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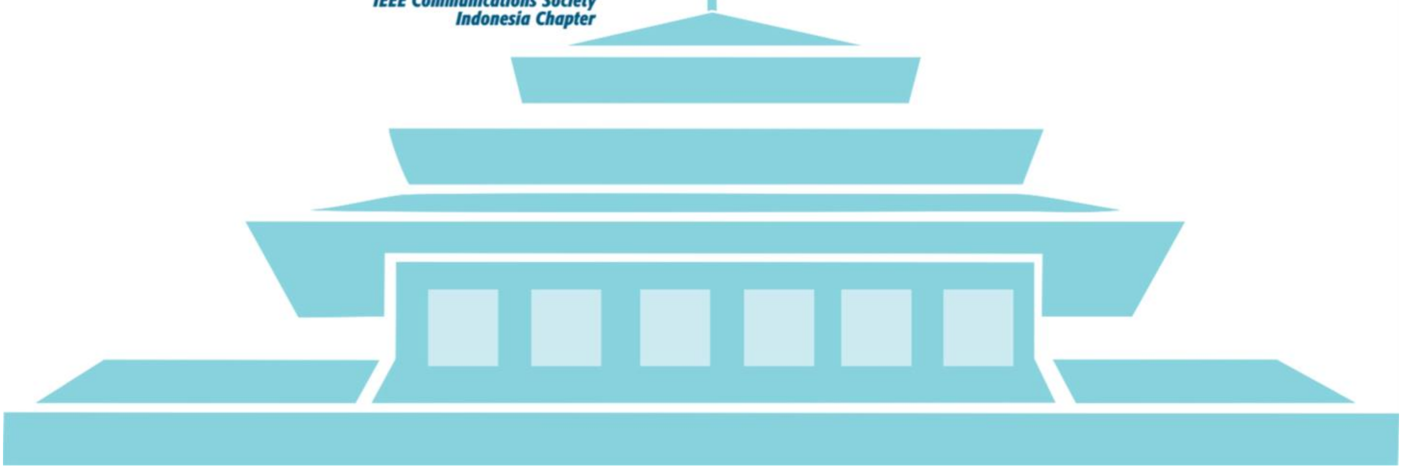

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Web-Based Monitoring and Control System for Aeroponics Growing Chamber

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Abstract – This paper presents a design and implementation of a system prototype for plant water and nutrients distribution. Furthermore, it has been implemented to support the optimal application of aeroponics system. It is based on a monitoring system which was used to observe the aeroponics growing chamber's parameters such as temperature, light, and pH. Meanwhile, the control system was used to manage actuators i.e. mist maker and fan for delivering water moisture. Sensor's data are transmitted via internet into server in order to facilitate easier monitoring for users. The prototype of the system is successfully implemented and provide a series of sensor's data.

Keywords— Aeroponics; growing chamber; monitoring system; control system; sensor; actuator

I. INTRODUCTION

With a vast area and large population, self-sufficiency in agriculture products to support the welfare of the Indonesia people is a necessity of a high importance. Despite the urgent need for improvement of agriculture productivity in Indonesia, this nation depends largely in imported goods rather than self-sufficiency [1][2]. The study has shown that current problems in the Indonesian agriculture sector could be divided into some aspects, with the four main accounted problems including: low productivity, ineffective marketing of farm products, high cost of farming supplies procurement, and farmers empowerment rate [3]. From this previous research, it was considered necessary to increase the agricultural production by increasing quality and quantity of the seeds in a controlled environment [3].

According to Blackmoore [4], there are four factors that are considered affected to agricultural productivity. These factors are described below.

- reduction of input,
- an enhanced control system,
- increased efficiency and,
- information management system

From this information, there is a method that can be applied to enable controlled environment in agriculture. This method is adopted from NASA and called by name "*Aeroponics*". The term *aero* comes from latin for "air" and "ponic" for work [5]. Aeroponics is the process of growing plants in an environment without the use of soil or aggregate but using mist or droplet. The basic principle of aeroponics is growing plants in a closed or semi-enclosed environment with an equipment necessary for spraying the plant's roots with nutrient and water. Basic aeroponics system diagram including the growing chamber is shown in Fig.1 [6]. According to NASA Spinoff [7], aeroponics can reduce water usage by 98 %, fertilizer usage by 60 %, and pesticide usage by 100 %, all while maximizing their crop yields by 45 to 75 %.

