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Design and Development of technique of IoT-powered wireless charger infrastructure of electric vehicles on the power grid.

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Abstract : The accelerated growth of electric vehicles (EVs) has led to an increased demand for effective, dependable and user-friendly charging infrastructure for EVs. In the Indian scenario, the projections are that income of the EV fleet is expected to grow from around 5.6 regional renewable electrical vehicle in 2025 to nearly 28 sq.v parallel in 2030 thus leading to a substantive improvement in public pay charge deficit. As a result motorists may start facing extended waiting times, a congested charging point, and a wastage of energy at the conventional charging points. This research reports the design and implementation of the wireless charging prototype that realizes the direct power transfer from the electrical grid to electric cars through inductive wireless power transfer (WPT). The system uses the electromagnetic induction process which allows the contactless transmission of power from a transmitter coil that is part of the ground assembly to a receiver coil carried on the underbody of the vehicle. The technology behind the prototype utilizes Internet of Things (IoT) technology via ESP32 microcontroller and ESP8266 Wi-Fi module which sends real-time charging data such as battery level, input voltage, current flow, charging time, etc., to a mobile app. In addition, the system includes a buck - boost converter to stabilize the voltage to comply with the specifications of the vehicle batteries. Experimental results show that the average power transfer efficiency is 68o to 80o percent depending on the alignment of the coils and air gap between the coils. The mobile application is used to remote control of charge operations, i.e., start and end charge cycles, and notify at completion, hence increasing user convenience. This research illustrates the possibility of contactless EV charging and highlights that it could help reduce pressure on the infrastructure and enhance interaction between the grid and the car. The findings support the move to intelligent systems for charging to be combined with renewable energy resources and multivariate technologies for self-driving vehicles.
Keywords: Wireless Power Transfer (WPT), Inductive Charging, Electric Vehicle (EV) Smart Charging Infrastructure, Contactless Energy Transfer, Grid-Integrated EV Charging, Power Transfer Efficiency, Autonomous Charging Systems

I. INTRODUCTION

India's voice and road are changing rapidly with electric vehicles because they are considered for sustainability, cost of fuel for an ever-growing nation is on the rise and because of incentives by our government. Projections by NITI Aayog and International Energy Agency (IEA) predict the EV numbers to grow from 5.6 thousand million in 2025 to above 28 thousand million by 2030. Despite this growth, the development of charging infrastructure lags behind and by 2030 it is estimated that 3.9 million public charging stations are required. This disparity could lead to massive congestion at the charging points, increased waiting time, and inefficient usage of the grid resource. Conventional plug-in chargers have physical degradation, environmental damage and user inconvenience hazards. To counter these issues, in the present project a wireless charging system for electric four-wheeler that is directly connected to the grid and an associated mobile application that gives real-time monitoring have been proposed. The system uses inductive coupling between a coil transmitted energized from the ground and a receiver coil onto the vehicle enabling safe and cableless charging. Moreover, line-follower technology is used for the automatic movement of vehicles after the charged of their batteries, which minimizes idle time at stations - similar to the idea of Tesla Motors to use "Idle Fee" to discourage supporting its chargers.

II. Literature Review

Wireless power transfer (WPT) for electric vehicles (EVs) has received significant research interest within the past few years following the rise of effective and non-contact charging modes. Shamsi et al. (2022) conducted an extensive review of WPT technologies and its challenges, as well as possible development. Their analysis indicated electromagnetic induction and resonant coupling as the leading ways in which a vehicle can be charged wirelessly, but revealed the fundamental shortcomings of wild things such as misalignment of coils, energy transfer losses and electromagnetic interaction (EMI). The authors also underlined the importance of compliance with safety requirements incorporating SAE J2954, which provide allowable electromagnetic field exposure limits and interoperability among systems. Although the review provided much technical insight and potential improvements, it did not go into small scale, user-friendly prototypes showing how to deploy these.

A recent published system review work by Abuajwa (2025) provides an extended look on WPT systems for EVs covering this development with a focus on achievements and persistent challenges. The critical aspects of the system like efficiency, safety, charging duration, coil configuration, energy dissipation and EMI etc. are highlighted along with compensation topologies such as series-series (SS), inductor-capacitance-inductor (LCL) and capacitance-inductor-capacitance (CLC). Control strategies such as constant maximum power point tracking (CMPPT include also. Abuajwa's review emphasizes the need to solve some of the practical problems of deployment such as misalignment tolerance and standardization in order to make WPT systems more applicable in the real world.

