Atal Bihari Vajpayee Indian Institute of Information Technology and Management Gwalior

PROJECT REPORT

WIRELESS ELECTRIC VEHICLE CHARGING SYSTEM

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Abstract: -

*The **"Wireless Charging System for Electric Vehicles"** project addresses the growing demand for **efficient** and **convenient charging solutions** in the **electric vehicle (EV)** industry. With the increasing adoption of electric vehicles, there is a need for advanced charging technologies that enhance user experience and contribute to the overall **sustainability of transportation**.*

This project focuses on the development and implementation of a wireless charging system that eliminates the physical connection between the charging infrastructure and electric vehicles. The proposed system utilizes inductive power transfer technology, enabling energy transmission between a charging pad embedded in the ground and a receiver module integrated into the electric vehicle.

Introduction: -

The development of wireless charging systems for electric vehicles has gained significant momentum over the past decade. Part of this is based on the desire of cities to push away from petrol and diesel-powered vehicles to help provide cleaner cities, given the intense urbanization that is occurring globally, and partly because electric vehicles are becoming more efficient and cost competitive. With wireless charging systems properly integrated into vehicles, and situated strategically around a city as well as at owners' homes there should be no need to ever plug in their vehicles. Drivers should simply park as usual over a coil placed on the ground or buried in it. However, adopting thistechnology also has the potential to solve several real and perceived problems.

Today, vehicles are charged at home or, in the case of fleets, at the owner's place of business. Tomorrow, they'll be charged in a variety of additional places, including at work, at the store, on the street and in places of interest. The provision of wireless electric vehicle charging points at these locations may increase employee/customer loyalty, attract new customers, and encourage wider adoption of wirelessly charged vehicles in larger population centers, thus reducing air pollution. Ideally, vehicles can be charged whenever and wherever they are parked and EV owners should not have to concern themselves with the grid connection, which will happen automatically.

This constant connection helps reduce range anxiety since the battery is then better able to be kept in a good state of charge, and also helps the network, because private vehicles do not arrive home demanding high power beyond the utility network design. In developed countries, electric utilities use consumption history to assume that each household will use a certain amount of power—about 2 kW, on average—and they build their infrastructure accordingly. Present EVs can demand as much as 8-10kW so that one or two EVs in a neighborhood could demand more than the design capacity and overrate the street transformer. To accommodate that demand, utilities would have to upgrade their transformers and other infrastructure, however if EVs are better managed by constant connection throughout the day, the demand at night can be minimized.

Thus, the wireless home charger would operate to top up the battery and may be cheaper and smaller as a result.

❖ *About Project: -*

***Magnetic induction charging** uses the energy exchange between two pads, one located on the ground and one underneath the vehicle. The **charging pad (on the ground)** is approximately 1m^2, while the receiving pad (on the car) is enclosed in a small device. In addition to the pad optionally mounted on the vehicle, the infrastructure consists of an induction charging station.*

*A **receiver (receiving coil)** is placed on the **bottom of the vehicle**, while several coils acting as transmitters are embedded in the road surface. The latter is supplied with electrical energy. This works as follows:*

The coils in the pavement produce a magnetic field using current. The magnetic field ensures that the coil on the vehicle receives this and can transform it back into electrical energy. This produced energy is used to charge the battery that runs the motor.

❖ *Principle: -*

*The first person to theorize about "wireless" electrical energy transfer was Nicola Tesla in 1896. The operating principle is similar to that of a transformer and is based on the **laws of magnetic induction**. A primary circuit, called a transmitter, generates a time-varying magnetic field. A secondary circuit receives this field, called the receiver, which is connected to the device to be powered. The most important parameters to take into account are certainly the **distance between the two circuits** and their alignment. Poor alignment and a relatively large distance degrade performance and make energy transfer inefficient.*

❖ *Inductive Charging: Power management and efficiency*

The communication between the antenna is based on DC power; as the power that comes from the grid is AC, the power must be converted to DC for the transmitter antenna. The receiver antenna receives the power as DC and then can be converted back into AC to interface with the same electrical infrastructure that the plug-in interface uses or stay in DC to interface directly with the DC battery management system.

