Simulation of On-Road Wireless Charging for Electric Vehicles Using IoT Technology

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Abstract—The increasing demand for sustainable transportation has accelerated the adoption of Electric Vehicles (EVs). On-road wireless charging (ORWC) technology presents a promising solution by enabling dynamic charging while EVs are in motion. This paper proposes a simulation-based approach to implementing an IoT-enabled ORWC system that enhances energy efficiency and optimizes charging infrastructure. The proposed system integrates inductive power transfer (IPT) technology with IoT-enabled smart grid management. Wireless charging pads embedded in road infrastructure transfer energy to EVs equipped with compatible receivers. IoT sensors and communication networks facilitate real-time data exchange, allowing intelligent monitoring, traffic-based energy distribution, and predictive maintenance. The simulation evaluates key performance parameters such as power transfer efficiency, energy consumption, and system scalability under varying traffic conditions. This contributes to paving the way for future sustainable mobility solutions.

Keywords-- ***Sustainable transportation, Electric vehicles (EVs), Wireless charging, IoT-enabled smart grid, Inductive power transfer.***

I. Introduction

As technology revolutionizing a result of rising gas prices and environmental concerns, more people are switching to electric vehicles (EVs), Instead of solely relying on traditional charging stations because Wireless Electric Vehicle Charging also known as dynamic wireless charging utilizes inductive power transfer on the go, a charging infrastructure embedded in the roads which generates an electromagnetic field that wirelessly transfers energy to the vehicle's receiver coils which is mounted in the EV cars. This innovative Dynamic Wireless Charging (DWC) technology aims to enable EVs to charge while driving on the road receives a continuous charge as they travel, by extending anxiety range and reducing frequent charging need stops. The energy transfer process is managed by the sophisticated control units that ensures efficient and safe operation. The system can track energy transfer, car position, charging state, and efficiency measures using sensor networks. The study utilized Internet of Things (IoT) [23] and ThingSpeak platform to accurately tracking the amount of voltage, current [26] and temperature required ,and provides the graphical representations of monitored parameters, allowing users to analyze trends easily. Instant data updates helps to detect fluctuations and prevent potential failures.

II. Related Work

In order to overcome the difficulties associated with charging electric vehicles (EVs), wireless power transfer (WPT) technology has shown promise in terms of efficiency, convenience, and sustainability. In order to optimize lane movements and vehicle location, Rajni et al. (2023) implemented an on-road charging system that uses cooperative driver assistance systems (ADAS). They showed that high traffic situations can dramatically increase energy usage by more than 50% when compared to low traffic conditions [1]. Similarly, in order to maximize power sharing and account for traffic fluctuation, Ghazizadeh et al. (2024) presented a power electronics control solution for dynamic WPT by utilizing synthetic load generation techniques [22]. The problem of restricted vertical space in EV chassis was addressed by research by Khan et al. (2024) on planar inductor-rectifier designs, which resulted in a 66% improvement in power density—essential for small and effective power transmission systems [3]. Additionally, an empirical assessment on resonant magnetic field coupling techniques and inductive power pad designs was presented by Kumar et al. (2023), who also offered comparative studies of different coil geometries and optimization factors for improved efficiency in in-motion EV charging [4].

Current developments also investigate how IoT can be integrated with wireless EV charging. The shortcomings of traditional plug-in stations and the possibility for more accessibility and convenience with IoT-enabled smart charging [12] infrastructure were emphasized by Sudha et al. (2024) [5]. A static WPT system was created by Ashritha et al. (2023) to prolong battery life and solve plug-in charging overheating problems [6]. The importance of smart wireless vehicle charging stations employing IoT was further explored by Devika et al. (2024), who emphasized the viability of wireless charging for both parked and moving automobiles [7]. The control system functionalities of an electric car wireless charging system were described by Gowresudarshan Ashok et al. (2023) [8]. In a related work, Sandeep et al. (2024) improved the effectiveness of wireless EV charging stations by integrating IoT with WPT for real-time monitoring and predictive maintenance [9].

An IoT-based agricultural irrigation system [25] by Loganathan D et al., as well as a smart parking and charging system to reduce urban congestion and charging delays [10], were offered by Phadtare et al. (2020) as a solution to infrastructure issues. Furthermore, Megahed et al. (2024) investigated photovoltaic (PV)-powered dynamic wireless charging, optimizing energy distribution and transmitter-receiver coil configurations via smart grid integration [11]. Collectively, these studies demonstrate that advancements in WPT, IoT integration [23], and optimized coil designs are crucial for the widespread adoption of EVs, offering sustainable and efficient alternatives to conventional charging methods.

