THE DEVELOPMENT OF INDUCTIVE POWER TRANSFER (IPT) SYSTEM FOR BIOMEDICAL IMPLANTABLE UNITS

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JUNE 2014

STUDENT'S DECLARATION

"I hereby declare that this report is the result of my own work except for quotes as cited in the references"

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ABSTRACT

Nowadays, implanted medical device is the most important electronic devices. This is because these devices are very useful in monitoring and diagnostic as well as safety and comfort for patients. Since 1950s, the researchers have given all of their efforts for the development of biomedical implanted unit and wireless telemetry bio-devices. One of the famous technologies that related to the development of the biomedical implantable unit is the inductive power transfer (IPT) systems. IPT system is one of the technologies that can be used to power up an electrical device wirelessly or without physical contact. Two types of IPT are closely coupled and loosely coupled. The further explanation of these two types of IPT system will be discussed later. The development of IPT for medical implantable units consists of designing a transmitter (primary) and receiver (secondary) circuit. The transmitter will transmit the power from DC voltage source and the receiver will receive that power and use it to charge the implantable unit. The designing of the compensation circuit for the maximum power transfer from a transmitter to a receiver also will be discussed in this paper. The simulation and experimental setup are done in order to test the designed circuit of the transmitter and receiver side and as well as to analyze the performance of the system.

ABSTRAK

Pada masa kini, peralatan-peralatan perubatan yang diimplan adalah peranti elektronik yang paling penting. Ini adalah kerana alat-alat ini adalah sangat berguna dalam memantau dan diagnosis serta keselamatan dan keselesaan untuk pesakit. Sejak tahun 1950-an, para penyelidik berusaha untuk membangunkan unit implan bioperubatan dan telemetri wayarles bio-peranti. Salah satu teknologi terkenal yang berkaitan dengan pembagunan unit implan bioperubatan adalah Pemindahan Kuasa Induktif, '*Inductive Power Transfer (IPT)*' sistem. Sistem IPT merupakan salah satu teknologi yang boleh digunakan untuk menghidupkan alat elektrik secara tanpa wayar atau tanpa sentuhan fizikal. Dua jenis IPT adalah rapat ditambah, '*closely coupled*' dan longgar ditambah, '*loosely coupled'*. Penjelasan lanjut mengenai kedua-dua jenis sistem IPT akan dibincangkan kemudian. Pembangunan IPT untuk unit implan perubatan terdiri daripada merekabentuk litar pemancar (primer) dan penerima (sekunder). Pemancar akan menghantar kuasa daripada sumber voltan AT (Arus Terus) dan penerima akan menerima kuasa itu dan menggunakannya untuk mengecas unit yang diimplankan. Merekabentuk litar pampasan, '*compensation circuit*' untuk pemindahan kuasa maksimum daripada pemancar kepada penerima juga akan dibincangkan dalam kertas ini. Simulasi dan persediaan eksperimen dilakukan untuk menguji rekaan litar pada pemancar dan penerima dan juga untuk menganalisis prestasi sistem.

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LIST OF ABBREVIATION

WPT	Wireless Power Transfer
IPT	Inductive Power Transfer
CPT	Capacitive Power Transfer
AC	Alternating Currect
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Wireless power transfer (WPT) is one of the popular methods for powering and also for charging the portable devices such as smart phones, electric toothbrush, laptops and cameras instead of wired technology. The wired technology can be defined as a technology that requires a wire power plug to be connected to an electrical wall outlet. So, the connection between the wired technology should be achieved manually and this might lead to safety risk in wet condition [1].

In order to replace the wired technology, WPT is more preferable due to its capability to transfer the power wirelessly. WPT system is the process of transmitting an electrical energy from a direct current, DC source to an electrical load by crossing an air gap using the induction coils. This type of technology is maintenance-free operations. It also has complete electric isolation between primary and secondary conductors as well as no sparking effects due to contact problem [2].

There are various types of WPTs such as the capacitive power transfer (CPT) and inductive power transfer (IPT).The CPT only can be applied to the low power range. The amount of coupling capacitance of CPT depends on the available area of devices. This situation is not practical in some applications or by targeting the low power applications [3]. For IPT system, this system is capable to transfer higher power compared to CPT system at the medium or large air gap. The potential of electric shock for IPT is low due to no exposed conductors. Other than that, the IPT is waterproof since the charging connections are fully enclosed and thus, make it suitable for harsh environments in general [4].

