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The Development Prototype of Lightning Strike Detector by Using Internet of Things

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Abstract: Lightning is a serious problem for modern society. Direct lightning strikes can damage or destroy objects and injure or even kill living beings. Indirect lightning strikes can damage electronic goods and microcontrollers. For that reason, lightning strike detection (LSD) is required to minimize losses caused by lightning strikes. Previous research primarily relied on the multi-station method in which the researcher recorded the lightning radius detected by several stations to determine the coordinate point of the lightning in a radius between 1km to 40 km. Therefore, the purpose of this project is to investigate the presence and frequency of a lightning strike. However, due to the dangers of lightning and limitation in a few aspects, the scope of this paper focuses more on the presence of electric current. In this paper, data collection was done through a documentation study by collecting the electric current, time, and the number of electric currents every time pass through the circuit. This method is an easy tool for collecting the data needed in real-time data. The main component to detect the electric current is by using a current transformer (CT) current sensor and comparing the result with the multimeter to test the accuracy of the reading. The result obtained showed that slightly different reading with the error of +-0.02 due to the electric magnetic field and current loss at the CT current sensor. Even though there is a slight error reading, the CT current sensor is still an effective measurement to collect the current data because the measurement results are not affected by the temperature of windings. Using a core with a high permeability with a low hysteresis magnetic material will reduce the error in the current transformer.

Keywords: Lightning Strike, Electric Current, Real-Time Data

1. Introduction

A lightning strike, also known as a lightning bolt, is an electric discharge that occurs between the atmosphere and the earth [1]. Thunderstorms and lightning are two of the most dangerous natural occurrences. They cost a lot of money and do a lot of damage, especially when they happen in a structure. Identification of the specific geographic region where they strike is essential for emergency services to improve their efficacy by providing comprehensive coverage of the impacted area. Due to

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lightning strikes, industrial systems are routinely subjected to high loads, which can cause both direct and indirect damage. The LM-S lightning monitoring system detects and analyses lightning surge currents, allowing the real system load to be calculated [2].

Researchers use many methods to detect the electric charge current flow such as Flux gate using the zero-flux method, Hall element, and even Rogowski Coil [3]. The technique has its advantages and for this paper, the prototype built focuses more on the Current Transformer (CT) current sensor. This device does not need extra driving circuitry to implement. By consuming a little power, it still can measure high current. Figure 1 shows the CT current sensor principles.

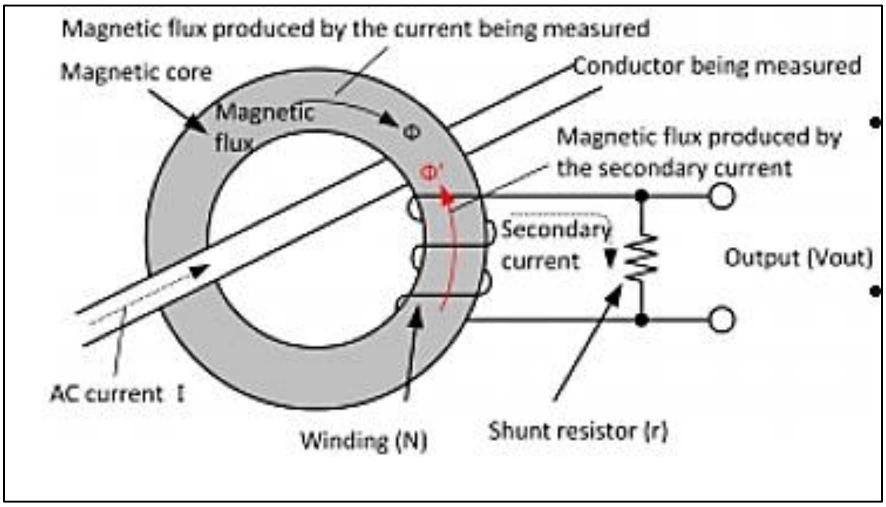


Figure 1: CT Current Sensor Principles

In detail, to counteract the magnetic flux generated in the magnetic core by the AC flowing in the measuring conductor, an AC equivalent to the turn ratio is applied to the secondary-side winding. The shunt resistor receives this secondary current, which causes a voltage to appear across its terminals. The voltage output of the measuring circuit is proportional to the current flowing through the wire being measured [4]. This paper focuses more on the comparison of the reading result and testing the character of each technique. Each technique has its performance and needs to consider a few aspects to choose the best technique.