*There is a slight drop in efficiency for each time that the power must be converted from AC to DC or from DC to AC. As such, most wireless charging devices will operate at **approximately 92%, ±2% efficiency**. However, this is not dramatically lower than a wired charging device. Wired charging tends to provide an efficiency of **96%, ±2%.***

*After the **resonant coupling** in the receiving antenna, the power is AC and needs to be converted in order to charge the battery. The next stage after the receiving antenna might be passive (diodes) or active (MOSFETs) rectification. Active rectification has lower losses but requires more careful control and is usually more expensive with respect to the silicon devices. However, the overall system cost can be lower, as lower losses can allow a smaller heatsink or cooling system. After rectifying the power, there will typically be a boost stage, which provides isolation and also aligns the voltage level with the battery and its state of charge.*

Research's already done: -

- *The DOE and ORNL are working to advance dynamic wireless EV charging to make EV use more convenient, cost-effective for consumers, and viable at highway* *speeds. The goal is to integrate high-efficiency wireless charging technology with the nation's power grid and maintain charging power for high-speed applications.*

- *Collaborators include the Idaho National Laboratory, the National Renewable Energy Laboratory, the Hyundai Motor Group, the American Center for Mobility, and the Virginia Tech Transportation Institute. This work is also supported by the DOE Office of Energy Efficiency and Renewable Energy's Vehicle Technologies Office.*
- *Researchers have already achieved numerous technical accomplishments, including high-level cost and feasibility studies, identifying a suitable architecture for* ***200 kW dynamic wireless power transfer (DWPT) couplers****, and analyzing large-scale deployment feasibility on Atlanta's primary roadways. Some research explores vehicle misalignment, electromagnetic field safety, and power density and efficiency challenges due to high current (~750A), high voltage (~4kV), and high frequency (~85 kHz) operation.*
- *The ORNL has developed dynamic wireless EV charging technology and has licensed it to Brooklyn-based HEVO. The license includes ORNL's unique* ***polyphase electromagnetic coil*** *and the* ***Oak Ridge Converter****. Under the agreement, ORNL and HEVO will work together to prepare the technology for commercial manufacturing.*
- *"We are excited to see another one of our technologies move into the private sector where it can create new green jobs and support the nation's clean energy goals," said Xin Sun, associate laboratory director for energy science and technology at ORNL.*
- *"EV charging must be simple, seamless and safe in order to accelerate mass adoption and prepare for an autonomous future," said Jeremy McCool, HEVO founder and CEO. "Our collaboration with ORNL utilizes HEVO's strength in designing, developing and commercializing wireless charging technology and software as the first and only company in the world that is compliant with both SAE and UL safety and performance standards."*

Modification and Couple of Features in our Project: -

- ✓ *The project include optimizing the efficiency of wireless power transfer, ensuring compatibility with various electric vehicle models, and enhancing user safety.*

- ✓ *We can also control the power frequencies and voltages of the electricity given for charging according to standard health safety concerns.*
- ✓ *At first, we make the static wireless charging stations, which include the charging of Electric Vehicles (EVs) at the fixed position like homes, restaurents, malls, offices and many more places.*
- ✓ *After successfully implementation of this prototype, we can go in the direction of making the prototype of dynamic wireless charging systems, which includes the charging technology by which the Electric Vehicles can do there charging when they are running on the road.*
- ✓ *It helps the people to take their electric vehicle at long distance routes without taking the stress about the charging of their EV.*

Objectives: -

- *The project includes optimizing the efficiency of wireless power transfer, ensuring compatibility with various electric vehicle models, and enhancing user safety.*
- *The research and development efforts also explore smart charging features, such as dynamic power control, real-time communication between the charging station and the vehicle, and integration with renewable energy sources.*
- *The wireless charging system aims to streamline the charging process, providing a seamless and user-friendly experience for electric vehicle owners.*
- *By reducing the reliance on traditional charging cables and connectors, the project contributes to the overall advancement of electric vehicle infrastructure and promotes a more sustainable and convenient transportation ecosystem.*
- *Reduces the pollution done by the petrol and diesel vehicles by reducing the dependencies of people on that type of vehicles.*

Methodology: -

Wireless electric vehicle charging systems can be separated into the following two important scenarios to transfer power from the source to the battery bank and into the car.

