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Electric Vehicle Charging Station

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***Abstract**: Wireless charging of gadgets is one of the new emerging technologies in the world at the moment. The most common methods used at the moment are wireless power transfer by inductive coupling and resonant coupling. Also, Electric Vehicle is the modern technology to help reducing the fuel consumption. So, this paper is combining these two technologies to get rid of the copper cables used for charging the batteries of the Electric Vehicles (EVs). A methodology and principle of operation are devised for wireless power transfer through resonant coupling, and a feasible design is modelled accordingly. The resonant coupling technique is used because of high efficiency and large amount of the energy transferred over a longer distance compared to inductive coupling. Also, to indicate its versatility and range of applications, the power transferred will be used to charge a battery with the aid of additional circuitry.*

***Keywords:** Battery Charging, Electric Vehicle, Electric Vehicle Charging Station, Resonant Coupling, wireless power transfer*

I. Introduction

The paper seeks to eliminate the use of wires in the transmission of power from the source to the device to be powered. Although WPT is based on electromagnetic induction, there are various methods that are used. Some are less efficient than others and costly while others don't allow for a longer range of transmission. In this paper, we are focused to design and construct an electronic device that shall transmit power within a small range. In the paper a suitable method will be used to ensure that enough power is transmitted wirelessly so that it can then charge batteries. The major challenge will be in the coupling circuit which comprises of the coils where electromagnetic induction occurs, the number of turns of the coil, inductance.

This concept was first discussed in the late 19th century. Nikola Tesla was the brains behind this concept. He together with Heinrich Hertz theorized the possibility of power being transmitted wirelessly. Tesla's main idea was to use the planet as the conductor to transmit power to any point on the earth. In 1899 Tesla successfully managed to illustrate the concept by powering fluorescent lamps 25 miles away from the source of power. In 1901 Tesla built the Wardenclyffe Tower for this purpose.

In order to respond the rising trend of the use of EV, research and developed a mass and flexible battery recharge system is necessary. One of the methodologies is wireless power transfer (WPT) system. In WPT technology there is no physical connection between the vehicle and charging device. Compare with the traditional conductive method, wireless power transfer can reduce the inconvenience and hazard. The initial objective of this paper is instead of using the power cord to charge EV; this paper will go for WPT technology while maintaining a comparable power level and efficiency.

The main objectives of this Paper is to discuss development of a system for effective and efficient method to charge the batteries of Electric Vehicles, to construct an isolated charging station for EVs and to implement the Principle of Wireless Power Transfer for charging the batteries in EVs.

II. Working Principle

2.1 Classification of wireless power transfer technologies:

The following tree diagram gives various methodologies of WPT. The main two types based on distance of power transfer are near field type and far-field type. Near field transfer is used in transformers, wireless battery charging, etc. While the far-field transfer is used by communication engineering, etc.

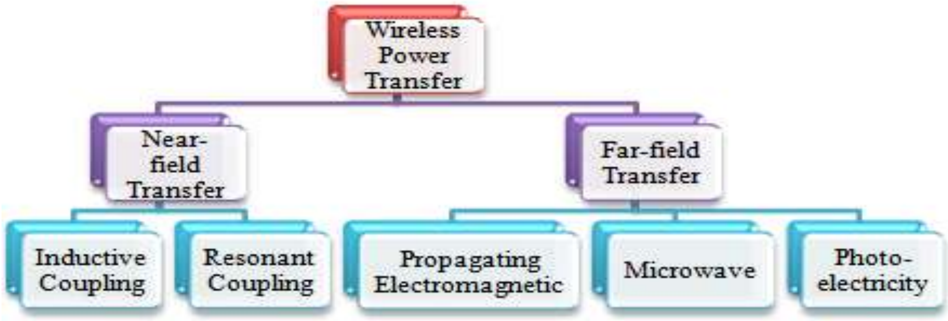


Fig. 2.1(a) Basic Technologies of WPT

The following table gives the comparison among Electromagnetic field, Electric field and mechanical energy transmission medium on the basis of power, range and efficiency.