Machura and Li (2019) had made a comparative analysis of the wireless charging technologies used in various traffic modes. Their review reported the development of dynamic charging systems in which the vehicles are charged while moving. The authors reasoned that combining WPT with renewable energy resources and smart grids could help people rely less on the conventional plug- in systems. They identified basic determinants of power transfer efficiency or PTE which included coil alignment, air gap distance and frequency stability. However, they recognised that for widespread adoption, compact, cost-efficient prototypes are needed that lends themselves to individual users, and not in large-scale highway installations. This leads us to their conclusion, which supports the need for designing scalable and user-friendly designed systems which is in line with the current project's motivation of developing an IoT-based wireless charging prototype.

In another great contribution, Tripathi et al. (2020) proposed an IoT enabled EV charging system that can perform real-time monitoring of charging status, voltage, current and battery health through a mobile interface. Their system proved the integration of sensors and cloud connection improves user assertion and taxes, placing data-driven perceptions to help optimum energy-use price and avoid overcharging, elongating the battery lifetime. While their work did successfully combine IoT and traditional plug-in charging, it did not include wireless energy transfer. Consequently, it is used as a basis for referencing the extension of IoT applications to WPT systems, as endeavored in the present research.

Finally, Khan et al. [10] studied the implementation of a smart and movable wireless charging system for electric vehicles using Internet-of-Things (IoT) technology. Their research proposes a hybrid architecture where wireless charging pads are incorporated with self-driving car relocation mechanisms in order to ease congestion at charging bays, which is similar to Tesla's idle fee system. The research was aimed at setting communication protocol between vehicles and charging stations in order to improve grid load management and its convenience to users; however, the prototype was still more theoretical and needed further empirical validation. The present project builds upon this framework by developing a full and operational prototype incorporating ESP32 and ESP8266 microcontroller(s) allowing to perform a real-time monitoring, control and feedback.

In summary, the available literature shows that there is a good deal of theoretical advancement in the field of wireless power transfer (WPT) technology. Nevertheless, most investigations appear to focus on enhancements in efficiency and large-scale infrastructural deployment, instead of focusing on small, deployable systems that are aimed at quotidian users. The current project tries to fill this gap by the pragmatic technology translation of theoretical knowledge into an IoT-enabled prototype that will provide wireless energy transfer and real time monitoring capabilities. This approach has been to convert academic ideas into building tangible innovation and promotion of evolution within smart connected charging solutions for electric vehicles.

III. Methodology

3.1 System Overview

The wireless charging system has two major subsystems. The Ground Assembly (GA) exposes a transmitter coil which is connected to the power grid; an alternating magnetic field is produced. The Vehicle Assembly (VA) includes a receiver coil mounted on the vehicle chassis; that receives the magnetic field in order to induce a current to be able to charge the cabin battery. Power transfer is done by electromagnetic induction according to Faraday's Law of Electromagnetic Induction.

3.2 Components Used

Component	Function
Lithium-ion Battery	Stores electrical energy for vehicle operation.
LCD Display (16x2)	Displays voltage, current, and power status.
Gear Motor	Converts electrical energy into mechanical motion for relocation demo.
SMPS (Switched Mode Power Supply)	Ensures efficient DC power conversion with minimal losses.
Relay Module	Controls safe switching of charging ON/OFF.
Capacitors	Stabilize voltage and reduce fluctuations.
Transmitter & Receiver Coils	Enable wireless energy transfer through magnetic coupling.
Buck & Boost Converter (LM2596)	Regulates voltage according to battery requirements.
Motor Driver (L298N)	Interfaces between microcontroller and motor for movement.
ESP32 Microcontroller	Manages system control, power monitoring, and data processing.
ESP8266 Wi-Fi Module	Enables IoT connectivity for remote data transmission.

