IoT Integrated Electric Vehicle Fire Detection System: Case Study of IMEI TEAM UMSIDA

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Abstract—In the modern era, electric vehicle technology is rapidly developing and emerging as a more environmentally friendly option than fossil fuel vehicles. Despite its many advantages, electric vehicles face safety concerns, especially fire hazards caused by problems with the battery, electrical system, or human error. Fires in electric vehicles can occur due to problems with the lithium-ion battery, accidents, or improper maintenance. Although rare, this risk needs to be considered by following maintenance and safety guidelines. Fire detection systems in electric vehicles are designed to detect and respond to potential fires, provide early warning, and take preventive or emergency action. The system uses NodeMCU esp8266 as the microcontroller, which is connected with a smartphone via WiFi. Data from the MQ2 sensor and the fire sensor are sent and recorded on the IoT platform on the smartphone. This tool is able to detect fires in real-time, but unstable internet or WiFi quality can affect data transmission. Thus, this system is expected to increase safety and reduce the risk of fire in electric vehicles, so that people feel safer and more confident in using this environmentally friendly technology.

Keywords— Electric Vehicles, Fire Detector, Monitoring

I. INTRODUCTION

In the modern era, electric vehicle technology is developing rapidly [1]. When compared to fossil fuel vehicles, electric vehicles (EVs) emerge as a more environmentally friendly option [2]. Although electric vehicles have many advantages, there are still safety concerns [3]. One of these problems is the danger of fire which can occur due to various things, such as problems with the battery, electrical system, or even improper human actions [4].

A fire in an electric vehicle is an incident where a vehicle with electric power experiences a fire [5][6]. This incident can be caused by several factors, including problems with the lithium-ion battery used, a traffic accident that damages the electrical system, or incorrect maintenance [7]. A battery that is overheating or experiencing internal failure could be the main cause [8]. Although fires in electric vehicles are relatively rare, the risk is worth noting, and electric vehicle manufacturers and owners must adhere to established maintenance and safety guidelines to minimize this potential risk and provide a rapid response in the event of a fire [9].

The fire detection system in electric vehicles is a technology designed to detect and respond to potential fires in electric vehicles [10]. The main purpose of this system is to provide early warning to the driver, as well as to take preventive or emergency measures if necessary [11].

This fire detection system is designed to increase the safety of electric vehicle drivers, the design of this tool uses NodeMCU esp8266 which functions because the microcontroller uses a smartphone via WiFi, the reading data comes from the MQ2 sensor and the fire sensor and is then sent and recorded on the IoT platform on the smartphone [12].

This tool is able to detect fires in electric vehicles in real time, the design of this monitoring tool uses NodeMcu esp8266 which functions as a controller in the hardware control system and the IoT platform [13]. Poor and unstable internet or WiFi speed greatly affects the process of sending data from sensors to the IoT platform [14].

Thus, the electric vehicle fire detection system developed using the MQ2 Sensor and Flame Sensor modules is expected to increase safety and reduce the risk of fire in electric vehicles, so that people feel safer and more confident in adopting this environmentally friendly technology [15]. The MQ-2 sensor is a sensor that can detect several types of flammable gases such as butane, methane, LPG, propane, alcohol, hydrogen and can detect PPM of carbon smoke [15].

II. RESEARCH METHODS

A. Research Steps

To achieve maximum results in the research, the author created a flowchart or research plot which was used as a guide or guide for the steps in this research. The research steps are shown in Figure 1.

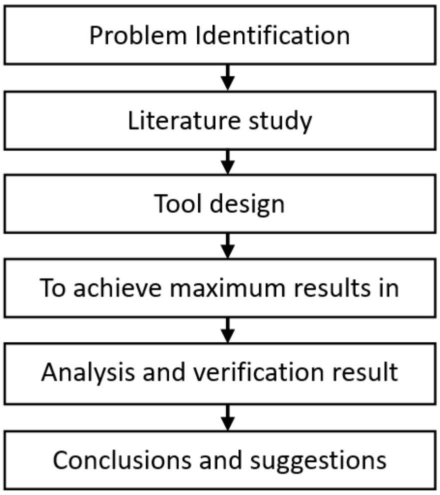

Figure 1. Research Steps

1. Identification of problems

Problem identification was carried out during the Shell Eco Marathon (SEM) competition and Kontes Mobil Hemat Energi (KMHE) to adjust the problems and needs of the team. From the results of the analysis during the competition, the main problems to be solved through the tools that will be created are obtained.

