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Solar Based Static Wireless Charging of Battery for Electric Vehicle (EV)

Mr.P. Pawan Puthra[1], Mrs. A. Susmitha[2], V Chandrika[3]
Department of Electrical and Electronics Engineering Gayatri Vidya Parishad college of Engineering(A)

ABSTRACT— The demand for efficient and sustainable energy solutions has led to significant advancements in wireless power transmission (WPT) technologies. This paper presents a solar-powered static wireless charging system for batteries, leveraging inductive coupling to enable contactless energy transfer. The proposed system integrates solar energy conversion with wireless power transfer, eliminating physical connectors, reducing energy loss, and enhancing safety. The setup consists of a solar panel, bridge rectifier, inverter, transmitter coil, receiver coil, and battery unit. A PI controller ensures stability, while a boost converter and bidirectional converter optimize energy flow. The energy harvested from the solar panel is efficiently managed through a series of power electronic circuits, ensuring that the power transmission remains stable and effective even under variable solar conditions. The system also enhances battery lifespan by incorporating optimized charging algorithms. MATLAB simulations validate the system's performance, showcasing effective power transmission efficiency and real-time charging characteristics. Simulation results demonstrate how key parameters such as coil alignment, resonance frequency, and transmission distance affect the efficiency of the charging process. The findings contribute to the advancement of wireless charging applications in renewable energy- based power systems and open pathways for future research in large- scale implementations of solar-powered wireless charging for electric vehicles and other battery-dependent applications.
Keywords—Wireless Power Transfer ,Inductive Coupling, PI Controller, Boost Converter, Bidirectional Converter, MATLAB Simulation, Static Wireless Charging.

I. INTRODUCTION

The project titled **"Solar-Based Static Wireless Charging System for Battery Applications"** presents a sustainable approach to modern energy transfer challenges by combining solar energy harvesting, wireless power transfer. With the increasing demand for clean and renewable energy sources, this project is designed to leverage solar energy as the primary input to ensure both environmental sustainability and energy independence. The system begins with solar panels that absorb sunlight and convert it into electrical energy. To optimize energy extraction under varying environmental conditions, a Maximum Power Point Tracking (MPPT) controller is employed. This MPPT unit ensures that the solar panels always operate at their most efficient point, maximizing the energy output regardless of changes in irradiance or temperature. To stabilize the voltage output from the solar array and maintain system reliability, a Proportional-Integral (PI) controller is implemented, which adjusts system to ensure smooth and stable voltage levels throughout operation. Recognizing the intermittency of solar energy, especially during nighttime or cloudy weather, a backup battery is integrated into the design to provide uninterrupted power availability.

This ensures the system remains functional even when the primary solar input is insufficient. The direct current (DC) generated from the solar panel and stored in the backup battery is converted into alternating current (AC) using an inverter. This AC output is necessary for enabling **wireless power transfer (WPT)**, which is achieved through a set of magnetically coupled coils—a transmitter coil on the power side and a receiver coil on the load side. This static wireless charging system allows for energy transfer without physical contact, reducing wear and tear, enhancing safety, and making the system suitable for various applications, including electric vehicle (EV) charging and off- grid power supply setups.After successful transmission, the AC power received by the receiver coil is passed through a full-wave rectifier to convert it back into DC.

This DC power is then used to charge the secondary battery. To intelligently manage the flow of power between the solar source, the backup battery, and the load, **bidirectional converters** are incorporated at both the primary and secondary battery interfaces. These converters allow energy to flow in both directions, facilitating charging, discharging, and energy redistribution based on demand and system status. This level of control is critical for maintaining system balance, protecting components, and enhancing overall efficiency. The combined functionality of MPPT, bidirectional converters, and the PI controller ensures a high level of operational stability and adaptability to varying load conditions.

