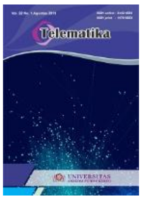

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Forest Fire Detector and Fire Fighting Monitoring System Using Solar Cell Based Internet of Things (IoT)

Raden Jasa Kusumo Haryo[1], Budi Artono[2], Hanifah Nur Kumala Ningrum [3], Kumala Mahda Habsari[4], Isnani Mila Rahma[5]

[1.2.3.4.5.] Teknik Listrik / Jurusan Teknik
Politeknik Negeri Madiun
E-mail: jasakusumo@pnm.ac.id[1] budiartono@pnm.ac.id[2] hanifah_nkn@pnm.ac.id[3]
kumalamahda@pnm.ac.id[4] isnanim25.im@gmail.com[5]

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Correspondece:
E-mail: jasakusumo@pnm.ac.id

ABSTRACT

Forest and land fires in Indonesia, based on National Board for Disaster Management (BNPB) are recorded that the burned area reached 328,724 hectares with 2,719 hotspots in the January – August 2019 period. The factors causing forest fires include climate change, human activities in forest areas, and forest officers that can't be monitored in real-time. The internet of things (IoT) based solar cell-based forest fire detection using for a monitoring system in real-time. This research uses PV (Photovoltaic) as power on the system. This IoT is integrated with the android application so that the user can monitor forest conditions at any time. This research uses ESP8266 12 – F as an IoT module, Arduino Uno for controlling the device, and relays. This result data are based on laboratorium test. The result of this research is a monitoring system that can monitor smoke (MQ-2 sensor), temperature and humidity (DHT22 sensor), water pressure (pressure transmitter), current and voltage in the battery charging remotely and can be controlled automatically when the sensor detects the flame.

INTRODUCTION

The Indonesia forest fires are one of the annual largest forest fires in the world. According to the Indonesia Ministry of Environment and Forestry data, the area of forest and land fires in Indonesia in 2019 reached 328,722 hectares (Ministry of Environment and Forestry,2019). National Board for Disaster Management (BNPB) noted that the burned area reached 328,724 hectares with 2,719 hotspots in the January – August 2019 period (Agus, 2019). Because several areas in Indonesia have peat soil in areas, this forest fire condition is expected to occur every year. The most significant impact of forest and land fires is the occurrence of smog which is very detrimental to public health such as respiratory disease and other health problems, transportation disruption due to visibility reduction, as well as ecosystem damage to flora and fauna.

Efforts to prevent forest fires have been carried out with various methods, but in each method, there are still shortcomings. The first method is routine patrols which require a lot of cost and human resources (Wibowo, 2019). The second method is observation through a watchtower, this method has drawbacks in terms of costs for the construction of a watchtower, human resource training, the monitored area is limited (Arief et al, 2019). The third method of monitoring satellites, this method has drawbacks in terms of long scanning cycle times, the low resolution of the resulting image, and this method is strongly influenced by cloud conditions in the observed area so that in the monitoring process it is difficult to get real-time information (Marques et al, 2018).

Internet of Things (IoT) is a technology that is widely used for various purposes, one of which is to get information in real-time (Raffei et al, 2020),(Artono, 2019). IoT has also been developed for low-cost energy protection and monitoring systems that can be used in many applications (Chooruang, K, 2018),(Tatik et al, 2018). Research (Achmad et al, 2018) developed a system that can detect early detection and prevention of house fires using ESP8266 and Blynk, the system has can monitor LPG gas leaks in the kitchen and fire levels using IoT technology integrated with android application. Another study (Desliana, 2021) designed an IoT-based flood detection system, the system functions to monitor water levels using the Internet of Things (IoT) so that the water levels can be monitored in real-time.

This research is an IoT development using ESP8266 as a wifi module that is often used to build IoT-based systems [Rudrendu, et al, 2018), (Siswanto et al, 2020) and Blynk as a platform for iOS and Android and suitable with Arduino, Raspberry Pi (Artono and Susanto, 2018). In this research, a PV system is used as a source of electricity that will convert solar energy into electrical energy with a stand-alone configuration. The battery uses as energy management to the system. This research is expected to help forest supervisors and residents around forest land to monitor forest conditions so that early prevention can be carried out before forest fires can spread.

