Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF 13.56 MHz CAPACITIVE WIRELESS POWER TRANSFER COUPLER FOR CHARGING SYSTEM

MUHAMAD FARIS MUQRI BIN MOHAMAD RASHIDAN

Bachelor of Electronics Engineering Technology with Honours

2022

DEVELOPMENT OF 13.56 MHz CAPACITIVE WIRELESS POWER TRANSFER COUPLER FOR CHARGING SYSTEM

MUHAMAD FARIS MUQRI BIN MOHAMAD RASHIDAN

A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours

Faculty of Electrical and Electronic Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek: **DEVELOPMENT OF 13.56 MHz CAPACITIVE WIRELESS POWER TRANSFER COUPLER FOR CHARGING SYSTEM**

Sesi Pengajian: **2022/2023**

Saya MUHAMAD FARIS MUQRI BIN MOHAMAD RASHIDAN mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

☐	**SULIT***	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD**	(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
✓	**TIDAK TERHAD**	

Disahkan oleh:

TS. DR. SUZIANA AHMAD
Pensyarah
Jabatan Teknologi Kejuruteraan Elektrik
Fakulti Teknologi Kejuruteraan Elektrik & Elektronik
Universiti Teknikal Malaysia Melaka

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

Alamat Tetap: NO. 1689, LORONG SELASIH ¼, TAMAN SELASIH 09000 KULIM KEDAH DARUL AMAN.

Tarikh: 27/01/2023 Tarikh: 30/01/2023

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this project report entitled "Development of 13.56 MHz Capacitive Wireless Power Transfer Coupler for Charging System" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Student Name : MUHAMAD FARIS MUQRI BIN MOHAMAD RASHIDAN

Date : 27/01/2023

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology with Honours.

Signature	:	
Supervisor Name	:	TS. DR. SUZIANA BINTI AHMAD
Date	:	30/01/2023
Signature	:	
Co-Supervisor Name (if any)	:	
Date	:	

DEDICATION

To my beloved mother, Saliza Binti Che Hasim, and father, Mohamad Rashidan Bin Man, who gave the little they had to ensure I would have the opportunity of an education. Their efforts and struggles have allowed me to have a key to unlock the mysteries of our worklines, and beyond.

ABSTRACT

This paper presents to investigate coupler structure for 13.56 MHz capacitive wireless power transfer (CWPT). This charging pad consists of a pair of power-transfer coupling plates, a metal sheet at the base that reduces the impact of nearby dissipative materials, and a dielectric layer in between. The impact of these structural components' dimensions on the system's performance is investigated, and tradeoffs between various options are examined. The design is supported by theoretical analysis and simulations, and a prototype 13.56-MHz 12- cm air-gap 500-W capacitive WPT system that uses these charging pads for power transfer has been experimentally tested. Fabrication process for PCB board will be conducted with the required components for the design process. The value of each components are estimated with solving equation part according to the requirement of the simulation circuit. Implementation in using software LTspice as common software in this project to get the output graph as expected results. The simulation circuit for the data components are defined from measured values with the NanoVNA. Experimental setup that involves voltage input sine wave at 13.56 MHz to test the functionality to transfer voltage from input to output.