1. *Static Wireless Vehicle Charging System*

*WEVCS unlocks another door to provide a user-friendly environment for consumers (and to avoid any safety related issues with **the plug-in chargers**). Static WEVCS can easily replace the plug-in charger with minimal driver participation, and* *it solves associated safety issues such as trip hazards and electric shock. Fig. shows the basic arrangement of static WEVCS. The primary coil is installed underneath in the road or ground with additional power converters and circuitry. The receiver coil,or secondary coil, is normally installed underneath the EVs front, back, or center. The receiving energy is converted from AC to DC using the power converter and is transferred to the battery bank. In order to avoid any safety issues, power control and battery management systems are fitted with a wireless communication network to receive any feedback from the primary side. The charging time depends on the source power level, charging pad sizes, and air-gap distance between the two windings. The average distance between light weight duty vehicles is* ***approximately 150–300 mm****. Static WEVCS can be installed in parking areas, car parks, homes, commercial buildings, shopping centers, and park 'n' ride facilities.*

2. Dynamic Wireless Vehicle Charging System

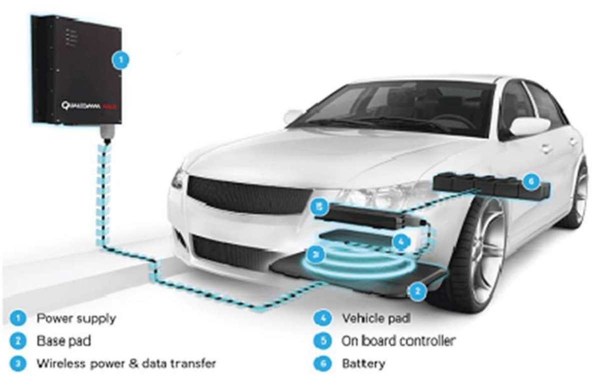
Plug-in or BEVs are suffering due to two major obstacles-cost and range. In order to increase range, EVs are required to charge either quite frequently or to install a larger battery pack (which results additional problems such cost and weight). In addition, it is not economical to charge a vehicle frequently. The ***dynamic wireless electric vehicle charging system (D-WEVCS)*** *is a promising technology, which can reduce the problems associated with range and cost of EVs. It is the only solution for future automation EV. It is also known as a ''roadway powered", ''on-line" or ''in motion" WEVCS. As shown in Fig., the primary coils are embedded into the road transparent sheets at a certain distance with high voltage, high frequency AC source and compensation circuits to the micro grid.*

Like static-WEVCS, the secondary coil is mounted underneath the vehicles. When the EVs pass over the transmitter, it receives a magnetic field through a receiver coil and converts it to DC to charge the battery bank by utilising the power converter and. Frequent charging facilities of EVs reduces the overall battery requirement by ***approximately 20%*** *in comparison to the current EVs. For dynamic-WEVCS, transmitter pads and power supply segments need to be installed on specific locations and pre-defined routes. The power supply segments are mostly divided into centralized and individual power frequency schemes as shown in Fig. In the centralized power supply scheme, a large coil (around 5–10 m) is installed on the road surface, where multiple small charging pads are utilized. In comparison with the segmented scheme, the centralized scheme has higher losses, lower* *efficiency including high installation, and higher maintenance costs. Overall, the installation of the initial infrastructure for this technology would be costly. With the help of a self-driving car in the future, it will help to create the perfect alignment between the transmitter and receiver coils which can significantly improve the overall power transfer efficiency. Dynamic-WEVCS can be easily incorporated into many EV transportation applications, such as light-duty vehicles, buses, rail, and rapid transport.*

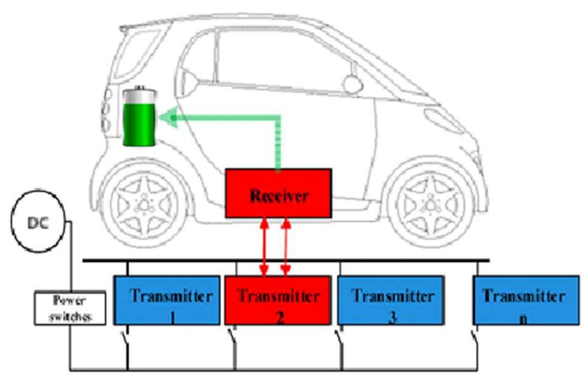
❖ *Technology Selection: -*

Nikola Tesla created the conventional ***Inductive Power Transfer*** *in 1914 to transmit power wirelessly. It draws inspiration from various EV charging systems. Inductive Power Transfer has been tested and used to transfer contactless power from the source to the receiver. It is used in numerous applications, ranging from milliwatts to kilowatts.*