RESEARCH METHODS

This section explains the methods and which types of equipment are used and how to solve the problem.

1. **Data Collection**

   The method used in data collection is the observation method. This method is done to get data by looking at the tool directly. Then observations were made by looking at and analyzing what deficiencies could be improved, so as to improve previous research (Yusuf et al, 2021)

   The next method is the experimental method. The data will be analyzed to get a conclusion so that further observations and experiments can be carried out.

2. **Hardware Design**

   a. DC Voltage Sensor Circuit and ACS712

   This research uses a DC voltage sensor and a 5A ACS712 sensor to monitor the voltage and current in the battery charging process. The DC and ACS712 voltage sensors have 3 pins, namely Vcc (+), out (s), and ground (-). For the installation of a DC voltage sensor on the Arduino, the Vcc pin is connected to the 5V Arduino, the out pin is connected to the analog port on the Arduino, and the ground pin is connected to the ground port on the Arduino. The series of DC voltage sensors and ACS712 can be seen in Figure 1.

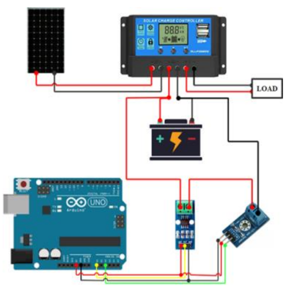

Figure 1. DC voltage sensor circuit and ACS712

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b. Pressure Sensor Circuit

The pressure transmitter serves to detect the water pressure in the water pump. The pressure transmitter has three pins; VCC, analog output, and ground. For Installing Pressure Transmitter on the Arduino, the Vcc pin is connected to the 5V Arduino, the analog output pin is connected to the analog port on the Arduino, and the ground pin is connected to the ground port on the Arduino. The fire detection sensor circuit can be seen in Figure 2.

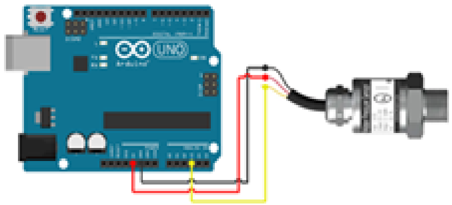

Figure 2. Pressure transmitter circuit

Fire detection uses three sensors; a temperature and humidity sensor (DHT22), a fire sensor (Flame sensor), and a smoke sensor (MQ-2). The DHT22 sensor has 3 pins, namely VCC, out, and ground. the out pin is connected to the analog port on the Arduino, and the ground pin is connected to the ground port on the Arduino. The flame sensor has 3 pins, namely VCC, ground, and digital output. The MQ-2 sensor has 4 pins, namely VCC, ground, digital output, and analog output. On this MQ-2 sensor, only 3 pins are used, namely VCC, ground, and analog output. The series of fire detection sensors can be seen in Figure 3.

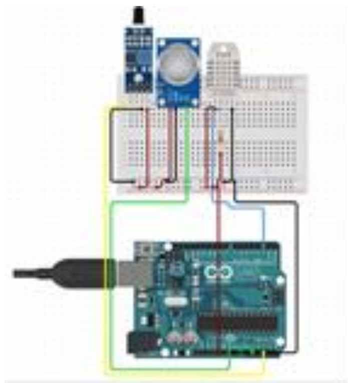

Figure 3. Sensor Fire Detector Circuit

c. Control Circuit

Control circuit uses a single relay module to control ON/OFF of a single phase motor (water pump). For installation, the COM relay pin is connected to the 220V source phase, the NO relay pin is connected to the 1 phase motor load phase (water pump), then the 220V source neutral and the 1 phase motor load neutral are connected. The VCC pin on the relay is connected to the 5V port on the Arduino, the GND pin is connected to the Arduino ground port, and the IN pin on the relay is connected to the D12 port on the Arduino. The installation of the control circuit can be seen in Figure 4.

