Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF 6.78 MHz CAPACITIVE WIRELESS POWER TRANSFER COUPLER FOR CHARGING SYSTEM

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Bachelor of Electronics Engineering Technology with Honours

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DEVELOPMENT OF 6.78 MHz CAPACITIVE WIRELESS POWER TRANSFER COUPLER FOR CHARGING SYSTEM

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A project report submitted
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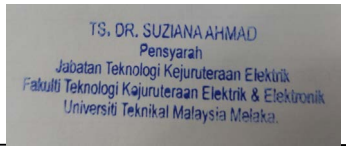

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DEDICATION

This project is dedicated to my family for always support me to achieve my dream and thank you for always be with me through this journey.

ABSTRACT

Capacitive Power Transfer (CPT) appears as an alternative to proliferating Inductive Wireless Power Transfer technology (IPT). It transfers power using high-frequency electric fields, which has three major benefits: little eddy-current loss, cheap cost and lightweight, and good misalignment performance. Because of its effectiveness and ease, wireless power transfer is becoming more popular nowadays. It's been used in consumer devices like cell phone charging and powering electric vehicles. In this study, we present a four plate arrangement with two shielding plate with operating frequency of 6.78 MHz. Besides, the objective of this project is to analyse coupler structure for 6.78 MHz capacitive wireless power transfer (CWPT) using LT Spice simulation circuit for charging system, to fabricate coupler structure for 6.78 MHz capacitive wireless power transfer using metal plate and to evaluate the performance of the fabricated coupler structure by using an experimental setup. Capacitive interfaces are useful for wireless charging stations because of their simplicity and inexpensive cost. Therefore, in this study, effort was paid to design capacitive wireless power transfer for charging systems. LT Spice software was used to create the model. After all components have been validated, they are integrated into a single subsystem and tested.

ABSTRAK

Pemindahan Kuasa Kapasitif (CPT) muncul sebagai alternatif kepada teknologi Pemindahan Kuasa Wayarles Induktif (IPT) yang semakin berkembang. Ia memindahkan kuasa menggunakan medan elektrik frekuensi tinggi, yang mempunyai tiga faedah utama: kehilangan arus pusar yang sedikit, kos yang murah dan ringan, dan prestasi penjajaran yang baik. Kerana keberkesanan dan kemudahannya, pemindahan kuasa tanpa wayar menjadi lebih popular pada masa kini. Ia telah digunakan dalam peranti pengguna seperti mengecas telefon bimbit dan menghidupkan kenderaan elektrik. Dalam kajian ini, kami membentangkan susunan empat plat dengan dua plat pelindung dengan frekuensi operasi 6.78 MHz. Selain itu, objektif projek ini adalah untuk menganalisis struktur pengganding untuk pemindahan kuasa wayarles kapasitif (CWPT) 6.78 MHz menggunakan litar simulasi LT Spice untuk sistem pengecasan, untuk membuat struktur pengganding bagi pemindahan kuasa tanpa wayar kapasitif 6.78 MHz menggunakan plat logam dan menilai prestasi daripada struktur pengganding yang direka dengan menggunakan persediaan eksperimen. Antara muka kapasitif berguna untuk stesen pengecasan wayarles kerana kesederhanaan dan kosnya yang murah. Oleh itu, dalam kajian ini, usaha telah dibayar untuk mereka bentuk pemindahan kuasa wayarles kapasitif untuk sistem pengecasan. Perisian LT Spice digunakan untuk mencipta model. Selepas semua komponen telah disahkan, ia disepadukan ke dalam satu subsistem dan diuji.

