Maximum efficiency scheme using superimposed and Taguchi method wireless charging for mobile phone

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Abstract: The magnetic resonance inductive coupling energy transfer from transmitter to receiver is designed in this project through magnetic inductive coupling. The transmitter sends energy through induction to the electrical devices from the transmitter to the receiver and then stores the energy in the batteries. Because the transmitter coil has a gap with the receiver coil. This wireless charging using two methods to show the output, first using the Taguchi Method and second using Superimposed Technique. The Result shows that output voltage must high than the input voltage and the same at secondary coil because using the same number of turns. The output voltage at the voltage regulator shows the output must in 5 Volts to charging the mobile phone with high efficiency.

1. Introduction

Mobile phone, also known as a mobile phone or handheld phone, and now the latest one, called a smartphone, is a device where a person can communicate with others basically by making and receiving calls using a radio link while moving across a wide geographic area [1]. For many applications that are used, the use of a mobile phone battery is not sufficient. Consequently, many companies have recently created a wireless charger for their mobile phone due to the widespread battery power of use that is not sufficient to accommodate continued mobile phone use. Because the wireless charger simplifies charging, it is necessary to use the smartphone widely at this point. Wireless communication would be the transmission of a distance in the energy without the use of wires or cables, where the distance could be short or long. Other methods are radio waves, such as microwaves or light technology beams [2]–[4]. This is not a new technology, but it will be possible for the user to prove that the phone can be charged without a cable [5].

Near-field WPT refers to the transmission energy distance within the transmitter antenna's wavelength. Depending on the type of coupling technique used, near-field mechanisms can be categorized into four groups which are magnetic resonant coupling, inductive coupling, capacitive coupling and magnet dynamic coupling[6]. Magnetic resonant coupling and inductive coupling are the most suitable methods because the amount of transfer power in capacitive coupling increases with the capacitance between the plates and the frequency. Therefore, the condenser's total surface area will be increased and the size will be large and high voltages will be required on the condenser plates [7], [8]. Next, two ways or methods that can be used in this project have been found from the research. The method used was the Taguchi method and the technique of superimposing. The Taguchi method which uses many parameters to obtain the parameter's best result [9]. For the superimposed technique, this technique actually uses at inverter that has must add component at the circuit of the inverter [10]. This paper consists of a transmitter and the receiver, another copper coil of similar size and diameter to which the mobile phone is attached to the powered. To make the coil oscillate, it will supply DC
and produce a magnetic field. Then analyse the circuit use the superimposed method at the transmitter circuit. Taguchi and Superimposed technique were used to increase the efficiency of wireless power transfer and compare the Taguchi and Superimposed power factor performance with the original circuit wireless charging.

2. Methodology

**Superimposed Technique**

For wireless charging, Superimposed Technique is using a transmitter circuit between the transmitter coil and DC power supply. This project has 34 turns for both side, transmitter and receiver circuit. Transmitter circuit will divide with two parts to show the direction, first, 17 turns in clockwise and another 17 turns in an anticlockwise direction. Refer to Figure 1, the superimposed technique is added one inductor at the centre of the transmitter coil and at the positive side of DC power supply. The inductor function to provide direct DC power to the transmitter coil. Value of inductor is using the basic value of another inductor and will change using another method.

Refer to Figure 2, this circuit is added one inductor between the centre of the transmitter coil and positive power supply. For the theory of superimposed technique, the power at the transmitter coil will show two times from the original value power. Based on the value of inductor at the superimposed circuit, this project chooses the 8.6 µH, this value is from the basic value of inductor at the transmitter circuit. This inductor value will change using the Taguchi method to show the power at the transmitter coil and the efficiency. This project still using 30 V as the input to show the different the power of wireless charging before use superimposed technique and after use it. The output of transmitter coil will be in AC voltage because of the DC voltage through of oscillator circuit.

**Taguchi Method**

Taguchi method is using from the original parameters of the circuit. Taguchi will show how the easier
use to show the best result in wireless charging without using formula. In this paper, the Taguchi method also gives a short time to solve the circuit which value is fit the parameters in the circuit of wireless charging. This method easy to use for any experiment especially project using formula.

Table 1. Parameters Of The Simulation System For Transmitter Circuit

| Parameter                  | Value       |
|----------------------------|-------------|
| Voltage Source, Vdc        | 30 V        |
| Capacitor, C               | 6.8 nF      |
| Toroidal Inductor, L1      | 8.6 uH      |
| Toroidal Inductor, L2      | 8.6 uH      |
| Transmitter Coil, Tc       | 34 turn     |
| Resistance, R1             | 93.1 Ω      |
| Resistance, R2             | 10 KΩ       |
| Resistance, R3             | 1 KΩ        |
| Resistance, R4             | 10 KΩ       |
| Resistance, R5             | 93.1 Ω      |
| Diode, D1                  | D4148       |
| Diode, D2                  | D4148       |
| MOSFET, Q1                 | IRF 540     |
| MOSFET, Q2                 | IRF 540     |
| Inductor superimposed, L5  | 8.7 nH      |

Refer to Table 1, the simulation uses a basic parameter for wireless charging. The Taguchi Method at a list of parameters also Superimposed Technique. This method changes the value of suitable with a parameter to choose the best result at output. To choose the best result for efficiency and constant output, this project must change more value of the parameter and use Taguchi method for reduce number of an experiment in the wireless power system (WPT).