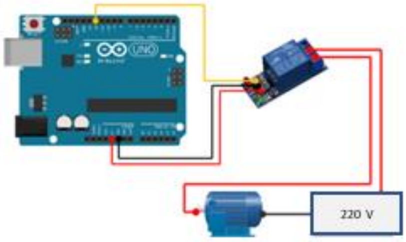

Figure 4. Control Circuit

d. ESP8266 – 12F Wifi Module Circuit

ESP826 12-F Wifi module uses as communication between Arduino Uno and Android smartphones. For the installation of the ESP8266 12-F with Arduino, the D11 (TX) pin on the Arduino is connected to the D2 (GPIO4) pin on the Wi-Fi module, the D10 (RX) pin on the Arduino is connected to the D3 (GPIO0) pin on the Wi-Fi module, and ground on the Arduino as figured in Figure 5.

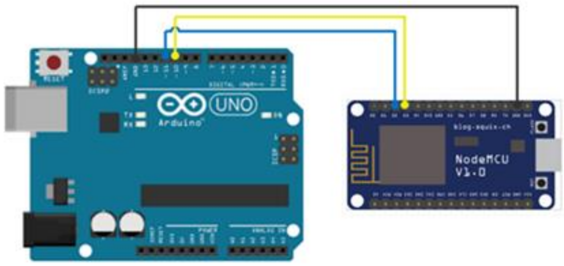

Figure 5. Wifi ESP8266 12-F Module Circuit

3. Software Design

In this section, the design of the software used in making the tool.

a. Arduino IDE

Software design consists of Arduino programs and flowcharts for control and monitoring systems. Programming language to program Arduino using C language.

b. User Interface on Android

In designing the Android display using the Blynk application, the ESP8266 sends data from the Arduino Uno to the IoT Cloud and Blynk server which will then be displayed on a smartphone with the android-based Blynk application.

4. Device Schematic

The Schematic device as shown in Figure 6 as working principles of this research.

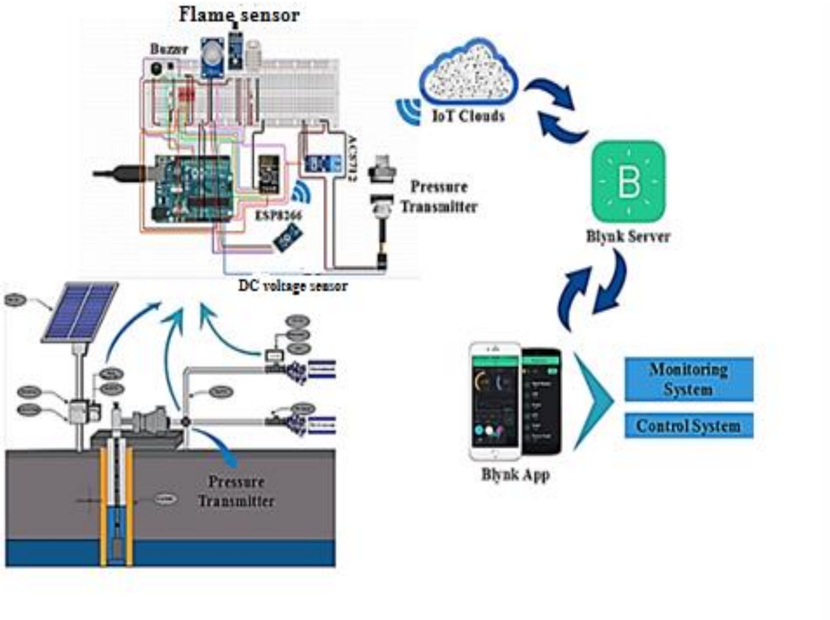

Figure 6. Device schematic

From the schematic in Figure 6 it can be explained that the remote monitoring and control system will work as long as there is an internet connection. The monitoring system starts from reading sensor data, namely the ACS712 sensor and DC voltage sensor to detect the current and voltage values in the charging process, then Pressure Transmitter sensor to detect water pressure in the pump, and fire sensors (DHT22, MQ-2, and Flame sensor) to detects the value of temperature & humidity, smoke and fire values which are then processed by Arduino and sent to the Blynk server via ESP8266.

