

WIRELESS ELECTRICAL VIA ELECTROMAGNETIC INDUCTION

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ABSTRACT

Wireless Electricity transmission or wireless power transmission is the process takes place in any system where electrical energy is transmitted from a power source to an electrical load without interconnecting wires. The traditional ways by electric power cables and electric batteries are often not satisfactory for mobile devices. Use of plugs and wires will limit the mobility. Therefore, this project is to build and demonstrated the concept wireless power transfer at relatively large distances based on magnetic induction coupling between electromagnetic resonant objects. It consists of a transmitter as an electromagnetic resonator and a receiver to which the device to be powered is attached. The transmitter emits a non-radioactive magnetic field resonating at MHz frequencies, and the receiving unit resonates in that field. The maximum voltage can absorbed by the receiver load is 10V at 0 distances and decreased to 0.567V at 6 cm distance. From the experiment, the receiver has the voltage of 2.582V for input current 3A, 1.356V for input current 1A and 0.678V for input current 500mA at 0 distances. The basic principle involved by taking two coils having same magnetic resonance and one is coupled to source and the other one is coupled to device. However, the short distance between the two coils and the large coil size that use more space will become a problem. Thus, the number of turn of coil with better quality of copper wire and input current source can be increased to improve the strength of magnetic field. This is because, when the strength of the magnetic field increased, the distance between the two coils can be longer while smaller size of coil can be used to reduce space.

ABSTRAK

Penghantaran Elektrik Wireless atau penghantaran kuasa tanpa wayar adalah proses yang berlaku dalam mana-mana sistem di mana tenaga elektrik dihantar dari sumber kuasa kepada beban elektrik tanpa penyambungan wayar. Cara-cara tradisional yang digunakan termasuk kabel kuasa elektrik dan bateri elektrik sering tidak memuaskan bagi peranti mudah alih. Penggunaan plug dan wayar akan menghadkan mobiliti. Oleh itu, projek ini bertujuan untuk membina dan menunjukkan konsep pemindahan tenaga tanpa wayar pada jarak berdasarkan gabungan aruhan magnet antara objek elektromagnet salunan. Ia terdiri daripada pemancar yang bertindak sebagai resonator elektromagnet dan penerima yang peranti yang akan berkuasa dilampirkan. Pemancar mengeluarkan medan magnet bukan radioaktif bergema pada frekuensi MHz, dan unit penerima bergema dalam bidang itu. Voltan maksimum yang diserap oleh beban penerima adalah 10V pada 0 jarak dan merosot kepada 0.567V pada 6 cm jarak. Daripada ujikaji tersebut, penerima mempunyai voltan 2.582V untuk input 3A semasa, 1.356V untuk input 1A semasa dan 0.678V untuk input 500mA semasa pada 0 jarak. Prinsip asas yang terlibat ialah dengan mengambil dua gegelung yang mempunyai resonans magnetik sama dan satu digandingkan kepada sumber dan satu lagi ditambah ke peranti. Walau bagaimanapun, jarak pendek antara kedua-dua gegelung dan saiz gegelung besar yang menggunakan lebih banyak ruang akan menjadi masalah. Oleh itu, bilangan giliran gegelung dengan kualiti yang lebih baik daripada wayar tembaga dan input sumber semasa boleh ditingkatkan untuk meningkatkan kekuatan medan magnet. Ini kerana, apabila kekuatan medan magnet meningkat, jarak antara kedua-dua gegelung boleh lebih lama manakala saiz yang lebih kecil daripada gegelung boleh digunakan untuk mengurangkan ruang.

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LIST OF ABBREVIATIONS

WET	-	Wireless Energy Transfer
WPT	-	Wireless Power Transfer
LED	-	Light Emitting Diode
WCV	-	Wireless Charging Vehicle
AC	-	Alternating Current
DC	-	Direct Current

CHAPTER 1

INTRODUCTION

1.1 Background

Electricity is an inevitability of today modern life. It is difficult live passing a day without electricity. The conventional use of electricity is made possible through the use of wires. Advanced technology has enabled a general variety of portable consumer electronic devices. However, users are still required to manually plug in these devices when battery is used up. Thus, wireless energy transfer (WET) is proposed to realize the possibility of connector battery free electronic devices, which could improve both size and reliability. So, there is the desire dream to use WET technology and eliminate the remaining wired energy connection.

