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Wireless Charging of Electric Vehicle while driving

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Abstract: Electric vehicles (EVs) are gaining traction as eco-friendly alternatives to internal combustion engine vehicles. However, they continue to face key obstacles, including extended charging durations and range limitations. A promising solution is dynamic wireless charging—often referred to as roadway-powered electric vehicles (RPEVs)—which enables in-motion energy transfer, reducing reliance on large onboard batteries. This technology typically employs inductive or capacitive coupling between transmitter (Tx) and receiver (Rx) units. Among these, inductive power transfer systems (IPTS) are favored for their strong coupling efficiency. Nonetheless, issues such as electromagnetic interference, alignment sensitivity, and complex control mechanisms persist. To mitigate these, this study introduces an auto-tuning control system (ACS) that dynamically adjusts current using variations in the Tx coil's self-inductance—eliminating the need for active sensors or switching components.

Keywords: ***Dynamic Wireless Charging, Inductive Power Transfer, Auto-Tuning Control, Electric Vehicle***

I. INTRODUCTION

In recent years, growing concerns about environmental pollution have led to a surge in interest and demand for electric vehicles (EVs).In response to increasing environmental concerns and the push for cleaner transportation, electric vehicles (EVs) have gained significant momentum, leading to a rapid expansion of the EV market. Despite their environmental advantages, EVs face persistent challenges such as extended charging durations and lower energy density compared to conventional internal combustion engine vehicles, which limits their driving range. To overcome these obstacles and facilitate wider adoption, dynamic wireless charging—commonly referred to as roadway-powered electric vehicle (RPEV) technology—has emerged as a promising solution. This method enables real-time energy transfer from the road to the vehicle, reducing the reliance on large battery capacities and minimizing charging downtime.

Dynamic wireless charging systems are primarily categorized into two types: inductive power transfer systems (IPTS) and capacitive power transfer systems (CPTS). IPTS utilizes magnetic coupling between transmitter (Tx) and receiver (Rx) coils, while CPTS relies on capacitive coupling through Tx and Rx plates. Among these, IPTS is more prevalent due to its advantages such as stronger coupling, lower voltage stress on circuit components, and more favorable material properties. As a result, IPTS-based solutions have attracted extensive research attention, and several implementations have reached commercial development stages.

These systems are typically configured using either centralized or segmented track designs. Centralized configurations, like those used in online electric vehicle (OLEV) systems, employ long Tx coils powered by a single inverter.

This setup simplifies control and reduces infrastructure cost but may pose risks related to electromagnetic field (EMF) exposure. Conversely, segmented systems consist of multiple short Tx coils driven by individual inverters, offering better EMF

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containment at the expense of increased system complexity and the need for additional sensors and control mechanisms.

To address these technical trade-offs, various research groups, including those at North Carolina State University, have investigated passive field management strategies that eliminate the need for active switches and sensors. However, in applications with narrow air gaps, the inclusion of ferrite materials in the Rx units can lead to increased Tx coil inductance, potentially affecting system performance. This study introduces a novel auto-tuning control system (ACS) that leverages the variation in the Tx coil's self-inductance to enable efficient and automatic current regulation. This approach removes the dependency on power switches and sensors, thereby simplifying the system while enhancing reliability and efficiency.

II. LITERATURE SURVEY

[1] Maharaj et al. (2018) conducted a comprehensive survey on Dynamic Wireless Power Transfer (DWPT) for electric vehicle (EV) charging. Their study emphasized the potential of DWPT to overcome limitations in EV battery systems, particularly regarding limited driving range and lengthy charging times. DWPT operates through inductive power transfer (IPT) between coils embedded in roadways and those on-board EVs, enabling continuous charging without the need for physical connectors. The research analyzed different DWPT configurations, including long loop, sectional loop, and spaced loop setups, demonstrating how these can extend driving range and reduce battery capacity needs under varying traffic conditions. Real-world initiatives such as Korea's OLEV, Qualcomm Halo, and trials by Oak Ridge National Laboratory were cited as indicators of the technology's maturity. Simulation studies in Trinidad and Tobago further validated DWPT's feasibility, particularly in regions with low to medium EV adoption, by highlighting reductions in energy consumption and system cost.

