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IoT Based Durian Tree Monitoring System

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Abstract: Due to the rapid advancement of Internet of Things in the 5G era, modern IoT for agriculture has starting replaced the traditional way of monitoring and irrigation for agriculture. With the implementation of the IoT in agriculture, the farmers can real-time monitoring their durian trees. The farmers can easily watch the tree's health parameters from cloud-based data. The farmers can know the condition of the trees in real-time such as the temperature of the environment, humidity of the environment, and soil moisture. The real-time data will be displayed by a chart and makes the farmers can watch the data conveniently. Besides that, the irrigation system can automatically detect the soil moisture and select the suitable time to water the durian trees. At the same time, for the traditional method of irrigation, most of the farmers need to water the trees by themselves. Meanwhile, the large-size durian farm requires more manpower to manage the field and there is not guarantee all the trees can be watering. Furthermore, this IoT system requires a power supply for the Raspberry Pi and sensors to work. Rural areas like durian farm do not have an On-Grid power supply. Therefore, the farmers need solar power system for generate electricity. A solar system is the most convenient power supply for the durian farm. To conclude, this project is suitable for the farmers to watch the health parameter of the durian tree, irrigation system for the farmers can reduce the manpower cost and solar system is the portable energy for the rural areas.

Keywords: Real-Time Monitoring, Durian Tree, Irrigation System, Raspberry Pi, Solar Power System

1. Introduction

The main idea of smart agriculture which architecture that incorporates IoT techniques for urban agriculture and smart cities [1]. The factors that resulted in the challenge of monitoring and watering durian trees when the farm is wide and how to increase the yield farming and overcome the drought seasons. In the future of agriculture, utilizing IoT for water irrigation systems will be a big trend [2]. There is an advantage when install solar panel when comparing with the circuit there is no installing solar panels which can supply the energy for the project [3].

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1.1 Raspberry Pi 4

The Raspberry Pi is a low-cost, credit-card-sized device that connects to a computer monitor or screen using a regular mouse and keyboard. It's a small, powerful machine that lets people of all ages experiment with Python programming languages. The Raspberry Pi has been used in a wide range of automatic manufacturing projects, including music machines, parent detectors at weather stations, and tweeting birdhouses via infrared cameras. The hard drive on the Raspberry Pi serves as the SD card on the board when it is inserted into the slot. The Raspberry Pi's row of GPIO (general-purpose input/output) pins along the top edge of the board is a powerful feature that has a 40-pin GPIO header. [4]

1.2 Monitoring system

The monitoring system aims for monitoring the plants to take advantage of automation by the concept of IoT in agriculture [5]. Real-time monitoring and control of various field and crop output parameters such as field moisture, nutrients, humidity, and temperature [6]. Therefore, the users can watch real-time data to overcome the labor monitor the plants [7]. Soil moisture sensors used to determine the moisture content of the soil and water is regulated based on the sensor's level [8]. Soil moisture sensors emits a voltage signal from the soil and proportional to the moisture content of the soil [9]. DHT22 sensor as the temperature and humidity sensor for the input of Raspberry Pi for processing [10]. MCP 3008 can convert the analogue data from sensor to digital pin for Raspberry Pi [11]. ThingSpeak Cloud is used to store and track data from sensors. Temperature, humidity, and soil moisture are reading from sensors and ThingSpeak output is shown from a line graph. Inside the ThingSpeak, the sensor readings for each sensor will be displayed [12].

1.3 Irrigation system

The irrigation system is a smart technique for avoiding the need for physical labor and regulating the amount of water used. The solution is based on Raspberry Pi and leads to an automatic system that determine relay turn on or off after receiving the value [13]. When there is a water shortage, the soil moisture sensor activates the irrigation system [9]. Relay can be operated electronically by connecting it to a microcontroller [14]. Water can flow out of the solenoid valve which needs a relay module to operate. The solenoid valve allows water to flow from the tank to the plant [15]. The goal of this study is to automate the control of the solenoid for watering system and maintain water consuming strategy by the proper irrigation [13].

