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

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This Report is Submitted in Fulfillment of Requirements for The Bachelor Degree of Electronic Engineering (Industrial Electronic)

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

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DEDICATION

I dedicate this dissertation to my parents and friends. People who have always been there to support me, congratulate me, and show me the best path to follow.

I also dedicate this dissertation to my loving fiance, Ho Kar Meng who has been there for me and supported me throughout the process.

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ABSTRACT

Conventionally, the energy or power transfer is done through the connecting wires to power up the electronic appliances but these wires create hazardous and messy environment. With wireless power transfer (WPT) technologies, the used of connecting cord can be reduced. WPT technology is the transmission of electrical energy or power between two points without connecting wire. WPT mechanism is classified into two: near-field transfer and far-field transfer. This project applied the near field transfer because it has higher power transfer efficiency over the far-field transfer in short transmission distance. There are three subtypes of near-field transfer mechanism which are inductive power transfer technique (IPT), capacitive power transfer technique (CPT) and acoustic power transfer technique (APT). IPT is chosen to be the WPT technique in this project due to its higher power efficiency in the transmission distance range of centimetre. The current mechanism deploys class-D inverter which has its limitation in supporting high power efficiency due to it consists of two switching MOSFETs. When the number of MOSFET used increases, the switching loss in term of heating issue will also increase. Therefore, a high-efficiency WPT system which can support four receivers at the same time using Class E inverter for transmitter via inductive power transfer (IPT) has been designed and fabricated instead of Class D inverter. The project performance based on the misalignment distance and the gap between the coils are analysed and discussed in term of output power efficiency. A future development is also recommended. The fabricated system is supplied at $12V_{DC}$ and capable of delivering power at 5W. During power delivery state, the prototype efficiency is 90.42%.

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

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ABSTRAK

Cara tradisi tenaga atau kuasa pemindahan adalah melalui penyambung wayar untuk mengaktifkan peralatan elektronik tetapi wayar mewujudkan persekitaran yang berbahaya dan tidak kemas. Dengan aplikasi pemindahan kuasa tanpa wayar (WPT), penggunaan penyambung wayar boleh dikurangkan. WPT adalah penghantaran tenaga elektrik atau kuasa di antara dua jarak tanpa penyambung wayar. Mekanisme WPT diklasifikasikan kepada dua: pemindahan medan dekat dan pemindahan medan jauh. Projek ini digunakan pemindahan medan dekat kerana ia mempunyai kecekapan pemindahan kuasa yang lebih tinggi berbanding dengan pemindahan medan jauh dalam jarak penghantaran yang dekat. Terdapat tiga jenis pemindahan medan dekat adalah seperti pemindahan kuasa beraruhan (IPT), pemindahan kuasa berdasarkan kapasitif (CPT) dan pemindahan kuasa berdasarkan akustik (APT). IPT dipilih menjadi teknik WPT dalam projek ini kerana ia memberi kecekapan kuasa yang lebih tinggi dalam lingkungan jarak penghantaran sentimeter. Mekanisme kini menggunakan kelas-D inverter yang mempunyai sekatan dalam menghasilkan kecekapan kuasa yang tinggi kerana ia menggunakan dua MOSFET sebagai suis. Apabila bilangan MOSFET digunakan bertambah, kehilangan kuasa dari segi isu pemanasan akan meningkat. Oleh itu, sistem WPT yang dapat menyokong empat penerima pada masa yang sama dengan menggunakan Kelas E inverter sebagai pemancar melalui pindahan kuasa beraruhan (IPT) telah direka dan difabrikasikan untuk menggantikan Kelas D inverter. Pelaksanaan projek dari segi jarak penjajaran dan jurang antara gegelung akan dianalisis dan dibincangkan dari segi kecekapan. Perkembangan masa depan juga dicadangkan. Sistem yang direka akan dibekalkan dengan $12V_{DC}$ dan mampu menghantar kuasa pada 5W. Kecekapan prototaip yang dihasilkan adalah 90.42%.

Kata Kunci: Pemindahan kuasa tanpa wayar (WPT), inverter kelas E, pemindahan kuasa berdasarkan induktif (IPT), pelbagai penerima untuk aplikasi yang berkuasa rendah.

