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# Wireless Power Transmission for Charging Electric Vehicles

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**ABSTRACT:** This paper presents the Wireless Power Transmission for Charging Electric Vehicles (EVs) that integrates Internet of Things (IoT)-based real-time monitoring with radio-frequency identification (RFID)-enabled automatic billing. The system employs inductive coupling between planar coils to deliver contactless energy from a fixed ground pad to a vehicle-mounted receiver. An infrared (IR) sensor detects vehicle presence; an RFID reader (RC522, 13.56 MHz) authenticates the vehicle against a cloud-hosted database, analogous to the FASTag electronic toll system. Upon successful authentication, the transmitter coil is energized and wirelessly transfers power to the receiver. A DC-DC boost converter (XL6009) conditions the received energy for storage in the traction battery, whose terminal voltage is continuously monitored. Billing data are automatically propagated to a Firebase cloud database after each session, enabling transparent, cashless transactions. Prototype experiments demonstrate peak power-transfer efficiency of 89.5% at 1 cm coil gap and 75.0% at the nominal 3 cm operational gap, RFID authentication latency of 180 ms with 99.5% success rate, and billing accuracy within 1.8% mean absolute percentage error (MAPE). These results confirm feasibility for next-generation autonomous EV charging infrastructure.

**KEYWORDS:** automatic billing, Arduino.

## I. INTRODUCTION

The accelerating global shift from internal combustion engine (ICE) vehicles to electric vehicles (EVs) is driven by tightening emission regulations, falling battery costs, and heightened environmental awareness. As EV adoption grows, demand for convenient, reliable, and safe charging infrastructure has intensified. Conventional plug-in systems introduce mechanical wear, safety hazards in wet environments, and user inconvenience.

Wireless power transfer (WPT) eliminates these limitations through contactless electromagnetic induction. When combined with IoT capabilities, WPT stations can automate vehicle identification, monitor charging in real time, and process billing without human intervention, creating a fully autonomous charging experience.

This paper describes a hardware prototype integrating: (i) IR-based vehicle detection, (ii) RFID authentication modeled on FASTag, (iii) resonant inductive power transfer at 100 kHz,

(iv) DC-DC boost conversion, (v) continuous voltage monitoring, and (vi) cloud-based automatic billing, all implemented on Arduino Nano microcontrollers.

The paper is organized as follows. Section II surveys related work. Section III describes system architecture. Section IV details hardware and software. Section V explains the operating workflow. Section VI presents experimental results. Section VII outlines future enhancements, and Section VIII concludes.

## II. RELATED WORK

Kurs et al. [1] demonstrated magnetically coupled resonant WPT at meter-range distances with efficiency exceeding 40%, providing the theoretical basis for modern EV pad charging. Budhia et al. [2] developed circular pad topologies for vehicle underbody mounting and reported efficiencies above 90% under controlled alignment, establishing the benchmark referenced in this work.

RFID-integrated EV charging was explored by Liu et al. [3], achieving vehicle identification under 200 ms. IoT-based charging telemetry was implemented by Rezk et al. [4] via ThingSpeak, with state-of-charge mean absolute error below

2%. DC-DC boost converter design guidelines from Mohan et al. [5] informed the voltage regulation approach adopted here.

Sallan et al. [6] improved ICPT efficiency through impedance matching. Zhang et al. [9] surveyed series-series, series-parallel, and LCC WPT topologies and their EV trade-offs. Bosshard and Kolar [10] discussed kilowatt-scale efficiency-cost considerations. The present work contributes a complete detection-authentication-transfer-billing pipeline validated on physical hardware.

### III. SYSTEM ARCHITECTURE

The proposed system comprises two principal subsystems—the Transmitter (Station) Block and the Receiver (Vehicle) Block—linked by electromagnetic coupling and cloud data exchange.

#### A. Transmitter Block

Installed at the charging bay ground pad, the transmitter block includes an IR proximity sensor for vehicle detection, an RFID reader (RC522) for authentication, a relay-switched transmitter coil, a 16x2 LCD for status display, an Arduino Nano as central processing unit, and a GSM or Wi-Fi module for cloud connectivity.

#### B. Receiver Block

Mounted on the vehicle underside, the receiver block consists of a magnetically coupled receiver coil, a full-wave bridge rectifier, an XL6009-based DC-DC boost converter, a 0-25 V voltage sensor, the traction battery, and a secondary Arduino Nano for monitoring and cloud communication. Battery voltage is sampled every 5 seconds.

#### C. Cloud and Billing Layer

A Firebase Realtime Database stores account credentials, session logs, and transaction records. After each session, delivered energy is computed from voltage-time integrals, the pre-paid account is debited, and a receipt is issued, enabling fully cashless, contactless billing.

### IV. HARDWARE AND SOFTWARE

#### A. Hardware Components

Table I summarizes the principal hardware components. Two Arduino Nano (ATmega328P, 16 MHz) units serve as station and vehicle microcontrollers. WPT coils are wound from enamelled copper wire: 20 turns, 10 cm diameter, resonant near 100 kHz. The RFID module uses SPI at 13.56 MHz. The voltage sensor employs a resistive divider over a 0-25 V range.

Step 6 - Billing: Delivered energy computed; account debited; transaction logged in cloud database.