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LIST OF SYMBOLS

Ω	-	Ohm
ω	-	Omega
²	-	Power of two
µ	-	Micro
P	-	Pico
m	-	Mili

LIST OF ABBREVIATIONS

CPT	-	Capacitive power transfer
CCWPT	-	Capacitive coupler wireless power transfer
WPT	-	Wireless power transfer
IPT	-	Inductive power transfer
IWPT	-	Inductive wireless power transfer
S-CPT	-	Shielded capacitive power transfer
DC	-	Direct current
AC	-	Alternative current
FR4	-	Flame retardant
EMI	-	Electromagnetic interference
EF	-	Electric field
EFR	-	Electric field resonant
PWM	-	Pulse-width modulation
PCB	-	Printed circuit board
TLT	-	Transmission line transformer
ZVS	-	Zero voltage switching

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CHAPTER 1

INTRODUCTION

Background

In general, wireless power transmission using capacitive power transfer (CPT) is a promising technique. It works by transferring power through high frequency electric fields, also known as electrical resonance [1]. In recent years, a variety of circuit topologies have been devised to construct both short and long range CPT systems, as well as to stimulate practical applications. The system of capacitive wireless power transfer (CPT) for electric car charging applications uses the vehicle chassis and the earth's ground to transmit power, which can replace two plates in a typical four-plate CPT system [1]. As a result, this CPT approach only requires the usage of two external plates. Current can flow forward to the vehicle side through the coupling capacitance, while current returns through the capacitances between the chassis and the earth ground. The voltage on the vehicle chassis can be lowered by decreasing the switching frequency, coupler structure design, and compensating circuit design in a CPT system.

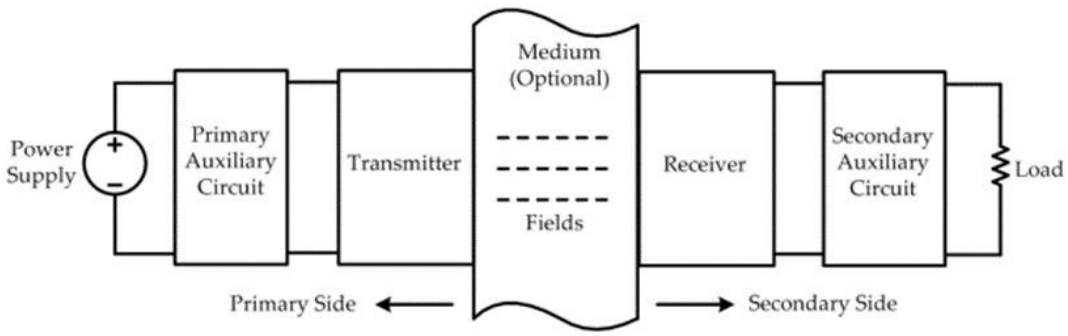

Figure 1.1 : Basic circuit of the wireless power trasnfer system (WPT).

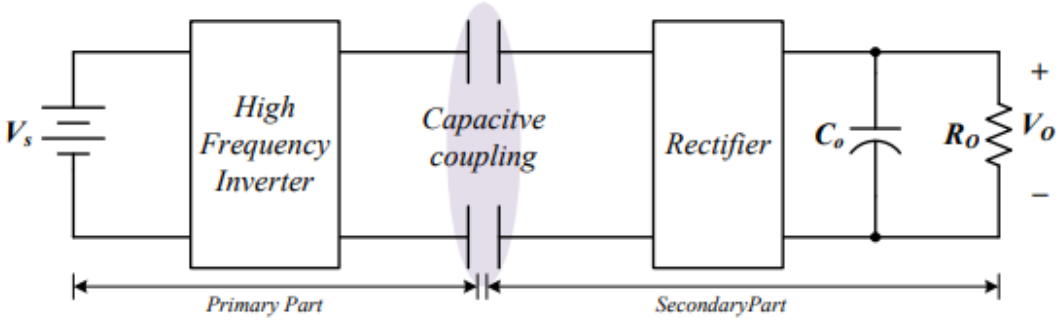

Figure 1.2 : The simple circuit for capacitive power transfer system (CPT).