For this final year project, the IPT system for charging the biomedical implantable units is proposed. It is the wireless battery charging project and this project is applying the concept of Faraday's and Ampere's law. These two laws are the function of alternating magnetic fields around the current carrying conductors to transfer power from a primary winding to a secondary winding. This project is proposed due to low cost and where battery replacement is impractical.

1.2 PROBLEM STATEMENT

The biomedical implantable devices have been around for several decades. At the early of intro to this implantable medical device, majority of the establishment of this medical device is focusing on the cardiac rhythm management. These devices are used for treating the heart rhythms like bradycardia (beating slowly) and tachycardia (beating too fast).

In the development of the implantable medical devices, the most concern one is the power management. There are many ways to charge or to power the implantable units. One of them is by using the cable. Formerly, in some of the clinical implantable applications, the transcutaneous power cables are used. However, this technique is inconvenient as it limits the mobility of the subject animal. This technique also introduced a significant path of infection. Thus, the transcutaneous power cables are not the proper way to power the implantable medical devices due to this disadvantage [5].

An implant battery is used to replace the transcutaneous cable. By using this method, a fully implantable system is achieved. This battery is a finite source. Hence, it will not last very long. Thus, at the end of its life time, many surgeries are required to replace the battery and this may include the higher cost. Therefore, the Inductive Power Transfer (IPT) system is developed to get an infinite lifetime to power up the implantable unit [6].

1.3 PROJECT OBJECTIVE

The objectives of this project are:

1. To develop an IPT system for biomedical implantable unit.
2. To design the compensation circuit for maximum power transfer.
3. To analyze and compare the overall performances of IPT system.

1.4 SCOPE OF PROJECT

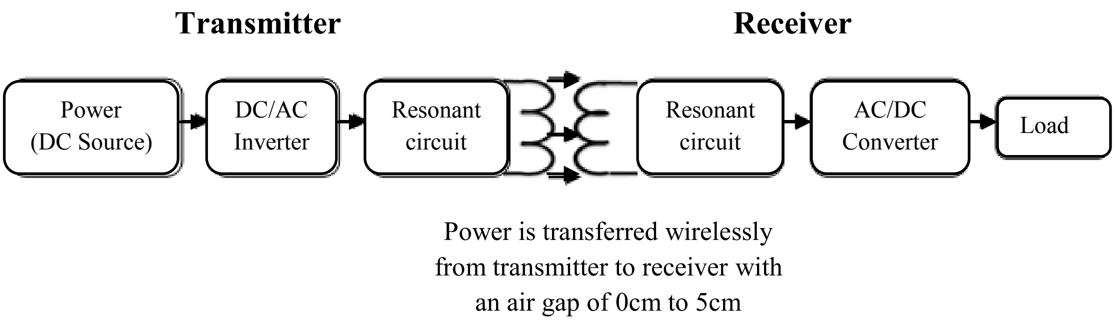

Figure 1.1: The layout of the project

Figure 1.1 shows the layout of the project. In this project, the IPT system for biomedical implantable units will be developed. The developing of IPT system consists of designing the transmitter and receiver circuit. In this project, the power that will be transferred wirelessly from a transmitter to a receiver is mW in range with an air gap is about 0cm to 5cm. The size of the pick-up circuit (receiver side) must be as small as possible, approximately 30mm x 30mm. The aim of this project is to design an IPT system that fulfills the below requirements:

1. The size of the IPT pick-up circuit must be as small as possible. The suggested size of this circuit is approximately 30mm x 30mm.

2. The output power of the pick-up circuit to supply the transducer is in mW.

3. Must have some air gaps, so a distance between the primary side and secondary side is about 0cm to 5cm.

1.5 REPORT OUTLINE

The thesis of 'The development of Inductive Power Transfer (IPT) systems for biomedical implantable units has five chapters. Chapter 1 discusses about the project introduction including the problem statement, the objectives of the project and the scope of the project. Chapter 2 is about the literature review. This chapter will review on the past research and also will review some theoretical concepts applied in this project. The next chapter is Chapter 3. It focuses on the methodology of the project. The flow chart of the project is included in this chapter in order to explain the procedures of designing the IPT system. For Chapter 4, it will discuss about the results of the designing circuit by using simulation and by experimental. The performance of the circuits is compared and analysed in this chapter. Finally, Chapter 5 will be concluded the whole chapters. The recommendation is provided in this chapter for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF INDUCTIVE POWER TRANSFER (IPT) SYSTEM

The IPT system is one of the WPT technologies. This IPT system gains much attention from the researches about less than 30 years ago. This IPT system can be applied in many sectors such as automated factories and clean factories. It is also suitable for lighting application, for instrumentation and for electronic system where its unique features can be exploited [7].

