Design and Application of underground Wireless Power Transfer Charging System in Electric Cars

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Abstract— In the recent years there is a significant development in the field of wireless power transfer. In the future, gasoline and oil powered engines are going to become obsolete. And hence as a result these oil powered cars and bikes are going to be replaced by EV also known as electric vehicles. Electric Vehicles (EV) are very much environmental friendly and they act as a perfect alternative source of energy .There is a gradual increase in the usage of electric cars. But there are also drawbacks and require a technological breakthrough to overcome them. One of the major drawbacks is the battery limitations and the time required to charge it to reach its maximum potential. In this project inductive coupling and magneto dynamic coupling methods are used to charge the batteries of EV. Wireless power transmission (WPT) or Electromagnetic power transfer (EPT) is the transfer of electrical power from the power source to a receiver without any physical connections by the use of varying electromagnetic field. WPT circuitry is placed inside the vehicle which gets activated when the vehicle reaches the charging spot on the road. The primary circuit is supplied from the charging station and the coils are placed under the surface of the road i.e., underground. Electromagnetic flux is radiated out of the primary coil and gets induced with secondary coil present in the EV. The induced voltage from secondary coil is then regulated, rectified and used to charge the EV battery. In this report different wireless power transmissions are compared and how Efficient wireless power transmission is done and control over electromagnetic induction and effective charging of battery will be achieved.

Keywords: Electric Vehicle (EV), Wireless Power Transmission (WPT), Inductive Coupling, Magneto Dynamic Coupling, Magnetic Flux, Underground

I. INTRODUCTION

The cost of fuels like petrol, diesel etc. has been steadily increasing due to increased number of vehicles and proportional excess usage of fuel. Depleting sources of these fuels are also a major concern. These age old designs of vehicles are the major contributors to the problem of greenhouse gases. The future of automotive technologies is moving toward electric vehicles which are considered as a replacement to oil-powered internal combustion engine driven vehicles, keeping in mind CO2 reduction. Alternate energy Plug-in Electric Vehicles (PEVs) have been proposed to achieve environment friendly transportation. Even though the PEV usage is currently increasing, a breakthrough would be required to overcome battery related drawbacks. Furthermore, PEVs have not been accepted as a preferred choice by many consumers due to charging related issues. This is the major issue faced in the field currently. This proposed project is an application of Faraday's laws of electromagnetic induction to Transfer power without the usage of physical connectors. According to Faraday's law, Electromagnetic Flux is induced in a coil when it is linked with the flux produced by another coil. The process of transferring power without the use of any physical connections is called Wireless Power Transfer (WPT). WPT is the transmission of electrical power from the power source to an electrical load without the use of any physical connectors. The proposed WPT system is activated when the vehicle reaches the charging area. Flux is radiated out from the primary coil and gets induced with the secondary coil which is present in the EV. The battery is connected to the secondary coil in the EV and hence battery gets charged. Electric Vehicle (EV), magneto dynamic coupling, Wireless Power Transmission, magnetic flux, underground,

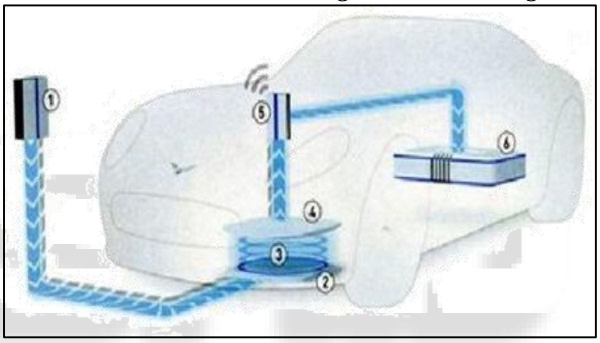

Fig. 1 A basic Wireless Charging Unit for a Car.
-Power supply, 2-Primary coil, 3-wireless power Transfer, 4-Secondary coil, 5- system controller, 6-EV battery.

The above fig.1 represents a basic Wireless Charging (WC) unit for a car. WPT for EV charging has many advantages compared to wired-PEV charging. Inconveniences in wired PEV charging process are major impediments in gaining the interest of consumers. Although the number of researchers is working on WPT technology, there are numerous challenges to overcome in making it a commercial level. Acceptable power transfer efficiency at high transfer range, increasing power level, misalignment tolerance and safety considerations are major technical challenges. Our project deals with the charging of miniature model of electric vehicle using WPT. The project aim is to make this technology which is to be branded as the focus of this field, feasible and accessible to all.

