THE DEVELOPMENT OF WIRELESS POWER TRANSFER TECHNOLOGIES FOR MULTIPLE DEVICES USING INDUCTIVE APPROACH

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ABSTRACT

Wireless Power Transfer (WPT) is a transmission of electrical energy across a medium without using electrical conductor or wire. There are three techniques of wireless power transfer in near-field which are inductive power transfer technique (IPT), capacitive power transfer technique (CPT) and acoustic power transfer technique (APT). Between these three techniques of wireless power transfer, IPT has the advantages of farther transmission distance and high efficiency compare with CPT and APT. Therefore, this project aims to use IPT for transferring power wirelessly. IPT will enable the power transmission from one transmitter coil to several receiver coils. Therefore, the electronic appliances such as digital clock and desk lamp are able to be power up without using cable or battery. To be specific, a class E inverter is designed in this work for converting a direct current (DC) source to alternating current (AC) source at high frequency with high efficiency. The performances analysis of the developed prototype done and discussed in term of output efficiency as well as the future recommendation of the proposed method is also presented. At the end of this project, the prototype is able to yield a 75% of efficiency.

Keywords: Wireless Power Transfer (WPT), Class E Inverter, Inductive Power Transfer (IPT), multiple low power devices.

ABSTRAK

Pemindahan kuasa tanpa wayar (WPT) adalah penghantaran tenaga elektrik melalui sesuatu benda tanpa menggunakan sebarang konduktor elektrik atau wayar. Terdapat tiga teknik pemindahan tenaga tanpa wayar dalam kategori medan dekat adalah pemindahan kuasa berdasarkan induktif (IPT), pemindahan kausa berdasarkan kapasitif (CPT) dan pemindahan kuasa berdasarkan akustik (APT). Antara ketiga-tiga teknik pemindahan tenaga tanpa wayar, IPT mempunyai kelebihan dalam jarak penghantaran yang jauh dan kecekapan yang tinggi berbanding dengan CPT dan APT. Oleh itu, projek ini bertujuan untuk menggunakan IPT sebagai teknik untuk memindahkan kuasa secara tanpa wayar. Dengan teknik IPT, kuasa akan menghantar daripada satu gegelung pemancar kepada beberapa gegelung penerima. Oleh itu, peralatan elektronik seperti jam digital dan lampu meja akan dapat kuasa tanpa menggunakan kabel atau bateri. Untuk menjadi tertentu, inverter kelas E direka dalam kejar ini untuk menukar sumber arus terus (DC) kepada sumber arus pada frekuensi yang tinggi dengan kecekapan yang tinggi. Analisis prototaip yang dibangunkan disiap dan dibincang dari segi kecekapan serta cadangan untuk masa depan juga dibentagkan. Pada akhir projek ini, prototaip ini mampu menghasilkan 75% daripada kecekapan.

Kata Kunci: Pemindahan kuasa tanpa wayar (WPT), inverter kelas E, pemindahan kuasa berdasarkan induktif (IPT), pelbagai peralatan elektronik yang kuasa rendah.

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CHAPTER I

INTRODUCTION

1.0 Overview

This section gives an introduction to the project with the title of "The development of wireless power transfer technologies for multiple devices using inductive approach". An overview about the wireless power transfer and wireless power transfer techniques are described in first part. The following parts are problem statement, project objective, scope of work and the structure of report.

1.1 Project Introduction

In recent years, various types of home appliances and electronic devices such as light bulb, fan, laptop, tablet, mobile phone and so forth are developed. Furthermore, each of them is required electric power to activate their functionality. The existing methods of the electric power transmission in the world are wired and wireless power transmissions. By comparing these two methods, the most popular and easy to find is wired power transmission whereas wireless power transmission has developed to enhance the convenience to people.

Wireless power transfer is described as electric power transmission from one place to another place in certain distance without any connecting wire. The first person who has the idea on wireless power transmission is Nicola Tesla. He had demonstrated "the transmission of electrical energy without wires" which depending on conduction of electrical as early as 1891[1] [2]. There is one experiment that Nicola Tesla had carried out in year 1893 at World Columbian Exposition in Chicago. This experiment is high frequency lighting system which lighting vacuum bulb without any connecting wire between bulb and source.

