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Monitoring System of Hydroponic Using Solar Energy

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Abstract: This project aims to develop a solar powered hydroponic monitoring system. Hydroponic system is a plantation system that uses water as the medium instead of soil. The solar energy acts as the main source and a supply for the Arduino Uno, a microcontroller to control all the sensors, collecting the data and display the data to users. The sensors used were DS18B20 temperature sensor, propylene float water level sensor and pH sensor. These sensors will monitor those elements and helping the users in hydroponics system. An Arduino Ide software was used to develop a coding for the monitoring system. The value of temperature, water level and pH has been measured and collected to be analyzed. For conclusion, this project is successful in that the data collected satisfied the objective and from the result, it shows the effectiveness of solar powered hydroponic monitoring system.

Keywords: Hydroponic, solar, arduino

1. Introduction

Solar energy is one of the most well-known energy and the technologies regarding solar energy is growing rapidly. The reasons behind the rapid growth of solar energy technologies are because of the coverage of sunlight that is available throughout the world and the amount of sunlight received by the earth is high every year. This shows that the sun is a major source of inexhaustible free energy to planet earth [1]. The technology to harvesting and collecting solar energy has improved throughout the year. Back in 1830s, the first person to apply the use of sunlight is British astronomer John Herschel. He used a solar thermal collector box that absorbed sunlight to cook food during an expedition to Africa [2].

Over the past few years, agriculture has grown rapidly around the world. Some new agriculture techniques have been developed to overcome the traditional soil-based gardening and one of the most mature and popular is hydroponics. Hydroponics is a technique of growing plants without using soil or others medium [3]. Urban areas such as rooftop and balconies could be use as breeding places by using the hydroponics systems [4]. This soilless cultivation technique helps farmers breeding crops without using agriculture lands that have declined due to modernization. In traditional soil based system, a lot of water has been wasted because the water used to watering the crops is absorbed by the soil [5]. Hydroponics also reduce the use of water in growing plants as the water can be reused without being absorbed by the soil. Hydroponic system is an advanced farming system that does not use soil as the medium. Instead, it uses nutrient water to replace the soil. The use of hydroponic system is very efficient in today's modern world as it uses less water and can be used to grows any plants without agriculture farm. Hydroponic can be divided into several

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systems which are Wick system, Ebb and flow system [6], Ebb and Flow system [7], Drip system, Deep Water Culture [8]and Nutrient Film Technique (NFT).

Paper [9] discusses the solar energy exploitation in agriculture and this paper focuses on the solar photovoltaic and solar thermal in pumping water, drying crops, cooling the storage and producing heating/cooling greenhouse. Next, paper [10] discusses solar application in agriculture. In this system, solar energy was used to power up brushless DC motor that was used for water storing in a pool and transferring of water waited in pool to drip irrigation. In paper [11], this journal discussing about the potential of using Renewable energy in Malaysia especially solar energy. In this paper [12], this paper discusses the use of solar energy in agriculture system such as to do a number of farm works, pumping water for irrigation, monitoring system and others. The research found that solar energy technologies for farming is divided into two systems which are photovoltaic cell system and uses solar capture heating system.

Paper [4] discusses the use of Nutrient Film Technique (NFT). The research monitored four elements which are water temperature, water level, pH value and concentration of nutrients (EC/PPM) with the help of IoT. The plants used in this test were pak choy, lettuce and kale. By using Arduino Uno as the microcontroller, WI-FI ESP8266 as the connectivity module and Raspberry Pi as the microcomputer, this system work successfully in displaying those elements to users by using IoT. In paper [5], Liquid Crystal Display (LCD) is used to display the result of monitoring pH level, water conductivity and water luminosity in Deep water culture technique. The plant used for this test is cucumber and those elements need to be given special care to successfully growing crops [13]. Next, in paper [15], it also discusses hydroponic monitoring system. This system is an advanced system as the system can monitor several elements such as pH level, air temperature and air humidity. It could also be used to control air pump, water pump and lamp. Paper [16] discusses about hydroponic monitoring system. This paper discusses about the importance of monitoring system to hydroponics as several elements need to have special care which are pH level, water level, lumens meter and water conductivity. Those elements will give impacts to crops, for example pH that is suitable for plants is from 5 to 5.5. If this requirement is not enough, it will disturb the growth of plants.

This work discusses the development of hydroponic monitoring system using solar energy as the main supply. The parameters involved for monitoring are water level, pH and temperature of the system. The Arduino is the main component of the system to control the sensor and collect the data for users.

