



Development Of An Inductive Wireless Charging Prototype For Electric Vehicles

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Abstract: The increasing demand for sustainable and efficient transportation systems has driven significant interest in wireless energy transfer technologies for Electric Vehicles (EVs). This project work focuses on the design and implementation of a wireless energy transfer system tailored for battery-operated vehicles. The primary objective is to enable contactless charging through inductive coupling, which enhances user convenience and safety while reducing dependency on traditional plug-in charging methods. The system comprises a transmitter coil integrated with a power source and a receiver coil mounted on the vehicle, designed to achieve efficient power transfer, which is detected by the LED bulb. Key aspects such as coil alignment and energy conversion efficiency are addressed to sharpen system performance. The proposed work also includes the development of a prototype to demonstrate the practical possibility, along with performance. This approach not only simplifies the charging process but also contributes to the advancement of smart and sustainable mobility solutions

Keywords—Wireless Charging Technology, Arduino Uno, Mutual Inductance, inductive coupling, Electrical Vehicle

I. INTRODUCTION

Due to their potential to address several financial and environmental challenges within the transportation industry, Electric Vehicles (EVs) have recently gained significant attention and importance. EVs represent a revolutionary advancement in transportation technology, notably reducing air pollution and greenhouse gas emissions by generating zero tailpipe emissions through electricity stored in batteries or fuel cells[1]. Wireless power transfer systems for battery-operated vehicles involve inductive resonant designs with carefully optimized coils, compensation topologies, and alignment control. System performance reduce on coupling efficiency, alignment strategy, and inverter design. Both static and dynamic charging modes are under active development, with real-world pilots underway to validate feasibility and efficiency[2]. This technology plays a critical role in powering electrical devices, providing a more flexible and efficient power delivery method by eliminating the need for direct physical connections through the application of mutual inductance principles. Notably, the automotive industry, particularly in the realm of EVs, holds promise for future WPT applications.

1.1 Problem statement:

Conventional plug-in charging of battery-operated vehicles adds user friction, wear on connectors and safety. The problem is to design and implement a safe, efficient, and misalignment-tolerant Wireless Power Transfer (WPT) system that can charge a vehicle's battery without physical connectors. The system must deliver regulated DC power to the battery over an air gap, operate within thermal and electromagnetic limits, and demonstrate reliability under realistic misalignment and load variation.

II.LITERATURE SURVEY

In one study [3] the United States is at the global leading level in hydrogen fuel cell vehicle market and hydrogen re fuel station utilization rate. By June 2020, the cumulative sales volume of hydrogen fuel cell passenger cars and hydrogen fuel cell forklifts in the United States reached 8,413 and over 30,000 respectively. Plug power basically monopolized the global hydrogen fuel cell forklift market. According to the statistics of the National Monitoring and Management Centre for New Energy Vehicles as of December 31, 2020 there are a total of 6,002 fuel cell vehicles have logged on to the platform. Among them the number of fuel cell logistics vehicles, buses and passenger vehicles reached 3,153, 2,846 and 3 which distributed in 37 different cities, 17 provinces across the country. Plug power basically monopolized the global hydrogen fuel cell forklift market. Explained in the below figure 2.1.

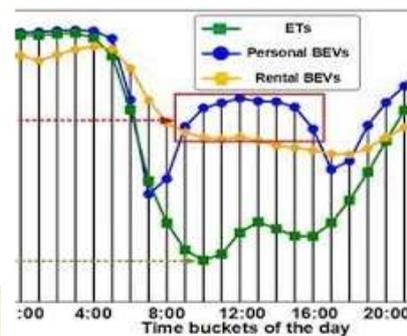


Figure 2.1: Statistical Analysis of Fuel Cell Vehicle

In another investigation [4] according to that research institutions and automakers current progress in this area, CWD inside design can be set up and put into general use within the next ten to 20 years. Because of this, several businesses have been exploring methods to use wireless charging to increase the range of EV's while also streamlining and automating the charging process. In the past ten years, there has been a lot of interest in WPT technology since it has a number of intrinsic advantages over conventional power transmission techniques. It has been suggested that it be used for a broad variety of applications, from electrical car chargers to vehicles in railways with an power of up to 95 percent otherwise more on certain systems prototype, to low-power medicinal implants. Magnetic field coupling is used in magnetic WPT devices to transfer electricity between magnetically coupled coils over a wide air gap. The two methods of charging an electric car are conductive (or wired) charging and wireless charging. The vehicle's charge inlet and the electric supply are connected during wired charging. Even assessing while cable is common, it has a lot of drawbacks, including untidy cords and safety concerns in moist atmosphere. Explained in the below figure 2.2.

