DEVELOPMENT OF CAPACITIVE POWER TRANSFER FOR ROTARY APPLICATIONS

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : DEVELOPMENT OF CAPACITIVE POWER TRANSFER FOR ROTARY APPLICATIONS

Sesi Pengajian : 2017/2018

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I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : …………………………………

Supervisor Name : PROF. MADYA DR. MOHD SHAKIR BIN MD SAAT

Date : 1 JUNE 2018

DEDICATION

To Allah and everyone who contributes towards this journey especially my parents.

ABSTRACT

Wireless power transfer (WPT), through the transmission of contactless energy, is not only being used for charging batteries in mobile devices, but it is also being increasingly used in the field of industrial applications. WPT by using capacitive approach (CPT) is introduced to enhance the convenience to the user. The proposed technique eliminates the use of connecting wire. A 10Watt wireless rotary CPT system is developed for applications having rotating parts such as a robot arm. To be specific, the capacitive based approach is utilized in this work because of its ability to transmit power through metal and in a metal surrounding environment where the inductive-based approach failed to perform. The project focuses on the coupling study of a rotary CPT application where the power supply is stationary while the load rotates and therefore allows the load to rotate 360 degrees free rotation. The Class E MOSFET power inverter is used in this project due to its ability to achieve high efficiency compared to other class of converters at high frequency. The prototype of the CPT for rotary application has also been successfully developed with disk plate thickness of 1mm-2mm. Overall, the developed CPT system for rotary application is able to deliver 5.5Watt with 83.33% efficiency. To enhance the power efficiency and ZVS conditions, a self-tuning circuit using phased-locked-loop has been proposed in this project. The efficiency of the simulation Class E without the self-tuning circuit is 96.83%. After the self-tuning circuit is added to transmitter part, the efficiency of the simulation is increased to 97%.

ABSTRAK

Pemindahan kuasa tanpa wayar (WPT), melalui penghantaran tenaga tanpa hubungan, tidak hanya digunakan untuk mengecas bateri dalam peranti mudah alih, tetapi juga semakin banyak digunakan dalam bidang aplikasi perindustrian. WPT dengan menggunakan pendekatan kapasitif (CPT) diperkenalkan untuk meningkatkan kemudahan kepada pengguna. Teknik yang dicadangkan menghapuskan penggunaan wayar penyambung. Sistem CPT berputar tanpa wayar 10Watt dibangunkan untuk aplikasi yang mempunyai bahagian berputar seperti lengan robot. Untuk lebih spesifik, pendekatan berasaskan kapasitif digunakan dalam kerja ini kerana keupayaannya untuk menghantar kuasa melalui logam dan dalam persekitaran sekeliling logam di mana pendekatan berasaskan induktif gagal dilaksanakan. Projek ini fokus kepada kajian gandingan aplikasi rotary CPT 10W di mana bekalan kuasa tidak bergerak sementara beban berputar dan dengan itu membolehkan beban berputar 360 darjah putaran bebas Penukar kuasa kelas E MOSFET digunakan dalam projek ini kerana keupayaannya untuk mencapai kecekapan tinggi berbanding kelas penukar lain pada frekuensi tinggi. Prototaip CPT untuk aplikasi berputar juga telah berjaya dibangunkan dengan ketebalan plat cakera 1mm-2mm. Secara keseluruhannya, sistem CPT yang dibangunkan untuk aplikasi berputar mampu menghasilkan 5.5Watt dengan kecekapan 83.33%. Untuk meningkatkan kecekapan kuasa dan keadaan ZVS, litar penalaan diri menggunakan gelung berkunci berperingkat telah dicadangkan dalam projek ini. Kecekapan simulasi Kelas E tanpa litar penalaan diri adalah 96.83%. Selepas litar penalaan diri ditambah kepada bahagian pemancar, kecekapan simulasi ditingkatkan kepada 97%.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my special thank and sincere gratitude to my project supervisor, Prof. Madya Dr. Mohd Shakir Bin Md Saat, for giving me an opportunity to exposed in this project, and also the moral supports and advises given throughout this project. I would also like to thank to Phd. students and Master students under Dr. Shakir who have lent their hands in assisting to complete the project.

Secondly, I would like to thank my beloved family members who always giving actuation and moral support to me throughout the whole studying life in UTeM and in this project.

The last but not least, I would also like to express my appreciation to all the technician, friends and all individuals that helped me throughout this Bachelor Degree Project 1 & 2 (PSM 1 & 2), which I have not mention their name. Without all of you, this project will not be finished successfully.

Thank you very much.

