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Wireless Charging System for Electric Vehicles

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A B S T R A C T

The increasing adoption of electric vehicles (EVs) has created a growing demand for convenient, efficient, and reliable charging technologies. Conventional plug-in charging systems require physical cable connections, which may cause inconvenience, cable wear, and operational limitations. This paper presents the design and development of a wireless charging system for electric vehicles based on the principle of electromagnetic induction and resonant inductive coupling. The proposed system consists of a ground-side transmitter coil, a vehicle-mounted receiver coil, power electronic conversion circuits, a rectifier, a voltage regulator, and a microcontroller-based control unit. Electrical energy is transferred from the transmitter to the receiver through a magnetic field without requiring direct electrical contact. The system incorporates coil alignment and resonant frequency adjustment to improve power transfer efficiency under different operating conditions. The performance of the proposed system is evaluated in terms of transmitted power, received voltage, current, power transfer efficiency, and operational safety. The project focuses on a stationary wireless charging configuration suitable for light electric vehicles, with particular emphasis on reducing charging complexity and improving user convenience. The proposed approach provides a foundation for the development of cost-effective and automated wireless charging solutions for future electric vehicle applications.

Keywords: Electric vehicles, wireless power transfer, resonant inductive coupling, electromagnetic induction, transmitter coil, receiver coil, power transfer efficiency

I. Introduction

The rapid development of electric vehicle (EV) technology has significantly transformed the transportation sector by providing an alternative to conventional fuel-powered vehicles. Increasing environmental concerns, rising fuel costs, and the need to reduce greenhouse gas emissions have encouraged the adoption of electric vehicles across various applications. However, the widespread utilization of EVs requires reliable and convenient charging infrastructure to ensure efficient battery charging and improved user experience. Conventional charging systems primarily depend on wired connections, where users must manually connect the vehicle to a charging station using charging cables. Although these systems are widely used, physical connections may lead to inconvenience, cable wear, maintenance requirements, and limitations in automated charging applications.

Wireless Power Transfer (WPT) technology offers an alternative approach to conventional wired charging by transferring electrical energy between two coils without requiring direct physical contact. The technology primarily operates on the principle of electromagnetic induction, in which an alternating current supplied to the transmitter coil generates a varying magnetic field. This magnetic field induces an electromotive force in the receiver coil positioned at a suitable distance from the transmitter. The received alternating voltage can subsequently be converted into direct current using a rectifier and voltage regulation circuit for charging the electric vehicle battery. Resonant inductive coupling can also be employed to improve energy transfer between the transmitter and receiver coils by operating them at an appropriate resonant frequency.

The performance of a wireless charging system depends on several parameters, including coil design, operating frequency, air gap, coil alignment, coupling coefficient, and power conversion efficiency. Misalignment between the transmitter and receiver coils can reduce magnetic coupling and result in lower power transfer efficiency. Similarly, variations in the distance between the coils and electrical loading conditions can influence the received voltage and current. Therefore, appropriate coil positioning, frequency adjustment, and power electronic circuit design are important considerations for developing an effective wireless charging system. Monitoring electrical parameters and incorporating suitable control mechanisms can further support reliable operation and provide protection during the charging process.

This project focuses on the design and development of a stationary wireless charging system for light electric vehicles using transmitter and receiver coils. The proposed system integrates power electronic conversion circuits, a rectifier, a voltage regulator, and a microcontroller-based control unit to facilitate contactless energy transfer and monitor the charging operation. The system is intended to demonstrate wireless power transfer under controlled

coil alignment and air-gap conditions. Its performance is evaluated based on transmitted and received voltage, current, power transfer efficiency, and operational safety. The proposed approach aims to reduce dependence on physical charging cables and provide a foundation for convenient, automated, and cost-effective wireless charging solutions for future electric vehicle applications.

II. Problem Statements

Conventional electric vehicle charging systems primarily rely on wired connections, requiring users to manually connect charging cables to the vehicle, which may result in inconvenience, cable wear, maintenance issues, and limitations in automated charging applications. These challenges highlight the need for an efficient and convenient alternative charging technology that eliminates direct physical connections. Although wireless power transfer technology provides a promising solution through electromagnetic induction, achieving reliable power transfer remains challenging due to variations in coil alignment, air gap, operating frequency, and coupling efficiency. Misalignment between the transmitter and receiver coils can lead to reduced power transfer efficiency and increased energy losses. Therefore, the problem addressed in this project is to design and develop a cost-effective stationary wireless charging system for electric vehicles that enables contactless energy transfer using appropriately designed transmitter and receiver coils, suitable power electronic conversion circuits, and a control mechanism to monitor charging parameters and improve the reliability, efficiency, and safety of the charging process.

