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Full Length Article

Solar Powered Wireless Charging Station For Electric Vehicles With IOT And RF

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Abstract
The rapid adoption of electric vehicles (EVs) has increased the demand for efficient and sustainable charging infrastructure. Conventional plug-in charging stations often depend on grid electricity and require manual cable connections, which may reduce user convenience and increase maintenance concerns. This paper presents the design and development of a solar powered wireless charging station integrated with Internet of Things (IoT) technology for smart monitoring and management. The proposed system combines photovoltaic energy generation, wireless power transfer, sensor-based measurement, and cloud connectivity into a unified charging platform. Solar energy captured through photovoltaic panels is regulated and boosted to energize a transmitting coil. A receiving coil mounted in the EV captures the transferred energy and routes it to the battery charging circuit. Voltage and current sensors continuously track charging performance, while a microcontroller processes data and displays system parameters on a local LCD interface. Through a Wi-Fi communication module, real-time data is uploaded to an IoT server for remote supervision. The developed model demonstrates an eco-friendly, cable-free, and intelligent charging solution suitable for parking areas, campuses, highways, and smart cities.
Keywords
Electric Vehicles, Wireless Charging, Solar Energy, IoT, Arduino, Renewable Energy, Smart Charging Station, Inductive Power Transfer

Introduction

The increasing demand for sustainable transportation has accelerated the adoption of electric vehicles (EVs) across the world. As EV usage grows, the need for efficient, accessible, and environmentally friendly charging infrastructure has become more significant. Conventional wired charging systems often rely on grid electricity and require physical connectors, which may lead to cable damage, user inconvenience, and safety concerns. To overcome these limitations, a Solar Powered Wireless Charging Station integrated with Internet of Things (IoT) technology is proposed as an innovative solution.This advanced charging system uses solar energy as the primary power source and transfers electrical energy wirelessly to EV batteries through electromagnetic induction or resonant coupling. By removing direct cable connections, the system improves charging convenience, operational safety, and long-term reliability. Since the charging energy is generated from photovoltaic panels, dependence on fossil-fuel-based electricity is reduced, helping lower carbon emissions and operating costs.The wireless charging mechanism consists of a transmitting coil placed in the charging platform and a receiving coil mounted underneath the vehicle. When the vehicle is correctly positioned above the charging pad, electrical energy is transferred through a magnetic field and converted into usable power for battery charging. This contactless method simplifies the charging process and enhances user comfort, especially in public charging stations, parking areas, and smart city environments.To improve intelligence and automation, IoT technology is integrated into the system. Sensors continuously monitor charging voltage, current, battery condition, solar power generation, and overall system status. The collected information is transmitted to a cloud platform through a Wi-Fi communication module, enabling real-time monitoring, remote diagnostics, and data analysis. Users and operators can track charging performance, energy usage, and equipment health through web or mobile interfaces.For secure access and user management, RFID technology can be incorporated into the charging station. RFID tags assigned to registered vehicles or users enable automatic authentication before charging begins. This feature is useful for controlled access, billing automation, and usage tracking in commercial charging networks.The proposed system also includes an energy storage unit that stores excess solar energy during peak sunlight hours. Stored energy can be used during cloudy weather or nighttime operation, ensuring uninterrupted service. Protection circuits such as overvoltage, overcurrent, and thermal safeguards further improve system reliability and safety.A solar powered wireless EV charging station offers several advantages including clean energy utilization, reduced maintenance, cable-free operation, smart monitoring, and scalability for multiple vehicles. It can be deployed in residential areas, shopping complexes, workplaces, highways, and public parking facilities. As cities move toward intelligent infrastructure and green mobility, such charging systems can play an important role in future transportation networks.Wireless power transfer technology also opens new possibilities beyond static charging. Charging pads can potentially be integrated into roads, parking bays, and traffic stops, allowing partial charging while vehicles are stationary or in motion. Combined with solar generation, this concept creates a more seamless and sustainable charging ecosystem.