❖ *Prototype Development: -*



STATIC CHARGING



DYNAMIC CHARGING

❖ *System Requirements: -*

1. Arduino UNO	*2. 1K, 56-ohm resistor*	*3. 1 nF and 20 nF capacitor*
4. IRF540N Mosfet Transistor	*5. Transmitter Coils (50 turns)*	*6. 50k ohm preset resistor*
7. 555 timer IC	*8. Receiver Coils (50 turns)*	*9. 100 µF capacitors*
10. LCD Display	*11. Vehicle Body*	*12. 100-ohm resistor*
13. Relay	*14. Breadboard*	*15. IR sensor*
16. Cable and Connectors	*17. Power Supply*	

❖ *Component Selection: Why These Choices?*

1. Relay: -

A relay is an electromechanical switch used to control the flow of electricity in a circuit. It allows a low-voltage signal to control a high-voltage circuit, providing isolation between the control circuit and the circuit being controlled.
When the vehicle passes over the IR sensor, the relay will activate the circuit and charge the battery.

2. 555 timer IC: -

The 555 timer IC is a versatile and widely used integrated circuit that can generate precise and stable time delays or oscillations. It has a variety of common uses. Timer IC will help to decide the time delay in the charging process.

3. IRF540N Mosfet Transistor: -

The IRF540N is a popular N-channel power MOSFET transistor commonly used in various electronic circuits where high-power switching or amplification is required. MOSFETs like the IRF540N are frequently used as switches in electronic circuits due to their fast switching speeds and low ON resistance. They are used in circuits where relays are used.

4. 50k ohm preset resistor: -

A 50k ohm preset resistor, also known as a potentiometer or trimmer resistor. It can be used as a variable voltage divider in the circuit, allowing you to adjust the output voltage by changing the resistance value. With the IRF540N transistor, it is used for biasing purposes to set the operating point of the transistor. This ensures proper transistor operation and stability.

5. Capacitors : -

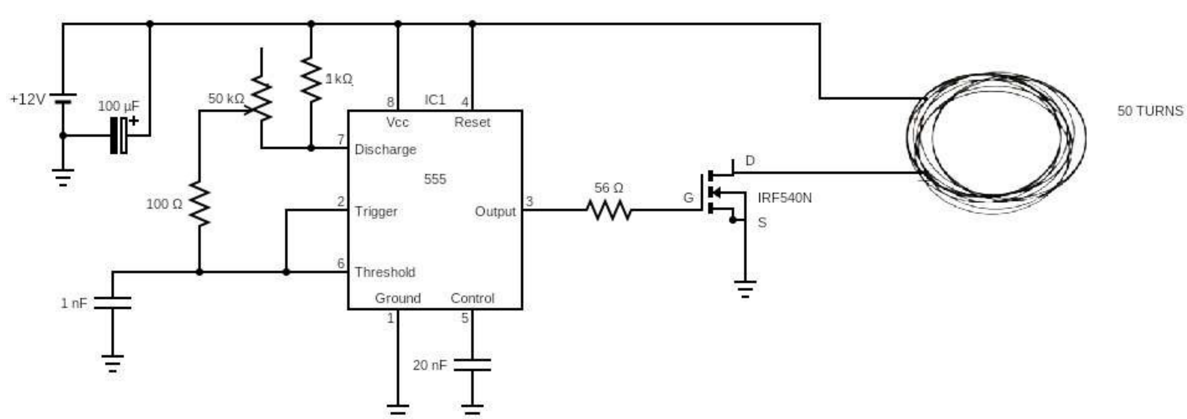
Capacitors are used for storing the charge as a sink and then use it as a voltage source when needed. Capacitors ensure stable voltage levels at the power supply pins of integrated circuits which reduces the chances of IC burning. A 100 µF capacitor is used to maintain a stable power supply to the 555 timer IC and the capacitors 20 nF and 1 nF are initially charged and then discharged according to the need of the circuit.

6. Arduino Uno: -

The Arduino Uno is a popular microcontroller board used for a wide range of projects in electronics, robotics, automation, and more. The Arduino Uno is widely used for prototyping new electronic projects. Arduino Uno can be used to collect data from various sensors and log it for analysis or monitoring purposes.