III. Proposed System

A. The System Design and Development

The proposed wireless charging system for electric vehicles is designed based on the principle of electromagnetic induction, which enables electrical energy transfer between two coils without direct physical contact. The overall system consists of a DC power supply, high-frequency inverter, transmitter coil, receiver coil, rectifier, voltage regulator, battery unit, and microcontroller-based monitoring and control system. The transmitter section converts the supplied DC power into alternating current using an inverter circuit, which generates a varying magnetic field around the transmitter coil. When the receiver coil is positioned within the effective magnetic field, an alternating voltage is induced across it through electromagnetic coupling. The received AC voltage is then converted into DC using a rectifier and regulated to obtain a suitable output for battery charging.

The transmitter and receiver coils are designed to achieve effective magnetic coupling and improved power transfer performance. Coil alignment and the air gap between the two coils are important design parameters because they directly influence the amount of energy transferred. The system incorporates suitable coil positioning and resonant frequency adjustment to improve the power transfer capability under different operating conditions. Litz-wire wound coils are considered for the transmitter and receiver sections to support the wireless energy transfer arrangement. The power conversion stages are designed and simulated using Proteus or Multisim to examine the operation of the inverter and rectifier circuits before hardware implementation.

A microcontroller-based control unit is integrated to monitor the operating parameters of the wireless charging system, including voltage, current, and coil alignment. Arduino IDE is used for developing the firmware required for monitoring and charging control. The receiver-side regulated DC output is connected to the battery charging section through an appropriate charging arrangement. The control unit supports monitoring of charging conditions and helps manage the system operation. Appropriate protection considerations are incorporated to improve operational safety and reliability.

The development process involves designing the circuit architecture, constructing the transmitter and receiver coils, integrating the power electronic circuits, implementing the control logic, and testing the complete system under different coil alignment and air-gap conditions. The developed prototype is evaluated by measuring the input voltage, received voltage, current, transmitted power, and output power. Power transfer efficiency is calculated by comparing the received output power with the supplied input power. The experimental observations are used to assess the effectiveness of the proposed wireless charging system and identify the operating conditions that provide improved energy transfer performance.

B. Block diagram

The proposed system consists of a transmitter section and a receiver section connected through electromagnetic coupling. The transmitter converts DC power into high-frequency AC using an inverter, which drives the transmitter coil to generate a magnetic field. The receiver coil captures the magnetic energy and converts it into electrical energy, which is rectified and regulated to provide DC power for charging the EV battery.

