DESIGN OF CAPACITIVE POWER TRANSFER FOR ELECTRIC VEHICLE CHARGING

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DEDICATION

Special dedication to my beloved family, Yusoff bin Alias and Rasinah binti Hamzah. Their encouragement and guidance has always be an inspiration to me along this journey of education.

ABSTRACT

This thesis is present the development of Wireless Power Transfer (WPT) for electric vehicle charging by using a capacitive approach. Capacitive Power Transfer (CPT) system is the technology which uses a capacitive coupler as a medium for transferring the electrical energy from the transmitter side to the receiver side. This system getting popular among researchers nowadays due to the advantages of this system in addressing the problem faced by one of the most well-known systems in WPT technology which is Inductive Power Transfer (IPT) system. Basically, the purpose of this project is to develop a CPT system by implementing a Class-E inverter with the combination of the LCCL impedance matching network. The reason for using Class-E LCCL inverter is due to maximum power transfer and high efficiency. Therefore, the analysis had been conducted to observe the effect of the ZVS condition, the input power, the output power, and the efficiency of the CPT system with the variation of load and coupling gap. All the circuits and results have been verified through simulation and been validated through experimental with the parameter of 24Vdc input voltage, 10W input power, 1MHz operating frequency, 0.5 duty cycle, and 1mm distance coupling gap. Finally, all the result from the simulation and the experimental prototype for electric vehicle charging has been recorded.

ABSTRAK

Tesis ini membentangkan pembangunan Pemindahan Tenaga Tanpa Wayar (WPT) untuk pengecasan kenderaan elektrik dengan menggunakan pendekatan kapasitif. Pemindahan Kuasa Kapasitor (PKK) merupakan sistem yang menggunakan plat kapasitif sebagai medium penghantaran arus elektrik dari bahagian masukan ke bahagian keluaran litar. Sistem ini semakin terkenal dikalangan pengkaji. Pada dasarnya, tujuan projek ini adalah untuk membangunkan sistem PKK dengan melaksanakan litar penyongsang Kelas-E dengan gabungan rangkaian litar LCCL. Penggunaan litar Kelas-E ini adalah bertujuan untuk menghasilkan pemindahan kuasa dan tahap kecekapan yang maksimum. Oleh itu, analisis telah dijalankan untuk melihat kesan kecekapan sistem terhadap perubahan jarak antara dua plat kapasitif dan perubahan nilai beban. Semua litar dan hasil kajian telah disahkan melalui simulasi dan prototaip projek telah dihasilkan dengan parameter: voltan input 24Vdc, kuasa input 10W, kekerapan operasi 1MHz, 0.5 kitar tugas, dan jarak plat kapasitif 1mm. Akhirnya, keseluruhan hasil projek ini telah direkodkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	:	Alternating Current
APT	:	Acoustic Power Transfer
CPT	:	Capacitive Power transfer
DC	:	Direct Current
EMI	:	Electromagnetic Interference
IC	:	Integrated Circuit
IPT	:	Inductive Power Transfer
LED	:	Light Emitting Diode
MPT	:	Microwave Power Transfer
OPT	:	Optical Power Transfer
PCB	:	Printed Circuit Board
WPT	:	Wireless Power Transfer
ZVS	:	Zero Voltage Switching

CHAPTER 1

INTRODUCTION

1.1 Project Introduction

Wireless Power Transfer (WPT) technology introduced a process of transferring electric power from the transmitter part to the receiver part without connectors, wires, or metal-to-metal contact [1]. WPT technology is divided into several techniques which are Acoustic Power Transfer (APT), Optical Power Transfer (OPT), Microwave Power Transfer (MPT), Inductive Power Transfer (IPT), and Capacitive Power Transfer (CPT) [2].

The basic principle of the WPT system must consist of a primary side known as transmitter unit and secondary side also known as the receiver unit. Both the transmitter and receiver unit contains the resonant power converter. For the transmitter unit, the DC-to-AC converter used to converts DC into high frequency AC energy.

While in the receiver unit, the AC-to-DC converter used to convert back the high frequency AC energy to meet the desired load parameters. Most important to mention is the transmitter and receiver unit are not physically connect to each other. It connects wirelessly via power energy transfer.

Among all power transfer technique of the WPT system, inductive coupling is the most well-known technique due to high efficiency and high power capability. However, there has been an increasing interest in the development of the CPT system in recent years due to the advantages of the CPT system that can overcome the limitations of the inductive coupling. As mention before, inductive coupling is the most well-known technique for WPT system which the magnetic coupling between two coils seems to offer higher power transfer than CPT. However, IPT systems require a magnetic core in order to provide good coupling and in some cases shielding in order to prevent electromagnetic interference (EMI). Besides, in practical application, safety concerns regarding the field emissions, and overheating caused by eddy-current losses in nearby metal objects are also becoming limitations.

In order to overcome the IPT system limitations, the development of the CPT system become popular in recent years due to the advantages of the CPT system over IPT system. One bigger advantage of this technique is the capacitive have the ability of metal penetration and the potential to reduce EMI. Besides, it is low cost, low weight, and low eddy-current loss in nearby metals. CPT system also can be used in short distance and low power application such as USB and mobile device charging, biomedical devices, integrated circuits (IC), and LED lighting.

1.2 Problem Statement

The limitation of CPT system for low watt scale application are exhibit the limited output power and efficiency. The efficiency of the system will drop with the increasing coupling gap distance and load variation. In order to overcome this limitations, the development of class-E converter with the impedance matching network will be utilized.