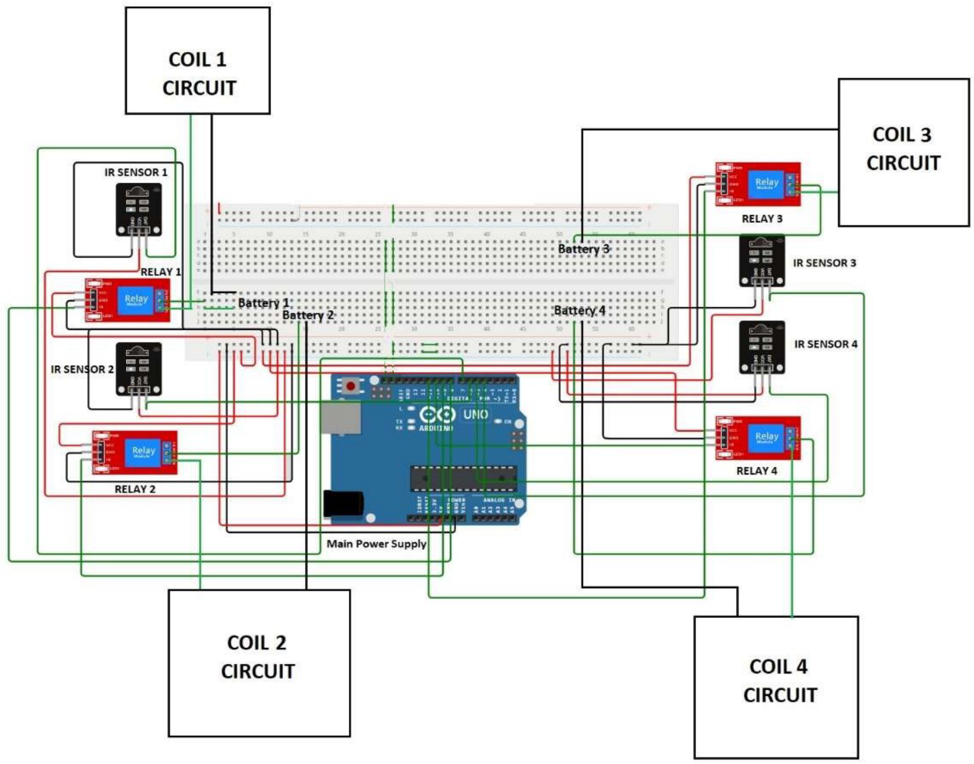
We are using Arduino to control the relay so that we can switch on or off the circuit according to our needs which will increase the efficiency of the prototype, showing output on the LCD, calculating the time of charging, and developing the billing system according to it.

