



Design and Development of Wireless Power Transmission System Optimization Using Spiral Coupled Inductor Based on IoT and Electromagnetic Induction Principle

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Article Info

Article history:

Submitted: October 5, 2024

Final Revised: October 18, 2024

Accepted: October 18, 2024

Published: October 30, 2024

Keywords:

Wireless Power Transfer

LCD

IoT

Electromagnetic induction

ABSTRACT

Wireless Power Transfer (WPT) constitutes a system designed to distribute electrical power without the utilization of cables as the connecting medium between the power source and the load. This system employs air as the transmission medium for energy via a sending circuit, referred to as a transmitter, and a receiving circuit known as a receiver. The methodology implemented involves the transfer of electrical energy through electromagnetic induction, wherein both circuits are equipped with coils for the transmission of electrical energy. An innovative aspect of this system is the incorporation of LCD and IoT technology for the monitoring of parameters such as voltage, power, and current, as well as for optimizing the distance between the coils and the load. The findings of the study indicate that at a distance of 0 cm between the coils, the WPT system based on electromagnetic induction is capable of transferring electrical energy with a maximum voltage of 18.81 V, a power output of 2.73 W, and a current of 0.145 A. Conversely, at a distance of 24 cm between the coils, the minimum recorded values are 2.94 V for voltage, 0.01 W for power, and 0.001 A for current. The load utilized in this experiment was a 3W LED bulb.

1. INTRODUCTION

In general, copper conductor wires are used to transmit electrical power from the source to the user or load. However, wireless power transmission systems are becoming increasingly important and are under development. Technology that transmits electrical energy without conductive materials such as wires and cables is known as wireless power transmission. This includes a transmitter circuit that produces resonant frequencies, consisting of an oscillator, amplifier, and transmitter coil; in other words, this circuit functions as a DC voltage generator that sends electrical power to the receiving circuit. Additionally, it employs a receiver circuit that acts as a passive circuit without input voltage, where the main function lies in the receiving coil that captures the frequency signal from the transmitter.

WPT primarily utilizes inductive coupling, where a magnetic field generated by the transmitter induces a current in the receiver coil, enabling energy transfer without physical connections ("Wireless Power Transfer", 2022). Efficiency Factors: The efficiency of WPT systems can be significantly affected by the distance between the transmitter and receiver. Closer proximity allows for higher energy capture, with over 70% efficiency achievable at minimal distances, Vikas et al., (2020), Sinaga, (2020). WPT is increasingly applied in various fields, including electric vehicles, medical devices, and consumer electronics, where it facilitates convenient and safe energy transfer ("Wireless Power Transfer", 2022), Meng et al., (2020). Recent advancements include systems capable of transmitting both high and low power packets, enhancing functionality in applications like intruder alarms, Tomasz & Tomasz, (2021). Wireless technology was originally used as a medium for sending information using electromagnetic waves. As time advances, wireless technology can also transmit electrical power by utilizing the phenomenon of electromagnetic resonance, Pradana, A., Zubaidah, T., & Al Sasongko (2018).

Wireless electrical power transmission continues to be developed because the use of cables is considered inefficient in activities and usage Disposable batteries cause other environmental impacts in the

form of electronic waste, Nintyas, F., & Julian, E. S. (2021). Technological developments require the development of wireless power transfer systems. Of the various types of technology, the magnetic coupling-based wireless power transfer system is one of the most widely used technologies, Hendinata, L. K. (2021). The maximum distance that the transmitter can send to the receiver is 5cm with a voltage of 1.3 volts. This proves that the greater the distance between the transmitter and receiver, the smaller the voltage and the smaller the power that can be transmitted, Nurmasyithah, N. (2022). Cordless power transfer is a system of power transfer without using cables that are directly connected between voltage sources and electronic devices that are expected to simplify and improve the quality of human lives, Prasajo, A. K., & Surjati, I. (2019).

