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A Breakthrough of Wireless Charging Prototype

Noramalina Abdullah
School of Electrical and Electronic Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia
Corresponding author: Noramalina Abdullah (e-mail: eenora@usm.my)

ABSTRACT In this modern era, every mankind requires a system that can transfer power in a very efficient and safe way. These research fields have become one of the researches' to be studied and considered for implementation into modern technologies. The circuit of the two individual coils that are used and simulated to get the best power transfer efficiency using the specialized software, MATLAB Simulink. The inductive power transfer technique is applied to transfer energy from the transmitter to the receiver through the air gap at an optimum distance to get the highest efficiency possible. By using MATLAB software, the effects of the parameters such as the inductance, resistance, capacitor, and mutual inductance value can be altered to be studied in detail to provide the efficiency goal needed. The relevant parameters that can provide the best efficiency towards the wireless power transfer can also be determined. Finally, the charger efficiency for charging the battery wirelessly can be determined to be charged at a lesser time without wasting the power source energy. The obtained knowledge from the researchers is used to reveal the design which is optimum for power transfer for the wireless charging prototype.

INDEX TERMS *Wireless Charging, Inductive Power, Coil, Air Gap, Efficiency*

I. INTRODUCTION

In wireless technology, Nikola Tesla is known as the father of wireless technology. Most of today's concepts are based on the basic concept which was already created by him [1]. The convenience of the wireless power transmission system (WPTS) through the inductive coupling process will change the way we charge mobile phones and other derivative products with similar concepts [2]. We are moving towards a wireless revolution, where the reduction of bundles and tangled wires is where most of us suffered in using it [3]. There are many technologies where it has been implemented wireless technologies successfully such as WLAN, Wi-Fi, wireless keyboard, wireless mouse, and many more.
There are ultimately many benefits and advantages that can be adapted to daily life usage such as it has good safety compared to wired charging, there is no mechanical wear and tear, and no electric spark [3 and 4]. The application of the wireless charging technology towards charging the battery can be tuned to an automated charging and end of charging which can greatly increase the independence of charging wirelessly of the battery [5]. One of the main disadvantages is that effectiveness in terms of efficiency becomes the most rejected of many companies to apply to modern technology [6 and 7]. Especially it is necessary to use high Q (quality factor) inductors and coupled coils to reduce conduction loss [8]. Besides, the power transfer capability is comparatively less than a wired one due to most of its energy loss as heat to the surrounding [7].

In this paper, a wireless charging system for a battery is developed. A few important parameters such as efficiency, performance, safety, compatibility, and environmental impact were studied and explored. The basic principle of wireless charging is studied and the efficiency of the WPT is derived [9]. The effects of various and multiple parameters on the output and the efficiency are designed using MATLAB Simulink. The system efficiency and amount of power transferred to the output (load) are mainly influenced by the source (transmitter) and load (receiver) impedances [10]. The general principle of the WPT is when the alternating current (AC) passes through the magnetic coil, the magnetic field will be generated across the coil and the magnetic field will be generated from the transmitter will induce voltage in the receiver coil. known as Faraday's Magnetic Induction Law [3]. The overall scheme of the wireless battery charging is designed through the hardware implementation through prototype where it uses the simulation from the MATLAB Simulink to verify for comparison in results value [12].

II. RELATED WORKS

A. Theoretical analysis of SS (Series-Series) topology

For this project, the wireless charging system utilizes the SS topology, so the wireless charging adopts the SS topology [7]. From this, the system circuit will resonate, and the energy will transmit from the transmitting coil to the receiving coil. From the circuit below resistance, inductance and capacitance do exhibit resistive characteristics when the inductance and capacitance resonate. The resistor of the transmitter of transmitter and receiver are R_1 and R_2, respectively. The overall efficiency of SS compensation is better when compared to (SeriesParallel) SP compensation [14].

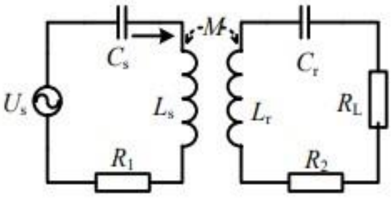

Figure 1. Simplified circuit of SS topology [7]

The researcher has concluded that between the implementation of the SS and SP topology circuits, it has shown that the SS topology circuit has a better efficiency rating versus frequency compared to the implementation of the SP topology circuit

B. Advanced WPT Method

In every near electromagnetic field source, there are two main types of fields that are electric (Efields) and magnetic (H-fields) around themselves [11]. In this, research has classified the far field are electromagnetic radiation whereas the near field is categorized as electromagnetic induction.
The near field has a distance that is less than $\lambda/2\pi$ compared to far-field transfers. It has a related definition between the E-field and H-field where the inductive coupling relates to the magnetic field. This is to add up where the E-field and magnetic field radiation decreases proportionally to distance.

