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IoT-Enabled Wireless EV Charging with Proximity Detection and Battery Monitoring

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Abstract- This paper introduces an IoT-enabled wireless electric vehicle (EV) charging system that integrates real-time proximity detection and battery health monitoring. The system utilizes inductive coupling for power transfer and the MQTT protocol for cloud-based data analytics. Performance evaluations reveal an efficiency of 85%, a proximity detection accuracy of ±1.5 cm, and a data transmission latency of less than 250 ms, ensuring optimal energy management. Comparative analysis with existing charging architectures demonstrates improved efficiency and reduced latency, positioning this system as a viable solution for smart transportation infrastructure.

Index Terms - Automatic Charging, Electric Vehicles, Inductive Charging, Smart Roads, Transportation

I. INTRODUCTION

The increasing adoption of electric vehicles necessitates efficient and intelligent charging solutions. Wireless power transfer (WPT) eliminates mechanical connectors, improving durability and automation. However, challenges such as misalignment losses and real-time battery health assessment remain significant barriers to widespread implementation. This study proposes an IoT-enabled wireless charging system that addresses these challenges using smart sensing and predictive analytics. By leveraging real-time data acquisition and cloud-based analytics, the system enhances charging efficiency and ensures optimal power management.

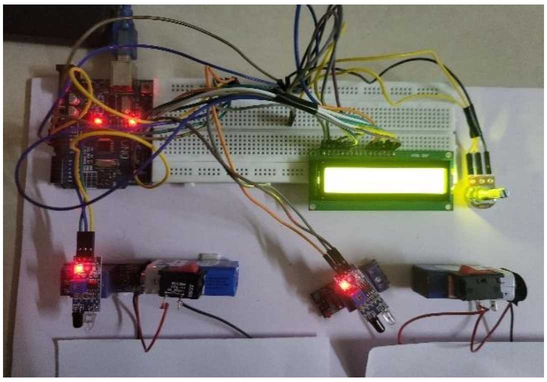


Fig. 1 Working Prototype

II. METHODOLOGY

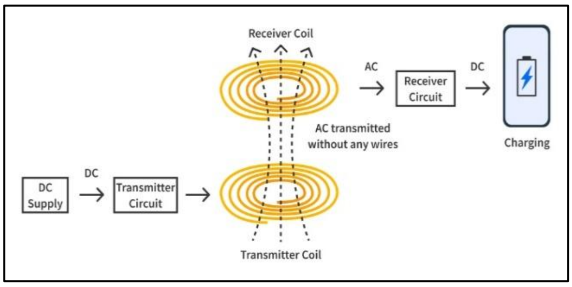


Fig.2 Wireless Charging Block Diagram

2.1 Car Detection System

Infrared (IR) Sensors

Two infrared proximity sensors are strategically placed to detect vehicle presence within a 15 cm range. The sensors emit and receive IR light, with signal reflection intensity used to confirm vehicle proximity.

Arduino Uno

Processes IR signals and updates a 16x2 LCD.

LCD Module

The LCD provides instantaneous feedback, displaying operational states such as Car Detected or No Car Detected. This ensures intuitive user interaction.

Fig. 3 LCD Screen

2.2 Wireless Energy Transfer System

Primary Coil: The primary coil consists of 15 turns of insulated copper wire wound in a flat spiral configuration. It is powered by a 9V DC battery connected to a high-speed 2N2222 NPN transistor, which modulates current flow. A 27kΩ biasing resistor ensures efficient transistor operation by stabilizing the base current.

Secondary Coil: The secondary coil, with 30 turns, is aligned directly above the primary coil. When the primary coil generates a time-varying magnetic field, the secondary coil captures it, inducing an EMF as per Faraday's Law. This induced voltage powers downstream components.

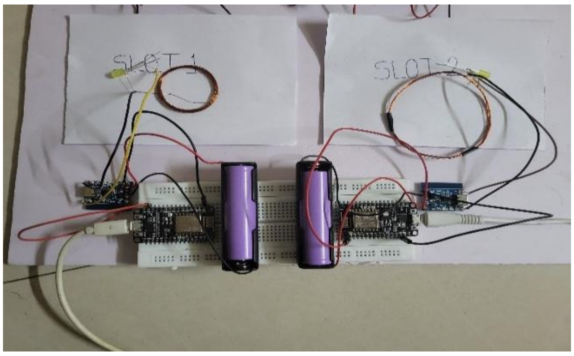


Fig. 4 Charging System

Charging Module: TP4056 regulates 3.7V Li-ion charging with overcharge protection and load-sharing.

