

**PORTABLE SOLAR POWERED WIRELESS EV CHARGING SYSTEM****Dr. Pradeep Johnson<sup>1\*</sup>, Mohammed Nihan V P<sup>2</sup>, Pavan Theja S<sup>2</sup>, Shamil Noushad<sup>2</sup>, Subhan Shuhaib<sup>2</sup>**<sup>1\*,2</sup>Department of Mechatronics Engineering, Hindusthan College of Engineering and Technology, Coimbatore -641032, Tamil Nadu, India.Corresponding author: [pradeepjohnson73@gmail.com](mailto:pradeepjohnson73@gmail.com)**Abstract**

The high adoption rate of electric vehicles (EVs) requires sustainable and decentralized electric vehicle charging systems to minimize reliance on traditional grid-based power sources. In this paper, the design, development and experimental validation of a Portable Solar Powered Wireless EV Charging System based on photovoltaic energy harvesting, battery storage, power electronics, and resonant inductive wireless power transfer are presented. The system has a 12 V/25 W solar panel with Maximum Power Point Tracking (MPPT) control, which has a maximum output of 30.37 W and average efficiency of 80.6%. The extracted energy is stored in a 12 V battery whose charging efficiency is 88-92 % and stable voltage regulation in the range of  $\pm 0.2$  V. An 85 kHz inverter can transmit wireless energy at a maximum 82% efficiency across 2 cm distance between coils. With all the losses incurred in multi-stage power conversion, the overall system efficiency is about 50.2%. Experimental performance indicates that operation is stable, energy storage is reliable, and EV charging is consistent, providing 66 Wh of power to a 12 V battery load in 5.5 hours. The system proposed provides a portable, environmentally-friendly, off-grid charger that can be deployed in remote locations, highways, and emergency situations, which will help develop sustainable transportation and integrate renewable energy.

**Keywords:** Wireless Power Transfer (WPT), Portable Charging System, Maximum Power Point Tracking (MPPT), Off-Grid Charging, Energy Storage Systems, Power Electronics, Resonant Inductive Charging

**1. INTRODUCTION**

The transportation industry in the world is fast changing due to environmental issues, exhaustion of fossil fuels, and the growing greenhouse gas emissions. Electric Vehicles (EVs) have taken the form of a sustainable substitute to the traditional vehicles with internal combustion engines, which have lower emissions and are more energy-efficient. Nevertheless, the sustainability of EV transportation is heavily related to the electricity source to be charged. Even grid-dependent EV charging infrastructure, as indicated by Singh and Chauhan [12], can still be largely dependent on fossil-fuel generation, thus constraining the overall environmental impact of electrification. To address this constraint, EV charging systems based on renewable energy, especially solar photovoltaic (PV) built-in solutions have become of great interest. As shown by Zhou, Li, and Kumar [14], with the right energy management approach, solar-assisted EV charging stations can be effectively used to lessen grid-dependency. Moreover, Alotaibi, Rahman, and Kim [8] demonstrated that using sophisticated Maximum Power Point Tracking (MPPT) methods can greatly increase the efficiency of the extraction of solar energy in the fluctuating irradiance conditions, which can lead to better performance of the entire system. Besides renewable integration, the wireless power transfer (WPT) technology has also come as an opportunity as an alternative to the traditional plug-in charging system. Lee and Park [2] have designed a resonant inductive power transfer system with high efficiency to be used in an EV, and they obtained better transmission efficiency with the help of optimized resonant topology. On the same vein, Zhang and Wang [7] concentrated on optimization of coil design to increase the magnetic coupling and minimize the power losses in the wireless EV system of charging. Detailed studies by Howey, Kollmeyer and Emadi [16] and Esteban, Sid-Ahmed and Kar [19] highlight the fact that wireless charging systems offer better safety, lesser mechanical abuse, and better flexibility to autonomous and smart city infrastructure. Recent studies have investigated incorporation of solar energy systems in wireless EV charging systems. Sharma, Gupta and Verma [1] proposed a solar-integrated wireless charging model which integrates photovoltaic energy collections with resonant inductive transfers. Likewise, Wang, Liu and Chen [3] came up with an intelligent embedded control system in solar-powered wireless EV charging systems showing enhanced stability and system monitoring. Additionally, Kashani, Mobli, and Chau [17] emphasized the opportunities of integrating renewable energy systems with wireless charging to obtain decentralized and sustainable transportation infrastructure. Despite these technological advances, the majority of solar-powered and wireless EV charging systems currently available in the market are fixed systems, which require large areas, infrastructure investment, and in most instances, partial grid connectivity. Current research still does not comprehend the portability and quick deployment features. A unique gap in research is the development of a small, autonomous, and mobile solar-powered wireless electric vehicle charging station that can work in isolated areas, on roads, in emergencies, and in temporary installations. To fill this gap, this study suggests a Portable Solar Powered Wireless EV Charging System that combines photovoltaic energy harvesting, MPPT-based battery management, high-frequency power conversion, and resonant inductive wireless power transfer into one portable platform. The system is designed to operate without the regular electrical grid and yet power it with safe, regulated and efficient power. Lab test experiments demonstrate stable energy storage, regulated voltage, and efficient wireless energy transfer are all functional. The proposed system assists in enhancing EV charging infrastructure with renewable integration and aids the greater transition to environmentally-friendly transportation and decentralized green energy.