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LIST OF ABBREVIATIONS

WPT	-	Wireless Power Transfer
Tx	-	Transmitter
Rx	-	Receiver
IPT	-	Inductive Power Transfer
CPT	-	Capacitive Power Transfer
APT	-	Acoustic Power Transfer
DC	-	Direct Current
AC	-	Alternating Current
PWM	-	Pulse Width Modulation
ZVS	-	Zero Voltage Switching
PIC	-	Peripheral Interface Controller

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CHAPTER I

INTRODCUTION

1.1 Overview

This chapter will briefly introduce the concept of wireless power transfer (WPT) for multiple devices using inductive approach. The problem statement, project objectives, scope of work and the structure of report will be highlighted in details here.

1.2 Project Introduction

Nowadays, wireless power transfer (WPT) technology has become one of the top research fields for its effective and reliable applicability especially in charging portable electronic devices such as electric toothbrush, smartcard system, high power electric vehicles (EV), mobile phones and home appliances [1]. Conventionally, these devices rely on the chemical storage of energy which is the battery to operate. The battery is charging through the ubiquitous power wire that is connected to the power source mounted on the wall. In other words, a connector is used to transfer the power from the main power source to the load.

Despite the conveniences of these advanced devices benefit the user, the danger of having long, hazardous and tangled wiring is not avoidable. These wired-technology products endanger the safety of consumer as tripping hazards due to the tangled wires and sparks might occurs due to the damage on the non-biodegradable plastic. On the other hand, the consumers found difficulties in looking for the socket to charge their devices

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due to the limited availability of the wall plug or socket in a house or room. Therefore, wireless power transfer (WPT) mechanism is introduced as an alternative power scheme and to enhance the convenience to the user.

Wireless power transfer (WPT) technology is the transmission of electrical energy or power from one point to another point through the vacuum or atmosphere without the connecting wire [2]. The proposed technique eliminates the use of connecting wire. It is also known as a non-contact power transmission technology. It can transmit power to the location where wired transmission is not favor. So, when WPT becomes feasible, all the devices capable of charging themselves without ever being plugged in.

The fact is, wireless power transfer system has been studied over years since Nikola Tesla demonstrated wireless illumination of phosphorescent lamp in 1893AD and due to this invention, he is known as "Father of Wireless". Nikola Tesla is the one who first conceived the idea of Wireless Power Transmission and demonstrated "the transmission of electrical energy without wires" that depends upon electrical conductivity as early as 1981[3]. Tesla demonstrated the wireless illumination of phosphorescent lamps of his design at World's Columbian College [4].

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Figure 1.1: The 187-foot Wardenclyffe Tower.

In 1901, Tesla's Wardenclyffe Tower was built as shown in Figure 1.1. It was a commercial and a scientific demonstration of trans-Atlantic wireless telephony, broadcasting and wireless power transmission system [4]. Tesla's intention was to demonstrate wireless transmission of electrical energy across the Atlantic. However, the tower was not fully functional and was demolished during the World War I.

Since then, magnetic induction has been studied intensively and hence produced wireless chargers for devices these days. Nonetheless, the efficiency of the transmission has always been an issue for wireless applications. According to [5], WPT system would completely eliminates the existing high-tension power transmission line cables, towers and sub-stations between the generating station and consumers as well as facilitates the interconnection of electrical generation plants on a global scale. WPT provides more freedom of choice of receiver and transmitter and ultimately mobile transmitter and receiver module are also based WPT system.

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Recently, WPT had emerged in the daily life applications such as the electrical toothbrush manufactured by Phillips and Oral-B. This toothbrush as depict in Figure 1.2 has a charging station operating as a transmitter while the toothbrush itself works as receiver. The rechargeable toothbrush with the receiving coil is placed on the source cradle for getting charged [6]. In addition, driven by industrial needs, multiple transmitter and receiver design has attracted much attention. The power mat is also making an appearance in the market shown in Figure 1.3. It is a single power source that can be used to transfer energy to more than one device, even when the devices have different power requirements. For example, instead of having a separate charger for each mobile phone in your family, you can have a charging surface that handles all of them at once [7].