2. Materials and Methods

The fundamental feature of the development prototype of a lightning strike detector (LSD) is mainly about the process of system architecture, the circuit, suitable hardware, and software collecting the data in real-time data via the Internet of Things (IoT), and plotting the graph result. This prototype uses current measurement principles as it can measure the alternating current (AC).

2.1 Materials and conditions

In electrical engineering, measuring the electric current may use several techniques. In this paper, the CT technique has been chosen as it is easy to use and can measure very high currents while consuming little power. There is another hardware used to complete the architecture. Table 1 shows the main components used to build the prototype.

Table 1: List of specific materials and conditions

Materials	Description
Arduino Uno R3	microcontroller board
SCT-013-000	Current Sensor
ESP8266 NodeMCU	WIFI controller
LCD Display	Display

This paper uses Arduino Uno R3 as a microcontroller as it has the processor board which is ATmega328P and runs at up to 20 MHz. The programming code for the project is connected to the processor via USB. The memory data collected is saved and even when the prototype turns off it still can save the data since the features in the microcontroller consist of 1kb of EEPROM, a memory that is not erased when powered off. The data was transferred using Arduino Wi-Fi Module by connecting the ESP8266 NodeMCU with Arduino Uno R3. Arduino Uno R3 does not have Bluetooth or Wi-Fi in the module hence, to have better communication between the module, to send the command and receive the data. Figure 2 and Figure 3 show the Pinout in the Arduino and NodeMCU, respectively.