There is a demand for wireless energy transfer system. Wireless data transfer via the Ethernet protocol or mostly known as WIFI was developed around 1988 by NCR Corporation and widely commercialized in 1999. Analysts predict that 100 million people will be using Wi-Fi by 2006. Homes, offices, colleges and schools around the world have installed Wi-Fi equipment to blanket their premises with wireless access to the internet. Wi-Fi access is available in a growing number of coffee shops, airports and hotels [1]. Therefore, it is not impossible to think that a developed wireless energy transfer technology would produce same potential in home and business applications as wireless data transfer experienced.

Many of the contactless feed systems are based on the electromagnetic induction's principle. Small distance wireless energy transfer is demonstrated through used of induction. Knowledge of electric circuit logic and electromagnetic theory is important to realize the practical design. The concept of Wireless electricity began with the experiments of Heinrich Hertz and Nikola Tesla at around the 1890s and it still under the research until today. It has been attempted many times throughout the last century [2].

The advantage of inductive wireless power transfer which is low cost and highly efficient method of transferring power. The design of an induction link is fairly straight forward and surprisingly efficient at small distances.

Therefore, his project was build and demonstrated the concept wireless power transfer at relatively large distances based on magnetic induction coupling between electromagnetic resonant objects [3]. It consists of a transmitter as an electromagnetic resonator and a receiver to which the device to be powered is attached. The transmitter emits a non-radioactive magnetic field resonating at MHz frequencies, and the receiving unit resonates in that field. The basic principle involved by taking two coils having same magnetic resonance and one is coupled to source and the other one is coupled to device. However, the short distance between the two coils and the large coil size that use more space will become a problem. Thus, the number of turn of coil with better quality of copper wire and input current source can be increased to improve the strength of magnetic field. This is because, when the strength of the magnetic field increased, the distance between the two coils can be longer while smaller size of coil can be used to reduce space.

1.2 Early History of Wireless Energy Transfer

The early history of wireless energy transfer involves two main figures that are Nikola Tesla and the group of researcher from Massachusetts Institute of Technology (MIT).

1.2.1 Nikola Tesla

Nikola Tesla was born on July 9, 1856 in Yugoslavia. Tesla had a special talent that is able to imagine things so well that they seemed real. This allowed him to build mental rather than physical prototypes that led to successful design. The weakness of him is took very poor notes. He only wrote down those things that he seem absolutely necessary or important. Tesla was far beyond his time in his experimentation. In 1899, he went to Colorado Springs to build a laboratory and try to find out some new ideas. One of the ideas was the wireless transmission of energy. He had build a resonant transformer called as Tesla coil, achieved a major breakthrough in his work by transmitting 100 million volts of electric energy wirelessly. In his experiment, he was able to light 200 lamps, 26 miles away from his lab to light up a bank and run one electric motor.

He claimed that can transfer electrical energy at 95% efficiency, but he technology had to be shelved because the effects of transmitting such high voltages in electric arcs would have been disastrous to human and electrical vicinity [2]. Tesla theories of the wireless transmission of energy were a little different than today's vision. It was centered on his consideration of the earth as a giant conductor. Tesla transferred energy directly through the earth's surface [3].

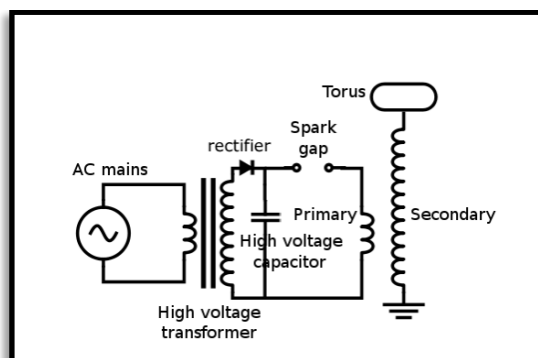


Figure 1.1.1: Basic configuration of Tesla coil.

