendly transportation. Solar wireless EV charging systems are designed to simplify the process of charging electric vehicles while harnessing clean energy from the sun (Amjad et al., 2022; Mwasilu et al., 2014). Traditional EV charging stations require physical connections between the vehicle and the charging infrastructure, which can be cumbersome and inconvenient. In contrast, solar wireless systems eliminate the need for cables and plugs, allowing EV owners to simply park their vehicles over a charging pad to initiate the charging process wirelessly. At the heart of these systems are solar panels, which capture sunlight and convert it into electricity. This renewable energy is then stored in batteries or directly transferred to the EV for charging. Wireless charging technology enables efficient power transfer between the charging pad and the vehicle (Ching et al., 2013; Triviño et al., 2021), ensuring a seamless and hassle-free charging experience for users. Recent advancements in solar wireless EV charging technology have focused on improving efficiency, reliability, and scalability.

Enhanced solar panel efficiency and energy storage capabilities have increased the system's ability to generate and store electricity, reducing reliance on the grid. Additionally, advancements in wireless charging technology have led to faster charging speeds and improved compatibility with a wide range of EV models. Despite these advancements, solar wireless EV charging systems face inherent challenges, including limited range and variability in sunlight exposure. To address these challenges, ongoing research and development efforts are focused on optimizing system design, increasing energy storage capacity, and integrating smart charging algorithms to maximize efficiency. Looking ahead, solar wireless EV charging systems are poised to play a significant role in the transition toward sustainable transportation. By leveraging renewable energy sources and innovative charging technology, these systems offer a practical solution to the growing demand for convenient and eco-friendly EV charging infrastructure. As technology continues to evolve and adoption rates increase, the future of electric mobility promises to seamlessly integrate with sustainable energy sources, paving the way towards a cleaner and greener transportation ecosystem.

4. Block Diagram

Implementing a solar wireless Electric Vehicle (EV) charging system incorporating solar panels, a transformer, battery, rectifier, capacitor, and diode involves a comprehensive approach that optimizes energy capture, storage, and transmission while ensuring safety and efficiency (Joseph & Elangovan, 2018). Figure 2 shows the block diagram. Here's a detailed overview of each component's role and the overall implementation process:

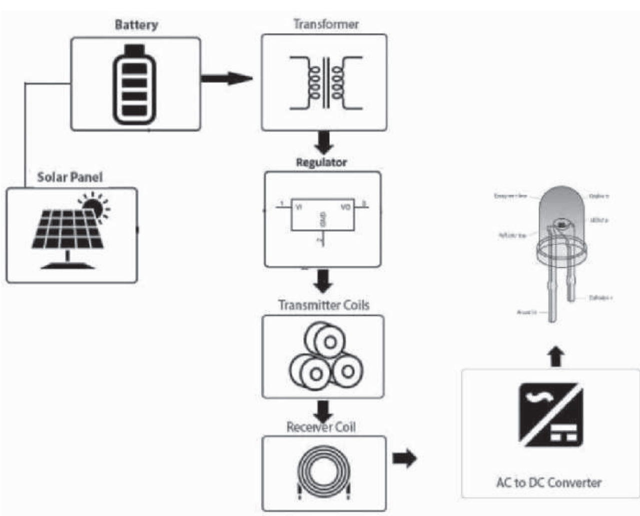

Figure 2. Block Diagram

4.1 Solar Panels

Solar panels are the backbone of the system, responsible for capturing sunlight and converting it into electrical energy. These panels consist of photovoltaic cells that generate Direct Current (DC) electricity when exposed to sunlight through the photovoltaic effect. The number and arrangement of solar panels depend on factors such as available space, sunlight exposure, and the desired power output of the charging system.

4.2 Transformer

A transformer plays a crucial role in regulating the voltage of the electricity generated by the solar panels. Solar panels produce electricity at varying voltages depending on factors such as sunlight intensity and temperature. The transformer adjusts the voltage as needed to match the requirements of the charging system and ensure compatibility with other components.