2. Study of literature

To achieve optimal research results, references from various sources are very useful in supporting the writing of the final assignment. By reviewing several scientific journals, books, papers, and other related literature related to tool design, you can gain understanding in identifying problems and finding solutions for this research [16].

3. Tool Design

The IoT integrated electric vehicle fire detection system is designed by combining several electronic components that are connected to a smartphone via an internet network to determine the vehicle's energy consumption in real time and can be accessed remotely [17].

4. Tool Testing

Testing the tool includes checking all the electronic components used starting from sensor readings, reading accuracy, data transmission and displaying the reading results on the smartphone [18].

5. Analysis and Verification

In this case, the resulting data is collected and analyzed. Analysis is used as a reference when carrying out the evaluation process of the results of the tools created [19].

6. Conclusions and recommendations

From the results of experiments, data collection and processing, as well as tool testing, conclusions can be drawn so that in the future readers can improve the tools that have been made by reviewing the suggestions given [20].

B. Block Diagram

To facilitate tool design and tool design, a block diagram of the entire system as a whole is created. The following is a block diagram of the IoT integrated electric vehicle fire detection system: the IMEI TEAM UMSIDA case study is described in figure 2.

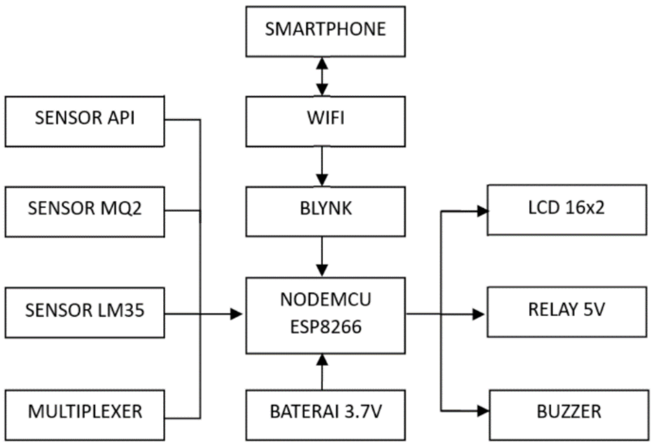

Figure 2. Block Diagram

Figure 2. block diagram, explanation of each block as follows:

1. Fire Sensor is a type of detector used to detect and react to the presence of fire or flame. This is a furnace safety component that monitors and verifies whether there is a fire burning inside the unit. This sensor is a rod that sticks out in front of the stove burner and senses the wavelength of the light source. If the sensor does not detect a flame, the furnace will be turned off to avoid gas leaks. The fire sensor is used to read the presence of fire in the vehicle control room.
2. The MQ2 gas sensor is an electronic sensor used to detect gas concentrations in the air. This sensor can detect gases such as LPG, propane, methane, hydrogen, alcohol, smoke and carbon monoxide. MQ2 gas sensor is also known as chemiresistor. It contains a sensing material whose resistance changes when it comes into contact with the gas. The MQ2 sensor is used to read the presence of smoke in the vehicle control room.
3. The LM35 sensor is a precision integrated circuit temperature sensor that provides an output voltage proportional to temperature in the range of -55°C to 150°C. These sensors are generally used in applications that require high accuracy temperature measurements, such as in industry and commercial buildings2. Manufactured by Texas Instruments, the LM35 is a low-power, low-cost sensor suitable for a wide range of environmental conditions. The LM35 sensor is used to read the temperature rise in the vehicle control room.
4. The ADS1115 multiplexer is a 16 bit ADC or Analog to Digital Converter module so it has a better level of accuracy compared to the analog port from the NodeMCU which only has 12 bit resolution. The ADS1115 multiplexer is used to convert input from analog to digital.
5. *Smartphones*used as a device tasked with remote monitoring.
6. *Wifi*functions as a medium that connects the smartphone with the NodeMCU ESP8266 microcontroller.