Hardware Requirements

2.2 Hardware Requirements

The system requires several hardware modules for power generation, storage, wireless charging, sensing, control, and communication. Solar panels are used to convert sunlight into electrical energy. Since the output from solar panels varies with weather conditions, a charge controller and boost converter are used to regulate the voltage and improve efficiency.A rechargeable battery bank stores excess solar energy and supplies power during nighttime or low sunlight conditions. Wireless charging is achieved using a transmitter coil installed in the charging pad and a receiver coil mounted beneath the vehicle. High-frequency switching circuits and inverters are used to energize the transmitter coil.The system also includes an Arduino Uno microcontroller for controlling the charging process, reading sensor data, and managing system functions. Voltage and current sensors continuously monitor system performance. A Wi-Fi module such as ESP8266 enables IoT connectivity for real-time data transmission. A 16×2 LCD display is used for local monitoring of charging parameters. Protection devices such as relays, fuses, and isolation circuits are included for safe operation.

Hardware Components

Solar Panel

The solar panel is the main source of power generation in the system. It converts sunlight into DC electrical energy using photovoltaic cells. High-efficiency panels are preferred for better output and long-term reliability.

Boost Converter

The boost converter is a DC–DC converter used to step up the low input voltage from the solar panel or battery to a higher regulated voltage required by the wireless transmission circuit. It ensures stable voltage supply under varying load conditions.

Lithium-Ion Battery

Lithium-ion batteries are used for storing solar energy and providing backup power. They offer high energy density, low maintenance, long cycle life, and efficient charging performance.

Transistor / MOSFET

Power transistors or MOSFETs are used in switching and inverter circuits. They convert DC power into high-frequency AC required for wireless power transfer. These components improve system efficiency and control.

Wireless Charging Coils

The transmitter coil creates an alternating magnetic field, while the receiver coil captures the magnetic energy and converts it into electrical energy. Proper alignment of the coils is necessary for efficient charging.

Arduino UNO

Arduino Uno is the main controller of the system. It reads data from sensors, controls relays, manages charging logic, and communicates with the IoT module.

Voltage Sensor

Voltage sensors measure solar panel voltage, battery voltage, and charging voltage. This helps in system regulation and protection.

Current Sensor

Current sensors monitor charging current and load current. They are useful for power calculation, overload detection, and battery management.

ESP8266 Wi-Fi Module

The ESP8266 module provides wireless internet connectivity. It uploads charging data such as voltage, current, battery level, and charging status to cloud platforms for remote monitoring.

LCD Display

A 16×2 LCD display shows charging voltage, current, battery status, and system conditions locally.

Working Principle

The system begins with the solar panel generating electrical energy from sunlight. This energy is regulated through a charge controller and boost converter before charging the battery bank. The stored energy is then supplied to an inverter circuit that converts DC into high-frequency AC.The high-frequency AC energizes the transmitter coil and produces a changing magnetic field. When the electric vehicle is parked above the charging pad, the receiver coil captures this magnetic field and induces voltage through electromagnetic induction.The received AC voltage is rectified and converted into regulated DC power for battery charging. Voltage and current sensors continuously monitor charging parameters. The Arduino controller processes this data, displays it on the LCD, and sends it to the IoT cloud through the ESP8266 module.

Proposed Methodology

Block Diagram

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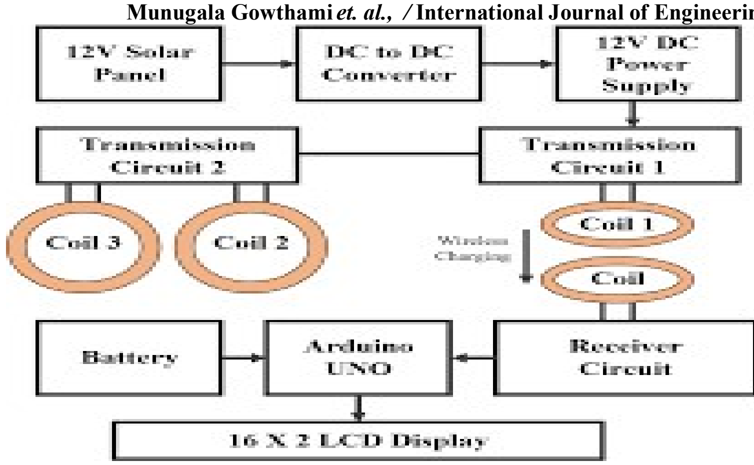


Fig :1 Block Diagram of Solar-Powered RF Coil-Based Wireless Charging System

Previous Work

Earlier EV charging systems mainly depended on wired charging stations powered by the electrical grid. Although effective, these systems required manual cable connection, regular maintenance, and high dependence on conventional electricity sources.Some research introduced solar-powered charging stations to reduce grid dependency. Other studies explored wireless charging using inductive coils for contactless power transfer. IoT-based charging systems were also proposed for remote monitoring of battery status, energy consumption, and charging schedules. RFID technology was introduced for authentication and automated billing.