The energy is transferred between the coils through electromagnetic coupling. This method is one of the important and popular technologies to transfer power without wires because of its simplicity and reliability [15]. The drawback of this is that it does have a limitation to a certain distance that it can transfer its energy wirelessly compared to far-field transfer. Apart from that, the benefits are to cover up the far field for instance it has better penetrability, high efficiency, and is practical.
Researchers have proven that H-field provides better higher power transfer efficiency as compared to EField.

C. Choosing Configuration Coil

The transmitter coil is able to produce a magnetic flux that can vary in the receiver coil, thus from here the electromotive force (EMF) is induced indirectly to the Rx coil based on Faraday's Law [11]. From here, the EMF is the one that drives the current in the secondary coil where the magnetic fields are opposing in the magnetic flux which is according to Lenz's Law. Most of the WPT systems implement the two important laws such as Ampere and Faraday's Law that will be related to the receiver and transmitter of the magnetically coupled coils that will then act as the induced coils that aid in the WPT system [11]. From the analysis of combining and mixing the circular, square, and hexagonal into the transmitter and receiver coils, it has been proven that the circular coil in the transmitter and receiver coil shows a better performance in terms of mutual inductance compared to other combinations [13]. As shown in Figure 2, it was proven that the advantage of this spiral design coil does have better efficiency compared to the single circular coil in terms of the distance between the coil's efficiency [9].

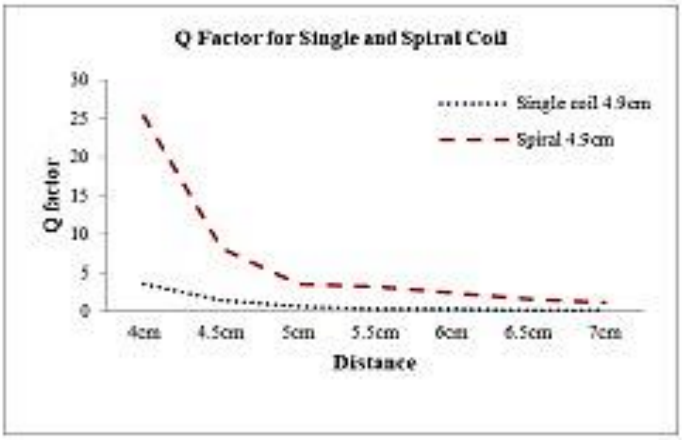

Figure 2. Q-Factor of single and spiral coil [2]

The quality factor of the spiral coil that as shown in Figure 2.6 of the spiral coil design. Figure 2 shows that the spiral coil produces a higher Q factor than the singular circular coil in the experiment results. This is very true as the Q factor does have an effect on the PTE and the effective distance between the coils which the spiral coil satisfies the characteristics.

III. METHODOLOGY

The charging to the battery characteristics of the SS topology circuit is analyzed with the influence of the various parameter on the wireless charging system. The parameters that are mainly analyzed are tested and then replicated with the prototype using the MATLAB Simulink software. In this chapter, the building of a simulation model which included the AC voltage source, full bridge rectifier, inverter-driven WPT circuit, dc chopper, mutual inductance of the coil coupling, and lastly the load resistance which acts as the load charging source are investigated. From the MATLAB Simulink results of the simulation are then compared to the prototype.

