Faculty of Engineering

DESIGN AND DEVELOPMENT OF SOLAR POWERED WIRELESS CHARGER USING INDUCTIVE COUPLING

Rembert Micheal

Bachelor of Engineering (Hons)

Electrical and Electronics Engineering

2019

UNIVERSITI MALAYSIA SARAWAK

Grade: A-

Please tick (√)

Final Year Project Report ☑

Masters ☐

PhD ☐

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DESIGN AND DEVELOPMENT OF SOLAR POWERED WIRELESS CHARGER USING INDUCTIVE COUPLING

REMBERT MICHEAL

A final year project report submitted in partial fulfilment of
the requirement for the degree of
Bachelor of Engineering (Hons) Electrical and Electronics Engineering

Faculty of Engineering
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2019

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ABSTRACT

Wireless power transmission has been commercialized for quite awhile now and since the mobile phone industry is thriving, there is a constant need in charging the mobile phone wirelessly. However, since the wireless charger was recently introduced, it comes with several limitations. One of which is the constant need to change the connections and components of the wireless charger. The changing of connections and components requires a big amount of research and this would incur additional charges to the production of these wireless chargers. Thus, this project aims to solve this problem by making modifications of the transmission coils. Through just modifications of the coil, manufacturers would be able to save a lot of manufacturing cost and this would definitely decrease its market price. So, to rectify this problem, the concept of the inductive wireless charging will be understood. Then, the characteristics of the coils will be understood by changing the parameters of the coils and then testing the charging of the mobile phone by placing the mobile phone on top of the transmission coil. Next, the transmission coils will be connected in series and parallel as well as adding magnetic sheet and tape as the magnetic shielding. The charging of the phone is observed on each of these configurations.

ABSTRAK

Transmisi kuasa tanpa wayar telah dikomersialkan dan selaras dengan perkembangan industri telefon pintar, terdapat permintaan tinggi dalam pengecasan telefon mudah alih tanpa wayar. Namun begitu, teknologi pengecas telefon mudah alih tanpa wayar ini mempunyai beberapa batasan. Salah satu daripadanya adalah keperluan dalam mengubah komponen serta sambungan komponen-komponen tersebut dalam pengecas tanpa wayar tersebut. Penukaran komponen dan sambungan akan memerlukan penyelidikan yang rapi dan ini akan menyebabkan kos pembuatan produk-produk tersebut meningkat. Oleh itu, projek ini bertujuan untuk menyelesaikan masalah ini dengan membuat pengubahsuaian pada gegelung transmisi. Pengeluar dapat minjimatkan kos pembuatan pengecas tanpa wayar tersebut hanya melalui pengubahsuaian gegelung transmisi. Sehubungan dengan itu, bagi mengatasi masalah ini, konsep pengecasan tanpa wayar secara induktif akan difahami. Setelah itu, ciri-ciri gegelung transmisi akan dipelajari melalui penukaran parameter gegelung tersebut dan kemudian, pengecasan telefon bimbit akan diperhatikan apabila telefon bimbit tersebut diletakkan di atas gegelung transmisi. Seterusnya, gegelung transmisi akan disambungkan secara siri dan selari. Di samping itu, helaian dan pita magnet akan diletakkan di bawah gegelung transmisi sebagai perisai magnetik. Akhir sekali, pengecasan telefon bimbit akan diperhati pada setiap konfigurasi gegelung transmisi.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
EMF	-	Electromotive Force
IGBT	-	Insulated-Gate Bipolar Transistor
IPT	-	Inductive Power Transfer
LED	-	Light Emitting Diode
MagMIMO	-	Magnetic Multiple Input Multiple Output
MIT	-	Massachusetts Institute of Technology
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
RMS	-	Root Mean Square
SEPIC	-	Single-Ended Primary-Inductor Converter
USB	-	Universal Serial Bus

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Wireless Charging

Wireless charging is no longer unknown to us nowadays as the technology has been introduced to us and has been implemented all around us. Wireless charging of cars has been commercialised by Tesla; wireless charging of phones has been introduced to us and electrical stove that uses the same concept as the wireless chargers are widely used. These technologies have opened for us opportunities in making our lives better, but it is certainly not perfect. A biggest disadvantage of this technology is that it charges mobile devices slower than conventional method and this is because of the losses of energy in the form of heat [1].