2. Theory of Hydroponic System

This part discusses of theory the Hydroponic system. The hydroponic system is an advanced farming system that does not use soil as the medium. Instead, it uses nutrient water to replace the soil. The use of hydroponic system is very efficient in today's modern world as it uses less water, growing any plants without agriculture farm. Hydroponic can be divided into several systems which are Wick system, Ebb and flow system, Drip system, Deep Water Culture and Nutrient Film Technique (NFT).

(i) Wick System

Wick system is a hydroponic technique that does not requires electricity to run hence using absorbent medium such as coco coir, vermiculite and others to absorb the nutrients by using wick. This system works well for small plants, herbs and spice and does not work effectively that needs a lot of water [3]. As the plants absorbed water and nutrients form the medium, the wick automatically replenished the solution by the difference in total potential and capillary action [6].

(ii) Ebb and Flow System

Ebb and Flow system is a simple hydroponics system which works on the principle of flood and drain. The nutrient water will be controlled by pump that is connected with a timer to move up into the flood tray. The nutrients water will stay in the flood tray for certain period of time before draining back to reservoir by drain tube using gravitational force. This system works with filling the growth media with nutrients and nutrient solutions that are not reabsorbed back into the reservoir [7]. Besides, it is possible to grow different kinds of crops but the problem of root rot, algae and mould us very common [3].

(iii) Drip System

Drip system is a system that supply the nutrient water directly into the roots of the plants. Water pump that is connected to timer will distribute directly the nutrient water into every plant. The nutrient water that has been used will flow back into the reservoir to be used again. Various crops can be grown systematically with more conservation of water.

(iv) Deep Water Culture

For deep water culture, roots of the plants are suspended in nutrient rich water and air is provided directly to the roots by an air stone [3]. Plants are placed in a net pot and the roots of the plants are hanging in water nutrients solution hence the nutrients will be directly absorbed by the roots. The advantage of deep water culture system is highly oxygenated, using less fertilizer, low maintenance cost and monitoring time [8].

(v) Nutrient film Technique (NFT)

NFT is a system similar to Ebb and Flow in which the system uses a pump to deliver nutrient into tray that consists of dangling roots of the plants. The differences between NFT and Ebb and Flow is that NFT tray is slanted a little to ensure that nutrient water from the tray flows back to reservoir because of gravitational force. New nutrient water is constantly pumped into the tray continuously as NFT is an active system as shown in Fig.1.

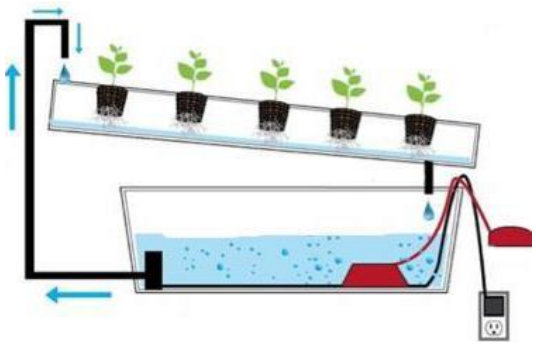


Fig. 1 - Nutrient Film Technique (NFT) system

3. Methodology

This session discusses the overall process of the project and the main components of the project.

3.1 Process of Project

The component of this project consists of solar panel, charger controller, rechargeable battery, Arduino Uno, I2C LCD, temperature sensor, pH sensor and water level sensor. Fig. 2 shows the overall process for the project in block diagram. Solar panel is used to capture and convert the solar energy to electrical energy. Then, the electrical energy is stored in 12V battery which is controlled by charger controller to avoid overcharging. Charger controller supplies direct electrical energy to hydroponic system during the daytime, while stored electrical energy in battery is used at night. Power supply is used to activate Arduino for the hydroponic monitoring system to run.

3.2 The Main Components of the Project

This part will discuss on the main components used in completing the project. The several main components discussed in this part such as a PV panel, a charger controller, a 12V lead acid battery, a buck converter, an Arduino Uno, a I2C LCD, a water level sensor, a temperature sensor, and a pH sensor. The software of Proteus 8, Arduino Ide and Sketch up is used in the project.

3.2.1 Photovoltaic Panel

PV panel is used for collecting the solar energy and convert the energy to electrical energy. PV panel consist of several PV cells that are arranged to collect the solar energy. The polycrystalline 10W solar panel has been chosen to be used in this project because it is suitable for charging 12V lead acid battery. Fig. 3 shows the polycrystalline 10W solar panel [17].