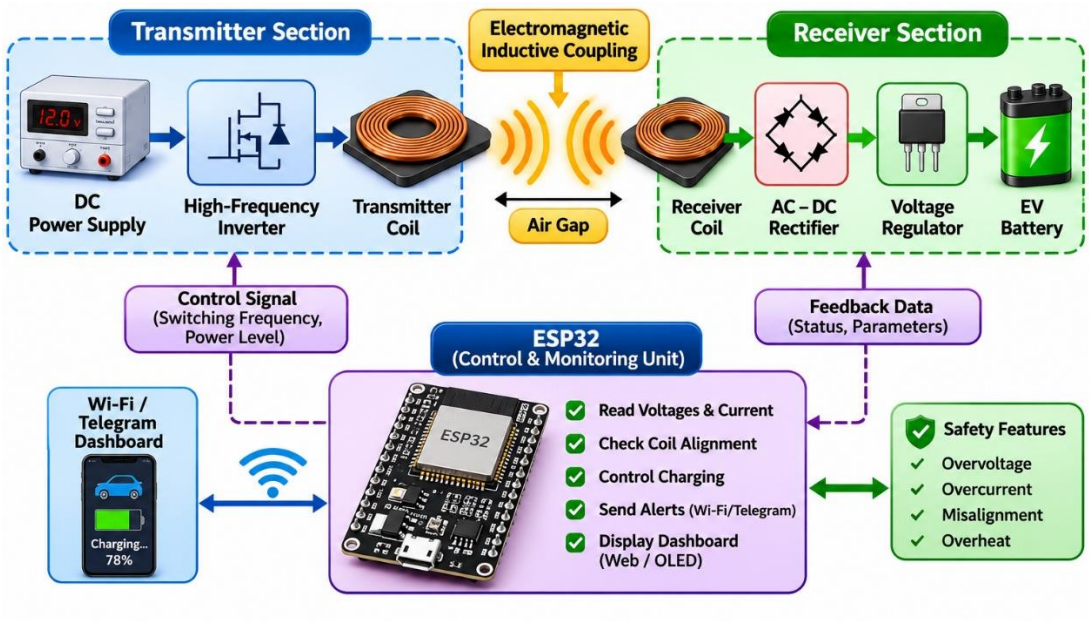


Figure 1: Block diagram of the proposed system

The proposed wireless charging system uses an ESP32 microcontroller as the central monitoring and control unit to manage and monitor the charging process. The system operates based on electromagnetic induction, where the transmitter coil generates an alternating magnetic field using power supplied through a high-frequency inverter. This magnetic field induces an alternating voltage in the receiver coil without requiring a physical connection. The received AC voltage is converted into DC using a rectifier and regulated to provide a suitable supply for the EV battery charging section. The ESP32 monitors important electrical parameters, such as voltage and current, and supports coil alignment monitoring and charging control. It can interface with suitable voltage and current sensors to obtain real-time operating information.

The ESP32 also provides wireless connectivity through its built-in Wi-Fi functionality, enabling remote monitoring through a web-based dashboard and Telegram notifications. The measured parameters and charging status can be displayed on an OLED screen or accessed through a mobile device or computer. Based on the monitored conditions, the controller can support charging management and protection functions against abnormal operating conditions such as overvoltage, overcurrent, and coil misalignment. The proposed integration of wireless power transfer and ESP32-based monitoring improves system automation, monitoring convenience, and operational reliability. Thus, the system provides a foundation for developing an intelligent and cost-effective wireless charging solution for electric vehicles.

B. Circuit diagram

The proposed wireless charging system uses ready-made wireless power transfer transmitter and receiver modules to transfer electrical energy without requiring a direct cable connection. The transmitter module is connected to a suitable DC power supply and generates an alternating magnetic field through its coil. When the receiver coil is positioned within the effective magnetic field, electrical energy is induced and transferred through electromagnetic coupling. The received electrical output is processed through the appropriate rectification and voltage regulation stages before being supplied to the EV battery charging circuit. The use of ready-made wireless charging modules simplifies hardware development and reduces the complexity of designing individual power electronic circuits.

An ESP32 microcontroller is integrated into the system for monitoring and controlling the charging operation. A voltage sensor and ACS712 current sensor are interfaced with the ESP32 to measure the electrical parameters of the charging system. The measured voltage, current, and charging status can be displayed on an I2C OLED display, while the built-in Wi-Fi functionality enables remote monitoring through a web dashboard or Telegram notifications. A relay module can be used for charging control, and a buzzer provides an audible indication of abnormal operating conditions. The integration of wireless power transfer modules with ESP32-based monitoring provides a convenient and automated approach to EV wireless charging, with scope for improved monitoring, protection, and system reliability.