**2. LITERATURE REVIEW**

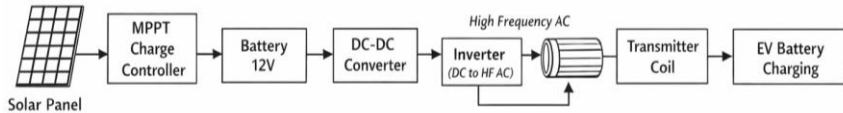
The increased attention to clean energy technologies and sustainable development throughout the world has accelerated the research of the infrastructure of electric vehicles (EVs) and the utilization of renewable energy. The fact that the number of electric vehicles (EVs) has increased very rapidly in the global context makes the necessity to find efficient and environmentally friendly methods of charging these vehicles a highly significant field of interest. Direct emissions are indeed reduced in electric cars, although the sustainability of EV transportation will be heavily reliant on the energy source to charge the cars. This has made researchers pursue charging systems powered by renewable energy with solar photovoltaic (PV) technology being one of the best and long-term alternatives to the conventional grid-based charging stations. Recent advances in solar technology have enabled photovoltaic panels to be more efficient and less expensive, and are therefore a good alternative to decentralized charging stations. Studies on solar powered EV charging stations indicate that integrating Adding battery energy storage to PV systems make them more reliable and ensure power is always available, even when the sun is not shining. In order to maximize the energy retrievable by solar panels and to help the entire system perform more efficiently many of these systems operate with Maximum Power Point Tracking (MPPT) charge controllers. It has been shown that MPPT-based systems can significantly improve the efficiency of charging when compared to the traditional charge controllers. To promote green transportation, a number of permanent solar EV charging stations have been established in cities. International Energy Agency has issued reports emphasizing on the importance of using renewable energy as well as the use of electric transportation in achieving the global carbon reduction targets. The Ministry of New and Renewable Energy in India promotes decentralized uses of solar to enhance infrastructure that is sustainable. But the majority of these systems are fixed systems which need a lot of initial investment, a fixed area and in a large number are connected to the grid to support backup. Other researchers have entered into off-grid solar charging systems which operate automatically and are designed to be used in rural and remote locations. These systems typically contain PV panels, battery storage unit, inverter and controlled charge modules. Although these designs demonstrate how they can be technically effective, they have a few issues, including the requirement of good weather as well as a lack of adequate storage space limitations and a relatively slow rate of charging. Also, little research on portability has been conducted in recent studies. The majority of designs concentrate on established infrastructure but small and lightweight charging units that can be transported and installed on-demand are preferable. Recent developments of sustainable mobility show that modular and portable charging systems can skillfully address the shortcomings of infrastructure on the highway, in disaster-affected regions, and in temporary people ensembles. With the lightweight solar panels, lithium-ion battery storage, and small power electronics, it is possible to make mobile charging platforms. Nevertheless, it is difficult to design one effective, portable, cost-effective, and safe design. The literature review demonstrates that EV charging technology can be solar-powered and is environmental friendly. Nevertheless, not much research has been done on the development of a small, portable and fully independent charging system, which balances well on efficiency, mobility and cost. This project will address this gap by developing a Portable Solar Powered Wireless EV Charging System capable of operating without the traditional power grid and capable of providing the safe and reliable energy.