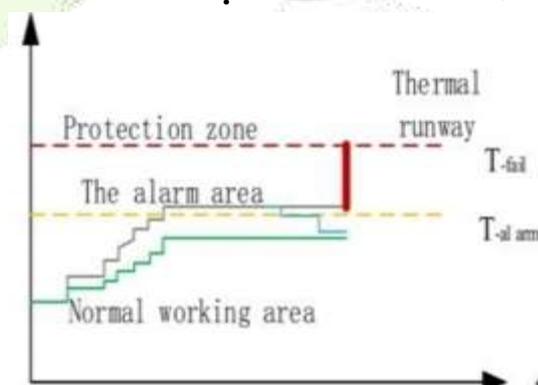
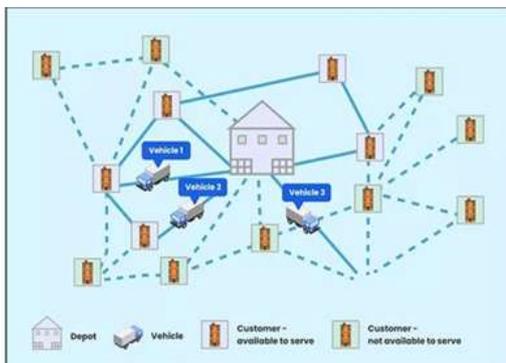


Figure 2.2: Optimization of Electric Vehicles.

In another paper [5] illustrate as recommendation for future investigation, researchers should concentrate on real-life HVRPs, taking into consideration real-time transportation information (road conditions, the traffic, the availability of parking spaces.) and use dynamic-real word data . researchers can also handle external factors and constraints such as weather condition since it has impacts on the fuel consumption and can apply comprehensive methods to measure the environmental impact through the entire life cycle of a vehicle. To the best of our knowledge, the dynamic and stochastic environment have not been investigated. This can be a promising field for future research. Researchers can also handle external factors and constraints such as weather

condition since it has impacts on the fuel consumption and can apply comprehensive methods to measure the environmental impact through the entire life cycle of a vehicle. To the best of our knowledge, the dynamic and stochastic environment have not been investigated. The success of this methodology relies heavily on inter disciplinary collaboration, including advancements in power electronics, magnetic field optimization, communication systems, and regulatory compliance. Explained in the below figure 2.3



In another paper [6] illustrates the wireless electric vehicle charging methodology focuses on efficient inductive power transfer, ensuring safe, reliable, and cost-effective charging solutions. As the technology continues to evolve, improvements in power efficiency safety, and user experience will play a significant role in making wireless EV charging a main stream option. The success of this methodology relies heavily on inter disciplinary col laboration including advancements in power electronics, magnetic field optimization, communication systems, and regulatory compliance. Explained in the below figure 2.4.

