Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF 6.78MHz CAPACITIVE WIRELESS POWER TRANSFER WITH ELECTRIC FIELD REDUCTION

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Bachelor of Electronics Engineering Technology with Honours

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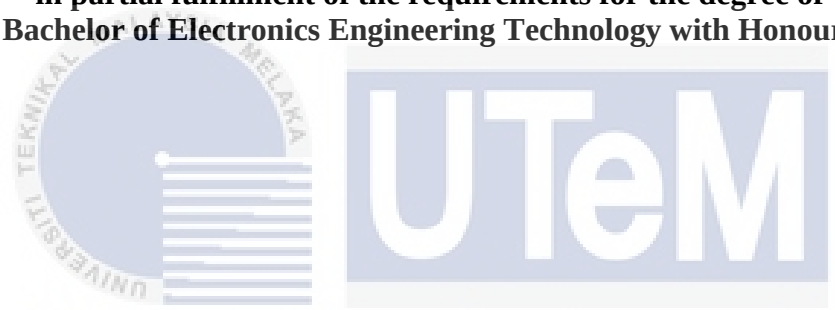
DEVELOPMENT OF 6.78MHz CAPACITIVE WIRELESS POWER TRANSFER WITH ELECTRIC FIELD REDUCTION

NURUL NADHIRAH BINTI MOHD RAZIB

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



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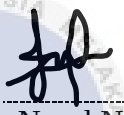
Signature : 

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DEDICATION

I dedicated this project analysis to my family, especially my parents, who have supported me since day 1.

ABSTRACT

This paper proposes a method to reduce an electric field emission of shielded capacitive power transfer (S-CPT) at an operating frequency of 6.78 MHz by utilizing different types of dielectric materials. FEA analysis was conducted to analyze which dielectric materials had the most significant effect on reducing electric field emissions. Specifically, air, mineral oil, paper, FR4, halowax, rubber and glass are the materials used in this proposed project. Those dielectrics were placed in between the coupler and the shielded plate. It also summarizes theoretical research in capacitive coupler structure. In addition, it illustrates the essential operating concept of the capacitive power transfer (CPT) system, including the CPT technology in several fields, such as medical devices, communication consumers, and transportation. The S-CPT system's impedance matching parameters were determined through analysis using the LTspice software. The experimental findings are demonstrated to show the effectiveness of the proposed solution.

Keywords: Capacitive wireless power transfer (CPT), shielded capacitive wireless power transfer (S-CPT), electric field emission, dielectric materials.

ABSTRAK

Kertas kerja ini mencadangkan kaedah untuk mengurangkan pelepasan medan elektrik pemindahan kuasa kapasitif terlindung (S-CPT) pada frekuensi operasi 6.78 MHz dengan menggunakan pelbagai jenis bahan dielektrik dan mengubah struktur plat, seperti ketebalan plat, jarak. dan panjang. Analisis FEA telah dijalankan untuk menganalisis faktor dan bahan dielektrik yang mempunyai kesan paling ketara dalam mengurangkan pelepasan medan elektrik. Secara khusus, udara, minyak mineral, kertas, FR4, lilin, getah dan kaca adalah bahan yang digunakan dalam projek yang dicadangkan ini. Dielektrik tersebut diletakkan di antara pengganding dan plat terlindung. Ia juga meringkaskan penyelidikan teori dalam struktur pengganding kapasitif. Selain itu, ia menggambarkan konsep operasi penting sistem pemindahan kuasa wayarles kapasitif (CPT), termasuk teknologi CPT dalam beberapa bidang, seperti peranti perubatan, pengguna komunikasi dan pengangkutan. Parameter padanan resonans dan impedans sistem S-CPT ditentukan melalui analisis menggunakan perisian LTspice dan QuickField. Penemuan eksperimen ditunjukkan untuk menunjukkan keberkesanan penyelesaian yang dicadangkan.