A. Planning of Project

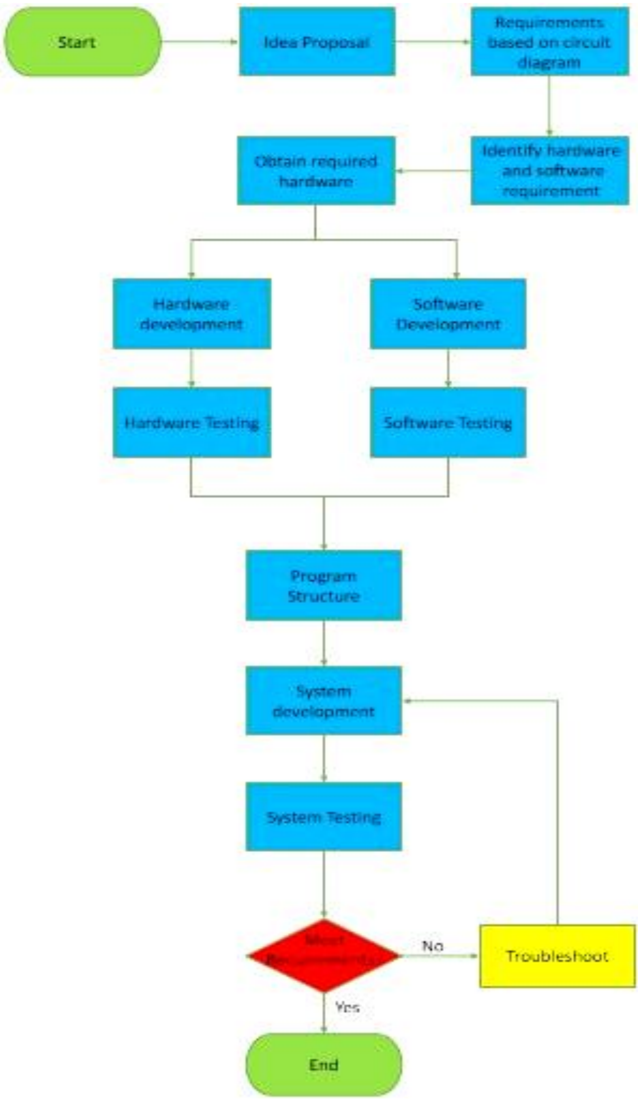

Figure 3. Project Flowchart

B. Data Collection

Data collection is one of the stages of the area of study that will be implemented into the prototype. Data is collected from the value simulated from MATLAB and from the experimental values. At this stage project planning that is obtained from literature review, journal, research papers, and articles are used to create this project. From the data collection, the study regarding the WPT system on the Internet was researched and modified to meet the requirements of the project. Once the project manual was obtained, electronic components and other material resources were researched to meet the objectives of the experiment. During planning, the project related were researched which includes the studying of step-down transformer, electronic components such as the resistor, capacitor, inductor, inductance coil, and the load resistance of the battery.

IV. RESULTS AND DISCUSSIONS

One of the WPT system's efficiency is simulated and detected with the number of turns of the coil. To achieve this, the number of turns of the coil of the transmitter is altered in order to get the highest output power of the system. The receiver coil remains constant in order to detect the maximum efficiency with the transmitter coil altered. The seven scenarios of the WPT system that is used and calculated to get the maximum efficiency and performance of the WPT.

C. Simulation Results correspond to the distance between coils of the coil

The figure below represents the blue and orange line graph which are represented with R, the radius of the coil, and D, the distance between the coils, respectively. The radius of the coils remained the same whereas the distance between the coils was changed.

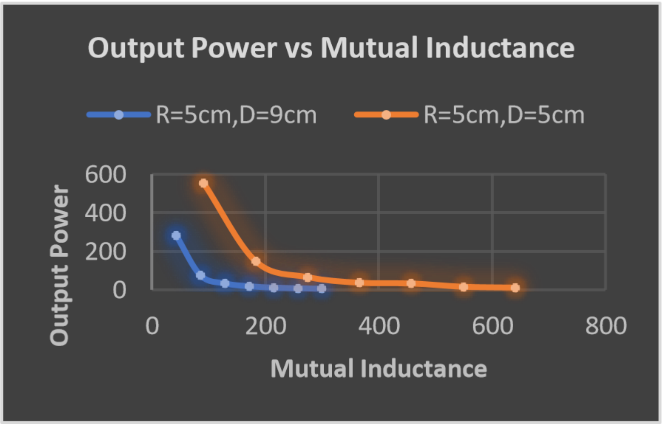

Figure 4. Graph of Output Power vs Mutual Inductance corresponds to the radius of coils.

As can be seen in Figure 4 the distance between the coils in the orange graph which is 5cm is much closer as compared to the blue graph which is 9cm which shows that when their physical distance is closer thus more magnetic flux can be generated within the first coil. Thus, this will induce relatively a larger emf which reduces the loss of magnetic flux. From this analysis, when the amount of emf is large, the output voltage will be higher where the orange line graph is able to peak its maximum power of 554.33W as compared to the blue graph which only can produce a maximum output power of 238.85W.

D. Simulation Results correspond to the radius of coil

This scenario in Figure 5 was studied based on the effects on the radius of coils being altered while maintaining the distance between the coupling coils which is 5cm. The effect of the radius of the coil was able to give a higher mutual inductance value which a peak of 660.59 µH as compared to the smaller coil,5cm was able to reach its peak mutual inductance of 300.11 µH which shows that it has lesser magnetic flux leakage as compared to the blue line graph with a smaller radius.