RESULT AND DISCUSSION

Step by step data analysis uses to test every equipment and working system of the whole process . This test is carried out to obtain data and to ensure that all parts of the system can work properly.

i. System testing

Tests are carried out to measure the performance and level of success of the system that has been developed. Tests are carried out to obtain correct data with the following objectives: (i) Knowing the system design that has been made (ii) Knowing the problems, shortcomings, errors of the system that has been made. (iii) Knowing the advantages and disadvantages of the system created.

ii. Testing stage

The tool testing phase begins by testing each part separately. Then the results of the test are used as a comparison between a series of tools that have been made with planning. At each stage of the test, the test steps, test results, analysis, and conclusions are carried out. The following is the testing of the tools on each circuit.

Considering Arduino as the processor in this research, Arduino Uno board testing is carried out to find out whether the program that has been uploaded to the Arduino Uno is functioning properly or not [19]. Testing the Arduino Uno board is carried out by the following steps: (i) Creating a program (Coding) on the Arduino IDE Software. (ii) Connect the Arduino Uno to the laptop's USB port using a connector cable (mini usb). (iii) Once connected, select the "Tools" menu then select the Arduino Uno board. Then also select the detected port. (iv) Compile the program needs to be done to ensure that the program made is correct in syntax and algorithms. After compiling, there will be a done compiling notification. (v) Upload the compiled program to the Arduino Uno board. When a Done Uploading notification appears, it means that the program has been successfully uploaded to the Arduino board.

Wifi Module ESP8266-12F: Testing the wifi module is done to find out that the wifi module can be connected and can communicate with wifi through the android application and determine the level of internet stability in the monitoring system. The steps for testing the nodeMCU ESP – 12F are carried out as follows: (i) Open the Arduino IDE Software. (ii) Open the file – preference menu, in the additional board manager URLs section, http://arduino.esp8266.com/stable/package_esp8266com_index.json. Then press OK. Open the Tools menu - Board - Boar Manager, then search for ESP8266 and click the install button. (iii) If the installation has been successful, then on the tools - board menu the NodeMCU 1.0 (ESP – 12E Module) option appears. Select the NodeMCU 1.0 (ESP – 12E Module) Compile board and upload the program to the Arduino which is connected to the Node MCU ESP – 12E wifi module. (iv) After done Uploading, open the serial monitor and type AT command. If there is a response that says "OK" then the NodeMCU ESP-12E wifi module can already be used to transfer data from Arduino. The test circuit for the NodeMCU ESP – 12E wifi module can be seen in Figure 7.

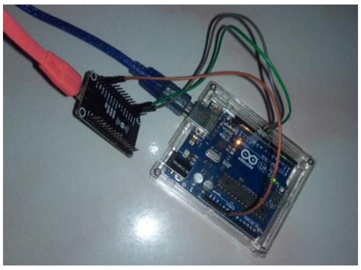

Figure 7. Wifi module testing

From the wifi module testing that has been done, it can be analyzed and concluded that the wifi module can work well. The level of stability depends on the speed of the wifi network that is connected to the wifi module.

DC Voltage Sensor and ACS712 Current Sensor: Testing the DC voltage sensor and ACS712 was carried out to determine the level of accuracy of the voltage and current in the ChargingAccu process with a voltage source from the Solar cell. The high accuracy of the two sensors affects the performance of this tool system. The following are the steps for testing the dc voltage sensor and ACS712 sensor: (i) connecting the DC voltage sensor VCC and ACS712 with 5VDC, while GND with GND. (ii) Connection of the output pin of the dc voltage sensor and ACS712 with the ADC pin on the Arduino Uno. (iii) Write down the program that will be used in the Arduino IDE Software. Then upload the program to the Arduino/Genuino Uno board. (iv) Display the results of the voltage sensor readings and ACS712 using PLX – DAQ (Ms. Excel) by opening the PLX – DAQ application, then selecting the port and baud that match the Arduino IDE, after that click connect then automatically real-time data from current and the charging voltage will appear. (v) connecting the DC voltage sensor input in parallel and ACS712 in series in the battery charging circuit with the solar cell source. (vi) Take voltage and current measurements using a digital multitester and compare them with sensor readings. (vii) Analysis of the measurement results obtained. then calculate the error percentage from the sensor. The circuit for testing the DC and ACS712 voltage sensors can be seen in Figure 8.