III. PROPOSED WORK

This paper proposes a wireless power transfer mechanism for electric cars that is efficient, tolerant of misalignment, and compact, A traffic numerical solution based on mesoscopic techniques is used to simulate freight distribution. This study explores. A new power[19] electronics control method has been proposed for dynamic wireless power sharing to maximize the number of cars charged when traffic slows down. A review of the IPT charging systems in EV applications[24] with an in-depth analysis of recent developments in coils design [18] as well as optimization techniques.

This initiative has taken to solved the problem of limited vertical space on the electric vehicle chassis for WPT by modelling and designed super planar-distributed magnets with integrated PCB windings considering the design space optimization constraints. This also solves the power density problem and results the step forward in distributed magnetics and automated magnetics design.

The goal is to create the prototype of toy car by design and assemble of a inductive power transfer (IPT). After the magnetic field of the IPT coil is created, the electronics model of the connected model is obtained to complete the design of the whole system with the electronic simulation tool [6]. This concept specially presents an evaluation on how the future EV development and wireless charging [14][16] methods can be implemented. Dynamic charging system can be implemented to charge the vehicle even when it is in motion the power sources can be transferred to the chargeable batteries through transformer windings.

Finally, this paper presents the integration of wireless charging systems with smart grid technology [20] is explored to enhance energy distribution and reduce peak load issues. Proposes a DWC system with multiple segment transmitters integrated with adaptive renewable photovoltaic (PV) units and a battery system by using the utility main grid as a backup [11][22].

IV. SYSTEM DESIGN

The diagram depiction of the interaction among the elements of a system .The Arduino Integrated Development Environment is an open-source software platform designed for writing, compiling, and to upload code to Arduino microcontroller boards.

The IR sensors is a digital sensor that provides a calibrated output in the form of a single wire communication which is ideal for microcontroller interfacing operates with a supply voltage of 3 to 5V. Input coils picks up the radios waves that are transmitted by a wireless charger's transmitters. A voltage regulator[21] is integrated circuits that helps to maintains a steady's outputs voltages.

Step 1: Detection & Authentication of Vehicles Detecting Vehicle Entry: The device uses an RFID sensor to identify the vehicle's unique ID when it sees an EV approaching. Infrared/ultrasonic sensor: identifies whether the car is in the charging lane.

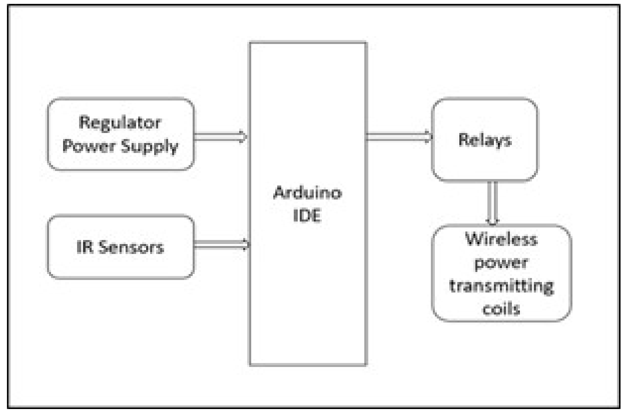

Fig 1: Block diagram

Step 2: Activating Wireless Power Transfer (WPT) A [13][15][17] magnetic field is produced by the transmitter coil (under the road). It is captured and converted to DC by a receiver coil(under the EV). Charging Commences: As the car moves, the battery starts to charge wirelessly.

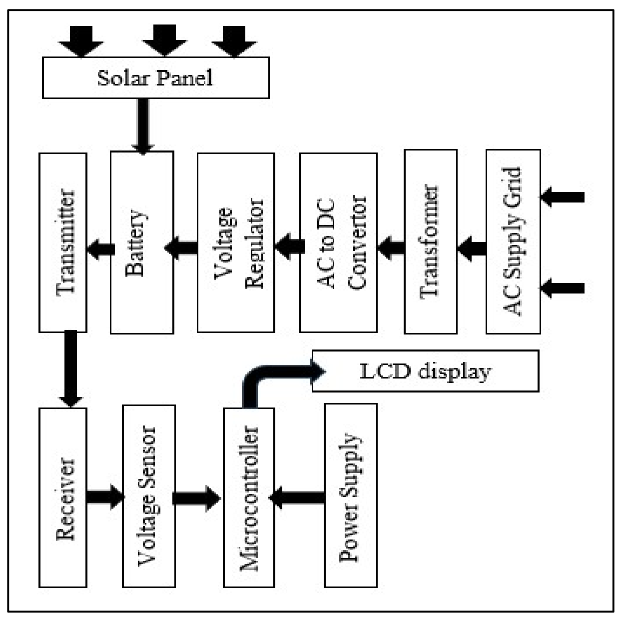

Fig 2: Shows the system workflow.