Table 2. Parameters for Receiver Circuit.

| Parameter           | Value       |
|---------------------|-------------|
| Diode, D1           | D4007       |
| Diode, D2           | D4007       |
| Diode, D3           | D4007       |
| Diode, D4           | D4007       |
| Resistor, R         | 1 KΩ        |
| Voltage Regulator   | IC LM 7805  |
| Receiver Coil       | 34 turns    |
| Capacitor, C1       | 6.8 nF      |
| Capacitor, C2       | 220 uF      |

Refer to Table 2, these parameters are used for the receiver circuit. This parameter will change use Taguchi method for showing the best output and suitable for that circuit. The Taguchi method will change the value in the same group such as resistor from Table 1, R1 will change with R2. Then the value of R2 will change R1, so choose the best output to show the right circuit using Taguchi method.

3. Result and Discussions

**Value Superimposed Technique**

To determine the value superimposed value, the value also through the Taguchi method to show the best value for the technique it. The value of Superimposed Technique has 4 value, the label value for this method is L5. The basic value comes from the L1 and L2 for Superimposed value without use formula. After choosing the value superimposed, the value will try in simulation to choose the value it. Table 3 and Figure 3 shows that value (1), value (2), value (3) and value (4) use the Taguchi method.
Table 3. Parameter using value Superimposed Technique

| Parameter                  | Original    | Added Inductor for Superimposed Technique |
|----------------------------|-------------|------------------------------------------|
|                            | 8 H         | 8.2 mH                                    |
|                            | 8.6 µH      | 8.7 nH                                    |
| Power (clockwise direction) (W) | 44.48 m    | 42.516 m                                  |
|                            | 32.067 m    | 16.772                                    |
|                            | 0.102       | 0.1                                        |
|                            | 0.069       | 0.149                                      |
|                            | 0.149       | 0.957                                      |
| Voltage (V)                | 18.507      | 18.529                                    |
|                            | 18.522      | 19.321                                    |
|                            | 24.107      |                                           |

The value of Superimposed Technique as an inductor, L5 is 8.7 nH because the value of power and power factor is higher than other values. Based on Table 1, the result from the original value when using some value of Superimposed technique will affect power transfer, power factor and voltage. The value will use in Taguchi method for all parameter in Table 4. This value will give a different output of power in value (1), value (2), value (3) and value (4).

Simulation using Taguchi and Superimposed Technique for Transmitter Circuit

Using the Taguchi method and Superimposed Technique in transmitter circuit wireless charging, the parameters of value, value (2) and value (4) is quite similar in power but different power factor. The value (3) cannot use it because the parameter is worse than others parameter. Wireless charging can use the value and value (2) for the efficiency of wireless charging. Parameter of value (4) and value (1) also can use because the voltage is higher than others parameters. For use in wireless charging, the efficiency is important to maintain the transmit power from the coil to coil. Value (2) can achieve high voltage than input with a number of turns of the coil as shown in Table 4 and Figure 4.

Table 4. Result Simulation Using Taguchi And Superimposed Technique

| Parameter | Power (W) | Power factor | Voltage (V) |
|-----------|-----------|--------------|-------------|
| Value     | 42.54     | 0.957        | 24.152      |
| Value (1) | 40.72     | 0.678        | 45.392      |
| Value (2) | 43.04     | 0.957        | 24.142      |
| Value (3) | 0         | 0            | 52.679      |
| Value (4) | 39.89     | 0.677        | 45.344      |
Simulation use Taguchi Method for Receiver Circuit

The parameters for the Receiver circuit is shown in Table 5. This table uses the Taguchi method like the Transmitter circuit. The Receiver circuit uses the Value parameters because these parameters show the best output.

| Parameter      | Value  | Value (1) |
|----------------|--------|-----------|
| Capacitor, C1  | 6.8 nF | 220 uF    |
| Capacitor, C2  | 220 uF | 6.8 nF    |

The part of the receiver, this project will choose the parameter value because the voltage at the receiver coil is quite the same but the voltage at the voltage regulator is a bit different. For voltage value is 5.001 V and the value (1) is 4.993 V. This voltage shows the parameter value is higher than the value (1). This value has different because the changes of value capacitor, refer Table 6.

| Parameter      | Voltage at Secondary Voltage (V) | Voltage at Voltage Regulator (V) |
|----------------|----------------------------------|----------------------------------|
| Value          | 24.169                           | 5.001                            |
| Value (1)      | 24.107                           | 4.993                            |

The distance between the primary coil and the secondary coil will affect the efficiency of the project for the hardware. If uses Taguchi method can get the best result of output and the best result also depend on the Superimposed Technique. The distance and diameter of the coil are the factors to get the best output. This is why Taguchi and Superimposed Technique are used so that the distance can be improved and get the efficiency of the wireless power transfer can be maintained.

4. Conclusion

The conclusion of the maximum efficiency scheme using the wireless charging method Superimposed and Taguchi for mobile phone is included already shown in this paper. From the research, the two methods use technique and Taguchi method superimposed in this project. The Taguchi method used for each component's parameter and value includes the new component from the superimposed technique circuit. In addition, many wireless transmission methods such as short, mid-range and long-range transmission. This project selects the short-range, using the two methods. From the result, Table 2 and Table4 output voltage showing the circuit wireless charging using Taguchi method and Superimposed technique. The goal of this project was to design and implement inductive coupling for wireless power charge. This project also showed that there will be significant improvements in the efficiency of wireless power transfer. In a wireless charging system, this project already used the two methods will yield the best result. Now, without wires, the world can transmit power, it's not a theory but a reality.

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