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Witricity: Design And Implementation Of A Wireless Power Transfer System Via Inductive Coupling

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***Abstract:** In this work Wireless Power Transfer (WPT) System using inductive coupling technique is presented. The project work was in two phase, the transmitting and receiving circuit. The transmitting circuit consist of a booster circuit (DC-DC boost converter) consisting of an IRF 540 transistor, a 9V battery, and a transmitting coil. The receiving circuit consist of a receiving coil with an LED (Light Emitting Diode). The transmitting and receiving circuits was set up and tests were carried out. The circuit was energized by a 9V battery, readings were taken using a multimeter. The test results were carried out at different distances, from 0 cm to 10 cm. The results showed that the transfer of power wirelessly using this setup is possible up to 8 cm distance. At distances above 8cm there was no sufficient power transferred as to power the LED. With this result, it is therefore possible for WiTricity to be incorporated in future systems where devices needs to be powered at a short range wirelessly.*

***Keywords:** Wireless Power Transfer – WPT, booster circuit, inductive coupling, LED, WiTricity.*

I. INTRODUCTION

Power transmission is the movement of energy from its place of generation to a location where it is applied to performing useful work. Power is defined formally as units of energy per unit time (the S.I unit of power is Watt (Wolfson, 2014).

In this study I have considered electrodynamics or inductive coupling. An inductive link is formed by a loosely coupled transformer consisting of a pair of coils that are usually placed in a coaxial arrangement. The external or the primary coil is excited by an alternating current, and thus an electromagnetic field is produced with its magnitude dependent on the dimensions of the coil, the drive current and the frequency of operation. A portion of the alternating flux lines generated this way link to the internal or the secondary coil, and the change in flux linkage produces a voltage in the secondary coil, which is proportional to the rate of change of the flux and the number of turns in the secondary coil (Faraday’s law of electromagnetic induction) (Matias, Cunha, & Martins, 2013) (Tapan & Sarkar, 2006).

Hardware design for the receiver and transmitter coil is shown and finally the comparative graph is plotted and the efficiency of the system is also computed by comparing the input and output voltage of the system.

This project addresses the following problems (Pranit, 2013):

- ✓ The use of wire cable (power cords) in powering electronic devices such as power adapter or chargers used for mobile gadgets, laptops, home appliances etc. most times makes homes and offices looks so messy.
- ✓ Most times managing a socket outlet becomes difficult and leads to damaged socket outlet even with the use of socket extensions, since most consumers usually have more electronic devices than socket outlets.
- ✓ Another problem is the cost of purchasing new batteries and socket extensions when they are damaged.

This project is aimed at testing how a contactless power transfer system works via inductive coupling between two

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coils which will allow future systems to be efficiently powered by wiTricity (wireless electricity) and how some design parameters influences it.

This paper presents a background and overview of wireless power transmission study, the methodology of the project work which entails the requirements for inductive coupling, the design and implementation of a wireless power transfer system using inductive coupling as well as the specifications of the components used, this is followed by the results from the design and measurements took to analyze the design. It also includes the analysis of the result using tables and graphical representation of data as well as discussions of results. We then reviewed the outcomes of the work presented in this project work and conclude the thesis. Recommendations for future work are also presented.

II. METHODOLOGY

Requirement for Wireless Power Transfer via Inductive Coupling:

This project is aimed at creating a system that can transmit power wirelessly. This can be achieved by connecting a power source to an inductive coupling system that uses magnetic fields to transfer the energy through air. The coupling system involves a transmitting coil component L1 sending energy to a receiving coil component L2.

