INVESTIGATION OF COMPENSATION NETWORK DESIGN FOR CLASS E INVERTER IN ULTRASONIC TRANSDUCER APPLICATION

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DEDICATION

This humble work is dedicated to my family, parents and friends.

ABSTRACT

This paper discussed on the emerging engineering technologies which involved in wireless power transfer system (WPT). Unlike from the existing WPT system which are inductive power transfer (IPT) and capacitive power transfer (CPT), the new alternative technique is proposed named as acoustic power transfer (APT). The APT system utilizes the vibration or sound waves propagation to transfer the power from transmitter unit to receiver unit. The compensation network design will be incorporate with ultrasonic transducer to generate the acoustic wave which electromagnetic free for the low power application. The project focus on analysis on power conversion performance in Class E ZVS inverter at transmitter unit and the suitable circuit designed in impedance matching to overcome the impedance variation. Furthermore, this paper also includes on previous study proven that the APT system had several advantages compare to IPT and CPT. Moreover, there are further explanation on WPT techniques and theory related to circuit design. Next, the methodology that being used in process and explanation the overall result regarding to the simulation and experimental conduct are also included. Lastly, the conclusion and recommendation for further development is suggested.

ABSTRAK

Laporan ini membincangkan tentang teknologi kejuruteraan baru yang melibatkan sistem permindahan kuasa tanpa wayar (WPT). Berbeza dengan sistem WPT yang sedia ada iaitu permindahan kuasa inducktif (IPT) dan permindahan kuasa kapasitif (CPT), alternatif baru diperkenalkan dikenali sebagai pemindahan kuasa akustik (APT). Sistem APT menggunakan getaran atau gelombang bunyi sebagai perambatan untuk memindahkan kuasa dari unit pemancar ke untuk unit penerima. Rangkaian litar akan melibatkan ultrasonik transducer untuk menghasilkan gelombang akustik yang mana bebas electromagnet untuk aplikasi pengunaan kuasa rendah. Projek ini memfokuskan analisis keatas prestasi pertukaran kuasa pada penyongsang Class E ZVS pada unit pemancar dan reka bentuk litar yang ideal untuk kesesuaian impedans to mengatasi variasi impedans. Selanjutnya, laporan ini juga merangkumi tentang kajian terdahulu yang membuktikan bahawa sistem APT mempunyai kelebihan berbanding IPT dan CPT. Tambahan lagi, terdapat penjelasan yang lebih lanjut mengenai teknik-teknik dalam WPT dan teori yang berkaitan dengan reka bentuk litar. Seterusnya, metodologi yang digunakan dalam proses dan penjelasan tentang keseluruhan keputusan mengenai simulasi dan kajian yang dijalankan juga

disertakan. Yang terakhir, kesimpulan dan cadangan untuk pembangunan selanjutnya juga dicadangkan.

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WPT	:	Wireless power transfer
APT	:	Acoustic power transfer
IPT	:	Inductive power transfer
CPT	:	Capacitive power transfer
ZVS	:	Zero voltage switching
ZCS	:	Zero current switching
AC	:	Alternating current
DC	:	Direct current
PCB	:	Printed circuit board
UV	:	Ultra-violet
PWM	:	Pulse width modulation
PZT	:	Piezoelectric device
Ω	:	Ohm
ω	:	Omega
Lf	:	Choke inductor
Cp	:	Shunt capacitor

CHAPTER 1

INTRODUCTION

1.1 Background of Project

In beginning of the technology, every machine, electrical equipment and many other devices needs power to do the job. This has proven the power transfer play a major part in powering the devices. However, there are limitation of these old methods which one of limit is they are bounded to transfer the power using cable or wire. It is undeniable that power transfer via wire much more direct and the possibility of power loss is very low. Unfortunately, not every application wherever use of wire is guarantee of convenient and safe. Thus, the industry needs different approach to replace wired power transfer. Because of that, the idea of wireless power transfer (WPT) is suggested as the alternative way to be explored, where the electrical energy is transferred contactless without use of wire. Thus, the development and study on wireless power transfer of which involve of Inductive Power Transfer (IPT) that utilizes magnetic coupling, Capacitive Power Transfer

(CPT) which use of electrical field coupling in capacitive plate and also using sound wave or vibration generate by ultrasonic transducer in Acoustic Power Transfer (APT) . As now in world market, IPT and CPT technology are already widely commercialized in devices and application for instance in gadget technology. Compared to APT which is a new concept of wireless power transfer which possesses the difference which can improve the power transfer in future. Although APT is still under a research, the results from experimental project in past have already proven that APT can exceed the limit of IPT and CPT.

APT is a technology that uses sound waves or vibrations to transfer energy wirelessly instead use of electromagnetic fields like CPT and IPT. As far as the principle of APT concerned, there are no restriction on medium type and condition when involve an APT system. Power can be transmitted through metal wall which overcoming the major drawback of IPT, under the water, in open air as well as in living human tissue. For an APT system, the miniaturization concept is possible as the separate between the transmitter unit and receiver unit of transducers can be a few orders larger than the measurement of the transducers for a given directionality of the transmitter. In addition, an APT system is electromagnetic-free and in a long distance of power transmission with high consistency, APT is better option compared to others.