Energy-carrying medium	Technology		Power	Range	Efficiency	Comments
Electromagnetic field	Near field	Traditional IPT	High	Low	High	Range is too small for EV charging
		Coupled Magnetic Resonance	High	Medium	High	Capable for EV charging
	Far field	Laser, Microwave	High	High	High	Need direct line-of-sight transmission path, large antennas and complex tracking mechanisms
		Radio wave	High	High	Low	Efficiency is too low for EV charging
Electric field	Capacitive power transfer		Low	Low	High	Both power and range are too small for EV charging
Mechanical	Magnetic gear		High	Medium	High	Capable for EV charging

Fig.2.1 (b) Classification and Comparison of Different WPT Technologies for EV Charging[9]

2.2 Inductive Coupling

Two devices are said to be mutually inductively coupled or magnetically coupled when they are configured in such a way that change in current through one coil induces a voltage across the ends of the other coil by electromagnetic induction. This is due to the mutual inductance.

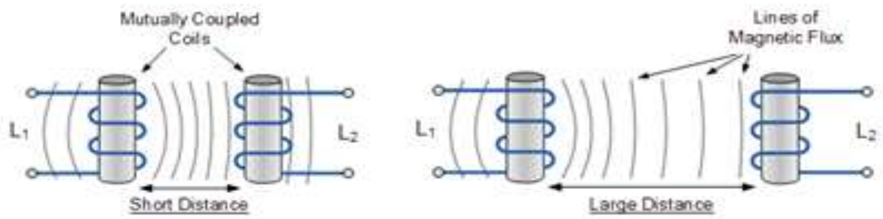


Fig.2.2 Inductive coupling

Transformer is an example of inductive coupling. Inductive coupling is preferred as of its comfort in addition with less use of wires and it is shock proof.

2.3 Resonance Inductive Coupling (RIC)

It is the combination of boththe inductive coupling and resonance. By implementing the concept of resonance it makes the two objects to interact each other very strongly.

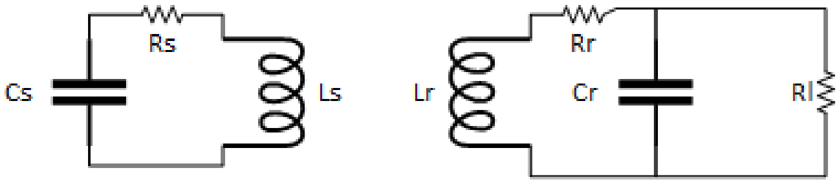


Fig.2.3 Resonance Inductive Coupling

Inductance induces current in the circuit. As seen in the fig.2.3, the coil provides the inductance. The capacitor is connected in parallel to the coil. Energy will be flowing back and forth between the magnetic field surrounding the coil and the electric field around the capacitor. Here the radiation loss will be negligible. [1]