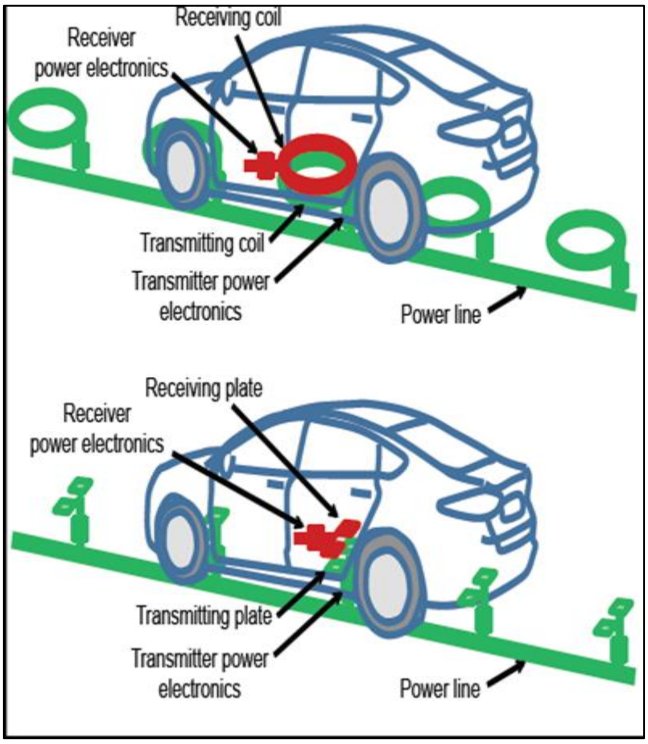

Fig. 2: Underground Wireless Charging Unit for a EV Car using coils & Fig. 3 Underground Wireless Charging Unit for a EV Car using Transmission plates.

The fig 2 represents the wireless transmission through coils which are placed under the bottom end of the vehicle.

The fig 3 represents the wireless transmission through plates.

II. Literature Review

Nikola Tesla discovered and applied the wireless transmission of power. He invented the concept of wireless power transmission and later refined and developed other scientists and used in applications like wireless mobile charging, electromagnetic toothbrush, electric vehicles etc., were invented. EV are the best breakthrough of tesla's discovery till date[1].

Most wireless power transfer use electromagnetic field as the means by which the energy is sent. They use lasers to send power via a beam of light to a receiving coil where the received photons are converted to electrical energy. Transmission over huge distance is possible but it requires state of the art tracking mechanisms which is needed to maintain proper balance between moving transmitters and receivers. And also there is a possibility of tiny particles or objects getting in between the transmission and receiving coil which could interrupt the power transmission and there is also a possibility of damage to the coils. At microwave frequencies, a comparative methodology can be utilized to productively transmit electricity over enormous separations utilizing the electromagnetic (EM) field from suitable radio wires [2].

EV charging could also have a drawback as it could cause a power outage. But this is unlikely to happen because there are many factors. The major factor would be limited charging station around the world. As for the impact of EV battery chargers on the power supply system, it depends on the technology of the chargers. Older version of chargers is based on full-wave rectification using diodes and progressively thyristors are used. Later designs use microprocessor-controlled charging technologies with several algorithms being implemented for parameter monitoring and control. Today, smart battery chargers are available which can interactively communicate with the utility system in order to receive and send information about the state of charge, energy availability, tariffs and management data in general. Such designs have resulted in reduction of harmonic distortion and power factor improvement [3].