Dynamic Coil Activation: To cut down on energy waste, only the coils beneath the car are turned on. Information Gathered via Sensors: Readings for voltage and current (which track power flow).Charging Efficiency(%) (identifies the work of misalignment-related losses). Battery SoC (%): Tracks the level of battery charging. Sensors for temperature (avoids overheating). Thing Speak receives sensor data and stores and visualizes it. Battery efficiency and power consumption trends are examined by Thing Speak (platform offers advanced features like real-time data visualization).

V. Results and Discussion

When a car passes over the transmitter, it observes a magnetic field using receiver coil and transforms it to DC using the power converter support and BMS to charge the battery bank the frequent charging infrastructure reduces the overall battery demand by about 20% for an EVs. Transmitter pads and power supply segments have to be installed for dynamic WC at particular positions along with the predetermined pathways, the power supply segments are primarily separated into individual and centralized power frequency schemes. Centralized plan lesser efficiency, high installation costs, and higher maintenance costs as compared to segmented network. A prototype has designed with sensors and electric car with movements in a periodical movement gets charging while moving.

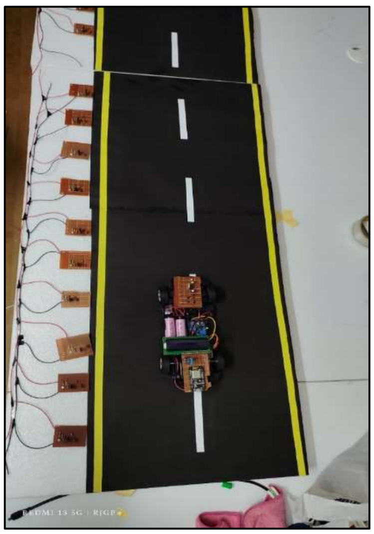

Fig 3: Dynamic Wireless Charging road System and Electric Vehicle - Prototype

The figure 4 provides a graphical representation of continuous voltage and temperature readings, offering a clear visual insight into their variations over time.

The figure 5 displays the precise voltage and temperature readings, updating every 15 seconds to ensure real-time monitoring.

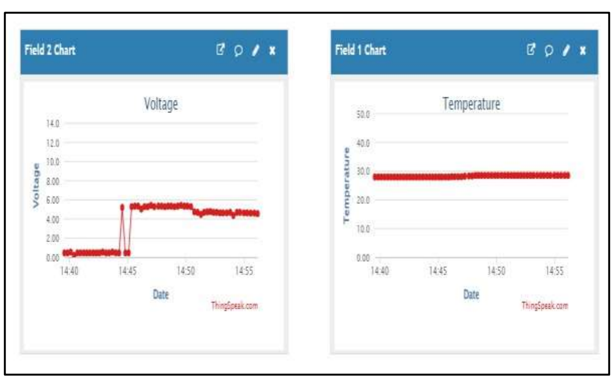

Fig: 4: Field Chart of temperature and Voltage

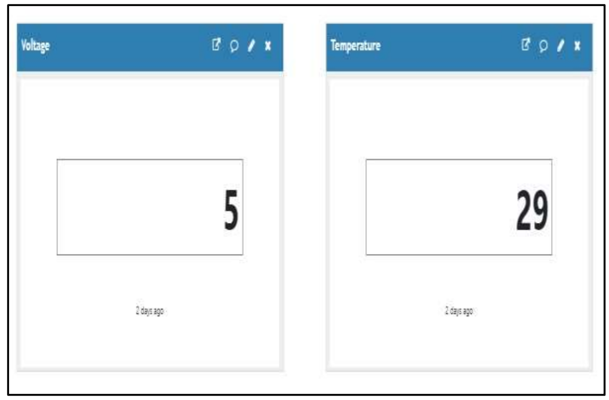

Fig: 5: Voltage and Temperature readings

V. Conclusion

An innovative step toward attaining sustainable, effective, and continuous electric transportation is the deployment of IoT-based on-road wireless charging for electric vehicles (EVs). This research effectively used Thing Speak software for real-time data monitoring and analysis to simulate a dynamic wireless charging system linked with IoT technologies

We used the simulation to show that wireless power transfer (WPT) with inductive charging technology integrated into the road infrastructure is feasible. This eliminates the need for frequent stops at charging stations and greatly reduces downtime by enabling EVs to charge while moving. We were able to gather, examine, and display real-time data from IoT sensors integrated into the system by utilizing Thing Speak.

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