2. LITERATURE REVIEW



Figure 1 . Inductor

An inductor is an electronic component that usually consists of a wire wrapped around a toroid or solenoid core. Its function is to store energy in the surrounding magnetic field.

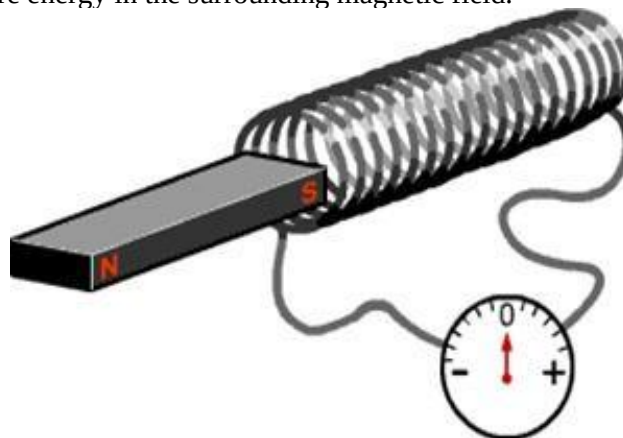


Figure 2 . Faraday's Experiment

Electromagnetic induction occurs when an electromotive force (EMF) appears in a conductor or coil due to changes in the magnetic field lines. Faraday's experiment demonstrated that a magnetic field can produce an electric current when its flux value changes.

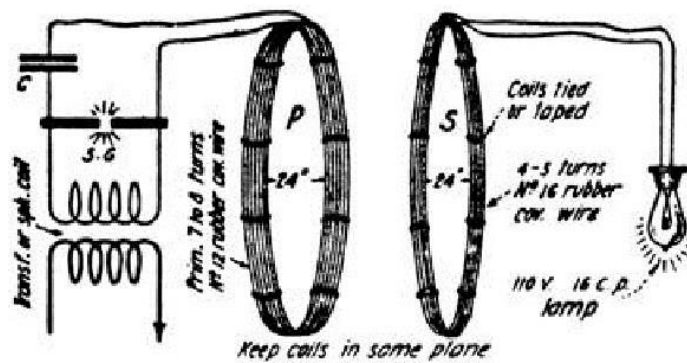


Figure 3 . Wireless Power Transfer

Wireless power transmission techniques utilize the electromagnetic field of a transmitter to send energy to one or more receivers that convert it into electrical energy. This method does not require copper conductors to transfer energy from the voltage source to the load.