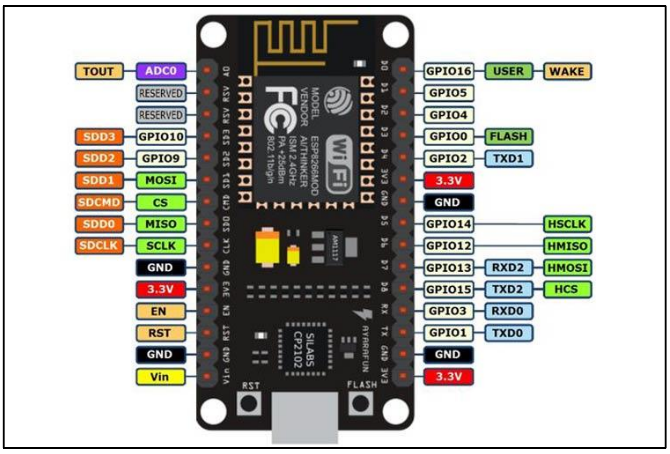


Figure 2: NodeMCU ESP8266 Pinout

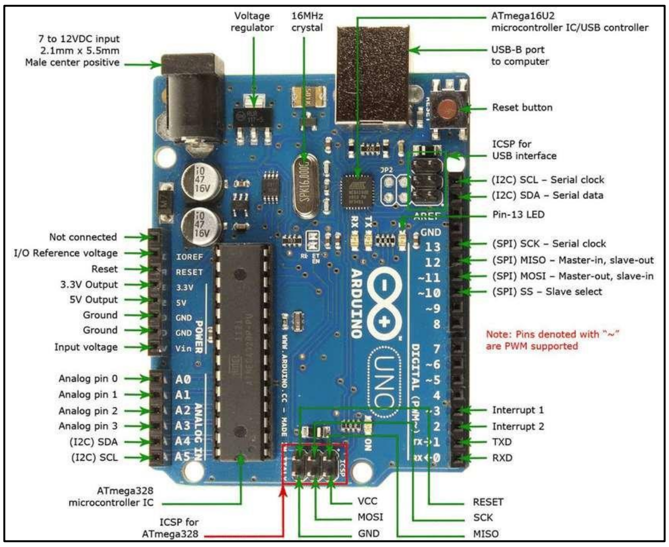


Figure 3: Arduino Uno R3 Pinout

2.2 Methods

The step involves in building a prototype designing, selecting hardware, prototyping, calibrating, developing software, and debugging an LSD system. The entire process of the proposed work began with a thorough assessment of the relevant literature concerning lightning strike detectors, effect lightning protection, and the IoT. Figure 4 shows the process flow of the prototype lightning strike detector system used in this work.