Furthermore, the system's design reflects its potential for real- world applications, particularly in the fields of renewable energy integration, EV infrastructure, and remote energy storage systems where accessibility and environmental constraints limit the use of traditional wired setups. The simulation results validate the system's effectiveness in delivering consistent power, efficient energy management, and seamless operation across different scenarios. By successfully implementing and simulating this solar-based static wireless charging system, the project demonstrates a forward-thinking solution that aligns with global efforts toward clean energy transition, smart grid development, and the enhancement of wireless energy technologies.Overall, this project shows how solar energy and wireless charging can work together to create a clean, efficient, and smart way to charge batteries. By using solar panels, backup batteries, MPPT, bidirectional converters, and a PI controller, the system ensures stable and reliable power. The wireless transfer between coils makes charging easier and safer, without the need for physical wires. This setup can be useful in many areas, like electric vehicle charging or powering devices in remote places.

II. BLOCK DIAGRAM

Solar wireless charging systems consist of different components for its smooth working. The figure illustrates a circuit diagram for static wireless charging of an electric vehicle (EV) using an AC power source. The system consists of a primary coil embedded in the charging station and a secondary coil located in the EV. The charging process begins with an AC power supply, which is converted into DC using a bridge rectifier. The DC power is then stored in a battery and later converted back into AC using an inverter. This AC power is supplied to the primary coil, generating a magnetic field that induces a current in the secondary coil through inductive coupling.

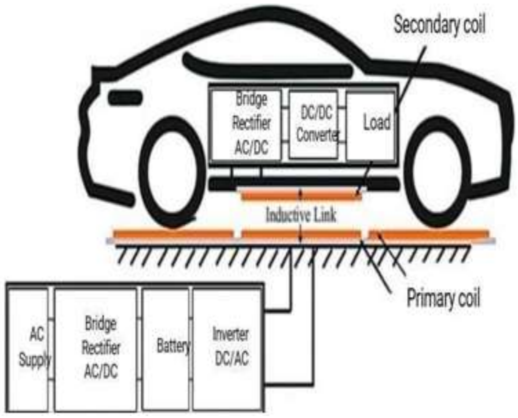

Fig.1. Block diagram of wireless power transmission through traditional source

The received AC power in the EV is rectified and converted into a suitable DC voltage using a DC/DC converter to charge the vehicle's battery. Additionally, in case of a power interruption from the AC source, the battery in the system will act as a backup power source to ensure uninterrupted operation of the circuit. This design enhances the reliability and efficiency of the wireless charging system while eliminating the need for physical charging cables.

III. WIRELESS CHARGING USING SOLAR

The integration of a solar photovoltaic (PV) system into a static wireless charging system enhances sustainability and energy efficiency. The PV array generates DC power from sunlight, which is optimized using a Maximum Power Point Tracking (MPPT) controller to ensure maximum energy extraction. The regulated DC power is either stored in a battery or converted into AC using an inverter. This AC power is then supplied to the primary coil, creating a magnetic field that transfer energy wirelessly to the secondary coil in the EV through inductive coupling. The received AC power is rectified and regulated by a DC/DC converter to charge the vehicle's battery.

The intermittency of solar energy, especially during nighttime or cloudy weather, a backup battery is integrated into the design to provide uninterrupted power availability.

This ensures the system remains functional even when the primary solar input is insufficient. The direct current (DC) generated from the solar panel and stored in the backup battery is converted into alternating current (AC) using an inverter.