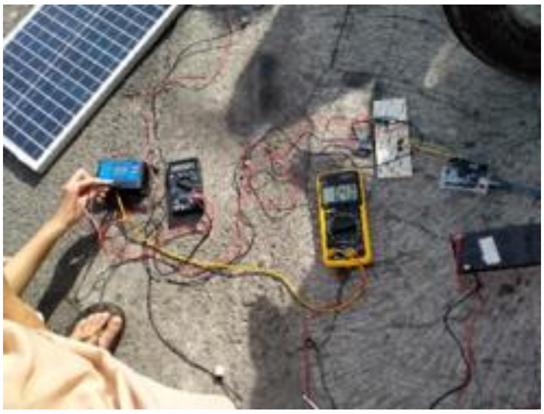

Figure 8. Testing the voltage sensor and ACS712

In Figure 8 you can see the value of the voltage and current sensor on the digital multitester. Testing of the dc voltage sensor and ACS712 is carried out to measure the accuracy of the voltage and current readings carried out by the two sensors.

$$\% \, error = \frac{AVO \ meter \ data - sensor \ data}{AVO \ meter \ data} x100\% \qquad (1)$$

The experimental results of the DC and ACS712 voltage sensors can be seen in table 1

Table 1. testing data of DC voltage and ACS712

Time	Voltage (V)	Current (A)
15:03:53	14,58	0,36
15:03:56	14,53	0,42
15:03:59	14,55	0,38
15:04:02	14,58	0,39
15:04:05	14,41	0,38
15:04:08	14,5	0,42
15:04:11	14,38	0,38
15:04:13	14,41	0,37
15:04:16	14,41	0,36
15:04:19	14,43	0,37

Table 2. Comparison data testing of DC voltage and ACS712 with digital multitester

No	Voltmeter measurement (V)	DC voltage *Sensor* (V)	*Error* (%)
1	14,42	14,58	0,01
2	14,40	14,53	0,01
3	14,45	14,55	0,01
	Average error		0,01
NO	**Amperemeter measurement (A)**	**ACS712 *Sensor* (A)**	***Error* (%)**
1	0,38	0,36	0,05
2	0,39	0,42	0,07
3	0,37	0,38	0,02
	Average error		0,05

From table 1 it can be concluded that the DC and ACS712 voltage sensor works well and it can be seen from the real-time results which are fairly stable with an average error of only 0.01% and 0, 05%.

Water Pressure Sensor (Pressure Transmitter): Testing the Pressure Transmitter sensor is carried out to determine the accuracy of the water pressure in the water pump (1 phase motor). The high accuracy of the sensor will affect the performance of the tool system. Steps for testing the Pressure Transmitter sensor: (i) connecting the VCC Pressure Transmitter sensor to 5VDC, while GND to GND. (ii) Connect the output pin of the Pressure Transmitter sensor to the ADC pin on the Arduino Uno. (iii) Write a program that will be used in the Arduino IDE Software. Then upload the program to the Arduino/Genuino Uno board. (iv) Display the readings of the Pressure Transmitter sensor using PLX – DAQ (Ms. Excel) by opening the PLX – DAQ application, then selecting the port and baud that match the Arduino IDE, after that click connect, the real time Pressure Transmitter sensor data will automatically appear. (v) Write and analyze the measurement results. The Pressure Transmitter sensor test circuit can be seen in Figure 9.