[2] Jeong et al. (2019) introduced a novel auto-tuning control system (ACS) for dynamic wireless EV charging aimed at simplifying control mechanisms and enhancing efficiency. The ACS works by automatically adjusting the current in the transmitter (Tx) coil as the receiver (Rx) approaches, utilizing changes in the Tx coil's self-inductance caused by the proximity of the ferrite core in the Rx coil. This approach eliminates the need for active sensors, power switches, or communication links. Experimental and simulation results demonstrated a significant improvement in performance, with the coupled Tx coil generating 11.6 times more current than its uncoupled counterpart and achieving up to 88.4% DC-DC efficiency at 766 W. The system also reached a peak efficiency of 96.7%, proving effective in applications involving narrow air gaps such as rail-based transport.

[3] Jia et al. (2020) proposed an improved method for constant voltage output in dynamic wireless EV charging systems. The authors identified challenges with traditional multi-stage transmitting rail systems that rely on LCC-S compensation topology, noting their structural complexity and high cost. To address this, they introduced a secondary-side relay coil to work alongside the primary transmitter and receiver coils, forming a series resonant circuit. This configuration streamlined the primary-side design, reduced component count, and lowered the total system cost while maintaining a consistent voltage output as the vehicle moved along the charging rail. Simulation results confirmed the system's ability to deliver stable output under varying load conditions, suggesting its suitability for long-distance dynamic charging scenarios.

[4] Razu et al. (2021) explored the advantages and limitations of wireless EV charging systems, particularly contrasting static and dynamic approaches. Static charging systems require vehicles to stop during

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the charging process and typically necessitate larger battery capacities to support extended driving range. Dynamic wireless charging, using mutual inductance between embedded road coils and in-vehicle receivers, offers a more efficient alternative by allowing in-motion charging. However, power transfer efficiency is highly dependent on coil alignment and air gap distance. Their findings indicate that optimized coil designs can yield efficiencies up to 92.4%, with dynamic systems poised for broader implementation within the coming decade. Although this approach can reduce dependence on large batteries and eliminate range anxiety, challenges remain in ensuring efficient power transfer during continuous vehicle motion.

[5] Pau and Deepa (2023) focused their literature review on Boost Converters (BC) and Interleaved Boost Converters (IBC) used in wireless EV charging applications. With the global push to replace fossil fuel vehicles and reduce greenhouse gas emissions, wireless charging systems (WCS) are gaining traction due to their safety, convenience, and energy efficiency. BCs and IBCs play a vital role in converting DC power into usable AC for wireless charging. Compared to conventional BCs, IBCs provide enhanced voltage gain, reduced current ripple, and improved efficiency, making them better suited for wireless power transfer (WPT) systems. The review highlighted the growing adoption of IBCs in both static and dynamic charging contexts, noting that simulations have confirmed their superior performance in minimizing voltage fluctuations and enhancing overall power delivery efficiency.

III. FLAWS IN THE EXISTING SYSTEM

The existing system for wireless charging of electric vehicles while driving faces several critical flaws. One major issue is the misalignment between the transmitter and receiver coils, which can drastically reduce power transfer efficiency when the vehicle is in motion. This challenge becomes more pronounced with dynamic charging, where maintaining precise alignment is difficult.

Additionally, the system requires complex infrastructure, including multiple sensors, control algorithms, and segmented coil tracks, which significantly increases installation and maintenance costs. These limitations hinder scalability and widespread adoption of the technology.