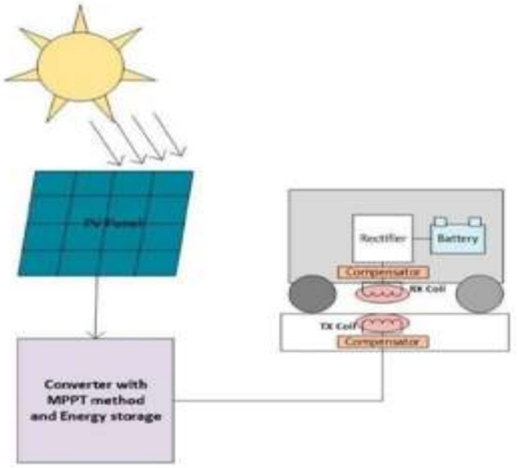

Fig.2. Block diagram of wireless power transmission through solar source

IV. MATLAB SIMULATION DESIGN

This simulation represents a solar-based static wireless charging system with efficient energy management using power electronic converters. A solar PV array with two parallel strings of two series- connected panels generates DC voltage, which is boosted to 230V for effective power transfer. A bidirectional converter, controlled by a PID controller, manages power flow between the solar battery and the load. During the day, solar energy charges both the solar and output batteries, while at night, the bidirectional converter discharges stored energy to the load.

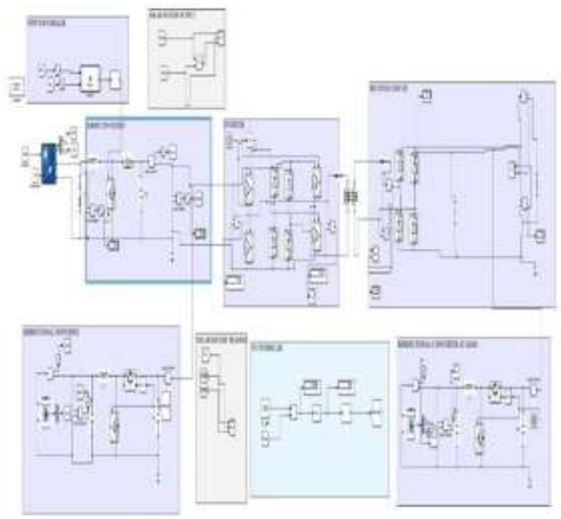

Fig.3.MATLAB Simulation

An inverter converts DC to AC for wireless transmission via mutual inductance, and a rectifier at the receiving end converts AC back to DC for battery charging. MPPT ensures maximum power extraction, optimizing efficiency for continuous power delivery. The MATLAB Simulink environment helps analyze voltage, current waveforms, and efficiency, optimizing factors like switching frequency, compensation design, and coil alignment for better performance.

A. Output waveform after boosted up the voltage:

This PV simulation design considers a photovoltaic (PV) array with two parallel strings, each containing two series- connected Aleo Solar S79U250 modules. Each module has a maximum power output of 250.205 W, an open-circuit voltage of 37.6 V, and a short-circuit current of 8.64 A. The voltage at the maximum power point is 30.7 V, while the current at this point is 8.15 A. The design also accounts for temperature effects, with a Voc temperature coefficient of - 0.38%/°C and an Isc coefficient of 0.09%/°C.

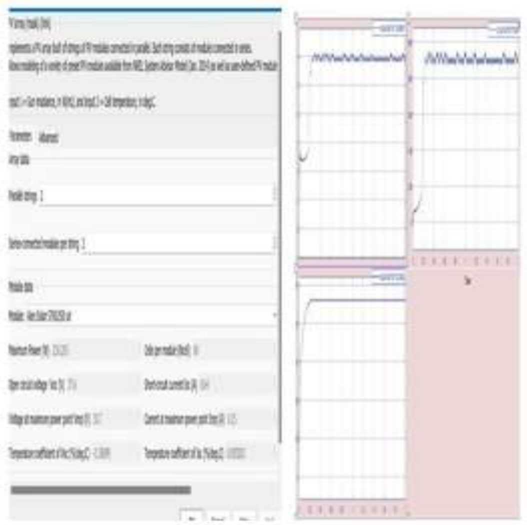

Fig.4.output waveform of boost converter

Calculations of pv system:
No of series strings = 2 ; No of parallel strings = 2 ;
Solar Output voltage = 2*37=74V
Solar Output Current=short circuit current * 2
8.64*2 = 17.28A
Solar Power output = 250*4 = 1000W

B. Output waveform of primary and secondary coils:

The output waveforms shown represent the voltage levels on the primary and secondary sides of a wireless power transfer system with a turns ratio of 4:1. The primary waveform displays a consistent square wave at around **228V**, while the secondary side shows a reduced square waveform of approximately **53V**, confirming the expected voltage drop according to the transformer turns ratio. The effective wireless energy transfer between the transmitter and receiver coils.