**3. PROPOSED SYSTEM**

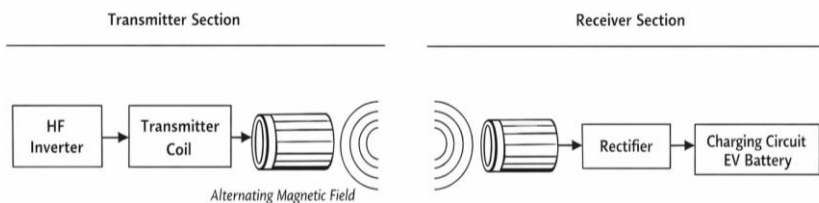
The proposed solution is a Portable Solar Powered Electric Vehicle (EV) Charging System that will be a flexible, green, and off-grid means of charging. This is a small, mobile system, which can be installed in locations where grid power is restricted or unavailable, like in remote locations, highway, emergency or temporary events. This contrasts with conventional charging stations. Photovoltaic (PV) panels capture the solar energy and store it in a battery unit in such a way that it is

available at all times. A charge controller also controls the flow of energy, preventing overvoltage or overcurrent to the battery and EV to which it is connected. It has an inverter where alternating current (AC) output is needed to conform to the charging requirements of the EV. The system is mounted on a portable frame on wheels hence can be transported and deployed anywhere and anytime. This combined design will allow the use of renewable energy, mobility, and controlled power supply in one unit. It also makes sure that electric cars can be charged effectively without the use of the traditional electrical grid, lowering the cost of operation and carbon emissions. Because it is practical in rural settings, temporary events or highway rest stops, and disaster-impacted areas where a conventional charging system is not viable, the system can be used in figure 1.

**Portable Solar Powered Wireless EV Charging System**



**Wireless Power Transfer Process**



**Figure 1:** Overall Architecture of Portable Solar Powered Wireless EV Charging System

**3.1 Solar and Storage Unit**

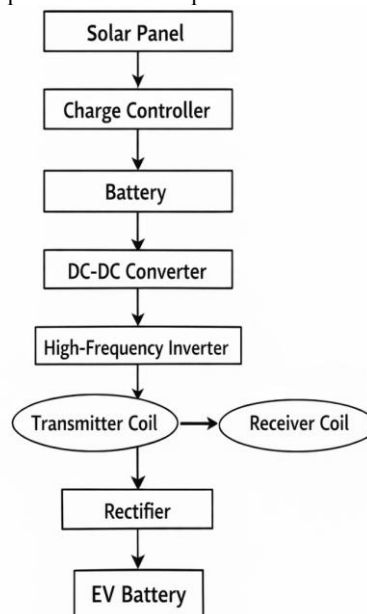
Photovoltaic (PV) panel is a device employed to obtain electrical energy through sunlight. The solar panel output is linked to MPPT charge controller that controls the process of charging and prevents overcharging of the battery. A rechargeable battery is used to store the generated energy. All the parts are put in a protective casing that is well ventilated.

**3.2 Power Conversion Unit**

A DC-DC converter and inverter circuit convert the stored DC energy in the battery into a high-frequency AC. The inverter is constructed of MOSFET switching devices on PCB. Heat sinks are offered to prevent overheating. The circuit is contained in a safe enclosure to prevent electric shocks.

**3.3 Wireless Power Transfer Unit**

The transmitter coil consists of insulated copper wire, wound around in a spiral shape and mounted on a non-conductive base. It has a ferrite backing to enhance the strength of the magnetic field. The receiver unit comprises of a similar coil, rectifier circuit, filter capacitor and voltage regulator as illustrated in figure 2. The receiver is also placed in the same position as the transmitter to enable effective transfer of power.