3. METHODOLOGY

3.1. Research Design

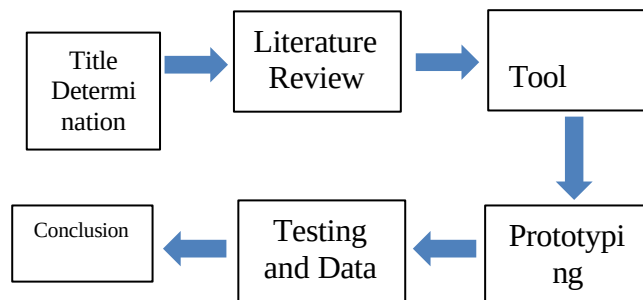


Figure 4. Research Design

3.2. Tool Design

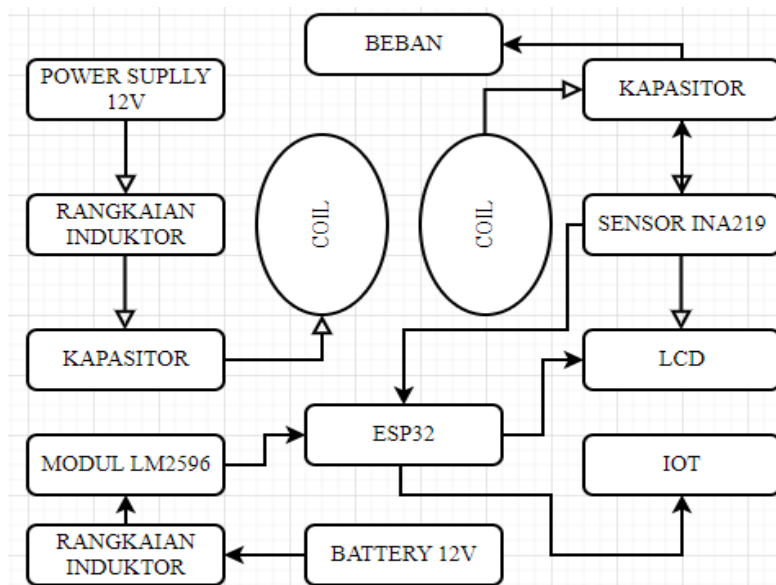


Figure 5. Tool Design

The sender and receiver are two coils in the design. Alternating voltage (AC) to direct voltage (DC) is generated by the power source. The load component consists of an LED lamp that functions as an indicator.

In other components, the ESP32 microcontroller is used as a data processor that will receive data from the sensor, while the sensor used is INA219. The INA219 sensor is a sensor used to monitor voltage, current, and power, which will then be displayed on the LCD and IOT.

3.3. Tool Components

3.3.1 Hardware

1. Inductor

An inductor is an electronic component that usually consists of wire wrapped around a toroid or solenoid core. Its function is to store energy in the surrounding magnetic field.

2. ESP32

ESP32 is a developer platform that is available as open source. Compared to other Arduinos, the ESP32 has an embedded Wi-Fi and Bluetooth module that allows users to easily connect devices to the internet or other devices

3. LM2596

The LM2596 Stepdown Module is a circuit that can drive a 3A load with a high capacity, has low line and crane regulation, and has a good load. This module has a DC-to-DC circuit that uses a step-down PWM (fixed frequency 150 kHz) and the LM2596 Regulator IC. ESP 32

4. INA219

This prototype uses the INA219 sensor, which has the ability to monitor voltage and current power in electronic circuits. The ESP32 microcontroller and INA219 sensor work with a voltage of 5V.

5. Power Supply

A power supply is a useful tool for use in electronic devices because it can be called a battery replacement. The power can convert alternating voltage to direct voltage.

6. Liquid Crystal Display (LCD)

A liquid crystal display (LCD) consists of two main components: a backlight and a liquid crystal. Liquid crystals function to produce images, but the LCD does not emit light; instead, they simply reflect and transmit light passing through them.

3.3.2. Software

1. Arduino IDE



Figure 6 . Arduino IDE

The Arduino IDE open-source software can be installed for free from the official Arduino IoT site and can be used for Windows, Mac OS, and Linux operating systems. Be sure to include the ESP32 port before using the Arduino IDE with the Arduino microcontroller.

2. XAMPP



Figure 7 . XAMPP

XAMPP is a local-host-based server with a General Public License (GNU) program that makes it easy to use and can serve dynamic IoT pages.

3.4. Testing Techniques

1. ESP32 Testing

The microcontroller testing technique aims to determine whether the ESP32 is in good condition and can process data or not. Buck Converter Testing

2. LM2596 Testing

The LM2596 module testing technique aims to determine whether the LM2596 module can reduce voltage perfectly or not. 3. INA219 Testing

3. The INA219

sensor testing technique aims to determine whether the INA219 sensor can read power, voltage, and current from the inductor output properly and normally

3.5. Data Analysis Technique

To solve this problem, the following methods are used to collect data:.

1. Literature research method

The process of exploring and investigating theories that help solve the problem being studied.

2. Library method

Using many reference books and information from lecturers and colleagues, as well as several internet sites, is very helpful in obtaining the theoretical basis used in this paper, as well as references related to the problems raised by the author.

3. Observation method

Includes many reference books and information from lecturers and colleagues, which is very helpful in obtaining theory as a source

4. Calculation analysis

For the construction of the designed components is given through the calculation analysis method.