Wireless power transfer is categorized into two types which are near-field technique and far-field technique. Figure 1.1 shows the each of the technique available in near-field technique and far-field technique. Based on Figure 1.1, near-field consists of inductive power transfer (IPT), capacitive power transfer (CPT) and acoustic power transfer (APT) whereas far-field consists of microwave power transmission (MPT) and laser.

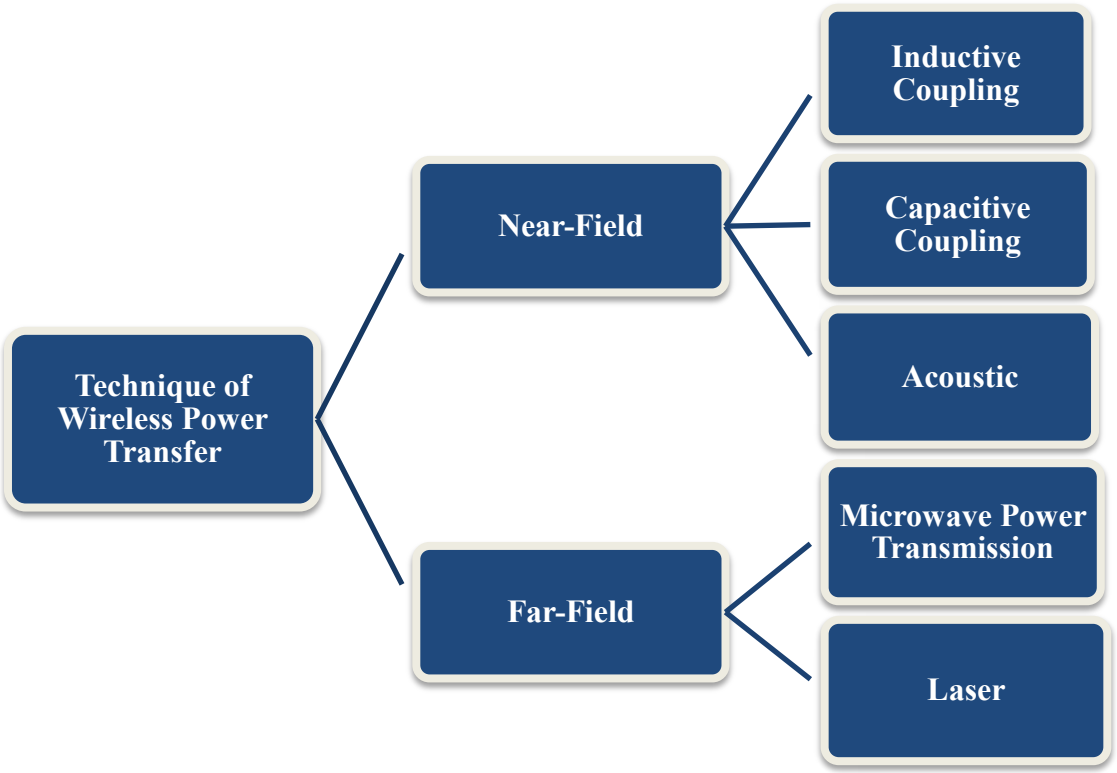


Figure 1.1: Technique of Wireless Power Transfer [1].

With the use of wireless power transmission technology, electric power can transmit to somewhere where the wired power transmission is unable to perform. Other than that, people are eased to activate their devices in anywhere as they do not need to plug in their devices connector into a socket for transferring electric power to devices. Besides that, this technology also brings the benefit of cost effective. The power loss in transmission of wireless power transmission is negligible. As a result, wireless power transmission has the higher efficiency compare with wired transmission, therefore the cost of consumed energy becomes less. Other than that, wireless power transmission can reduce accidental occurrence in human life where no quality wire is used. In addition, the pollution can avoid as this technology is not emitted radiation and also reduce the use of non-biodegradable plastic.

In conclusion, the development of this technology brings a simple and convenience way to people life. Therefore, wireless power transfer should continue enhancing in different field such as industrial, mobile devices, consumer electronics and so forth.

