# Solar Energy-Based Wireless Charging System for Electric Vehicles

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**A B S T R A C T**

In the upcoming years, significant transportation sectors are anticipated to transition to complete electrification, highlighting the importance of creating more accessible and efficient solutions for charging electric vehicles (EVs). Wireless charging is becoming a highly convenient method, enabling electric vehicles to charge even during operation. Accurate power transfer during wireless charging relies on sophisticated mathematical models. These models need to take into account multiple elements, including coil parameters, coil shapes, the selected compensation topology, and the nature of the system, whether it is stationary or dynamic. This project offers an in-depth examination of wireless charging systems tailored for electric vehicles, emphasising prevalent charging topologies and architectures, while concentrating on the mathematical frameworks employed to determine the power transferred in relation to the vehicle's position and speed on the road. With these models, one can achieve a more accurate prediction of an EV's autonomy while navigating roads that feature wireless charging technology. This work provides valuable insights by comparing two distinct models, examining energy transmission methods, and investigating the role of renewable energy sources in facilitating the wider use of wireless charging for electric vehicles.

Introduction

Novel applications are progressively incorporating cutting-edge technologies to provide groundbreaking solutions. Since the dawn of the 21st century, there has been a consistent increase in the prevalence of electric vehicles (EVs). Nonetheless, obstacles like extended battery charging durations and restricted driving distances have hindered their broader acceptance. Consequently, chargers and power cables have integrated into daily life, limiting the mobility that vehicles are designed to offer. To address these issues, comprehensive investigations have been undertaken, and wireless power transfer for electric vehicles has surfaced as a promising and practical solution.

Several years back, systems for Wireless Power Transfer (WPT) utilising high-intensity, time-varying electromagnetic fields were developed. At that time, there was minimal interest in wireless power, as conventional cable-based power distribution systems were typically more efficient and cost-effective for electrical devices. Currently, devices utilising electromagnetic induction for wireless short-range power transfer are gaining popularity in industrial products for contactless charging. Technologies utilising resonant coupling have demonstrated encouraging outcomes, effectively increasing the transfer distance to over two or three times the dimensions of the transmitter or receiver.

## 1. Introduction

As electric vehicles (EVs) gain popularity, the demand for creative and eco-friendly charging solutions has emerged as a central theme in development efforts. Conventional charging techniques, dependent on plug-in systems, face obstacles like restricted convenience, reliance on the grid, and inefficiencies in energy use. To tackle these challenges, the idea of a solar energy-powered wireless charging system has surfaced as an innovative solution.

Wireless charging functions based on the concept of electromagnetic induction. When a device is positioned on a wireless charging pad, an electromagnetic field is generated, leading to the induction of an electric current in the device's receiver coil. The current is subsequently transformed into DC power, facilitating the charging of the device's battery. Wireless charging, often referred to as inductive charging, utilises electromagnetic fields to convey energy from the charging pad to the vehicle's battery, thereby removing the necessity for physical connections. Utilising solar energy, a sustainable resource, allows the system to operate autonomously from the electrical grid, presenting an eco-conscious alternative. This is particularly beneficial for electric vehicles (EVs), given their dependence on electricity for energy. Utilising solar energy contributes to a significant decrease in the total carbon footprint. The energy is meticulously controlled and utilised to operate a wireless charging unit that functions through inductive power transfer

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(IPT) or resonant inductive coupling, enabling the electric vehicle to charge without the need for physical cables. This provides increased convenience and improves automation. The system minimises reliance on grid electricity, encourages the adoption of renewable energy sources, and facilitates cleaner transportation options. It typically comprises solar panels, an inverter, energy storage solutions (such as batteries), control circuits, and wireless power transfer coils that are installed on both the ground and the vehicle.

