

RFID Based EV Charging System

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Abstract— This report presents a comprehensive analysis and design of a Radio Frequency Identification (RFID)-Based Electric Vehicle (EV) Charging System. This project uses tap-to-pay cards (RFID) to make electric vehicle (EV) charging stations fully automated. It handles user login, tracks electricity usage, processes payments, and unlocks the charger automatically. As more people buy electric cars, charging stations need to be smarter, safer, and easier to use without needing human staff. The system connects tap card readers, mini-computers (microcontrollers), online databases, and payment systems. When a driver taps their card, the station identifies them, allows them to charge, calculates the bill, and charges their account.

I. INTRODUCTION

RFID technology makes electric vehicle charging as simple as tapping a contactless hotel key or transit card against the station to instantly start the power supply. It replaces the frustrating process of downloading multiple mobile apps, typing credit card numbers on public screens, or waiting for phone signals in underground parking garages to pay for parking. Instead, the card directly sends a secure, unique ID code to the machine, which automatically tracks energy usage and charges the linked account. This provides a highly reliable, weather-proof, and secure charging experience that works instantly even when your phone has no battery or cellular reception.

II. MOTIVATION

RFID technology is becoming popular in EV charging because it fixes the most annoying parts of plugging in a car. Currently, public charging is a mess of broken mobile apps, poor phone signals in parking garages, and confusing payment screens. RFID replaces all that confusion with a simple plastic card or key fob that is tapped against the station to instantly start the power. It provides drivers with a fast, reliable way to charge that works every single time, even if their phone dies, while helping charging companies securely track electricity and handle payments without needing a constant internet connection.

Demand for real-time monitoring and usage analytics for energy management

- ☐ Government mandates for smart grid integration and green energy initiatives
- ☐ Cost efficiency and operational simplicity for charging station operators
- ☐

III. OBJECTIVES

Secure Tapping: Drivers tap a card, and the charger instantly verifies their identity using a secure online database before releasing electricity.

- ☐ **Auto-billing** : Built-in meters track the exact energy used and automatically charge the driver's saved credit card when they unplug.
- ☐ **Live Monitoring** : The charger remains connected to the Internet to report its health and allows technicians to fix software issues remotely.
- ☐ **Cloud Storage** : All charging history, times, and payments are saved online to help owners track business trends and peak hours.
- ☐ **System Testing** : Engineers regularly check the network to ensure that it processes taps quickly, blocks hackers, and can handle thousands of new chargers.
- ☐

IV. SYSTEM OVERVIEW

A. Concepts

- ☐ **The Unique Card** : Every registered driver receives a personal plastic card with a built-in digital identity token.
- ☐ **Quick Tap** : The driver taps their card on the charger to instantly prove their identity.
- ☐ **Auto-Start** : The charger unlocks and begins pumping electricity into the vehicle without requiring any button presses.
- ☐ **Live Tracking** : Built-in sensors monitor the energy flow to measure the amount of power required by the car.
- ☐ **Hands-Free Pay** : The system automatically bills the driver's linked account and stops the session the moment they unplug.
- ☐ **B.Key fetures**
- ☐

1. The Quick Tap (Secure RFID Entry)

Drivers tap an encrypted plastic card on the chargers. The machine instantly checks a secure database via the Open Charge Point Protocol (OCPP) to confirm that the user is real and authorized, preventing electricity theft.

2. The Auto-Wallet (Automated Billing)

The system tracks the exact amount of electricity consumed. Once the driver is unplugs, the cost is automatically calculated. By integrating with payment gateways such as Stripe or specialized APIs such as Plugsurfing, it securely charges the driver's saved credit card or digital wallet without requiring manual intervention.