This is done by sending an energy signal (AC signal) through the L1 coil, and creating a magnetic field B. the L2 coil then creates an energy signal using the magnetic field. The coupling system is shown in the figure below:

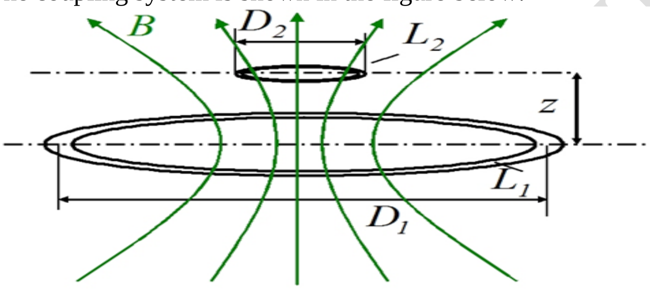

Figure 1: Inductive Coupling System.

The system's efficiency is based on the size ratio D2/D1 of the two coils and the distance between the two coils (Z). As the ratio D2/D1 decreases, the efficiency of the system will decrease. As the distance between the two coils increases, the efficiency of the system also decreases.

A power source supplies the primary coil, D1, with a high frequency AC, ranging from some KHz to some MHz, this causes a magnetic field to be generated in the primary coil, according to Biot-Savart's Law [1]. The magnetic field generated in the Primary coil, induces a high frequency AC voltage in the Secondary coil according to Faraday's Law of induction [1]. This voltage is rectified and used to power a load (charging of mobile).

III. DESIGN OF THE SYSTEM

Block Diagram:

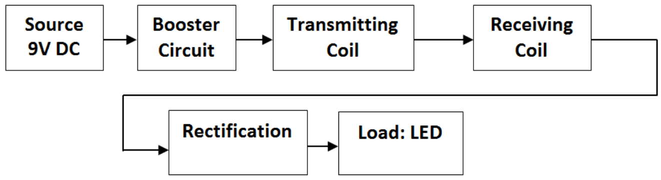

Figure 2: Block Diagram of a Wireless Power Transfer System

- ✓ Source: The supply given here is 9V (DC).
- ✓ Booster Circuit: A booster circuit is a DC-DC power converter with an output voltage greater than its input voltage. It is of a switched-mode power supply (SMPS) containing one semiconductor (a transistor), at least one energy storage element, a capacitor, an inductor, or the two in combination (Samer, 2014).
- ✓ Transmitter Coil: The transmitter coil is the one which transmits power wirelessly to the receiver coil.
- ✓ Receiver Coil: The receiver coil is the one which receives power from the transmitter coil
- ✓ Rectifier: The rectifier is a half wave rectifier that consist of a diode, which enables conversion to DC, and enables the voltage received by the receiver coil to be measured using the multimeter.
- ✓ Load: The load is an LED.

Circuit Diagram of the System:

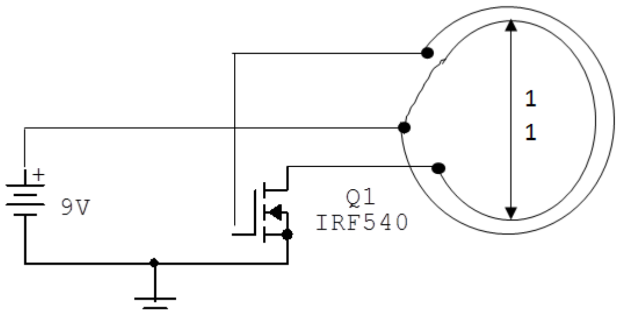

Figure 3a: Transmitter Circuit

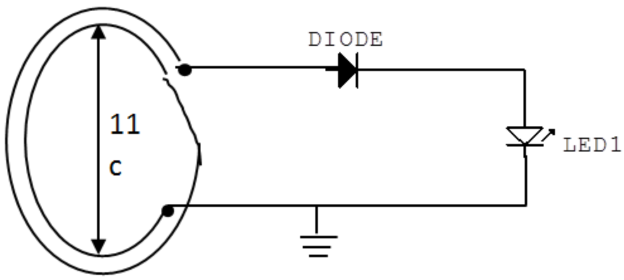

Figure 3b: Receiver circuit

The Fig. 3 shows the circuit diagram of a wireless power transfer system. The input power to the system is DC supply of 9V is given. The booster circuit is also known as (boost converter or step-up converter) is a DC-DC power converter with an output voltage greater than an input voltage. It is a switched-mode power supply (SMPS) containing one semiconductor (a transistor) and at least one energy storage

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element, a capacitor, inductor, or the two in combination [8] – [10].

