

# Wireless EV Charging System with BMS & ML-Based Battery Life Prediction

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## Abstract

Wireless charging for electric vehicles (EVs) is an innovative solution that supports the vision of smart cities by enabling seamless and automated energy transfer. The proposed system removes the need for physical plugs and cables by using resonant inductive coupling for wireless power transfer. The system integrates ESP32 microcontrollers, IoT communication, real-time monitoring, and machine learning-based battery health prediction. Charging infrastructure can be embedded in parking spaces, garages, roads, and transit hubs. When an EV parks over a charging pad, energy transfer begins automatically without driver intervention. The proposed system enhances convenience, safety, reliability, and battery lifespan while supporting future smart city infrastructure. Machine learning algorithms analyze voltage, current, charging cycles, and operational data to estimate battery State of Health (SoH) and Remaining Useful Life (RUL). IoT integration enables cloud-based monitoring, analytics, and predictive maintenance. The system provides a scalable and intelligent charging solution suitable for sustainable transportation ecosystems.

**Keywords:** Wireless Charging, Electric Vehicles, ESP32, IoT, Smart Cities, Machine Learning, Battery Health Prediction, Resonant Inductive Coupling

## 1. Introduction

The rapid growth of electric vehicles has increased the demand for efficient, safe, and intelligent charging systems. Conventional wired charging methods suffer from several limitations such as connector wear, manual handling inconvenience, electrical safety concerns, and maintenance requirements. Wireless Power Transfer (WPT) technology has emerged as a promising alternative that eliminates physical connectors and improves charging convenience.

The proposed system uses resonant inductive coupling to transfer power wirelessly between transmitter and receiver coils. An ESP32-based control system manages sensing, communication, and charging automation. The station module detects vehicle presence using an IR sensor and activates charging through relay-controlled power transfer. The vehicle module receives power through wireless coils, regulates

voltage, and charges the battery safely. IoT integration enables cloud-based monitoring while machine learning algorithms predict battery degradation and improve maintenance planning.

## 2. Literature Survey

Recent research has focused on wireless EV charging technologies, IoT integration, and smart city applications. Naoui Mohamed et al. (2022) analyzed wireless charging systems including inductive and resonant power transfer methods. M. M. Irfan and S. S. Rangarajan (2024) reviewed dynamic wireless charging and compensation topologies. Xiang Ma et al. (2024) discussed communication standards such as ISO/IEC 15118 and SAE J2954 for EV charging systems. Several researchers emphasized the importance of automation, cloud communication, battery monitoring, and intelligent analytics for future EV charging infrastructure.

However, existing systems lack integrated battery health prediction, real-time monitoring, and scalable smart city deployment. The proposed system addresses these gaps using IoT-enabled monitoring, ESP32 automation, machine learning-based battery analytics, and resonant wireless charging.