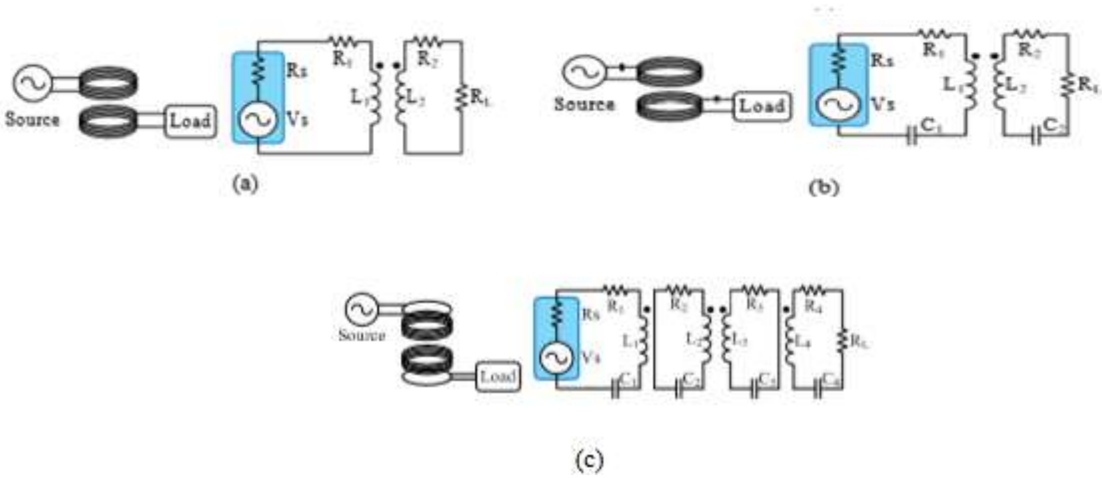


Fig.2.3 Topologies and equivalent circuit models of near-field wireless power transfer technologies: (a)

traditional IPT; (b) coupled magnetic resonance; and (c) strongly coupled magnetic resonance.

Coupled magnetic resonance is a near-field WPT technology but with some differences from traditional IPT, as shown in Fig.2.3. Two pairs of RLC resonators are used to enhance power transfer efficiency and to extend transfer range. As shown in Fig.2.3. (b)the two capacitors connected in series. However, both primary and secondary side compensation capacitors can be connected in series or parallel, which results in four different prototypes. Intensive research has been done on analysing and comparing those prototypes. Generally, the primary side is compensated to lessen the reactive power and therefore decrease the VA rating of the power supply. The secondary side is adjusted so that the load acquires almost all of the transferred power, enhancing the power transfer capability. The choice of topology is application oriented. Series compensation on secondary side is suitable for constant voltage application, while parallel compensation is capable to support a constant current application. The series-connected primary can reduce the power supply voltage which is very attractive in long track application, while the parallel connected primary is capable to support a large supply current. By using 2 loops and 2 coils, the internal resistance of power supply(R_S) and the load resistance (R_L) are not included in the RLC resonators, which results a much higher quality factor of circuit (Q) than conventional 2 coils resonators. This means with the same coupling coefficient; more energy could be transferred to the load. Also, to increase the transfer efficiency, the internal resistance of RLC resonators is further decreased by using the coil parasitic capacitance instead of lumped resonant capacitors (C2 and C3 as shown in Fig.2.3(c)). Therefore, with a highly reduced resistance, the resonators can transfer energy efficiently even when the coupling coefficient is low.

III. Present Scenario in Electric Vehicle Charging

Since early 1990s, Auckland University has been doing research on inductive power transfer technology. Its IPT® technology actually employs the coupled magnetic resonance as shown in Fig.2.3 (b). Supported by this technique, some early achievements have been made by ConductixWampfler, such as the 20kW charging bay for 5 golf buses in New Zealand during 1997 to 2007 and the 60kW wireless charging urban electric bus fleets in Genoa and Turin, Italy in 2002 and 2003. The University possessed the company HaloIPTwhich had released a 3kW evaluation kit in 2010, which could achieve 85% overall efficiency through 180mm air gap. It was acquired by Qualcomm in 2011. Qualcomm announced a pre-commercial trial in London in as soon as it acquired the company, using similar kits but aiming to increase the reach of this technology to the consumers [6].

The ORNL, mostly focusing coils design, announced two prototypes for Plug-in EV in 2012. The 7kW (SAE Level2) prototype has two identical 800mm diameter coils with Litz wire and soft ferrite plates could reach around 93% coil-to-coil efficiency. The 2kW model, using a 330mm diameter coil design, was tested on a GEM EV powered by 72V lead-acid battery. Experiments have been done in both stationary and dynamic charging applications. The highest tested coil-to-coil efficiency is around 91% with an air gap of 75mm. By implementing the same technology, the pulse-free power produced by Evatran could transfer an output power of 3.3kW about 100mm. It has an over 90% plug-to-battery efficiency as claimed. It has already been successfully installed in NissanLeaf or Chevrolet Volt. At the end of 2012, they announced a trial named as Apollo Launch Program, aiming to the integration of this technology for current on-sale EVs across the United States. MIT (WiTricity) and Delphi employs a different 4 coils design as shown in Fig.2.3(c), the strongly coupled prototype proposed by MIT in 2007 suggests a possible way to transfer energy through a relatively large distance (60W over 2m) . In 2010, a set of 3.3kW development kits based on this technology was released. It has a very low profile on both primary and secondary sides, which could achieve an overall efficiency of 90% with 180mm air gap as claimed. [10]

IV. Key Features of Coupled Magnetic Resonance Wept

High Efficiency:The coupled magnetic resonance WPT is most effective and efficient way of transferring the power wirelessly.It delivers maximum of the input power and available at the receiver circuit also receives maximum of input power delivered over a longer distance ranging from 5 to 10cm.