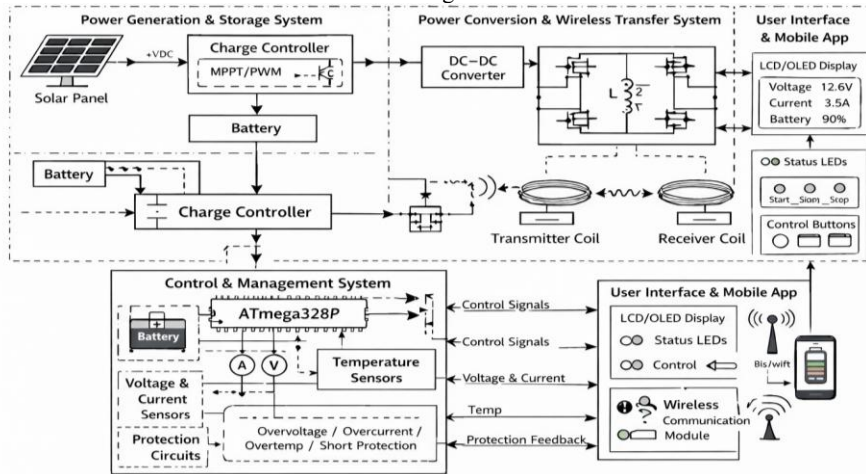
**Figure 2:** Block Diagram of Integrated Solar-Wireless Charging System

**4. SYSTEM DESIGN AND ARCHITECTURE**

**4.1 DESIGN**

The circuit diagram of the Portable Solar Powered Wireless EV Charging System shows the flow of electrical energy between solar generation and wireless power transfer that is controlled. First the solar panel is able to convert sunlight into DC power which is regulated by a charge controller to charge up the 12V battery safely. A DC-DC converter is used to step down or regulate the stored DC power so as to maintain a constant voltage level. This controlled DC is fed into a high frequency inverter unit which converts DC to high frequency AC which is needed in wireless transmission. The transmitter coil is energized by the AC, forming an alternating magnetic field. By using electromagnetic induction,

power is sent wirelessly to the receiver coil, which is then transformed back to DC using a rectifier circuit and filtered and then back to EV battery. The microcontroller used in the system is the ATmega328P which is the control unit that measures the voltage, current and temperature in the system using sensors and offers protection against overvoltage, overcurrent and overheating. It also controls user interface features like the LCD display, status LEDs and wireless communication module in figure 3.



**Figure 3:** Circuit Diagram of the Proposed System

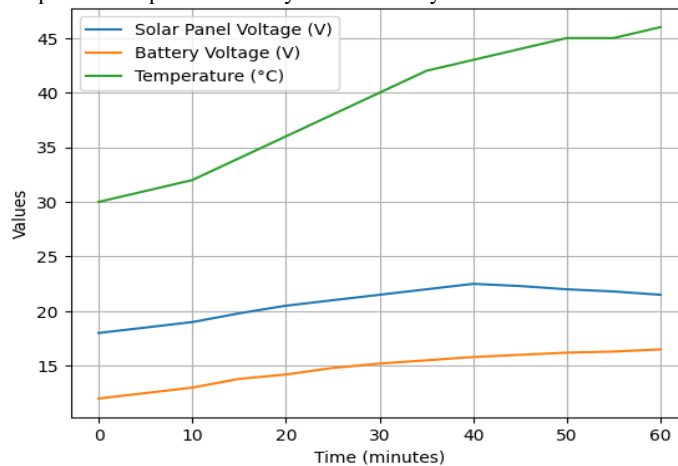
### 4.2 CIRCUIT DIAGRAM

The suggested portable solar-powered wireless EV charging system is comprised of integrated power generation, energy storage, power conversion, wireless transfer, control, protection, and user interaction modules, which work in a coordinated way. The system will start with a photovoltaic (PV) solar panel which transforms the solar irradiance into direct current (DC) electric power. The DC power output is controlled by an MPPT/PWM-based charge controller, which measures the maximum power point of the panel to enhance energy harvesting and provide constant charging conditions. This controller will avoid overcharging and will transfer energy efficiently to the battery storage unit. The battery acts as a store of energy, where the collected solar energy is stored and provides a constant DC source to the subsequent power electronics step in times of fluctuation or at low irradiance levels. The stored DC energy is converted by a DC to DC converter that steps up or regulates the voltage to the desired level that can be efficiently converted by the inverter. A conditioned DC is then supplied to a high-frequency inverter bridge MOSFET based which transforms the DC supply into high-frequency alternating current (AC). This high-frequency AC induces the transmitter coil which is a component of a resonant tank circuit that produces an alternating magnetic field. The electromagnetic induction causes the receiver coil to pick up this magnetic flux without coming into physical contact, thus transferring power wirelessly. The AC power received is then rectified and filtered to supply a suitable DC output to charge the EV battery. This non-contact design is safer, has less mechanical wear, and the systems last longer. The control and management subsystem revolves around the ATmega328P microcontroller that controls the entire operation of the system. Voltage sensors are used to measure the level of input and output voltages, current sensors are used to measure the charging current, and temperature sensors are used to measure the thermal conditions of power electronics and coils. These sensing elements will feed real-time information to the microcontroller allowing to regulate dynamically and detect faults. Protection circuits are built in to prevent overvoltage, overcurrent, overtemperature, and short-circuit and ensure safe and stable operation at different loads and at different environmental conditions. The user interface subsystem has an LCD/OLED display to show real-time system parameters like voltage, current, and battery state-of-charge. Status LEDs are used to show operational states and fault conditions, and control buttons can be used to start and stop manually. And a wireless communication module (Bluetooth/Wi-Fi) allows remote control and monitoring using a mobile application, which increases user convenience and accessibility to the system, and, overall, renewable energy harvesting, advanced power electronics, intelligent control, and wireless energy transfer make up an efficient, safe, and sustainable solution to portable EV charging applications that are applicable to the modern smart energy system.