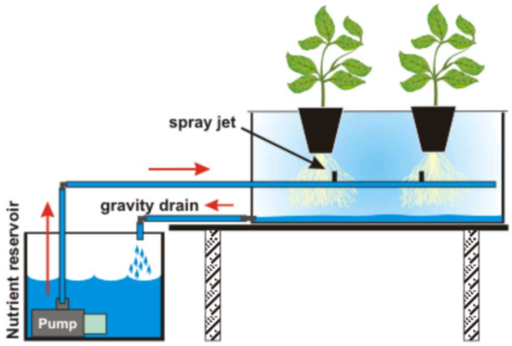

Fig. 1 Basic aeroponic system diagram [6].

On the disadvantage side [6,7], one major issue with an aeroponics system is the issue with its dependency on electronics and electrical system i.e. water pump. The plants can dry out and die very quickly if the water pump is inactive. In an aeroponics system, the water pump has to be relatively large because the high pressure is needed to micro spray the roots. This means the electricity demand is greater and a solar power backup system is needed. Other issues are with the water changes. If the reservoir's pH or nutrient levels get out of balance a water change is necessary.

TABLE I BASIC REQUIREMENT OF MONITORING AND CONTROL SYSTEM DEPLOYMENT ON AEROPONICS [6, 7, 8, 9]

No.	Parameter	Common Value
1.	Nutrient Delivery	Mist/Aerosol/Droplet
2.	Growing Medium	None
3.	Desirable pH Nutrient Solution	pH value 5.5 – 6.5.
4.	Cycle Timer Interval	For younger or new plants: 1 min ON, 5 min OFF For mature or older plants: 1 min ON, 15 min OFF
5.	Temperature	Generally the temperature is 22 °C-28 °C
6.	Light	Root area inside growing chamber need dark condition

Until recently many researchers have carried out several experiments to overcome the problems and develop a more effective and efficient aeroponics system. Early work by Idris et. Al. [10] has demonstrated that using ultrasonic mist maker in aeroponics system can give more efficient result especially on power and water/nutrition consumption. Meanwhile, Laksono et al. [11] focused on designing and implementating wireless sensor and actuator network (WSAN) for the control, monitoring and conditioning of aeroponic growing chamber inside greenhouse. They suggest that data transmission should be the main concern of aeroponics growing chamber monitoring and control. Using Short Message Service (SMS) was applicable for the purpose but it's inefficient in terms of cost. They recommend that these results are taken into account through utilizing more efficient data transmission method from the growing chamber to server such as GSM/GPRS/3G modem. Table I summarized the reference/guidelines for monitoring and control system deployment in agriculture application.

This paper presents an alternative method for monitoring and montrolling aeroponics agriculture using Wireless Sensor and Actuator Network. This work aims to extend the information from growing chamber to the end users via GSM/GPRS. The rest of this paper is organized as follows. In section II, we proposed the design of wireless sensor and actuator network. In section III, we present a result and discussion. Finally, the conclusion of this work is given in section IV.

II. PROPOSED MONITORING AND CONTROL SYSTEM

The general concept of the proposed system is shown in Fig.2 The system is consisted in 2 parts, namely monitoring & control system and solar panel system. This system shall enable automation for the related actuators with a user-defined settings.. The growing chamber that used in this research is a 50x40x20 cm box. From [12], the coverage of sensor nodes for agricultural application must be dense (i.e. 1 sensor/m^2) so this chamber only need one sensor per parameter. For online monitoring, sensors (pH, temperature, and light) data will be transmitted to server and displayed on a website .

The system consists of sensors, microcontroller, actuators and communication module, which monitor and control several parameters on growing chamber : temperature, water pH, and light intensity. The sensors that was used in this research are LM35 (temperature sensor), pH sensor, and LDR (light intensity sensor). This microcontroler is programmed using Arduino IDE. On the actuator, there are two relay, that activate Ultrasonic mist maker and fan on specific cycle time interval. The following are specifications for the designed system:

- System would be able to measure growing-chamber's temperature, pH, and light intensity.