IV. PROPOSED SYSTEM

The proposed Auto-Tuning Control System (ACS) for dynamic wireless EV charging aims to improve the existing systems by eliminating the need for active sensors, communication modules, and power switches, thereby simplifying the design and reducing control complexity. It uses the self-inductance variation of the transmitter (Tx) coil to automatically adjust the current depending on the proximity of the receiver (Rx) coil. This system relies on inductive power transfer (IPT), where energy is wirelessly transferred through magnetic coupling, ensuring that only the coil beneath the vehicle is active, minimizing electromagnetic field (EMF) leakage and enhancing safety.

The ACS enhances system efficiency up to 96.7% in lab experiments, reducing energy loss during transfer. Its modular and scalable design supports various road configurations and vehicle types, making it adaptable for future use. By incorporating a solar-powered supply and efficient components like H-Bridge drivers and Arduino microcontrollers, the system is both eco-friendly and cost-effective. It supports smaller battery sizes in EVs, reducing vehicle weight and cost.

The system allows seamless charging while the vehicle is in motion, reducing charging time and increasing the driving range. By removing the need for frequent plug-in charging and large batteries, it helps alleviate range anxiety. Real-time monitoring is enabled via an LCD display and Bluetooth control, allowing for manual overrides. The design is well-suited for smart city deployment with segmented track systems, activating energy transfer

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only when a vehicle is detected. Its modularity allows easy integration into existing road infrastructure with minimal modifications, promoting sustainable transportation and facilitating wider EV adoption.

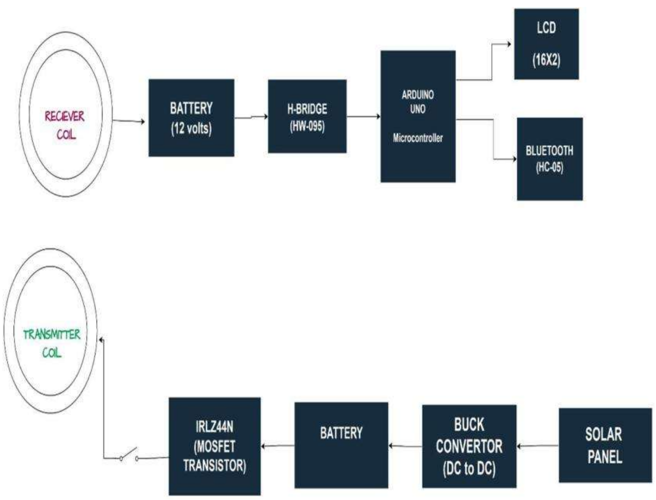


Fig 1 Block diagram

Objective :The objective is to develop a dynamic wireless EV charging system that automatically adjusts power based on vehicle proximity, enhancing efficiency, safety, and scalability. This system reduces control complexity, charging time, and reliance on large batteries, promoting sustainable EV adoption.

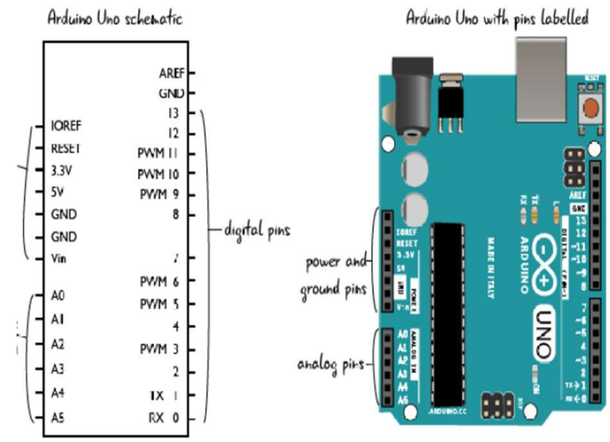
Study Area and Data Collection Study Area : The study area focuses on the development and testing of a dynamic wireless electric vehicle (EV) charging system integrated into a controlled test track environment. This environment simulates urban road conditions to evaluate real-time performance, efficiency, and safety. Key factors considered include road layout, vehicle types, traffic flow, and ambient conditions relevant to smart city infrastructure.