❖ *Circuit Diagram: -*

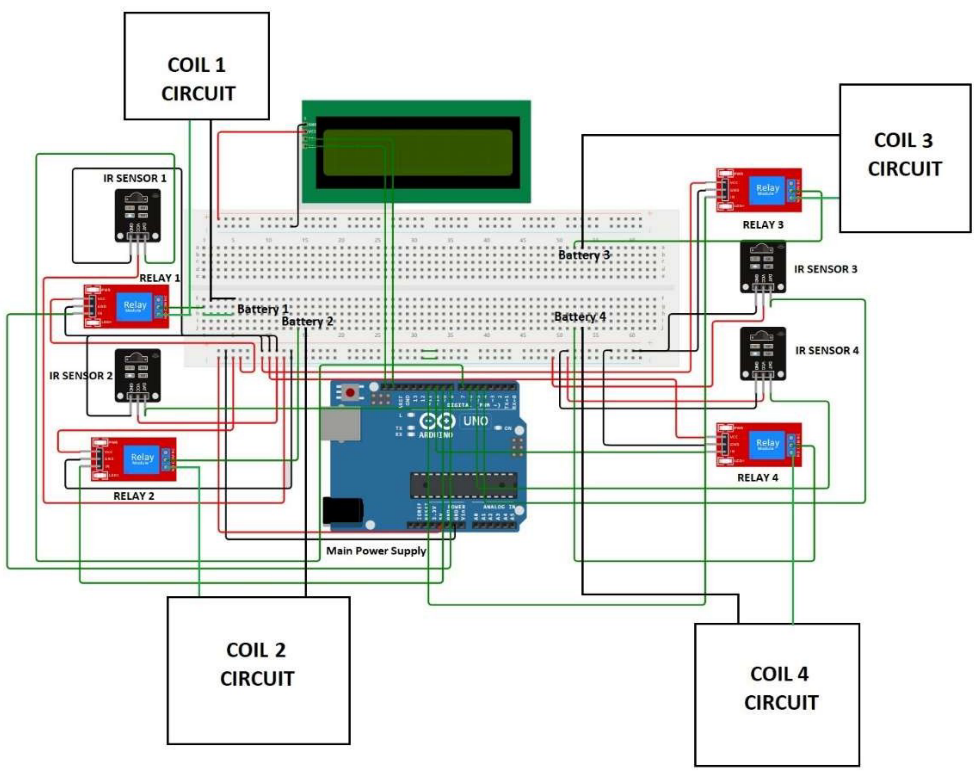


CIRCUIT DIAGRAM FOR A TRANSMISSION COIL

Wireless Electric Vehicle Charging System



DYNAMIC WIRELESS CHARGING STATION CIRCUIT FOR ELECTRIC VEHICLES



STATIC WIRELESS CHARGING STATION CIRCUIT FOR ELECTRIC VEHICLES

❖ *Final Project Prototype Photos:-*

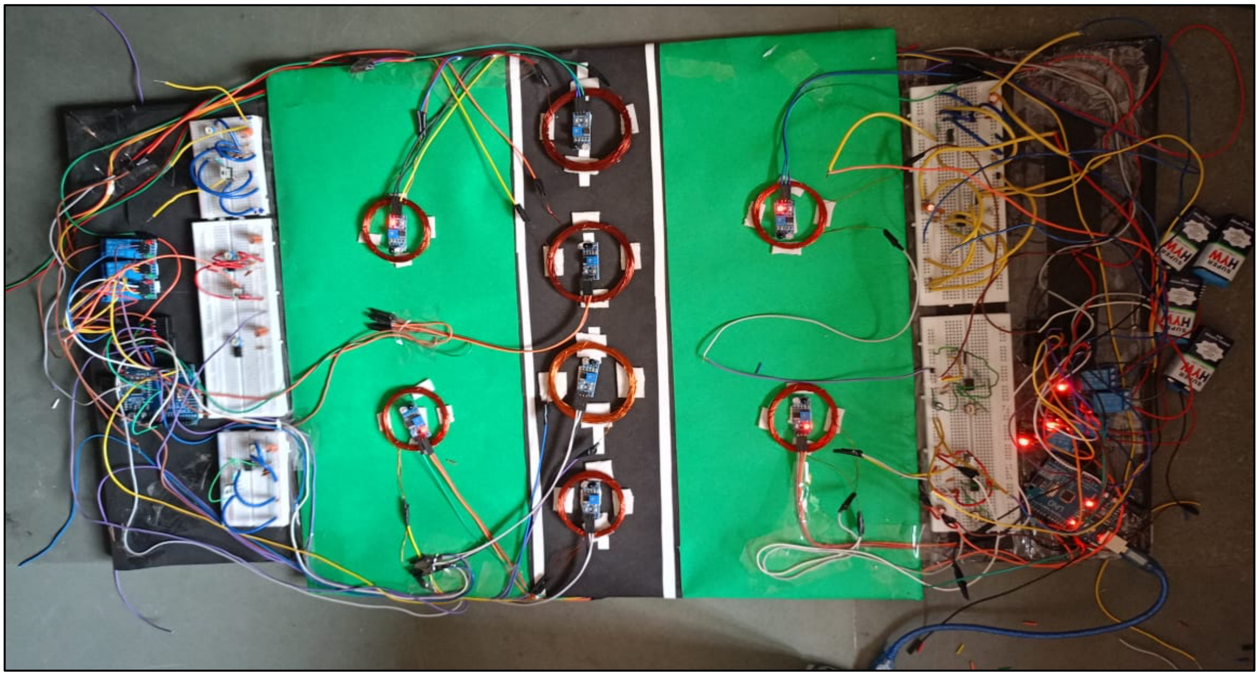


Figure 1

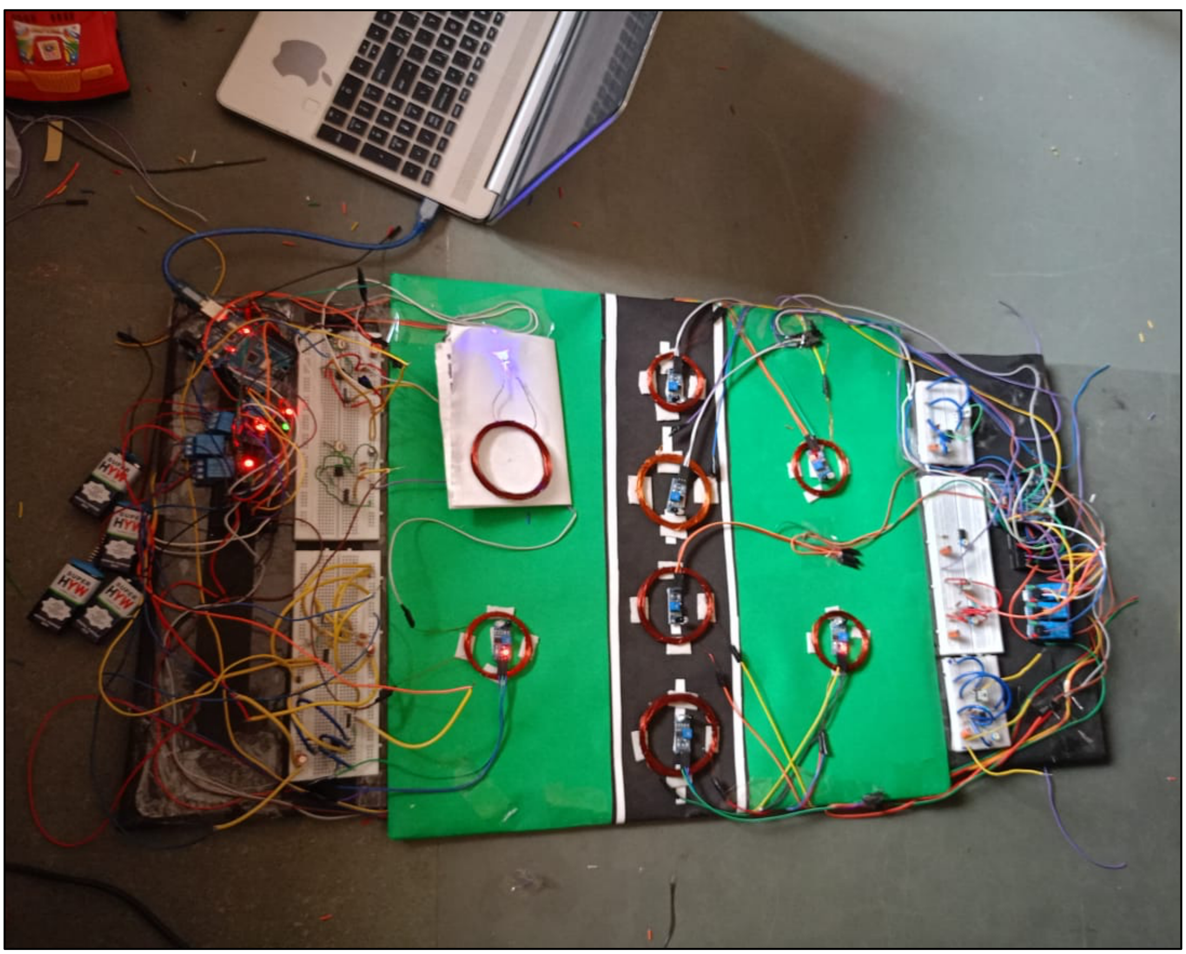


Figure 2

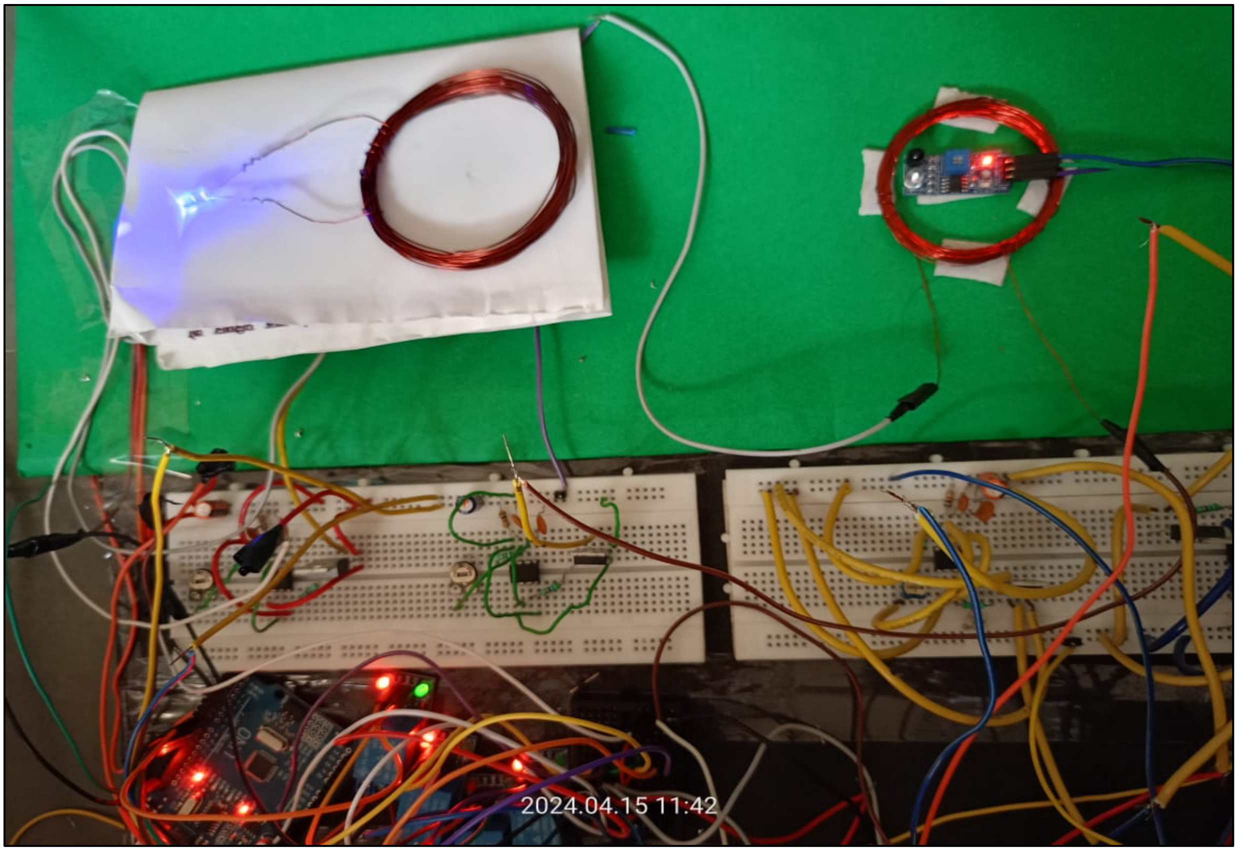


Figure 3

❖ *Limitations –*

1. ***Efficiency:*** *Wireless charging is generally less efficient than wired charging. Energy is lost during the transfer due to electromagnetic induction, resonant coupling, and other factors. This inefficiency can lead to longer charging times and higher energy costs.*

2. ***Cost:*** *The infrastructure required for wireless charging, such as charging pads and power electronics, can be expensive to install and maintain. This cost can be a significant barrier, especially for widespread deployment in public spaces or large-scale adoption.*