Various wireless methods of electric vehicle charging are in development and cannot compete with the gasoline vehicles as they are too expensive to afford. Wireless power transfer is a generic term for a number of different technologies for transmitting energy by means of electromagnetic fields. The following table represents the different technologies used in wireless power transmission and their range of transmitting power, weather the transmitter should be directly aligned with the receiver, and also the types of electromagnetic energy they use. [4]

Sources of wireless power transmission	Distance of transmission	Directivity	frequency	Receivers used	Applications in the future
Light waves	Long	High	≥THz	Tuned wire coils, lumped element resonators	Charging portable devices, powering drone aircraft, powering space elevator climbers.
Micro-waves	Long	High	GHz	Metal plate electrodes	Solar power satellites powering drone aircraft, charging wireless devices
Magneto dynamic coupling	Short	----	Hz	Rotating magnets	Charging electric vehicles, biomedical implants
Capacitive coupling	Short	low	kHz – MHz	Parabolic dishes	Charging portable devices, power routing in large-scale integrated circuits, Smartcards, biomedical implants
inductive coupling	Mid-	low	kHz – GHz	Lasers, lenses	Electric vehicles, powering buses, trains, biomedical implants, charging portable devices

Table 1: represents different types of sources of power transmission.

III. OBJECTIVES AND METHODOLOGY

Aim of the project is to Design and develop the Electric vehicle charging system to charge an Electric Vehicle battery using Wireless Power Transfer Technique.

A. Objectives

The objectives of project are given below:
1) To design a 3Dmodel of the wireless transfer technology by using fusion 360 software.
2) To find the best wireless transfer technology that can be used in EV's.
3) To design a wireless power transfer circuitry and obtaining its performance characteristics.
4) To design a power electronic circuit for converting AC to DC and charging Electric Vehicle (EV) battery.
5) To Design a primary and secondary coil and to find which material is suitable for the process.
6) To obtain acceptable power transfer efficiency after implementing the circuitry with coils in a miniature model.

B. Methodology Adopted:

1) Methodology for Objective 1:
- Survey will be made to understand the current National and international status and developments made in wireless power transmission (WPT)
- The specifications and design models of the wireless power transfer technology will be analysed and Extracted from various journals and specification manuals.
- Using of fusion 360 as a base for designing the wireless technology Model.

2) Methodology for Objective 2:
- Testing and determining best wireless power transfer technology.
- Analysing and simulating the obtained losses for the amount of power to be transferred.
- Designing the power electronic components and connecting them to reduce power losses in electro-magnetic induction process.

3) Methodology for Objective 3:
- The design will focus on the following specifications:
- Development of hardware power rectifier and voltage regulator.
- Designing the power electronic circuit for better rectification.
- Integrating the circuitry on the Printed Circuit Board.
- Selection of the battery to be used in electric vehicle.
- To charge the Rechargeable electric vehicle battery from the rectified output obtained.

4) Methodology for Objective 4:

The hardware testing to be performed which will include the following steps:
- Assembly of all the required components on PCB.
- Winding the primary and secondary coils for effective induction.
- Supplying the power and testing the charging level of the battery.
- Decreasing the coils misalignment if present and increasing the power level of charging.

5) Methodology for Objective 5:
- The developed system will be connected to car battery and its functioning will be observed and charging time is recorded.
- The flux interference will be monitored as it has to be under the acceptable level according to Indian standard.
- The advantages of new design will be validated against the performance of existing system.
- Conclusions will be drawn based on the validation studies.

IV. EXPERIMENTAL WORK

The design of the model is made in the fusion 360 software and various pros and cons are analysed.

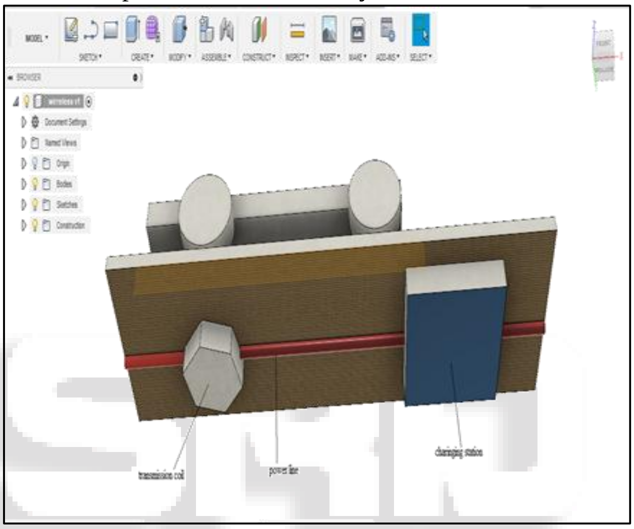

Fig. 4: represents the top-side view of the model car where the receiving coil will be placed.