3.3 Wireless Power Transfer (WPT) Subsystem:

Describe the resonant inductive coupling principle used. Detail the design of the Power Transmitter/Receiver Coil, including its shape and size, as well as the use of ferrite. Explain how the Buck and Boost converter (LM2596) regulates the voltage received for battery charging.

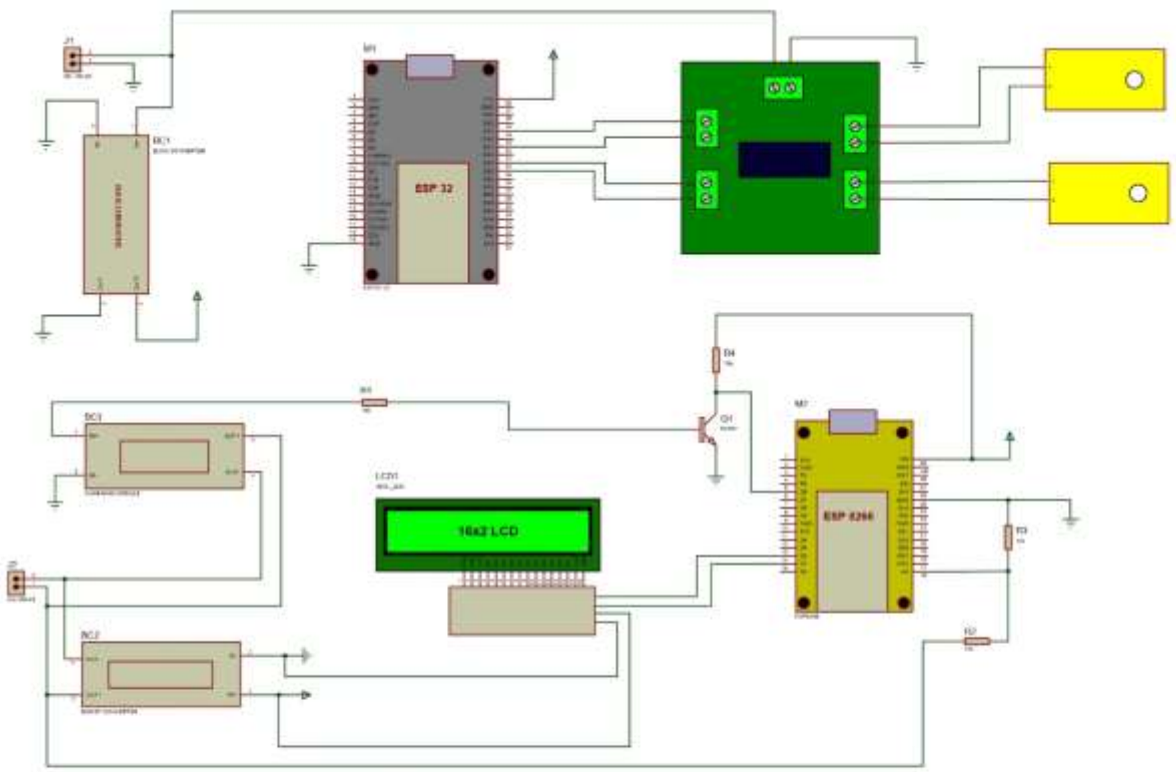

Fig.1 Circuit Diagram of the Wireless Power Transfer System

The circuit diagram shown in Fig.1 illustrates the overall connection layout of the wireless charging prototype. It includes the power supply from the grid, rectifier and inverter stage, transmitter and receiver coils, buck-boost converter, charge controller, and the IoT monitoring components (ESP32, sensors, and Wi-Fi module). This diagram provides a clear representation of the system's power and signal flow from the input grid to the vehicle battery.

3.4 IoT and Monitoring Subsystem :

Detail the use of the ESP32 for control and monitoring of voltage and current, along with the ESP8266 for Wi-Fi communication. Explain the mobile app's features, including real-time battery level and charging status, remote Start/Stop, and full charge notifications.