## 2. Literature Survey

N. Mohamed et al. [1], in their work "Efficient Power Management Strategy of Electric Vehicles Based on Hybrid Renewable Energy," concentrate on the integration of renewable energy sources with electric vehicles (EVs) to enhance energy efficiency, minimise costs, and foster sustainability. Their analysis explores different approaches and enhancement strategies focused on boosting overall system efficiency while tackling the difficulties associated with integrating renewable energy and electric vehicle technology. A. Ahmad, Z. et al. [2], in "A Review of the Electric Vehicle Charging Techniques, Standards, Progression, and Evolution of EV Technologies in Germany," present an extensive examination of the advancements in EV technologies and the growth of charging infrastructure in Germany, emphasising key trends, policies, and challenges faced by the industry. P. García et al. [3], in "Operation Mode Control of a Hybrid Power System Based on Fuel Cell/Battery/Ultracapacitor for an Electric Tramway," analyse the implementation of hybrid power systems in tramways, highlighting advancements in efficiency and decreases in environmental impact. In a similar vein, A. Triviño-Cabrera et al. [4], in "Independent Primary-Side Controller Applied to Wireless Chargers for Electric Vehicles," explore the advantages of independent primary-side control in wireless charging systems, highlighting improved efficiency, streamlined operations, and enhanced compatibility among various EV models. B. H. Mouna et al. [5], in "Influences of Photovoltaic Cell Number on the Charging System for Electric Vehicles," examine the considerations necessary for determining the ideal quantity of photovoltaic (PV) cells for EV charging systems, emphasising the need to align the number of cells with the charging requirements of vehicles in particular regions. Lastly, Y. Wang et al. [6], in "Study on Energy Optimisation Control Strategy of the Hybrid Electric Vehicle Based on Pontryagin's Minimum Principle," illustrate the efficacy of utilising advanced optimisation strategies and likely concludes by emphasising the success of applying Pontryagin's Minimum Principle to the energy optimisation challenge in hybrid electric vehicles. Through the resolution of the optimisation problem, the control strategy can effectively reduce fuel consumption. Enhance the longevity and performance of the battery. Minimise emissions without compromising vehicle performance. Provide a structured approach for advancing energy management systems in hybrid electric vehicles.

## 3. Problem Formulation

### a. Existing System

The efficiency of wireless charging may not match that of traditional wired methods, resulting in energy losses throughout the transfer process. This may lead to extended charging durations and higher energy expenses. Most existing systems operate at low charging speeds and may not be ideal for high-power uses, which restricts their effectiveness for extended journeys. The process of wireless charging utilises IPT or resonant inductive coupling, facilitating the transfer of energy from a charging pad on the ground to a receiver coil in the EV without the need for physical connections. Power electronics, including inverters and rectifiers, play a crucial role in transforming the DC electricity generated by solar panels or batteries into the AC power necessary for the wireless charging system.

### b. Proposed System

This system integrates solar energy generation, energy storage, and wireless power transfer (WPT) to develop a sustainable and efficient EV charging solution. Solar panels harness sunlight to produce electricity, and energy storage systems, such as batteries, retain surplus energy for times when solar output is diminished. The stored energy fuels the WPT system, enabling the wireless transmission of power from a ground pad to a receiver coil on the EV.

This removes the necessity for physical connectors, simplifying the charging process and enhancing safety. Despite challenges such as efficiency and cost, continuous advancements and exploration are facilitating the broader acceptance of this innovative technology. The inductive power transfer (IPT) technology facilitates wireless charging by enabling energy to be transmitted from a ground-based charging pad (transmitter) to a receiver coil integrated into the EV's undercarriage. This removes the necessity for physical cables, resulting in a more convenient and user-friendly experience. To enhance the system, the integration of dynamic wireless charging could be considered, enabling electric vehicles to charge while in motion. This would provide a continuous power supply during travel and alleviate concerns about range.

This proposed system enhances the convenience of wireless charging for electric vehicles while supporting eco-friendly transportation through the utilisation of solar energy and minimising dependence on fossil fuels. This initiative promotes environmentally friendly transport options and has the potential to greatly decrease greenhouse gas emissions, representing an essential advancement towards a more sustainable and energy-efficient future.

A centralised control system has the capability to oversee the charging process, monitor energy production and consumption, and modify operations to achieve optimal efficiency. Through the integration of IoT sensors and machine learning algorithms, the system has the potential to anticipate energy requirements by analysing variables such as weather forecasts and vehicle usage patterns, leading to a more responsive and adaptable approach. The system should be engineered to function effectively under different conditions of solar energy availability. The system is required to attain a minimum efficiency of 80% for wireless charging. The system should be designed to be economical and streamlined, ensuring simplicity is maintained throughout. This problem statement offers a detailed overview of the challenges and goals associated with creating an effective wireless charging system for electric vehicles that utilise solar energy.

## 4. Design and Implementation

Inductive coupling enables the transfer of power wirelessly across short distances. Power is conveyed through the process of mutual induction involving two coils. The receiving antenna consists of the secondary coil, while the transmitting antenna is represented by the primary coil.