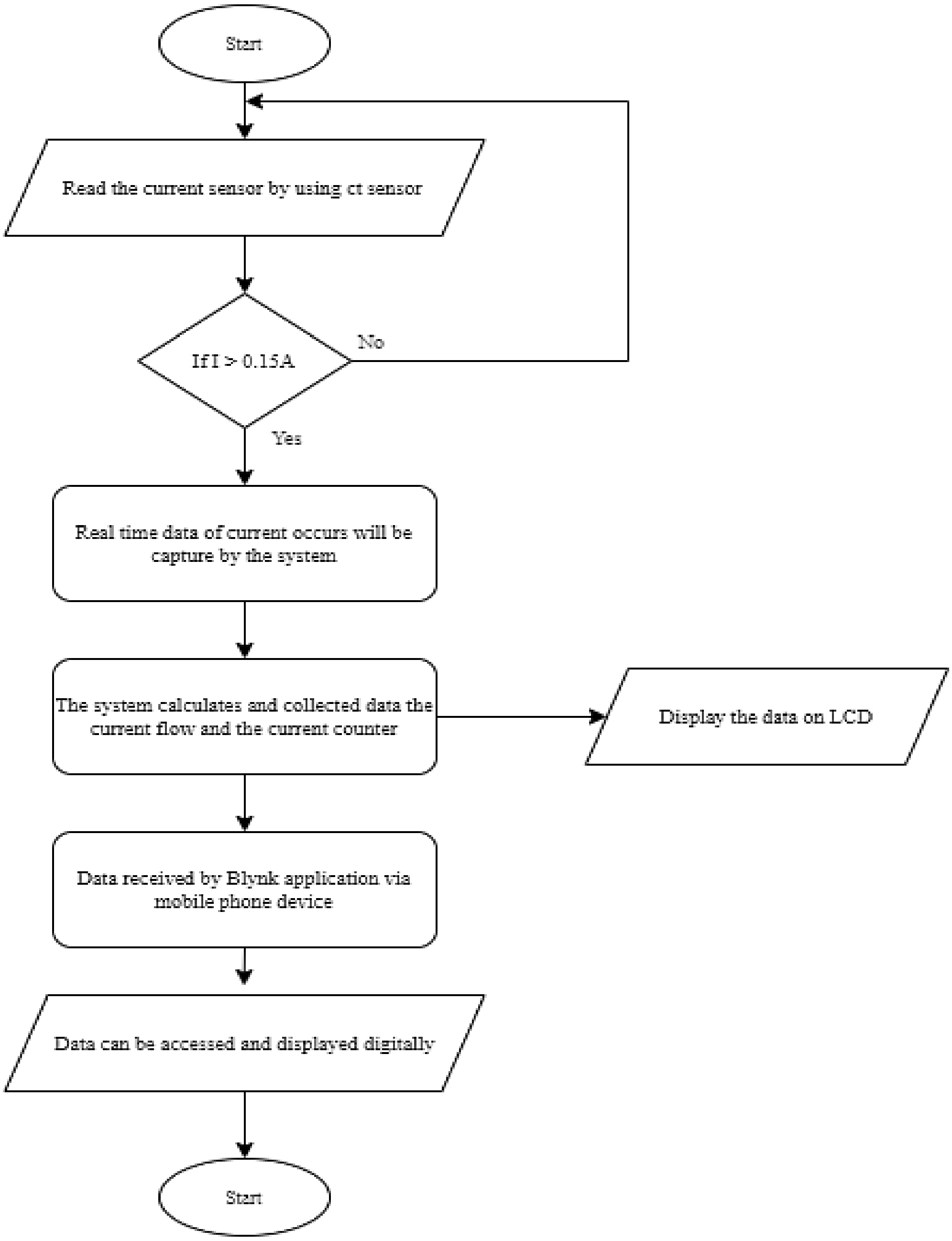


Figure 4: Process Flow of Prototype Lightning Strike Detector System

2.3 Design topologies and specifications

2.3.1 System Architecture of The Prototype

The data collection method begins with the current transformer and the voltage sensor. The current sensor is clamped to the live cable and based on the ratio of the CT, converts the current measurement to a voltage output. The sensors will send an analog current output to the microcontroller. The output from the sensor will be linked to the microcontroller's analog input ports, which in this setup is the NodeMCU Esp8266. Using an ADC converter, the microcontroller will transform the analog input into a digital signal. This microcontroller employs an ADC converter of 10 bits [6-7]. After converting the input, the microcontroller will conduct the calculation algorithm to determine the current and counterstrike. Using Blynk Apps, all data is presented on a protected LCD and monitored mobile phone. It is also important to note that the accuracy of measured current and voltage values should be within 0.02% of the real value. Figure 5 shows the system architecture of the project prototype.

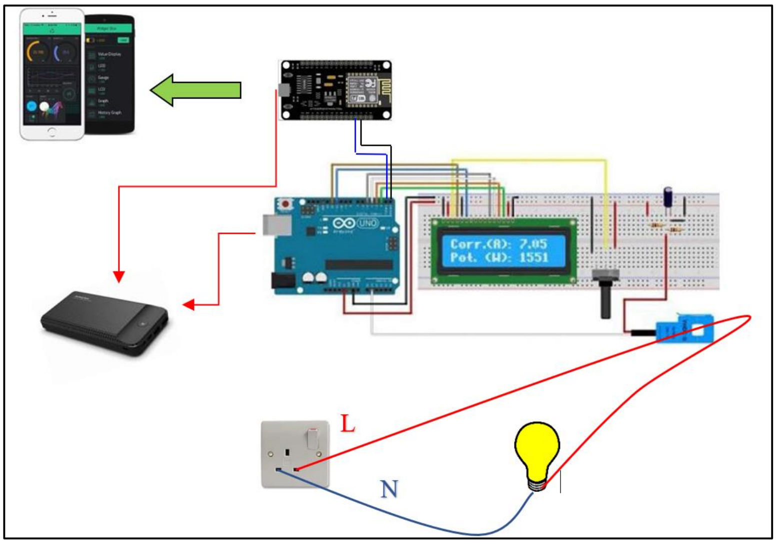


Figure 5 : System Architecture of The Prototype

2.3.2 Blynk as a Monitoring Platform

Blynk software is used as a monitoring platform due it supports both microcontroller and ESP8266 NodeMCU in this project. The USB is used as a connection and controls it through serial communications. However, there is other connections type to use such as Bluetooth and Wi-Fi. Before running the project needs to download the library from the Arduino IDE and place the library in the folder. The NodeMCU has one serial port and that is why this project needs software serial to prevent any crashes during downloading the coding. After finishing the setup in the Blynk, the project can run and monitor via PC and mobile phone. Blynk received the data whenever the CT sensor detects the current. Figure 6 shows the connection of Blynk between Arduino Uno R3 and NodeMCU Esp8266.