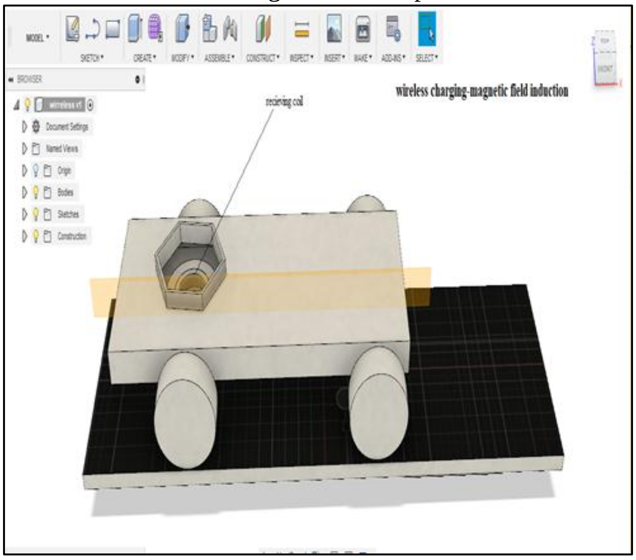

Fig. 5: represents the bottom view underground where the transmission coil, power line and charging station are present

In the above figures 4 and 5 different tools are used to design the model and the dimensions of the model are found out and accordingly the design aspect. The length and diameter of the coil to be used are also found out.

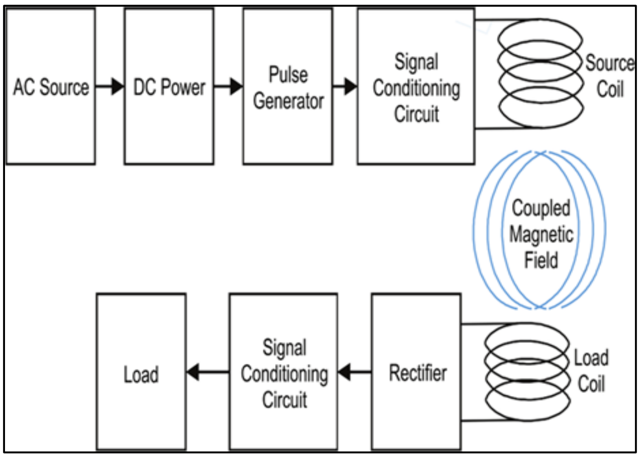

Fig. 6: Block Diagram of WPT Circuitry

Fig. 6 illustrates the block diagram of the WPT system based on inductive coupling. There are two coil winding which are connect to the transmitter and the receiver and are known as source coil and receiving coil. Hence the power is transmitted through coupled magnetic field by the use of electromagnetic induction.

The source loop is combined with the load loop to produce the electromagnetic field. In the receiver a stable dc voltage is produced and hence wireless power transfer is achieved by the use of faradays law of electromagnetic induction.