.**Problem Statement**

The increasing number of electric vehicles has created a strong demand for reliable and sustainable charging stations. Conventional charging systems face several limitations such as grid dependency, cable wear, charging inconvenience, lack of automation, and poor real-time monitoring.Wireless charging systems also face challenges such as energy loss, coil misalignment, and installation cost. Solar energy systems depend on sunlight availability and require storage solutions. Therefore, a smart charging system is needed that combines renewable energy, wireless power transfer, IoT monitoring, and secure access control.

Proposed Work

The proposed system develops a solar powered wireless EV charging station integrated with IoT and RF coil technology. Solar panels generate renewable energy, which is stored in batteries for continuous operation. Stored DC power is converted into high-frequency AC and supplied to the transmitter coil.When an electric vehicle is positioned above the charging pad, the receiver coil mounted under the vehicle receives energy wirelessly through electromagnetic induction. The received power is rectified and used to charge the vehicle battery.The system includes Arduino Uno as the main controller for managing charging operations. Voltage and current sensors monitor charging performance. IoT communication through ESP8266 allows remote monitoring of charging status, battery level, and energy usage. RFID authentication can be added for secure user access and automated billing.

Operation

During daytime, solar panels generate electricity and charge the storage battery. The battery supplies power to the transmitter unit whenever charging is required. The inverter converts stored DC power into high-frequency AC, which energizes the transmitter coil.When the vehicle is parked above the charging pad, the receiver coil captures the magnetic energy and converts it into electrical power. This power is processed and used for battery charging.

The Arduino continuously monitors voltage, current, battery status, and charging time. The LCD displays real-time system information. Through the Wi-Fi module, charging data is uploaded to a cloud platform where users can monitor the station remotely using a smartphone or computer.

Applications

Solar-powered wireless charging stations for electric vehicles integrated with IoT and RF coil technology offer a modern, sustainable, and intelligent charging solution for a wide range of environments. By combining renewable solar energy, contactless wireless power transfer, and real-time digital monitoring, these systems improve charging convenience, reduce dependence on conventional electricity, and support the transition toward green transportation. Their flexibility makes them suitable for urban areas, industrial zones, highways, and remote locations.

One of the most significant applications of this technology is in smart city infrastructure. Wireless charging pads can be installed in parking areas, traffic signals, bus stops, and designated charging zones to provide automatic vehicle charging without manual cable connections. Such systems can be integrated with urban traffic management platforms and smart parking solutions. In future smart cities, dynamic wireless charging embedded into roads may allow electric vehicles to receive power while moving, reducing charging delays and improving vehicle range.These charging stations are also highly beneficial in remote and off-grid regions where conventional electricity infrastructure is weak or unavailable. Since the system uses solar energy as its primary power source, it can operate independently in rural villages, isolated highways, tourist locations, border regions, and disaster-prone areas. This capability provides a reliable charging solution for electric mobility in places where grid expansion is difficult or expensive.Fleet management is another important application area. Public buses, taxi services, delivery vehicles, warehouse transport units, and logistics fleets can benefit from wireless charging combined with IoT monitoring. Fleet operators can track charging schedules, battery condition, vehicle energy consumption, and charging station utilization in real time. This data-driven approach improves operational efficiency, reduces downtime, and supports predictive maintenance planning.Public and commercial spaces such as shopping malls, office campuses, airports, universities, hospitals, and hotels can adopt solar-powered wireless charging systems to provide convenient charging services for employees, customers, and visitors. These installations enhance user satisfaction while demonstrating environmental responsibility. Contactless charging is particularly useful in busy locations where frequent cable handling may cause wear or safety concerns.Residential communities and apartment complexes can also implement this technology to support shared charging infrastructure. Solar wireless charging stations installed in common parking areas can reduce electricity costs through renewable generation and simplify daily charging for residents. Such systems encourage wider EV adoption in urban housing environments where private charging access may be limited.Highways and long-distance transit corridors represent another promising application. Wireless charging pads placed at toll plazas, service stations, bus depots, and rest areas can help extend the travel range of EVs and reduce range anxiety. Public transport vehicles and commercial trucks can use scheduled charging stops for efficient energy replenishment during operation.Industrial facilities and smart campuses can use these charging systems for internal electric mobility such as carts, forklifts, autonomous vehicles, and maintenance transport units. By replacing fossil-fuel-powered utility vehicles with solar charged electric alternatives, organizations can lower emissions and improve energy efficiency.In summary, solar-powered wireless EV charging stations with IoT and RF coil technology have broad application potential across transportation, residential, industrial, and public sectors. Their ability to deliver clean energy, automated charging, and intelligent monitoring makes them an essential component of future sustainable mobility infrastructure.