5. Trials

Carried out to collect information about the results of simulation program experiments that help solve problems.

6. Discuss

consultation and guidance with educators and other parties who can assist in implementing this design.

4. RESULTS AND DISCUSSION

4.1 Research Results

The research results discuss the results of tests carried out on the designed tool. The purpose of this test is to determine whether the tool design works well and whether it has met the planning.

In this study, the thing that must be tested is the monitoring system for the results of electrical energy transfer using an induction system. The stages of testing the monitoring system carried out are the results of power, voltage, and output current from the transmitter circuit to the receiver circuit, which are displayed on the LCD as manual monitoring and displayed on the IOT as automatic monitoring.

4.2. Tool Design

The design creation is an initial description of the project or tool being created. The design creation is divided into the creation of a tool design and the creation of a circuit design.

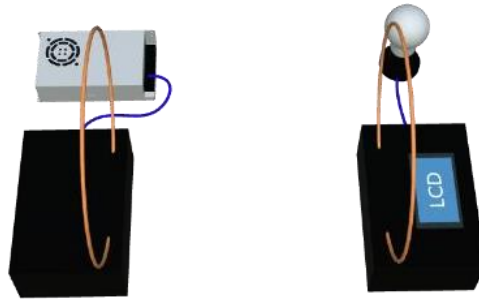


Figure 8. Tool Design

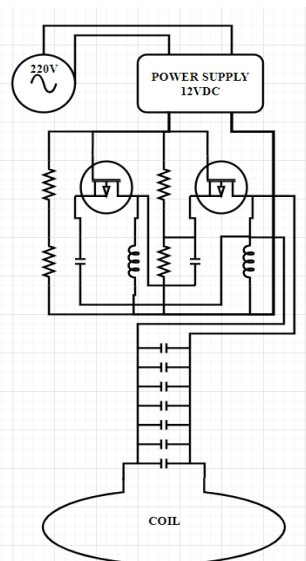


Figure 9. Transmitter Circuit Tool

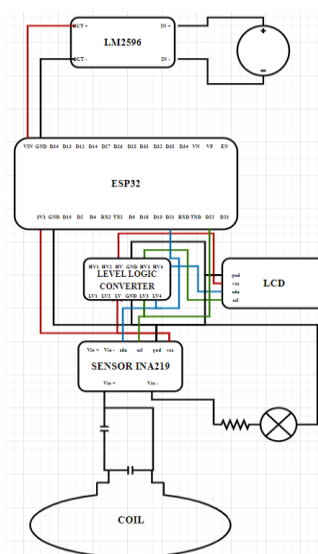


Figure 10. Receiver Circuit Design**4.3. Discussion of Research Results****4.3.1. Solar Panel Testing****a. Power Supply Testing**

Power source testing is carried out to evaluate its performance by measuring and observing the input and output voltages. The following are the measurement results of the power supply.

Table 1. Power Supply testing

Test	V input	V output
1.	217,5 Vac	6,87 Vdc
2.	219,6 Vac	6,91Vdc
3.	221,2 Vac	6,94Vdc
4.	218,3 Vac	6,89Vdc
5.	217,8 Vac	6,87Vdc

Analysis Results:

Power supply testing shows that the power supply is capable of producing an input voltage close to 220 Vac, which is the standard ac voltage in Indonesia, although there are also results below 220 Vac. While the output voltage produced.

b. INA219 Testing

INA219 sensor testing is carried out to determine whether the sensor installed on the device is working normally. INA219 sensor measurements include measuring the input voltage received from the receiver, which is then sent to the LCD to be displayed in visual form and displayed on the IOT as online monitoring. The following is the test data from the INA219 sensor.

