WIRELESS POWER TRANSFER DEVICE

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A project report submitted in partial fulfilment of the requirement for the award of the degree of Electrical Engineering with Honours

Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka

JULY 2021

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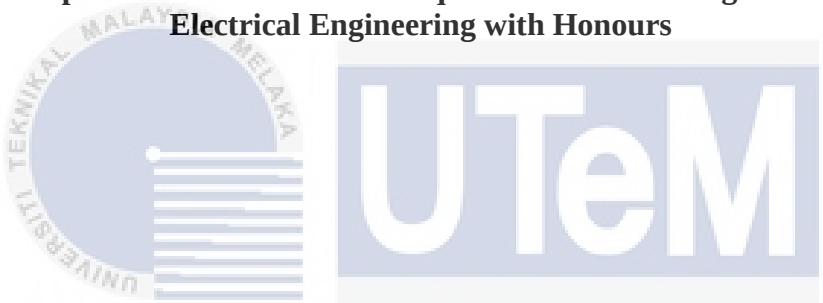

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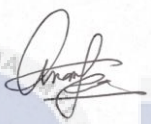
Signature : 

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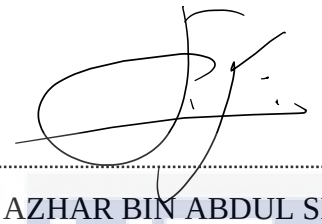
Signature : 

Supervisor Name : FAIRUL AZHAR BIN ABDUL SHUKOR

Date : 5 JULY 2021

DEDICATIONS

Dedicated to my supervisor, lecturers, my family and all my friends.

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First and foremost, praises and thanks to Allah SWT for His abundance of blessings throughout the process of my final year project as I able to complete the research work successfully.

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Any attempt at any level cannot be successfully completed without my family's unending love and encouragement to help me out despite their busy schedule and various occasions.

ABSTRACT

This report presents the study of the wireless power transfer device carried out for Final Year Project 2. The purpose of this project is to construct the wireless power transfer (WPT) module with different combination of winding turns of primary and secondary windings. Indeed, this project aims to design, construct and program a single phase inverter to inject variable frequency AC signal to wireless power transfer module. The main factor of this project problem is the presence of complicated, cumbersome and dangerous wires cable in certain devices and appliances used in the daily life. In the construction of WPT system, the methodology of the project is divided into design and develop a WPT device and single phase inverter. The design of the single phase inverter is divided into two part which are software and hardware development. The single phase inverter circuit and PCB layout is design and the initial part of the programming part of the system is well described. After the construction of this project, the basic principle of WPT system is being studied and applied. By conducting experiments in the laboratory, measurement data is collected and analysed. This paper describes the construction of a prototype as well as the complete schematic of the prototype. The RL characteristics of the WPT is analysed. The experiment starting with the hardware fabrication of the WPT module and the single-phase inverter.To summarize the results, it capable of constructing a wireless power transmission structure. When making the WPT module, distinct parameters are used in both the primary and secondary coils.The findings of the experiment reveal that the frequency and air gap have an impact on the inductance and resistance of the module.

ABSTRAK

Laporan ini mengemukakan kajian mengenai alat pemindahan kuasa tanpa wayar yang dijalankan untuk Projek Tahun Akhir 2. Tujuan projek ini adalah untuk membina modul pemindahan kuasa tanpa wayar (WPT) dengan kombinasi lilitan gegelung wayar primer dan sekunder yang berbeza. Jelas, projek ini bertujuan untuk merancang, membina dan memprogram penyongsang satu fasa untuk menyuntikkan isyarat AC frekuensi yang berubah-ubah ke dalam modul pemindahan kuasa tanpa wayar. Faktor utama masalah projek ini adalah adanya kabel wayar yang rumit, tidak praktikal dan berbahaya pada peranti dan peralatan tertentu yang digunakan dalam kehidupan seharian. Dalam pembinaan sistem WPT, metodologi projek dibahagikan kepada reka bentuk dan pembentukkan peranti WPT dan penyongsang satu fasa. Reka bentuk penyongsang satu fasa terbahagi kepada dua bahagian iaitu pengembangan perisian dan perkakasan. Litar penyongsang satu fasa dan susun atur PCB adalah reka bentuk dan bahagian awal bahagian pengaturcaraan sistem dijelaskan dengan baik. Selepas pembinaan projek ini, Prinsip asas sistem WPT dikaji dan diterapkan. Dengan melakukan eksperimen di makmal, data pengukuran dikumpulkan dan dianalisis. Laporan ini menjelaskan pembinaan prototaip serta skema lengkap prototaip. Ciri-ciri RL WPT dianalisis. Eksperimen dimulakan dengan pembuatan perkakasan modul WPT dan penyongsang satu fasa. Untuk meringkaskan hasilnya, ia mampu membina struktur penghantaran kuasa tanpa wayar. Semasa membuat modul WPT, parameter yang berbeza digunakan pada gegelung primer dan sekunder. Hasil eksperimen menunjukkan bahawa frekuensi dan jurang udara mempunyai kesan terhadap aruhan dan rintangan modul.