1.2 Problem Statement

Nowadays, people are living in a technology environment. The technologies that used in everyday are lamp, fan, mobile phone, rice cooker, television, radio and so forth. Each of these devices is required power to activate the device through a wire or connector to transfer the power from main power source to device. This may cause the connecting wire or cable placed anywhere in house and caused inconvenience to people due to the limited range of power transfer. When the wire or cable is placing anywhere, there is possible for accident occur if the wire is broken. This is because of high voltage is passing through the wire. If the protected cover of the copper wire is spoil, then it will cause a spark at the particular point. This may also increase the risk of injure towards human in house. Other than that, the limited of socket in a room also becomes a problem for people who need to power up multiple devices simultaneously. Moreover, people require bringing along multiple sockets for preparing to power up their devices. Therefore, wireless power transfer technology is designed to solve these problems. There are three major techniques which are inductive, capacitive and acoustic. But inductive is the best solution because of high efficiency, low cost and middle range transmission. However, the current problem of the IPT method is low efficiency due to losses occur when transmission in long distance. Therefore, class E inverter will be designed to improve the efficiency of this project.

1.3 Objectives

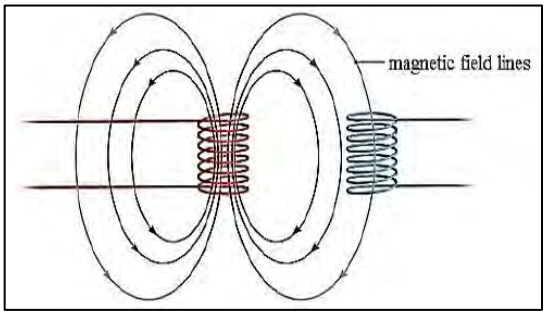
The objectives of this project are:

a) To develop a prototype to power up multiple devices using inductive power transfer approach.
b) To design class E inverter circuit that able to improve the efficiency of the project.
c) To analyze the performance of the proposed method in term of output efficiency.

1.4 Scope

Figure 1.2 shows the scope of work of this project in the form of diagram. While, the scope of this project is declared as follows:

a) Inductive coupling approach is used.
b) At least two loads are used in this project; i.e. lamp and digital clock.
c) Specification of this project are listed in below:
    - Input voltage: 12Vdc – determines based on the specification of the loads.
    - Operating frequency: 1MHz – in order to design a small scale system and low power losses.
    - Output power: 5W – determines based on the specification of the loads.



(a)

(b)

Figure 1.2: (a) Image of Inductive Power Transfer and (b) Loads of This Project

1.5 Structure of Report

This report consists of five chapters. Firstly, the introduction about this project is descripted in chapter I. The introduction included overview of wireless power transfer, problem statement, objective and scope of project.

Chapter II is literature review which described about the background of wireless power transfer, description of each technique of wireless power transfer, class E inverter description and other elements related to this project is also considered.

Chapter III discusses the methodology used to complete this project. In this chapter, several design equations and the circuit designs are included.

Next, Chapter IV is results and discussion of this project based on the output of each part of the project. There are two types of result which are simulation result and practical result regarding to this project. The comparison between simulation and practical results also carry out as an analysis.

Lastly, conclusions and recommendations are described in Chapter V.

CHAPTER II

LITERATURE REVIEW

2.0 Overview

Literature review concludes the existing work and present research that have done by the different group of the researcher. By referring the research paper that done by these different groups of the researcher, the improvement of the efficiency of wireless power transfer can be identified. In this section, several detail theories about wireless power transfer also included.

2.1 Wireless Power Transmission (WPT)

Power transmission can be described as power transmission from one place to another place. In general, power transmission uses alternating current (AC) for transmission because of the voltage can be stepped down and up easily by a transformer. As a result, the transmission conductor which is used to transfer the power over a far distance obtains a low resistive. However, this power transmission has a major issue in power transmission and distribution which is the losses of power. In recent year, the power losses in transmission are higher as the usage of power generation is increased which is required in order to fulfill the demand of power system.