In Figure 1.1, an APT system consists of a primary unit that generates a high voltage sinusoidal waveform to drive the primary ultrasonic transducer. The primary ultrasonic transducer will convert the electrical energy into a mechanical acoustic wave known as sound wave for the power propagation. Then, the generated sound wave propagates through a small gap medium. Next, at pickup unit, the pickup ultrasonic transducer converts back the mechanical energy into electrical energy. Then, the DC power at the receiver unit can be supplied to power up the load.

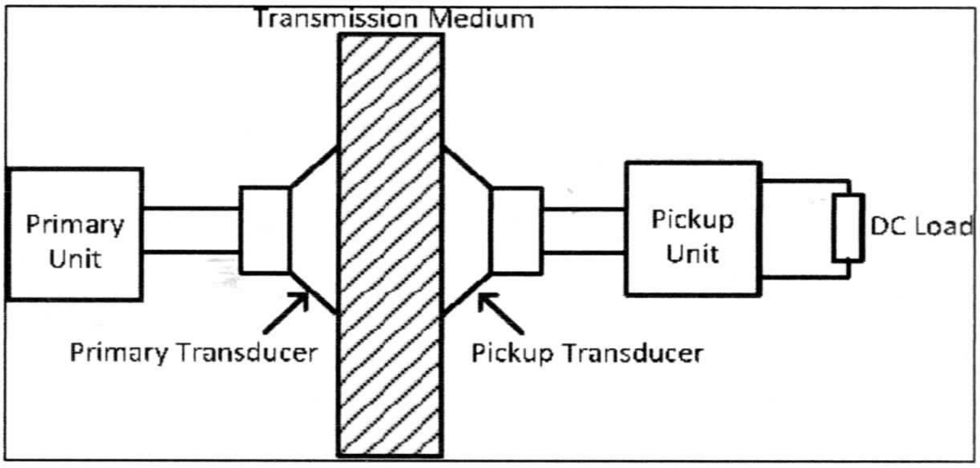

Figure 1.1: Basic ideal diagram of acoustic power transfer

1.2 Problem Statement

Acoustic power transfer (APT) is an alternative approach to the wireless transfer of energy which used the sound wave or vibration to transmit the power. However, there are few problems that may face by an APT system network design that will cause downside in APT performance. Firstly, an imprecise circuit design for Class E ZVS inverter in the transmitter unit which lead to low efficiency of power conversion. This is because during the conversion of electrical energy from DC to AC, there is switching loss happened along the way of conversion, so if this issue does not taken care of it will affect the entire of APT system performance. At the end of this, the output power system will not meet the expected value, where the condition of zero voltages switching (ZVS) is fails to achieve. Next, the integration between Class E ZVS inverter and ultrasonic transducer in transmitter unit will cause impedance variation in the network design. This because the Class E ZVS inverter work ideally in purely resistive, but when Class E ZVS inverter is combined with ultrasonic transducer, the impedance will be no longer in a simple network or can be say a impedance variation (complex impedance) for Class E ZVS inverter which can resulting in power loss and lead to low efficiency of power conversion in the transmitter unit.

1.3 Objectives

1. To construct a suitable network design for Class E ZVS inverter in order to improve the efficiency of the power conversion in acoustic power transfer (APT) system.
2. To investigate the most relevant impedance matching to overcome the impedance variation.

1.4 Scope of Project

1. This project will focus on power conversion and power transfer by using APT to achieve wireless power transfer using 40 kHz operating frequency.
2. The analyzation will be covered on the compensation networks to determine the most suitable impedance matching design to stabilize the impedance variations.
3. The Class E ZVS inverter model for power conversion will be design and evaluated.

4. All the schematic design and simulation will be used MATLAB via Simulink and Proteus 8 Professional.
5. Evaluation and analyze mainly cover on the zero voltage switching (ZVS), power input, power output and the efficiency of the APT system

1.5 Thesis Outline

This project report consists of five chapters that briefly discuss on the concept of the project and all the activities in achieving the objectives of this project. The structure of the report is arranged as below:

- Chapter 2 provides an overview of wireless power transmission systems and background study. Besides, the previous study and works are being discussed on APT systems will be presented. In addition, this chapter also explains some important details in APT systems, including the power inverter Class E ZVS inverter and matching impedance.
- Chapter 3 is methodology part which explains on the method being used from the beginning until the end of this project. It consists on the development of the simulation and hardware for the project. The fundamental process or flowchart in creating an APT system are discussed in this chapter. The simulation and experimental result are conducted to be compared with theoretical result.
- Chapter 4 will be covered on result and discussion. It presents the outcome of investigation of compensation networks in APT system. The overall performance of the circuit construction will be evaluated and presented in this chapter. It will also determine which