ABSTRAK

Kertas kerja ini membentangkan untuk menyiasat struktur pengganding untuk pemindahan kuasa tanpa wayar kapasitif (CWPT) 13.56 MHz. Pad pengecas ini terdiri daripada sepasang plat gandingan pemindahan kuasa, kepingan logam di pangkalan yang mengurangkan kesan bahan pelesapan berdekatan dan lapisan dielektrik di antaranya. Kesan dimensi komponen struktur ini terhadap prestasi sistem telah disiasat, dan pertukaran antara pelbagai pilihan juga diperiksa. Reka bentuk ini disokong oleh analisis dan simulasi teori, dan prototaip 13.56-MHz 12-sm sistem WPT kapasitif 500-W jurang udara yang menggunakan pad pengecas ini untuk pemindahan kuasa telah diuji secara eksperimen yang dijalankan. Proses fabrikasi untuk papan PCB akan dijalankan dengan komponen yang diperlukan untuk proses reka bentuk. Nilai setiap komponen dianggarkan dengan menyelesaikan bahagian persamaan mengikut keperluan litar simulasi. Pelaksanaan dalam menggunakan perisian LTspice sebagai perisian biasa dalam projek ini untuk mendapatkan graf output seperti hasil yang diharapkan. Litar simulasi untuk komponen data ditakrifkan daripada nilai yang diukur dengan NanoVNA. Persediaan eksperimen yang melibatkan gelombang sinus input voltan pada 13.56 MHz untuk menguji kefungsian untuk memindahkan voltan daripada hasil masukan ‘input’ ke hasil pengeluaran ‘output’.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Ts. Dr. Suziana Binti Ahmad for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through providing the facilities and platform resources which enables me to accomplish the project. Not forgetting my fellow colleague for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents and family members for their love and prayer during the period of my study. An honourable mention also goes to Saliza Binti Che Hasim for all the motivation and understanding.

Finally, I would like to thank all the staffs at the Universiti Teknikal Malaysia Melaka (UTeM), fellow colleagues and classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

CC	-	Coupling capacitance
CP	-	Parasitic capacitance
Gi	-	Requisite gain
Xs	-	Nominal coupling reactance
Ω	-	Ohm
ω	-	Omega
^{2}	-	Power of two
μ	-	Micro
p	-	Pico
m	-	Mili

LIST OF ABBREVIATIONS

SMA	-	SubMiniature version A
WPT	-	Wireless Power Transfer
IPT	-	Inductive Power Transfer
CWPT	-	Capacitive Wireless Power Transfer
EV	-	Electric Vehicle
RF	-	Radio Frequency
CPT	-	Capacitive Power Transfer
FEA	-	Finite Element Analysis
EMI	-	Electromagnetic Interference
AVR	-	Active Variable Reactance
STIF	-	Semi-toroidal Interleaved Foil
VMS	-	Variable Message Sign
LC	-	Resonant circuit
CLLC	-	Resonant circuit
PCB	-	Printed circuit board
VNA	-	Vector network analyzer

LIST OF APPENDICES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Background

Capacitive Wireless Power Transfer (CWPT) means of delivering electricity between circuits without the need of wires. Inductive Power Transfer (IPT), which was developed over two decades ago, is the most well-known and fully investigated technique. The IPT technology, on the other hand, has significant disadvantages. From the current topology, high power factor can be overcome by high common mode source impedance in the system.

The operating frequency of inductive systems is further constrained by ferrites losses of large high frequency, which limits their size reduction potential. Capacitive WPT systems are less expensive, smaller, and simpler to install in the roadway. Because ferrites are not present, lowering the size and boosting the efficiency may operate at high frequency without incurring significant losses in the system.

This study shows how to make capacitive WPT device charging pads in an innovative way. In power transmission, this charging pad is made up of two coupling plates. In example, the metal sheet is on the bottom to reduce the dissipative materials impact. A large airgap was described in a high-performance of capacitive wireless power transfer (WPT) for charging EV in this research. By using appropriately built inductor 2 with a coupling lower capacitor matching network, as well as a high switching frequency at 13.56 MHz and a high switching efficiency.

1.2 Problem Statement

The issue of radio frequency (RF) exposure and wireless power transmission has risen at relevance as on number of consumer electronic gadgets grows. Finally, wireless charging provides near field coupling magnetic and energy transfer of far field RF was entirely safe. The RF exposure standards for these goods must be followed in your area. Used of the electromagnetic frequency and wireless power transfer will limit the quantity of power that sent safely.

Even though, the wireless power transfer idea has been successfully explored and used in industrial applications, it is still in its early stages in the transportation sector. Another severe issue with the existing electric vehicle plug-in cable is the risk of electrocution if the cable system is destroyed. Wireless charging may escape this calamity since it doesn't need any cables or connections and the energy is provided electromagnetically.