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LIST OF SYMBOLS AND ABBREVIATIONS

WPT	-	Wireless Power Transfer
PCB	-	Printed Circuit Board
MOSFET	-	Metal Oxide Semiconductor Field Effect Transistor
PMA	-	Power Matters Alliance
IGBT	-	Insulated-gate bipolar transistor
MCU	-	Microcontroller Unit
XTAL	-	Crystal
IC	-	Integrated circuit

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Interest in this area has recently resurfaced, largely due to the introduction of mobile electronic devices that are constantly on the move and need to be charged regularly. WPT can be described as a means of transmitting electrical energy from a power source to an electrical system without cable conductors. WPT is, in the simplest terms, the transfer of energy between two objects, without wires or cables.

American physicist Nikola Tesla invented the idea of wireless power transfer, and his initial patent on the matter was granted over 100 years ago. [1] Tesla also conducted successful experiments to wirelessly transfer electricity, using the technology to successfully light wireless light bulbs.

The aim of this project is to analyse and research the technologies and physics behind wireless power transfer. The initial attempt to investigate the WPT in order to keep up with the rapidly growing industry and to evaluate the industry's current needs and solutions. The basic wireless power transmission system, the transmitter circuit and the receiver circuit, is divided into two parts. It utilises the process of inductive coupling to wirelessly transfer electricity.

In addition, the design of PCB, assembly and testing, and the development of original prototypes were the main objectives. The primary coil, series resonant capacitor, and DC to AC inverter are included in the power transmitter circuit. The inverter is utilized between two coils for magnetic field induction.A secondary coil, a parallel resonant capacitor and an AC to DC converter are found in the power receiver circuit. From the figure 1.1, it shows the K-chart of WPT device project. The k-chart illustrated the overflow of the project which is divided into two parts, software and hardware development.