1.3 Objective

The objectives of this project are:

1. To design a CPT system for electric vehicle charging application based on Class-E resonant inverter topology that can enhance the efficiency of the system by meeting the ZVS condition.
2. To optimize the efficiency of CPT system by using multistage impedance matching circuit that is capable of improving ZVS conditions that are less sensitive to the load and coupling variation.
3. To analyze the performance of the developed CPT system for electric vehicle charging based on ZVS conditions, input power, output power and efficiency.

1.4 Scope of Project

This project will focus primarily in wireless power transfer technology which is the development of lab scale prototype of Capacitive Power Transfer for electric vehicle charging with desired parameter of 24Vdc input power, 10W output power, 1MHz operating frequency, 50% duty cycle and more than 80% efficiency. On the other hand, this project will only involve on class-E inverter with LCCL impedance matching network. For performance evaluation, this project use MATLAB software

to run the simulation circuit. Finally for the prototype module, the capacitive coupler plate will be built using PCB in square shape.

1.5 Thesis Layout

This thesis consists of five chapters. Chapter 1 is about the project overview which is objectives of project, problem statement, scopes of project, methodology and report outlines. This chapter will briefly discussed which purposely to provide the reader an understanding of the project introduction.

Chapter 2 will discuss more on literature review on current approach and method in development of Capacitive Power Transfer system. This section also contains the limitations of the models through analysis of the applied methods and their performances from previous researchers.

Chapter 3 is about the design and methodology of the project. This chapter will explain the methods in details such as software implementation, model testing and performance evaluation.

Chapter 4 is about the observation, result and the analysis of the project. It will discusses briefly and show the student observation that gain during the development of this project. This chapter also consists of the recorded data analysis and the result of the project.

Chapter 5 will discuss the conclusions and recommendations for improvement for the further research.

CHAPTER 2

BACKGROUND STUDY

This chapter will discuss more on literature review on current approach and method in development of Capacitive Power Transfer system. In order to get more understanding about this project, a background study has been done by referring books, journals, and articles about this topic. This section also contains the limitations of the models through analysis of the applied methods and their performances from previous researchers.

2.1 Wireless Power Transfer Technology

Wireless power transfer (WPT) technology is a system which allow a power to be transfer between two or more physically unconnected electric circuits or devices. This system technology has developed an ability to supply electrical energy from transmitter to receiver side without using wires, connectors or without having metal

to metal contact [1], [2]. In other word, this system allowed a device to power up wirelessly. The basic structure of WPT system is shown in Figure 2.1.

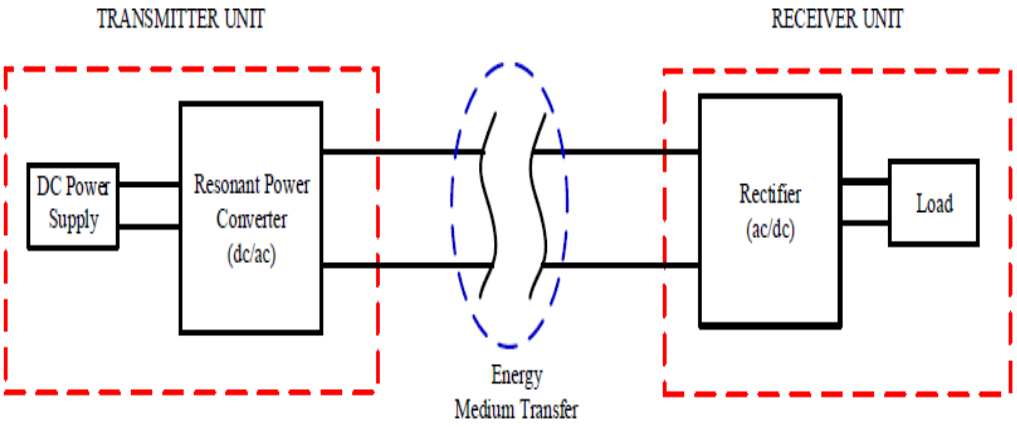

Figure 2.1 Block Diagram of WPT System [3]

WPT systems technology can be divided into several category as shown in Figure 2.2 which is acoustic power transfer (APT), optical power transfer (OPT), microwave power transfer (MPT), inductive power transfer (IPT), and capacitive power transfer (CPT). Every category of WPT system have their own advantage and disadvantage which are suitable for different applications.

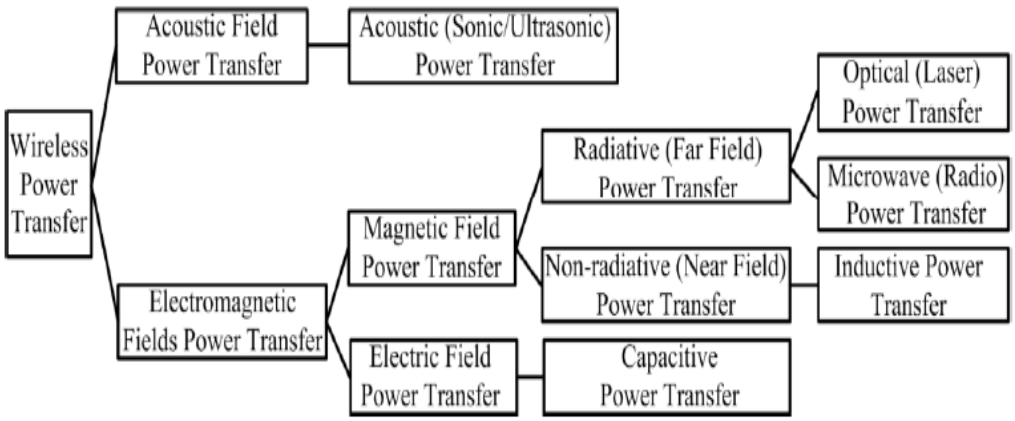

Figure 2.2 Category of Wireless Power Transfer Technology [2]