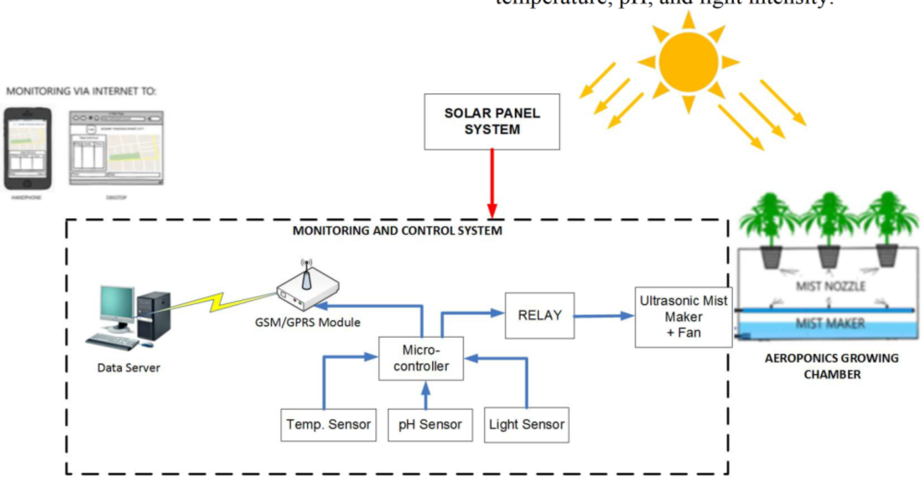

Fig. 2 System design.

- This system control timer for ultrasonic mist maker and fan activation.
- Sensor measurements will be displayed on a website.
- System is designed to transmit data using GSM/GPRS.

1) Temperature Sensor Subsystem

To obtain temperature data, LM35 sensor was used. This sensor is connected to signal conditioning circuit as shown in Fig.3.

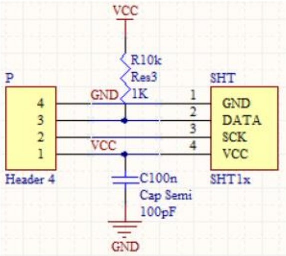

Fig. 3 Temperature sensor schematic diagram.

2) pH Sensor Subsystem

For pH levels data acquisition from the nutrition tank, a pH sensor, Lutron PE-03 (Fig.4) is used. The output of this sensor is connected to a signal conditioning circuit (Fig.5) that amplify the output signal while transmitting it to the ADC pin of the microcontroller.

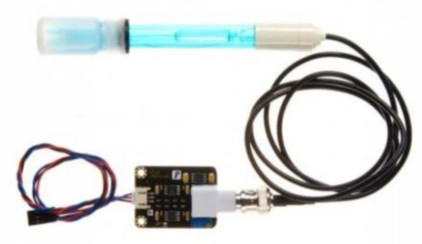
Fig. 4 pH Sensor.

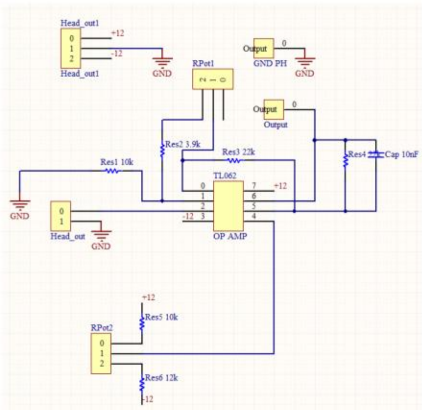

Fig. 5 pH sensor signal conditioning circuit design.

3) Light Sensor Subsystem

Light sensor is used to obtain light intensity measurements. It works based on a principal that it will generate current which will be proportional to the received light intensity. This sensor is also needed to be connected to signal conditioning circuit (Fig.6) before connected to microcontroller.

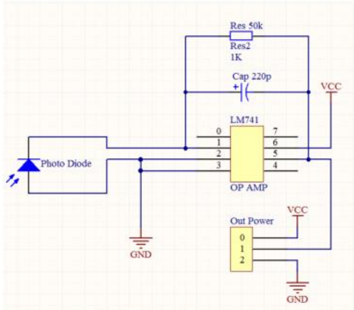

Fig. 6. Light intensity sensor signal conditioning circuit design.

Control system (Fig 7) is designed to maintain the timing how the actuator work. The timing cycle is shown in Fig. 8 and described as follow.

1. Mist maker will be turned on for a 2 minutes and turned off for 10 minutes.
2. Fan will be turned on when mist maker is activated to blown the water moisture.

The on / off time intervals are set on microcontroller timer. The timer intervals are need to be adjusted accordingly. For instance if the condition in a very dry area the off time needs to be reduced. In a place of wet or humid area the off time may need to be increased. The on time isn't as critical because the excess water is returned back to the reservoir. In other words the critical part is not drowning the roots, but rather the roots drying out.