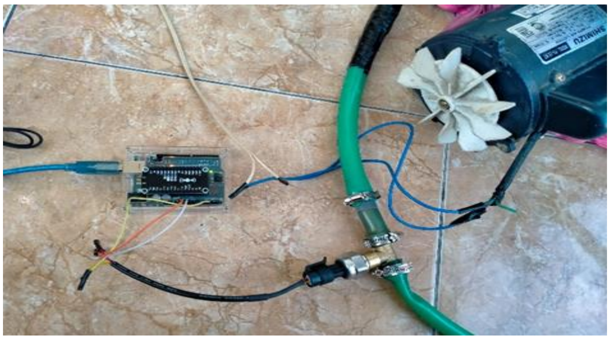

Figure 9. Pressure transmitter sensor test

The experimental results of the Pressure Transmitter sensor can be seen in Table 2

Table 3. pressure transmitter sensor test data

Time	Voltage	Pressure (Psi)
16:28:19	0,47	-0,27
16:28:20	0,47	-0,06
16:28:21	0,57	3,98
16:28:22	0,58	4,61
16:28:23	0,56	3,55
16:28:24	0,56	3,76
16:28:25	0,59	4,83
16:28:26	0,59	4,83
16:28:27	0,58	4,61
16:28:28	0,61	5,89

From table 3, the Pressure Transmitter sensor can work properly. Real-time results data are stable per second and for the water pressure, it is in the range of 3-5 Psi depending on the flow of the water on the pump system.

Fire Detection Sensors: Testing of fire detection sensors which include DHT22, MQ-2, and Flame sensors is carried out to determine the accuracy of temperature and humidity, gas and smoke content, and to detect whether there is an element of fire in an open environment such as forest and land. The high accuracy of the three sensors will affect the performance of this tool system so that it can run properly. The following are the steps for testing the fire sensor: (i) connecting the fire sensor VCC to 5VDC, while GND to GND. (ii) Connection of DHT sensor output pins and Flame sensor with digital pins and smoke sensor with analog pins on Arduino Uno. (iii) Write a program that will be used in the Arduino IDE Software. Then upload the program to the Arduino/Genuino Uno board. (iv) Display the results of the fire sensor readings using PLX – DAQ (Ms. Excel) by opening the PLX – DAQ application, then selecting the port that corresponds to the Arduino IDE, after clicking connect then the real-time Pressure Transmitter sensor data will automatically appear. (v) Write and analyze the measurement results obtained.

DHT22 sensor testing: This DHT22 sensor test is carried out to determine the level of accuracy of the sensor when reading data. The sensor setpoint value for temperature is 40°C and humidity is 65%. When the sensor data value exceeds the setpoint temperature and is less than the setpoint humidity, LED indicator 2 will turn ON automatically (standby condition). The experimental results of the DHT22 sensor can be seen in table4.

Table 4. sensor DHT22 testing data

Time	**Temperature (°C)**	***Humidity (%)***
12:22:57	39,7	62,5
12:22:59	39,8	62,3
12:23:01	39,8	63
12:23:03	39,9	61,7
12:23:05	39,9	61,9
12:23:07	39,9	61,6
12:23:09	39,9	62,7
12:23:11	40	62,4
12:23:13	40	62,2
12:23:15	39,9	61,6

From table 3 it can be seen that the DHT22 sensor is able to work well and according to the plan, real time results on excel data can be said to be stable every 2 seconds. DHT22 data graph can be seen in Figure 10.