The essential circuit of wireless power transfer is depicted in Figure 1.1. An auxiliary circuit is normally required on the main side to convert electric power into a form that can excite the transmitter device, which can then create the necessary fields and broadcast to the secondary side. Although a medium is not always necessary in the power transmission process, it typically improves system performance. The receiver device can transform the fields back into electricity and supply it to the load through a secondary auxiliary circuit. The basic circuit for a capacitive wireless power transfer system is shown in Figure 1.2. The two primary metal plates are powered by a high-frequency inverter, which transforms direct current (DC) electricity to alternating current (AC) voltage. The displacement current might travel through two secondary plates close to the structure because of the electric field. To obtain the DC output voltage, a rectifier can be employed. Energy transfer and system stability are both influenced by coupling capacitance. However, the capacitance that may be achieved is limited by the device's accessible surface. The high frequency AC voltage is generated using a series resonant power conversion circuit [2]. A simple full-bridge inverter is also used in other ways to induce series resonance between the inductor and coupling capacitor. If the resulting capacitance is small, the fundamental resonant circuit limits transmission.

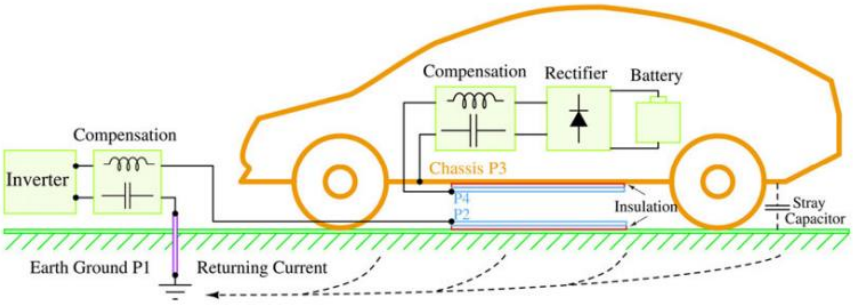

Figure 1.3 : CPT in electric vehicle with two plate structure.

Furthermore, based on Figure 1.3, it shows that an inverter is used to give ac simulation on the main side, followed by a compensation circuit. The transmitter is made up of an earth ground P1 and a metal plate P2, with an insulating layer between them. The current returning route is the parasitic capacitance between the vehicle chassis and the earth ground. To further decrease conductivity loss, the earth ground might be linked to a metal plate in practical situations. It's important to keep in mind that the ground-side plate is an option. It should have a good connection to the earth's ground if it is employed. It might be buried in the ground, for example, to maintain a good connection. If the ground connection is acceptable, the ground-side plate can be substantially smaller than the vehicle chassis. All parasitic displacement currents from the chassis to the earth ground will be aggregated on this ground-side plate and then flow back into the compensation circuit since the compensation circuit is directly linked to the ground-side plate.

Problem Statement

Currently in Malaysia, capacitive wireless power transfer is extremely beneficial for powering electrical equipment in situations where linking cables is difficult, dangerous, or impossible. Capacitive power transfer (CPT) has been extensively studied for use in charging mobile devices and electric cars. Magnetic resonance, inductive coupling, and

capacitive coupling are the three types of wireless power transfer [2]. The capacitive wireless power transfer system with a frequency of 6.78 MHz is proposed and analysed in this paper, and it is discovered to have many advantages, including a simple structure, low standing power loss, and the ability to transfer power through metal barriers.

On the other hand, the capacitive power transfer system operates at 6.78 MHz, which is the lowest frequency for MHz wireless power transfer in the industrial, scientific, and medical bands [2]. Because it has little or no influence on other allowed bands, the International Telecommunication Union Radio recommends adopting 6.78 MHz as the operational frequency [3]. As a result, 6.78 MHz operation can fulfil wireless standards while inhibiting other devices and assisting energy transmission via capacitive coupling wireless power transfer with a modest capacitance.

Project Objective

The project work has the following specific objectives:

a) To analyse coupler structure for 6.78 MHz capacitive wireless power transfer (CWPT) using LT Spice simulation circuit for charging system.

b) To fabricate coupler structure for 6.78 MHz capacitive wireless power transfer using metal plate.

c) To evaluate the performance of the fabricated coupler structure by using an experimental setup.

Scope of Project

The scopes of the project work are as follow:

a) This project focused on 6.78 MHz operating frequency capacitive wireless power transfer system.

b) This project is limited to modelling and simulation using LT Spice.

c) The metal plate are used for fabrication coupler structure and air core inductors are mode to complete the capacitive power transfer (CPT) model.

d) The experimental setup only includes the input voltage with the operating frequency of 6.78 MHz for the capacitive power transfer (CPT) model to determine the effectiveness of wireless transfer capabilities.