4.3 Battery

Integrating a battery into the system serves multiple purposes. Firstly, it acts as a storage device for excess solar energy generated during periods of peak sunlight. This stored energy can be utilized during periods of low sunlight or high demand, ensuring a consistent power supply to the EV charging station. Additionally, the battery helps stabilize the output voltage and provides backup power in case of grid outages or fluctuations.

4.4 Rectifier

Since solar panels generate DC electricity, whereas most EVs use Alternating Current (AC) for charging, a rectifier is needed to convert the DC output from the solar panels into AC. The rectifier ensures that the electricity is compatible with the charging requirements of electric vehicles, allowing for seamless charging operations.

4.5 Capacitor

A capacitor can be incorporated into the system to help stabilize the power supply and improve energy efficiency. Capacitors store electrical energy temporarily and release it when needed, helping to smooth out fluctuations in the power output from the solar panels and ensuring a more consistent flow of electricity to the charging station.

4.6 Diode

Diodes are semiconductor devices that allow current to flow in only one direction. In a solar charging system, diodes prevent reverse current flow, ensuring that electricity generated by the solar panels does not discharge back into the system when sunlight is unavailable. This prevents energy loss and protects the components from potential damage.

5. Implementation Process

System Design and Sizing: The first step in implementing a solar wireless EV charging system is to design the system layout and determine the appropriate sizing of components such as solar panels, batteries, and transformers based on factors like energy requirements, available space, and budget constraints.

Component Procurement and Installation: Once the system design is finalized, the necessary components are procured from reliable suppliers. Solar panels are installed on rooftops or ground-mounted structures, ensuring optimal sunlight exposure. The transformer, battery, rectifier, capacitor, and diode are installed in a control unit or power conversion unit near the charging station.

Integration of Wireless Charging Technology: Wireless charging technology is integrated into the system by installing charging pads on the ground at designated parking spots for electric vehicles (Zhang et al., 2022). These charging pads are equipped with electromagnetic coils that transmit power wirelessly to the receiver unit installed on the vehicle.

Wiring and Connection: The components of the charging system, including the solar panels, battery, rectifier, capacitor, and diode, are interconnected using appropriate wiring and cables. Careful attention is paid to safety protocols and electrical codes to ensure proper insulation and grounding.

Testing and Commissioning: Once the installation is complete, the system undergoes rigorous testing to verify its functionality, efficiency, and safety. Tests may include voltage and current measurements, charging pad alignment checks, and wireless charging performance evaluations.

Monitoring and Maintenance: After commissioning, the system is monitored regularly to track its performance and identify any issues or inefficiencies. Routine maintenance tasks such as cleaning the solar panels, inspecting electrical connections, and testing battery health are performed to ensure optimal operation and longevity of the system.

Regulatory Compliance and Safety: Throughout the implementation process, compliance with relevant regulations, standards, and safety guidelines is ensured. This includes obtaining necessary permits, adhering to electrical codes, and implementing safety measures to protect users and equipment.

Implementing a solar wireless EV charging system requires careful planning, integration of various components, and adherence to safety and regulatory standards. By optimizing energy capture, storage, and transmission, such a system can provide a sustainable and efficient solution for charging electric vehicles using renewable energy sources.

6. Result

The system demonstrates how electric vehicles can be charged while moving on the road, eliminating the need to stop for charging. Figure 3 shows the solar wireless charging. The solar panel is used to power the battery through a charge controller. The battery is charged and stores DC power. Table 1 shows the Solar Panel Performance Metrics. A copper coil is also mounted

