

# Analysis and Design of Wireless Power Transfer

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**Abstract:** One of the most important basic needs of human life today is electrical energy, where the process of shipping from a power source to the electrical load, in general, is still using the power cord. This paper discusses Wireless Power Transfer, which is a way of transmitting electrical energy through the air media so that electrical energy can be transmitted from a power source to an electrical load without using a conductor or cable. The method used for wireless energy delivery systems is by using the principle of electromagnetic resonance induction, which consists of a transmitter circuit and a receiver circuit. The effect of distance between the transmitter and receiver is very influential. The maximum distance that the transmitter can send to the receiver is 5 cm with a voltage of 1.3 volts. The farther the distance between the transmitter and the receiver, the smaller the voltage will be, and the transmitted power will be smaller as well. Similarly, if the distance between the receiver and transmitter is closer, the voltage, and power that can be emitted will be even greater. The maximum power that can be generated from the transmitter circuit at the maximum voltage of the adapter 15 volts at a distance of 2cm is 1.38 watts with a voltage of 2.76 volts.

## 1 INTRODUCTION

Along with the development of technology, we now have developed electrical energy transfer system without using cable.

Wireless Power Transfer is one way to transmit electrical energy through the air media so that electrical energy can be transmitted from a power source to the load without going through a cable. This development has an impact on the reduction of cable usage because it can be replaced by Wireless Power Transfer.

Wireless energy delivery technology was first discovered and introduced by a physicist named Nikola Tesla by building a tower named Wardenclyffe Tower (Ahsan, 2015) shown in Figure 1. However, this study was discontinued for cost reasons. Subsequent research on the delivery of wireless energy was halted for decades until it was re-developed by MIT researchers Marin Soljajic in 2007 who managed to transfer electrical power without cables with a distance of more than 2 meters and power of 60 watts, where the efficiency reaches 40 % (Kurs, 2007). Even in subsequent research, it has been developed for the implementation of

Wireless Power Transfer system for transportation system especially railway (Hwang, 2012).

The delivery of wireless electrical energy is a method of sending electrical energy from a power source to an electrical load without the use of a cable intermediary. Generally, the Wireless Power Transfer system consists of a series of Transmitters and Receiver circuits.



Figure 1: Wardenclyffe Tower (Ahsan, 2012).

## 2 MATERIALS AND METHOD

There are two underlying concepts about the transmission of electrical energy without cables, namely the concept of near field and the concept of far field (Stanimir, 2012). With a near-field method, it is capable of transmitting electrical energy just less than 1 meter while the concept of far-field allows further distance delivery.

The delivery of electrical energy, as well as the transmission of wireless information based on the concept of far field, i.e., a laser beam (narrow beam) and radio waves, is often used in the field of telecommunications. Radio transmission is very ineffective in the delivery of wireless electrical energy because most of the radiated power delivered is wasted into free air. To increase the amount of energy that can be captured by the receiving side, the power delivered from the sender side must be large as well.

With the concept of direct radiation as shown in Figure 2, the antenna is directly directed from the source to the receiver, the energy acceptable to the receiver is increased, but it will have a direct impact with the organism and can be dangerous. So the concept of direct radiation cannot be used either in the delivery of electrical energy without wires.

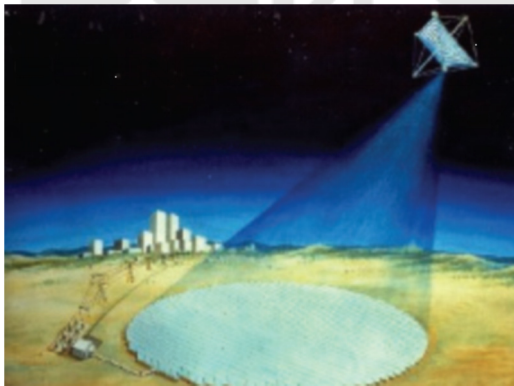


Figure 2: Direct Radiation Concepts (Stanimir,2012).

The technology of wireless power transmission referred to in this paper is non-irradiated and refers to the near-field method. The concept of the near field is different from that of radio waves and direct radiation because the process of power delivery does not require a barrier between the transmitter circuit and the receiver circuit.

Electromagnetic induction is an event of electric current caused by the change of magnetic flux. Magnetic flux is the number of lines of magnetic force penetrating a plane.

In a transformer, an electric current flows into the primary coil and induces the secondary coil, the two coils are not touching but are at a very close distance. The transformer's efficiency level will be greatly reduced if both coils are kept away.

EMF (Electromotive force) induction can occur at both ends of the coil if inside the coil changes the number of magnetic force lines (magnetic flux). EMF arising from the change in the number of magnetic force lines in the coils is called EMF induction. Electric current induced is called induced current. The incidence of induced EMF and induced current due to changes in the number of magnetic force lines is called electromagnetic induction.