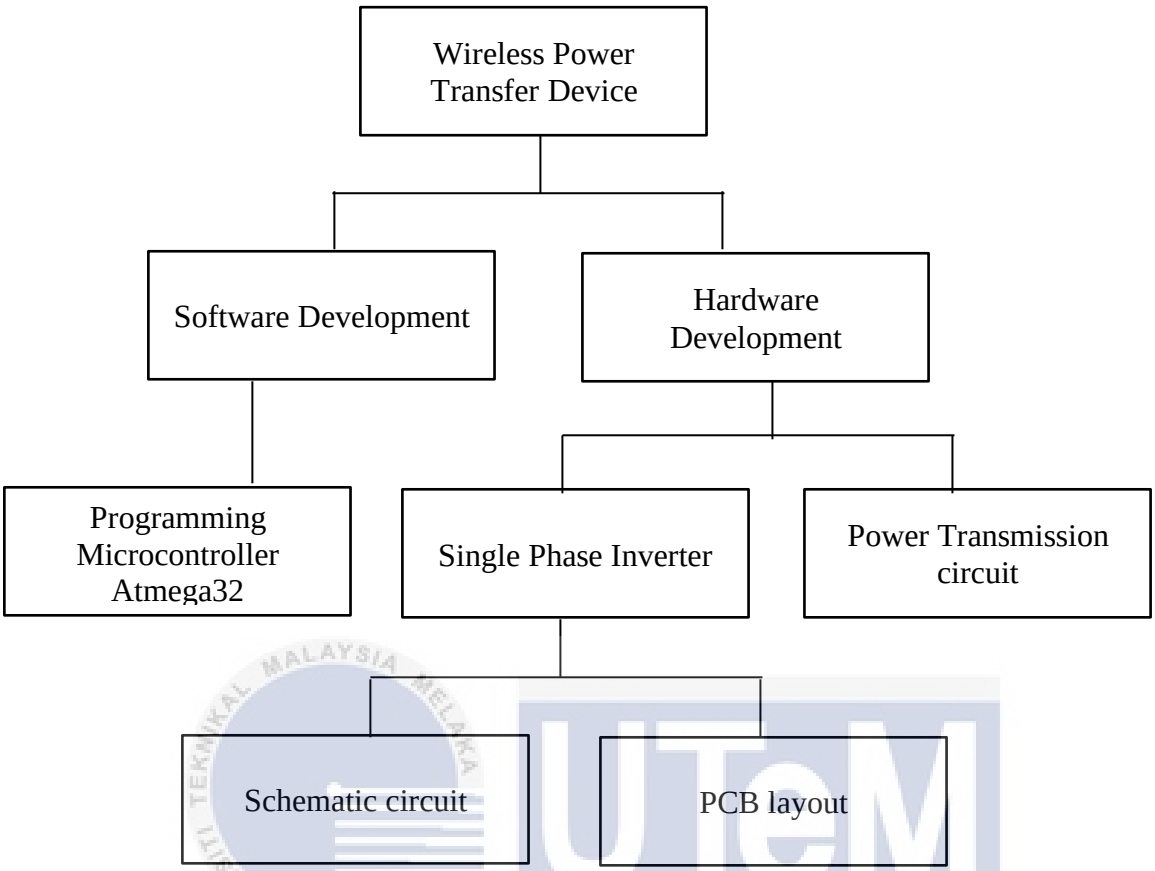


Figure 1.1: K-chart of Wireless Power Transfer Device Project

1.2 Motivation

The motivation for wireless power comes from wires being bulky and messy. The idea of wireless power is nothing new but this idea in today's world of rapid technological development, WPT considers more prominent spatial opportunity between the power source and the gadget. Hence, implementation of WPT method spur new roads of research in various applications to add convenience in so many aspects.

1.3 Problem Statement

The main problem is the connecting wires in the most of devices application make it difficult for users to deal with when there is mislaid of wires happened and it also limits the portability of device. Because of this disability, WPT device system was built. The first problem statement is wireless power transfer is helpful for connecting wiresto electrical devices that are bulky, unsafe or impossible. With wireless power transfer, the need for cables is eliminated. Besides, in general, power transmitted in AC. the WPT scheme ought to consequently be incorporated with DC to AC power, accompanied by energy transmission. Lastly, the transmission efficiency of WPT depend on the distance. Decreased efficiency with increased distance.

1.4 Objective

The objectives of this project are:

i. To construct the wireless power transfer module with different combination of winding turns of primary and secondary windings.

ii. To design, construct and program a single phase inverter to inject variable frequency AC signal to wireless power transfer module.

iii. To analyze performance and characteristics of the wireless power transfer module.

1.5 Scope

This project study limits into 3 main parts which are wireless power transfer module, single phase inverter and performance measurement. The wireless power transfer module uses ferrite based core and has two windings which are primary and secondary. The windings are self-created. Besides, the single phase inverter part consist of design of single phase invertert PCB layout, fabrication of PCB board and component assembly of single phase inverter. In the performance measurement, the frequency range of inverter is set between 100Hz -1kHz depends on the capability of the microcontroller Atmega32. Furthermore, the measurement

of air gap is set between 2mm to 5mm between two cores. The voltage and the R-L characteristics measurements are calculated for primary and secondary windings.

1.6 Thesis outline

This outline is divided into five chapters to provide better understanding of the whole project. The first chapter, which contains the introduction, covers the project outline, problem statement, project goals and scope of the project for the Wireless Power Transfer System. In chapter 2, discusses fundamental project theory, the system fundamentals, and provides past studies relevant to the project subject.

Meanwhile, Chapter 3 includes the proper procedure in designing, relevant experimental method and descriptive techniques used in the WPT project. It provide details explanation of the flow of methodology is and flowchart is illustrated to give a better understanding. Furthermore, in chapter 4, the result of all project development is presented. It provide comprehensive discussion related to preliminary result obtained and also implications of the findings of the project undertaken. Lastly, chapter 5 covers the conclusions of the preliminary result drawn and future work is recommended.