High Alignment Tolerance: Alignment tolerance is another important issue in EV charging application. The operation of system varies with this function. It allows the flexibility of station equipments and vehicle charging port. The transmitting efficiency will be also higher.

Less Interference: This method of WPT is less responsible for the interference with communications lines and radio communication. This method work like an isolated system hence it is free from any kind of interference. This is the most effective method against interference.

V. Circuit Operation

The flow of power from input to the battery and motors is as shown in the Fig.5.1. The transmitting medium used is air which is denoted by the circle. The part above the circle comprises of transmitter and the other part is the receiver circuit.

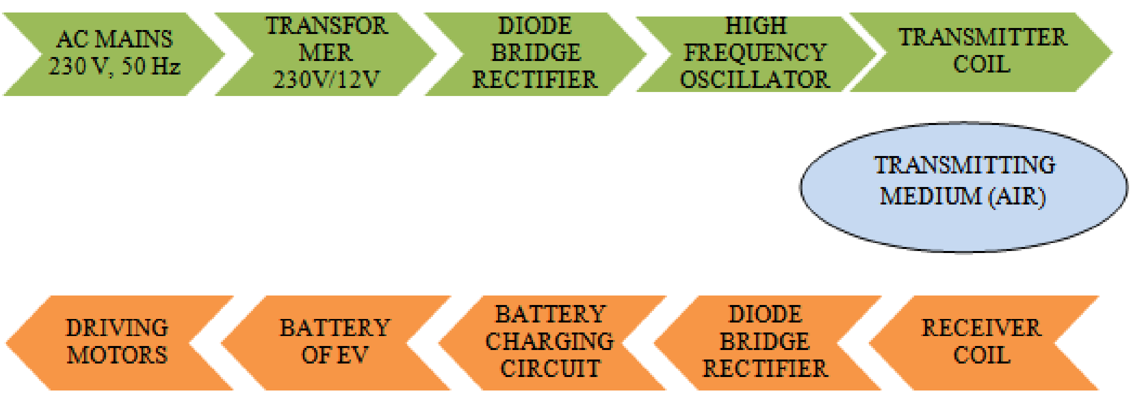


Fig.5.1 Block Diagram

5.1Transmitter circuit

5.1.1 Input and Rectifier

The input to the charging station is taken from 230V, 50 Hz supply mains which given to the transmitter circuit. A transformer is used to step down the voltage to 15V. The diode bridge rectifier is used to convert the ac into dc. Then, after the capacitor filter, the dc supply is given to the Hartley Oscillator.

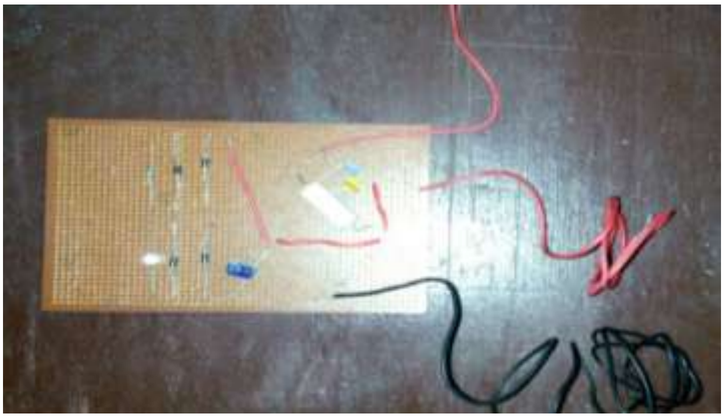


Fig.5.2 Transmitter Circuit

5.1.2 Hartley Oscillator

The rectifier output is given to a Hartley Oscillator circuit. A high frequency inverter can also be used as an option.The rectifier-inverter circuitry can also be replaced by a cycloconverter circuit. The output frequency of the oscillator can be calculated by the following equation.