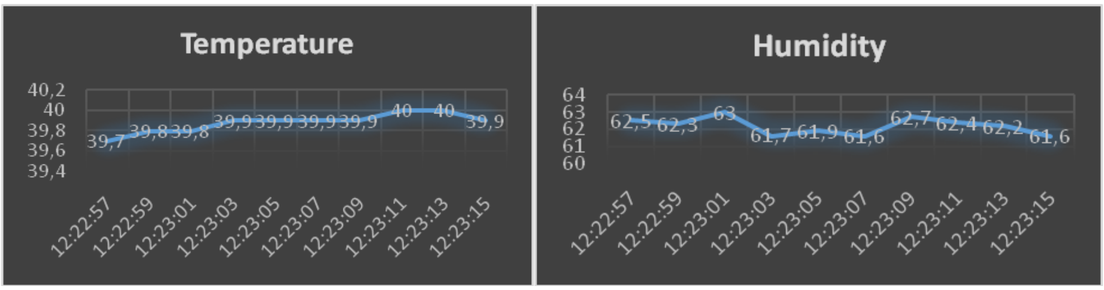

Figure 10. Data from DHT22 sensor

Sensor MQ – 2: Testing the accuracy of the sensor MQ-2 (smoke sensor) has been done. The sensor setpoint value is 300 ppm. When the sensor data value exceeds the setpoint, the LED indicator will turn ON automatically (alert condition). The experimental results of the MQ-2 sensor can be seen in table 5.

Table 5. Sensor MQ-2 testing data

Time	Smoke level (ppm)
15:19:56	220
15:19:57	244
15:19:58	285
15:19:59	250
15:20:00	261
15:20:01	243
15:20:02	225
15:20:03	283
15:20:04	315

From table 5 it is known that the MQ-2 sensor works well and according to the plan, real time results are seen when a lot of smoke or gas smell around the sensor, the sensor data value will increase. On the other hand, if there is a slight smoke or gas smell around the sensor, the sensor data value will decrease. The MQ-2 data graph can be seen in Figure 11.

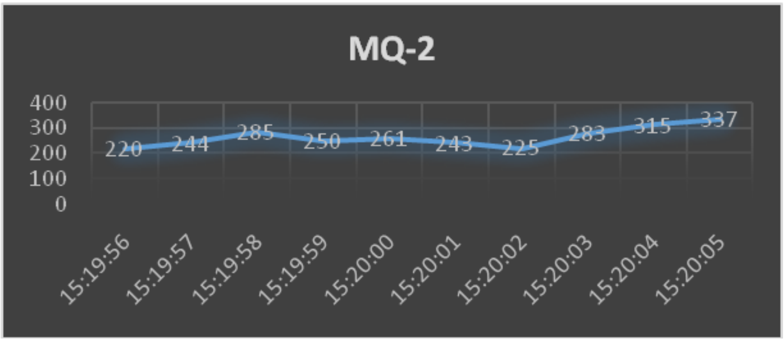

Figure 11. Data from MQ-2 sensor

Flame sensor testing: This test is carried out to measure the accuracy of the sensor when reading data. When the Flame sensor detects a fire source, the indicator LED 1 and the buzzer will light up automatically (dangerous condition). Flame sensor test circuit can be seen in Figure 12

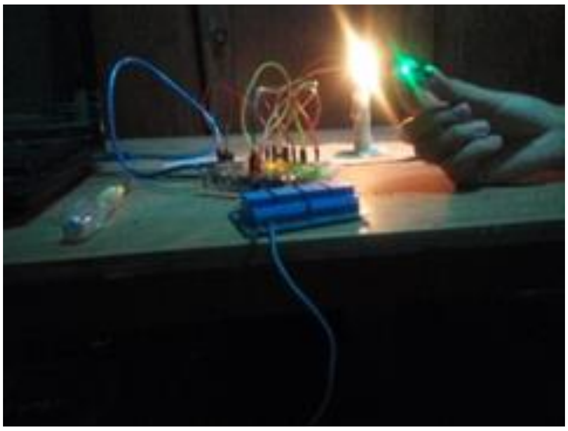

Figure 12. Flame sensor test

Flame sensor experimental results can be seen in table 5.

Table 5. Resut of Flame sensor

Fire source position	Distance	Responses of *Flame sensor*
In front of	5 cm 10 cm 20 cm 30 cm	Detects fires
On the side	-	Not detect
Behind	-	Not detect

From table 5 it can be concluded that the Flame sensor can work properly and the maximum distance that can be reached by the Flame sensor in this experiment is 30 cm, because basically the Flame sensor used in this system can only detect fire in front of the sensor and is more sensitive when exposed to sunlight.