Conventional power transfer for all electrical and electronic equipment does not allow full mobility of the device. The use of cords to charge them restricts the mobility of the devices and in certain cases would cause terrible incidents. It is not unheard of the news circulating regarding the sudden fires caused by faulty wires at homes and it has made us more cautious on the condition of these cords. One solution for this would be the wireless technology.

This technology enables us to transfer power through air without cords. In wireless charging, the particles are energized to produce its own oscillating field and this oscillating field will propagate through the air to the receiver. Since the oscillating field carries the energy, the circuit at the receiver will then convert the oscillating energy into electrical energy [2].

1.2 Problem Statement

In the wireless phone charger industry, there is a high demand on having a wireless charger that is able to charge multiple devices at once. In order for the manufacturers to comply with their demands, the manufacturers made changes to the PCB and the components of the wireless chargers. This would increase the cost in making these wireless chargers and these costs would be affected with the pricing of these chargers in the market.

The manufacturers would have to increase the power output of the wireless charger to charge more than one device at once. This increment in power output would require an increment in power input. Thus, the specification and ratings of the components of the wireless chargers would be changed as well. There could also be an increase in the number of components in the wireless charger PCB. Besides that, a number of tests would be conducted to ensure that the components used would comply with the projected life span of the product. These steps taken would incur additional costs in research and development of the product.

Not many manufacturers have tried in changing only the configurations of the coils of the wireless chargers. In changing the coils of the wireless charger, the manufacturers would be able to reduce the cost of production on these wireless chargers and at the same time supply the demands of the customers. Thus, it would be a great idea if changing the transmission coil of the wireless charger would be able to charger multiple devices at once.

1.3 Scope of Project

The wireless charging technology in this project will be based on the inductive coupling concept which includes the usage of transmitter and receiver coil. This method is chosen as this is the most common technology used in wireless charging.

This project focuses on increasing the power transfer of the charger so that it can charge multiple devices at once. So, the main parameters here are the quality factors, inductance, AC resistance of the transmission coils and the overall efficiency of the power transmission. Charging process is observed by charging a mobile phone using the charger and receiver coil made.

In this project, a mini solar panel will be used to supply the PCB of the wireless chargers. Then, several different configurations of transmission coils, with different number of turns and radius would be connected to the PCB. The magnetic sheet and tape would be placed behind the transmission coils to observe the charging of the mobile phone. The charging of the mobile phone will be observed based on the indicator in the mobile phone.

1.4 Objectives

- To understand how inductive power transfer works
- To understand the factors affecting the efficiency of the inductive power transmission
- To improve the current inductive power transfer method that would be able to charge multiple mobile devices at once through modification of the transmission coil

1.5 Topics Outline

The report includes five chapters and each chapter gives an insight of a specific aspect of the project. The first chapter introduces the wireless technology that has been a part of our life and their limitations. Brief introduction will also be included in this chapter where the problem statement, scope and objectives of the project will be outlined and explained. This chapter will give a brief idea on what this project is about.

Chapter two is literature review where all the subjects related to this project is explained. In this part the history of wireless charging gives the idea on how wireless charging was found and its development over the course of the years. Besides that, the different technologies used for wireless charging will also be explained. The basic working principles will also be explained. Components used in the project will thoroughly explained in this chapter so that full understanding of each technologies used will be achieved.

Chapter three is methodology where the steps taken to observe the characteristics of the conventional wireless charging pads. Besides that, the methods used to develop and implement the improvements on the wireless charger will be explained thoroughly in this chapter. Configurations of the transmission coils will be included in this chapter.

Chapter four is the results and discussion. In this chapter, the results of the project will be listed out and will be explained in detail. Additional graphs and tables for reference are placed in the Appendix section.

Chapter five concludes the whole project and highlights the main point of the project. The recommendations are also included here in case this project is continued by other students.

CHAPTER 2

LITERATURE REVIEW

2.1 The History of Wireless Charging

2.1.1 Theoretical Aspect

A study of electromagnetism by H.C. Oersted in 1819 discovered that electric current produces magnetic field surrounding it. This investigation has led to the derivation of Faraday's Law, Biot-Savart's Law and Ampere's Law. These laws are used to describe the fundamental characteristics of magnetic field. In 1864, Maxwell's equations were derived based on these fundamental laws. Unlike the previous laws, Maxwell's equations portray how magnetic and electric fields were produced and are affected by one another. Afterward, a book published by J.C. Maxwell entitled *A Treatise on Electricity and Magnetism* in 1873 [3], brought together all investigations regarding electricity and magnetism and then concluded that these two elements are regulated by a similar force. Later, in 1884, John H. Poynting linked the Poynting Vector to the electromagnetic energy [4].