According to [1] [3] [4], the power loss in the process of transmission and distribution in term of percentage is within 26% and 30%. This power is consumed by the resistance of conductor or wire that use for transmission and distribution process in an electrical grid. As a result, the efficiency of the system of electrical distribution is only 70% to 74%. By referring the research of World Resources Institute (WRI), India is the country where to have the highest power losses in

transmission and distribution of electricity grid in the world which is approximately 27% [3]. With wired power transmission, the voltage can be easily stepped up and down based on the specification but, it also brings inconvenience to some location where the wire is impossible to equip and disadvantage of power losses. Therefore, wireless power transmission is developed to enhance and improve the difficulties of wired power transmission.

The first invention of wireless power transfer is discovered by Nikola Tesla at the end of the 19th century. He also referred to as "Father of Wireless" and demonstrated "the transmission of electrical energy without wire" that depending on conduction of electrical as early as 1891 [1] [3] [4] [5]. The first patent of Tesla is a complete description of a high-frequency lighting system. This system has the feature of only one supplying wire is used to and patented single terminal carbon lamps without return wire as shown in Figure 2.1 [6]. In 1893, Tesla demonstrated that vacuum bulb can be lighting up without wires for transmission by this lighting system at World Columbian Exposition, Chicago [5]. In this experiment, a resonant circuit with a grounded terminal successfully lighted up the vacuum bulb. The connection for lower end and the upper end of a coil outside laboratory is connected to the ground and no connection respectively. A current can be induced in three turns of wire that wound around the lower end of the coil [7]. As a result, the vacuum bulb is lighted up as shown in Figure 2.2. This demonstration also shows that high currents and voltages do not influence any injury towards people immediately.

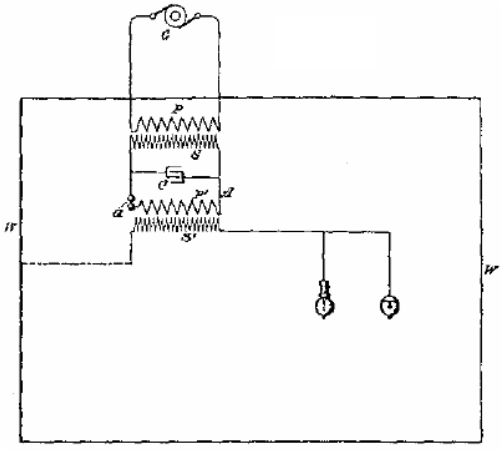


Figure 2.1: High Frequency Lighting System [6]

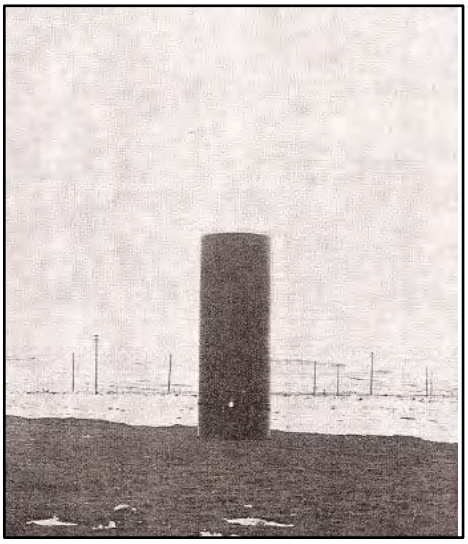


Figure 2.2: Experiment of Nikola Tesla [7]

In 1904, Nikola Tesla had successfully designed and constructed an 187-foot or 57m high of Wardenclyffe Tower which is called as Tesla Tower. The purpose of this Wardenclyffe Tower is focused on wireless electrical power transmission rather than telegraphy [1] [3] [4] [5]. In addition, the Wardenclyffe Tower is meant for trans-Atlantic wireless telephony and demonstration of wireless transmission of electrical power [7] [8]. Figure 2.3 shows the Wardenclyffe Tower that was designed by Tesla in 1904 and Figure 2.4 shows the system of Tesla.

