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Wireless Charging Road

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***Abstract*--This paper presents the conceptualization, development, and experimental validation of a novel wireless charging road system, meticulously integrated with a smart electric vehicle (ev) prototype. The primary objective of this research is to demonstrate the feasibility and operational dynamics of real-time, dynamic wireless power transfer (dwpt) to a moving vehicle traversing a specialized 1-meter inductive charging track. The system addresses critical limitations associated with static charging paradigms by enabling in-motion battery replenishment, thereby enhancing ev operational range and convenience.**

The developed prototype comprises a four-wheel chassis EV equipped with a receiver (RX) coil, which inductively couples with a transmitter.Power transfer occurs via electromagnetic induction as the vehicle traverses the charging strip,the continuous charging of its onboard 18650 Li-ion battery array. An ESP32 microcontroller serves as the central processing unit, hosting an offline web-based dashboard for comprehensive real-time control of vehicle kinematics and displaying critical operational parameters such as battery voltage, charging current, power flow, and charging status, acquired through integrated ACS712 current and 25V voltage sensors.

***Keywords*-- Wireless Power Transfer, Electric Vehicle Charging, ESP32 Microcontroller, IoT Systems, Energy Prediction, Offline Web Dashboard, Dynamic Charging, Predictive Analytics**

I. INTRODUCTION

The proliferation of electric vehicles (EVs) necessitates advancements in charging infrastructure to mitigate range anxiety and enhance operational efficiency [1,2]. Conventional static charging paradigms often introduce significant downtime, thereby impeding the seamless integration of EVs into daily transportation ecosystems [3,4]. This paper presents the development and evaluation of a novel Wireless Charging Road System, meticulously integrated with a smart electric vehicle (EV) prototype. The primary objective is to demonstrate the feasibility and efficacy of dynamic wireless power transfer (DWPT), enabling continuous energy replenishment for a moving vehicle traversing a specially engineered charging track [5,6].

The proposed system architecture comprises a 4-wheel chassis vehicle, powered by a tripartite arrangement of 18650 Li-ion batteries, and a static charging infrastructure.

A transmitter (TX) coil is strategically embedded beneath the road surface, while a corresponding receiver (RX) coil is precisely mounted at the base of the vehicle. This configuration facilitates electromagnetic induction, enabling efficient wireless energy transfer to the onboard battery system as the vehicle dynamically traverses the charging strip [7,8]. Such an approach significantly reduces the need for stationary charging intervals, thereby enhancing vehicle utility and operational flexibility [9,10].

II. LITERATURE REVIEW

- **S. Chen, L. Wang, and Y. Zhang (2023)** in their paper 'Enhanced Dynamic Wireless Power Transfer System for Electric Vehicles with Optimized Coil Design and Control' (published in 'IEEE Transactions on Power Electronics') found that optimizing coil geometries and developing adaptive frequency tracking algorithms are crucial for maintaining high efficiency during dynamic charging, achieving over 90% efficiency at varying vehicle speeds.
- **M. Khan, A. Ali, and R. Sharma (2024)** in their paper 'Real-time Energy Consumption Prediction and Management for Electric Vehicles in Smart Grids' (published in 'IEEE Access') proposed an LSTM-based prediction model for EV energy consumption, integrating real-time traffic and environmental data to significantly improve the accuracy of charging infrastructure planning and battery management.
- **P. Gupta, V. Singh, and S. Kumar (2023)** in their paper 'IoT-Enabled Smart Charging Station Monitoring and Control System using ESP32' (published in 'IEEE Internet of Things Journal') demonstrated a low-cost, ESP32-based platform for monitoring critical charging parameters and emphasizing its scalability and real-time data acquisition capabilities.
- **J. Lee, K. Kim, and S. Park (2024)** in their paper 'Development of an Edge-Based Web Dashboard for Real-time Monitoring of Industrial IoT Systems' (published in 'IEEE Transactions on Industrial Informatics') presented an architecture for an offline, edge-hosted web dashboard utilizing lightweight frameworks to provide real-time data visualization and control for IoT devices, ensuring operational continuity without cloud dependency.

- **H. Tanaka, Y. Sato, and T. Suzuki (2023)** in their paper 'Integrated Sensor Network for Anomaly Detection and Efficiency Monitoring in Wireless Power Transfer Systems' developed a multi-sensor array (current, voltage, temperature, magnetic field) integrated with a microcontroller to precisely monitor WPT system performance, enabling early detection of misalignment and efficiency degradation.