Hardware- components: Selected Arduino microcontroller as the core processing unit.. Bluetooth Module,Solar panel, H Bridge(HW095),Transmitter(TX)andReceiver(RX)Coil,12VoltMotor,Battery,Buckconverter,LCD,Transistor.

V. SYSTEM ARCHITECTURE

The system is composed of following components:

1. Arduino uno



The Arduino UNO is a widely-used microcontroller board based on the ATmega328P chip, known for its simplicity and versatility, making it a favorite among hobbyists and educators. It features 14 digital input/output pins (6 of which can produce PWM signals) and 6 analog input pins, providing ample connectivity for various sensors and actuators. With 2 KB of SRAM, 32 KB of flash memory, and 1 KB of EEPROM, it supports sufficient data storage for most projects. The board can be powered via USB or an external power supply, allowing for flexible deployment. The Arduino IDE offers a user-friendly programming environment, complemented by extensive libraries that facilitate quick integration of components. Its strong community support and vast online resources make it an ideal platform for a wide range of applications, including robotic, automation,and environmental monitoring, enabling users to easily prototype and learn about electronics and programming.

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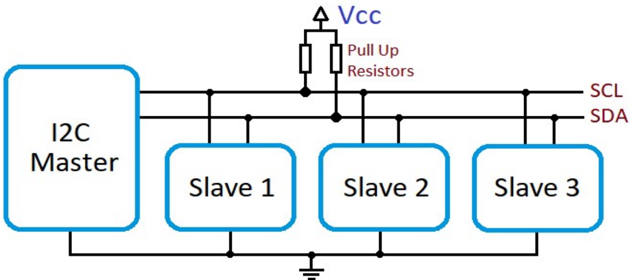
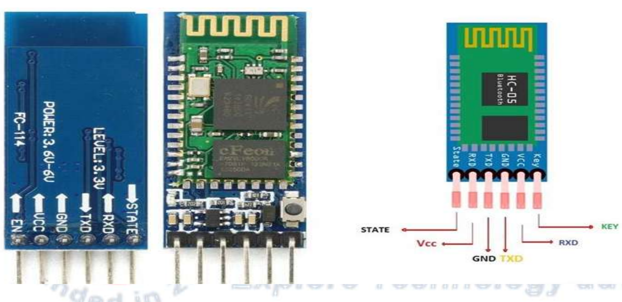
2. I2C Interface Module



Used to interface a character LCD with the microcontroller, the I2C module minimizes the number of required GPIO pins by converting serial I2C data into parallel signals for the display. It simplifies wiring and supports multiple devices on a single bus through adjustable addressing.

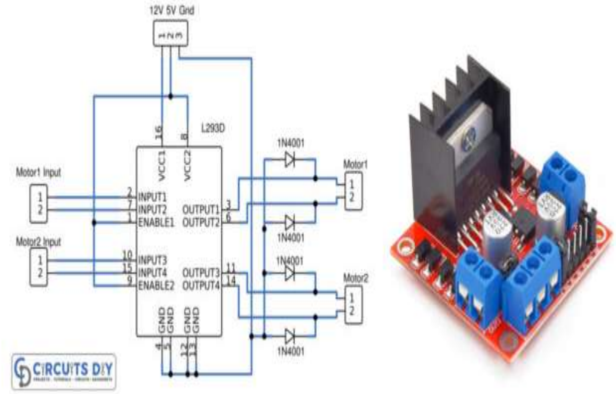
3. Bluetooth Module



This module provides a wireless interface between the microcontroller and a mobile device. It operates on Bluetooth 2.0 with enhanced data rate (EDR), enabling real-time transmission of commands such as vehicle direction control. Its UART interface allows seamless integration with Arduino boards.