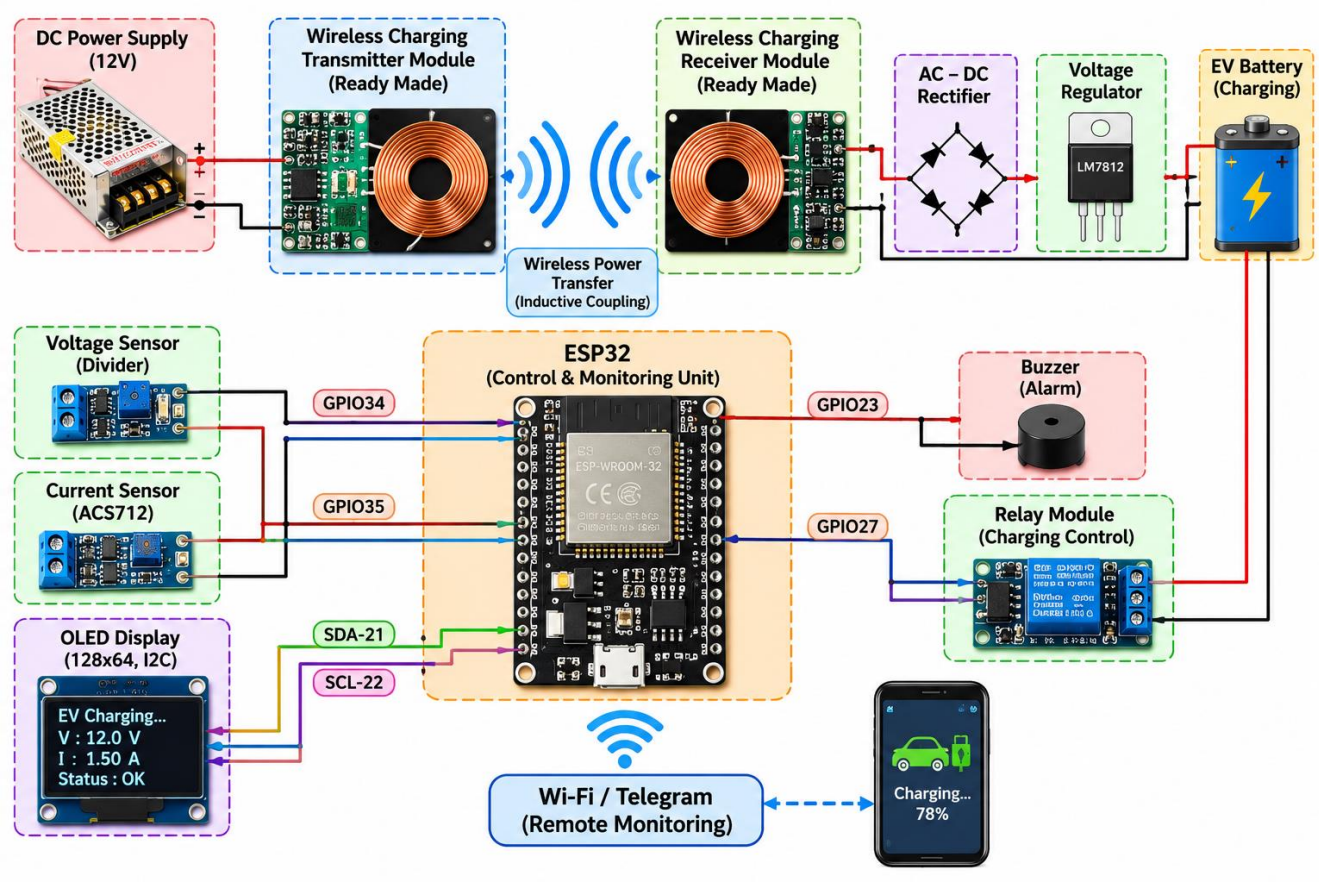


Figure 2: detailed circuit and hardware interconnection diagram of the proposed auto indoor hydroponic fodder grow chamber.

4. Result analysis

The developed prototype of the wireless charging system for electric vehicles is shown in Fig. 5. The hardware implementation consists of a compact wheeled vehicle platform integrated with an energy storage unit, control circuitry, power management modules, and relay-based switching arrangements. The prototype incorporates rechargeable lithium-ion battery cells as the primary energy storage source and supercapacitors rated at 2.7 V, 500 F for additional energy storage and power management experiments. A DC-DC converter is integrated to regulate the supply voltage required by the electronic circuits. The microcontroller-based control unit is connected to the supporting electronic modules to facilitate system monitoring and control. The relay module provides switching functionality for managing the connected electrical circuits.

The experimental prototype demonstrates the integration of energy storage, power management, and embedded control components within a compact electric vehicle platform. The arrangement of batteries and supercapacitors provides a platform for investigating energy storage and power delivery characteristics under different operating conditions. The DC-DC converter supports voltage regulation, while the relay module enables controlled switching of the electrical loads. The developed hardware establishes a foundation for integrating wireless power transfer technology with an ESP32-based monitoring system. Further experimental evaluation can be carried out by measuring input voltage, receiver output voltage, charging current, charging time, and power transfer efficiency at different coil distances and alignment positions. These measurements will help assess the charging performance, energy transfer capability, and overall reliability of the proposed system.