Fig.5. output waveform of primary and secondary

C. **Output waveform of backup battery:**

The above figure represents the waveform of the backup battery at the solar panel. The first graph shows the battery voltage, which gradually increases and stabilizes as the charging process progresses. The second graph illustrates the battery current, which initially fluctuates before reaching a steady- state condition. The third graph represents the state of charge (SOC) of the battery, which increases over time as the battery gets charged. This confirms that the backup battery effectively stores energy from the solar panel during the daytime, ensuring its availability for later use, such as night time operation.

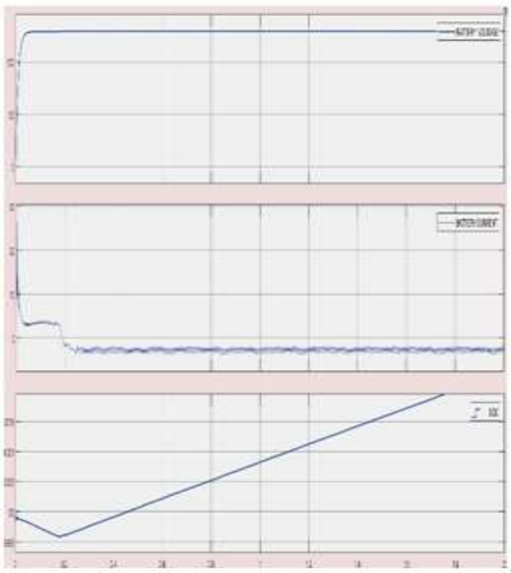

Fig.6.waveform of solar battery

Battery calculations:

For a 120V, 30Ah battery, the standard charging current is typically 10% of the battery's capacity, which is 3A. Including an additional 1A to account for charging losses, the total charging current becomes 4A.
Using the formula Charging time = Ah / A, the battery charging time is calculated as 30Ah ÷ 4A = **7.5 hours**.
Similarly, for discharging, 10% of the battery capacity is also considered, giving a discharging current of 3A. Thus, the discharging time is calculated as 30Ah ÷ 3A = **10 hours**.

D. Output waveform of load battery:

After rectification, the AC voltage of 53V from the secondary coil is converted into a DC voltage of approximately 50V. However, since the output battery operates at 24V, a bidirectional DC-DC converter is used to step down the voltage efficiently. In step-down (buck) mode, the converter reduces the 50V DC to a stable 24V DC, ensuring safe and optimal charging of the battery. This setup allows controlled power transfer, where the bidirectional converter regulates the voltage and current flow to maintain battery health and efficiency. By integrating rectification and voltage conversion, the system ensures a smooth and reliable charging process for the 24V battery.

In our project, we utilized a lithium-ion battery at the output stage to evaluate the final performance of the wireless power transfer system. This battery was chosen due to its high energy density, efficiency, and reliability in low-power applications. The lithium-ion battery plays a crucial role in storing the wirelessly transmitted energy and supplying it to the connected load efficiently. It ensures a stable power supply, making it suitable for low-power applications such as small electronic devices, IoT systems, and portable gadgets. Additionally, lithiumion batteries offer advantages like a longer lifespan, low self-discharge rate, and high charge.

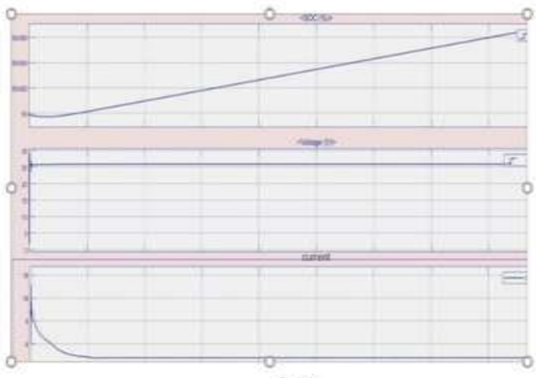

Fig.7. output waveform of load battery

The battery status in both conditions (daytime and night time) indicates how energy is stored and utilized in the system.