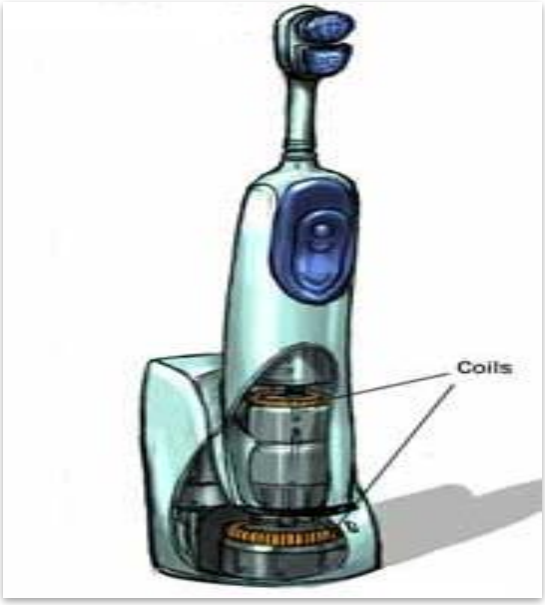

Figure 1.2: The electrical toothbrush.

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Figure 1.3: The power mat by Witricity.

Generally, WPT has higher efficiency in power transmission compared to wired transmission as loss of transmission is negligible. According to the author [2,5], the resistance of the wire used in the electrical grid distribution system causes a loss of from 26% to 30% of energy generated. Besides, the risk of having power failure due to short circuit and fault on cables is lesser. WPT offers greener environment as it reduces the environmental waste by eliminating the need of power cords which made of non-biodegradable materials. Therefore, power transmission wirelessly may be the decent alternative for efficient power transmission.

1.3 **Problem Statement**

Statement 1:

Nowadays there is a rapid increase in electronic devices such as mobile phones, laptops, television and other home appliances. These devices need batteries to power up by a cable connected to the power supply which is the socket mounted on the wall. Despite the conveniences of these advanced devices benefit the user, there are some drawbacks in the usage of wired power transfer technology. The physical connection wires or cables create hazardous environment. For an instance, electrical connections may cause risky

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sparking and electrical shocks due to the damage of insulated layer. The connecting cable cord in wired device creates messiness due to arrangement of the multiple devices in multiple wall plugs. The long wires are easily tangled and will cause the users trip on them. Therefore, in this project a wireless power transfer technologies will be applied in order to overcome the above-mentioned problems. This project aims to develop a wireless power transfer (WPT) by using inductive coupling approach (IPT). WPT defines the noncontact power transmission technology by providing galvanic isolation between the power source and load.

Statement 2:

However, by considering the IPT system, the major challenge is to maintain the output efficiency during power transmission. Current IPT system deploys Class D amplifier to invert the DC constant supply to AC supply in the transmitter. Class D consists of two switching elements which are MOSFETs. It is hard to maintain the simultaneous on-off operation of the two MOSFETs to maximize the switching efficiency. This IPT system with class D amplifier ultimately has higher switching losses due to two switching elements. Therefore, in this work, Class E will be proposed instead of Class D. The properties of Class E inverter are only one MOSFET used as switching element and it has resonant tank to reduce the power loss during switching stage. Also, to enhance the power efficiency, an impedance matching circuit is designed to obtain the desired output power at specified supply voltage at high operating frequency.

1.4 **Objectives**

The objectives of this project are:

a) To design class E inverter circuit to improve the efficiency of the Inductive Power Transfer System.

b) To analyse the performance of the proposed method in term of output efficiency.

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c) To develop a prototype to power up the multiple devices by using inductive coupling approach.

1.5 Scope

This research will discuss the wireless power transfer application in charging multiple devices inclusive of:

a) The study is only on inductive coupling approach.

b) At least three loads are powered up; i.e. table lamp, digital clock and Nokia brand mobile phone

c) The construction of power converters to replicate charging signal.

d) The specifications of this project are shown in table 1.1.

Table 1.1: The specification of the project.

Parameters		Description
1.Output Power	$P_o = 5W$	The minimum power required to charge mobile phone.
2.Operating Frequency	$f = 1\ MHz$	High frequency beneficial to small scale system design and power losses reduction.
3.Quality Factor	$Q_L = 10$	High quality factor in inverter design to achieve sinusoidal output signal.
4.Input Voltage	$V_{DC} = 12V$	The minimum input value required.
5.Transmission Distance	1cm – 2cm	The inductive approach specification.

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