## 5. RESULTS AND DISCUSSION

### 5.1 Solar Panel Performance Analysis

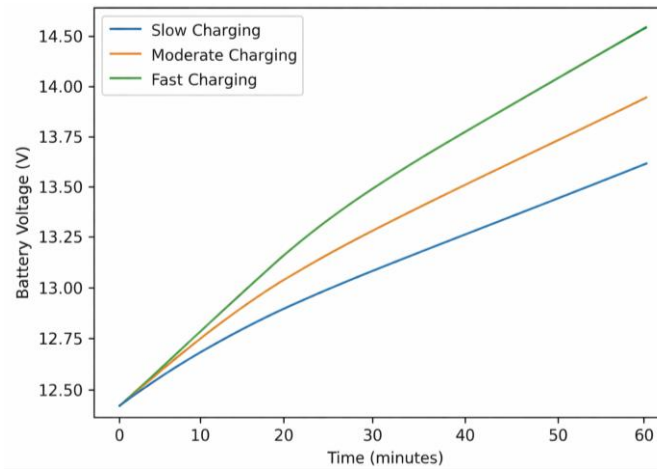
The performance of the photovoltaic (PV) panel was measured with a 60-minute experimental time duration under the normal sunlight conditions as shown in figure 4. The maximum voltage output was 22.5 V at about 35 minutes of operation which was the maximum solar irradiance. The maximum output current was 1.35 A under optimal conditions. As a result the highest power output of the panel was determined to be 30.37 W. The test period average power was determined as 24.2 W, which represents an effective utilization efficiency of about 80.6. Following the peak period, the voltage, current and power levels showed a slow decrease with irradiance and thermal effects due to decreased irradiance and thermal effects, which was expected of the operation of photovoltaic systems under dynamic environments.



**Figure 4:** Photovoltaic Panel Output Characteristics (Voltage, Current, Power vs Time)

### 5.2 Battery Charging Characteristics

The battery charging performance was examined in various conditions of charging. Indeed, the battery was charged at a rate of 1.3 A during fast charging and it was fully charged to a terminal voltage of 13.0 V in 3.1 hours. The battery was able to reach 12.8 V under moderate charging conditions (0.9 A) in about 4.2 hours and 6.5 hours under slow charging conditions (0.5 A) to reach 12.6 V. It was noted that the charging efficiency was ranging between 88% and 92 % and the voltage control was within the range of +0.2 V to -0.2 V displayed in figure 5. The MPPT charge controller was able to control the charging process efficiently and without overcharging and providing a safe and efficient transfer of energy to the battery.