By referring to figure 1.1.1, the high voltage capacitor forms two resonant circuits: one with the primary coil, and another with the secondary coil. The voltage is supplied by the high voltage transformer. The spark gap consists of two electrodes separated by a gap, filled with an inert gas. When high enough voltage is applied across it, a spark forms, ionizing the gas, and allowing conduction. As the voltage across the spark gap increases, the charge across the capacitor also increases. When the gap sparks, the capacitor discharges into the primary and the secondary. Thus, the voltage “bounces” back and forth at an extremely high rate. When the rate of discharge between the capacitor and primary coil, matches that of the capacitor and secondary coil, the two circuits will be in resonance. The voltage rises to such high levels that it is discharged through the discharge terminal in the form of an electric arc [2].

1.2.2 MIT Scientist

In 2007, for the first time after almost 120 years, a group of scientist from the Massachusetts Institute of Technology (MIT) led by professor Marin Soljagic had a breakthrough in the principle of wireless energy transfer and carried out a middle

distance wireless energy transfer by resonance coupling of electromagnetism, where its efficiency was about 40%[4]. By using electrodynamic induction, they successfully wirelessly powered a 60W light bulb from a distance of 2 meters. MIT researchers has proposed a high frequency more than 10MHz scheme based on strongly coupled resonance for medium range and non radiative wireless energy transfer. The scheme which is considered to be non-radiative and anti-jamming could achieve a medium range wireless energy transfer. They investigated the range and rate of coupling and the interference of extraneous objects in the view of magnetic field coupling [5].

1.3 Problem Statement

Wireless energy transfer is useful in cases where instantaneous or continuous energy transfer is needed but interconnecting wires are inconvenient, hazardous, or impossible. However, when the battery runs out, users have to plug in their electric device. Many of today's electronic devices, such as cell phones, laptop computers, and personal digital organizers, is that despite their portability and ability to communicate wirelessly, these devices still require regular charging usually by plugging into a wall outlet. The other problem is about of statement is high cost of wiring and maintenance. With wireless energy transfer model, the wiring system at homes or offices also can be reduces. Due its air core design the flux leakage is very high. This results in a high power loss and low efficiency. But when combined with the resonant principle power loss can be reduced with an increase in efficiency. The size of coil is also a problem. This is because the use of a large coil will lead to greater use of space. Therefore, a smaller coil is needed to save space and easy for the product to be kept at home, office or building. From the previous project, the distance between the coils is small. Therefore, the distance should be increase in other to make the product become more efficient by increasing the strength of magnetic fields.

Furthermore, conventional power transfer provides unacceptable problems such as the tripping hazard. Tripping hazard is difficult to prevent unless we think about them as we work with the things that can create them. The only way to avoid the tripping hazard is to reduce the use of wire or it can be improve by Wireless Electricity product. Furthermore, another serious unacceptable problem occurred with current wire power transfer system is people might get electrical shock during flood. There are too many incident happen ill electric shock victims during flood. Wireless Electricity can prevent this incident happen because no wire is required and it's transfer energy in electromagnetic form. Therefore, people will not get electrical shock in this kind of energy transfer.

1.4 Objective

The main objective of this final year project is:

- i. To analyzed the wireless electricity system in term of distance and size of coil.
- ii. To investigate the efficiency of transfer energy wirelessly.

1.5 Scope of Work

Transfer energy wirelessly was chose based on magnetic couple resonator. For the aspects of hardware it consists of a transmitter, a handmade air core inductor which acts as an electromagnetic resonator and a receiver, another copper coil of similar dimensions to which the 3V LED to be powered is attached. We use 12V transformer to step down voltage from 240V to 12V. We will supply 12V AC to make the coil to oscillate and produce magnetic field. It also will connect to function generator to supply high frequency to transmitter. We will analyze the parameter based on frequency and distance. Means, from the prototype model we will show how the distance will affect the transferring of electrical energy transmitter to

receiver. In this project we need to improve distance in range of 6cm-12cm with about 200 numbers of turn of coil and 6cm of coil radius.

1.6 Methodology

This experiment was conducted in order to investigate the energy transfer efficiency of Wi-tricity system. After that, designing the project circuit is important to make sure the efficiency of the system. Last but not least, the troubleshooting will be done to detect the problems that arise in order complete the research.

1.7 Thesis Outline

The remainder of this thesis is organized as follows:

Chapter 1, *Introduction*, the background of the Wi-tricity system control is studied to understand its function and application for human life.

Chapter 2, *Literature Review*, history of wireless energy transfer is analyzed and the propose project is compared with the current technology. Besides that, the others method of transferring energy is also analyzed.