## 3. Problem Statement

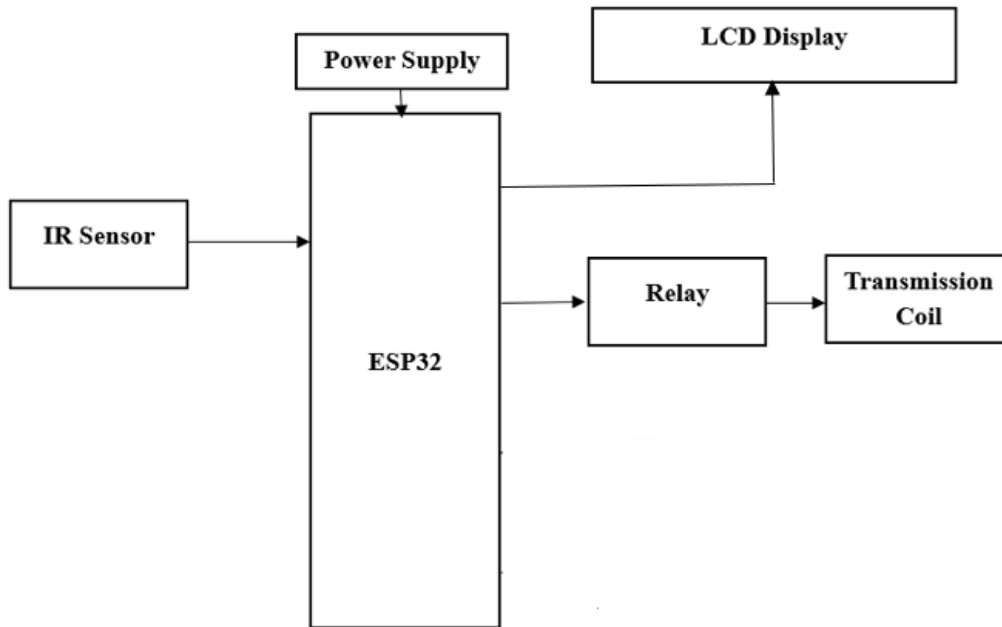
Battery degradation and inefficient charging infrastructure remain major challenges in EV technology. Existing charging systems do not provide predictive battery analytics or intelligent monitoring. Conventional wired charging also introduces connector damage, maintenance cost, and operational inconvenience. Therefore, an intelligent wireless charging system integrated with IoT and machine learning is required to improve charging efficiency, battery lifespan, and smart city compatibility.

## 4. Objectives

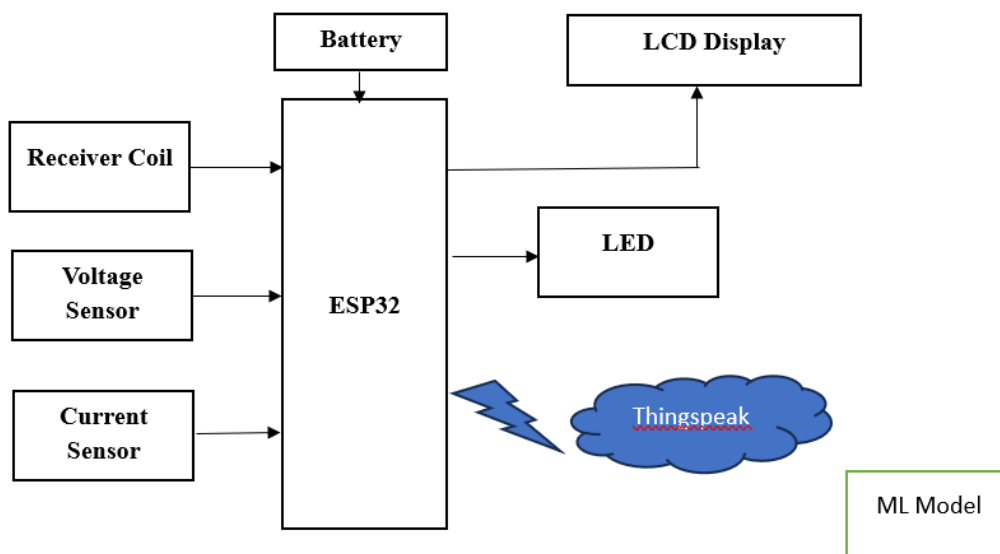
- Design an efficient wireless charging infrastructure for EVs.
- Implement ESP32-based automation and monitoring.
- Enable IoT-based real-time cloud communication.
- Monitor voltage, current, and charging parameters continuously.
- Predict battery State of Health (SoH) using machine learning.
- Improve charging safety, efficiency, and battery lifespan.

### 5. Methodology

**Station Module:**



**Vehicle Model:**



The proposed system consists of three major modules: Station Module, Vehicle Module, and Machine Learning & Cloud Integration Module.

The Station Module includes an ESP32, IR sensor, LCD display, relay module, and transmitter coil. When a vehicle is detected by the IR sensor, the ESP32 activates the relay to energize the transmitter coil. The LCD displays charging status and system messages.