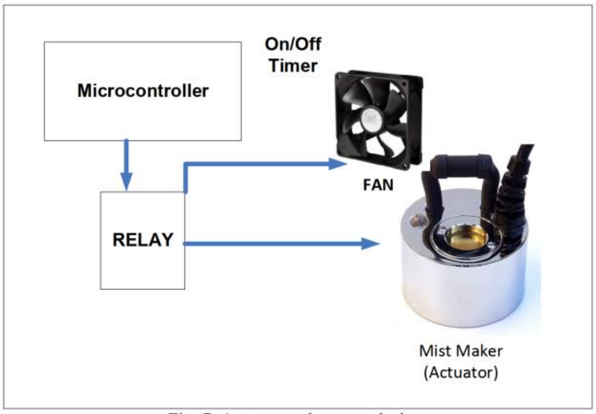

Fig. 7. Actuator subsystem design.

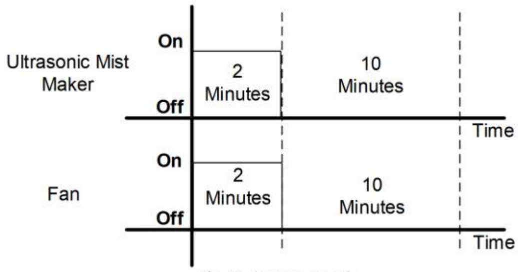

Fig. 8. Actuator cycle

B. Server System

Fig. 9 shows the flowchart that used for the web-based monitoring and control system. The server send signal 1 or 2 then in sequentially receive sensor data from aeroponics growing chamber. End users may connect directly with the server through internet using web browsers. Data from sensor node will be sent to server via GSM/GPRS.

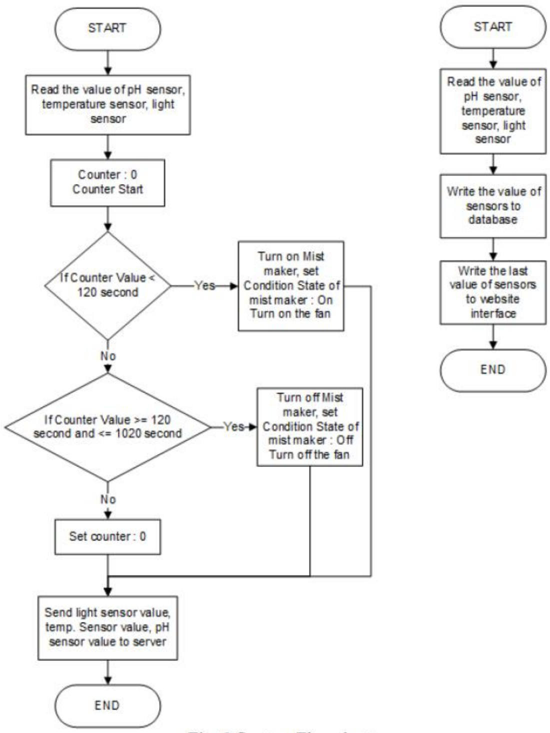

Fig. 9 System Flowchart.

C. Solar Panel System.

Solar Panel System (Fig.10) consists of Solar Panel, Solar Charge Controller, Battery, and DC-to-AC inverter.

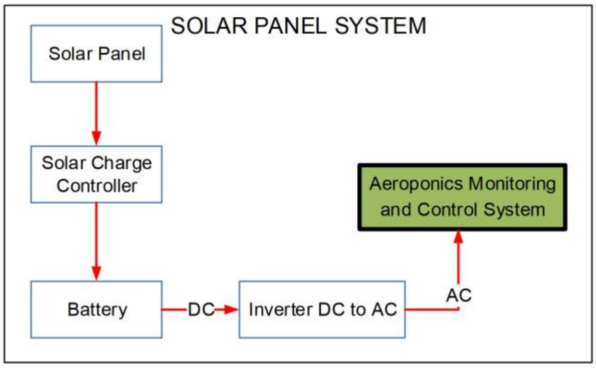

Fig. 10 Solar panel system block diagram.

This module convert light energy from the sun to electricity. Solar charge controller regulates the solar panel output to charge the battery. The inverter is used to convert from DC to AC.