Table 2 INA219 Testing

Test	Distance from transmitter to receiver	Voltage
1.	0 cm	17,19 V
2.	5 cm	13,33 V
3.	10 cm	9,27 V
4.	15 cm	6,21 V
5.	20 cm	3,82 V

Analysis results:

Based on the results of the measurement data that have been tested from the INA219 sensor, it can be seen that the sensor can work normally where the measurement data by the multimeter is almost the same as the results displayed on the LCD because there is an error tolerance from the INA219 sensor itself. In taking this data, the author conducted several experiments with different distances so that the data obtained could be compared between the measurements and those displayed on the LCD.

c. LM2596 Testing

LM2596 testing was carried out to ensure that the LM2596 could function normally when lowering the 12V voltage from the battery to 5V for the ESP32 as a microcontroller.

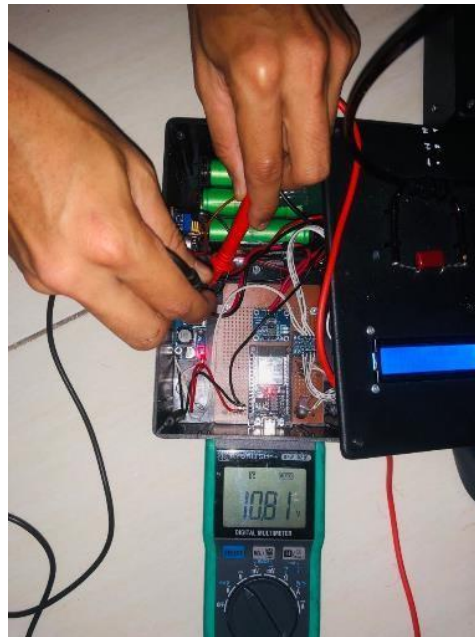


Figure 11. *Input LM2596 Test*



Figure 12. *Output LM2596 Test*

d. Tool Testing

In this tool testing, the author conducted a tool test that aims to compare the magnitude of voltage, current, and power to each distance tested and provide an explanation of the IOT distance testing with the tool. Data collection for this tool testing was carried out by providing a distance between the transmitter and receiver from 0 cm to 30 cm with a difference of 1 cm, and then for testing the IOT distance with the tool, a distance test was carried out between 0 cm to 100 cm with a difference of 10 cm.

Voltage Testing (V)

Table 3. Voltage Testing

Distance (cm)	Voltage (V)		
	IOT	LCD	Manual
0	18,52	18,81	17,06

Distance (cm)	Voltage (V)		
	IOT	LCD	Manual
1	18,04	18,18	16,37
2	17,25	17,54	15,83
3	16,56	16,46	15,07
4	15,68	15,99	14,59
5	14,21	15,39	13,38
6	13,77	15,47	12,88
7	12,32	12,53	11,32
8	11,64	11,98	10,68
9	10,93	11,13	9,77
10	10,12	10,38	9,38
11	9,30	9,55	8,55
12	8,55	8,75	7,99
13	7,83	7,94	7,35
14	7,15	7,24	6,68
15	6,67	6,58	6,18
16	6,02	5,97	5,67
17	5,51	5,39	5,11
18	5,14	4,93	4,63
19	4,67	4,46	4,26
20	4,28	4,09	3,86
21	3,85	3,94	3,54
22	3,52	3,49	3,29
23	3,24	3,21	2,98
24	3,02	2,94	2,74
25	2,86	2,82	2,56
26	2,68	2,59	2,39
27	2,41	2,30	2,22
28	2,26	2,12	1,99
29	2,04	1,87	1,80
30	1,82	1,72	1,68

Test Results: The results of the wireless power transfer test are in the form of an output table in the form of voltage, current, and power. The table above shows the results of the voltage output test carried out from 0 cm to 30 cm using IOT, LCD, and manual measurements. Measurements using LCD show higher results than IOT and manual measurements because the results measured by the sensor are sent directly to the LCD, but if the measurement uses IOT, a stable internet connection is required so that the results show

the same results as the LCD. Manual measurements use a multimeter, which shows the smallest results. This is because manual measurements are prone to shifting of the cathode and anode of the multimeter.