CHAPTER 2

LITERATURE REVIEW

Introduction

This chapter describes the overview of the project being undertaken and provides basic information to understand and to be clear about the project. It also explains the comparison between 1 MHz, 6.78 MHz, and 13.56 MHz capacitive wireless power transfer couplers for charging systems. Overall, this chapter concentrated on the related research for this project.

Research, Ideology and Concept Previous Project

2.1.1 Shielded Capacitive Power Transfer (S-CPT) without Secondary Side Inductors

Reiji Hattori, et al., proposed a wireless power transmission using shielding plate in capacitive power transfer to get stability in grounding connection. It also explained about a four-plate structure with two shielding plates and to produce shielded capacitive power transfer (S-CPT) at an operating frequency of 6.78 MHz for a 10W system. The parameters of the S-CPT system relating resonance and impedance matching were obtained using MATLAB software, and the suggested coupler structure was examined using electric field modelling. Besides, by analysing both simulation and hardware experiment data, the shield plate voltage stability was also evaluated. To confirm the analytical results and illustrate the voltage at the shield plate of the proposed coupler structure, a prototype of S-CPT was built. Furthermore, power is conveyed between plates in the CPT system through an electric field,

and this CPT technology has become a hot issue in various applications, including electric car charging systems, drones, and rotary operations [2].

In the capacitive power transfer (CPT), it consists of a DC supply, an inverter, a capacitive coupler, and a load. The AC supply is resonated with the CPT system's designated operating frequency using a resonant inverter, such as a class-E inverter. The coupler, which serves as an interface and transmits the electric field between the primary and secondary components, is an important part of the CPT system. According to the journal, it also established an S-CPT system with a class-E power amplifier with a 6.78 MHz operating frequency by removing the inductor on the secondary side. Figure 2.1 shows the design of a four-coupler structure with a shielding plate. The S-CPT system is shown in Figure 2.1a on a printed circuit board made of FR4 material with a thickness of 1.6 mm, and Figure 2.1b shows the shield plate and coupler plate stacked in parallel with air as the dielectric.

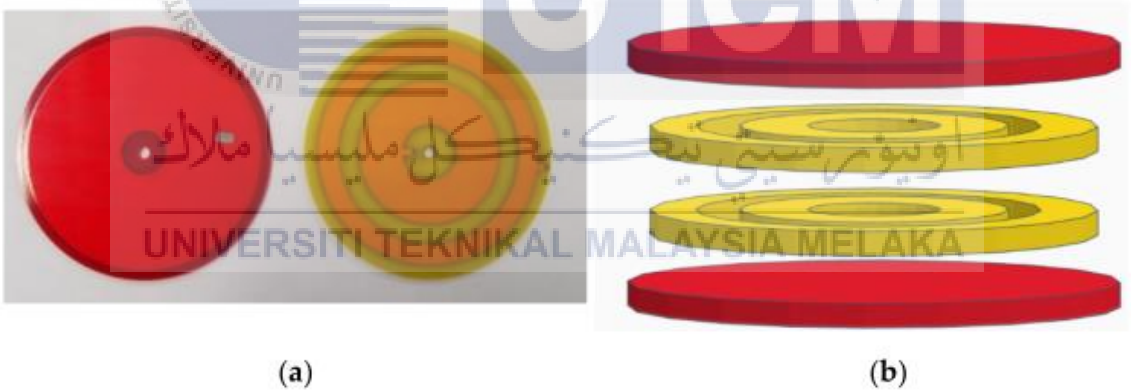

Figure 2.1 : Design of a four-coupler structure with a shielding plate. (a) Hardware for coupler fabrication. (b) Coupler arrangement.

2.1.2 6.78MHz Capacitive Coupling Wireless Power Transfer System

The research offers a journal for capacitive coupling wireless power transfer (CCWPT) system with 6.78 MHz class-D inverter with an LC low pass filter, capacitor between a transmitter and a receiver, and impedance transformers based on Kang Hyun Yi's