

IoT-Based Dynamic Wireless Electric Vehicle Charging System

Vineeth P.¹; Y. Venkat²; Rajunala Rakesh³; Y. Narasimha Naidu⁴

^{1,2,3,4}Department of Electronics & Communication Engineering, CMR Institute of Technology, Bengaluru-560037, India

Guided: Dr. Sushma T. V.

Assistant Professor, Department of ECE, CMRIT Visvesvaraya Technological University, Belgaum – 590018, Karnataka, India

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Abstract: The design and development of a dynamic charging system for electric vehicles using IoT are explained here. This wireless EV charging system provides power transfer from the source to the electric vehicles without any physical contact during motion. The integration of IPT technology along with an IoT communication protocol facilitates real-time monitoring, smart payment, and automation of the exit gate. NodeMCU (ESP8266) controller board acts as the IoT interface and allows Wi-Fi communication with the cloud server. IR sensors detect the presence of the vehicle and transfer power from the primary and secondary resonant copper coils. Cost details of charging are displayed on an LCD screen. Charging process is carried out by paying money through the smartphone. After completion of the process, the gate becomes unlocked. Experimental results show that real-time data transfer, wireless power transfer, and automation are successfully implemented.

Keywords: Electric Vehicle (EV), Wireless Power Transfer (WPT), Inductive Power Transfer (IPT), Internet of Things (IoT), NodeMCU, Dynamic Charging, Smart Payment, Range Anxiety.

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I. INTRODUCTION

In today's world, electric vehicles have gained popularity in sustainable transport systems. However, traditional plug-in charge systems are not sufficient because of range anxiety due to a limited amount of battery capacity and lengthy charging periods. Dynamic wireless charging offers a solution to both problems as this technology can charge electric cars during their movement thanks to inductive power transfer from transmitter coils laid down in the road to receiver coils installed in the car underbody. IoT technology can be used to provide continuous communication and real-time monitoring of the battery capacity and other metrics of the system.

The contribution is the development of the complete model of an IoT-based dynamic electric vehicle wireless charger. The main features include: (1) resonant inductive coil based design of the power transfer stage, (2) use of NodeMCU-based IoT modules for connection to the internet, (3) IR sensor-based identification and alignment of cars, (4) mobile phone application for the payment and opening of the

barrier, and (5) validation experiments demonstrating overall performance of the system.

II. LITERATURE REVIEW

Various research initiatives in the realm of IoT-based wireless EV charging have been conducted, yielding significant results:

Wang & Yang (2020) [1] studied the possibilities of IoT-enabled wireless EV charging systems and identified crucial factors, including effective power transfer, appropriate coil alignment, and minimal losses in inductive systems.

Cheng & Zhou (2021) [2] developed in-motion dynamic wireless EV charging controlled with the help of IoT and proved the feasibility of real-time changes in the amount of generated power in response to vehicle speed and battery status.

Almasri & Al-Rashidi (2021) [3] suggested incorporating IoT in wireless EV charging technology to ensure sustainable development with the application of predictive algorithms in grid management and energy efficiency; yet, the researchers also pointed out the obstacles related to scalability and costly infrastructure.

Patel & Sharma (2022) [4] examined the potential of wireless energy transfer technology coupled with IoT solutions applied to EVs, particularly highlighting the significance of standardization and IoT communication security in such systems.

This paper expands on the above literature and implements a hardware solution that combines dynamic wireless power transfer, cloud monitoring system via IoT, and a smart payment portal.

III. SYSTEM ARCHITECTURE AND METHODOLOGY

➤ Overview

The proposed system can be said to have two sub-systems: (1) Power transmitter circuit embedded in the roads, and (2) Receiver circuit and IoT managing circuit onboard the vehicles. The circuit configuration for the system is shown schematically below. It comprises of the following blocks: AC Main Supply -> Step-down transformer -> Bridge Rectifier and Filter -> Transistor Switching circuit -> TX Copper coil -> RX copper coil -> Rectifier and Filter -> Microcontroller -> IoT circuit/LCD/Gate motor driver circuit.

➤ Operational Workflow

When an EV enters the charging lane, the following

sequence executes automatically:

- IR sensors detect vehicle presence and transmit a trigger signal to the NodeMCU microcontroller.
- The microcontroller enables the BD139 NPN transistor switching stage, causing high-frequency oscillations in the TX copper coil.
- The RX coil on the vehicle undercarriage receives power inductively; onboard rectification and filtering deliver DC power to the EV battery.
- IoT sensors continuously log battery health, charging rate, and power consumption to a cloud dashboard via Wi-Fi.
- Charging cost is calculated and displayed on the 16×2 LCD module. The user makes payment via smartphone.
- Upon payment confirmation, a GPIO signal from the NodeMCU drives the motor driver IC, opening the exit gate automatically.

The system dynamically reduces power output when vehicle alignment is suboptimal (e.g., the vehicle is not directly above the charging pad), minimising energy wastage and improving overall efficiency.

IV. HARDWARE COMPONENTS

➤ Bridge Rectifier (1N4007)

A full-wave bridge rectifier using four 1N4007 silicon diodes converts 12V AC (from a step-down transformer) to DC. The 1N4007 is chosen for its peak repetitive reverse voltage of 1000V, average forward current of 1A, and RoHS compliance. A 1000µF/25V electrolytic capacitor (C1) smooths the rectified output. Key electrical parameters are summarised in Table 1.