Kata kunci: Pemindahan kuasa tanpawayar (WPT), pemindahan wayar kapasitif (CPT), penghasilan medan elektrik, pengganding kapasitif enam plat, bahan dielektrik.

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LIST OF SYMBOLS

Ω	-	Ohm
μ	-	Micro
E	-	Permittivity
ω	-	Omega
π	-	Phi

LIST OF ABBREVIATIONS

V	-	Voltage
OPSAC	-	One pulse switching active capacitor
A	-	Ampere
m	-	Meter
kW	-	kiloWatt
MHz	-	Megahertz
CPT	-	Capacitive power transfer
S-CPT	-	Shielded capacitive power transfer
IPT	-	Inductive power transfer
WPT	-	Wireless power transfer
EV	-	Electric vehicle
EMI	-	Electromagnetic interference
EF	-	Electric field
PWM	-	Pulse width modulation
AC	-	Alternating current
DC	-	Direct current

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CHAPTER 1

INTRODUCTION

1.1 Background

In the early 20th century, Nikola Tesla attempted to transfer power using a wireless device. For the convenience of flexible movement, wireless mechanisms have been adopted by many systems, such as gadgets, machines, and many more [1]. However, there has recently been a surge in interest in using wireless power transfer (WPT) as an alternate power source. Adopting a WPT mechanism offers greater flexibility, such as the ability to charge an electrical device while moving.

WPT is a system that allows power to be transferred between two or more devices that are not physically linked. This cutting-edge technology has opened new options for supplying electrical energy to related devices by eliminating wires and connectors. WPT is ideal for various applications due to the following benefits [1], [2]:

i. In an electrically hazardous environment, electrical connections can result in dangerous sparking and shocks. Because there would be no physical touch between the power supply and the gadget, these issues can be avoided by employing a wireless mechanism.

ii. The wireless mechanism provides for more flexible and unrestricted robot movement in the production line.

iii. Medical implants (such as pacemakers) can be charged using WPT without the need for a dangerous medical procedure to replace the batteries.

iv. Avoiding the use of unsecured wires and connectors during the charging process and battery replacement. Such occurrences may cause a moveable or portable equipment that is charged using normal electrical connections to malfunction.

The inductive power transfer (IPT) approach is the most widely used way of achieving wireless power transmission. It has been used with magnetic solutions for decades. Due to the limits of the IPT approach, the researchers seek to explore new boundaries of capacitive wireless power transfer (CPT), which is also part of WPT technology.

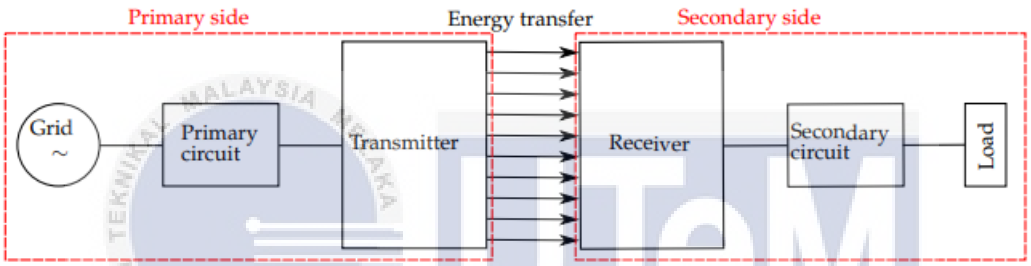

Figure 1.1 Structure of a WPT system in general.

Figure 1.1 shows that on the primary side, an auxiliary network is generally intended toconvert the electrical energy into a condition that can stimulate the transmitter equipment, generating the necessary fields and transmitting it to the secondary side. Although the existence of a medium is not always essential in the power transmission process, it usually helps to improve system performance. The fields can be converted back into electric power by the receiver deviceand delivered to the load via an auxiliary circuit on the secondary side.

Modern WPT systems can be classified into a few categories as shown in the figure below. But the focus of this paper will be on CPT.