- ☐ **The Control Room (Real-Time Monitoring)**
- ☐

The charger remains connected to the Internet using cellular 4G/5G or Wi-Fi to send constant updates. If a station overheats or breaks down, the team can immediately view the error on a centralized dashboard and flag it for maintenance. [1, 2, 3]

4. The Smart Dispatcher (Dynamic Load Management)

The system constantly tracks the grid usage and electrical capacity. When multiple cars are plugged in simultaneously, the system dynamically balances the load. It intelligently slows down or staggers the power distributed to each vehicle, avoiding expensive peak demand charges and keeping the local power grid safe from overloads.

☐ **The Plug & Play (ISO 15118 Autocharge)**☐

Modern chargers completely eliminate the need for physical cards. By adhering to communication protocols, such as ISO 15118, the vehicle's onboard computer communicates directly with the charger. As soon as the driver plugs in, the car and charger perform a secure digital handshake to identify the vehicle, authorize the user, and start the charge.

System Workflow

- ☐ User presents RFID card/tag to the charging station reader
- ☐ System reads the unique UID from the RFID tag
- ☐ Backend server validates the UID against the registered user database
- ☐ Upon successful authentication, charging relay is activated
- ☐ Energy meter starts recording consumption in real time
- ☐ User removes the connector to end the session
- ☐ System calculates cost based on kWh consumed and applicable tariff
- ☐ Billing amount is deducted from the user's account or digital wallet
- ☐ Session summary is sent to the user via SMS or email
- ☐

V. HARDWARE ARCHITECTURE**A. Core Hardware Components**

The hardware layer of the RFID EV Charging System consists of the following key components:

Component	Specification	Function
RFID Reader	RC522 / PN532 (13.56 MHz)	Reads RFID tags at the charging point
Microcontroller	ESP32 / Arduino Mega	Central processing unit for system logic
RFID Tags/Cards	MIFARE Classic 1K / ISO 14443A	User identification credential
Power Supply	230V AC to 12V/5V DC	Powers the control system
Relay Module	5V/12V SPDT, 10A rated	Controls the EV charging circuit
Energy Meter	PZEM-004T / ADE7758	Measures voltage, current, kWh
LCD/OLED Display	16x2 LCD / 0.96" OLED	Displays session status
GSM/Wi-Fi Module	SIM800L / ESP8266	Remote communication
RTC Module	DS3231	Accurate time-stamping
Buzzer & LED	5V Passive / RGB LED	Audio-visual feedback

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B. RFID Operating Frequencies

- ☐ Low Frequency (LF): 125–134 kHz — Short range, access control
- ☐ High Frequency (HF): 13.56 MHz — Standard for EV charging (ISO 14443, ISO 15693)
- ☐ Ultra High Frequency (UHF): 860–960 MHz — Long range, logistics
- ☐

The proposed system primarily uses HF (13.56 MHz) RFID, providing an ideal balance of read range (up to 10 cm), data security, and cost-effectiveness for EV charging applications.

C. RFID Card Security

- ☐ 128-bit AES encryption on MIFARE DESFire EV2 cards
- ☐ Unique 4-byte or 7-byte UID per card preventing cloning
- ☐ Mutual authentication between card and reader
- ☐ Anti-collision support for multiple cards in the field
- ☐

D. Charging Infrastructure

Charging Level	Voltage	Power	Time
AC Level 1	120V AC	1.4–1.9 kW	8–20 hrs
AC Level 2	240V AC	3.3–19.2 kW	1–8 hrs
DC Fast	200–900V DC	24–350 kW	15–45 min
Ultra-Fast	800–1000V DC	350+ kW	5–15 min

VI. SOFTWARE ARCHITECTURE

A. System Software Stack

- ☐ Embedded Layer: Firmware on microcontroller for real-time hardware control
- ☐ Backend Layer: Server-side application for data processing and business logic
- ☐ Frontend Layer: Web and mobile dashboard for users and administrators
- ☐