Table 1 - Parameter of photovoltaic panel

Rated	10W; maximum output can reach 12V
Efficiency	~16.5%
Dimension	36cm x 24cm
Weight	1.5kg
Thickness	17mm

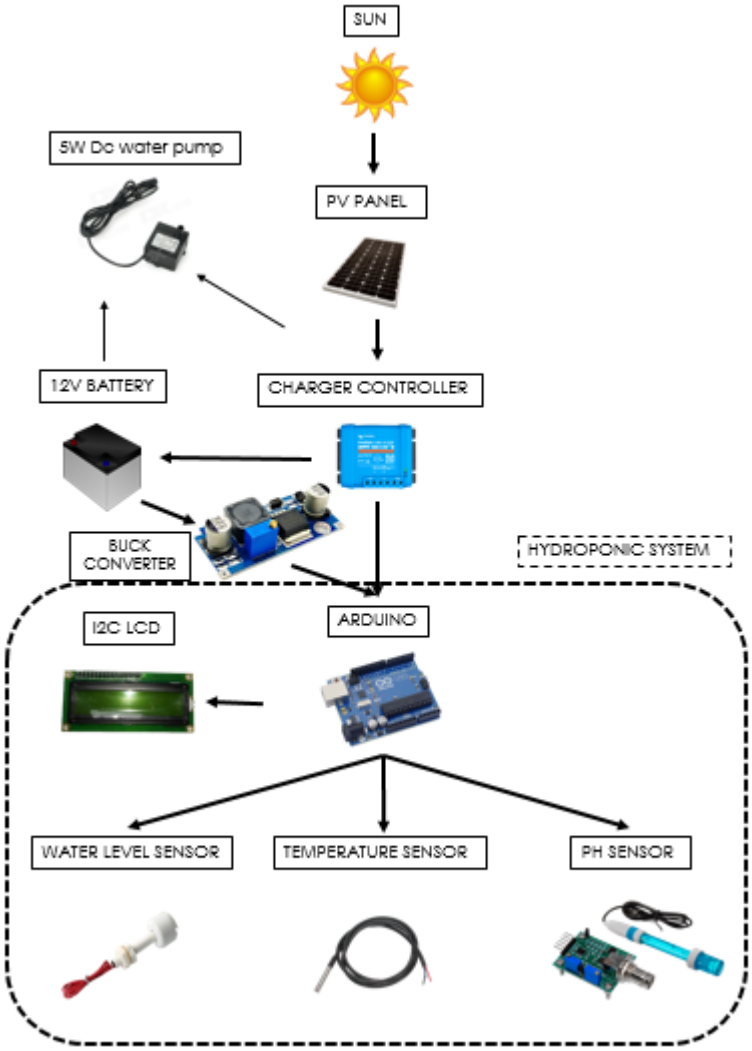


Fig. 2 - The block diagram of project

Fig. 3 - Polycrystalline 12V photovoltaic panel

3.2.2 Solar Charger Controller

Solar charger controller is a device that limits electric currents from added in battery. This solar charger will prevent the battery from being overcharging and could also protect against overvoltage. Solar charger controller is made up of several elements combined to become a circuit and very important for the project. Fig. 4 shows solar charger controller [18].

Fig. 4 - Solar charger controller

3.2.3 12V Lead Acid Rechargeable Battery

A 12V lead acid rechargeable battery is used in this project to supply electricity for hydroponic system at night. This type of battery is common for use because of its cheaper price, robust and need low maintenance. Absorbed sunlight that produces DC power supply will be stored in the battery and be used at night. Fig. 5 shows the 12V lead acid rechargeable battery, while Table 2 shows the specification of the battery [19].

Table 2 - Specifications for 12V lead acid rechargeable battery

Voltage	12V
Capacity	1.2 AH
Origin	Malaysia

Fig. 5: 12V Lead Acid Rechargeable Battery

3.2.4 Arduino UNO Board

Arduino Uno is a microcontroller that is used to control the system by following the instruction command by Arduino IDE. Arduino is an open source microcontroller for simple programming, deleting and reprogramming at any time [20]. Arduino Uno is used as a brain for the project that control all the sensors and collecting the data to display the result.

3.2.5 Water Level Sensor

Polypropylene Float Switch is a sensor used to detect level specifically to detect water level sensor in a tank. This water level sensor acts as a mechanical switch that extended into 2 wires. The sensor is surrounded by float- able cylinder and the switch will open when the cylinder is at the bottom while the switch closes when the water level pushes the cylinder upwards. This sensor is compatible with many microcontrollers and is easy to use.

