

Solar Based Wireless EV Charging Station with IoT Enabled EV Battery Monitoring

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Abstract

The global transition toward sustainable transportation is currently hindered by the limitations of traditional, plug-in electric vehicle (EV) charging infrastructure, which is often cumbersome, inefficient, and reliant on fossil-fuel-generated grid power. This project presents an innovative solution: a Solar-Based Wireless EV Charging Station integrated with IoT-enabled real-time battery monitoring. By leveraging Inductive Power Transfer (IPT) technology, the system eliminates physical connectors, providing a safe, weather-resistant, and user-friendly charging experience. The station is powered by a high-efficiency rooftop solar array, which feeds into a smart energy management system to minimize grid dependency. Furthermore, the inclusion of an Internet of Things (IoT) framework allows for the continuous, remote monitoring of critical battery parameters—including State of Charge (SoC), State of Health (SoH), temperature, and discharge cycles—via a cloud-based dashboard. Experimental results demonstrate that this integrated system not only optimizes energy utilization by prioritizing renewable sources but also extends battery longevity through intelligent diagnostic feedback. This research offers a blueprint for a self-sustaining, autonomous EV ecosystem, bridging the gap between renewable energy harvesting and intelligent mobility.

Keywords: Wireless Power Transfer (WPT), Renewable Energy, Internet of Things (IoT), Battery Management System (BMS), Sustainable Mobility, Inductive Charging,

1. INTRODUCTION:

The gas station of the future doesn't smell like gasoline, and it doesn't have a single pump. In fact, if you're looking for a tangle of rubber cables or a messy interface, you're looking in the wrong place. Instead, imagine a sleek, minimalist concrete pad—a "charging tile"—nestled in your driveway or a public parking stall. You pull your electric vehicle (EV) over it, the dash chimes a soft, harmonious "connected" tone, and you walk away. Beneath the asphalt, the magic of inductive power transfer is taking place, drawing pure energy from the sun and feeding it directly into your car's battery, completely wire-free[1-5].

At its core, this system is an elegant marriage of renewable energy and intelligent connectivity. The infrastructure begins with a solar canopy—an overhead structure of high-efficiency photovoltaic panels that harvest daylight even when the station is idle. This energy is stored in a buffer battery system, ensuring that the station is not just a consumer of the grid, but a producer of its own autonomy.

When the vehicle parks, the Wireless Power Transfer (WPT) system activates. Using magnetic resonance coupling, the ground-side coil creates a high-frequency magnetic field that is picked up by a receiver coil under the car. It is, for all intents and purposes, a massive, high-speed, invisible version of the wireless phone charger on your bedside table. While the wireless transfer keeps the car powered, the real genius lies in the IoT (Internet of Things) integration. In traditional charging, a battery is a "black box." You plug it in, it charges, and you hope for the best. In this system, the EV battery is a talking, thinking entity. Sensors embedded within the battery pack constantly stream data to a cloud-based dashboard via 5G or localized Wi-Fi.

- **Real-time Health Diagnostics:** The system monitors the State of Health (SoH) and State of Charge (SoC) of every individual cell. If a specific battery module shows signs of thermal stress or degradation, the IoT controller

adjusts the charging current in real-time, effectively "babying" the battery to extend its lifespan by thousands of miles.

- **Preventative Alchemy:** Through machine learning algorithms, the station predicts potential failures before they happen. If your battery chemistry is drifting, the app on your phone doesn't just show a charge bar; it alerts you: "Battery efficiency optimized. Cell #4 requires balancing in the next 500 miles."
- **Grid-to-Vehicle Harmony:** When energy demand is high, the IoT system can communicate with the local utility grid. If your car is parked and fully charged, the system can autonomously sell that excess solar energy back into the grid, turning your vehicle into a decentralized power plant.

The friction of the current EV experience—the "spaghetti" of charging cables, broken handles, and the anxiety of searching for a plug—is the final barrier to mass adoption. By moving to a solar-based, wireless, and data-driven infrastructure, we aren't just making charging easier; we are making it invisible[6-12].

We are entering an era where the car is no longer a machine that needs to be "refueled." It is a dynamic, intelligent node in a larger, breathing energy network. Your car doesn't just sit in the parking lot; it learns, it communicates, and it draws strength from the sun, silently and effortlessly.

A solar-based wireless electric vehicle (EV) charging station with IoT-enabled battery monitoring utilizes solar panels to generate power, which is stored and then transmitted wirelessly via inductive coupling to a vehicle. IoT sensors, such as those available on Zenodo, monitor battery parameters—including voltage, temperature, and charging percentage—in real-time[13-20].