### 2.1 Factor magnitude EMF

There are three factors that affect EMF induction, namely:

- The speed of magnetic movement
- Number of windings (N)
- Magnetic field (B)

The electric flux generated by the B field on the surface of the area of dA is represented by Eq. 1.

$$B = \phi / A \quad (1)$$

Where :

B = Power field strength (Wb / m<sup>2</sup> or Tesla)

$\phi$  = electric flux (Weber)

A = Surface area (m<sup>2</sup>)

### 2.2 Inductance

The inductance is a property of the circuit that connects the voltage induced by the flux change with the rate of change of current (William, 1984). The initial equation which can explain the inductance is to connect the induced voltage to the rate of flux change which includes a circuit. The induced voltage is represented by Equation 2.

$$e = \frac{d\phi}{dt} \quad (2)$$

Where :

e = induced voltage (Volt)

$\phi$  = number of series axle fluxes (Weber-turns)

If the current in the circuit varies, the magnetic field it generates will also vary. If it is assumed that the

medium in which the magnetic field is generated has constant permeability, the amount of the coupling flux is directly proportional to the current, and therefore the induced voltage is proportional to the rate of change in current. So the induced voltage obtained can be shown by Equation 3.

$$e = L \frac{di}{dt} \quad (3)$$

Where:

L = Inductance (H)

at / dt = Current rate change (A / s)

### 2.3 Principle of Energy Delivery Magnetic

The wireless energy delivery system uses the principle of electromagnetic resonance induction consisting of a transmitter circuit and a receiver circuit. In the transmitter circuit, an alternating current source is rectified in advance with a DC module, then into the LC circuit, in this case, the Inductor (L) and capacitor (C), to create a non-radiative, On the receiver side circuit, there is also an LC circuit, where L and C function to generate resonance from the magnetic field generated by the transmitter circuit to receive electrical power. This type of winding will be designed in a Wireless Power Transfer system using a copper cable. As for many windings required for the sender, the side circuit can be found using Equation 4.

$$L = \frac{r^2 N^2}{9r + 10l} \quad (4)$$

Where:

L = Inductance (H)

N = Number of turns

r = The coil radius (m)

l = Length of coil (m)

The design of the winding at the receiving end shall be equal to or close to the existing coil on the sender side.

### 2.4 Electromagnetic Resonance

Electromagnetic resonance is closely related to the phenomena of the electromagnetic field which is also closely related to the process of electric current.

Electromagnetic fields can be classified in electric fields and magnetic fields. And because the magnetic field is much safer when compared to the electric field, the magnetic field becomes an appropriate choice to be used as an energy delivery medium when compared to the electric field in its utilization for electromagnetic resonance energy transfer (Kautsar, 2010).

Two systems with the same resonant frequency will produce strong magnetic resonance and form a magnetic resonance system. If there are more than two resonance generators in the range that are still effective, they can also join this magnetic resonance system. The magnitude of the resonant frequency can be calculated using Equation 5.

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (5)$$

where :

$f_r$  = Resonance Frequency (Hertz)

L = Inductance (Henry)

C = Capacitance (Farad)

### 2.5 Experimental Set up

The method used in the delivery of cordless electrical energy is by using the principle of electromagnetic resonance induction. The steps taken in the manufacture of this cordless energy transfer system are as follows:

In the initial calculation phase, a calculation of the area of the loop cross-section, the number of loops and the length of the wire required to form the transmitter and receiver windings.

The design of Wireless Power Transfer system is done by using software for electronic circuit design. Wireless Power Transfer System consists of a series of Power Supply, Transmitter, and Receiver. The Power Supply circuit intended in this research is a series of adapters. This Adapter circuit serves to convert electric current from AC current into DC current. A DC Power Supply or Adapter basically has 4 main parts in order to produce a stable DC current. The four main parts are shown in Figure 3, i.e., Transformer, Rectifier, Filter and Voltage Regulator.

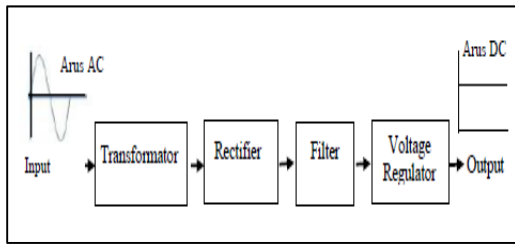


Figure 3: DC Power Supply Block Diagram (Adapter)

The transmitter circuit is a very important circuit in the Wireless Power Transfer system because without a transmitter circuit the electromagnetic resonance process will not happen and the transmission of electrical energy without cables is not possible. The transmitter circuit works on the principle of electromagnetic resonance generated by an oscillator. The oscillator functions as a resonator that generates electromagnetic waves of a certain frequency and is induced inductively to the receiver circuit. The oscillator used in this paper is Osley Oscar.