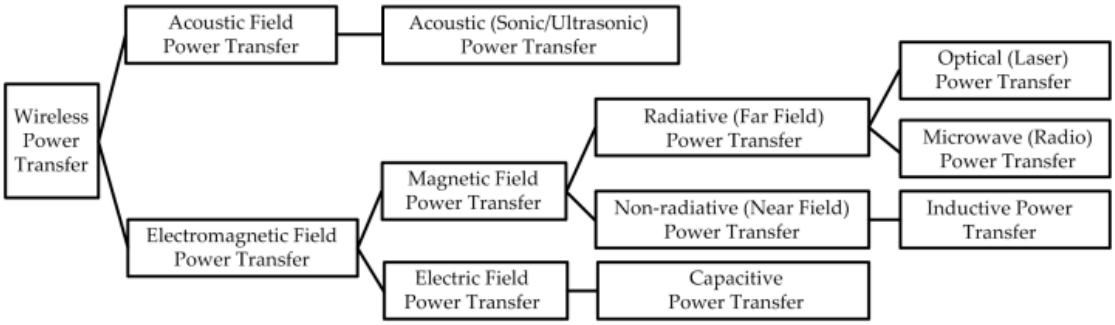

Figure 1.2 Category of a WPT system.

1.2 Problem Statement

Despite the rapid development of CPT structures over the years, several critical issues still need to be studied further before they can implement the technology in real life, such as safety concerns. In WPT technology, safety is always a big worry; and it turns out to be a severe issue in actual applications. Despite the effectiveness of the CPT system in transferring electricity over a long distance, the procedure must be adequately safe enough for the public to employ.

Excessive emissions of electric fields into the surrounding became the main focus of this paper.The electric field emission is supposed to be low and stay within its safe limit. This is because too much exposure to the electric field can harm humans who use CPT system-based devices. For instance, the level of electric field exposure in applications like biomedical and high power electric vehicle (EV) charging need to be considered thoroughly since it can affect the human body, such as the brain and heart, which can lead to severe illness and other major health problems [3].

Hence, the development of S-CPT architecture model with electric field reduction is proposed in order to overcome this matter.

1.3 Project Objective

The main aim of this project is to propose a systematic and effective methodology to estimate the purpose of the study can be achieved. Specifically, the objectives are as follows:

i. To analyze the performance on resonant and matching impedance of S-CPT model at 6.78MHz on LTSpice software.

ii. To investigate S-CPT model coupler structure with electric field reduction by using various dielectric materials on Quickfield software.

iii. To recommend the S-CPT model coupler structure with electric field reduction by comparing the electric field emission produced by seven dielectric materials used.

1.4 Scope of Project

To avoid any uncertainty of this project due to some limitations and constraints, the scope of the project are defined as follows:

i. This project is limited to modelling and simulation of S-CPT model at 6.78MHz using LTSpice software.

ii. This project is restricted to modelling and simulation of S-CPT model coupler structure utilizing QuickField software.

iii. The models that were developed cover the seven types of medium to minimize the electric field emission.

iv. This project only covered the study of the S-CPT coupler structure to become a system that emits a low electric field and is safe for users to use in the long term.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a section of a report that focuses on the journals, articles, and books that earlier research works have cited and the primary topics that the author concentrated on. The title, abstract, introduction, conclusion, and entire text simplify the data. All information that focuses on the same or different objectives is compared, which helps to improve the project's outcome.

2.2 Background of CPT

2.2.1 History of CPT

Transferring electricity without wires has been a significant scientific issue during the past century. Compared to wired approaches, WPT can offer convenience and security. Several WPT methods, including CPT, IPT, and Energy Wireless Power Transfer Harvesting, have been developed. IPT and CPT are typically employed over short distances, while RF and Microwave generally are applied over greater distances. These WPT techniques are used in various contemporary research fields, including consumer electronics, transportation electrification, and biomedical implants, among others.

IPT is currently favored for short distance WPT due to low frequency and high power density demand while CPT has traditionally been utilized in low-power applications to transfer power over a short distance.