4. H-Bridge Motor Driver

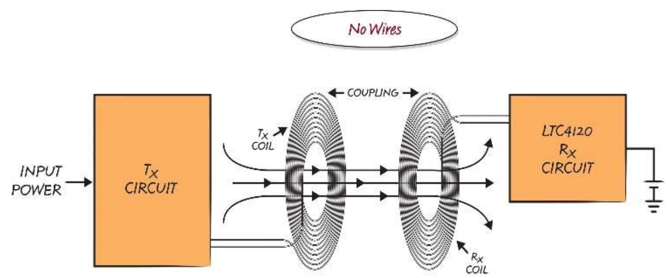
This dual H-Bridge driver module enables bidirectional control of DC motors. It allows the system to manage the motion of the vehicle model by varying motor direction and speed through PWM signals. The L298D includes internal protection features such as thermal shutdown and current limiting.



5. Solar Panel

A solar photovoltaic panel is incorporated to supply renewable power to the system. It converts incident sunlight into electrical energy, reducing dependency on non-renewable sources and enhancing the eco-friendly nature of the setup. This approach supports sustainability and off-grid functionality.

6. Transmitter and Receiver Coil



The transmitter (Tx) and receiver (Rx) coils form the core of the inductive power transfer system. Constructed with precise dimensions and number of windings, these coils enable efficient magnetic coupling. As the vehicle moves over the Tx coil, power is transferred wirelessly to the Rx coil mounted beneath the vehicle.

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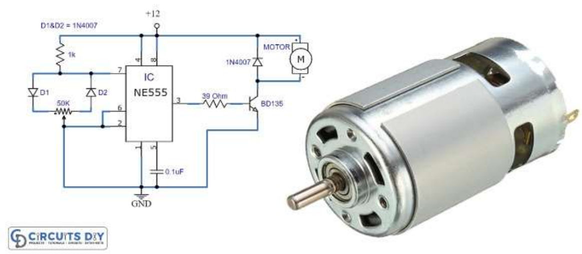
Coil Specifications :

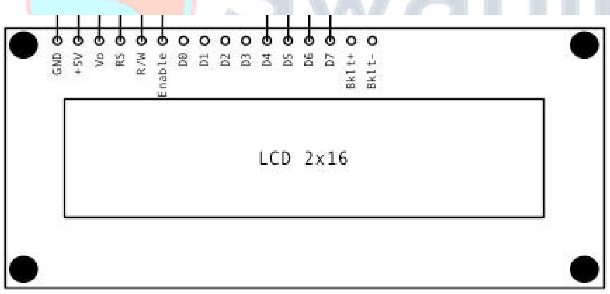
1. Outer Diameter (D out): 232.5 mm
2. Inner Diameter (Din): 140 mm
3. Radius Change per Turn (T): 5.3 mm
4. Diameter of Wire (D wire): 0.5 mm
5. Number of Turns (N): 30

7. 12 Volt Motor



A low-speed, high-torque DC motor is used to simulate the motion of the electric vehicle. It is powered and controlled through the H-Bridge, responding to user commands received via the Bluetooth interface.

8. LCD Display



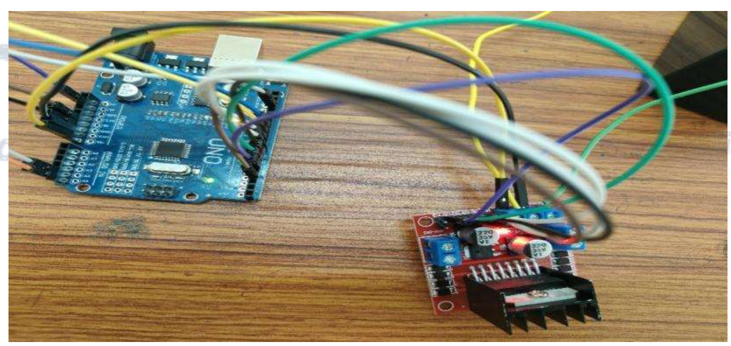
A 16-column, 2-row character LCD is employed to visually display system parameters like voltage, current, and efficiency. Integrated with an I2C interface, it communicates with the Arduino using only two data lines, simplifying the overall circuit layout.

VI. IMPLEMENTATION

Open Arduino IDE version 2.3.3 or later, click on file then followed by sketch, where you can type the code to upload in to the Arduino UNO.