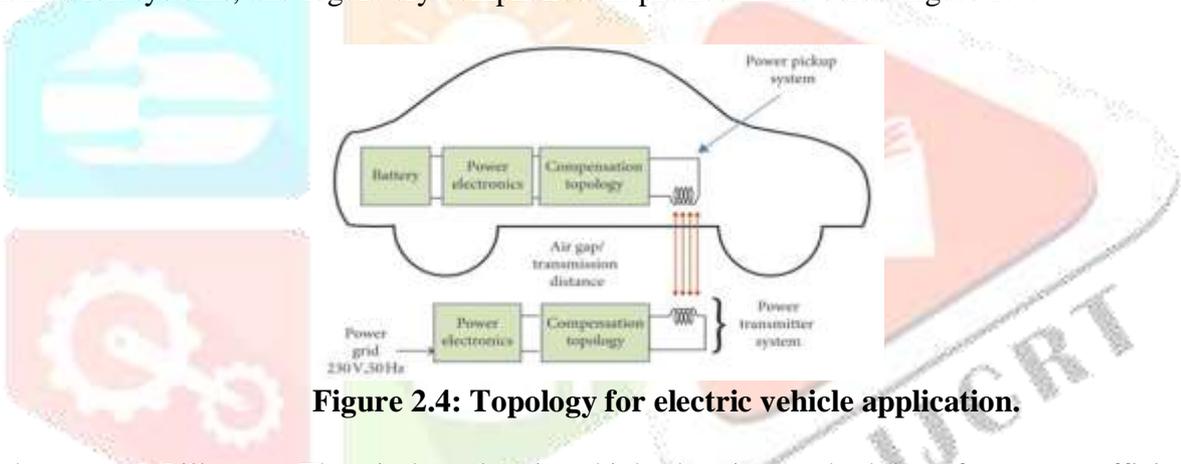


Figure 2.4: Topology for electric vehicle application.

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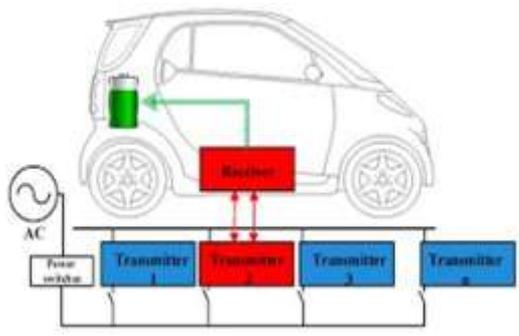


Figure 2.5: Wireless Electric vehicle Charging System.

In another paper [7] illustrate Induction brazing is a process that uses high-frequency electromagnetic fields to heat a metal workpiece, typically for joining or brazing operations. The copper coil in an induction brazing system plays a key role in generating the electromagnetic field necessary to heat the metal and the filler material (usually a brazing alloy) to the required temperature for bonding. Designing a copper coil for an induction

brazing system requires careful consideration of factors such as heating uniformity, efficiency, material properties, and safety. Below is a step-by-step methodology for designing a copper coil for this purpose. The copper coil in an induction brazing system plays a key role in generating the electromagnetic field necessary to heat the metal and the filler material (usually a brazing alloy) to the required temperature for bonding. Explained in the below figure 2.6.

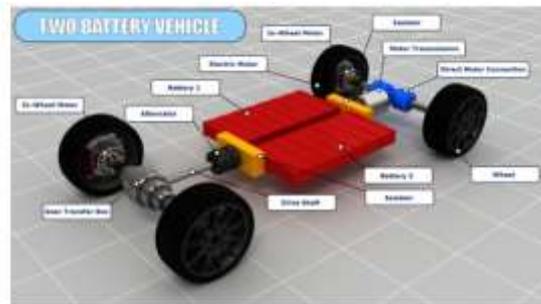


Figure 2.6: Induction brazing system

III. METHADODOLOGY

3.1 Hardware and Software Components

The wireless power transfer prototype was designed using a combination of hardware modules and embedded software tools.

3.1.1 Hardware Components:

Arduino Uno: Serves as the primary controller. Based on the ATmega328P microcontroller, it operates at 5 V with an input voltage range of 7–12 V. It provides 32 KB flash memory, 2 KB SRAM, and 1 KB EEPROM for program execution.

Wireless Power Transfer (WPT) Module: Enables contactless energy transmission between transmitter and receiver coils. The transmitter operates at 12 V DC, while the receiver delivers 3–5 W at up to 600 mA depending on coil spacing (1–20 mm). Both coils are flat spiral, 30 turns, and 5 cm diameter with inductance of 30 μ H.

Voltage Sensor: Detects under-voltage, over-voltage, or voltage band operation for safe charging. It supports time-delayed trip curves for system reliability.

Relay Unit: A 12 V DC single-channel relay with ULN2003A driver and IN4007 diode ensures reliable coil switching.