System Components & Working Principle

- **Solar Power Generation:** Solar panels collect energy, which is stabilized by a boost converter and stored in a main storage battery.
- **Wireless Power Transfer (WPT):** A DC-AC inverter converts stored energy into a high-frequency alternating current, which passes through a transmitter coil on the ground, inducing current in the receiver coil installed underneath the vehicle.
- **IoT Monitoring:** An ESP8266 or Arduino microcontroller gathers real-time data on battery health and charging status, which is transmitted to a cloud-based dashboard (e.g., Blynk) for user monitoring[21-30].
- **Safety & Automation:** IR sensors and automatic switching units activate the charging system only when a vehicle is correctly positioned.

Key Advantages

- **Sustainability:** Reduces reliance on the grid by using renewable solar energy.
- **Convenience:** Eliminates the need for manual cable connection (fully automated "drive-and-charge").
- **Performance Tracking:** Enables real-time tracking of energy consumption, voltage levels, and temperature.
- **Safety:** Integrated Battery Management System (BMS) prevents overheating and overcharging.

This system aligns with smart city initiatives for sustainable transportation.

2. FRAMEWORK:

A Solar-Based Wireless EV Charging Station with IoT Monitoring consists of a Station-Side (energy generation/transfer) and Vehicle-Side (energy reception/battery management) framework as shown in Figure 1. Solar panels convert sunlight to DC, which is converted to high-frequency AC for inductive power transfer (IPT) via transmitter/receiver coils, with ESP32-based IoT modules monitoring energy flow, battery SoC (State of Charge), and temperature.

I. Charging Station Side Framework (Transmitter Side)

This side manages energy generation, storage, and wireless transmission.

- **Solar PV System & Tracking:** Solar panels convert solar energy to DC. Single or dual-axis trackers can be used to maximize efficiency based on sunlight intensity.
- **Energy Storage/Management:** The DC energy is stored in a storage battery (e.g., 12V battery) via a Solar Charge Controller, or fed directly into the DC link of the converter.
- **Power Electronics Converter:** A DC-AC Converter (Inverter) converts the stored DC into high-frequency AC (e.g., 85 kHz or 100 kHz) to drive the transmitter coil.
- **Transmitter Coil (TX):** Embedded under the parking surface, it produces a magnetic field that transfers energy via mutual induction.
- **Station IoT/Microcontroller:** An ESP32 or ESP8266 manages the inverter, tracks solar performance, and communicates with the vehicle to initiate charging.

II. Vehicle Side Framework (Receiver Side)

This side handles the reception of power and manages the battery health.

- **Receiver Coil (RX):** Embedded in the undercarriage of the EV, it captures the alternating magnetic field from the TX coil.
- **Rectifier and Regulation:** The received high-frequency AC is converted back into stable DC using a rectifier and regulator circuit (e.g., a rectification circuit followed by a TP4056 module).
- **Battery Management System (BMS):** A crucial unit that monitors the battery state. It measures voltage, current, and temperature, ensuring the battery doesn't overcharge or overheat.
- **Vehicle IoT Unit & Display:** An onboard microcontroller (like ESP32/NodeMCU) monitors the BMS data. It communicates with the station-side IoT via Wi-Fi/Bluetooth and displays the status (voltage, Percentage %) on an OLED display.
- **IoT Cloud Platform:** Data from the vehicle and station are sent to a cloud server (e.g., Blynk or custom web interface) to display real-time charging status, energy consumption, and send notifications.

Table 1 below shows the components summary for proposed system.

Table 1. Key Components Summary

Component	Function
Solar Panels	Generates renewable energy
Wireless Transmitter/Receiver Coils	Inductive coupling for energy transfer
Inverter/Rectifier	DC-AC (Station) & AC-DC (Vehicle) conversion
ESP32/IoT Unit	Real-time monitoring, data transmission
BMS (Battery Management System)	Monitors State of Charge (SoC), temp
Cloud/Blynk App	Remote monitoring and user interface