The Vehicle Module contains a receiver coil, rectifier circuit, voltage regulator, battery, voltage sensor,

current sensor, and ESP32 controller. The receiver coil captures the electromagnetic field generated by the transmitter and converts it into usable electrical energy. The ESP32 monitors charging voltage, current, power, and battery State of Charge (SoC).

IoT integration enables cloud-based data storage and monitoring. Historical battery data including voltage, current, charging cycles, and temperature variations are analyzed using machine learning algorithms to predict battery State of Health and Remaining Useful Life.

## 6. Hardware Requirements

- ESP32 Microcontroller
- LCD Display
- Voltage Sensor
- Current Sensor
- IR Sensor
- Relay Module
- Battery
- Wireless Transmitter Coil
- Wireless Receiver Coil

## 7. Software Requirements

- Arduino IDE
- Embedded C
- Python
- IoT Cloud Platform

## 8. Results and Discussion

The proposed wireless EV charging system demonstrated successful wireless energy transfer using resonant inductive coupling. Real-time monitoring of voltage and current was achieved through ESP32 and IoT integration. Experimental results showed battery voltage increasing from 0.0V to 3.29V during wireless charging, confirming successful energy transfer.

The system achieved improved efficiency, automation, safety, and monitoring compared to conventional charging systems. Machine learning algorithms successfully predicted battery health trends and Remaining Useful Life. Cloud connectivity enabled remote monitoring, data analytics, and predictive maintenance. The proposed architecture demonstrated scalability and smart city compatibility for future EV charging infrastructure.

