



# On-Road Wireless EV Charging System Using IoT

**Dr.M.Ramesh Kumar, Jayaraman C, Killivalavan V, Abishek S**

Under the Guidance of Dr. M. Ramesh Kumar M.E., Ph.D.  
Professor and Head, Department of CSE (Internet of Things)  
Paavai Engineering College, Namakkal, India

**Abstract-** This paper presents the design and experimental validation of an On-Road Wireless EV Charging System integrated with Internet of Things (IoT) monitoring. The system embeds resonant inductive transmitter coils beneath road surfaces at high-dwell locations such as traffic intersections and toll plazas, enabling contactless energy transfer without mandatory vehicle downtime. An ESP32-based edge controller manages closed-loop power regulation and RFID-based vehicle authentication, while a Firebase cloud backend and Flask web dashboard deliver real-time telemetry, session management, and automated billing. Experimental results confirm a DC-to-DC transfer efficiency of 83.2% at a 10 mm air gap and energy metering accuracy within  $\pm 1.4\%$  of reference instruments. The system successfully passed all functional test cases including cloud synchronization, fault detection, and session deduplication, demonstrating a viable path toward eliminating range anxiety in urban EV ecosystems.

**Keywords—**Wireless EV Charging, Resonant Inductive Coupling, IoT, ESP32, Firebase, RFID Authentication, Smart Infrastructure.

## I. INTRODUCTION

The proliferation of electric vehicles (EVs) across global transport networks has exposed a critical infrastructure bottleneck: the inadequacy of conventional plug-in charging. Static charging stations require mandatory vehicle downtime ranging from 30 minutes to several hours, impose range anxiety on drivers, and demand costly fixed installations at predefined geographic points [1].

Dynamic and quasi-dynamic wireless power transfer (WPT) resolves these structural limitations by embedding inductive transmitter coils beneath road surfaces and charging EVs during natural stops—traffic signals, toll booths, and parking bays—without any physical connector. When combined with IoT sensing and cloud analytics, such a system transforms passive road infrastructure into an intelligent, self-monitoring energy delivery network [2].

This paper presents the complete hardware-software co-design of an On-Road Wireless EV Charging System using IoT, covering resonant coil topology, ESP32 firmware, Firebase cloud integration, and Flask dashboard, validated through laboratory prototype testing.

### **Cloud Layer (Firebase):**

A hierarchical NoSQL JSON tree organises session logs by date, zone ID, and vehicle ID. Asynchronous background threads push records without blocking the power control loop. A local SQLite database caches data during connectivity loss and synchronises upon reconnection.



### **User Interface Layer (Flask Dashboard):**

A Flask web server streams live sensor data using Python generator functions (Server-Sent Events), rendering real-time coil current, voltage, active sessions, and alert banners on an HTML5/JS dashboard accessible from any device.

Fig. 1 depicts the five-layer architecture and data-flow paths between physical hardware and the operator dashboard.

Fig. 1. Layered system architecture: Physical → Edge → Communication → Cloud → UI

## **II. SYSTEM ARCHITECTURE**

The platform follows a localized edge-processing paradigm combined with cloud synchronization. All time-critical computation—power regulation, closed-loop current control, and RFID authentication—executes on an ESP32 edge controller co-located with the charging pad, eliminating cloud-dependent latency in the control loop. Non-critical analytics and historical records are offloaded to Firebase.

The architecture spans five layers:

### **Physical Layer:**

Litz-wire transmitter coils (150 mm diameter, 10-turn) embedded beneath 15 mm of road surface generate an alternating magnetic field. Current, voltage, temperature, and object-detection sensors feed raw telemetry to the edge node.

### **Edge Processing Layer:**

The ESP32-WROOM-32 (dual-core 240 MHz) runs a FreeRTOS application with dedicated tasks for ADC sampling, PWM generation, RFID polling, and MQTT transmission.

### **Communication Layer:**

Processed telemetry is published over Wi-Fi using lightweight MQTT packets to a Raspberry Pi 4 broker, minimising bandwidth and control-loop jitter.

## **III. KEY MODULES**

### **A. Wireless Power Transfer Control Module**

The WPT subsystem uses a series-series (SS) LC compensated topology. Transmitter and receiver coils are independently tuned to a shared resonant frequency (85–145 kHz, per SAE J2954) to cancel reactive impedance and maximise real power across the air gap [3].

Closed-loop current control is implemented by sampling the transmitter coil current via an ACS712 Hall-effect sensor at 100 ms intervals. The ESP32 adjusts the inverter duty cycle to maintain current within safe operating bounds. A vehicle is flagged present only after the proximity loop confirms metallic chassis detection, after which the RFID authentication gate opens.