During Daytime (When Sunlight is Available):
The output battery status graph shows a gradual increase in voltage and state of charge (SOC), meaning the battery is charging as sunlight is available.

The storage battery status graph shows an increase in stored energy, meaning solar energy is being converted and stored efficiently. The charging current remains stable, and the SOC reaches a higher level as time progresses, indicating effective charging.

During Night time (When Sunlight is Not Available):
The output battery status graph still shows a gradual increase in voltage and SOC, but at a lower rate compared to daytime since no solar input is available .The storage battery status graph shows a decline in stored energy, meaning the battery is discharging to supply power. The SOC decreases as energy is drawn from the battery to maintain power output, indicating that stored energy is being utilized for load requirements.

Significance of Battery Performance Monitoring: Monitoring battery status under varying conditions is essential for evaluating the **efficiency, reliability, and sustainability** of the energy system. The observed charging and discharging patterns not only confirm the functionality of the solar energy harvesting setup but also provide insights into **energy management and storage optimization**.

A well-regulated SOC ensures longer battery life and uninterrupted power supply, especially during non-solar hours which means during peak hours.

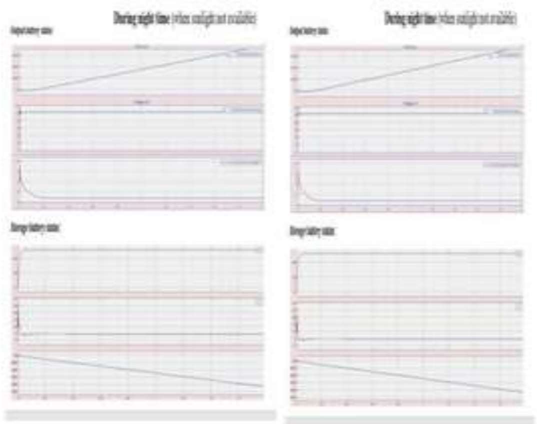

Fig.8. output waveform of two batteries during

Calculations of Boost Converter:Assumptions:

- Power (P) = 1000 W
- Switching frequency (Fs) = 10,000 Hz
- Input voltage (Vin) = 74 V
- Output voltage (Vout) = 230 V

The voltage equation for a boost converter is given by:
Vout = Vin / (1 - D), where D is the duty cycle.

To find the duty cycle:**D = 1 - (Vin / Vout)**
= 1 - (74 / 230)
= 0.679

Next, we calculate the output current (Iout):
Iout = Pout / Vout
= 1000 / 230
= 4.34 A

Ripple Current (ΔI):
Ripple current is typically considered as 20% to 40% of " I". Taking 40% of Iout:**ΔI = 0.4 × 4.34 × (230 / 74)**
= 1.736 A

Ripple Voltage (ΔVL):
Ripple voltage is taken as 1% of the output voltage.
ΔVL = 0.01 × 230
= 2.3 V

Inductance (L):
The inductance is calculated using the formula: **L = (Vin × (Vout - Vin)) / (ΔI × Fs × Vout)** Substituting the values:
L = (74 × (230 - 74)) / (1.736 × 10,000 × 230)
= **9.3 × 10^{-4} H**

Capacitance (C): Capacitance is calculated using the formula:
C = (Iout × D) / (Fs × ΔV)
= (4.3 × 0.679) / (10,000 × 2.3)
= **1.26 × 10^{-4} F.**