3.6. Workflow Summary

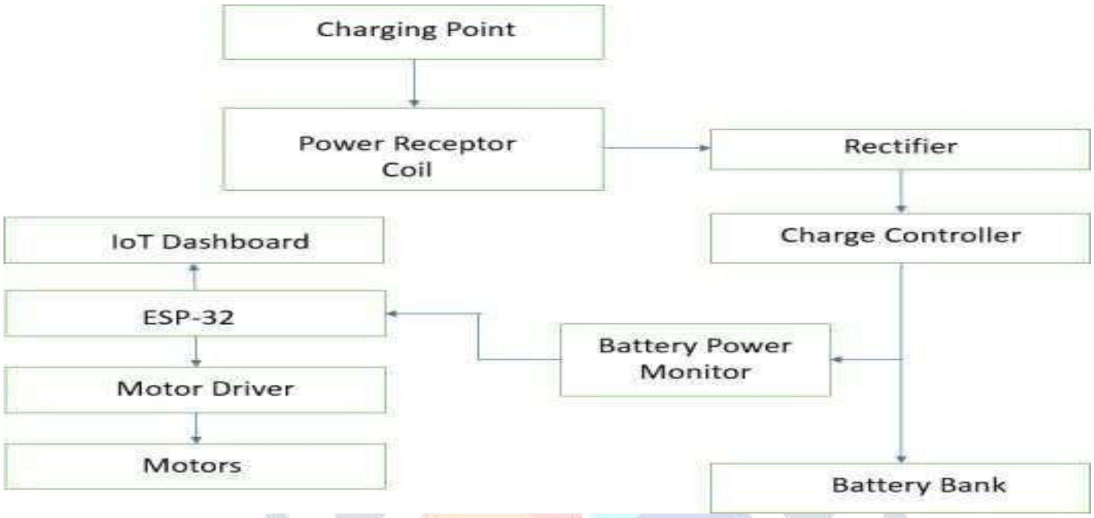

Fig. 2 Flowchart

Charging Point (Power Source)

The approach is that the system start at the charging point with an alternating current (AC) supply fed to the system by the electrical grid, normally with 230 V AC. This is the voltage that is used as the major input source to the wireless charging arrangement. In all electrical appliances, elements like fuses and surge suppressors are fitted to act as a protective measure against electrical shocks.

Rectifier (DC to AC Conversion)

The alternating current provided in the charging point is directed to a rectifier circuit, which converts the alternating current to direct current (DC). The operation of the high frequency inverter needs this conversion. A constant DC bus is therefore generated and this enables the production of the oscillatory magnetic field in the transmitter coil. Elements that will be used in filtering include capacitors and inductors that will help eliminate the voltage ripples and stabilise the DC output.

Coils of Power Transmitters and Receivers (Wireless Power Transfer Stage).

The rectified and conditioned DC power is connected to an inverter to provide energy to the transmitter coil which produces an alternating field of magnetic forces. This magnetic field is taken up by the receiver coil that is located under the electric vehicle or model car, and after magnetic induction converts it into an AC voltage. Efficiency of the coupling between the two coils is determined by the alignment of these coils and their distance, therefore, optimal magnetic design reduces wastage of energy. The resulting AC excited on the receiver coil is then rectified to back to DC to charge batteries.

Charge Controller

The charge controller controls the DC output that emanates out of the receptor coil generating safe and effective battery bank charging. It has voltage, current and cutoff threshold modulation depending on the state of charge (SOC) of the battery. In addition, it offers defense against over-charging, deep discharge as well as short circuiting thus maintaining the health of batteries.

Battery Bank

The DC power stored in the charge controller is stored in the battery bank, which is either Li-ion or lead-acid cells. This is accumulated energy that forms the major source of power to the vehicle. Voltage, current and temperature parameters of the battery are constantly measured to follow its performance.

Battery Power Monitor

A separate monitoring unit, e.g. using INA219 or ACS712 voltage current sensors undertakes real time measurements of battery operation. The obtained data are sent to an ESP-32 microcontroller that works with the received data and sends the information to an IoT dashboard. This allows users to check charging conditions and power usage and battery health in real time.

ESP32 microcontroller

ESP32 microcontroller includes an open core embedded platform used in IoT applications, along with a built-in operating system and a considerable amount of flash and RAM.<|human|>ESP-32 MICROCONTROLLER (IoT CONTROL UNIT)

The ESP-32 is the hub of the system on which processing and communications are carried on. It collects information of different sensors, e.g. the battery current and temperature sensors, and manages peripheral devices, e.g. the motor driver. It also has Wi-Fi connected to it and the information it monitors is uploaded to the IoT dashboard and can also be commanded by the dashboard to initiate or shut down the level of charging along with being able to modulate motor operations.