### **B. IoT Energy Monitoring Module**

Accurate power metering of high-frequency AC waveforms employs a sliding-window RMS algorithm. The ESP32 ADC accumulates  $N$  samples into a fixed-length buffer; the RMS voltage and current are computed as:

$$V_{rms} = \sqrt{(1/N \cdot \sum v^2_i)}, \quad I_{rms} = \sqrt{(1/N \cdot \sum i^2_i)}$$



Instantaneous power  $P = V_{rms} \cdot I_{rms} \cdot \cos(\varphi)$ , where  $\varphi$  is measured via zero-crossing detection. Session energy is the time-integral of  $P$  over the charging duration. The sliding-window approach provides continuous updates without halting acquisition.

### C. RFID Vehicle Authentication & Deduplication

When a vehicle is detected, the MFRC522 reader (13.56 MHz HF) captures the 64-bit EPC code returned by the vehicle-mounted passive transponder. The ESP32 matches the EPC against registered entries in the local SQLite database. A session is opened only if: (i) the EPC matches a registered record, and (ii) no active session exists for that vehicle on the current date—enforcing strict deduplication to prevent double-billing. Unrecognised codes are timestamped and logged to a security dashboard table.

### C. Energy Metering Accuracy

The sliding-window RMS algorithm reported power within  $\pm 1.4\%$  of reference meter readings across a 10W resistive load. The  $\pm 2\%$  design target was comfortably met, validating the algorithm for billing-grade energy accounting.

### D. Functional Test Results

All six planned test cases passed (Table I), covering vehicle detection, RFID authentication, WPT activation, energy metering, cloud synchronisation under network outage, and safety fault handling.

TABLE I. Functional Test Case Summary

TC ID	Module	Status
TC-01	Vehicle Detection	Pass
TC-02	RFID Auth	Pass
TC-03	WPT Efficiency	Pass
TC-04	Energy Metering	Pass
TC-05	Cloud Sync (Offline)	Pass
TC-06	Safety/Fault Alert	Pass

### E. Firebase Integration & Offline Resilience

The Firebase Admin SDK (Python, server-side) pushes session records, live global stats, and administrative alerts to a structured JSON tree. An asynchronous threading model spawns background push commands to decouple cloud I/O from the FreeRTOS power control task. When Wi-Fi is unavailable, all records accumulate in SQLite and are batch-synchronised upon reconnection, guaranteeing zero data loss.

### F. Multi-Role Authentication

Flask session management enforces role-based access control (RBAC). Administrators may configure system parameters and view all zones; fleet managers access per-vehicle reports; vehicle owners view their own session history. Secure cookies with defined expiry times prevent session hijacking, and all login events are audit-logged.

## IV. RESULTS & DISCUSSION

Testing was conducted on a scaled prototype: a 150 mm transmitter coil embedded beneath a 15 mm acrylic panel, paired with a matching 100 mm receiver mounted on an EV chassis mock-up. The ESP32 FreeRTOS application ran concurrently with a Flask server on a Raspberry Pi 4.



### **A. Power Transfer Efficiency**

DC-to-DC transfer efficiency was measured by comparing inverter-stage input power with rectifier output power using calibrated reference instruments. At 10 mm air gap with centre-aligned coils, efficiency reached 83.2%, exceeding the >80% target. A lateral misalignment of 20 mm reduced efficiency to ~71%, underscoring the importance of road-marking guidance in practical deployment.

### **Economic Feasibility**

Total per-zone deployment cost is estimated at ₹47,000 (~USD 565), utilising open-source firmware (ESP-IDF, Python) and the Firebase Spark free tier, eliminating recurring software licensing fees. This compares favourably with proprietary fast-charging hardware installations, supporting scalable smart-city deployment.

## **V. CONCLUSION**

This paper demonstrated a fully operational on-road wireless EV charging system integrating resonant inductive WPT, ESP32 IoT sensing, RFID-based session management, and Firebase cloud analytics. The system achieved 83.2% DC-to-DC efficiency,  $\pm 1.4\%$  metering accuracy, and zero data loss under simulated network outage. RFID deduplication entirely prevents double-billing, while real-time fault detection safeguards coil hardware. Future work will explore Vehicle-to-Grid bidirectional transfer, AI-based frequency optimisation for misalignment compensation, and blockchain-based billing ledgers for multi-operator transparency.

## **REFERENCES**

1. J. Huh et al., "Narrow-width inductive power transfer system for online electrical vehicles," *IEEE Trans. Power Electron.*, vol. 26, no. 12, pp. 3666–3679, 2022.
2. P. Sharma and R. Verma, "IoT-based energy monitoring for EV charging infrastructure," *Int. J. Electr. Eng.*, NIT Trichy, 2020.
3. A. Kurs et al., "Wireless power transfer via strongly coupled magnetic resonances," *Science*, vol. 317, pp. 83–86, 2019.
4. A. Gupta and S. Nair, "Cloud-integrated EV session management and billing," *Proc. IEEE SmartGridComm*, 2022.
5. Zhang et al., "Adaptive wireless power transfer for dynamic EV charging," *IEEE Trans. Transp. Electrif.*, 2021.