Control system testing: conducted to find out that the tool can perform control automatically. The sensor that becomes the benchmark in this control system is the Flame sensor. When the fire source faces the Flame sensor, the relay will make the water pump turn ON automatically and vice versa. The steps for testing the control system: (i) connecting the VCC relay and Flame sensor to 5 VDC, and GND to GND. (ii) Connect the relay output pins and Flame sensor to the digital pins on the Arduino Uno. (iii) connect the COM port of the relay to the 220VAC source phase, the NO relay port to the AC load phase (1 phase motor), then the AC load neutral (1 phase motor) and the 220VAC source are connected. (iv) Write down the program that will be used in the Arduino IDE Software. Then upload the program to the Arduino/Genuino Uno board. (v) Turn on the fire in front of the Flame sensor, automatically the 1 phase motor load will be ON (on) and when the fire source goes out, the 1 phase motor load will be OFF (off).

From the control system testing that has been carried out, it can be concluded that the control system on this tool can work well. The response of the relay is also fast depending on the delay set in the Arduino program for the ON / OFF condition.

Monitoring System Testing on Smartphones: This test uses an Android smartphone that has the Blynk application installed for monitoring and testing whether the device can receive data sent by the NodeMCU ESP – 12E wifi module. The steps for testing the monitoring system on a smartphone are as follows: (i) connecting the toolbox to a 220VAC source. (ii) turn on the portable router and make sure the internet network used is stable enough to obtain real-time data. (iii) Connect the smartphone with wifi and make sure the internet network is stable enough. (iv) First install the Blynk application on the smartphone, then open and login to the Blynk application on the smartphone for monitoring the device system. (v) After logging in to the application, press the play button in the upper right corner to start the tool monitoring system. (vi) Observe and analyze the sensor data values listed on the Blynk application. (vii) Press stop in the upper right corner to stop the monitoring system of the device. The series of monitoring system tests on smartphones application can be seen in Figure 24.

Figure 13. Monitoring system test circuit

The display of the monitoring system using the blynk application on a smartphone in Figure 14.

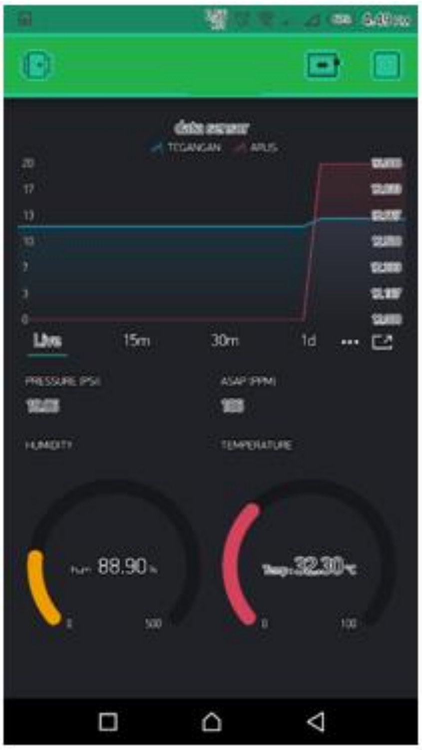

Figure 14. Display of the monitoring system on a smartphone

From overall sensor data that has been obtained, it can be analyzed and concluded that smartphones application can monitor the device properly based on data (all sensors) in real-time.

CONCLUSIONS AND RECOMMENDATIONS

The results showed that the system based on laboratory testing was able to monitor and detect fires to monitor forest conditions in real-time, as evidenced by all sensors being able to take good readings, but the level of accuracy was still not maximized. This is more due to the lack of accuracy in the sensor calibration process. The solar cell has succeeded in supplying electricity and the system has succeeded in controlling the water pump by functioning automatically when there is a source of fire around the device indicated by the water pump being able to work on and off if it detects a fire point. A less stable internet network can result in a slight delay in the response from the application. Suggestions for the development of further research to be able to choose a wifi module that has been integrated with a microcontroller such as Raspberry Pi in order to eliminate delays in the data transmission process.

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