B. Embedded Firmware

- ☐ RFID tag scanning and UID extraction via SPI communication protocol
- ☐ User authentication via API call to the backend server
- ☐ Relay control to start and stop the charging circuit
- ☐ Real-time energy monitoring through UART with the energy meter module
- ☐ LCD/OLED display updates for session status messages
- ☐ Periodic data synchronization with cloud server via MQTT or HTTP
- ☐

C. Backend Server Technologies

- ☐ Runtime Environment: Node.js / Python Django
- ☐ Database: MySQL / PostgreSQL for user and session data
- ☐ Cache Layer: Redis for session management and real-time data
- ☐ Message Broker: MQTT protocol for IoT device communication
- ☐ Authentication: JWT-based token authentication for API security
- ☐ Payment Gateway: Integration with Stripe, Razorpay, or PayU
- ☐

D. Cloud Integration and Dashboard

- ☐ Real-time monitoring dashboard with live station status
- ☐ Historical usage analytics and energy consumption reports
- ☐ User management: registration, card linking, and account top-up
- ☐ Tariff management: time-of-use pricing and dynamic rate configuration
- ☐ Alert and notification system for faults and session events
- ☐ OTA (Over-The-Air) firmware update support for station controllers
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VII. COMMUNICATION PROTOCOLS

A. OCPP Integration

The system is compliant with the Open Charge Point Protocol (OCPP), a globally accepted standard for communication between EV charging stations and backend management systems. OCPP 1.6 J and OCPP 2.0.1 are supported, enabling remote start/stop, configuration retrieval, firmware update management, real-time heartbeat reporting, and smart charging via power-schedule management.

B. Network Communication Protocols

Protocol	Layer	Usage
MQTT	Application	IoT device-to-cloud messaging
HTTP/HTTPS	Application	REST API communication
WebSocket	Application	Real-time dashboard updates
Wi-Fi 802.11n	Physical/Data	Station internet connectivity
4G/LTE	Physical/Data	Remote location connectivity
SPI	Physical	MCU to RFID reader
UART	Physical	MCU to energy meter
I2C	Physical	MCU to LCD/RTC

VIII. BILLING AND PAYMENT SYSTEM

A. Billing Models

- ☐ Per kWh Billing: Users are charged based on actual energy consumed
- ☐ Time-Based Billing: Charging is calculated per minute or per hour
- ☐ Flat Rate: Fixed fee per charging session regardless of energy consumed
- ☐ Subscription Plans: Monthly/annual plans with discounted rates
- ☐ Dynamic Pricing: Rates vary based on time-of-day and grid load
- ☐

B. Payment Integration

- ☐ Pre-paid wallet: Users top up their account balance via app or web portal
- ☐ UPI / QR Code payments for session-end billing in real-time
- ☐ Credit/Debit card tokenization via PCI-DSS compliant gateways
- ☐ Fleet billing: Corporate accounts with monthly invoice generation
- ☐

C. Billing Flow

- ☐ RFID authentication captures user account and current balance
- ☐ Charging session initiates with balance verification
- ☐ Energy meter sends consumption data to backend every 30 seconds
- ☐ Low balance alerts are sent to user when balance drops below threshold
- ☐ Session ends — final kWh consumed is calculated with precision
- ☐ Bill is generated and deducted from the user wallet instantly
- ☐ Digital receipt is sent via SMS, email, and in-app notification
- ☐

IX. SECURITY ARCHITECTURE

A. Physical Security

- ☐ Tamper-evident enclosures with intrusion detection sensors
- ☐ IP54-rated weatherproof housing for outdoor installations
- ☐ Vandal-resistant charging connectors and cable locking mechanisms
- ☐ Surveillance camera integration support with ONVIF compliance
- ☐

B. Cyber Security

- ☐ End-to-end TLS 1.3 encryption for all network communications
- ☐ RFID card data encrypted with AES-128/AES-256 algorithms
- ☐ Secure boot and code signing for embedded firmware
- ☐ Role-based access control (RBAC) for operator dashboard
- ☐ Intrusion detection system (IDS) on backend servers
- ☐ Regular security audits and penetration testing
- ☐