3. ***Power and Speed:*** *Current wireless charging systems often have lower power output compared to wired charging, which means they may not be suitable for fast charging or high-capacity batteries. This limitation can be a drawback for EVsthat require quick recharge times.*

4. ***Interoperability:*** *There is currently no universal standard for wireless charging in the EV industry. Different manufacturers may use proprietary technologies or standards, leading to compatibility issues and limiting interoperability between charging stations and vehicles.*

5. ***Heat Generation:*** *Wireless charging systems can generate heat during operation, which may affect the efficiency of charging and potentially impact the lifespan of batteries if not managed properly.*

❖ *Budget-*

Components	***Quantity***	***Prize***
Arduino UNO	*2*	*800*
IRF540N MOSFET Transistor	*8*	*240*
555 timer IC	*8*	*120*
1k ohm resistor	*8*	*16*
56-ohm resistor	*8*	*16*
50k ohm preset resistor	*8*	*40*
100 µF capacitor	*8*	*40*
1nF capacitor	*8*	*16*
20 nF capacitor	*8*	*16*
100-ohm resistor	*8*	*16*
Relay	*8*	*480*
IR sensor	*8*	*400*
Transmitter coils	*8*	*400*
Receiver coils	*1*	*50*
Breadboard	*6*	*480*
LCD	*1*	*250*
Car	*1*	*200*
Battery	*10*	*200*
Miscellaneous	*-*	*700*
TOTAL -		*4,480*

❖ *Integration with Renewable Energy Sources: -*

We can integrate this technology with renewable energy sources, such as solar or wind power, into the wireless charging system to promote sustainability.

Outcome of the Project: -

The outcomes of this project have the potential to significantly impact the electric vehicle industry, making wireless charging a viable and widely adopted solution for the future of clean and efficient transportation.

Reference: -

1. *https://tec.ieee.org/newsletter/march-2018/wireless-charging-for-electric-vehicles*
2. *https://www.powerelectronicsnews.com/wireless-charging-technology-for-evs/*
3. *https://e-vehicleinfo.com/static-and-dynamic-electric-vehicle-wireless-charging-system/*
4. *And many more...........*