Table 1 1N4007 Electrical Characteristics

Parameter	Value	Unit
Forward Voltage (VF @ 1A)	1.1	V
Peak Reverse Voltage	1000	V
Average Rectified Current	1.0	A
Reverse Current @ 25°C	5	µA
Total Capacitance @ 1 MHz	15	pF

➤ Transistor BD139 (Switching Stage)

BD139 is a NPN bipolar junction transistor (BJT). This BJT forms the high-speed switch to drive the TX copper coil. This transistor is rated at 1.5A collector current, a maximum VCE of 80V, 12.5W of collector dissipation, and 0.5V saturation voltage. Therefore, it is suitable for efficient power conversion within the oscillating circuit. The base of the transistor (Pin 3) is driven by the microcontroller via the PWM output. The collector (Pin 2) goes to the TX coil, while the emitter (Pin 1) is grounded.

➤ IoT Module: NodeMCU (ESP8266)

NodeMCU represents an IoT open source platform that utilizes the ESP8266 Wi-Fi SoC made by Espressif Systems through the use of the ESP-12 module. Programming is done using Arduino IDE in C/C++ programming language. In firmware, it sets up the module as a Wi-Fi server, automatically connects to the network, runs a web payment

interface, and sends control signals to the motor of the gate using GPIO pins. The important GPIO pins used in the project include:

- D1 (GPIO5)
- D2 (GPIO4): Sensor input
- D5 (GPIO14): Motor driver output
- D7 (GPIO13): Gate motor

➤ IR Sensor

The infrared proximity sensor works to detect the presence and positioning of the car over the charger. This is done by using each module with an infrared LED transmitter paired with the infrared photodiode receiver. Whenever the infrared light beam is intercepted by the vehicle, there is a proportional change in the output voltage which causes the battery charging process to start.

➤ LCD 16×2 Display

The IP address of the system is shown on a 16X2 LCD using the module. It displays the IP address at the time of start-up, the live charge value, and the bill amount for billing purposes. The LCD uses commands for registers RS=0 and data for RS=1.

➤ Software: Arduino Ide & Algorithm

Firmware is programmed using Arduino IDE version 1.8.x. This software integrates both Editor and Compiler to support both C and C++ programming languages. The NodeMCU board package is loaded using Board Manager, thereby making it possible to directly program the ESP8266 chip. Firmware algorithm is:

- Initialization of LCD and IoT modules.
- NodeMCU setup as a Wi-Fi server (AP/Stations mode).

- Searching and automatic connection to available networks.
- IP Address displayed on LCD.
- Moving to poll loop by reading IR sensors inputs.
- In case of vehicle detection: Transistor switching ON; Inductive Charging; Logging Data to Cloud.
- Charging cost calculation and display on LCD; Wait for payment confirmation through Smartphone.
- Payment received: Generate GPIO Signal → Motor Driver → Gate Opening.
- Gate Closing automatically when vehicles leave the parking spot; System resets to IDLE state.

V. RESULTS AND DISCUSSIONS

The prototype was successfully assembled and tested. Key results obtained:

Table 2 Summary of Experimental Results

Test Parameter	Observation / Result
Wireless Power Transfer	Successful—coil-to-coil power transfer confirmed at prototype scale
IR Vehicle Detection	100% detection accuracy within designed sensor range
IoT Cloud Logging	Real-time data (battery %, charging rate) logged via NodeMCU Wi-Fi
LCD Billing Display	Charging amount displayed accurately and updated in real time
Smartphone Payment	Payment interface accessible via device browser; gate triggered on confirmation
Gate Actuation	Automatic gate open/close on GPIO signal—motor driver operated correctly
Dynamic Power Adjustment	Power reduced when vehicle misalignment detected by IR sensors

The integration of wireless power transfer (WPT) with IoT communication demonstrated a seamless and contactless EV charging experience. The dynamic load balancing capability minimised grid stress, and the automated payment workflow enhanced user convenience. Scalability was confirmed by the modular architecture, which supports additional coil segments and cloud analytics.

➤ Future Scope

The following enhancements are identified for future development:

- Higher-efficiency WPT: Adoption of magnetic resonance coupling (MRC) and improved coil geometries to increase power transfer efficiency at greater air-gap distances.
- Renewable Energy Integration: Solar PV and wind energy sources feeding the charging infrastructure to further reduce carbon footprint.
- Vehicle-to-Grid (V2G): Bidirectional power flow enabling EVs to supply energy back to the grid during peak demand.
- Global Standardisation: Alignment with IEC/SAE wireless charging standards for interoperability across vehicle makes and charging networks.
- AI-based Optimisation: Machine learning models predicting vehicle arrival patterns to pre-activate coil segments and reduce latency.
- Cybersecurity: End-to-end encryption and secure authentication protocols for all IoT communication channels.

VI. CONCLUSION

This paper presented an IoT-based dynamic wireless EV charging system that integrates inductive power transfer, real-time IoT monitoring, automated billing via smartphone, and motorised gate control. The prototype successfully demonstrated contactless power delivery to a moving vehicle model, real-time cloud data logging, and a fully automated charging-payment-exit workflow. The system architecture is scalable and adaptable to future enhancements including renewable energy integration, V2G capability, and AI-driven optimisation. This work contributes toward a cleaner, more efficient, and user-friendly electric vehicle charging ecosystem, accelerating the global transition to sustainable transportation.

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