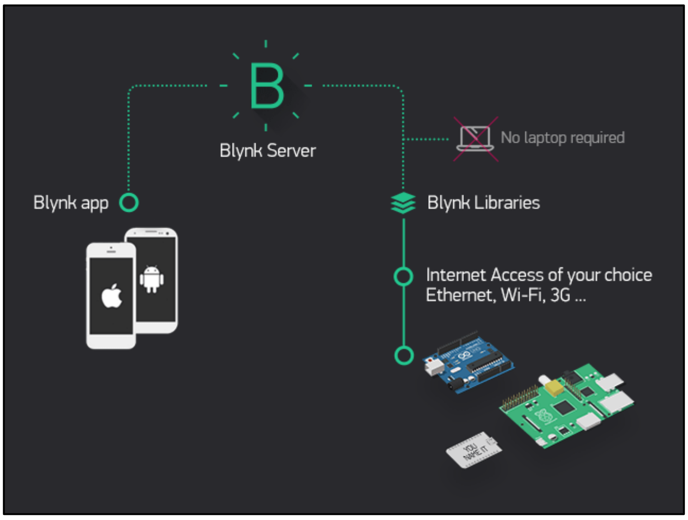


Figure 6: Blynk Connection

2.3.3 Current Sensor Based on Watt's Law

SCT-013-000 sensor is a current sensor that uses Faraday's Law to get the data. The reason for using the current sensor despite other techniques is because when safety requirements require electrical isolation, the sensors automatically create a physical barrier between the current to be measured and the output signal. This makes these current detecting devices obligatory. In a 1-meter wire circuit, 3 live (L), natural (N) and earth (E) wires were connected to the fluorescent bulbs and socket. The presence of a lower current for a single-phase can be calculated [5]:

$$P = IV$$
$$I = P/V \qquad Eq. 1$$

Where;

P = Power (Watts)
I = Current (Ampere)
V = Voltage (Volts)

3. Results and Discussion

3.1 Data Taken by CT Sensor

Data obtained in Table 2 shows that the current sensor detects the alternating current passing the circuit. To test the accuracy of the sensor, this project uses a clamp meter to read the current as well. It shows that the accuracy of the sensor increases at the 7 counter and reaches 0 error reading based on multimeter reading however, the accuracy decreases after counter 9 and becomes inconsistent afterward with the error of +-0.02. The maximum current of SCT013-000 can go is 100A, the current output is 50mA (100A:50mA), the maximum current of SCT-013-030 is 30A (30A/1V), and the voltage output is 1V.

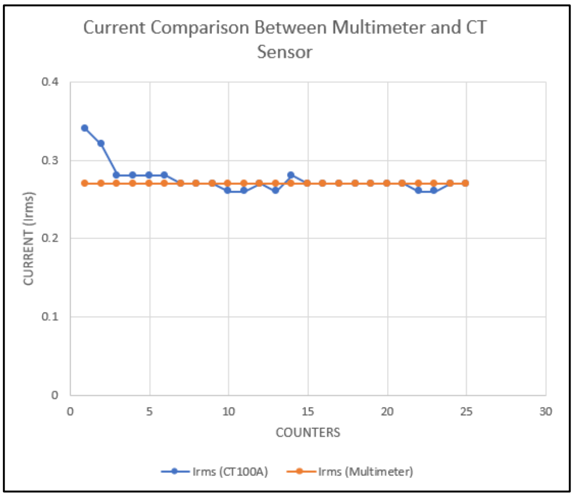
Table 2: Data Taken by the CT Sensor

Counters	Timestamp	Irms (CT100A)	Irms (Multimeter)	Error of CT100A [%]
1	1:46:57 AM	0.34A	0.27A	+20.5
2	1:46:58 AM	0.32A	0.27A	+15.6
3	1:46:58 AM	0.28A	0.27A	+1
4	1:46:59 AM	0.28A	0.27A	+1
5	1:47:00 AM	0.28A	0.27A	+1
6	1:47:00 AM	0.28A	0.27A	+1
7	1:47:01 AM	0.27A	0.27A	0
8	1:47:02 AM	0.27A	0.27A	0
9	1:47:03 AM	0.27A	0.27A	0
10	1:47:03 AM	0.26A	0.27A	-3.7
11	1:47:04 AM	0.26A	0.27A	-3.7