After opening Arduino IDE click on tools where you can see board, where board is the type of Arduino your using currently e.g. UNO, Nano etc. once we seletected the tools then board, we have to select the respective Arduino board. Our Arduino board is Arduino UNO. After selecting the board we have to select and confirm in which port we have inserted the A-B cable to transfer the data into Arduino e.g. COM3.

1. H-Bridge to Arduino UNO



The H-bridge [HW-095] operates at 2.5V- 12V with a current of 2Amps . We can directly give 12v or 5v to the H-Bridge..The DC motor operating should be 9v – 12v.

Pins and Connections to Arduino: VCC: Connect to 12V from the Arduino ,GND: Connect to the Arduino GND,IN1: Connect to one Arduino digital pin for controlling motor direction.,IN2: Connect to another Arduino digital pin for controlling motor direction,ENA (Enable): Connect to an Arduino PWM pin to control motor speed.

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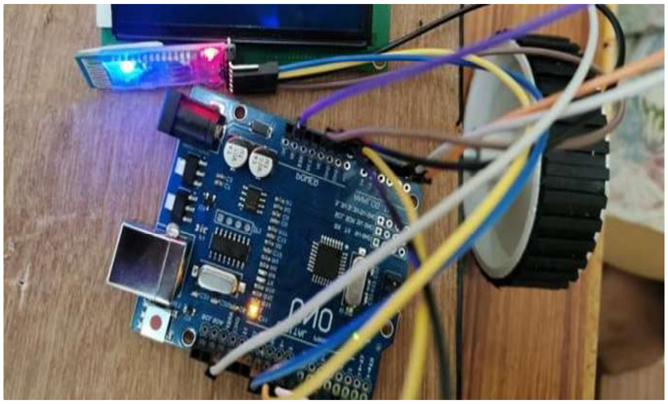
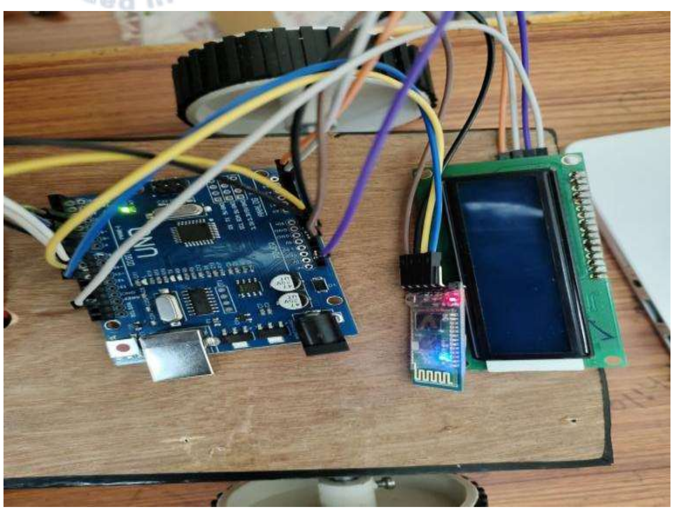
2. *Bluetooth Module(HC-05) to Arduino UNO*



A Bluetooth module enables wireless communication, data transmission, and device control within a range of 30 feet. It allows for hands-free voice transmission, file transfer, and internet connectivity. HC-05 allows you to control the movements of motors.Operates at 5V, supplied by the Arduino UNO.The bluetooth module has six pins: VCC, GND, TXD-pin, RXD-pin, STATE-pin and EN-pin,VCC – 5V,GND – GND,RXD-pin– Arduino UNO (11),TXD-pin – Arduino UNO (10).