2.1.2 Technical Aspect

The possibility of wireless power transmission as an option to replace the conventional transmission line power distribution was emerging as a hot topic in the late 19th century. Both Heinrich Hertz and Nikola Tesla hypothesized the likelihood of wireless power transmission [5]. Both had their ways in proving their hypothesis. In the year 1888, H. Hertz used an oscillator to transmit electricity over a miniscule distance connected to induction coils. This was the first experiment to confirm the presence of electromagnetic radiation. Nikola Tesla, who was the founder of alternating current, started the first experiments on wireless power transfer involving microwave technology. He prioritises experiments on long-distance wireless power transfer and in he was able to realize the transfer of microwaves over a distance over the distance of about 48 kilometres. In 1899, another breakthrough was achieved by transmitting 10^8 volts of high-frequency electrical power to 200 light bulbs and an electric motor over 25 miles [6]. The technology used by Tesla, however, had to be put aside as emitting such high voltages in electric arcs would have negative implications to humans and nearby electrical equipment [7].

At the same time, Tesla also introduced his famous “Tesla Coil” which contributed greatly to the advancement of magnetic field. He then built the Wardenclyffe Tower in 1901 which can transmit electrical energy through the Ionosphere without using wires. Despite the originality his demonstrations and his personal desires in commercializing wireless power transmission, he soon ran out of funding as it was cheaper to lay copper than to build the equipment needed to transmit power by radio waves. The technical constraints during this period also contribute to the underdevelopment of its technologies [8], [9].

2.2 Current Technologies of Wireless Charging

Current wireless charging technologies can be classified into two types namely non-radiative coupling-based charging and radiative RF-based charging. Non-radiative coupling-based charging includes three techniques which are inductive coupling [10], magnetic resonance coupling [11] and capacitive coupling [12]. On the other hand, radiative RF-based charging includes directional RF power beamforming and non-directional RF power transmission [13]. For capacitive coupling, the coupling capacitance that can be achieved is dependent on the available area within the device [14]. Nonetheless, for a typical sized portable electronic device, there is a difficulty in generating sufficient power density for charging, which implies a sophisticated design limitation. In directional RF power beam forming, one restriction exists where the location of the receiver must be known by the charger with great accuracy. Thus, because of the clear restrictions of the two methods above, conventional wireless chargers normally make use of the other techniques which are magnetic resonance coupling, non-directional RF radiation and magnetic inductive coupling [9].

Magnetic resonance and magnetic-inductive coupling operate in the low distance range, where the electromagnetic field that is generated, is higher in strength and density near the transmitter or scattering objects. This near field attenuates based on the cube of the reciprocal of the charge distance. On the other hand, the microwave radiation operates at a more prominent separation. The square of the reciprocal of the distance of the charging describes how the far-field power reduces in amplitude [15]. In the far-field method, the transmitter does not affect the retention of the radiation. However, in near-field methods, retention of the radiation influences the transmitter's load [16]. This is because, in the far-field method, the transmitter and receiving antenna are not coupled as they were in the non-radiative methods [17].

2.3 Inductive Coupling

The utilization of magnetic field induction to transmit electrical energy from one coil to another is called inductive coupling [9]. The magnetic field which is time-varying is utilized to transmit power without wires between the two coupled coils [18]. Figure 2.1 shows a model for reference. In wireless Inductive power transfer (IPT), the primary coil of a transmitter produces its own magnetic field which is constantly changing while the secondary coil would be within the magnetic field of the primary coil which is usually less than one wavelength. Then, voltage or current will be induced in the secondary coil of the receiver and the voltage can be used to charge a device or storage system wirelessly. Usually, this technology operates at frequencies within the kilohertz range [9]. The frequency of the secondary coil can be changed to the same frequency as the operation to improve the efficiency of the wireless charging [19]. Normally, the quality factor of this charger is in small values (example: below 10 [20]) as the power transmitter would decrease drastically with higher quality factor [21]. Because of the lack of compensation of high-quality factors, the effective charging distance is usually within 20 cm [19]. In spite of the restricted range of transmission, the viable power for charging wirelessly can be high [9] (example: power transmitted to charge electrical vehicles can reach up to kilowatts [22]).