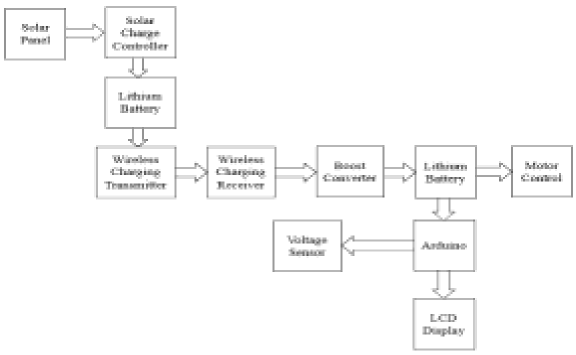



**Fig. 1- Block Diagram of wireless charging system**

The design steps of wireless charging systems are as follows

Step 1: Capturing Solar Energy

- Position solar panels in an appropriate area (e.g., parking lot, roadside).
- The MPPT system enhances the efficiency of energy collection from solar panels.

Step 2: Power Conversion

- The DC-DC converter adjusts solar energy to an appropriate level for wireless charging.
- The PCU facilitates effective energy transfer and maintains a stable output voltage.

Step 3: Inductive Power Transfer

- WCT delivers energy without wires to WCR embedded in the electric vehicle.
- WCR harnesses energy and transforms it into DC power

Step 4: Charging the Vehicle

• Direct current energises the battery of the vehicle.

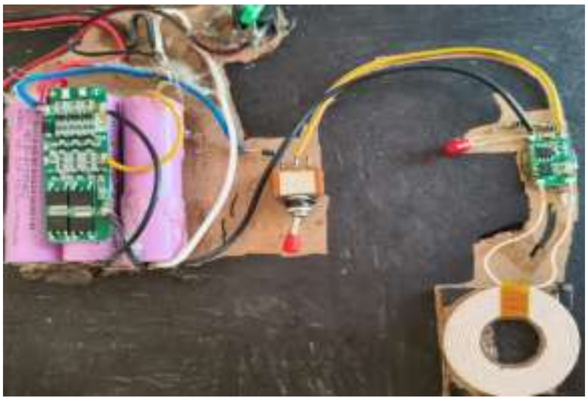
Step 5: Implementation and Activation

• Implement the wireless charging system at the specified site.
• Integrate the system with the electrical grid and the solar panel array. Initiate the system and conduct comprehensive testing and verification.

Step 7: Final Charge Completion

• When the EV's battery reaches full capacity, the system automatically halts the charging process, ensuring that overcharging does not occur.

In this configuration, the secondary coil functions as the receiving antenna, whereas the primary coil serves as the transmitting antenna. Eliminating the necessity for physical connectors enhances the convenience and safety of charging electric vehicles (EVs), particularly in adverse weather conditions. This configuration emphasises significant progress in inductive charging technology, contributing to the advancement of sustainable transportation in the future. The detailed procedure outlines the functioning of wireless charging for electric vehicles utilising solar energy, merging sustainable power with advanced wireless technology to provide an effective and environmentally friendly charging



solution while addressing issues such as electromagnetic interference and overheating.

**Fig. 2-Lithium Battery is connected to Transmitter coil**

A solar charge controller serves as an essential element in a wireless charging system that harnesses solar energy. The system regulates the distribution of energy among the solar panels, a lithium battery, and the wireless charging transmitter to ensure optimal performance. The solar panels harness sunlight and convert it into electricity, which is then managed by the charge controller to ensure the safe charging of the lithium battery. Employing an MPPT (Maximum Power Point Tracking) controller is optimal, as it enhances power transfer while safeguarding the battery against overcharging or deep discharging.

A wireless charging system utilising solar energy incorporates a lithium battery linked to a transmitter coil, facilitating effective wireless power transfer. Electricity is generated by solar panels, and a solar charge controller manages this process to ensure the safe charging of the lithium battery. The battery accumulates the energy harnessed from sunlight and delivers it to the wireless power transmitter. This transmitter is composed of a coil and an electronic circuit designed to transform DC power into high-frequency AC. The system is subsequently linked to both the electrical grid and the solar panel array.