Infrared (IR) Sensors: Used for vehicle presence detection. These operate at 3.3 V input and provide analog signals to the Arduino.

Battery: A rechargeable 12 V, 2.5 Ah secondary battery stores the received energy and powers the DC motor for vehicle operation.

LCD Display: A 24 V LCD module provides system feedback and user interaction.

Supporting Components: BJT (2N2222) and resistors (2.3 Ω) for current control, and LEDs for visual charging indication.

3.1.2 Software Components:

Arduino IDE: The programming environment used to develop and upload embedded C code to the Arduino Uno.

Embedded C Code: Implements control logic using two key functions:

setup() initializes I/O pins, LCD display, and sensor configurations.

loop() continuously monitors sensor inputs, activates relays, controls transmitter coil, and updates the LCD.

Program Logic: The software begins with IR sensor detection of vehicle presence. Based on the sensor signal, the Arduino activates the relay to energize the transmitter coil. If coupling is successful, the receiver coil captures energy, charging the battery, and the system displays charging status on the LCD.

IV DESIGN AND IMPLEMENTATION

The proposed wireless power transfer system was realized through the integration of hardware and software components, as illustrated in the experimental setup.

4.1 Transmitter Circuit

The transmitter section consists of the copper transmitting coil, BJT transistor (2N2222), 2.3 Ω resistor, IR sensor, relay, Arduino Uno, and an LCD display. The Arduino serves as the central control unit, monitoring the IR sensors and energizing the relay to activate the transmitter coil when the vehicle is detected.

4.2 Receiver Circuit

The receiver side is mounted on the vehicle and includes a copper receiving coil, rechargeable battery, and an LED indicator. Energy captured by the receiver coil through mutual inductive coupling charges the battery. The LED illumination confirms successful charging, while the stored energy powers the DC motor to drive the vehicle prototype.

4.3 Experimental Setup

The complete block diagram of the system is shown in Figure 3. It consists of the Arduino Uno, IR sensors, transmitting and receiving coils, relays, rechargeable battery, DC motor, LED indicator, and LCD display. When the IR sensor detects the presence of the vehicle, a signal is sent to the Arduino, which in turn activates the relay corresponding to the vehicle's position. This process energizes the respective transmitting coil, enabling wireless power transfer. The system is designed to operate with multiple coils embedded in the road for extended coverage.

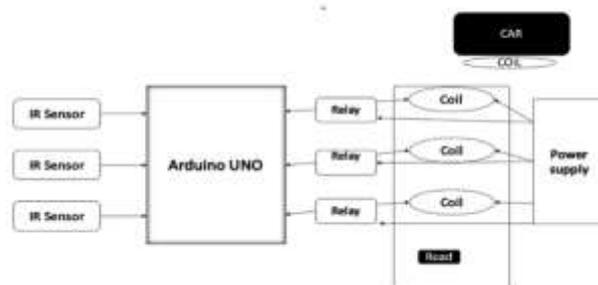


Fig. 3: Block diagram of the prototype system

4.4 Software Setup

Programming of the Arduino Uno was carried out using the **Arduino IDE**. The software environment supports embedded C, where programs are referred to as sketches. Each sketch contains two mandatory functions:

setup() — executed once after power-up to initialize hardware components such as input/output pins, relays, IR sensors, and the LCD display.

loop() — runs continuously after initialization, ensuring real-time monitoring of sensor inputs and execution of control logic for coil activation and system feedback.

A void function type is used in both cases, indicating that no return value is required.



Fig. 4: Arduino IDE interface

During the initial configuration, the **Tools** → **Board** option in the Arduino IDE is used to select the appropriate hardware (Arduino Uno in this case). Once compiled, the sketch is uploaded to the microcontroller for execution. This setup ensures that system initialization and continuous monitoring are automated, thereby supporting efficient wireless charging control.



Fig. 5 Selecting board

4.5 Program Flow

The program logic is illustrated in the flowchart (Fig. 6). At system startup, the Arduino initializes the IR sensors and relay modules. The controller then continuously monitors the IR sensors, waiting for a trigger signal that indicates the presence of the vehicle.