7. *Blynk*is an Internet of Things (IoT) software platform that is used to connect IoT-based hardware with an IoT platform. The Blynk application is used as an IoT-based communication device that is capable of monitoring hardware remotely.
8. The ESP8266 MCU node is an electronic component based on the ESP8266 chip with the ability to carry out microcontroller functions and internet connectivity (WiFi). The ESP8266 chip can be programmed using the Lua programming language, and is supported by various IDEs (Integrated Development Environment) such as Arduino IDE and NodeMCU firmware. This research uses nodeMCU as a device for reading data.
9. A 16×2 LCD is a display device that uses liquid crystals to display 32 characters in 2 rows and 16 columns. Each character is made of 5×8 pixel dots. The 16×2 LCD can be connected to a CMOS/TTL device and displays any digit of the ASCII1 code. The 16x2 LCD is used for close-range monitoring.
10. A 3.7V lithium ion battery is used as the main power in hardware which provides electrical power to power each component.
11. A 5v relay is an electromechanical switch that is used to open and close electrical circuits and stimulate small electricity into a larger current. The 5v relay is used as a vehicle battery voltage breaker when smoke/fire/heat is detected.
12. A buzzer is an electronic component that can produce sound vibrations in the form of sound waves. The buzzer is used as an indicator when smoke/fire/heat is detected.

C. Tool Design

Design of an IoT integrated electric vehicle fire detection system using the ESP8266 based blynk application as an IoT integrated communication device with a 3.7V lithium ion battery as the main source. The nodeMCU ESP8266 microcontroller acts as the main controller which will carry out processing and sending data to the IoT platform. This system utilizes IoT communication-based technology to obtain information regarding the presence of fire, smoke and temperature increases in electric vehicles in real time and can be accessed remotely. The overall system circuit is shown in Figure 4.

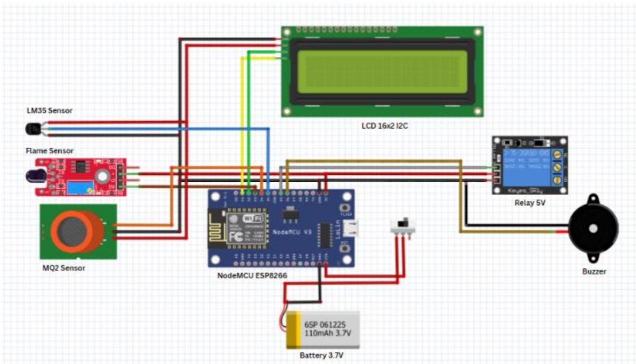

Figure 4. Circuit Schematic

D. Software Design

Software design processIoT integrated electric vehicle fire detection systemuse Arduino IDE software to create programming sketches. Programming is carried out to connect the microcontroller with other hardware such as fire sensors, MQ2 sensors, LM35 sensors and 16x2 LCDs. The process flow diagram of the software work system that has been designed can be seen in Figure 5.

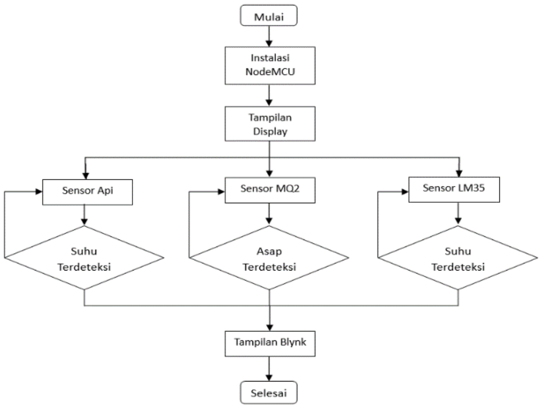

Figure 5. Flow Chart

From Figure 5. the software working system can be explained as follows:

The first process is to start the nodeMCU microcontrol to ensure the microcontrol address is correct. After this stage is complete, each sensor will detect the condition of each detected device. The microcontroller will convert the data collected from each sensor into the required set of parameters. The microcontroller will process the data and show it on the IoT platform which is displayed on the smartphone and 16x2 LCD.

III. RESULTS AND DISCUSSION

A. Hardware Design Results

Fire contains various potential dangers for humans, so we need intelligent equipment that can tell us that a fire has occurred in a public or private transportation vehicle [21]. All hardware components designed in the IoT integrated electric vehicle fire detection system use the ESP8266-based Blynk application as an IoT-based communication device. The hardware system consists of an ESP8266 microcontroller, a fire sensor as a fire detector, an MQ2 sensor as a smoke detector, an LM35 sensor as a temperature detector, a relay as a battery voltage breaker, a buzzer as an indicator when fire/smoke/light intensity is detected, and a 16x2 LCD as screen display on the hardware.