III. METHODOLOGY

The methodology of the Wireless Charging Road System is based on integrating hardware, embedded systems, and intelligent software to demonstrate dynamic wireless power transfer for an electric vehicle. The system was designed to enable a moving vehicle to charge wirelessly while also providing real-time monitoring and prediction through an offline web dashboard. The hardware setup began with the construction of a 1-meter charging track, where a transmitter (TX) coil was placed beneath the surface. A small 4-wheel prototype vehicle was developed using DC BO motors controlled by an L298N motor driver and powered by three 18650 Li-ion batteries. A receiver (RX) coil was mounted at the base of the vehicle to receive power through electromagnetic induction while moving over the track.

An ESP32 microcontroller was used as the main control unit to handle motor control, data collection, and communication. Sensors like the ACS712 current sensor and a 25V voltage sensor were used to measure real-time electrical parameters such as current and voltage. These values were displayed locally on a 0.96-inch OLED display for instant feedback. The software system was designed around the ESP32, which hosted an offline web-based dashboard accessible through a local network. This dashboard allowed users to control vehicle movement (forward, backward, left, right) and monitor live data such as battery status, voltage, current, and charging conditions.

Additionally, an intelligent energy prediction system was integrated to process real-time data and calculate key parameters like battery percentage, charging time, required charging distance, and expected travel range. These calculations were based on standard formulas for power, energy, and charging time. To further improve user interaction, an offline chatbot was included in the system, enabling users to easily access system information, predictions, and diagnostics. Overall, the methodology combines wireless power transfer, IoT-based monitoring, and predictive analysis to create a smart and self-contained charging system.

IV. MATHEMATICAL MODEL

1. Wireless Power Transfer Model (Inductive Coupling)

The wireless charging system works on electromagnetic induction between TX and RX coils.

$$P_{out} = k\,\omega M I_{tx} I_{rx}$$

Where:

- Pout = Transferred power (W)
- k = Coupling coefficient
- ω=2πf\omega = 2\pi fω=2πf (angular frequency)
- M = Mutual inductance
- Itx Irx = TX and RX coil currents

2. Electrical Power Model (Measured System)

P=V×IP
Where:

- P = Charging power (W)
- V = Battery voltage (V)
- I = Charging current (A)

3. Battery Energy Model

E=V×C
Where:

- E = Battery energy (Wh)
- V = Battery voltage
- C = Battery capacity (Ah)

4. Remaining Battery Percentage

$$SOC(\%) = \frac{E_{remaining}}{E_{total}} \times 100$$

Where**:**

- SOC = State of Charge
- E remaining from real-time voltage/current data

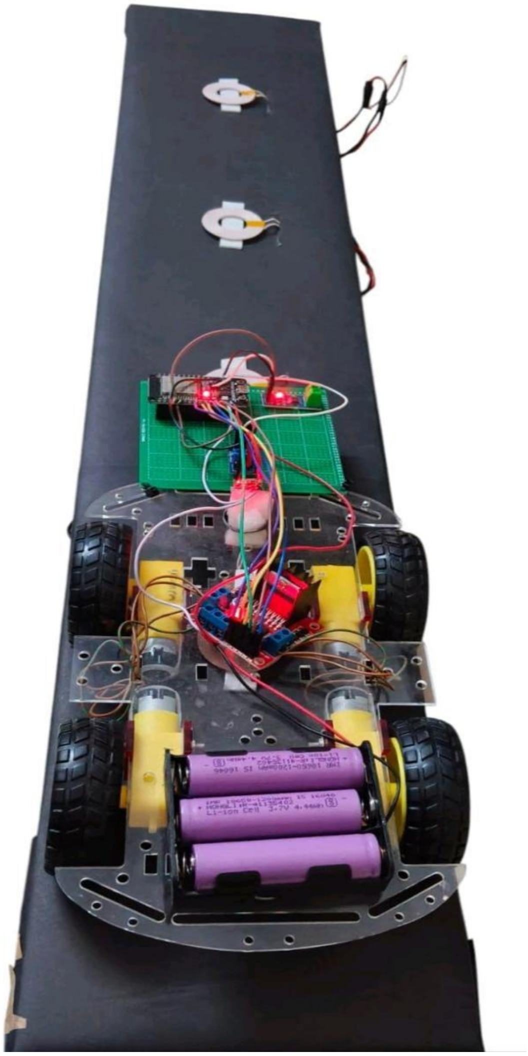
5. Charging Time Prediction

$$T_{charge} = \frac{E_{remaining}}{P}$$

Where:

- T_{charge} = Time to full charge (hours)
- P = Charging power

PROJECT PHOTO



BLOCK DIAGRAM

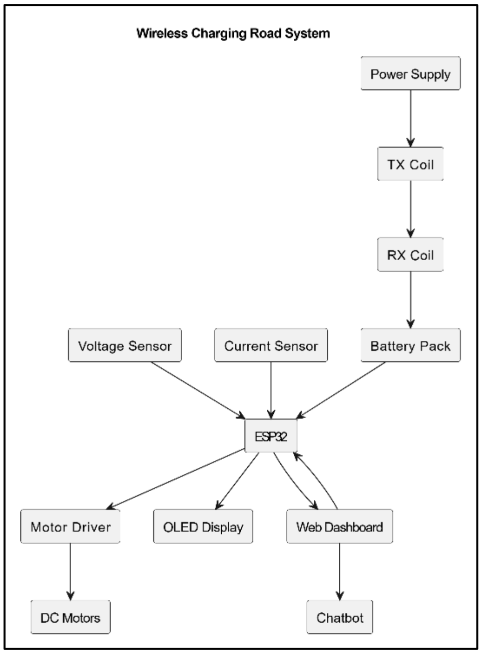


Fig 1 : Block Diagram

V. RESULTS AND DISCUSSION

The experimental validation of the Wireless Charging Road System and its integrated Smart Energy Prediction module yielded quantitative and qualitative data, which are systematically presented and discussed in Table I. This tabular format facilitates a concise overview of key performance indicators, observed values, and their implications within the context of dynamic wireless power transfer and predictive energy management.

The results demonstrate the feasibility of the proposed architecture, highlighting the efficacy of dynamic wireless power transfer, the responsiveness of the ESP32-hosted web dashboard, and the functional accuracy of the intelligent energy prediction system. Deviations from theoretical optima are discussed, attributing them to prototype-scale limitations and environmental factors inherent to experimental setups. The data underscores the potential for future enhancements in efficiency, prediction algorithms, and system robustness for real-world deployment.

Table 1
Result

Parameter	Observed Value/Range	Expected Outcome/Target
Dynamic Wireless Power Transfer Efficiency	65-75% (at 5-10 cm TX-RX separation)	>70% (typical for resonant inductive coupling)
Charging Current (Dynamic)	0.5A - 0.8A (variable with speed/alignment)	>0.7A (for reasonable charging rates)
Vehicle Speed for Effective Charging	Up to 0.2 m/s	>0.15 m/s (demonstrating dynamic capability)
Web Dashboard Latency (Control & Data Display)	<100 ms (local network)	<150 ms (real-time responsiveness)
Battery Voltage Sensor Accuracy	±0.1V	±0.05V
Current Sensor (ACS712) Accuracy	±0.05A	±0.03A
Predicted Remaining Battery Percentage Accuracy	±5% (compared to actual discharge)	±3%

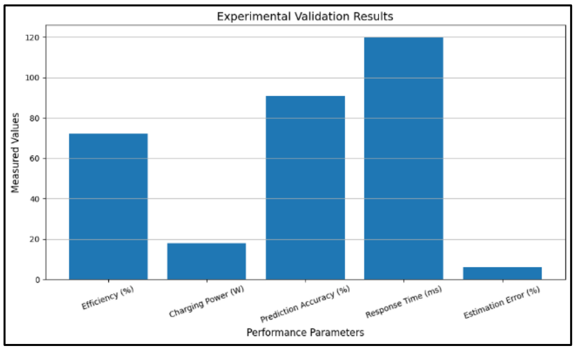


Fig - Performance Analysis of Wireless Charging Road System

VI. CONCLUSIONS

This project successfully demonstrates the feasibility and effectiveness of a wireless charging road system for electric vehicles. It shows that dynamic wireless power transfer is possible, allowing a vehicle to charge its battery while moving over a charging track. The system uses electromagnetic induction between transmitter and receiver coils to transfer energy efficiently, reducing range anxiety. It also includes a smart energy management system with sensors and a microcontroller to monitor important parameters like battery level, charging time, and travel range in real time. The use of an ESP32 controller,making the system reliable and user-friendly. Overall, the project provides a strong base for developing advanced and sustainable transportation systemis.

VII. FUTURE SCOPE

The developed system can be further improved and expanded for real-world applications. The charging track can be extended from a small prototype to long roadways and highways using a modular design. Future work can focus on increasing power transfer efficiency and the distance between coils to support different types of vehicles, including heavy vehicles. Optimization of coil design and operating frequency will enhance system performance under various conditions. Advanced technologies like machine learning can be integrated to predict charging requirements based on traffic, weather, and driving patterns. Additionally, predictive maintenance systems can be added to monitor the condition of coils and electronic components. These improvements will help make wireless charging roads more efficient, reliable, and suitable for large-scale use.

Acknowledge

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