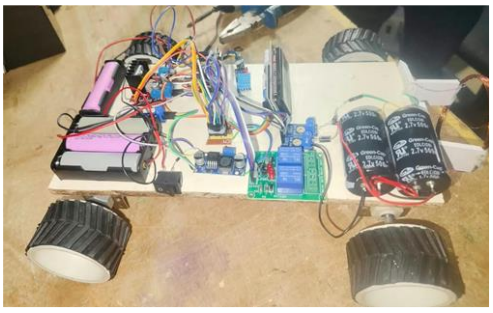


Figure 3(a) : Vehicle

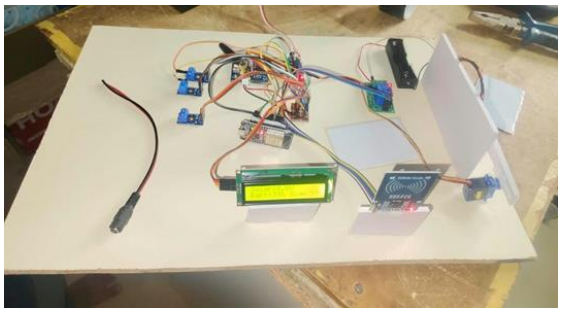


Figure 3(b) : Charging station

The prototype also demonstrates the compact integration of multiple electronic subsystems within the vehicle chassis. The battery pack supplies electrical energy to the connected control and power management circuits, while the supercapacitor bank provides an additional energy storage arrangement for investigating transient power delivery and energy management. The relay-based switching circuit supports the control of electrical loads, and the DC-DC converter helps maintain the required operating voltage for the electronic components. The physical arrangement of these modules demonstrates the feasibility of integrating battery storage, power conditioning, and embedded control into a small-scale electric vehicle prototype

The developed system provides a suitable experimental platform for evaluating wireless charging integration in electric vehicles. Further testing can be performed by positioning the vehicle over a wireless charging transmitter and measuring the receiver-side output under different coil alignment and separation conditions. The ESP32 can be used to monitor voltage, current, battery charging status, and operating conditions, with the collected data helping to evaluate charging characteristics and energy management performance. The experimental analysis can also include charging time, power transfer efficiency, voltage stability, and energy storage performance. These investigations will help identify system limitations and provide opportunities for improving the efficiency, reliability, and automation of the proposed wireless charging system.

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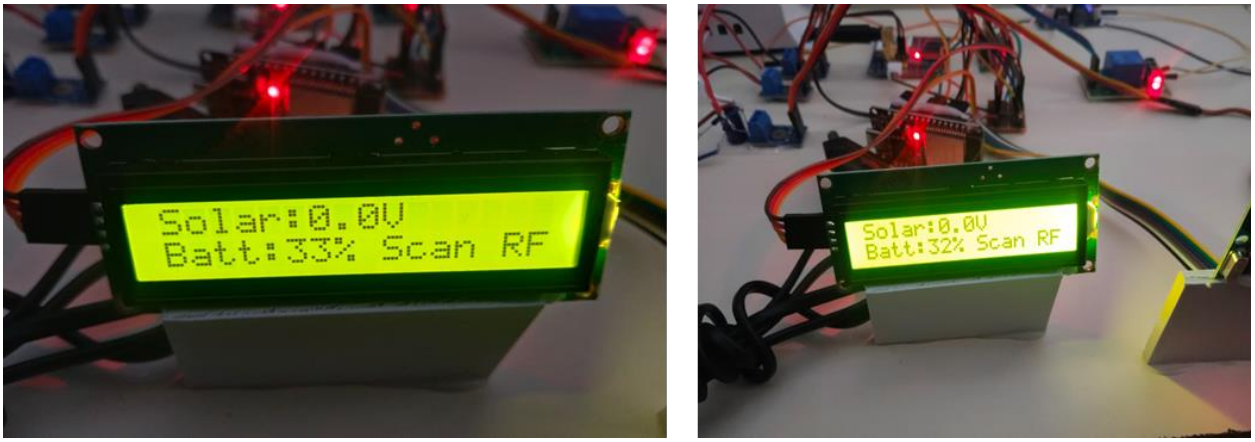


Fig 3(c): LCD display provides information about the system status and battery condition

The RFID-based authentication mechanism provides an additional level of access control to the charging system. When an RFID card is presented to the reader, the controller is designed to identify the card and verify the associated user information. Following successful authentication, the system checks the available account balance before enabling the charging process. If the card is invalid or the balance is insufficient, the charging operation is restricted. This arrangement can help manage access to a shared charging facility and provide a foundation for implementing a prepaid charging mechanism. The relay interface is incorporated to support controlled activation and deactivation of the charging unit through the microcontroller, subject to the electrical requirements of the selected module.