Results and Discussion

System Operation and Working

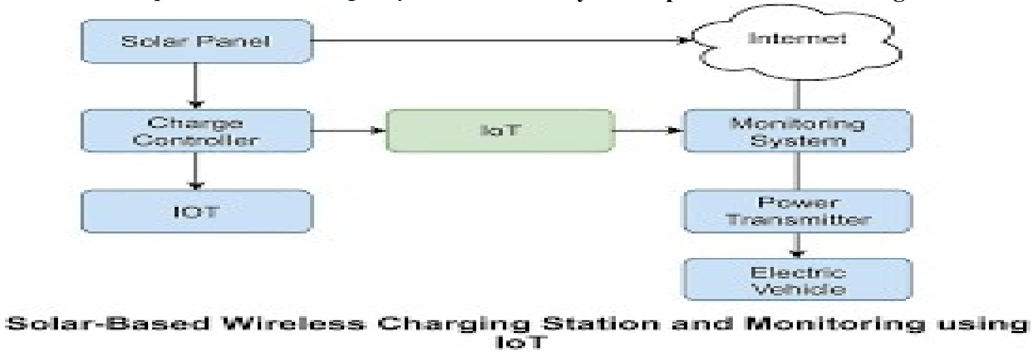
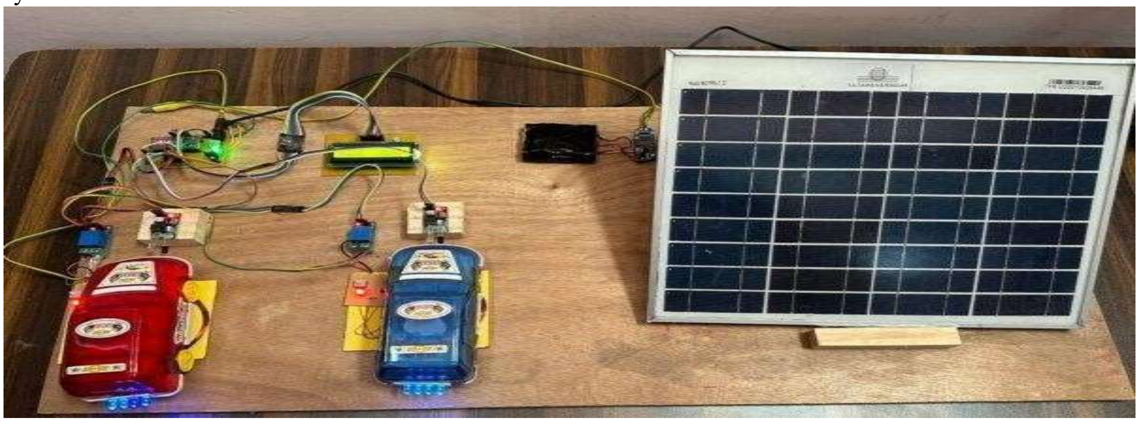


Fig:2 Block Diagram of Solar-Based Wireless EV Charging Station with IoT Monitoring System

The developed solar-powered wireless EV charging system combines photovoltaic generation, battery storage, RF coil based wireless power transfer, and IoT communication into one integrated platform. Solar panels convert sunlight into direct current electricity, which is regulated through a charge controller and stored in a rechargeable battery bank. This stored energy ensures uninterrupted operation even during low sunlight conditions.When an electric vehicle is parked above the charging station, the transmitter and receiver coils align to establish magnetic coupling. A microcontroller then activates the charging circuit. The stored DC power is converted into high-frequency AC through an inverter and supplied to the transmitter coil. This creates an alternating magnetic field around the charging pad. The receiver coil installed in the vehicle captures this magnetic field and converts it into electrical energy through electromagnetic induction.The received AC power is rectified into DC and supplied to charge the EV battery. During operation, sensors continuously measure charging voltage, current, battery level, and temperature. These parameters are processed by the controller and transmitted through the ESP8266 Wi-Fi module to cloud platforms or mobile applications. This enables users and system operators to remotely monitor charging progress, power consumption, and system health in real time.