3. *LCD Display to Arduino UNO*

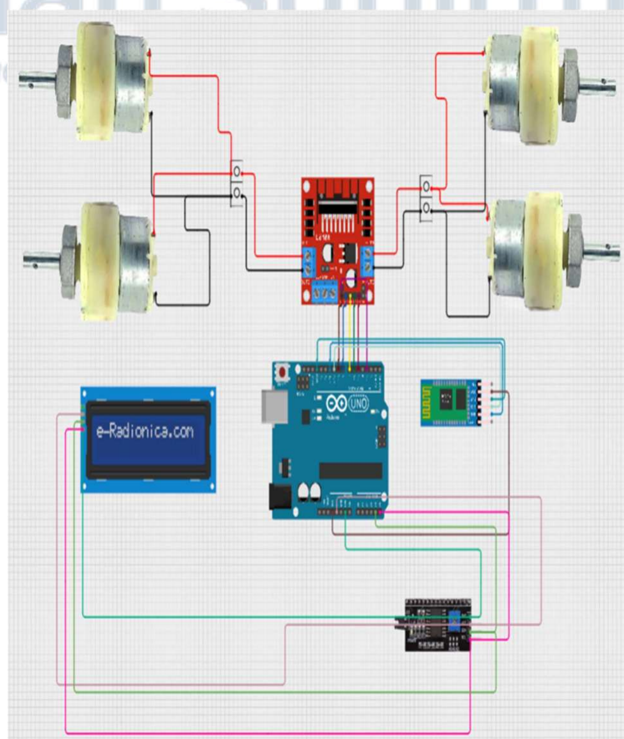


Operates at 5V, supplied by the Arduino UNO. Simplifies connections by using only four pins: VCC, GND, SDA, and SCL to manage all input and output functions of the LCD.VCC - 5V,GND - GND,SDA - Arduino UNO (A4),SCL - Arduino UNO (A5).

4. *Tx and Rx coil*

Outer Diameter (D out): 232.5 mm, Inner Diameter (Din): 140 mm,. Radius Change per Turn (T): 5.3 mm., Diameter of Wire (D wire): 0.4 mm., Number of Turns (N): 30 in TX and 60 in RX.Ratio= 1:2.

5. *Circuit Design Implementation*



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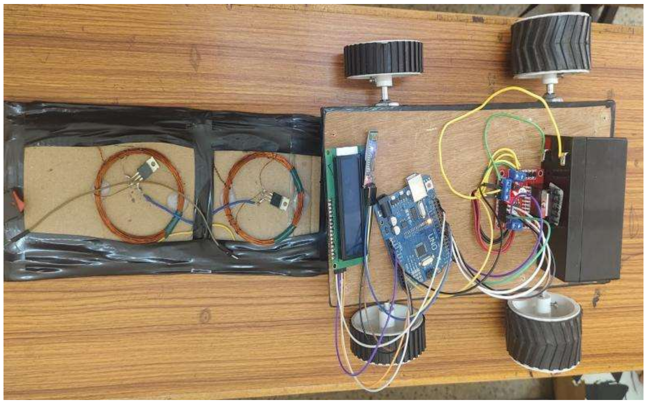
VII. RESULT



The developed prototype of a dynamic wireless charging system was evaluated under controlled conditions to verify its functionality and efficiency. The system was designed to charge an electric vehicle model wireless while in motion, eliminating the need for direct electrical connections.

The core charging mechanism relied on the inductive power transfer between a transmitter coil embedded in the track and a receiver coil mounted beneath the vehicle. The system was able to detect the presence of the receiver coil based on inductance variation, activating the power flow automatically without external sensors.

During testing, the system operated consistently, with the LCD displaying real-time data such as current and voltage values. Receiver voltage readings ranged from 7.5V to 8.5V across five update cycles, while transmitter current was simulated between 0.1A and 1.0A. Efficiency calculations based on these values yielded results as high as 85%.Motor movement was effectively controlled using Bluetooth commands via a mobile interface. The motor responded promptly to forward, reverse, and stop commands, confirming the successful integration of the H-Bridge driver and wireless control module.The solar panel functioned as an auxiliary power source, showcasing the system's potential for renewable energy integration. Overall, the auto-tuning control system proved capable of handling coil misalignment and dynamically adjusting power delivery.