Booster circuit also power devices at small scale applications, such as portable lighting systems. An LED typically requires about 0.7V and above to glow. The transmitter coil made up of copper turns of America Wire Gauge (AWG) of 18 is used to transmit power wirelessly to the receiver coil. The receiver coil is also made of same wire gauge as transmitter coil. The magnetic field generated by the transmitter coil couples with the receiver coil, exciting the coil and causing energy to be build up in it. This energy is coupled out of the receiver coil to do useful work, for example directly powering a load. The LED is used as a load. The voltage received by the receiving coil is rectified, by means of a half wave rectifier. The transmitter coil and the receiver coil is constructed with 8.5cm radius and I have constructed both coils with 12 turns [8].

SPECIFICATION OF COMPONENTS

TRANSMITTER COIL SIDE:
Input voltage = 9Volts
Transistor (IRF540)
Turns = 12
RECEIVER COIL SIDE:
Turns = 12
Diode = IN4001
Load = LED (Light Emiting Diode)

MODEL PICTURE FOR 10 TURNS (SINGLE LOAD)

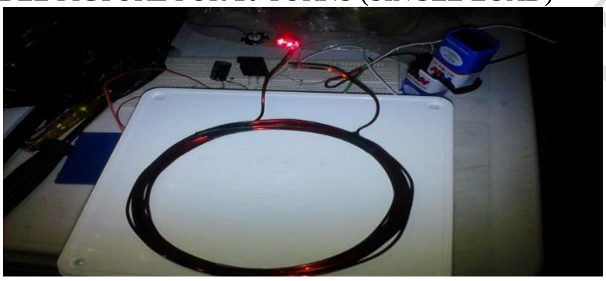

Figure 3.4: Model picture of a Wireless Power Transfer System for single load

IV. EXPERIMENTATION RESULTS

RESULTS BY PLACING COILS AXIALLY WITHOUT OBSTACLE

We have carried out the experiment by placing the coils at different distance, and taking readings of the voltage using a multimeter, as the distance increases from 0cm to 10cm. The corresponding readings are as shown in the table below:

Distance (cm)	Input voltage (V)	Output voltage (V)	Efficiency (%)
0	9	7.16	79.6
1	9	6.36	70.7
2	9	6.05	67.2
3	9	5.73	63.7
4	9	5.45	60.5
5	9	5.08	56.4
6	9	4.52	50.2
7	9	3.98	44.2
8	9	3.58	39.8
9	9	3.21	35.7
10	9	3.16	35.1

Table 1: Comparison between Distance, voltage, and Efficiency, when coils are placed without obstacle

Experimental graph of receiver coil without obstacle:

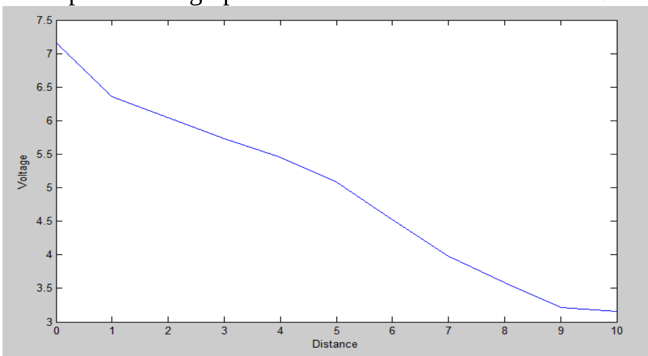

Figure 4: Graph between Voltage and Distance (without obstacle)

RESULTS BY PLACING COILS AXIALLY WITH A PLASTIC OBSTACLE BETWEEN COILS

Distance (cm)	Input voltage (V)	Output voltage (V)	Efficiency (%)
0	9	7.02	78.0
1	9	6.24	69.3
2	9	5.98	66.4
3	9	5.69	63.2
4	9	5.32	59.1
5	9	5.02	55.8
6	9	4.51	50.1
7	9	3.52	39.1
8	9	3.38	37.5
9	9	3.18	35.3
10	9	3.08	34.2