CHAPTER 2

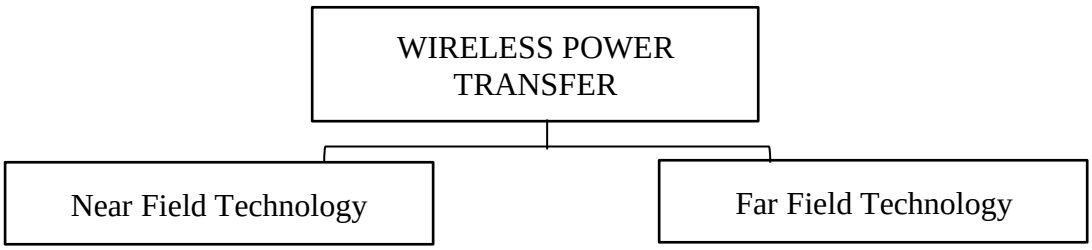
LITERATURE REVIEW

2.1 Introduction to study of Wireless Power Transfer (WPT)

This chapter overview the concept of the wireless power transfer device.WPT system is being implemented in many devices work and application. Thus, in this chapter cover the type and the basic principle of the software and hardware parts of the system. Moreover, the classification ,techniques and technologies of WPT are also being described. Besides, this chapter also provides details description of a few components that are being used in the project.

2.1.1 Wireless power transfer (WPT) method

There are plenty of techniques to transmit power without any direct physical contacts. In this project, it will be focusing on the electromagnetic induction in the Near Field Technology. Near field technology is a non radiative method to transfer power. It is a technology which can perform transmission of energy by using wires coils. Figure 2.1 shows the different types of WPT methods that has been used in various technology. Basically the classification is based on the possible distance power can travel.



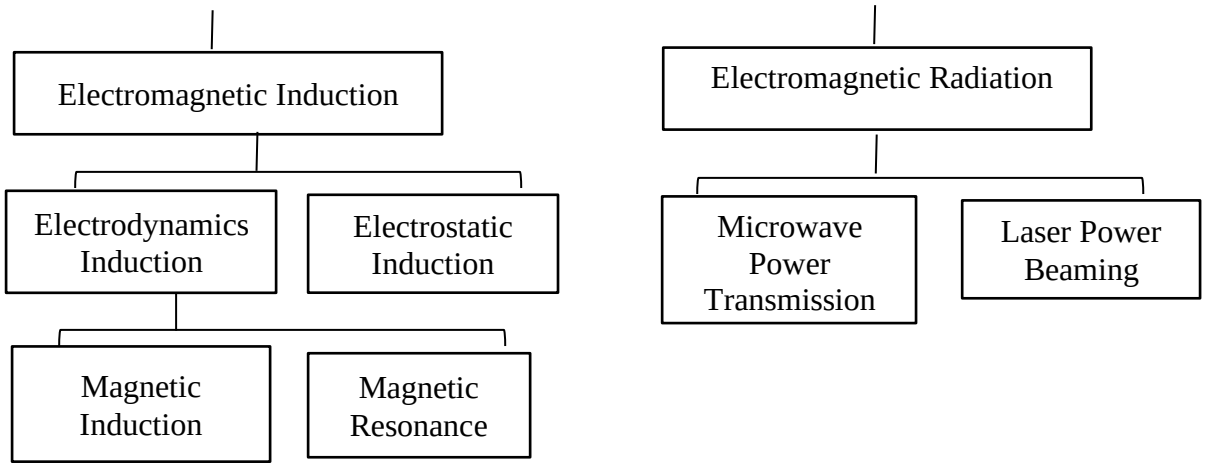


Figure 2.1 K-Chart of WPT Method

Both electromagnetic induction and magnetic resonance involved magnetic field coupling. In the magnetic induction, when wire wind with a coil, the magnetic field is generated. The more the number of windings the higher the strength of magnetic field produced.In the electromagnetic process, a permanent magnet may also be placed. The electromagnetic induction mechanism occurred when it was possible to generate voltage by altering the magnetic field or moving the coils.

Whereas , in the electromagnetic resonance , the higher the current in the primary side, the higher the voltage induced in secondary part. Figure 2.2 shows the block diagram of Electromagnetic Resonance. It started with the DC power that is supply into the driver and controllers. Then, it is carried into the primary compensation and secondary compensation of the coil. The power is then undergoes voltage conditioning and then will be transmitted into load of any devices or battery.