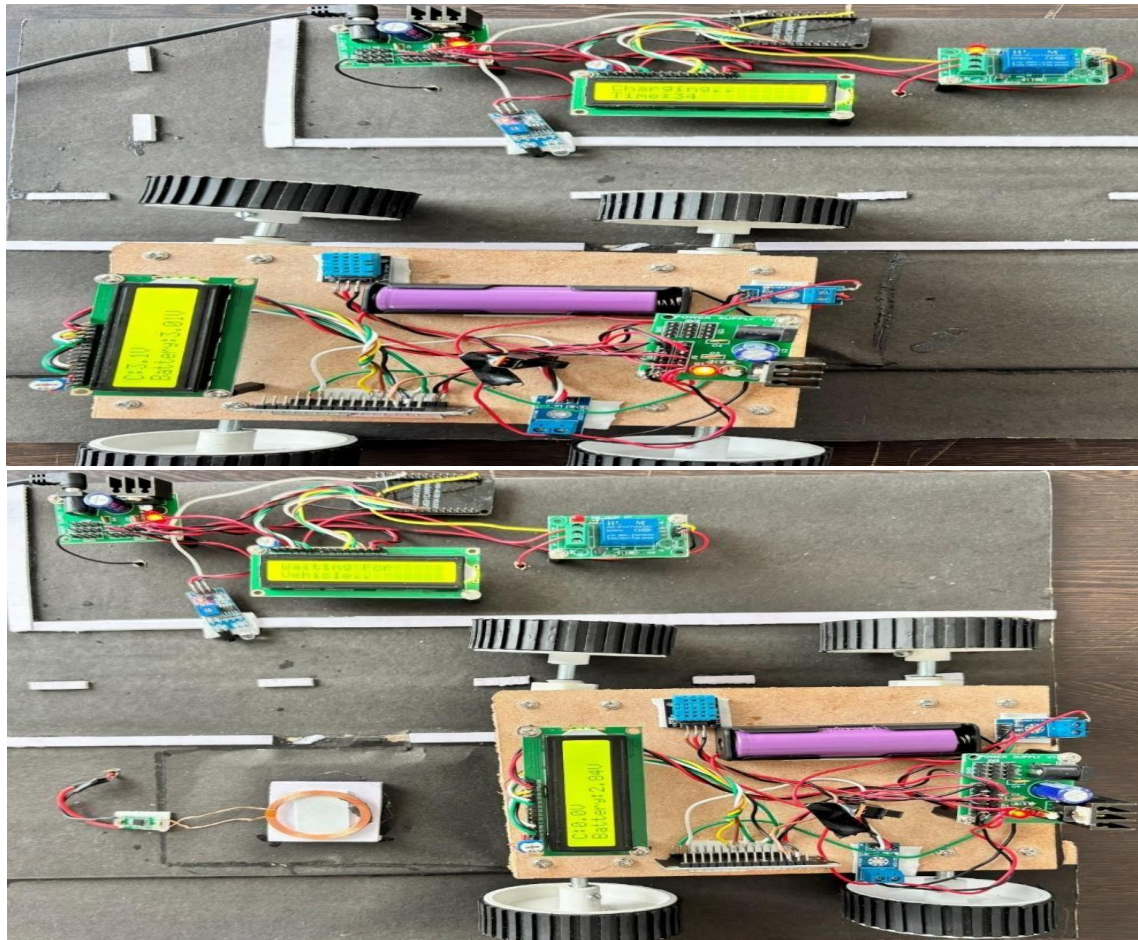


Fig 8.1: Prototype

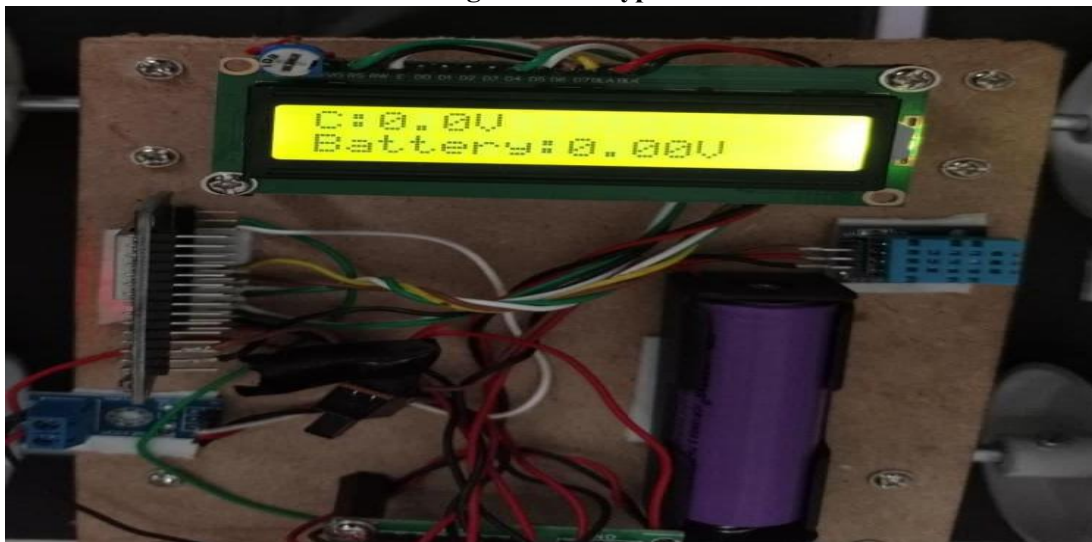


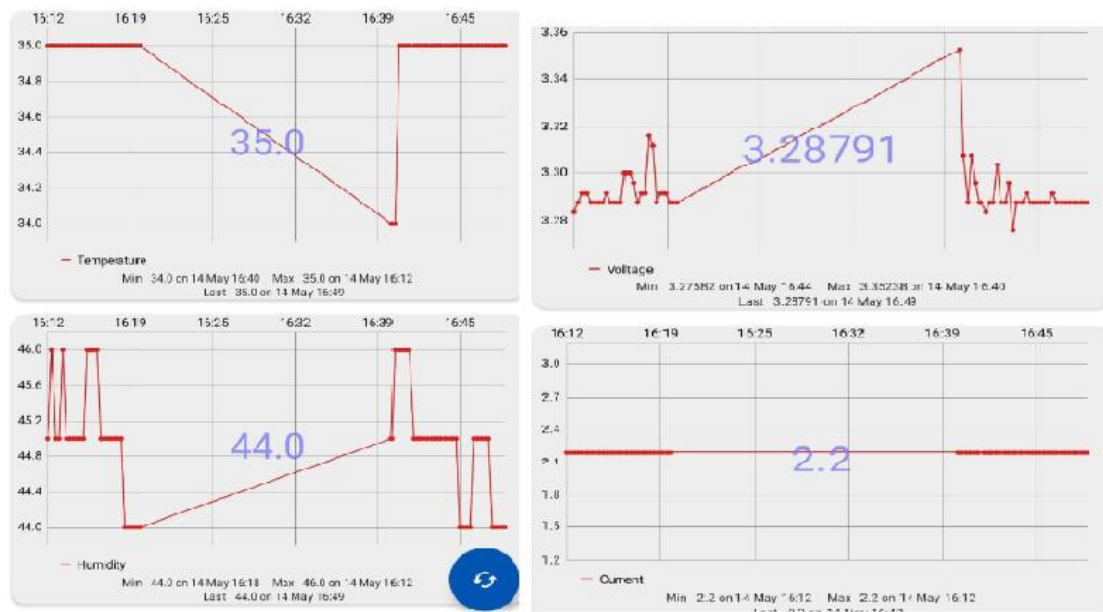
Fig 8.2: Initial coil and the battery voltage of 0.0v



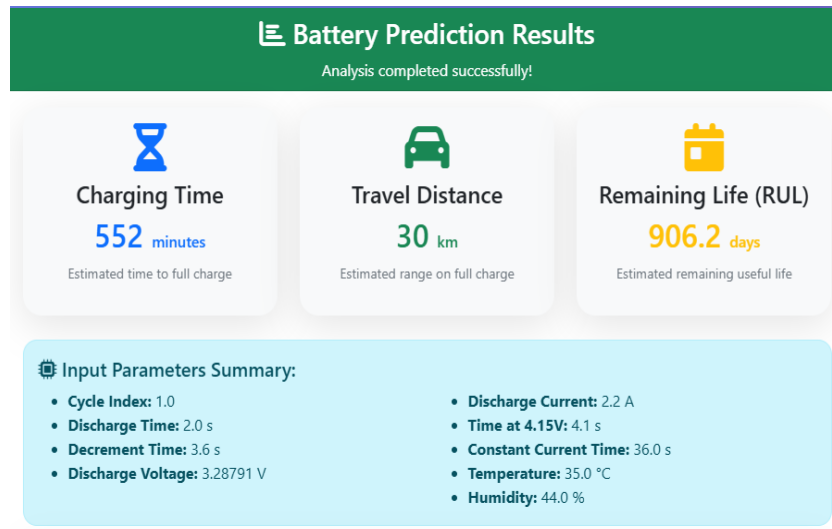
**Fig 8.3: Battery voltage has increased to 3.29V, confirming that wireless charging successfully transferred power.**



**Fig 8.4: Humidity and temperature readings**



**Fig 8.5: Think speak Output**



**Fig 8.7: Battery life prediction**

## 9. Applications

- Smart public charging stations
- Dynamic wireless charging roads
- Smart parking systems
- Electric public transportation
- Autonomous EV charging systems
- Smart homes and commercial buildings
- Renewable energy integrated charging stations
- Vehicle-to-Grid (V2G) applications

## 10. Conclusion

The proposed Wireless EV Charging System provides an intelligent, scalable, and sustainable charging solution for next-generation smart cities. By integrating resonant inductive charging, ESP32 automation, IoT communication, and machine learning-based battery health prediction, the system improves charging efficiency, user convenience, safety, and battery lifespan. The modular architecture and cloud integration make the system suitable for future smart transportation ecosystems and sustainable urban infrastructure.

## 11. Future Scope

- Dynamic on-road wireless charging
- AI-based Battery Management System
- Solar-powered wireless charging stations
- Fast wireless charging through optimized coil design
- Mobile app-based monitoring and billing
- Vehicle-to-Grid (V2G) compatibility

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