1.4 Solar power system

The solar power system was using solar panel, solar controller and batteries for completing the systems. During the hours of sunlight, power is supplied from the solar panel to the charge controller. If the solar panel fails receive sunlight in entire day, a battery will power the device for an entire day. Solar controller manages the battery's charging from the solar panel and as the power supply to the load. If the solar panel voltage greater than 12 V, the charge controller starts charging the battery [16]. The power converter connects from a solar panel to maintain the remaining voltage level across the battery. It was allowed to obtain a suitable range of voltage levels to recharge the battery [3].

2. Materials and Methods

Throughout the project and development of the IoT based durian tree monitoring system. The materials and system will be planning for this project. This paper will be concentrated on the design and development of the IoT based durian tree monitoring system for monitoring and watering the durian trees. Solar system will be used as the power supply for this system.

2.1 Materials

The material of the hardware in this project was using: (1) Raspberry Pi 4, (2) DHT 22 sensors, (3) relay, (4) FC-28 soil moisture sensors, (5) solenoid, (6) MCP 3008, (7) 10 W solar panel, (8) solar controller, (9) 12.0 V 40 Ah battery, and (10) RGB LED. The software will be using: (1) Thonny IDE, (2) ThingSpeak, (3) Raspberry Pi Imager, and (4) PuTTy configuration.

At first, Raspberry Pi 4 is connected the supplied with 5.0 V 3.0 A DC power supply via USB Type C connectors from the solar power system. For the DHT 22 sensors is connected at the GPIO 26 (D 101 durian tree) and GPIO 20 (Black Thorn tree). MCP 3008 is the ADC of soil moisture sensors and it will connect the SPI pin in Raspberry Pi 4 which are located at GPIO 8, GPIO 9, GPIO 10 and GPIO 11. The input of the MCP 3008 is at CH 1 until CH 8. The ground of MCP 3008 will be connected at CH 9 and CH 14 while the voltage pin is located at CH 15 and CH 16 with constant 5.0 V. The clock signal CLK in MCP 3008 is at GPIO 11, digital input D_in is at GPIO 10, digital output D_out is at GPIO 9 and shutdown pin SHDN connect with GPIO 8. The analogue of soil moisture sensor of D 101 durian tree will connect with CH 1 while the soil moisture sensor of Black Thorn durian tree will connect with CH 2.

The relay will connect with GPIO 19 (D 101 durian tree) and GPIO 26 (Black Thorn durian tree). The solenoid valve is the circuit connected in series circuit and it will be using the 12.0 V power supply from solar power system. The circuit in the relay will be connect with normally open (NO) and common (COM). RGB LED of D 101 durian tree will connect with red pin at GPIO 12, green pin at GPIO 6 and blue pin at GPIO 5 while RGB LED of Black Thorn durian tree will connect with red pin at GPIO 24, green pin at GPIO 23 and blue pin at GPIO 22. The schematic diagram of the proposed monitoring system, irrigation system and solar power system is visualized in Figure 1 below:

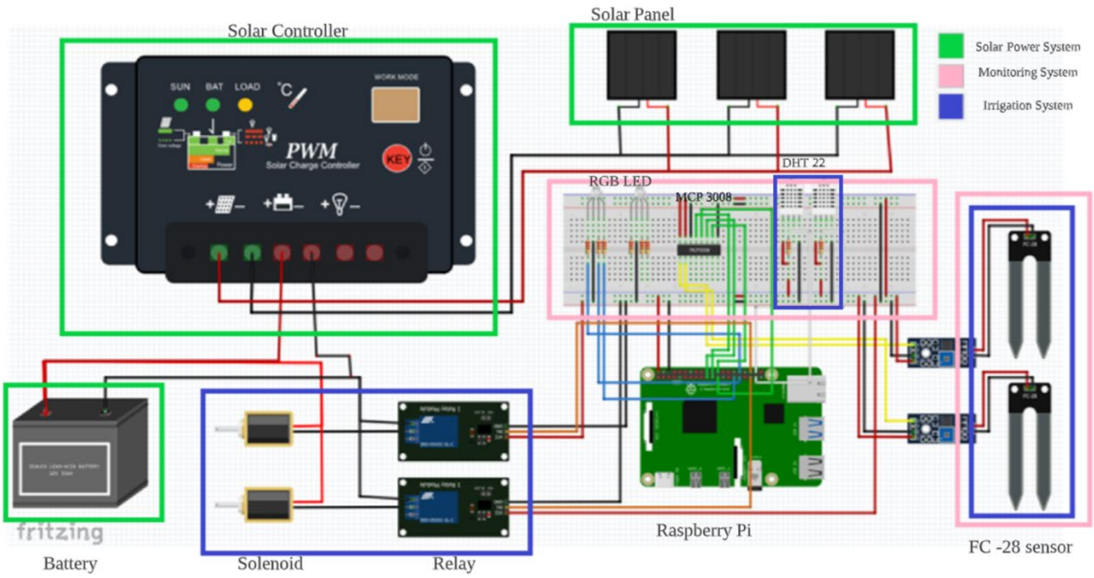

Figure 1: Schematic Diagram

2.2 Block diagram

It is the concept of the monitoring, irrigation and solar system which consists of Raspberry Pi, soil moisture sensors, DHT22, relay, solenoid valve, 10 W solar panel, solar controller and the RGB LED indicators. The block diagram illustrates the interconnection between the sensors and Raspberry Pi 4. The block diagram of the system is illustrated in Figure 2 below.