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LIST OF SYMBOLS AND ABBREVIATIONS

WPT	:	Wireless Power Transfer
IPT	:	Inductive Power Transfer
CPT	:	Capacitive Power Transfer
APT	:	Acoustic Power Transfer
MPT	:	Microwave Power Transfer
LPT	:	Light Power Transfer
ZVS	:	Zero Voltage Switching
DC	:	Direct Current
MOSFET	:	Metal Oxide Semiconductor Field Effect Transistor
PLL	:	Phase Locked-Loop
PWM	:	Pulse Width Modulation
IC	:	Integrated Circuit
UTeM	:	Universiti Teknikal Malaysia Melaka

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter will briefly introduce the concept of wireless power transmission (WPT) for rotary applications using capacitive approach. The project background, project objectives, problem statement of the project, scope of work and the structure of report will also be included.

1.1 Project Background

Nowadays, wireless power transfer (WPT) technology has turned out to be one of the top research fields for its reliable applicability especially in low power applications such as phones charger, smart card system, high power electric vehicles (EV), and biomedical devices [1]. WPT is the transmission of electricity or energy from a power source to an electrical load without the connecting wire, across an air gap [1]. WPT system would completely eliminate 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 technology plants on a worldwide scale [3]. The advantages of WPT on cable elimination and maintenance-free operation are helpful especially for rotary applications to power up aside common electronic devices that we use every day [5].

The classification of WPT is divided into two categories that are near-field WPT and far-field WPT. Moreover, the near-field technique can be divided into three sections namely as inductive power transfer (IPT), acoustic power transfer (APT) and capacitive power transfer (CPT) [2]. In near-field power transfer, the IPT is using a coil that will produce the magnetic field to transfer power while CPT is using the capacitive plate that will produce an electric field to transfer power. Next, APT is using sound waves to wirelessly convey energy [2].

Nowadays, IPT is currently the most famous way to recognize wireless power transfer as shown in Figure 1.1. While IPT is a successful technique to transfer large power without metal contact, it has few disadvantages, such as magnetic field cannot pierce through metals [7]. For this project is more focuses on CPT system as shown in Figure 1.2 because due to many advantages. CPT system is a potentially convenient method based on the coupling capacitor approach, with the use of capacitor plate to come out with better EMI [3]. This CPT method is utilizing electric field rather than magnetic field used for the inductive approach which prone to misalignment disadvantages and the fact that it is unable to penetrate metal shielding as it will induce the eddy current in metal [25]. Since capacitive power transfer used the electric field coupling, it has been the key part for the new improved method to achieve non-contact power transfer and gives greater effects onto the frequency, output power, and power efficiency of the system. This method can be the solution for drawback of the IPT system [2].

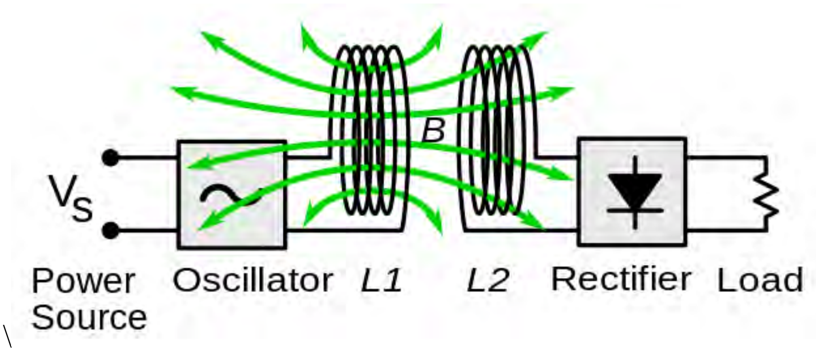

Figure 1.1: Basic Diagram of Inductive Power Transfer

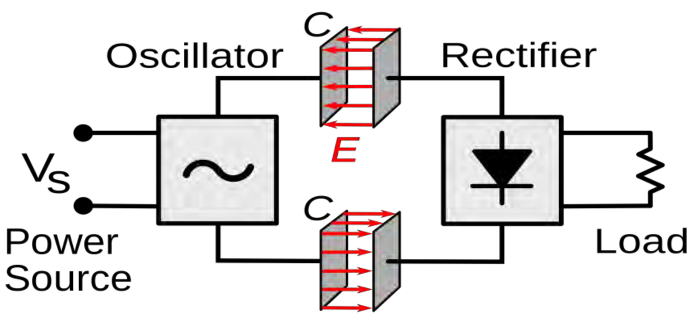

Figure 1.2: Basic Diagram of Capacitive Power Transfer

Wireless power transfer (WPT), through the transmission of contactless energy, is not only being used for charging batteries in mobile devices, but it is also being increasingly used in the field of industrial applications. WPT by using capacitive approach (CPT) is introduced to enhance the convenience to the user. The proposed technique eliminates the use of connecting wire. A 10W wireless rotary CPT system is developed for applications having rotating parts such as a robot arm.