If no sensor is activated, the system remains idle to conserve power.

When an IR sensor detects the vehicle, the Arduino identifies the specific sensor position and activates the corresponding relay.

The energized relay switches on the transmitter coil aligned with the vehicle, enabling inductive coupling and wireless energy transfer.

This stepwise process ensures that only the relevant transmitter coil is powered at a given time, thereby reducing unnecessary energy consumption and improving the overall efficiency of the wireless charging system.

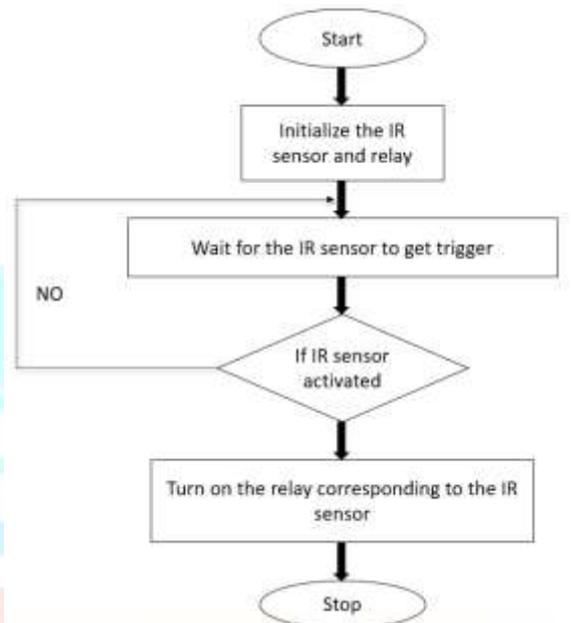


Fig. 6: Flowchart of the program logic

V. RESULTS AND DISCUSSION

The prototype wireless power transfer system was successfully implemented and tested under laboratory conditions. The Arduino Uno acted as the central controller, coordinating the IR sensors, relay modules, transmitting coils, and feedback display.

5.1 System Operation

When the vehicle passed over the road segment containing the transmitting coils, the IR sensors detected its presence and relayed signals to the Arduino Uno. Based on sensor input, the corresponding relay was activated, energizing the respective transmitter coil. The implementation of transmitter circuit is as shown in figure 7. This selective activation minimized power loss by ensuring that only one coil was energized at a time.

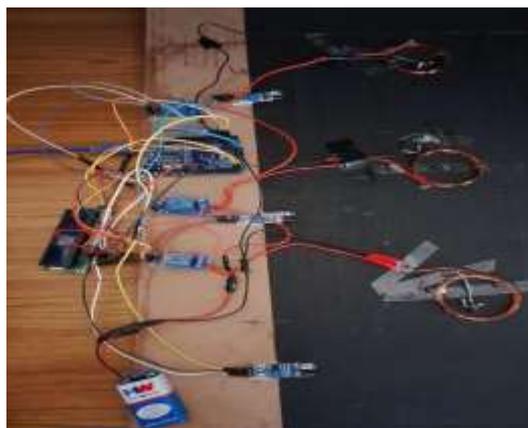


Fig:7 Transmitter side circuit implementation

During operation, the Arduino Uno triggered the relay corresponding to the detected vehicle position, thereby activating the associated transmitter coil. As the vehicle moved into proximity with the energized coil, the receiving coil successfully captured power through mutual inductive coupling. The onset of charging was visually confirmed by the illumination of the LED indicator mounted beneath the chassis.

The inclusion of the 2N2222 transistor in the transmitter circuit provided stable current amplification, ensuring reliable coil excitation and efficient energy transfer. This configuration enabled smooth, contactless charging of the prototype vehicle as it traversed along predefined paths embedded with transmitting coils. The seamless switching between coils demonstrated the potential of this approach for dynamic wireless charging applications.

5.2 Observations

LED Indication: The LED consistently glowed upon successful alignment between transmitter and receiver coils, confirming stable wireless power transfer.

Coil Alignment: Maximum charging efficiency was achieved when the transmitting and receiving coils were closely aligned. Minor misalignments (up to 5–7 mm) still enabled charging but with reduced intensity, as indicated by dimmer LED illumination.