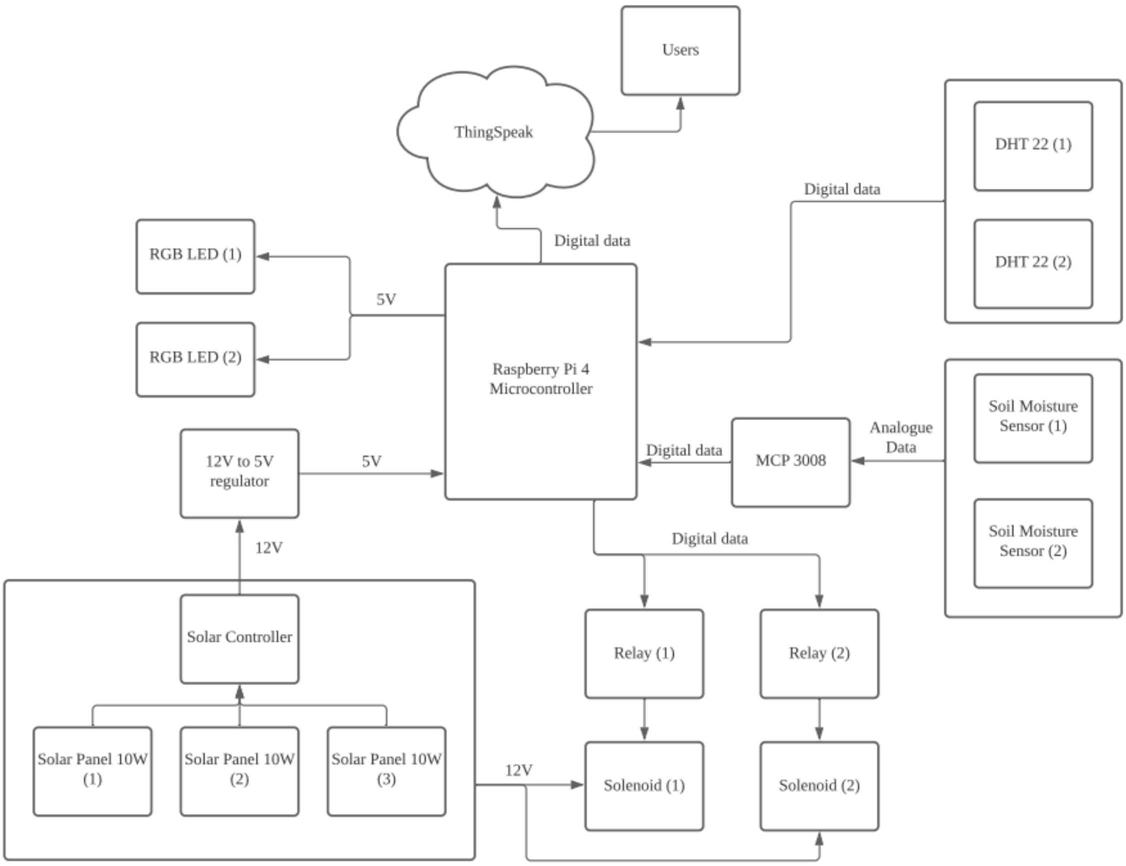

Figure 2: Block Diagram

2.3 Solar power system

Solar power system will be using solar panels, a solar controller, and a 12.0 V 40 Ah battery. The large capacity of the battery will be able to supply for this project in whole day. During the daytime, the solar panel will generate a voltage around 16.0 V to 20.0 V. Then the solar power generate from the solar panel will be delivered current to a solar controller. The solar controller will step down the voltage which was 13.2 V for charging the batteries. The battery will provide constant 12.0 V for the solenoid when the relay is on the solenoid can be turn on which will allow water supply to the durian tree for irrigation. For the Raspberry Pi 4, the specification of this microcontroller only can at the range of 5.0 V 3.0 A which is needed a step-down controller of 12.0 V to 5.0 V 3.0 A. The power capacity generated equation as the following:

$$Battery\ capacity(Wh) = Electric\ Charge\ (Ah) \times\ Voltage\ (V)\ Eq.\ 1$$

$$40\ Ah\ X\ 12.0V\ = 480\ Wh$$

$$Hardware\ comsumption\ (Wh) = Ampere\ (A\ ) \times Voltage(\ V) \times Time\ (hrs)\ Eq.\ 2$$

$$1.5\ A\ X\ 5.0\ V\ X\ 24 = 180\ Wh$$

$$Solar\ power\ generated = Watt\ (W)\ \times\ Time\ (hrs)\ \times\ efficiency\ (\eta)\ Eq.\ 3$$

$$30.0\ W\ X\ 10\ X\ 0.7 = 230\ Wh$$

$$Extra\ Power\ (Wh) = Solar\ power\ generated(Wh) - Hardware\ comsumption(Wh)\ Eq.\ 4$$

$$230\ \ Wh - 180Wh = 60\ Wh$$

Based on the calculation above, assume that the hardware consumption is 1.5 A per hour because the power idle of Raspberry Pi is around 0.7 A until 1.3 A per hour and solenoid power consumption is 0.5 W which is 41 mA per hour, and it will not affect the power usage. From the solar power generated, assume that the efficiency is 70.00 % which include the weather of rainy day and sunny day. The power generated from the solar power can be 230 Wh. The power extra of the solar system can be 60 Wh and can be store in the battery. The battery will not be overcharge and controller by the solar controller. The solar power collected is enough for the consumption of the system in a whole day.

2.4 Remote display connection

Raspberry Pi can be using the XRDP server to graphically control the operating system that installed in Raspberry Pi. Firstly, need to flash Raspbian OS on the 64GB micro-SD card with the Raspberry Pi imager v1.6.2. Then select the Raspbian OS (32bit) and flash it into a micro-SD card. Since the Raspbian image has flashed in the Raspberry Pi 4, open the boot directory in the File Explorer on the PC. Create a text file of wireless networking with SSID and password for the Raspberry Pi 4 and change the extension to ".conf". Besides that, create a text file name SSH and change the extension to SSH to enable the SSH system for the Raspberry Pi 4.

Next, boot the Raspberry Pi 4 and using PuTTY Configuration to communicate with Raspberry Pi 4. Then using the command to update and upgrade the Raspbian version to the newest version with the command of "$sudo apt update" which updates the system package list. Next need to using the command to upgrade all installed packages to the latest version which is "$sudo apt full-upgrade". Next is to restart the device with the command "$sudo shutdown – r now". Lastly to install the XRDP server for Raspberry Pi 4 which is using the command of "$sudo apt-get install xrdp". Finally, can connect the Raspberry Pi 4 with the Windows 10 devices by using a Remote Desktop connection. The Raspberry Pi 4 screen can be remotely displayed on Windows 10 LCD display.

2.5 Overall Programming Flowchart

For the overall programming in Figure 3, it started with declaring all the variables. Next the programming will read dry level, humidity and temperature data from Black Thorn durian tree from soil moisture sensor (1) and DHT 22 (1) while read data from D 101 durian tree from soil moisture sensor (2) and DHT 22 (2).