Current Testing (A)

Table 4. Current Testing

Distance (cm)	Current (A)	
	IOT	LCD
0	0,139	0,145
1	0,136	0,140
2	0,128	0,134
3	0,124	0,124
4	0,113	0,120
5	0,099	0,114
6	0,090	0,115
7	0,077	0,088
8	0,075	0,083
9	0,072	0,076
10	0,065	0,068
11	0,058	0,060
12	0,051	0,053
13	0,044	0,046
14	0,038	0,039
15	0,028	0,034
16	0,028	0,028
17	0,024	0,023
18	0,030	0,019
19	0,016	0,015
20	0,013	0,011
21	0,009	0,010
22	0,006	0,006
23	0,004	0,003
24	0,002	0,001
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0

Test Results:

The results of the wireless power transfer test are in the form of an output table in the form of voltage, current, and power. The table above shows the results of the voltage output test carried out from 0 cm to 30 cm using IOT and LCD measurements. Measurements using LCD show higher results than IOT measurements because the results measured by the sensor are sent directly to the LCD, but if the measurement uses IOT, a stable internet connection is required so that the results show the same results as the LCD. Manual measurements are not carried out because manual measuring instruments are unable to read current scales that are too small.

Power Test (W)

Table 5. Power Testing

Distance (cm)	Power (W)	
	IOT	LCD
0	2,577	2,73
1	2,442	2,55
2	2,205	2,35
3	2,040	2,05
4	1,766	1,93
5	1,412	1,76
6	1,232	1,78
7	0,950	1,10
8	0,906	0,99
9	0,789	0,84
10	0,664	0,70
11	0,541	0,58
12	0,434	0,47
13	0,343	0,37
14	0,274	0,29
15	0,185	0,22
16	0,171	0,17
17	0,131	0,12
18	0,098	0,09
19	0,074	0,06
20	0,052	0,05
21	0,035	0,04
22	0,021	0,03
23	0,012	0,02
24	0,005	0,01
25	0	0
26	0	0
27	0	0
28	0	0
29	0	0
30	0	0

Test Results:

The results of the wireless power transfer test are in the form of an output table in the form of voltage, current, and power. The table above shows the results of the voltage output test carried out from 0 cm to 30 cm using IOT and LCD measurements. Measurements using LCD show higher results than IOT measurements because the results measured by the sensor are sent directly to the LCD, but if the measurement uses IOT, it requires a stable internet connection so that the results show the same results as the LCD. Manual measurements were not carried out because the current was not read, which resulted in the power not being able to be calculated.

5. CLOSING**5.1. Conclusion**

Based on the test results and research discussions above, the following conclusions can be drawn:.

1. In this study, the wireless power transmission system uses a real-time online IOT monitoring system with the hope that the wireless power transfer system can be monitored at any time and anywhere if the device still gets a data network or Wi-Fi.
2. In this study, the wireless power transfer system was tested for optimization from the original distance of 0 cm to 30 cm and produced a voltage of 18.5V, a current of 0.139A, and a power of 2.577W at a distance of 0 cm to a distance of 30 cm with a voltage of 1.80V, a current of 0A, and a power of 0W.

5.2. Suggestions

After all the tool tests and writing stages have been passed, the author provides input and suggestions for further analysis to be carried out with the aim of obtaining more precise and accurate results. Here are some suggestions that the author can convey.

1. To get the best results, data collection settings must be carried out carefully and thoroughly. For example, when the distance setting is done manually, if the hand moves slightly and deviates from the set distance, the voltage, current, and output power values of this tool will change, so do it carefully and thoroughly to get more precise results.
2. For further researchers who will develop this tool, add an automatic control system as a distance regulator that can be done automatically and not using manual methods.

5.3. Acknowledgements

The researcher would like to thank everyone who helped the research from beginning to end, especially the researcher's parents and the academic community of Surabaya Aviation Polytechnic.

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