Figure 2.3: Wardenclyffe Tower (Tesla Tower) [1] [3] [4] [5]

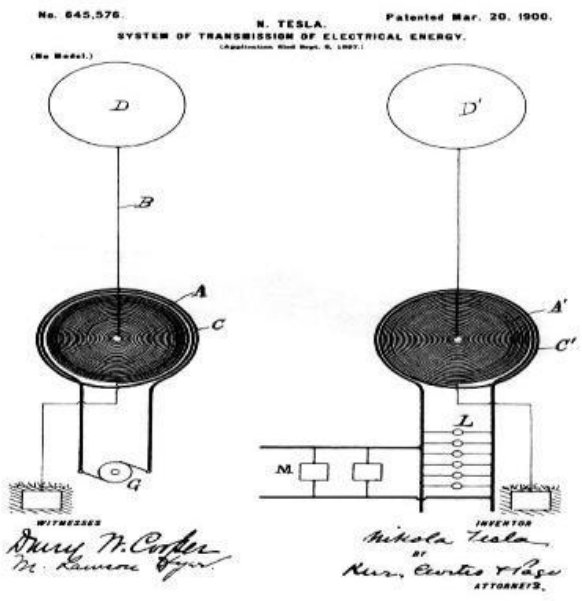


Figure 2.4: System of Tesla [7]

After the innovation of Nikola Tesla, a 0.1 horsepower of airship ship motor is operated by using the power transmission through the air gap with the distance least 100 feet [1] [3]. And then, William C. Brown had released the first paper which proposes a new transmission of power with the use of microwave energy in the year 1961. A rectenna is invented by Brown which straight away converts the microwave energy into DC current [7]. As a result, a microwave-powered helicopter is invented by William C. Brown. According to [9], a microwave-powered helicopter is demonstrated to the public by William C. Brown. In this experiment, the microwave-powered helicopter can receive a beam of microwave energy from 2.45 GHz to 2.5 GHz frequency which is the whole required power for flight. This demonstration is sponsored by Raytheon Company and Rome Air Development Center in October of 1964. Figure 2.5 shows the microwave powered helicopter flight at 60 ft. (around 18 m) above transmitting antenna.

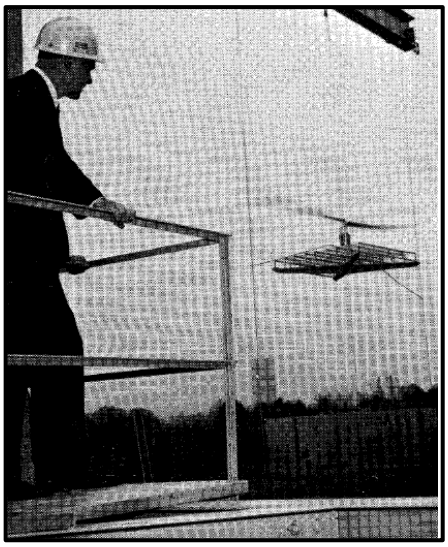


Figure 2.5: Microwave-Powered Helicopter [9].

The first microwave power transfer experiment in the ionosphere is conducted in Japan in 1983 which is called as Microwave Ionosphere Non-linear Interaction Experiment (MINIX) rocket experiment [3]. In 1987, the first fuel-free airplane that used microwave energy to power up from ground was reported at Canada [3]. It is called Stationary High – Altitude Relay Platform (SHARP). An airplane indoors that use laser to power up is demonstrated by Dryden Flight Research Centre of NASA in 2003 [3]. In the following year, wireless charging of electric motor vehicles with the use of microwave power transfer is proposed by Japan [3].

In recent year, wireless power transfer technology still has the potential in research and development by the different group of people. In 2007, at Massachusetts Institute of Technology (MIT), a physical research group which led by Prof. Marin Soljacic was demonstrated an experiment of illuminating a 60W light bulb with 40% efficiency [3] [5] [8]. This research group used two coils with a diameter of 60cm for transferring power and it can transfer more or less than 2m (7ft) away from the power source. Furthermore, there is no connection between light bulb and power source [5]. Figure 2.6 shows the diagram of wireless power by 'WiTricity'.