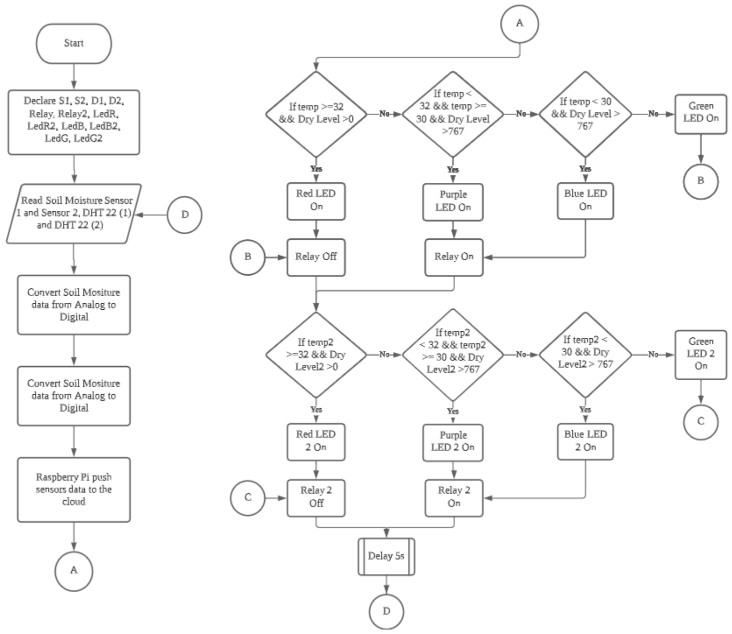

Figure 3: Flowchart

Both soil moisture sensor data output is analogue data and it will be converted to digital data by analogue to digital converter (ADC). The data will be sent to central unit which is called as Raspberry Pi 4. The central unit will be sent sensor data to the cloud which is called as ThingSpeak for monitoring system. Next is using if else statement from the selection structure to select the condition of the irrigation system. The first selection structure is the programming using in Black Thorn durian tree while second selection structure is the programming using in D 101 durian tree. Two different variant of durian tree using similar programming structure. Lastly the programming will start the delay 5s and then it will be looping back to the reading sensors data for monitoring system.

3. Results and Discussion

The findings of both qualitative and quantitative analysis will be presented in this chapter. This chapter will be discussed about the data uploaded to the platform and the automatic irrigation system of two different variant durian tree.

3.1 Results

The quantitative and qualitative results of the monitoring and irrigation system will be displayed for a single day. It will export quantitative results from the platform and plot the line chart by showing the data from different variant of sensors for durian tree monitoring system. Besides that, the qualitative results include the operation of the sensors, RGB LED's and the relays for durian tree irrigation system. The platform and observation for testing will be displayed by quantitative and qualitative results.

3.2 DHT 22 temperature sensors

For the DHT 22 temperature sensor, both temperature sensor has ±0.5 °C. In the chart, the highest temperature for D 101 durian tree is 33.0 °C while the lowest temperature is 24.1°C. The highest temperature for the Black Thorn durian tree recorded is 32.9 °C, but the lowest temperature is 24.0 °C. There is a weather change around 3:00 p.m. until around 8:00 p.m and will be decrease fluctuated. At 8:29 p.m. was the lowest because there is the small mountain shape at night. After that, both sensors temperature reading increases due to sea breeze [17]. For the next morning 6:17 a.m., the temperature started increases as the sunrise until 10:22 a.m. The cloud sometimes hid the sun and causing the temperature drop at 9:33 a.m. and 10:22 a.m. The time section of 10:22 a.m. until 2:34 p.m. was constant because there was hot sunny day in this time section. The heat was absorbed by the sun and the sun was at the centre place at noon which will be causing temperature the hottest temperature at 11:11 a.m. until 1:45 p.m. When the time section between 2:34 p.m. until 3:14 p.m., the weather turns to cloudy day while the accuracy of the entire system is plotted in Figure 4 below.