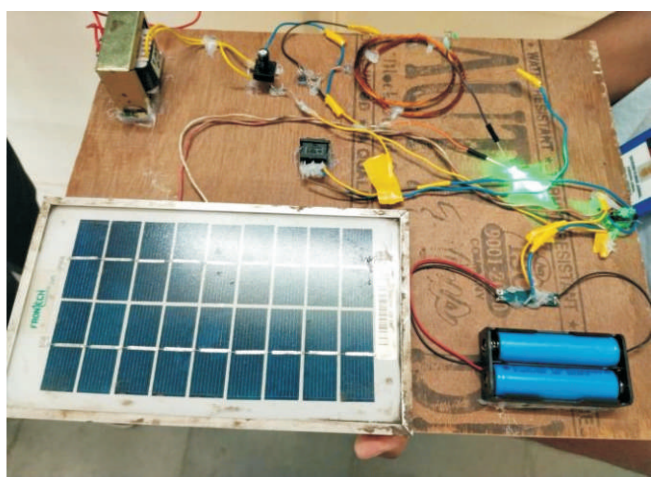

Figure 3. Solar Wireless Charging

Subject	Voltage	Current	Power
Rated Value of Solar Panel	8.9 volt	0.34 amp	3 watt
Actual Reading of Solar Panel	8.4 volt	0.31 amp	2.6 watt
Load Consumption (Output)	3.2 volt	20 milli amp	0.64 watt

Table 1. Solar Panel Performance Metrics

underneath the electric vehicle. When the vehicle is driven over the coils energy is transmitted from the transmitter coil to EV coil. Still DC current is induced into this coil. Now we convert this to DC again so that it can be used to charge the EV battery. We use AC to DC conversion circuitry to convert it back to DC current. Now we also measure the input voltage using an atmega microcontroller and display this on an LCD display. Thus the system demonstrates a solar powered wireless charging system for electric vehicles that can be integrated in the road (Zhang et al., 2022). Table 2 shows the components for Solar-Powered Electronic Projects.

Conclusion

This paper has delved into the realm of solar wireless electric vehicle (EV) charging systems, exploring the intersection between renewable energy and advanced charging technologies. The comprehensive literature survey provided a nuanced understanding of the current state of research, highlighting key advancements, challenges, and potential future directions in the field. The exploration of solar power integration underscored the pivotal role of efficiency in harnessing sunlight for EV charging. These works not only examined the effectiveness of solar panels but also provided insights into the economic and environmental sustainability of solar-integrated EV charging through life-cycle analysis.

Future Scope

Smart Charging Station: The back-end solution serves as the foundation for smart EV charging. The charging stations may be controlled depending on various signals, such as local energy usage, if they are cloud-connected. Using smart charging stations allows us to quickly locate charging locations, quickly and safely charge our devices, save money and the environment, and prevent conflicts with our neighbors.

Renewable energy-based charging stations: These stations use a combination of solar and wind power. Solar or wind-powered charging stations are a good way to protect the environment from pollution. We may generate electricity during the day and utilize it to charge Electric Vehicles (EVs) at night by utilizing solar-powered charging stations.

Solar Panel	8.67V
Zener Diode	
Capacitor	
Transformer	240/12v, 1A
Rectifier	
Li-ion Cell	3.7v (2 piece)
bms module (Battery Management System)	
Enamelled Copper Wire	0.5mm
2N2222A Transistor	
Resistor	22k

Table 2. Components for Solar-Powered Electronic Projects

References

[1]. **Amjad, M., Farooq-i-Azam, M., Ni, Q., Dong, M., & Ansari, E. A. (2022).** Wireless charging systems for electric vehicles. *Renewable and Sustainable Energy Reviews*, 167, 112730.

https://doi.org/10.1016/j.rser.2022.112730

[2]. **Ching, T. W., & Wong, Y. S. (2013, December).** Review of wireless charging technologies for electric vehicles. In 2013 *5th International Conference on Power Electronics Systems and Applications (PESA)* (pp. 1-4). IEEE.

https://doi.org/10.1109/PESA.2013.6828235

[3]. **Joseph, P. K., & Elangovan, D. (2018).** A review on renewable energy powered wireless power transmission techniques for light electric vehicle charging applications. *Journal of Energy Storage*, 16, 145-155.