III. RESULT AND DISCUSSION

A. Hardware Result

Fig. 11 shows the aeroponics system is deployed. *Chili* (*Capsicum frutescens*) is used as test plant's experiment (Fig.12). Solar panel system can be seen in Fig.12.

Fig. 11. System implementation.

Fig. 12. Plant for experiment.

Fig. 13. Solar panel system implementation.

B. Experimental Result

After implementation, a test is conducted to test functionality of the system's components.

1) Temperature Sensor Test Result

The result from temperature and humidity sensor experiment indicate that the temperature sensor. A testing in order to validate and calibrate the readings of the sensor was done by implementing other digital temperature reader which has a known tolerance and reliability, Lutron HT-3005. The sensor's value is still within its tolerable range.

TABLE II. TEMPERATURE AND HUMIDITY TEST RESULTS

Parameter	Designed circuit	Reference unit Lutron HT-3005
Average Temperature	28.5	27.1

2) pH Meter Test Result

A pH meter is tested using nutrient water mixture for aeroponics. The result on Table III and Fig.14 shows that in 1 hour, the pH level reading is consistent between 6.2 – 6.7 (neutral value). This results indicate that the sensor works consistently for aeroponics application.

TABLE III. PH METER TEST RESULT

Time (minutes)	pH
0	6.2
10	6.3
20	6.1
30	6.25
40	6.4
50	6.5
60	6.7

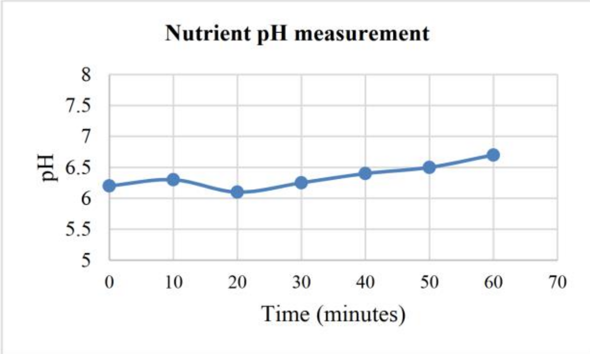

Fig. 14. pH sensor experiment result.

3) Light Intensity Sensor Test Result

Light sensor is tested was done by correlating the changes in the input with the readings obtained through a multimeter.

TABLE IV.
Light intensity sensor test results.

Condition	Output voltage
Light is lit	4.05V
Light sensor is covered	2.55V
Light is turned off	1.89V

This test results have been used to calibrate the sensor to obtain calculation and correlation between the voltage and light intensity.

4) Actuator Test Result

This test is conducted to obtain the information about the performance of actuator (mist maker and fan). Tabel V and Fig. 15 shows that within 7 hours the water and nutrient mixture decreased only 5 litre (± 0.7 L/hour) (see Table V and Fig.15). The result indicate that by using aeroponics system, nutrient usage is very efficient.

TABLE V. ACTUATOR AND TANK CAPACITY RESULT

Time (Hour)	Tank Capacity (litre)
1	40
2	39.5
3	37
4	36.8
5	36
6	35.8
7	35.2

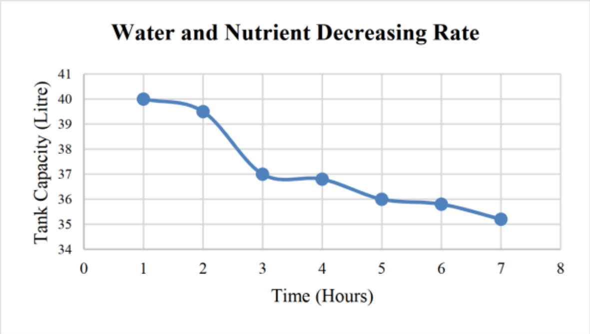

Fig. 15. Actuator test result.

5) Data Transmission Test Result

Data transmission to internet using GSM/GPRS module was done by sending data packets from the microcontroller to the server. This data transmission was scheduled once in every minute, each data packets containing data obtained from the sensors.

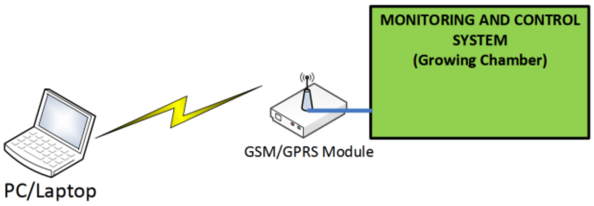

Fig. 16 Data transmission test.