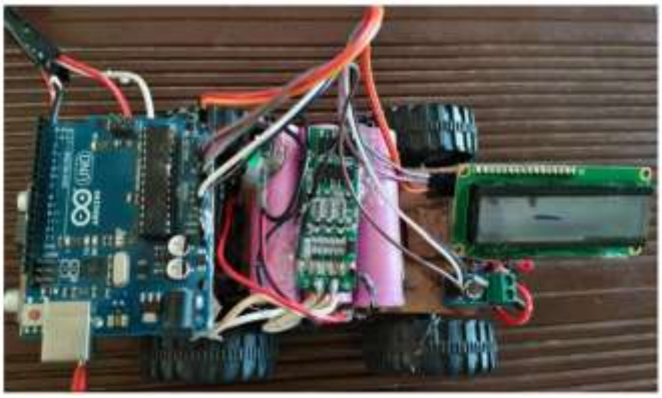


**Fig. 3 - Receiver Coil connected to Arduino UNO.**

A wireless charging system designed for electric vehicles utilising solar energy incorporates a receiver coil integrated into the vehicle's body, which is linked to an Arduino UNO for effective monitoring and control. Electricity is generated by solar panels, and a solar charge controller manages this process to ensure the safe charging of a lithium battery. The accumulated energy is subsequently delivered to a wireless power transmitter, in which a transmitter coil generates an alternating magnetic field. The receiver coil integrated within the vehicle harnesses this energy and transforms it into DC power once again. The Arduino UNO, linked to the receiver coil, observes essential metrics such as voltage, current, and battery status to guarantee safe and effective charging. It has the capability to manage relays, present charging data, and interact with the vehicle's power management system. A DC-DC converter is commonly employed to modify the voltage to align with the specifications of the EV's battery. This system facilitates effortless, contactless charging, enhancing the convenience and sustainability of EV charging through the utilisation of clean, and renewable solar energy.

## 5. Results and Discussion

The outcome of implementing solar energy in a wireless electric vehicle charging system is an effective, eco-friendly, and touch-free approach that enhances convenience and diminishes dependence on fossil fuels. Solar panels harness renewable energy, subsequently regulated by a solar charge controller to charge a lithium battery. The efficiency of wireless charging generally falls between 80% and 90%, influenced by variables such as the distance between the transmitter and receiver coils, their alignment, and the specific technology employed. In the context of electric vehicle (EV) charging, the efficiency tends to be sufficiently high for practical applications, although meticulous design is crucial to reduce energy loss. This is subsequently overseen by a solar charge controller to facilitate the charging of a lithium battery. Typically, the duration required for charging wireless systems exceeds that of conventional wired charging methods. Nonetheless, utilising high-efficiency solar panels can lead to a substantial generation of power throughout the day, which may decrease the total charging duration when a battery storage system is implemented.

The energy output of solar panels is influenced by various elements such as geographic location, weather conditions, and the efficiency of the panels themselves. In regions abundant with sunlight, the system has the potential to supply nearly all the energy required for the vehicle's daily operations. Nonetheless, energy storage plays a crucial role in enabling the vehicle to receive charging even when the sun isn't shining. The overall performance of this system is influenced by the dimensions of the solar array and the capacity of the battery storage.Although the upfront expense of setting up a wireless charging pad and solar panels may be significant, the potential savings on electricity over time, along with the positive impact on the environment from utilising renewable energy, render it a valuable investment for electric vehicle (EV) owners. This holds especially in regions that experience abundant sunlight. Harnessing solar energy for EV charging leads to a notable decrease in greenhouse gas emissions when contrasted with electricity sourced from the grid, particularly in areas where fossil fuels dominate the energy supply. This approach facilitates the advancement of cleaner transportation and minimises the carbon footprint associated with electric vehicles.