TABLE I: Hardware Components and Specifications

Component	Specification	Qty	Role
Arduino Nano	ATmega328P, 16 MHz	2	MCU (Tx & Rx)
WPT Coil (Tx)	Cu, 20T, 10 cm dia.	1	Power Tx
WPT Coil (Rx)	Cu, 20T, 10 cm dia.	1	Power Rx
RFID RC522	13.56 MHz, SPI	1	Authentication
IR Sensor	Digital, 5V	1	Detection
Voltage Sensor	0-25 V, analog	1	Battery Monitor
DC-DC Boost XL6009	V <sub>out</sub> adj., 4A max	1	Regulation
LCD 16x2 I2C	HD44780, 5V	1	Status Display
L298N Motor Driver	Dual H-Bridge, 2A	1	Motor Control
DC Motor	6V, 200 RPM	1	EV Simulation

### B. Software Environment

All firmware is developed in Embedded C using Arduino IDE v2.x. The MFRC522 library drives RFID communication; LiquidCrystal I2C manages the LCD. Cloud updates use HTTP POST requests to Firebase REST API. Timer1 interrupts generate the 100 kHz switching signal for the transmitter coil driver circuit.

## V. WORKING PRINCIPLE AND WORKFLOW

### A. Inductive Power Transfer

Faraday's law governs the system: alternating current in the transmitter coil induces a time-varying magnetic flux which drives an EMF in the receiver coil. Received AC is rectified by a full-wave bridge and stepped up by the boost converter to the required battery charging voltage. The coil- capacitor tank is tuned to 100 kHz. At a 3 cm coil gap the measured coupling coefficient was  $k = 0.45$ , yielding 75% end- to-end efficiency.

### B. Step-by-Step Workflow

The system executes a deterministic sequential workflow:

- Step 1 - Detection: IR sensor sends HIGH signal on vehicle arrival.
- Step 2 - Authentication: RFID reader scans tag; Arduino validates UID against cloud database.
- Step 3 - Activation: Relay energizes transmitter coil upon successful authentication.
- Step 4 - Charging: Receiver captures energy; boost converter stores conditioned DC; voltage sensor monitors every 5 s.
- Step 5 - Termination: Charging stops when battery reaches target voltage or vehicle departs (IR goes LOW).
- Step 6 - Billing: Delivered energy computed; account debited; transaction logged in cloud database

### B. RFID Authentication

Over 200 successive trials across temperatures of 20-45 degrees C and varying ambient light, the system achieved a 99.5% recognition rate with mean latency of 180 ms from tag presentation to relay activation. The 0.5% failure rate was attributed to extreme-temperature coil detuning, addressable through adaptive antenna compensation.

### C. Billing Accuracy

Billing accuracy was evaluated against a calibrated power meter over 50 test sessions. The mean absolute percentage error (MAPE) was 1.8%, within the plus-or-minus 5% tolerance acceptable for commercial billing per IEC 62053-21.

### D. System Response Time

End-to-end latency from vehicle detection to full power delivery averaged 2.3 s over 100 trials. Cloud billing updates completed within 4.1 s of session termination. Table III summarizes all key performance metrics.

## VI. EXPERIMENTAL RESULTS

### A. Power Transfer Efficiency

The prototype was tested across coil gaps from 1 cm to 6 cm. Table II presents measured input power, output power, and efficiency at each gap. Efficiency falls monotonically with increasing separation, consistent with electromagnetic coupling theory. At the nominal 3 cm operational gap, 75.0% efficiency was achieved, consistent with published prototype-scale WPT systems [2].

**TABLE II Power Transfer Efficiency vs. Coil Gap**

Gap (cm)	Pin (W)	Pout (W)	Efficiency (%)
1	12.4	11.1	89.5
2	12.4	10.5	84.7
3	12.4	9.3	75.0
4	12.4	7.8	62.9
5	12.4	5.9	47.6
6	12.4	4.1	33.1

**B. Software Environment**

All firmware is developed in Embedded C using Arduino IDE v2.x. The MFRC522 library drives RFID communication; LiquidCrystal\_I2C manages the LCD. Cloud updates use HTTP POST requests to Firebase REST API. Timer1 interrupts generate the 100 kHz switching signal for the transmitter coil driver circuit.

**TABLE III Summary of System Performance Metrics**

Metric	Value
Peak WPT Efficiency (1 cm gap)	89.5%
Nominal WPT Efficiency (3 cm gap)	75.0%
RFID Success Rate	99.5%
RFID Latency (mean)	180 ms

**VII. FUTURE ENHANCEMENTS**

Several enhancements are planned for future work:

- High-Power Scaling: Extend to 3.3-11 kW compliant with SAE J2954 Level 2 WPT standards.
- Dynamic Charging: Deploy road-embedded transmitter arrays for in-motion vehicle charging.
- Renewable Integration: Couple photovoltaic or wind generation with battery storage for sustainable station power.
- Advanced IoT: Migrate to AWS IoT Core or ThingSpeak for predictive maintenance and mobile application support.
- AI Load Management: Apply machine learning to predict demand and dynamically allocate power across multiple bays.
- Security Hardening: Adopt AES-128 encrypted RFID protocols and blockchain-based billing ledgers.

**VIII. CONCLUSION**

This paper has presented and experimentally validated a smart wireless power transfer system for EV charging that integrates inductive energy delivery, RFID-based authentication, IoT monitoring, and automatic cloud billing on a single Arduino-based hardware platform. At the nominal 3 cm operational coil gap the prototype achieves 75.0% power transfer efficiency, 99.5% RFID authentication accuracy with 180 ms latency, and billing precision within 1.8%

MAPE. End-to-end operational latency averages 2.3 s, confirming real-time capability suitable for commercial deployment.

The modular architecture is scalable to higher power levels and broader scenarios including smart parking facilities, autonomous mobility hubs, and electrified highways. Future work will target kilowatt-scale power electronics, dynamic in- road charging, and renewable energy integration.

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