3.2.6 pH Sensor

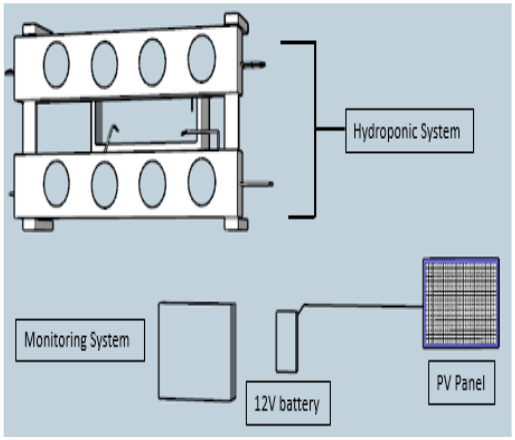
pH sensor is used to measure the pH value of water in Hydroponic system. In hydroponics, pH level is very important to be controlled because it will affect the growth of the plants. The value of pH for hydroponic is from 5.5 to 6.5. This PH sensor is composed of a PH glass electrode with a silver chloride silver references electrode and be used to measure pH value of aqueous solution.

4. Results and Discussion

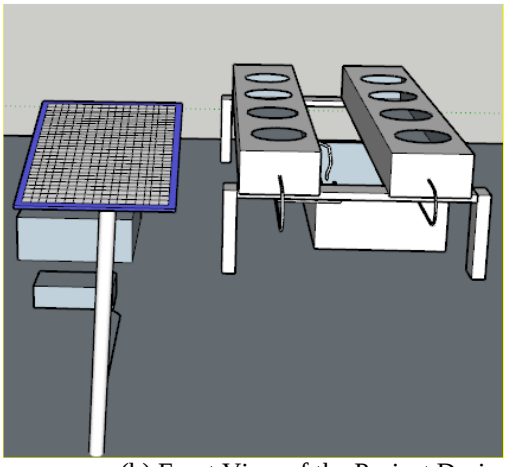
This section discusses the details of project design being sketched by using SketchUp software, simulation of temperature sensor, water level sensor and pH sensor by using Proteus software. The hardware development of the project is divided into several parts with are solar system part, monitoring system part, hydroponic monitoring system and the result discussion to test the effectiveness of the monitoring system.

4.1 Project Design

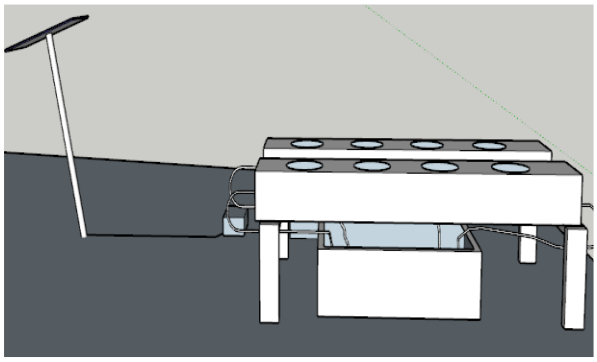
The SketchUp software is used in designing the project of Solar Powered Hydroponic Monitoring System. Fig. 6 (a) to (d) shows the top view, front view and side view of the hydroponic system and photovoltaic panel being used in the project.