Energy Storage: The 12 V, 2.5 Ah rechargeable battery demonstrated reliable charging under repeated trials, enabling short-duration operation of the prototype vehicle motor.

Sensor Accuracy: The IR sensors effectively detected vehicle presence, with negligible false triggering under normal lighting conditions.

5.3 Performance Analysis

The prototype demonstrated the feasibility of wireless charging for small-scale electric vehicles. However, system efficiency was observed to decrease with increasing air gap and coil misalignment, consistent with theoretical expectations of inductive coupling systems. The limited power output (3–5 W) was sufficient for proof-of-concept validation but would require scaling for practical EV applications.

5.4 Discussion

The results validate that a simple Arduino-based control system can manage wireless charging in a dynamic environment. Selective coil activation reduces energy wastage and highlights the potential for road-embedded charging infrastructure. Nevertheless, the system exhibits limitations in terms of:

Transfer Distance: Effective charging was limited to short air gaps (≤ 20 mm).

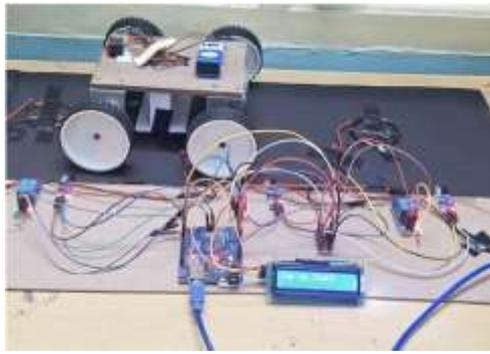
Efficiency: Misalignment sensitivity reduced efficiency beyond optimal coil positioning.

Scalability: The present design is suitable for small-scale prototypes; full-scale EVs require higher power transfer and robust thermal management.

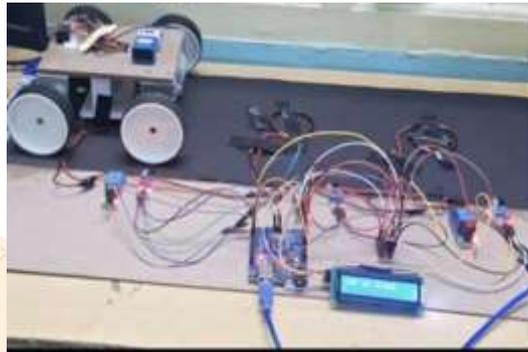
Future improvements may include optimized coil design, resonant compensation topologies, and integration of high-frequency inverters for greater efficiency. Intelligent alignment correction using machine learning algorithms could further enhance practical deployment in real-world electric vehicle charging systems.



(a)



(b)



(c)

Figure 8: Results of three charging slots (a) Car at slot 1 (b) Car at slot 2 and (c) Car at slot 3

The prototype was tested with three charging slots, each equipped with an independent transmitting coil. The Arduino Uno controlled the activation of these coils through corresponding relays based on vehicle position.

Slot 1: When the vehicle was detected at the first slot, Relay 1 was energized, activating the first transmitter coil and initiating wireless charging (**Fig. 8a**).

Slot 2: As the vehicle advanced to the second slot, Relay 2 was triggered, energizing the second transmitter coil for continued charging (**Fig. 8b**).

Slot 3: At the third slot, Relay 3 was activated, switching on the final transmitter coil to sustain charging of the vehicle battery (**Fig. 8c**).

IV.CONCLUSION

This Project demonstrated the design and implementation of a wireless power transfer system for battery-operated vehicles, achieving safe and contactless charging through inductive coupling. The prototype validated feasibility, with Arduino-based control enabling automated operation and LED indicators ensuring user feedback. Although efficiency and range limitations remain, the study highlights pathways for further development, including high-frequency resonant circuits, improved magnetic coupling, and dynamic charging scenarios. The proposed system contributes to sustainable mobility solutions by simplifying EV charging and enhancing safety. Future research may focus on scaling up power levels, incorporating AI-based alignment correction, and integrating the system into smart grid frameworks for large-scale deployment.

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