Internet of Things Dashboard (User Interface)

The IoT dashboard is created on basis of such platforms as: Blynk, ThingSpeak or Firebase showing real-time parameters (including):

By stating what is charged and what is passing, the spark prevents the discharge through each side of numerous ducts, but can cause the spark to occasionally pass through only a single duct; like the solder being struck in the process of solder iron making.

- Battery state of charge (SOC)

Power consumption and efficiency The amount of energy used by a device or system manufactured at a specific time.

- Temperature of the system, general health condition.

The dashboard will feature an interactive control panel to be used in remote monitoring, analytics, and notifications e.g. alert to say charging is complete.

Motor Driver

The board connecting the ESP32 microcontroller with the drive motors of the electric vehicle is a motor driver, whether that of L298N or BTS7960. Signal ESP-32 helps regulate the driver, thereby bending and regulating motor speed and movement. As the battery is charged up to an adequate level, the ESP -32 switches on the driver, hence accelerating the vehicle.

The motors make up the propulsion subsystem of the vehicle, which transforms the electrical energy that is stored in the battery bank into mechanical movement.

The Mateth L298 two full-bridge motor driver IC permits the control of speed and direction with great accuracy. It accepts normal TTL logic levels and can operate on a range of operating voltages of +5 V to +46 V, and it can also deliver up to 3 A per channel which would make it especially appropriate in medium-power DC motor applications.

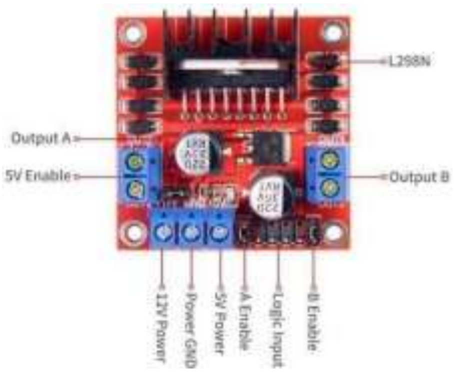

Fig. 3 Motors Connected to the L298 Motor Driver Module

IV. RESULTS

Distance Between Coils (cm)	Input Voltage (V)	Output Voltage (V)	Output Current (A)	Efficiency (%)
2.0	12.0	10.2	0.68	85.0
3.0	12.0	9.8	0.65	83.2
4.0	12.0	9.3	0.63	81.5

Compute output power:

$$P_{\text{out}} = V_{\text{out}} I_{\text{out}} = 10.2 \cdot 0.68 = 6.936 \text{ W}.$$

Given reported $\eta =$

0.85, back-calc input power:

$$P_{\text{in}} = \frac{P_{\text{out}}}{\eta} = \frac{6.936}{0.85} \approx 8.158 \text{ W}.$$

Then input current:

$$I_{\text{in}} = \frac{P_{\text{in}}}{V_{\text{in}}} \approx \frac{8.158}{12.0} \approx 0.680 \text{ A}$$

CHARGING PERCENTAGE TABLE (0–100%)

1)Distance = 2.0 cm
(Full time = 64.2 min)

Charge	Time
0% → 10%	7.6min
20%	15.1min
30%	22.7min
40%	30.2min
50%	37.8min
60%	45.3min
70%	52.9min
80%	60.4min
90%	68.0min
100%	75.6min

2)Distance = 3.0 cm
(Full time = 69.6 min)

Charge	Time
0% → 10%	7min
20%	13.9min
30%	20.9min
40%	27.8min
50%	34.8min
60%	41.8min
70%	48.7min
80%	55.6min
90%	62.6min
100%	69.6min

3)Distance = 2.0 cm
(Full time = 64.2 min)

Charge	Time
0% → 10%	6.4min
20%	12.8min
30%	19.3min
40%	25.7min
50%	32.1min
60%	38.5min
70%	45.0min
80%	51.4min
90%	57.8min
100%	64.2min