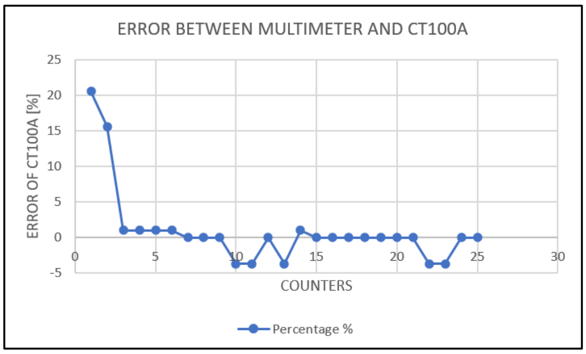
12	1:47:27 AM	0.27A	0.27A	0
13	1:47:28 AM	0.26A	0.27A	-3.7
14	1:47:29 AM	0.28A	0.27A	+1
15	1:47:29 AM	0.27A	0.27A	0

3.2 Comparison between the CT Sensor and Multimeter

As mentioned earlier, a multimeter is added to compare the reading with the CT sensor. Figure 7 shows the graph between the multimeter and CT sensor. From the graph, can conclude that the accuracy can be off only 1-2% with a +-0.02 error.



(a) Current Comparison Between Multimeter and CT Sensor



(b) Error Between Multimeter and CT Sensor

Figure 7: The Reading Taken Between Multimeter and CT Sensor

From Figure 7, the blue line indicates of SCT-013-000 sensor that can go until 100A max while the orange line indicates the graph for the multimeter. The graph shows the inconsistency of the SCT-013-000 reading due to the error. To get the highest accuracy, need to ensure that the core has been properly closed. Even a small air gap can cause a 10% deviation. However, the SCT013 introduces a variable of the phase angle, whose value depends on the load that travels through it and is able to reach up to 30. Figure 8 shows the data taken by the Blynk app.

a) Current Counter b) Current Value

Figure 8: The Real-Time Data Taken by Blynk Apps

As a comparison to Figure 7 and Figure 8, Figure 8 clearly shows that at counter 2 Blynk app collects the current value which is 0.29A, while the data recorded by the SCT-013-000 sensor at counter 2 is 0.32A. There is a slight decimal point difference between the manual reading and the Blynk reading. Data errors are caused by delays in transferring data to the Blynk application from the system and a set of decimal places from the NodeMCU encoding. Figure 7(a) shows that there is a large change between counters 1 to 2 which is 20.5% and 15.6%. This is because the current transformer has an electric magnetic field and has a large storage current or current loss at the start of the reading. In addition, errors may stem from human error and instrumental error when humans take inaccurate readings.

4. Conclusion

The architecture prototype of lightning strike detector (LSD) through the Internet of Things (IoT), in this work the data collected, was electric current, can comply with Industrial Revolution 4.0 which emphasizes the internet revolution conceptualizing rapid changes in technology, industry, and social patterns and processes in the 21st century of increasing connectivity and smart automation. The capabilities of IoT technology today, can facilitate the monitoring of lightning strike devices in appliances even for the entire industrial area can be realized, where instead the data sent to smartphones are displayed at the tip of human hands. Such basic work is capable of measuring currents, and countering electric currents using sensors and displaying them using an Arduino microcontroller. The industry can imply the architecture design with a suitable sensor by replacing the CT sensor with the AS3935 Lightning Sensor.

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