The Receiver circuit consists only of the inductor in the form of a wire winding which is not much different from the wire winding on the transmitter which is then connected to the load. The Receiver circuit acts as a magnetic resonance induction capture from the transmitter circuit to receive electrical power to be supplied to the load. The diagram block of the Wireless Power Transfer system comprising the transmitter and receiver circuit is shown in Figure 4.

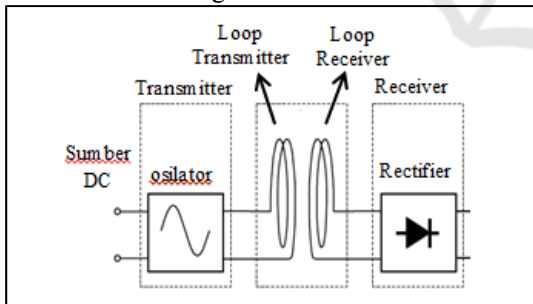


Figure 4: Block Diagram of the System.

The wireless energy delivery system that has been designed is shown in Figure 5.

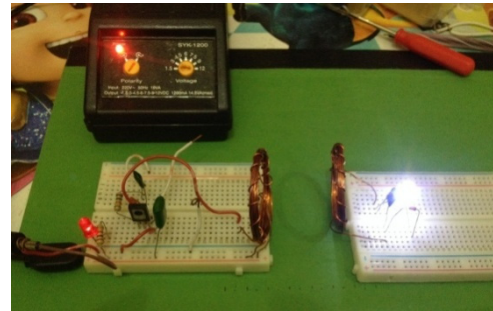


Figure 5: Wireless Power Transfer Setup.

Testing of Wireless Power Transfer system is done on two types of copper loops with different diameter cross-section. The diameter of the first copper wire is 0.3 mm and the diameter of the second copper wire is 0.6 mm. For each type of copper wire diameter tested, 3 kinds of testing are done by varying the input voltage ranging from 8 volts, 12 volts, and 15 volts. As for each tested voltage, the value also varied the distance between the transmitter and receiver side until the LED indicator lights up.

### 3 RESULTS AND DISCUSSION

The results data of all the tests that have been performed are shown in Table 1. Of the three tests performed, the magnitude of the voltage sent from the sender side greatly affects the acceptable voltage. The distance between the transmitter and receiver side also greatly affects the acceptable voltage level. The farther the distance between the transmitter loop and the receiver loop shown in Figure 4, the more acceptable power the receiver side will be. The effects of electromagnetic fields that can be captured by the side of the smaller receivers make the acceptable power smaller. Similarly, if the distance between the transmitter and the receiver's side is closer, the electromagnetic field generated by the transmitter side will be greater captured by the receiver side.

Table 1: Data Testing the cross-sectional area of the loop of 0.6 mm.

Source (Volt)	Distance (cm)	Received (volt)	I <sub>transmit</sub> (A)	I <sub>received</sub> (A)	LED Indicator
8	2	2.6	0.058	0.019	ON
	2.5	2.5	0.056	0.018	ON
	3	2	0.043	0.008	OFF
12	2	2.68	0.08	0.03	ON
	2.5	2.60	0.078	0.026	ON
	3	2.34	0.076	0.012	ON
	3.5	2.02	0.075	0.004	OFF
15	2	2.76	0.117	0.034	ON
	2.5	2.68	0.116	0.028	ON
	3	2.63	0.113	0.015	ON
	3.5	2.57	0.112	0.009	ON
	4	2.51	0.11	0.005	ON
	4.5	2	0.09	0.001	OFF

From the test data in Table 1, when the 8-volt source voltage with the distance between the sender and receiver side 2 cm and 2.5 cms, the accepted voltage by the receiver side is 2.6 volts, and 2.5 volts and the LED indicator lit with currents of 0.019 amperes and 0.018 amperes. But when the distance between the transmitter and the receiver side is 3 cm the LED indicator turns off, with the voltage on the receiver is 2 volts.

The maximum power that can be generated from the transmitter circuit at the maximum voltage of the adapter 15 volts at a distance of 2cm with a voltage of 2.76 volts and maximum current 0.034 A. The Power output, therefore, can reach up to 1.38 watt.

The affecting factor is the increasing distance of transmission between the two coils so that the electromagnetic induction will also be smaller.

Conversely, when the closer the voltage gets bigger the better the radiated power so that the LED indicator lights very bright.

## 4 CONCLUSION

Based on the results of the discussion the conclusions are:

1. Transfer of electrical energy can be done without using cable.
2. The farther the distance between the receiver circuit and the transmitter circuit the smaller

the power that can be received by the receiver circuit.

3. The change in energy value sent is proportional to the input energy given, the greater the input energy, the greater the energy delivered.
4. The maximum power that can be generated from the transmitter circuit at the maximum voltage of the adapter 15 volts at a distance of 2cm is 1.38 watts with a voltage of 2.76 volts.

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