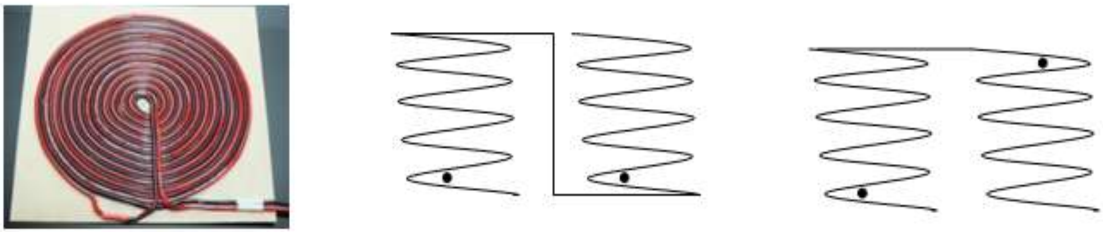
$$f = \frac{1}{2\pi\sqrt{[(L_1 + L_2)C]}} \qquad \text{---(5.1)}$$

5.2 Transmitter and Receiver coil

Two bifilar Tesla coils are used each for transmitter and receiver.

A bifilar coil is an electromagnetic coil that consists of two closely spaced, parallel windings. In engineering, the word bifilar is used for wire which is made from two filaments or strands. It is commonly used to denote special types of wire for transformers windings. Coils can be purchased in bifilar form, usually as different coloured enamelled coil bonded together.

This type of coil forms a centre tapped inductor coil.



(a) Bifilar Tesla Coil (b) Tesla Bifilar (c) Hooper Bifilar

Fig.5.2

5.3 Receiver

The receiver coil is connected across one more diode bridge rectifier. This rectifier circuit along with a filter are at receiver side inside the vehicle. The 12V battery in the vehicle is charged after regulating this voltage.

Fig.5.3 Receiver and Battery Charging Circuit

5.4 Battery Charging Circuit

This circuit involves all the measures to smoothen the charging current and increase the charge-discharge cycles. The rechargeable battery is also fitted in the vehicle which is used to drive the motor control circuit. The ampere-hour rating is taken into account while using it for any application.

5.5 Motor Speed Control Circuit

This circuit is used to control the speed and direction of the motor in the vehicle. There are also some miscellaneous circuitries used for various purposes inside the vehicle. The regenerative braking can also be efficiently implemented in the model to lessen the charging hours of the battery.

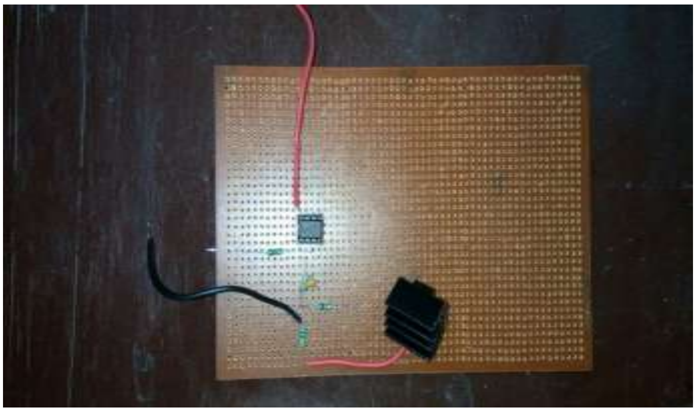


Fig.5.4 Motor Control Circuit

VI. Conclusion

In this paper, different wireless power transfer techniques are reviewed on the basis of EV charging application. The paper gives the easier way of charging the batteries of electric vehicles. It gives designing of efficient and effective mode of charging the vehicles. Cost Effectiveness and Low Communication Interference can be obtained. Multiport charging is possible.

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