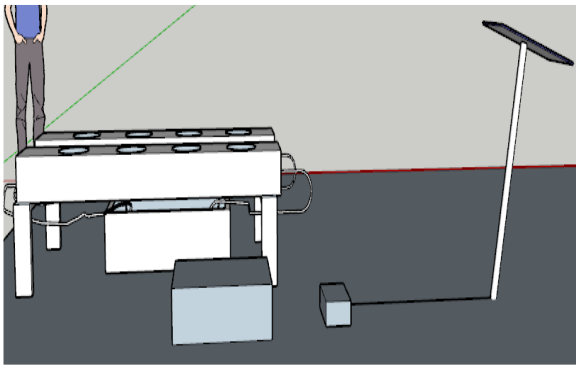
(a) Top View of the Project Design



(b) Front View of the Project Design



(c) Side View 1 of the Project Design



(d) Side View 2 of the Project Design

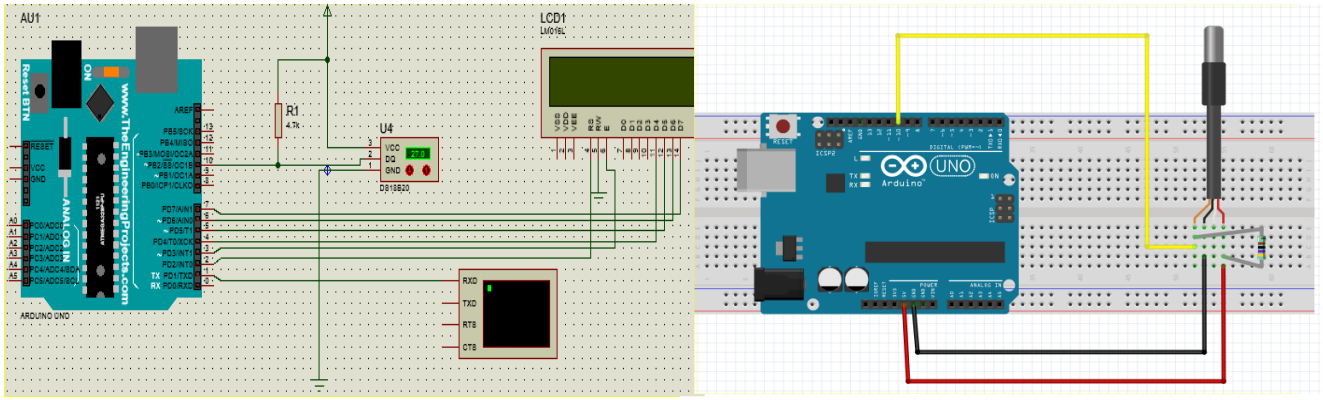
Fig. 6 - Design of Project using SketchUp Software

4.2 Simulation Development

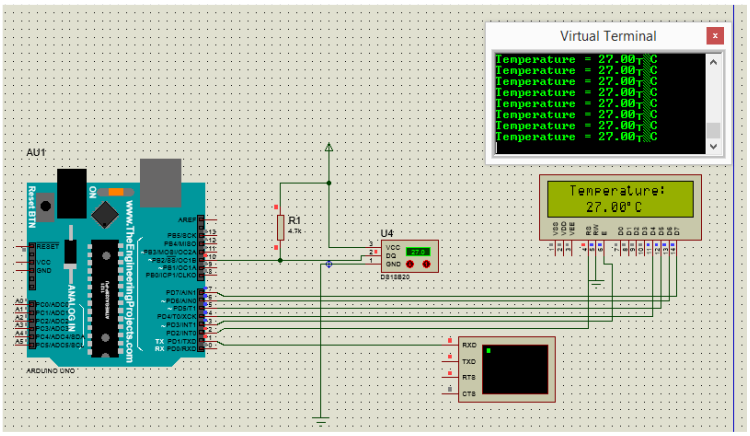
This part shows all the circuit connection between Arduino and all the sensors which are temperature sensor circuit, a water level sensor circuit, a pH sensor circuit and a solar charger controller circuit simulation. In the simulation, Arduino has also been set by uploading the coding into Arduino using Arduino IDE. The simulation between those sensors is separated by different circuit to ensure a higher understanding on the sensors.

4.2.1 Circuit of Temperature Sensor

Temperature sensor used in this project is DS18B20 that has three wires to be connected with Arduino. Fig.7(a) and Fig.7(b) show the circuit configuration between temperature sensor DS18B20 and Arduino UNO. Fig. 7(c) shows the result after simulation is started. The temperature sensor DS18B20 detects the surrounding temperature and by using the direct conversion of temperature to digital, the result is shown on the LCD. The result is refreshed after 1 second due to the coding on the Arduino. Based on Fig. 7(c), the LCD display the temperature of 27˚C and keep updating after 1 second until the simulation stop.



(a)Circuit Configuration of Arduino (b) Circuit of Arduino and Temperature sensor