V. HARDWARE DESIGN

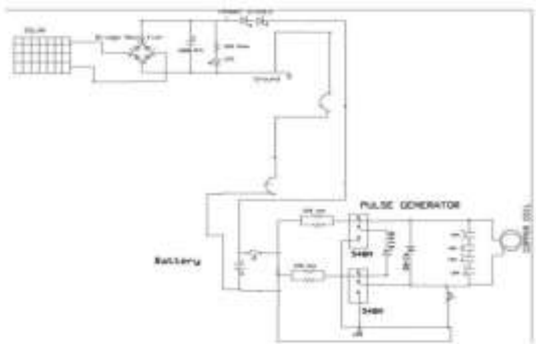

Fig.9. Hardware design of wireless charging using solar

The circuit diagram represents the implementation of a wireless charging system powered by a solar panel. The solar panel generates DC power, which is then converted into a stable DC output using a bridge rectifier and filtering components. The rectified power is directed to charge a battery, ensuring energy storage for later use.

A pulse generator circuit, built using transistors and passive components, creates high-frequency AC pulses. This AC signal is fed to the transmitter coil, enabling wireless power transfer through electromagnetic induction. The receiver coil captures this transmitted energy, which is then rectified and regulated to charge the battery efficiently. This system integrates renewable energy with wireless power transfer for efficient charging applications.

Components ratings :

Name of the component	Ratings	Quantity
Solar panel	12v,5W	01
Bridge rectifier	12v,1A	02
Lithiumion Battery	4V,1A	03
Transmitter coil	5v,1A	01
Reciever coil	5v,1A	01
Lithiumion battery	3.3V	01
LED	5V	01

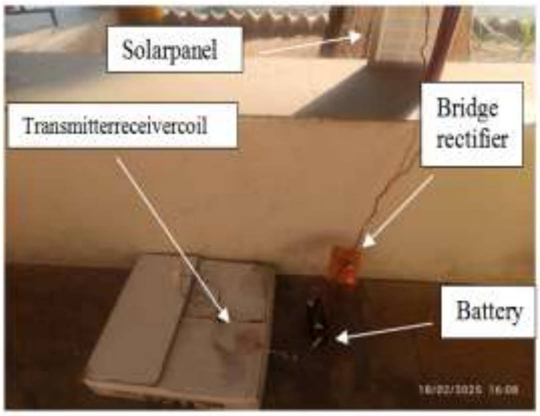

Fig.10. solar integration to the wireless charging system

A. Integration of solar to the wireless charging system

In this setup, the solar panel (12V, 5W) is connected in parallel with the backup battery bank (three 4V, 1A lead-acid batteries in series, providing 12V, 1A).

The parallel connection ensures that both the solar panel and the battery contribute to powering the transmitter circuit for wireless charging. When sunlight is available, the solar panel supplies energy to the transmitter coil and simultaneously charges the backup battery. The transmitter coil, with its built-in inverter, converts the DC power from both sources into high-frequency AC for wireless power transfer. The receiver coil picks up this transmitted energy, and its built-in rectifier converts it back to DC, which is then used to charge the load.In low sunlight or at night, the battery acts as a backup power source, ensuring uninterrupted wireless charging. This hybrid configuration improves efficiency by utilizing solar energy while maintaining a reliable backup for continuous operation.

B. Output battery charging

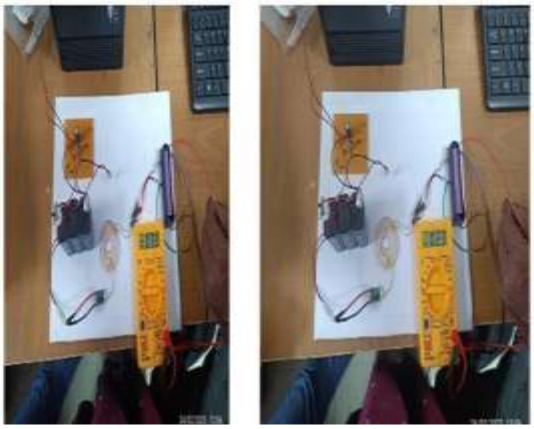

Fig.11.output battery charging

The images show the testing process of the output for battery charging in a wireless charging setup. The experimental setup consists of a transmitter circuit, a receiver circuit, a rechargeable battery, a multimeter, and other necessary electronic components.