C. Fraud Prevention

- ☐ UID whitelist validation — only registered RFID cards are accepted
- ☐ Transaction anomaly detection using machine learning algorithms

- ☐ Duplicate transaction prevention with session ID verification
- ☐ Real-time alerts for suspicious activities and unauthorized access
- ☐

X. USE CASES AND APPLICATIONS

A. Residential Complexes

RFID-based charging stations can be deployed in apartment complexes and gated communities, where residents are issued RFID cards for exclusive access. The system enables individual metering and billing for each resident and is integrated with the building management system.

B. Public Charging Infrastructure

Municipal and commercial public charging stations benefit from RFID for user authentication, enabling roaming between networks using interoperability standards. A single RFID card can grant access to multiple charging networks through OCPI roaming agreements.

C. Corporate and Fleet Management

- ☐ Centralized billing and consolidated monthly invoicing
- ☐ Per-vehicle energy consumption tracking for fleet efficiency analysis
- ☐ Scheduled charging during off-peak hours for cost optimization
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- ☐ Driver authentication and vehicle tracking integration
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D. Highway and Expressway Charging

High-power DC fast-charging stations on highways use RFID for rapid session initiation, minimizing wait time. Session pre-authorization ensures that users can start charging within seconds of arrival.

E. Smart Grid Integration

The system participates in vehicle-to-grid (V2G) programs, where EVs feed energy back to the grid during peak demand. RFID authentication manages bidirectional energy sessions and compensates vehicle owners.

XI. ADVANTAGES AND CHALLENGES

A. Advantages

Advantage	Description
Ease of Use	Simple tap-and-charge interaction, no smartphone required
High Security	Encrypted RFID credentials prevent unauthorized access
Scalability	Scales from a single charger to thousands of stations

Automation	Fully automated billing eliminates manual payment processes
Real-time Monitoring	Live tracking of energy consumption and status
Cost Efficiency	Reduces operational overhead and management costs
Interoperability	OCPP compliance ensures compatibility with any backend
Reliability	Operates offline with local caching if internet is unavailable

B. Challenges and Mitigations

Challenge	Mitigation Strategy
Card Loss/Theft	Instant card deactivation via mobile app or support portal
Connectivity Issues	Local offline mode with data sync upon reconnection
RFID Cloning Risk	AES-encrypted MIFARE DESFire cards with mutual auth
System Integration	Standardized OCPP and REST APIs for seamless integration
Hardware Vandalism	Tamper-proof enclosures with real-time intrusion alerts
Price Fluctuation	Dynamic tariff management with automated updates

XII. COST ANALYSIS

A. Hardware Cost Estimate (Per Charging Station)

Component	Unit Cost (USD)	Total (USD)
RFID Reader Module (RC522)	\$5 – \$15	\$5 – \$15
Microcontroller (ESP32)	\$8 – \$20	\$8 – \$20

RFID User Cards/Tags (50)	\$0.50 – \$2	\$25 – \$100
Energy Meter (PZEM-004T)	\$15 – \$30	\$15 – \$30
Relay Module	\$3 – \$8	\$3 – \$8
GSM/Wi-Fi Module	\$5 – \$20	\$5 – \$20
LCD/OLED Display	\$5 – \$15	\$5 – \$15
Power Supply Unit	\$20 – \$50	\$20 – \$50
Enclosure & Hardware	\$50 – \$150	\$50 – \$150
Charging Hardware (AC L2)	\$300 – \$800	\$300 – \$800
TOTAL ESTIMATE		\$436 – \$1,208

B. Return on Investment

Based on an average of 15 charging sessions per day at \$5 per session, a single charging station generates approximately \$2,250 monthly revenue. With a hardware cost of \$800–\$1,200 per station, the payback period is typically 1–3 months for high utilization deployments.