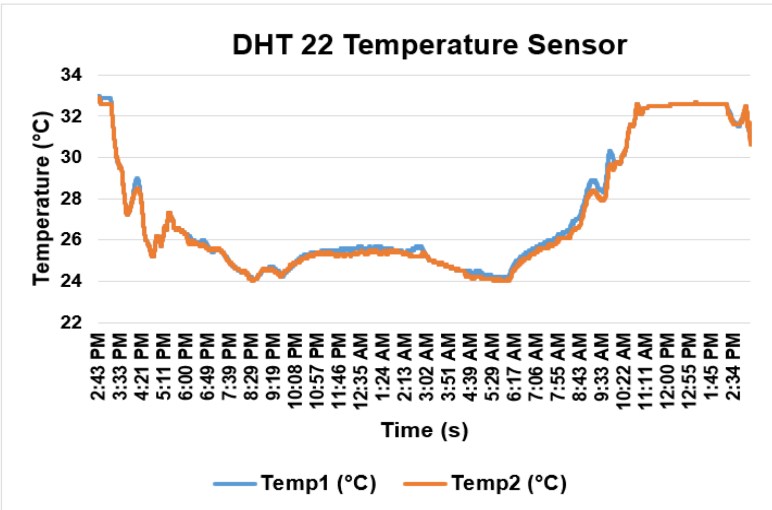

Figure 4: Graph of DHT 22 Temperature sensors

3.3 DHT 22 humidity sensors

DHT 22 humidity sensors in Figure 5 measure the humidity in surrounding both variant durian tree. The highest humidity percentage for D 101 durian tree was RH 82.5 percent, while the lowest humidity level was RH 32.4 percent. The highest humidity level in the graph was RH 84.4 percent for the Black Thorn durian tree, while the lowest humidity level was RH 40.9 percent. There is the accuracy difference of RH ±2.00 % until ±5.00 % for two different variant durian tree. The highest humidity percentage for D 101 durian tree was RH 82.5 percent, while the lowest humidity level was RH 32.4 percent. The highest humidity level in the graph was RH 84.4 percent for the Black Thorn durian tree, while the lowest humidity level was RH 40.9 percent. At midnight was happened sea breeze situation which will be causing the graph undulated. [17] From 6:17 a.m. to 2:34 p.m., the sunrise and temperature were getting hotter, causing the humidity to rise. Finally, the time from 2:34 p.m. to 3:14 p.m. was increasing as the weather changed to a rainy day.

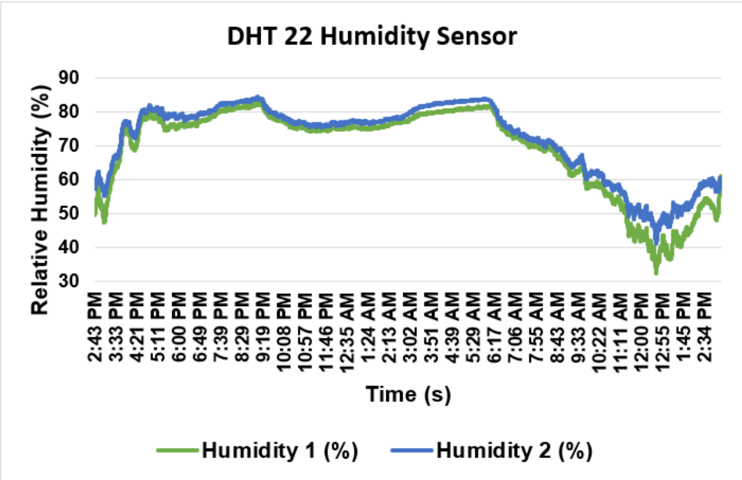

Figure 5: Graph of DHT 22 Humidity sensors

3.4 Soil moisture sensors

Soil moisture sensors in Figure 6 measure the dry level of soil for different variant of durian tree. The dry level of D 101 durian tree was higher than that of Black Thorn durian tree because the water pressure was higher. The highest dry level for the D 101 durian tree was 75.00 % and the lowest was 54.00 %. Meanwhile, the highest dry level in the graph for the Black Thorn durian tree was 75.00 %, while the lowest was 46.00 %. The weather was hot sunny day and causing the evaporation of water from the soil for first 50 minutes. There was rain from 3:33 p.m. to 5:11 p.m. and causing the dry level decreased in this period. The rain stopped at 5:11 p.m. and remained constant until 9:19 p.m. because the soil was very wet and cold. Because the soil's water evaporated from the soil to the atmosphere between 9: 19 p.m. and 7: 06 a.m. the next day, there was a slight increase.

As the sun rose slowly after 7:06 a.m., the water evaporated faster than the period at midnight. The D 101 durian tree chart dropped sharply at 9:28 a.m. because irrigation systems began to water the durian tree when the temperature was less than 32.0 °C and the dry level was greater than 75.00 %. The Black Thorn tree was watering at 9:41 a.m., and the dry level was more than 75.00 % with a temperature of less than 32.0 °C. The difference dry level for different durian tree after durian tree was because the solenoid pressure was difference. The Black Thorn tree's solenoid allowed water to flow faster than the D 101 durian trees. It was steeply increased after watering because the weather became hotter, causing the water to evaporate much faster. When the time was 1:45 p.m. until 3:14 p.m., the weather changed from sunny to cloudy, and it began to rain at 3:00 p.m.