**Figure 5:** Battery Charging Characteristics under Different Charging Modes

### 5.3 Energy Storage and Stability

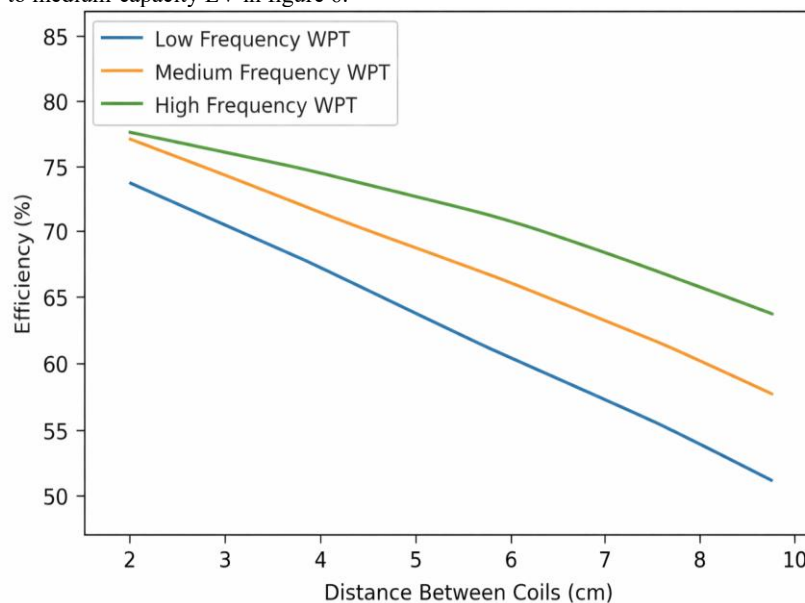
Use of low solar irradiance conditions was used to test the energy storage capability of the system in order to emulate the evening or cloudy conditions. The battery was able to stabilize to a constant output voltage of between 11.8 V and 12.4 V with a variation of less than 3%. The system had the capacity to run about 2.8 hours continuously without the solar input. There were no major voltage drops, interruptions or thermal instabilities were noted during the test which verified the stability of the battery management system and the voltage regulation circuitry in providing stable energy supply.

### 5.4 Wireless Power Transfer Performance

The transfer system of wireless power was tested by changing the distance between the receiver and transmitter coils. The system obtained an output voltage of 11.2 V at a separation distance of 2 cm with a maximum efficiency of 82. At 4 cm the voltage dropped to 9.6 V with an efficiency of 74% and to 7.8 V with 63% efficiency at 6 cm distance. This system had a frequency of 85 kHz and this was suitable to provide resonant inductive coupling. The findings are quite clear that the power transfer efficiency is directly related to the inverse of coil separation distance because of the less magnetic coupling, and it is advisable to align the coils properly.

### 5.5 EV Charging Performance

A battery model of 12 V and 7 Ah tested the EV charging capability of the system. The voltage at which the system was charged was between 11.5 V and 12.8 V with a range of 0.8 A to 1.2 A of charging current depending on the conditions of the system. The overall time took was around 5.5 hours, which provided 66 Wh of power. The charging was also stable during the test and there were no fluctuations or interruptions in the charging process. Despite the lower rate of charge than the conventional grid-based fast chargers, the system proved to have a reliable and safe operation applicable in low to medium-capacity EV in figure 6.



**Figure 6:** Energy Storage and Voltage Stability Performance

## 5.6 Overall System Efficiency

Calculation of the overall system efficiency took into consideration the efficiencies of the subsystems. The solar panel had a rate of approximately 80 % efficiency, the battery system was 90 %. Calculated to be about 50.2%. This efficiency can be found acceptable in a standalone renewable energy-based wireless charging system as there are several energy conversion steps.

## 6. CONCLUSION

This paper introduces a design and deployment of a successful Portable Solar Powered Wireless EV Charging System that combines the renewable energy production and intelligent power control with contactless energy transfer into a small and solitary platform. An experiment has verified that the system can produce a peak solar power of 30.37 W at an average efficiency of 80.6% and the battery charging efficiency is 88% to 92 %. At an optimal coil alignment the maximum efficiency of the wireless power transfer module was 82% and the resonant frequency was 85 kHz. The total system efficiency was calculated as about 50.2 which is satisfactory given the numerous energy conversion processes that the system entailed. The system exhibited consistent voltage regulation, dependable energy storage, and continuous operation in different environmental conditions, which could provide 66 Wh of energy to charge EV in 5.5 hours. The incorporation of the ATmega328P-based control system made it possible to achieve real-time monitoring, shield against electrical errors, and improve the safety of operations. The proposed solution offers a sustainable, portable, and affordable alternative to low- to medium-capacity EV applications although the charging speed is lower than the conventional grid-based fast charging systems. The system is especially appropriate in places that are remote, rural, rest stops along highways and in cases of emergencies where the infrastructure of the grid is missing. Future directions have the potential to enhance the efficiency of a system via enhanced resonant topologies, efficient coil design, enhanced capacity solar panels and intelligent energy management methods. As it evolves, the suggested system bears great prospects of assisting next-generation green mobility, and decentralized energy systems.

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