XIII. FUTURE SCOPE

A. Technology Enhancements

- ☐ Integration of NFC for smartphone-based virtual RFID cards
- ☐ Biometric authentication (fingerprint or facial recognition) as secondary layer
- ☐ AI-powered predictive maintenance for proactive fault detection
- ☐ Machine learning-based demand forecasting for energy optimization
- ☐ Blockchain integration for transparent, tamper-proof transaction records
- ☐

B. Smart Grid and V2G

- ☐ Vehicle-to-Grid (V2G) support enabling EVs as distributed energy storage
- ☐ Vehicle-to-Home (V2H) capability for residential energy management
- ☐ Dynamic energy pricing based on real-time grid supply and demand
- ☐ Renewable energy integration with solar canopies and wind power
- ☐

C. Enhanced User Experience

- ☐ Mobile app with pre-booking, navigation, and real-time station availability
- ☐ QR code support as an alternative to physical RFID cards
- ☐ Loyalty programs and rewards for frequent charging users
- ☐ Integration with EV manufacturer telematics for automated sessions

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D. Regulatory and Market Trends

- Compliance with ISO 15118 (Plug & Charge) for cable-based vehicle authentication
- OCPI roaming for cross-network RFID card interoperability
- Government subsidy integration for EV charging incentives
- Support for emerging standards: CHAdeMO 3.0, CCS2, NACS
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XIV. CONCLUSION

The RFID Based EV charging system represents a significant advancement in the design and management of electric vehicle charging infrastructure. By combining proven RFID technology with modern cloud computing, IoT communication protocols, and automated billing systems, the proposed solution addresses the critical challenges of accessibility, security, scalability, and user experience in EV charging systems.

The system's compliance with international standards, such as OCPP 1.6 J and OCPP 2.0.1, ensures interoperability with a broad ecosystem of backend management systems. The multi-tiered security architecture, encompassing encrypted RFID credentials, TLS-secured communications, and fraud detection mechanisms, provides a robust defense against both physical and cyber threats.

From residential complexes and corporate fleet depots to public highways and smart grid installations, the RFID EV Charging System is versatile enough to serve a wide spectrum of deployment scenarios. Its modular hardware design and scalable software architecture make it suitable for both small-scale pilot projects and large-scale national charging networks.

As the global EV market continues to grow exponentially, intelligent charging infrastructure powered by RFID technology will play an indispensable role in accelerating the transition to sustainable mobility. Future enhancements incorporating NFC, AI-driven analytics, blockchain, and V2G capabilities will further elevate the value proposition of the system.

REFERENCES

- International Organization for Standardization (ISO) . (2016). ISO/IEC 14443: Identification cards — Contactless integrated circuit cards. ISO.
-
- CharIN e.V. (2020). Combined Charging System (CCS) Specification, Version 2.0.
- Open Charge Alliance. (2019). OCPP 1.6 J : Open Charge Point Protocol. Open Charge Alliance.
- Open Charge Alliance. (2020). OCPP 2.0.1 : Open Charge Point Protocol. Open Charge Alliance.
- IEC Standard 61851. (2017). Electric Vehicle Conductive-Charging System. International Electrotechnical Commission (IEC) .
- Finkenzeller, K. (2010). RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identification , and Near-Field Communication (3rd ed.). Wiley.
- U.S. Department of Energy. (2023). EV Charging Station Infrastructure Guidelines. Office of Energy Efficiency and Renewable Energy.
- NXP Semiconductors. (2018). MIFARE DESFire EV2 product specifications . NXP.
- Espressif Systems. (2022). ESP32 Technical Reference Manual. Espressif Systems.
- BlueNRG-M2 Application Note. (2021). RFID Reader Design for EV Charging. STMicroelectronics.
- International Energy Agency (IEA) . (2024). Global EV Outlook 2024. IEA Publications.
-