https://doi.org/10.1016/j.est.2017.12.019

[4]. **Joseph, P. K., Devaraj, E., & Gopal, A. (2019).** Overview of wireless charging and vehicle to grid integration of electric vehicles using renewable energy for sustainable transportation. *IET Power Electronics*, 12(4), 627-638.

https://doi.org/10.1049/iet-pel.2018.5127

[5]. **Mwasilu, F., Justo, J. J., Kim, E. K., Do, T. D., & Jung, J. W. (2014).** Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and Sustainable Energy Reviews*,

34, 501-516.

https://doi.org/10.1016/j.rser.2014.03.031

[6]. Okasili, I., Elkhateb, A., & Littler, T. (2022). A review of wireless power transfer systems for electric vehicle battery charging with a focus on inductive coupling. *Electronics*, 11(9), 1355.

https://doi.org/10.3390/electronics11091355

[7]. Rayan, B. A., Subramaniam, U., & Balamurugan, S. (2023). Wireless power transfer in electric vehicles: A review on compensation topologies, coil structures, and safety aspects. *Energies*, 16(7), 3084.

https://doi.org/10.3390/en16073084

[8]. Sun, L., Ma, D., & Tang, H. (2018). A review of recent trends in wireless power transfer technology and its applications in electric vehicle wireless charging. *Renewable and Sustainable Energy Reviews*, 91, 490-503.

https://doi.org/10.1016/j.rser.2018.04.016

[9]. Tazay, A. F. (2021). Design and implementation of solar powered electric vehicle for on-campus university applications. *International Journal of Engineering Research & Technology (IJERT)*, 10(10).

[10]. Triviño, A., González-González, J. M., & Aguado, J. A. (2021). Wireless power transfer technologies applied to electric vehicles: A review. *Energies*, 14(6), 1547.

https://doi.org/10.3390/en14061547

[11]. Tummapudi, S., Mohammed, T., Peetala, R. K., Chilla, S., & Bollavarapu, P. P. (2023, February). Solar-powered wireless charging station for electric vehicles. In *2023 International Conference on Power, Instrumentation, Energy and Control (PIECON)* (pp. 1-4). IEEE.

https://doi.org/10.1109/PIECON56912.2023.10085752

[12]. Zhang, X., Zhu, C., & Song, H. (2022). *Wireless Power Transfer Technologies for Electric Vehicles*. Springer.

ABOUT THE AUTHORS

Shraddha Kaushik is serving as an Assistant Professor at the Bhilai Institute of Technology in Durg, India. She is pursuing her Ph.D. from the Vignan Foundation for Science, Technology and Research, Guntur, India. She received her Bachelor's degree in Electrical and Electronics Engineering from Government Engineering College, Raipur, India, in 2009. She completed her Master's in Engineering (Power Systems and Automation) from GITAM University, Visakhapatnam, India. She has 10 years of teaching experience in Electrical Engineering courses at both undergraduate and postgraduate levels. She has supervised 6 ME scholar theses and published 21 articles in peer-reviewed journals and conferences. Her research interests include Power Converters, Active Filtering, Power Conditioning, Machine Learning, Artificial Intelligence, Power System Analysis, And Electric Vehicles.

Shraddha Mishra has been pursuing a B.Tech in Electrical Engineering from Bhilai Institute of Technology, Durg, Chhattisgarh, India, since 2022. Her research interests include Power Systems, Solutions, and the Study of EV Charging Systems and Procedures.

Saurabh Soni has been pursuing a B.Tech in Electrical Engineering from Bhilai Institute of Technology, Durg, Chhattisgarh, India, since 2022. His research interests include Electrical Circuit Analysis, Power Systems, Solutions, and the Study of EV Charging Systems and Procedures.

Saurabh Kumar Jaiswal has been pursuing a B.Tech in Electrical Engineering from Bhilai Institute of Technology, Durg, Chhattisgarh, India, since 2022. His research interests include Electrical Machines and the Study of EV Charging Systems and Procedures.