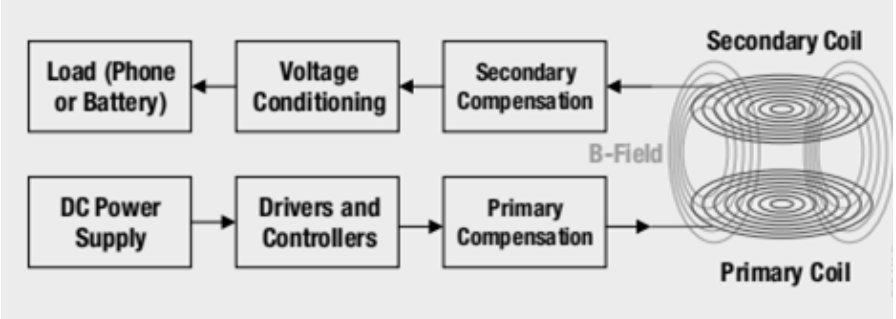


Figure 2.2: Block diagram of Electromagnetic Resonance

2.1.2 Wireless power transfer standards

Qi is a specification of an open interface that defines wireless control by inductive charging, switch over distances up to 4 cm. Table 2.1 shows the Qi's standards for WPT. It is classified into technology, power and frequency.

Table 2.1: The Qi's Standards for WPT [2]

Technology- Inductive, Resonant	Low Frequency
Power	5W-15W Qi Cordless kitchen appliances: 100W- 2.4kW
Frequency	110 - 205kHz

Based on Power Matters Alliance (PMA)'s standards a suite of interface specifications for smart and energy-efficient wireless power transfer are formulated and advanced. In order to provide advanced inductive and resonant control, the PMA effectively distributed a set-up of guidelines based on inductive coupling innovation. Table 2.2 shows the classification of PMA's standards for WPT devices. The range of power and frequency for PMA's standards is large compared to Qi standards. Nevertheless, both standards applicable for WPT.

Table 2.2 : The PMA' Standards for WPT

Technology- Inductive, Resonant	High Frequency
Power	3.5W - 50W
Frequency	277 -357kHz

2.1.3 Advantages and Disadvantages of WPT

There are a few advantages and disadvantages of the WPT system. One of the advantages of the WPT is it has a simple design. Besides, WPT can eliminates the existing system that using interconnecting wires which is troublesome and inefficient. Moreover, for everyday applications, the cost of transmission and receiving of the system will be

lower. In term of portability, in the absent of wires or cables, the device which uses the WPT system is very superior compared to other system. Furthermore, Power failures minimization causes by short circuit and faults could be achieved. [3].

The disadvantages of the WPT is the radiation level accomplished by the WPT is close or somewhat higher than the radiation of mobile phones. [4] Besides, the transmission of the system is inefficient for long distance. Moreover, initial expense for functional installation of the system is quite high. In addition, interference could possibly happened to interrupt the transmission of power and signal to the load. Lastly, compared to direct touch, the wireless transfer of power could increase resistive heating. [5].

2.2 Basic principle of the Wireless Power Transfer Device

WPT system can be defined as power transmission from one source to an electrical charge without any interconnecting wires or cables. WPT allows power to be supplied through an air gap without any wires or cable. Depending on strength and space, energy may be effectively transmitted by an electric field, magnetic field, or electromagnetic (EM) waves. e.g. radio, microwave, or even light waves. Figure 2.3 shows the basic diagram for the transmission of electrical energy of WPT. In general, the transmission of energy in WPT started with a power supply injected into two main parts, transmitter and receiver before being transfered to the load.

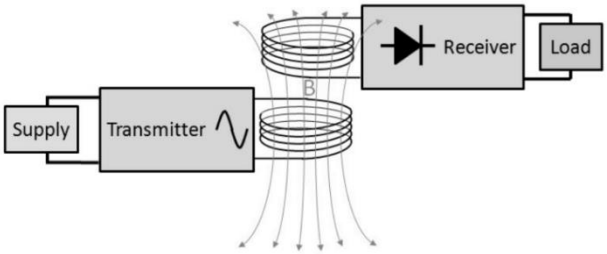


Figure 2.3: The transmission of electrical energy of WPT

2.2.1 Working principle of WPT

Wireless power transfer works on the inductivepower transfer principle, as discovered in conventional transformers.The main difference being that while the two coils are