Experimental Results



1 Results

The prototype successfully demonstrated wireless charging powered by solar energy. The solar panel generated sufficient DC power under standard sunlight conditions, and the battery storage unit maintained stable output during temporary shading or low irradiance periods. The boost converter and inverter circuits operated effectively to energize the transmitter coil.When the receiver coil was positioned directly above the transmitter coil, successful wireless power transfer was observed. The battery connected to the receiver side charged continuously, confirming effective inductive energy transmission. Indicator LEDs and measurement displays verified the charging state and operational stability of the system.Voltage and current sensor readings were accurately displayed on the LCD screen and transmitted to the IoT dashboard. Users could monitor charging voltage, charging current, battery condition, and solar availability remotely. This demonstrated the effectiveness of real-time monitoring and data logging features.The prototype also highlighted the importance of coil alignment. Maximum power transfer occurred when the transmitter and receiver coils were properly aligned. Slight misalignment reduced charging efficiency, indicating that positioning assistance mechanisms may further improve practical implementation.

Discussion

The results confirm that integrating solar energy with wireless charging technology provides a practical and environmentally responsible solution for electric vehicle charging. Solar power reduces dependency on conventional electricity sources and lowers operational cost. The battery backup system ensures continuity during non-solar hours, making the charging station more reliable.Wireless charging significantly improves user convenience by removing cables and connectors. It also reduces mechanical wear and lowers the risk of electric shock, sparking, and connector failure. These advantages make the system suitable for public parking areas, campuses, residential complexes, and commercial charging hubs.The IoT platform enhanced system intelligence by enabling remote monitoring, fault identification, and usage analysis. Operators can evaluate system efficiency, detect abnormalities, and optimize maintenance schedules using collected data. Historical records can also support energy planning and charging demand prediction.

Conclusion

The proposed solar-powered wireless electric vehicle charging station demonstrates an effective combination of renewable energy generation, contactless charging technology, and intelligent monitoring systems. By using solar energy as the main power source, the system decreases dependence on conventional grid electricity and supports environmentally sustainable transportation. Energy captured from photovoltaic panels is regulated and stored before being delivered to transmitter coils, which create a magnetic field for wireless power transfer to receiver coils installed in the vehicle. This non-contact charging approach improves user convenience while reducing cable damage, connector wear, and safety risks commonly associated with plug-in charging methods.The integration of IoT technology significantly improves operational performance by enabling continuous observation of important parameters such as voltage, current, temperature, battery condition, and charging efficiency. Real-time data communication to cloud platforms allows remote supervision, fault identification, and predictive maintenance. As a result, the charging station can operate as an adaptive and self-managed system capable of responding to changing energy demand and environmental conditions.

Future Scope

The future development of solar-powered wireless EV charging systems is expected to focus on improving automation, charging speed, transfer efficiency, and large-scale deployment. Dynamic wireless charging can allow vehicles to receive power while moving, reducing the need for frequent stops and minimizing range anxiety. Such technology can transform highways, public transport routes, and smart road infrastructure.Further progress in coil design, resonance control, and power electronic converters will increase charging efficiency while reducing transmission losses. Better alignment systems using sensors and automated vehicle positioning can also improve energy transfer performance. In addition, next-generation batteries and advanced storage systems will support faster charging cycles and improved energy availability during low sunlight conditions.Artificial intelligence and machine learning can be integrated to predict charging demand, optimize solar energy utilization, and manage load sharing among multiple charging stations. Smart grid connectivity and bidirectional power flow may also enable EVs to return stored energy to the grid when required. Standardized wireless charging protocols will promote compatibility between different vehicle manufacturers and infrastructure providers.In the long term, solar wireless charging stations can become an important component of sustainable smart cities by delivering clean energy, intelligent mobility support, and scalable charging infrastructure for future transportation ecosystems.

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