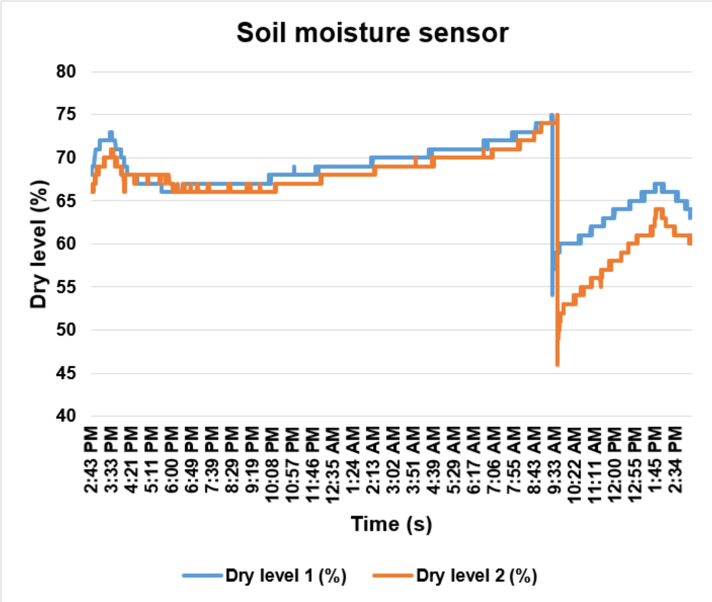

Figure 6: Graph of soil moisture sensor

3.4 Irrigation system

Initially, the red colour displayed in RGB LED was at a temperature greater than or equal to 32.0 °C and a dry level greater than 0. During hot weather, the irrigation system will stop watering because the plant's water evaporates rather than absorbing into the soil and roots. The purple colour indicates that the current weather is greater than or equal to 30.0 °C until 32.0 °C, and the soil moisture level was greater than or equal to 767 which is approximately 75.00 % dry level. Finally, the green LED will indicate the other condition. The irrigation system operating condition will be displayed in Table

Table 1: Irrigation system operating condition

Conditions	Red	Green	Blue	Solenoid	RGB LED colour
Temp <= 32.0 °C and Dry level > 0	ON	OFF	OFF	OFF	RED
Temp <= 32.0 °C and Dry level > 0	ON	OFF	ON	ON	PURPLE
Temp <= 32.0 °C and Dry level > 0	OFF	OFF	ON	ON	BLUE
Other condition	OFF	ON	OFF	OFF	GREEN

3.5 Solar power system

For a 25-hour experiment, the operation of a solar power system was successful. The solar power system was charged for 13 hours, or 52.00 % of the time, while it was not charged for 12 hours, or 48.00 % of the time. For the charging status, the solar panel collected energy during the day, from 2p m to 6 pm, and the next day are from 7 am to 3 pm. The solar panel can produce more current in the afternoon whereas the time duration in the morning and evening produced less current for charging the batteries [18]. During the night, the solar panel did not receive any light energy. As a result, there was no energy output for the solar power system at night.

4. Conclusion

Through this paper, the monitoring system reads the parameters from different varieties of durian trees with soil moisture sensors and DHT 22 sensors. The system will automatically update the data every 20 seconds, allowing users to watch the durian tree from anywhere. The irrigation system will be using DHT 22 sensors and soil moisture sensor to determine the correct condition for the durian tree watering.

Furthermore, the solar system can help the project can be done at rural areas and can be installed at anywhere under the sun. The energy was using one of the cleanest energy in the world and there was no pollution for the environment. The Raspberry Pi 4 functioned as the microcontroller for the monitoring and irrigation system.

For the recommendation soil moisture sensors can be changed from FC-28 sensors to Capacitive soil moisture sensors. pH probe sensors can be connected to Arduino Uno or Mega to send the data to Raspberry Pi 4 by Lora or USB type B serial communication. The system can be using 4G or 5G communication as internet provider for the Raspberry Pi to upload the data.

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