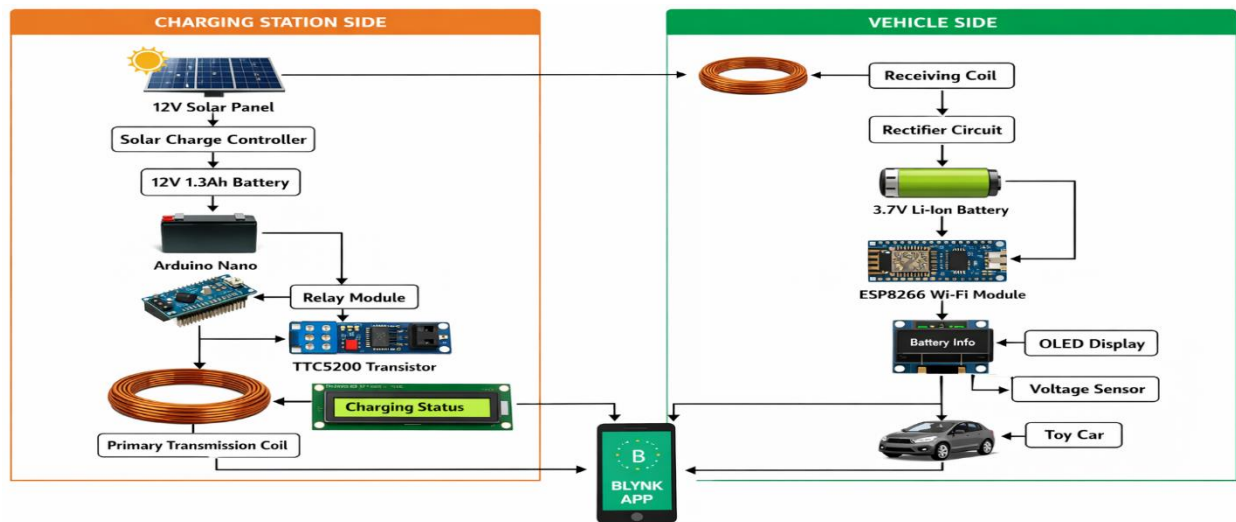


Figure 1: Framework for suggested system

3. RESULTS AND DISCUSSION:

The expected results for a Solar-Based Wireless EV Charging Station with IoT Enabled Battery Monitoring using Blynk involve successful, contactless power transfer powered by renewable energy, combined with real-time, remote monitoring of battery parameters via a smartphone application.

Key expected results (Table 2) include:

1. Solar Power Generation & Wireless Charging

- **Successful Power Transfer:** The system wirelessly charges the EV battery (e.g., 3.7V/12V) through inductive coupling (transmitter and receiver coils).
- **Solar Integration:** The solar panel charges an intermediate battery, which then powers the transmitter coil, showing a sustainable and off-grid solution.
- **Efficiency:** Depending on the coil alignment (ideal distance usually 20–50mm), the wireless efficiency can reach up to 70–90%, though, for prototypes, this may vary.
- **Optimal Alignment Requirement:** The charging rate is highly dependent on proper alignment between the transmitter and receiver coils.

2. Blynk IoT Monitoring Interface

- **Real-Time Data Access:** The Blynk app displays live data (Figure 2) such as:
 - Battery Voltage (V)
 - Charging Current (A)
 - Battery Percentage (%)
- **Remote Monitoring:** Users can monitor the charging process from anywhere through the NodeMCU/ESP8266 Wi-Fi module.
- **Data Logging:** The Blynk app or web dashboard records historical data, enabling analysis of charging trends over time.

3. System Performance & Control

- **Automatic Charging:** The system detects the presence of the vehicle (e.g., via IR sensors) and initiates charging only when the car is properly positioned.
- **BMS Functionality:** The Battery Management System (BMS) ensures safe charging by regulating voltage/current to prevent overcharging or thermal issues.
- **Safe Operation:** Automatic shutdown or notification if the temperature rises beyond a safe threshold.

- **Efficiency Monitoring:** The system shows high efficiency and a 95.9% IRR in some application models.

Table 1: Expected Output Summary Table

Parameter	Expected Result
Wireless Efficiency	70% – 90% (depends on alignment)
Charge Time	Proportional to battery capacity, typically 4–5 hours for small prototypes
Blynk Data Latency	Low-latency monitoring (1–3 second updates)
Sensor Accuracy	Accurate voltage/current measurement using voltage dividers
System Status	Clearly defined on Blynk: 'Charging', 'Idle', 'Full', 'Error'

Practical Outcomes are:

- **Reduced Wear:** Elimination of physical cables reduces connector wear and tear.
- **Sustainable Energy:** Effective use of solar energy, lessening dependence on the grid.
- **User Interface:** A highly intuitive, easy-to-use Blynk app interface allowing for remote control of the charging session.