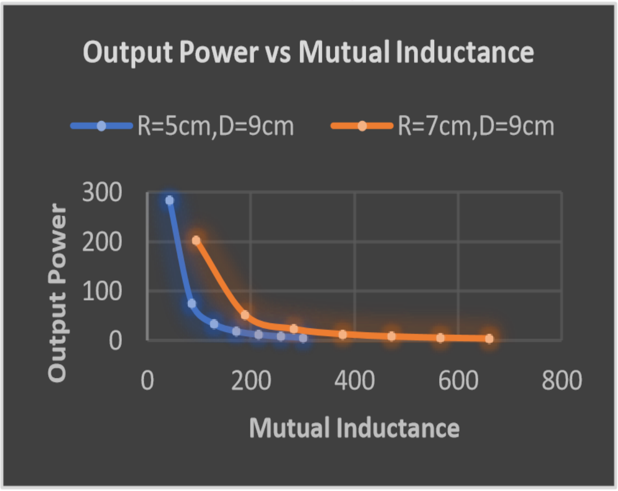

Figure 5. Graph of Output Power vs Mutual Inductance corresponds to the radius of coils.

Apart from that, the output power in the smaller radius of the coil was able to reach its highest peak at 283.85W as compared to the bigger radius which only can be achieved at 203.08W. In summary, it can be said the smaller radius of the coil can greatly reduce the effect of sparse magnetic field intensity which leads to a higher voltage and better efficiency.

E. Different Modes correspond to the same number of the transmitter coil

Figure 6 shows how different modes of how output voltage versus the four main modes being simulated and tested. Number 1 represents data of R=5cm, D=9cm, number 2 represents R=5cm, D=5cm, number 3 represents R=7cm, D=9cm and lastly is the prototype which shares the same mode as number 1. Each mode is taken into account into a constant number of turns of coil which is the number of turns of the transmitter coil is 45 while the number of turns of the receiver coil is 100.

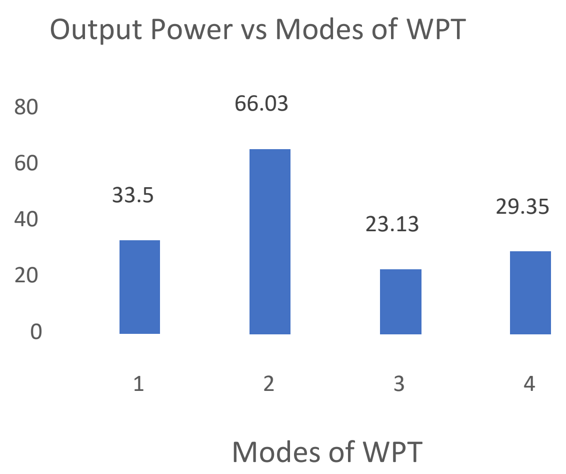

Figure 6 Output voltage vs different modes of WPT

From the bar chart where the number of turns of both coils is the same in Figure 6, it is shown that 2 modes that are number 1 and 2 surpassed the current highest output power of wired charging. Besides, mode 2 has proven to go beyond the limit of 30W barriers which shows that the mode has the highest efficiency among all the modes. The prototype which is mode 4 was able and close to reaching the 30W mark. In conclusion, it is thus proven that mode 2 has given the highest output and efficiency as compared to the rest of the modes based on the same number of turns of coil on the transmitter and receiver coil which is 45 and 100 turns of coils, respectively. The output power is obtained by the formula of Vo x Io which represents voltage output and current output, respectively.

V. CONCLUSIONS

This research provides innovative techniques to improve the performance of wireless power transmission concepts. Based on the thesis, using MATLAB Simulink to design it and compare it with the prototype design, the concept of inductive coupling to WPT was studied and understood. Finally, it can be concluded from simulations and experiments that the efficiency of the WPT system basically is relatively very dependent on the coil radius and the distance between the coils, which plays an important role in providing the generally maximum power output in a sort of major way. As the distance between the coupled coils increases, the output power will decrease due to magnetic flux leakage, which is quite significant. At the same time, a coil with a smaller radius can sort of better literally maintain high output voltage and current, thus achieving maximum efficiency, kind of contrary to popular belief. For future improvement, we have explored 2 aspects to improve the performance of the prototype. The first aspect is the type of magnetic materials such as ferrites to maximize the efficiency of the wireless charging system. The second aspect is using a different conductive material such as copper or aluminum to attain better conductivity and reduce energy loss during wireless power transformation.

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Noramalina Abdullah received her Bachelor's degree in Quality Control and Instrumentation (B. Tech) from Universiti Sains Malaysia in 2000. Then, she pursued her Master degree in Mechatronic and Automation Engineering from Universiti Teknologi Malaysia in 2009. She received her PhD in Electrical Power System in 2015 from Chulalongkorn University, Thailand. Her research interest is power system, electrical fault detection and Internet of things (IoT)