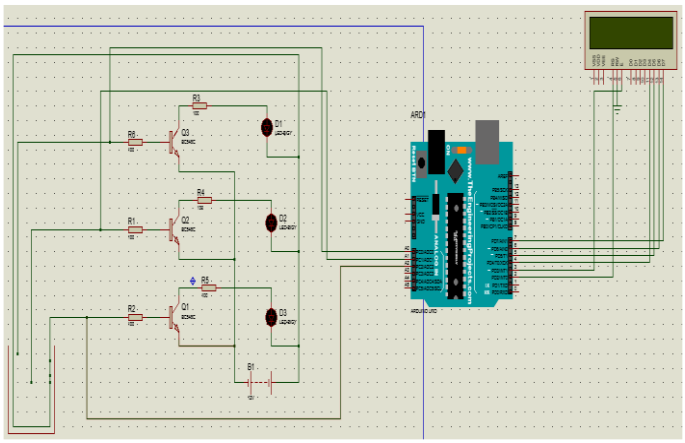


(c) Results of Temperature Sensor

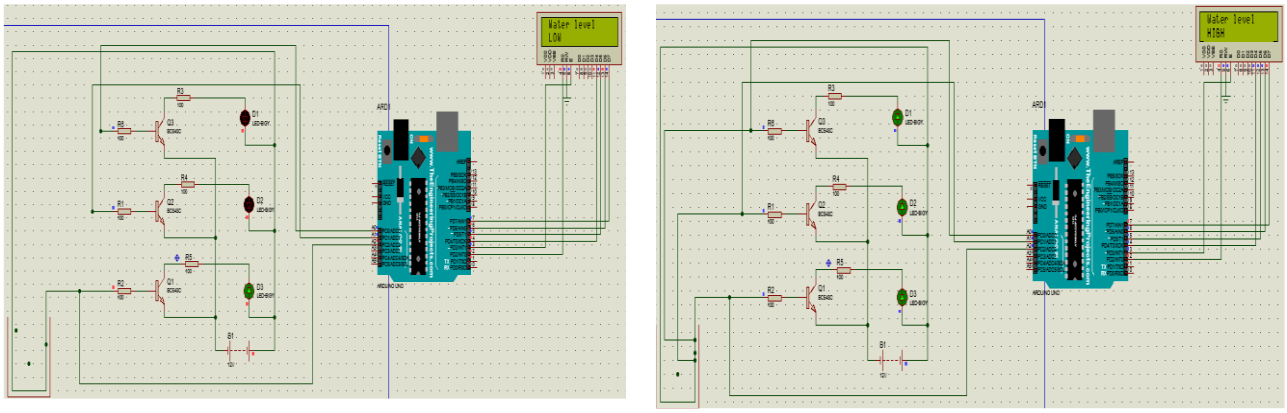
Fig. 7 - Circuit Simulation of Temperature Sensor

4.2.2 Circuit of Water Level

A water level sensor used in this project is polypropylene and is connected with Arduino UNO with several LED to indicate value of water in a water tank. Water level sensor is function as a switch to indicate the water level. The switch will open when the level of water is low while switch will close when the water level is high. Fig. 8 (a) shows the circuit configuration between water level sensors with Arduino UNO, while Fig. 8 (b) to (c) shows the circuit simulation of water level sensor. The sensor will detect on the water level and will transfer the data to Arduino, hence Arduino will process the data and display the result on the LCD. Based on the simulation, it shows that the LCD will notify the users by displaying the result of the water level on the LCD.



(a) Circuit of water level sensor



(b) Result when the water level is LOW (c) Result when the water level is HIGH

Fig. 8 - Circuit Simulation of Water Level

Table 3 shows the simulation result of water level sensor circuit. From the results, it shows that when the level of water is empty, LED D1 and LED D2 will be off and LED D3 will turn on with the LCD will display “Water level: Low” to indicate user that the water level is low. On the other hand, when the water level is full, LED D1, D2 and D3 will turn on with the LCD display “Water level: High” to show the users that the water level in the tank is full.

Table 3 - Results of Water Level in Simulation

WATER LEVEL	LED D1	LED D2	LED D3	LCD
Zero	Off	Off	On	“Water level : Low”
Full	On	On	On	“Water level : High”

4.2.3 pH Sensor Circuit

The Fig. 9 shows the circuit connection between a PH sensor and an Arduino UNO. In the figure, a PH sensor module along with a probe that use to measure the pH of the water because controlling pH in hydroponic system is very crucial. A PH sensor module will be connected to an Arduino UNO to display the result on LCD. Table 4 shows the result for PH sensor simulation. Based on the results, a PH sensor will shows the value of pH on the LCD. The value will indicate the solution acidity, for example pH 3.0 is acid solution, pH 7.0 is neutral solution and pH 8.0 is Alkali solution. The PH sensor could detect from 1 to 14 pH value, 1 to 6 pH value indicates acid while 8 to 14 indicates alkali.

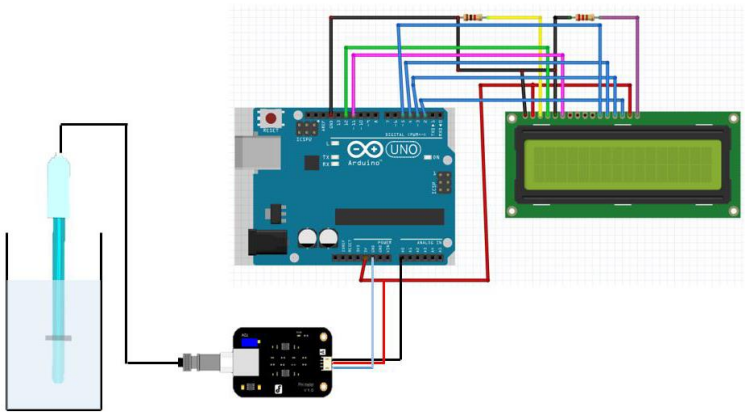


Fig. 9 - Circuit of pH Sensor

Table 4 - Results of pH Circuit in Simulation

pH	Solution
3.0	Acid
7.0	Neutral
8.0	Alkali

4.3 Hardware Implementation

This part will discuss on the result of the solar system prototype, after combining all the sensors, the prototype structures and the complete circuit of the project.