The first image displays the initial stage of testing, where the components are properly connected, and the system is ready for evaluation. In the second image, the multimeter indicates a positive current of 0.23A, confirming that the battery is receiving a charge. This suggests that the wireless power transfer is functioning, and energy is being transmitted from the transmitter coil to the receiver coil, which is then used to charge the battery. The setup effectively demonstrates the feasibility of wireless battery charging, validating the working principle of inductive power transfer.

The images show the testing of a wireless charging setup with a transmitter, receiver, battery, and multimeter. In the first image, the system is set up for testing. In the second, the multimeter reads 0.23V, confirming successful wireless power transfer and battery charging through inductive coupling.

This result confirms that the system is capable of transferring energy wirelessly and initiating battery charging. It highlights the potential of inductive power transfer for efficient, contactless energy delivery in practical applications.

VI. RESULTS:

Simulation Results:

The simulation successfully validated the theoretical design of the wireless battery charging system. It demonstrated efficient energy transfer between the transmitter and receiver coils, and the battery charging behavior was stable under various simulated conditions. These results confirm that the circuit design and selected parameters were appropriate for effective wireless power transfer.

Sno.	PARAMETERS	SIMULATION CALCULATIONS
01.	Solar output	230V, DC
02.	Inverter input	230V, DC
03.	Inverter output	228V, AC
04.	Secondary output	53V, AC
05.	Bridge rectifier input	53V, AC
06.	Rectifier output	51V,DC
07.	Bidirectional converter input	51V, DC
08.	Battery at load	24V, DC

Prototype Results:

The physical prototype was built using a transmitter circuit, receiver circuit, and a rechargeable battery. During testing, the multimeter displayed an output current of 0.23A, confirming that the battery was receiving charge. This proves that energy was being wirelessly transmitted from the transmitter coil to the receiver coil and then utilized for charging the battery.

The prototype effectively verified the working principle of inductive power transfer in real-time conditions

VII. CONCLUSION

The development and analysis of the solar-based wireless charging system through both simulation and prototype testing have collectively demonstrated the feasibility, efficiency, and practicality of the proposed design. The simulation phase provided critical insights into the theoretical functionality of the system, validating the stability and reliability of energy transfer between the transmitter and receiver coils. By effectively modeling real-world conditions, the simulation confirmed that the battery charging process remained consistent under varying parameters, and the chosen circuit design was well-suited for optimized wireless power transfer. This phase played a vital role in refining system parameters, ensuring that the integration of components such as the boost converter, inverter, and bidirectional converter were functioning harmoniously with the solar PV input and control mechanisms like MPPT and PI controllers.

The prototype phase served as a practical realization of the theoretical model, bringing the simulated design into a tangible, working setup. The successful wireless transmission of energy from the transmitter to the receiver coil, as confirmed by a measurable output voltage of 0.23V on the multimeter, demonstrated the system's functionality under real-world conditions. This practical verification not only reinforces the accuracy of the simulation results but also highlights the viability of inductive power transfer as a core technology for future energy solutions. The ability to charge a battery through wireless means, powered by a renewable energy source like solar, signifies a major step toward the adoption of sustainable and user-friendly charging systems for electric vehicles and remote devices.Together, the simulation and prototype have proven that a solar-based wireless charging system is not only technically sound but also scalable for larger applications. This dual validation bridges the gap between theoretical design and real-world implementation, offering a promising solution to reduce dependency on conventional wired charging infrastructures and fossil fuel-based power sources. With further refinement, improved coil alignment, and increased voltage output, this system has the potential to revolutionize how energy is delivered, stored, and utilized in modern-day applications—especially in the evolving landscape of green transportation and smart grid technologies.

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