The disadvantages of wireless power transmission systems include high initial construction costs, the avoidance of air ionisation, distance constraints, the necessity for a high-frequency supply, and field strength should be kept to a minimum. The effectiveness of the CPT system has been seen to decrease as the coupling gap lengths increase. Furthermore, high efficiency can be achieved only when the coupling gap is 3 closed. To decrease the capacitance shift caused by the flatness flaw, the connecting plates must also be secured together.

1.3 Project Objective

This chapter contains a detailed overview of project objectives:

a) To apply coupler structure for 13.56 MHz capacitive wireless power transfer (CWPT) using LTspice simulation circuit for charging system.

b) To implement 13.56 MHz capacitive wireless power transfer (CWPT) coupler structure using metal plate.

c) To evaluate the performance on matching impedance of 13.56 MHz capacitive wireless power transfer (CWPT) using experimental setup.

1.4 Scope of Project

The following are the details of the project' scope:

a) This research focused on a 13.56 MHz high-performance capacitive wireless power transfer (CWPT) system.

b) For modelling and the simulation process of this project using LTspice.

c) Capacitance coupler and inductor construction to complete capacitance coupler structure model.

d) Experimental setup that involves voltage input sine wave at 13.56 MHz to test the functionality to transfer voltage from input to output.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An overview is provided in this chapter for project as well as key details that will help you completely comprehend how it works. It also compares Capacitive Wireless Power Transfer (CWPT) couplers for charging systems at 1 MHz, 6.78 MHz, or 13.56 MHz. Research linked with the project was the emphasis of this chapter.

2.2 Research and Concept of Previous Project

2.2.1 A Large Air-Gap Multi-MHz Capacitive Wireless Power Transfer System Using Compact Charging Pads

This journal provides a unique description of a huge airgap multi MHz system of capacitive WPT with charging pads for small devices. Dissipative substances nearby have an influence and dielectric layer in between of the charging pad is made up of a pair of transmission power at coupling plates to reduce the metal sheet. WPT systems have the potential to boost EV adoption by enables stationary, semi dynamic, or dynamic charging, may help to cost-cutting, time of charging, and range limit [1]. Electric was transfer from the roadway to vehicle, either electric fields between capacitively connected plates or magnetic flux between coupled coils. Ferrites, which are pricy, thick, and fragile, are required for flux steering in inductive WPT systems (and hence difficult to implant in the highway). Massive high-frequency ferrites losses further restrict the frequency of operation in inductive systems, limiting their size reduction potential. Capacitive WPT systems should not need ferrites on either side, making them cost-effective, not heavy, and easy to install on the road. Because ferrites aren't present, these systems may operate at high frequency with incurring significant loss, reducing the size and perhaps enhancing the efficiency.

Figure 2.1 has shown the system of capacitive WPT in EV charging construction The clearance of an electric vehicle on the ground has separate the coupling plates for this approach.

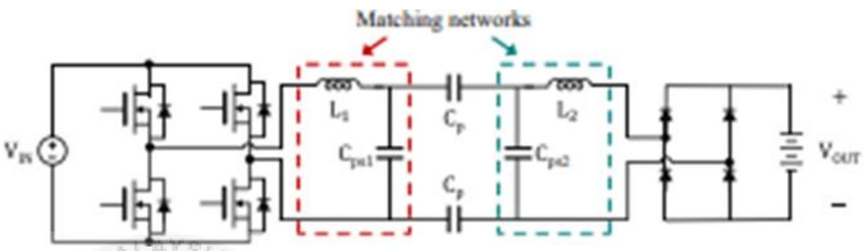

Figure 2.1 WPT system using single stage L-section networks that match.

An inverter is used to convert dc voltage into higher frequency ac voltage, which is step up the system from L-section networks that match. Because of the higher voltage between the plates for coupling at side of the roadway, higher amounts of power may be transmitted through the airgap with minimum displacement current, resulting in modest fringing fields. The networks that match for vehicle side steps up the current displacement to the required level EV battery charging. By making the inverter's impedance resistive, the networks that match completely compensate in the reactance of capacitive couplers, decreasing circulating currents and lowering circulating currents. For this system, the charging process was used by the parasitic capacitances to construct the network capacitances that match in improving the reliability and efficiency.