4.3.1 Solar System

In this part, discussion on the solar system prototype is shown to ensure that the prototype function successfully. The component used for the solar system is 10W of solar panel, a solar charger controller and 12V of lead acid rechargeable battery. Fig. 10 shows the process of battery charging by using the solar panel, while Fig. 11 shows the value of voltage being charged on the battery. The value of the voltage depends on the sunlight provided to the solar panel.

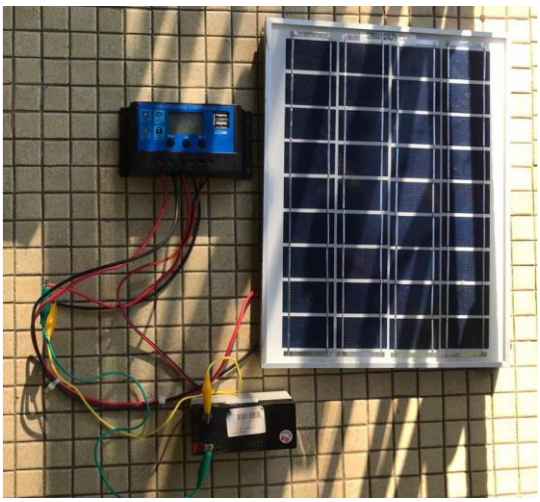


Fig. 10 - Solar system of project

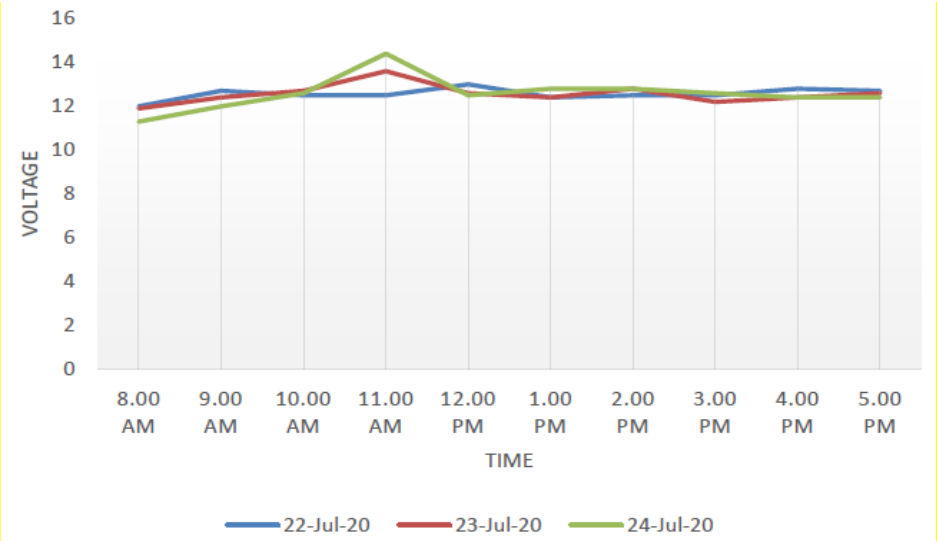


Fig 11 - Graph of voltage charging the battery

4.3.2 Monitoring System

All the sensors are configured in one system with the use of Arduino Uno in controlling the system. This monitoring system will be useful in many applications especially for hydroponic system as the monitoring system will control three sensors at the same time with the compilation of the data being shown to the users. Fig. 12 shows the complete configurations of the monitoring system.