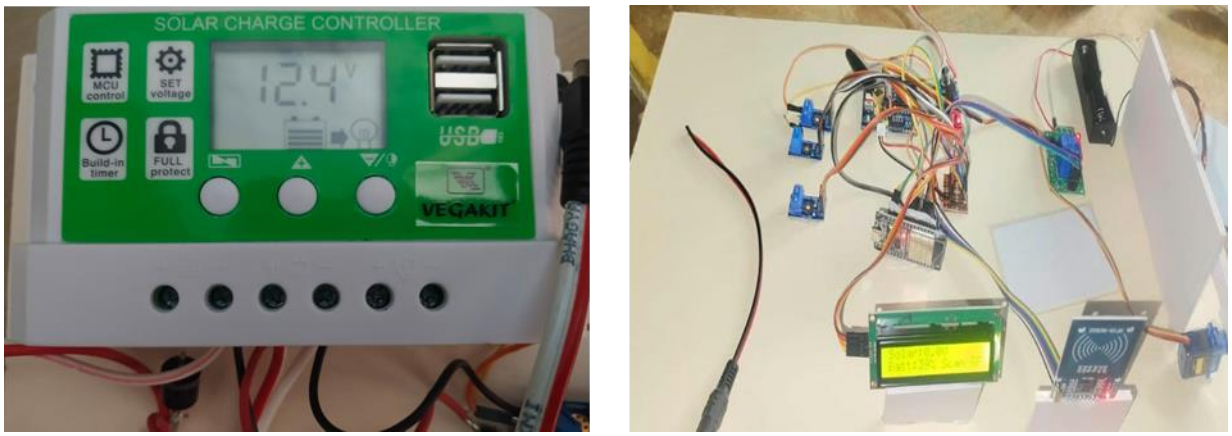


Fig 6.3 :Solar Charger controller & RFID-based authentication mechanism

The ESP32-based monitoring arrangement supports the collection and display of important operating information. Voltage and battery-status readings can be processed by the controller and presented through the LCD interface, allowing the user to observe the system condition. The integration of the controller with the RFID reader and relay module also provides a coordinated approach to authentication and charging control. The displayed information improves the usability of the prototype by communicating the system status without requiring a separate monitoring instrument. Further software development can extend this functionality to include charging-current measurement, energy-consumption calculation, account-balance deduction, and wireless data logging.

5. Conclusion and Future scope

The proposed project presents the design and development of a wireless charging system for electric vehicles with an ESP32-based monitoring and control arrangement. The developed prototype integrates a compact electric vehicle platform, rechargeable battery pack, supercapacitors, DC-DC converter, relay module, and embedded electronic control circuits. The system aims to demonstrate the feasibility of contactless power transfer using ready-made wireless transmitter and receiver modules, reducing the dependency on conventional wired charging connections. The ESP32 provides a flexible platform for monitoring electrical parameters, controlling charging operations, and enabling remote monitoring through Wi-Fi connectivity. The integration of energy storage, power management, and embedded control provides a foundation for developing convenient and automated wireless charging solutions for electric vehicles.he proposed system can be further enhanced by implementing automatic coil alignment detection to improve wireless power transfer efficiency under different positioning conditions. Integration of voltage, current, temperature, and battery monitoring sensors can provide more comprehensive charging supervision and protection. IoT-based monitoring can be extended through a web dashboard or mobile application to display real-time charging parameters, battery status, and historical charging data. Further improvements can include optimization of transmitter and receiver coil design, investigation of different air-gap distances, enhancement of power transfer efficiency, and implementation of intelligent battery management techniques. The system can also be extended towards dynamic wireless charging, where electric vehicles receive electrical energy while moving over specially designed charging tracks, providing opportunities for advanced electric vehicle charging infrastructure.

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