This design successfully demonstrated seamless charging while moving, confirming its viability for future smart transportation infrastructure.

VIII CONCLUSION

The wireless charging system developed in this project demonstrates a promising approach to dynamic electric vehicle (EV) charging, addressing key limitations associated with conventional plug-in and static wireless charging methods. By enabling real-time energy transfer while the vehicle is in motion, the system reduces dependency on large battery packs and long charging stops, directly contributing to the reduction of range anxiety among EV users.

The core of the system utilizes inductive power transfer (IPT) through transmitter and receiver coils, with energy being transferred based on the relative proximity of the vehicle. The novel use of self-inductance variation in the transmitter coil for auto-tuning eliminates the need for active sensors and power switches. This not only reduces control complexity but also enhances system robustness and cost-effectiveness.

Experimental results confirm that the system operates efficiently, reaching up to 85% efficiency in a lab-scale model. The integration of a Bluetooth-based control interface and real-time voltage display via LCD enhances user interaction and provides intuitive monitoring. The motor control through mobile commands also demonstrated stable operation, validating the effectiveness of the control logic.

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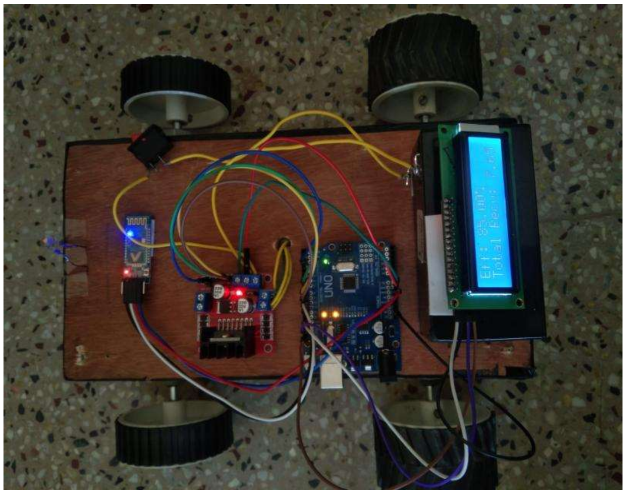

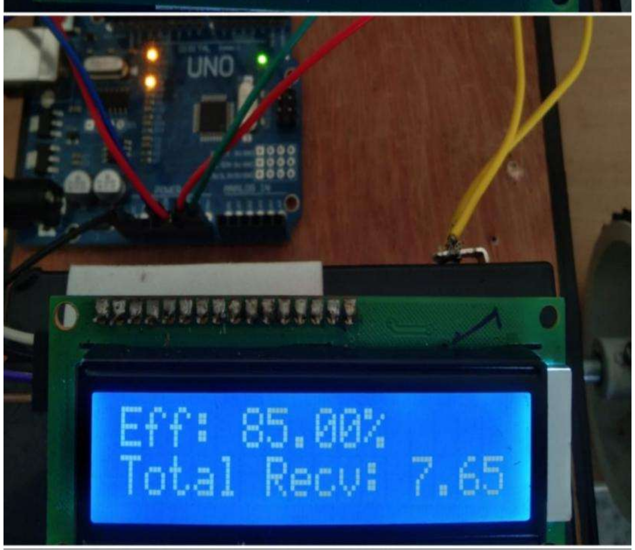

The motor control through mobile commands also demonstrated stable operation, validating the effectiveness of the control logic.

A solar panel was successfully used to power the system, supporting the concept of renewable energy integration and environmental sustainability. Furthermore, the modular design allows for scalability and adaptation to various road types and vehicle configurations, making it suitable for future smart city infrastructure.

Overall, the project proves the feasibility of dynamic wireless EV charging using a simplified, sensor-free control approach. With further development, such systems can lead to the deployment of smart roads that offer continuous, safe, and eco-friendly EV charging. This innovation has the potential to transform modern transportation by supporting cleaner, more efficient mobility solutions.

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