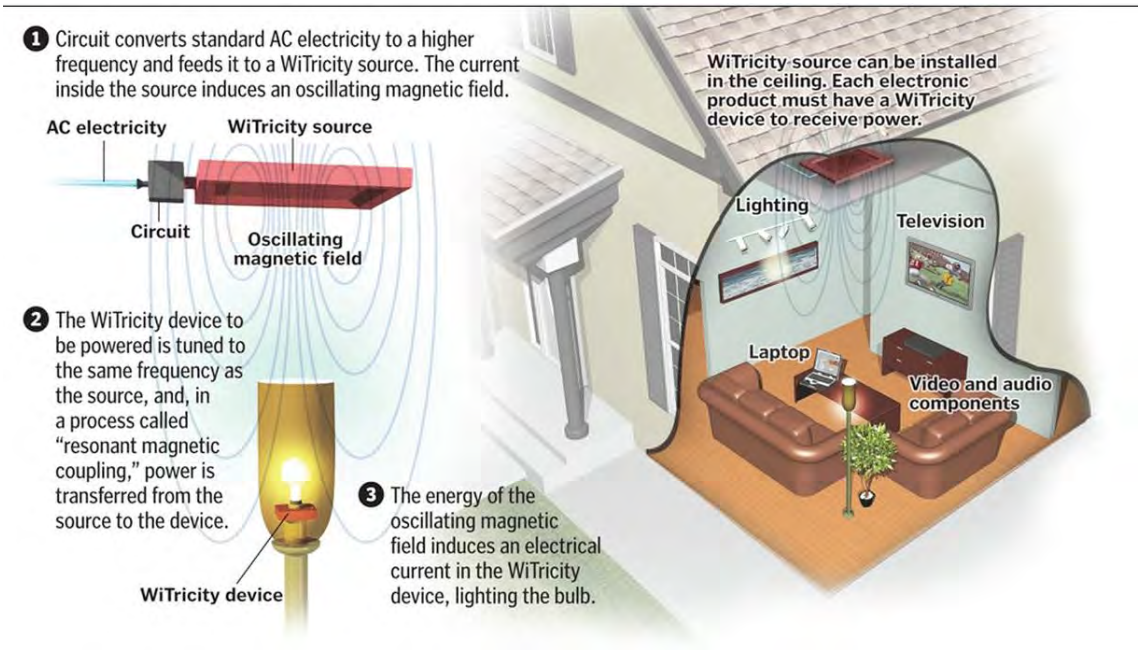


Figure 2.6: Diagram of Wireless Power by 'WiTricity' [5]

In the following year, Intel reproduced the experiment that done by MIT's group with 75% efficiency at a shorter distance [3]. The working principle of this technology is done by produce a resonant induction phenomenon which described as generate a resonance between two magnetic fields. This research project is led by Joshua R. Smith. Figure 2.7 shows the experiment of Intel.

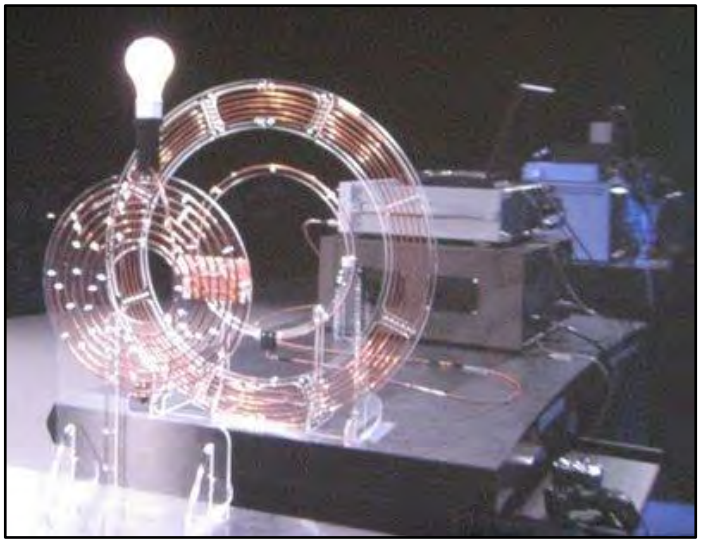


Figure 2.7: Experiment of Intel [7]

In conclusion, wireless power transfer can be achieved by using a different method such as tesla coils transmission that propose by Nikola Tesla and microwave