Chapter 3, *Research Methodology*, the proper procedure in designing and manufacturing of the system is discussed.

Chapter 4, *Result and Discussion*, the result of the experiment is presented. The experimental result is discussed and analyzed for future improvement.

Chapter 5, *Conclusions and Recommendations*, conclusions from the results is drawn and a future area for research is recommended.

CHAPTER 2

LITERATURE REVIEW

2.1 Wireless Power Transfer and Application to Sensor Network

Energy constraints are widely regarded as a fundamental limitation of wireless and mobile devices. For sensor networks, a limited lifetime due to battery constraint poses a performance bottleneck and barrier for large scale deployment. Recently, wireless power transfer has emerged as a promising technology to address energy and lifetime bottlenecks in a sensor network.

2.2 WPT Technologies

There are three categories of WPT technologies, namely, inductive coupling, EM radiation, and magnetic resonant coupling.

2.2.1 Inductive Coupling

Inductive coupling works by magnetic field induction, which is an alternating current in a primary coil (connected to a source), generates a varying magnetic field that induces a voltage across the terminals of a secondary coil at the receiver. An electrical transformer is a good example of inductive coupling. Due to its simplicity,

convenience, and safety, inductive coupling has been an important and popular technology to transfer power without wires. It has been successfully commercialized to a number of products, including electric toothbrush, charging pad for cell phone or laptop and medical implants [8].

In 2010, the Wireless Power Consortium approved the world's first wireless charging standard (Qi) for low-power inductive charging ($< 5\text{W}$). Today, inductive coupling is considered a mature technology, and is considered a stepping stone for new WPT developments such as magnetic resonant coupling. Under inductive coupling, power transfer falls off steeply even over a very short distance. It works best when the charging node and power receiving node are close in contact and have accurate alignment in the charging direction. Due to these limitations, inductive coupling is not suitable for WSNs.

2.2.2 EM Radiation

EM radiation emits energy from the transmit antenna of a power source to the receive antenna via radiative EM waves. Depending on the energy-emitting direction, it can be classified into omnidirectional radiation and unidirectional radiation. For omnidirectional radiation, a transmitter broadcasts EM waves in an assigned ISM band (e.g., 850–950 MHz or 902–928 MHz in the U.S.,² both with a center frequency of 915 MHz), and a receiver tunes to the same frequency band to harvest radio power. Although suitable for transferring information, omnidirectional radiation suffers from a serious efficiency problem in energy transfer since EM waves decay quickly over distance.

Moreover, to prevent potential health hazards to humans from EM radiation, omnidirectional radiation is only appropriate for ultra low-power sensor nodes with very low sensing activities like temperature, moisture and light. For most microwave-based systems, wireless power is transmitted on microwave frequencies of either 2.45 or 5.8 GHz, both in the ISM frequency band. In the 1980s, a prototype

aircraft, designed as a communications relay by Canada's Communications Research Center, could receive power beamed from a large ground-based microwave transmitter (about 80 m in diameter). A rectifying antenna, mounted on the lower body of the plane, could receive and convert microwave power (at a frequency of 2.45 GHz) to DC electricity. Unidirectional radiation is not suitable for a WSN due to several undesirable requirements, such as LOS, complicated tracking mechanisms, and the inherent large scale of devices.

2.2.3 Magnetic Resonant Coupling

This technology is based on the well-known principle of resonant coupling, which mean, by having magnetic resonant coils operate at the same resonance frequency so that they are strongly coupled via nonradiative magnetic resonance induction. Under resonant coupling, energy can be transferred efficiently from a source coil to a receiver coil with little loss of energy to extraneous off-resonant objects.

Kurs *et al* highlight his experiment, was to power a 60-W light bulb from a distance of 2 meters away, with about 40 percent power transfer efficiency which significantly differs from inductive coupling that was limited to very close range, or EM radiation that was restricted to low-power (~mW) energy transfer. The diameter of both source and receiving coils was 0.5 m, which means that the charging distance can be 4 times the coil diameter.

Kurs et al. said that, compared to inductive coupling, magnetic resonant coupling can achieve higher transfer efficiency while significantly extending the charging distance from a very close range to several times the coil diameter. Compared to EM radiation, magnetic resonant coupling has the advantages of offering much higher power transfer efficiency even under omni-direction, and not requiring LOS.