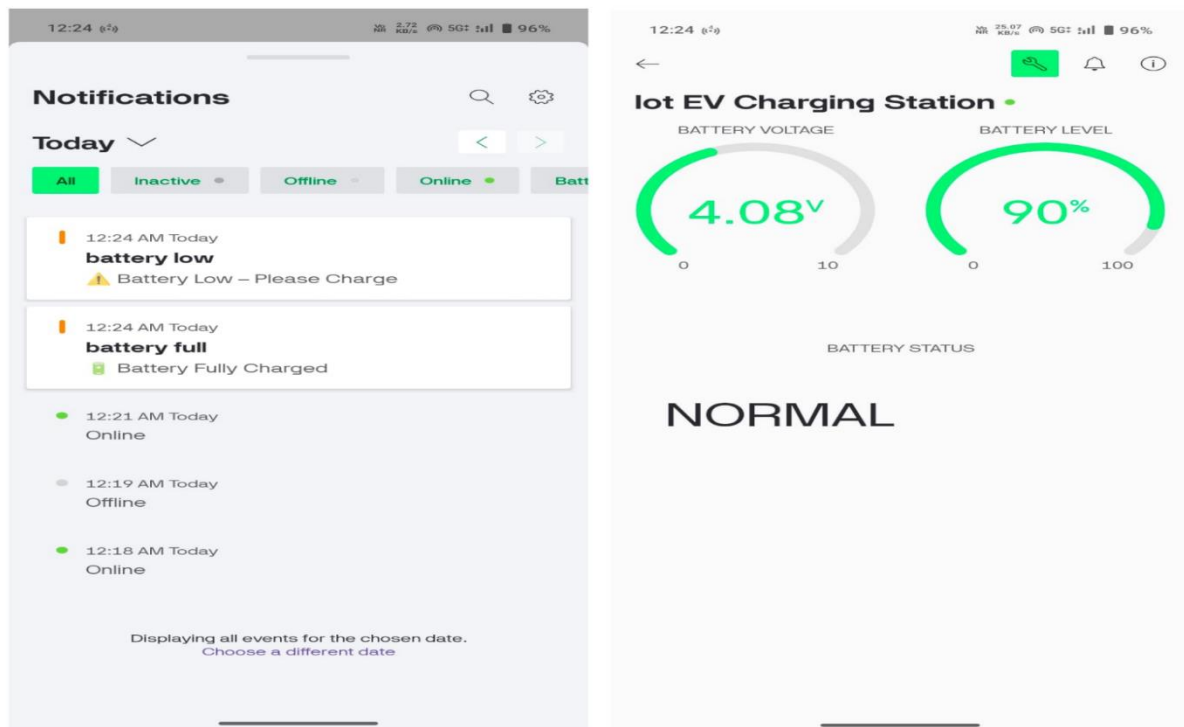


Figure 2: Blynk user interface for suggested system

The expected outcome of this technology is a frictionless energy ecosystem. It transforms the EV from a machine that requires frequent, awkward refueling into a self-sustaining asset that manages its own health, optimizes its energy consumption, and contributes to a decentralized, green power grid (Table 2). The battery is no longer just

a storage tank; through IoT and solar-wireless integration, it becomes a smart, communicative component of a modern, intelligent infrastructure. Figure 3 shows the Blynk user interface for proposed system.

Table 2: The Shift in Paradigm

Feature	Current Wired System	Solar-Wireless IoT System
Operation	Manual, active effort	Hands-free, passive
Energy Source	Grid (mostly fossil)	Solar (renewable)
Maintenance	Reactive (when broke)	Predictive (data-driven)
Hardware	High wear & tear	Solid-state / Weather-shielded
Grid Role	Single-direction Load	Dynamic Energy Hub

4. CONCLUSION

In conclusion, this project successfully demonstrates that the convergence of wireless power transfer, solar energy, and IoT connectivity is the key to accelerating the widespread adoption of electric vehicles. By removing the physical barriers of plug-in charging and utilizing clean solar energy, the proposed station significantly reduces the carbon footprint associated with EV maintenance. The integration of IoT monitoring ensures that the nature of EV batteries is replaced with transparent, data-driven health tracking, preventing overcharging and thermal degradation.

While the system proves the technical feasibility of stationary wireless charging, the modular nature of this design allows for future scalability, including the potential for dynamic "charging-while-driving" infrastructure. The synergy between autonomous power generation and remote diagnostic monitoring marks a pivotal step toward smarter, greener, and more resilient urban mobility. Moving forward, continued refinement of electromagnetic transfer efficiency and the integration of machine learning algorithms for predictive battery maintenance will further solidify this system as an essential component of the future smart city grid.

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