The system workflow for detecting fire is when the three sensors measure conditions in the room. Variables that are indicative of fire are temperatures above 450 C, smoke content above 100 sps and the appearance of fire in the room which is indicated by the large intensity of light detected in the room. If these three sensors detect an indication of fire, the Arduino will process it into a fire warning, so that the warning indicator will light up. The warning is in the form of a buzzer sound and the turning on of the water pump which aims to extinguish the fire. The alert prototype will also send alerts to smartphones. Smartphones can monitor remotely via the internet network using serial communication using the Nodemcu ESP8266 module. The results of the hardware design can be seen in Figure 6.

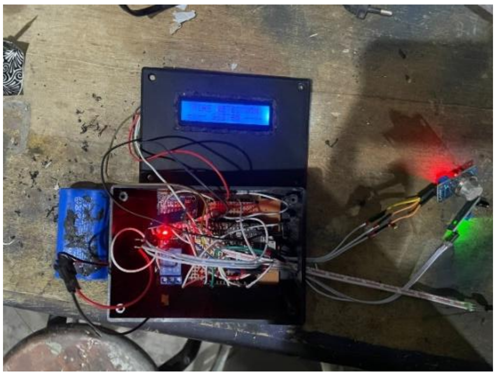

Figure 6. Hardware

B. Software Design Results

Software design for the system uses the blynk application on a smartphone which is connected to the hardware system on the electric vehicle via an internet network. There are several parameters displayed on the Blynk application screen, namely, light intensity value (lux), smoke content value, and temperature value (Celsius). In the Blynk application display, it utilizes the graphic feature to see the magnitude of the changes in energy produced, making it easier to carry out further analysis regarding the strategy to be used, as well as the relay (red) and buzzer (orange) icons which will light up when the value from the fire/smoke/temperature sensor go on. The appearance of the Blynk application that has been designed can be seen in Figure 7.

Figure 7. Appearance of the Blynk Application

C. Flame Sensor Test Results

1. Flame Sensor Testing

Figure 8. Flame Sensor Testisng

The fire sensor testing in this section was carried out using paper media at a distance of 5 cm, 15 cm and 30 cm. The fire sensor test is carried out as in Figure 8. The room light intensity in the fire sensor test is 5 Lux, 15 Lux and 30 Lux. After the light intensity value is obtained, testing is carried out on the fire sensor. Where the results of the fire sensor test are shown in Figure 9 below:

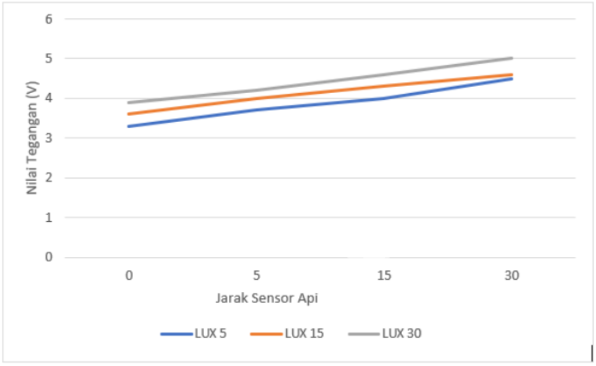

Figure 9. Comparison graph for Fire Sensor testing

Based on the graph in Figure 9, it is known that the fire sensor reading value is influenced by the distance and light intensity. As the distance increases, the sensor reading decreases, this applies to sensor types with a reading range of 0 – 1023, while for sensor types with a range of 1023 – 0 it will be reversed. At a light intensity of 5 Lux, the sensor has a maximum reading point at a distance of 5 cm. For a light intensity of 15 Lux, the sensor has a maximum reading point, namely at a distance of 15 cm, and a light intensity of 30 Lux has a maximum reading point, namely at a distance of 30 cm. It can be concluded that the sensor can read the presence of fire well. Flame sensor readings are influenced by distance and light intensity.

D. Smoke Sensor Test Results

Figure 10. Smoke sensor testing

Smoke sensor testing in this section was carried out using several types of materials, namely wood, paper and cigarettes. The smoke sensor used works by detecting the amount of CO gas in the room. Some types of this material are burned first to produce combustion smoke. When the smoke has been produced, the next step is to place the smoke under the smoke sensor and then test the smoke sensor readings. The results of the smoke sensor test are shown in Figure 11 below:

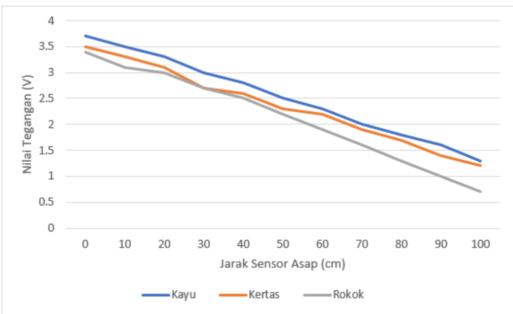

Figure 11. Comparison graph of Smoke Sensor testing using wood, paper and cigarettes

Based on Figure 11 above, the smoke sensor reading value is influenced by the type of material and the density of the smoke produced. This MQ2 smoke sensor is used to detect carbon monoxide (CO) gas. The amount of carbon monoxide gas produced by burning these three materials differs based on the composition of lignin and cellulose. The chemical composition of lignin and cellulose influences the carbon element content. In this research, wood material has a high cellulose and lignin content so that the CO gas produced is also the highest. Paper is a derivative product from wood so it still contains cellulose but in smaller amounts. Cigarettes are made from tobacco which mostly contains cellulose fiber only. Therefore, the level of CO gas produced from combustion is minimal. In this way the sensor can work well as evidenced by the highest CO gas readings in wood materials. The results of measuring CO gas are also influenced by distance because there are several factors, namely the farther the sensor reaches the smoke producing point, the smoke will spread in every direction in a particular room.

E. Temperature Sensor Test Results

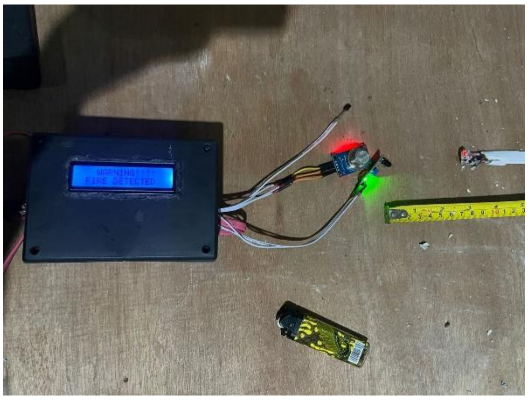

Figure 12. Temperature sensor testing

Testing the temperature sensor in this section is carried out by placing the sensor at the top of the room to obtain accurate reading values as shown in Figure 12. Temperature sensor measurements are carried out at intervals of every five minutes. Where the results of the temperature sensor test are shown in Figure 13 and Table 1 below:

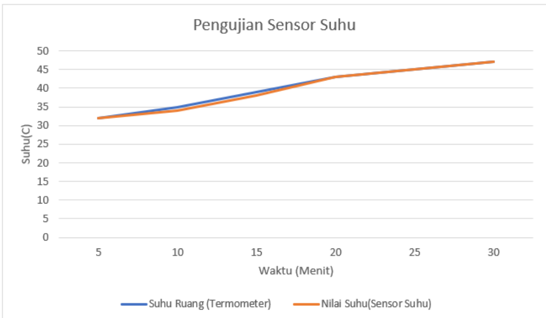

Figure 13. Temperature Sensor Test Graph

Table 1 Temperature Sensor Test Results

No	Time (Minutes)	Room Temperature (C)	ADC value	Rated Voltage (V)	Temperature Value (C)
1	5	32	35	0.32V	32
2	10	35	40	0.34V	34
3	15	39	45	0.38V	38
4	20	43	51	0.43V	43
5	25	45	56	0.45V	45
6	30	47	61	0.47V	47

Based on Figure 13, it is known that the temperature sensor reading value is in accordance with the actual room temperature. The ADC value increases as the room temperature increases. The temperature sensor works well and can detect temperature according to the actual room temperature.

F. Sensor Testing When No Fire Occurs

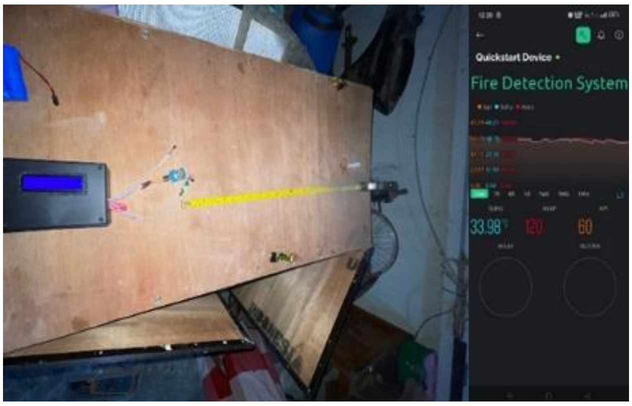

Figure 14 Testing the sensor when there is no fire

Testing of the fire sensor, temperature sensor and smoke sensor in this section is carried out simultaneously with the range setting according to the room conditions. then measurements are taken when there is no indication of fire in the room, the condition indicator on the application will show SAFE. This measurement was carried out with 5 repetitions. Where the results of testing three sensors are shown in Table 2 below.