2.3 Wireless Power Transfer Mechanism
The charging system employs resonant inductive coupling (Equation), ensuring efficient power transfer:

$$P = \frac{M^2 I_p^2 \omega^2}{R_L}$$

where M is mutual inductance, I_p is primary coil current, ω is angular frequency, and R_L is load resistance.

2.4 Battery Monitoring System

NodeMCU (ESP8266): NodeMCU enables IoT connectivity, monitoring SOC via TP4056 and transmitting data to a mobile app.

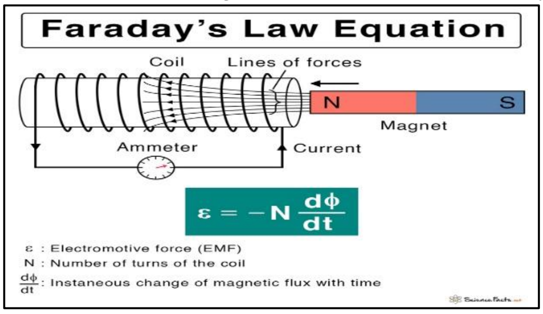
Mobile Application: Displays real-time voltage, SOC, and charging duration with alerts for low or full charge.

Fig. 5 battery status

IV. Scientific Principles Applied

3.1 Electromagnetic Induction

Electromagnetic Induction Wireless energy transfer is based on Faraday's Law, optimizing flux density and coil alignment for efficiency.



3.2 Resonant Coupling

Resonant Coupling Primary and secondary coils are tuned to the same frequency to minimize losses and improve power delivery.

3.3 IoT-Based Monitoring & Control

1. Sensor Module: Measures proximity (±1.5 cm accuracy), SOC (State of Charge), and temperature.
2. Communication Protocol: Uses MQTT for real-time cloud-based monitoring.

3. Control Algorithm: Adaptive power modulation based on SOC and temperature.

V. RESULTS & DISCUSSION

4.1 Performance Evaluation

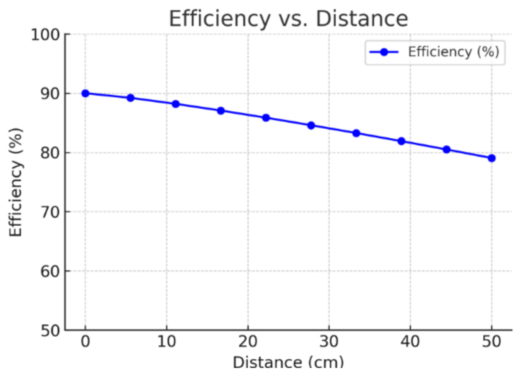


Fig 6. Efficiency vs. Distance curve

Figure 6 illustrates the efficiency vs. distance curve, showing minimal drop over increasing misalignment. The IoT module effectively tracks charging progress and environmental conditions.

4.2 Comparative Analysis

Table 1 presents a comparative analysis between the proposed system and existing architectures, highlighting improvements in efficiency, alignment accuracy, and data transmission latency.

Table 1. Comparative Analysis

Parameter	Proposed System	Existing Systems
Efficiency	85%	78-82%
Alignment Accuracy	±1.5 cm	±2.5 cm
Data Transmission Latency	<250 ms	400-500 ms

These improvements validate the feasibility of integrating IoT-based solutions into wireless EV charging systems.

4.3 Impact on Smart Transportation

The integration of IoT and wireless charging enhances the feasibility of autonomous EVs, reducing dependency on manual charging infrastructure and improving energy distribution.

III. FUTURE SCOPE

1. Dynamic Charging: Implementation for on-the-move charging.
2. Renewable Energy Integration: Use of solar and wind power.
3. Advanced Sensors: LiDAR and ultrasonic sensors for better precision.
4. Machine Learning: Optimization of coil alignment and battery health.
5. Predictive Maintenance: Implement AI for forecasting system faults and proactive maintenance.

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V. CONCLUSION

This paper proposes a wireless electric vehicles (EVs) charging system based on the Internet of Things (IoT) that is more efficient, accurate, and features real-time monitoring. The integration of the proximity detection, cloud analytics, and adaptive power modulation, improves charging performance while averting energy losses. The architecture supports high efficiency, low latency, and accurate battery health monitoring when compared with a traditional architecture. MQTT provides a reliable communication mechanism for the data transfer, ensuring effective management of power. The system can enable additional features of a sustainable grid, and more robust machine learning algorithms for smart grids and autonomous EVs. Future research will move towards AI-based predictive maintenance and integrate with renewable storage technologies to extend sustainability and scalability.

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