The wireless power transmission is gaining great attention since Ampere and Faraday find out about the electric engineering based on their laws. These two laws are the function of alternating magnetic fields around the current carrying conductors to transfer power from a primary winding to a secondary winding. The illustration of these laws is shown in figure 2. The coil 1 in Figure 2.1 acts as a transmitter and coil 2 acts as a receiver. The function of coil 1 is to generate magnetic fields from alternating current (AC) sources and induces a voltage to coil 2. The coil 2 will receive the induces voltage from coil 1. Then, the induces voltage can be used for mobile devices or battery charging.

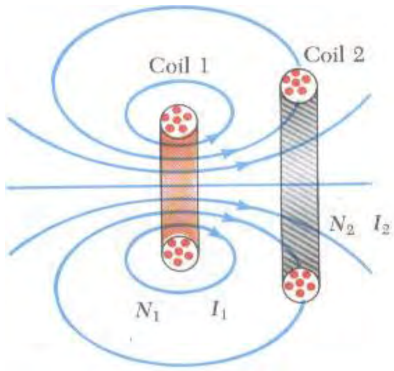

Figure 2.1: Illustration of Ampere's and Faraday's Law

According to Ampere's law, for the case when the displacement current is neglected:

$$\S_{c1} H.dl = \int_{s1} J.Ds, \qquad (2.1)$$

An alternating current through the primary coils will create an alternating magnetic field over any closed contour C that encloses the primary conductors. Since the currents through all primary turns are equal,the equation (1.1) can be simplified as:

$$\S_{c1} H.\ dl = N_1 I_{1,} \qquad (2.2)$$

It indicates that the field intensity directly depends on the number of turns and the primary current. Faraday's law states that if the secondary coil is exposed to a time varying field, an induced voltage will appear at the coil terminals:

$$\oint_{c2} E.dl = -\frac{\delta}{\delta t}\int_{s2} B.dS \qquad (2.3)$$

and power will be delivered to the load [8].

Early on, Faraday's work leads to an invention of the direct current (dc) and alternating current (ac) machines. This machine are enhancement of the induction machine that invented by Nikola Tesla. At this time, the power is coupled from a stator to a rotor. It is usually converted from electrical power to mechanical power at the same time. The efficiency of the machines is high. However, the coupling distance is a small and very constraint [9].

In 1991, the IPT system that potentially suitable for handling and other applications (U.S. Patent 5 293 308) have been produced by Boys and Green from University of Auckland. This patent is the basis of the works in IPT systems over the past 20 years. This is also the first systematic approach to an IPT system as the components of such systems are identified and separately improved. For the development of IPT system, the important elements involved are[7], [9]:

1. An utility of VLF (very low frequency 3 - 30 kHz) or LF (low frequency 30 – 300 kHz) power supply for energizing a track.

2. The track itself with its frequency compensation and magnetic construction methodology.

3. A pickup system for taking power magnetically from the track.

4. A controller for controlling the power transfer process to a DC output voltage.

2.2 INDUCTIVE POWER TRANSFER (IPT) SYSTEM FOR BIOMEDICAL IMPLANTABLE UNITS

2.2.1 The Implantable Unit

Biomedical implantable devices have been available for more than sixty years. Basically, there are two parts of implanted device which are the internal part located underneath the body skin and an external part such as controller. The function of the external part is to power the combination and sending data to the outside world. The feature of implantable devices are self operating devices. They will adjust their operation depending upon the patient's condition. These devices also do not rely on external sources of power. There are several characteristics that are shared by most biomedical implantable devices including low power consumption, high reliability and low frequencies as well as small size [10]

The main requirement for medical implant devices is low power consumption. It is because the large dissipation in power inceases the possibility in damage the soft tissues in the human body. The process of charging batteries can be costly and risky for the patient. Other than that, the reliability for the implanted devices must be very high because the failure of an implantable medical device can result pain or death for the patient. Another requirement for implantable unit is low