Table 2 Sensor measurement results when there is no fire

NO.	Flame Sensor		Smoke Sensor		Temperature Sensor		Results
	ADC value	Rated Voltage (V)	ADC value	Rated Voltage (V)	Temperature	Rated Voltage (V)	Fire < 1000 Smoke > 50 Temperature > 45°
1	57	5V	38	0.08V	27°	0.27V	Indicator SAFE
2	50	4.99V	38	0.08V	27°	0.27V	SAFE Indicator
3	56	5V	53	0.18V	27°	0.27V	Indicator SAFE
4	46	4.53V	47	0.14V	36°	0.41V	Indicator SAFE
5	45	4.46V	50	0.16V	38°	0.42V	Indicator SAFE

The variables used as limits in determining safe indications are temperature below 40C, smoke below 350 sps and the fire sensor shows an ADC value below 100. From testing 5 times and in different conditions, the system response shows a safe indicator. The percentage of success on the sensor when there is no fire in the room can be concluded that the success rate reaches 100%.

G. Sensor Testing When a Fire Occurs

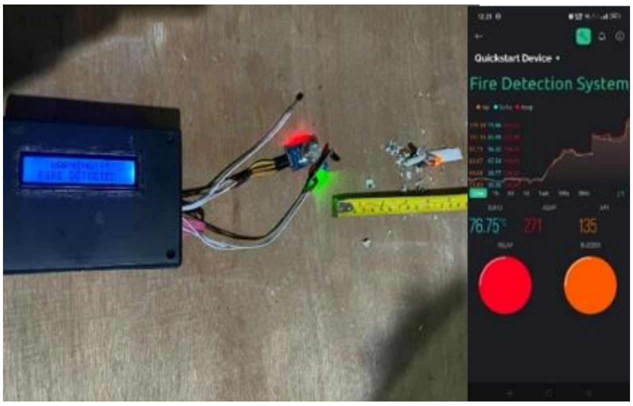

Figure 15 Sensor testing when a fire occurs

Testing of fire sensors, temperature sensors, smoke sensors in this section is carried out simultaneously by setting the range according to room conditions and then measurements are taken when there is an indication of fire in the room. The condition indicator in the application will show danger (WARNING) if the sensor detects a temperature above 40C, smoke conditions exceed 350 sps, and the fire sensor shows an ADC value above 100. This measurement is carried out with 5 repetitions. Where the results of testing three sensors are shown in Table 3.

Table 3 Sensor measurement results when a fire occurs

NO.	Flame Sensor		Smoke Sensor		Temperature Sensor		Results
	ADC value	Rated Voltage (V)	ADC value	Rated Voltage (V)	Temperature	Rated Voltage (V)	Fire < 1000 Smoke > 50 Temperature > 45°
1	107	3.01V	352	1.51V	45°	0.45V	Indicator WARNING
2	105	3V	355	1.54V	47°	0.47V	WARNING indicator
3	108	3.02V	353	1.52V	47°	0.47V	WARNING indicator
4	111	3.04V	356	1.54V	50°	0.50V	Indicator WARNING
5	115	3.06V	360	1.57V	54°	0.54V	Indicator WARNING

When a fire occurs with an indication of temperature above 40C, smoke above 350 sps and the fire sensor shows an ADC value of more than 100, the system will provide a danger indicator. From 5 tests, the system succeeded in showing danger indicators. It can be concluded that the success rate in detecting fires reaches 100%.

IV. CONCLUSION

After designing, implementing, testing and analyzing, it can be concluded that the IoT integrated electric vehicle fire detection system which uses the NodeMCU ESP8266 with fire sensors, smoke sensors and temperature sensors as input is in accordance with the plan and functions well. This system consists of hardware and software integrated into one fire detection control system. The system designed using NodeMCU ESP8266 with input from fire sensors, smoke sensors and temperature sensors to detect fire indications can process information about fires and send this information via LCD and application notifications via the internet network. The software for the IoT-based fire detection control system was created using Blynk software to support remote monitoring via smartphone. The speed of data transmission is very dependent on the speed of the internet network.

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