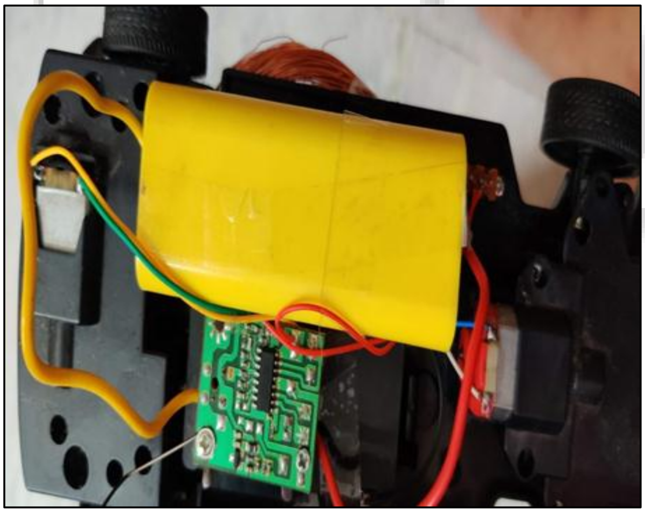

Fig. 7: model of electric car with battery

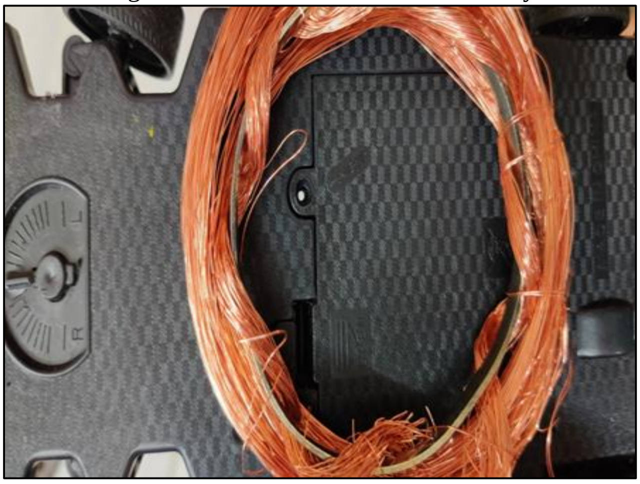

Fig. 7: receiving coil attached to bottom end of model

Fig. 8: design of secondary coil.

Fig. 9: secondary coil places under Cardboard box representing underground

Thickness of coil (m)	Inductance (μH)		
	Circular	Rectangular	Square
0.001	0.1188	0.1399	0.1416
0.002	0.1012	0.0709	0.0726
0.003	0.0882	0.0523	0.0545
0.004	0.0781	0.0410	0.0427
0.005	0.0701	0.0330	0.0347
0.006	0.0636	0.0267	0.0284
0.007	0.0582	0.0215	0.0232
0.008	0.0536	0.0172	0.0189
0.009	0.0498	0.0134	0.0151
0.01	0.0464	0.0100	0.0117

Table 2: represents the thickness vs inductance of coil

A. Primary and Secondary Coil:

Several factors were kept in consideration while designing the number of turns and size of the primary and secondary coil like, flux density, voltage, losses and other variations. If there is a gradual decrease in the number of turns then consequently the voltage and flux density decreases.

As the number of turns increases the flux density increases and in turn the variations and losses also increases. Similarly when there is a gradual decrease in the number of turns the flux density and the voltage also decreases.

$$\mathbf{B} = \mu \frac{N}{l}\ \mathbf{I},$$

In Tesla
Where,
N= number of turns
l= length of coil,
I= current in Amps And
μ = permeability of free space.

The flux radiated between the coils depends on the Area of the conductor and the flux density as area increase the flux per Webber increases and flux density reduces.
The flux radiated is given by:

$$\text{Ø} = \text{flux} = A * B$$

Where,
A=area of the coil.
So taking all these parameters into considerations coils are designed.

To design primary and secondary coils, the material used is copper. Previously aluminium coils were used which are very cheap but flux radiation is very less. Litz wires are frequently used to lower the parasitic resistance and therefore high Q-factor. Litz coil consists of many individually insulated thin conductor strands wounded in particular patterns. But these wires are prone to skin effect and other proximity effects. So to overcome all these copper wires or hollow copper tube were used even though it's costlier. Copper is a good flux radiator and efficient. So we used copper material in our project for effective wireless power transfer for this miniature model of electric vehicle.

V. Conclusion

Literature review on various wireless power transmission system and control of power converter circuit gave a broad idea on WPT systems. Based on the experimental result, the study on wireless power transfer using inductive coupling has much aspect in terms distance of primary and secondary coil, number of turns, area of the coil.

Proper alignment and positioning of the coil is achieved in this project. A miniature model demonstration with power getting transferred from primary to secondary is achieved. The same concept could be adopted with scaling features in electric vehicles.

Acknowledgments

I genuinely believe that the future of the transportation is completely dependent on the electric vehicles and to improve their efficiency and mobility I did this research on wireless power transfer charging system.

According to many scientists around the world the natural oil deposits will be depleted in 54 years. And the cars running on the gasoline will be obsolete. The main danger to the humanity is that there would be a war fought for the last remaining oil reserves. My effort is to reduce the chances of that happening.

I record with a great feeling of gratitude towards the scientist and business man's contributing in the field of alternative power source.

I also thank ELON MUSK for making tesla an open source and inspiring many people in the field of EV'S

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