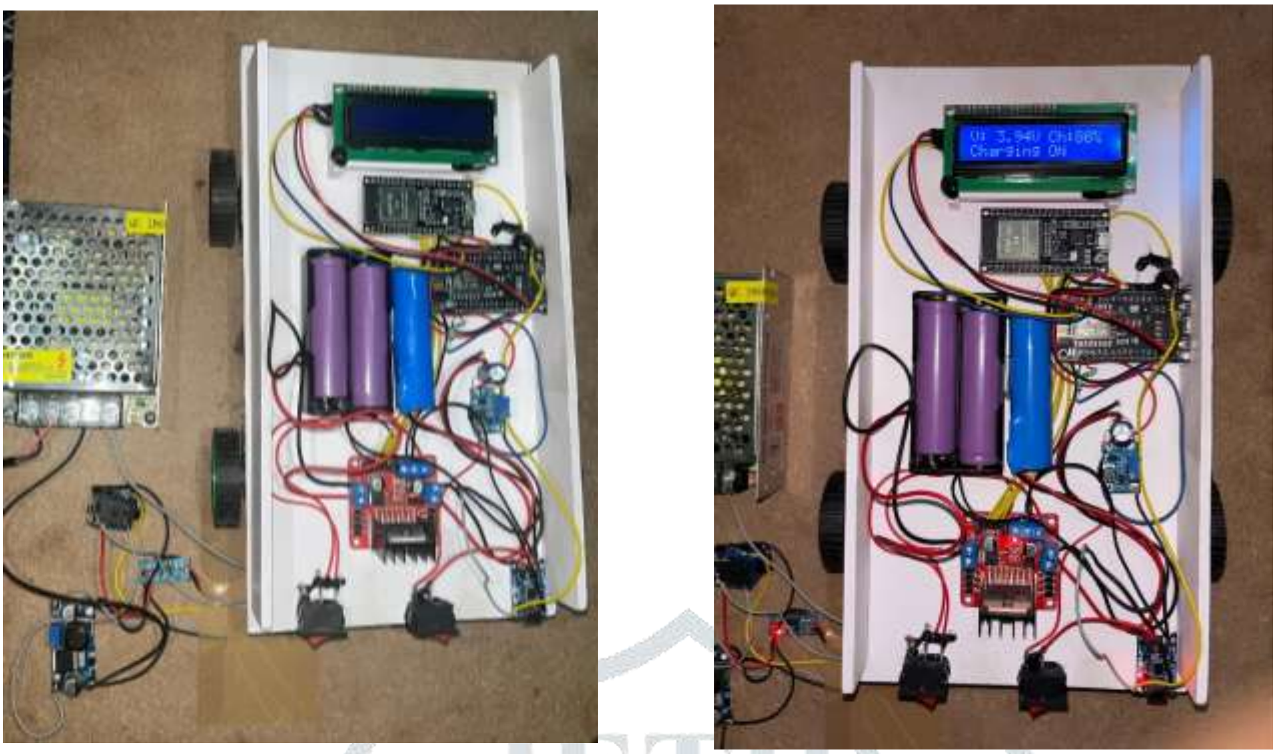

Fig. 4 Model of Project

Fig.5 Battery Voltage Measurement

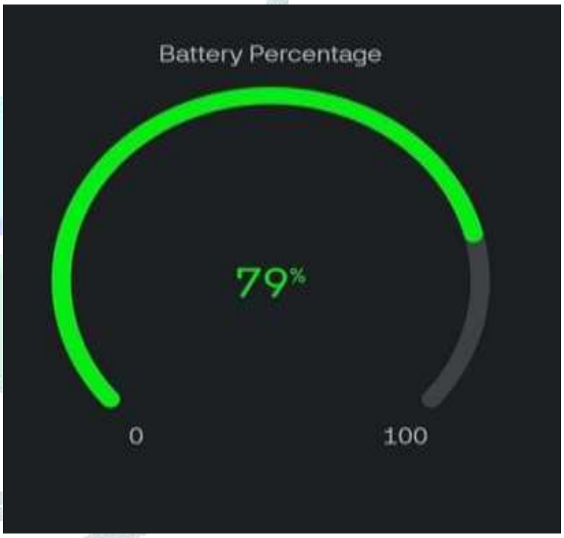

Fig. 6 Battery Percentage Display

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