Table 2: Comparison between Distance, Power, and Efficiency, when coils are placed with an obstacle in between them

Experimental graph of receiver coil with obstacles

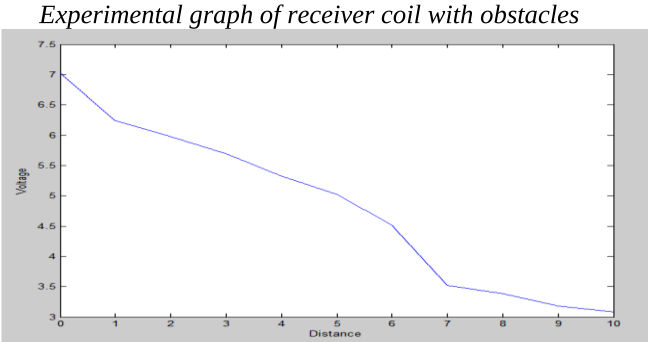

Figure 5: Graph between voltage and Distance (with obstacle)

V. DISCUSSION OF RESULTS

We carried out the experiment by placing the coils at different distance, ranging from 0cm to 10cm and the readings

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I recorded is as shown in table 1 above. It could be observed from the graph below table 1 that as the distance increases the voltage decreases, as well as the efficiency decreases, this is because as the receiving coil moves farther from the transmitting coil the strength of the magnetic flux generated by the transmitting coil reduces i.e. becomes weaker, hence the voltage received according to faradays law of induction becomes smaller as the two coils are separated by distance axially. The maximum efficiency that I obtained was about 80% at 0cm as shown in the table 1 above.

Table 2 presents the results of the experiment, obtained by placing an obstacle between the transmitting and receiving coils. From the graph it could be observed that when an obstacle (a plastic electrical junction box cover) was placed between the coils, the voltage received by the receiving was not up to that received without the obstacle, but there was power transfer at a good efficiency of about 78%, which is efficient enough to power devices that requires low power to function. From these results and analysis, though the distance was restricted to a few centimeters, due to the input voltage and the size of the coils, I have been able to show that wireless power transfer via inductive coupling can be fully incorporated in future electronic systems.

VI. CONCLUSION AND RECOMMENDATION

The main purpose of this project work was to design a device that provides wireless transfer of power at medium distance through inductive coupling which will allow future systems to be efficiently powered by wiTricity (wireless electricity). This concept is an Emerging Technology, and in coming years the distance of power transfer can be enhanced as the research across the world is still going on. Wireless power transfer can make a remarkable change in the field of the electrical engineering which eliminates the use of conventional copper cables and current carrying wires. This will lead to no more messy wires and with widespread enough use it could even eliminate costly batteries. Without wires, power transmission is often a more suitable, greener alternative to conventional plug-in charging.

In the glowing of an LED via inductive coupling the distance was restricted to a few centimeters, due to the input voltage and size of the coils. Wireless technology will be a key enabler for future smart applications. However, there are still many research to be made in order to achieve a successful implementation of this technology.

VII. FUTURE APPLICATIONS OF INDUCTIVE WIRELESS POWER TRANSFER SYSTEM

Some areas where wireless power transmission may be useful includes:

- ✓ Automatic wireless charging of mobile electronics (phones, laptops, game controllers, etc.) in home, car, office, Wi-Fi hotspots… while devices are in use and mobile.
- ✓ Direct wireless powering of stationary devices (flat screen TV‘s, digital picture frames, home theater accessories, wireless loud speakers, etc.) … eliminating expensive custom wiring, unsightly cables and ―wall-wart‖ power supplies.
- ✓ Direct wireless powering of desktop PC peripherals: wireless mouse, keyboard, printer, speakers, display, etc. eliminating disposable batteries and awkward cabling.

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