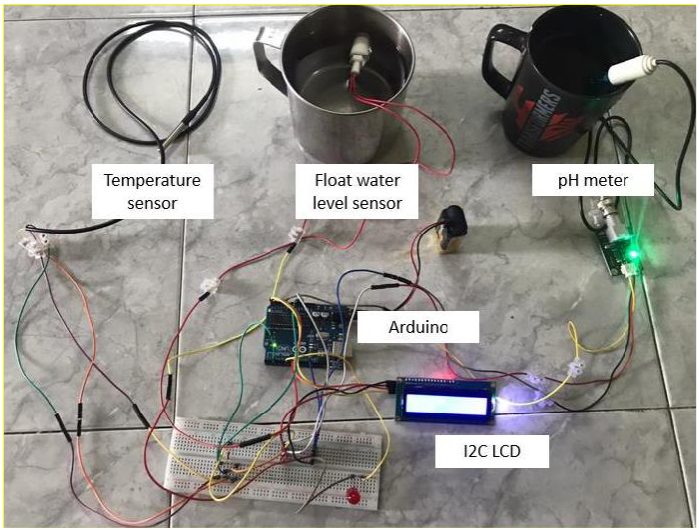


Fig. 12 - Monitoring System

The result for hydroponics monitoring system that consists of temperature, water level and pH sensor has been observed and recorded in the actual environment. The outdoor testing was done in Machang, Kelantan on 5th July, 6th July and 7th July 2020. The testing was done from 9.00 am to 6.00 am and the data was recorded once in an hour. The result shown above is the result for testing process after configuration for all sensors. The result is continuous as long as the Arduino is supplied by the power source. The results are shown in Fig. 13 and 14, respectively. Based on the result, the value of temperature for three days ranges from 25°C to 33°C. Meanwhile, the value of PH of water for three days ranges from 6.5 to 6.57. The value is neutral and suitable for vegetable.

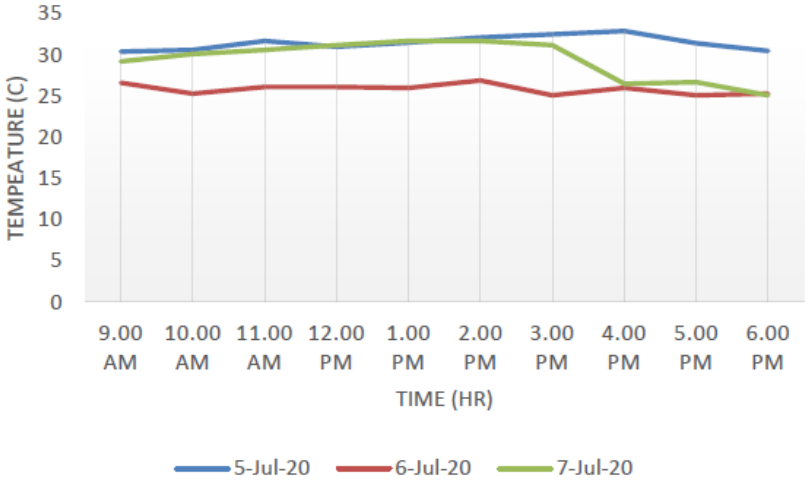


Fig. 13 - Graph of temperature for three days

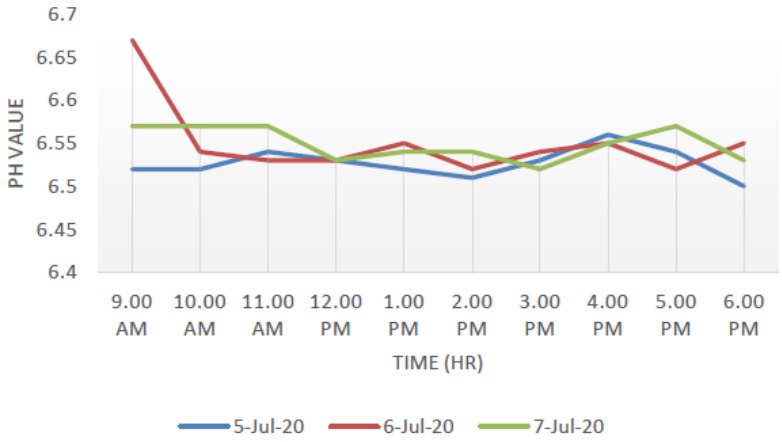


Fig. 14 - Graph of pH value for three days

5.0 Conclusion

In conclusion, the project of solar powered hydroponic monitoring system has achieved all the objectives stated. Arduino Uno and sensors are used in developing the monitoring system with the solar energy as the main source to monitor the value of temperature, water level and pH value. The first objective is to redesign a hydroponic system using solar energy as the main source. By using a 12W solar panel, a solar charger controller and 12V lead acid rechargeable battery, the system can be used in hydroponic system. The second objective is to develop monitoring system consisting of temperature, water level and pH monitoring. By using the Arduino Uno as the microcontroller, a system of monitoring system has been developed to monitor the element stated. DS18B20 temperature sensor, propylene float water level sensor and pH sensor have been connected with the Arduino and the data measured by those sensors has been displayed on the LCD that control by the Arduino. Lastly, the third objective is to test the effectiveness of solar powered hydroponic monitoring system. The data collected that consists of temperature, water level and pH has been analyzed in order to satisfy the third objective. The monitoring system will help the users to focus more time used for monitoring instead of testing the elements itself.

Acknowlegment

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