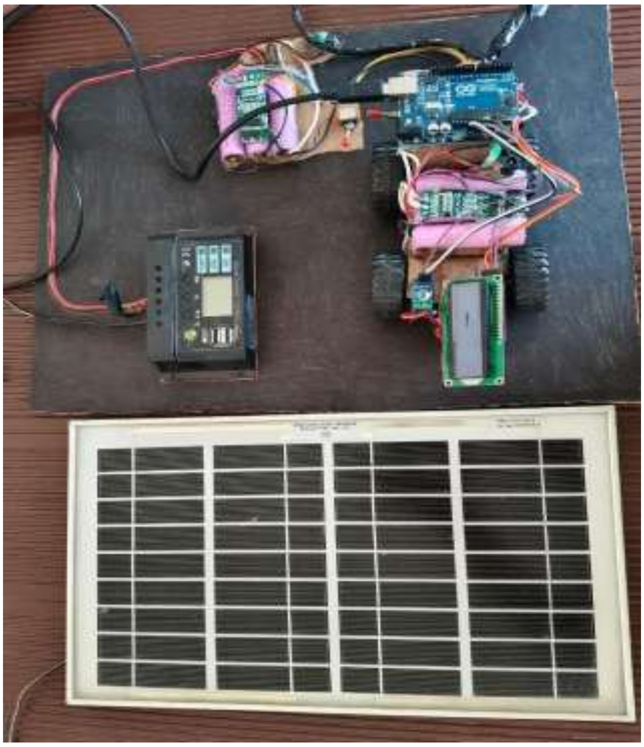


**Fig. 4- Overview of wireless charging system**

A wireless charging system for electric vehicles (EVs) powered by solar energy presents a clever, sustainable approach that merges convenience, innovation, and environmental responsibility. Solar panels harness sunlight and transform it into electricity, which is subsequently utilised to charge electric vehicles via a wireless power transfer (WPT) system. This system eliminates the necessity for physical connections by utilising magnetic fields to convey energy from a transmitter coil located on the ground to a receiver coil situated in the vehicle. The process operates effectively and has potential for further enhancement through the integration of energy storage systems to retain surplus solar power, guaranteeing that the vehicle remains capable of charging even during periods of low sunlight.

This system minimises dependence on the electrical grid, decreases carbon emissions, and enhances the convenience of charging EVs by removing the necessity for plugs and cables. Solar-powered wireless charging systems can be implemented in off-grid locations, fostering the advancement of sustainable infrastructure, particularly in remote areas where conventional charging solutions may be lacking. The combination of wireless charging systems and solar energy for electric vehicles (EVs) represents a significant advancement in creating a more sustainable and convenient mode of transportation. Wireless charging removes the necessity of plugging in by utilising inductive power transfer or resonant magnetic coupling, enabling electric vehicles to charge automatically when positioned over a charging pad. Utilising solar energy enhances the eco-friendliness of this system, as it depends on renewable sources rather than grid electricity, which can still be derived from fossil fuels. Solar panels produce direct current electricity, which can be utilised right away for charging or saved in batteries for future use, guaranteeing a dependable energy source even during overcast conditions. This system offers significant advantages, including decreased carbon emissions and reduced operational expenses for electric vehicle owners. Nonetheless, certain obstacles exist, including the need to sustain optimal energy transfer efficiency, address variations in solar power, and contend with significant initial installation expenses. Progress in battery storage, power electronics, and energy management systems is crucial to address these challenges. In light of these challenges, the wireless charging of EVs through solar energy presents a promising avenue for achieving a cleaner, smarter, and more convenient future for personal and public transportation.

## 6. Conclusion and Future scope

### a. Conclusion

The incorporation of wireless charging systems for electric vehicles (EVs) utilising solar energy represents a significant advancement for transportation and energy infrastructures. By removing the necessity for physical connections, wireless charging enhances the convenience, safety, and ease of use for EV owners. This system, when integrated with solar energy, offers a sustainable approach that diminishes dependence on the electricity grid and contributes to a reduction in carbon emissions. This also creates new possibilities for energy autonomy, particularly in isolated or off-grid regions, and provides adaptable, sustainable frameworks to accommodate the increasing prevalence of electric vehicles. Wireless charging driven by solar energy offers a highly innovative approach for eco-friendly transportation. This system merges the ease of wireless power transfer with the ecological advantages of solar energy, tackling significant issues associated with carbon emissions, energy efficiency, and user experience. Despite ongoing technical and economic hurdles like efficiency losses and installation expenses, progress in solar technology, wireless charging efficiency, and energy storage is consistently enhancing the practicality of these systems. With the increasing need for sustainable energy solutions and electric transportation, the integration of solar-powered wireless charging within urban and residential frameworks will be crucial in fostering a more environmentally friendly and efficient future.

### b. Future scope

In the future, efforts on wireless charging systems for electric vehicles powered by solar energy should concentrate on enhancing energy transfer efficiency, refining solar energy harvesting, and reducing system costs. The focus should be on advancing materials for wireless coils to minimise energy losses and enhance charging distance. Enhancing battery storage systems will be essential for effectively managing the variable characteristics of solar power. Furthermore, integrating intelligent energy management and advanced algorithms could enable immediate adjustments to charging in response to environmental factors and vehicle needs. Future designs could investigate the potential of dynamic wireless charging integrated into solar-powered roads, enhancing the convenience of EV charging. In summary, ongoing advancements and extensive evaluation are crucial for enhancing the practicality, affordability, and readiness of solar-powered wireless charging systems for real-world use.

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