The website is hosted on *Geeknesia* and can be accessed and displayed using web-browser (Fig. 17). The website provides the information about temperature, light intensity, pH level, and mist maker activation status.

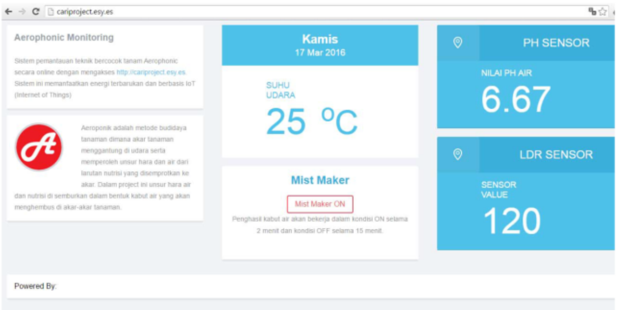

Fig. 17 System information is displayed on website

IV. CONCLUSION

This paper successfully presented an alternative method for monitoring and controlling aeroponics agriculture system. Firstly, the system can monitor environment condition using sensor data. Secondly, the system is programmed to automated actuator activation on specific time period. Thirdly, the data from sensor to server via internet using GSM/GPRS and can be accessed on website. Future research on this field should be directed at visual monitoring system i.e. camera installation.

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Web-Based Monitoring and Control System for Aeroponics Growing Chamber

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Web-Based Monitoring and Control System for Aeroponics Growing Chamber

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***Abstract* – This paper presents a design of a system prototype for plant water and nutrients distribution. Furthermore, it has been implemented to support the optimal application of aeroponics system. It is based on a monitoring system which was used to observe the chamber's parameters such as temperature and humidity. Meanwhile, the control system was used to manage actuators i.e. mist maker and fan for delivering water moisture. Sensor's data are transmitted via internet into server in order to facilitate easier monitoring for user. The prototype of the system is successfully implemented and provide a series of sensor's data.**

Keywords— Aeroponics; WSAN; monitoring system; control system; sensor; actuator

I. INTRODUCTION

With a vast area and large population, self-sufficiency in agriculture products to support the welfare of the Indonesia people is a necessity of a high importance. Despite the urgent need for improvement of agriculture productivity in Indonesia, this nation depends largely in imported goods rather than self-sufficiency [1][2]. The study has shown that current problems in the Indonesian agriculture sector could be divided into some aspects, with the four main accounted problems including: low productivity, ineffective marketing of farm products, high cost of farming supplies procurement, and farmers empowerment rate [3]. From this previous research, it was considered necessary to increase the agricultural production by increasing quality and quantity of the seeds in a controlled environment [3].

According to Blackmoore [4], there are four factors that are considered affected to agricultural productivity. These factors are described below.

- reduction of input,
- an enhanced control system,
- increased efficiency and,
- information management system

From this information, there is a method that can be applied to enable controlled environment in agriculture. This method is adopted from NASA and called by name "*Aeroponics*". The term *aero* comes from latin for "air" and "ponic" for work [5]. Aeroponics is the process of growing plants in an environment without the use of soil or aggregate but using mist or droplet. The basic principle of aeroponics is growing plants in a closed or semi-enclosed environment with an equipment necessary for spraying the plant's roots with nutrient and water. Basic aeroponics system diagram is shown in Fig.1 [6].

According to NASA Spinoff [7], aeroponics can reduce water usage by 98 %, fertilizer usage by 60 %, and pesticide usage by 100 %, all while maximizing their crop yields by 45 to 75 %.

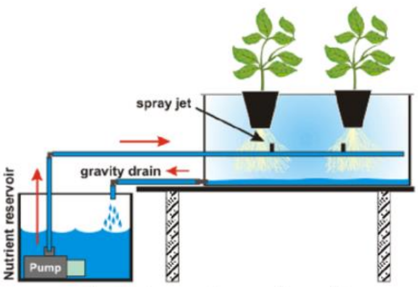

Fig. 1 Basic aeroponic system diagram [6].

On the disadvantage side [6,7], one major issue with an aeroponics system is the issue with its dependency on electronics and electrical system i.e. water pump. The plants can dry out and die very quickly if the water pump is inactive. In an aeroponics system, the water pump has to be relatively large because the high pressure is needed to micro spray the roots. This means the electricity demand is greater and a solar power backup system is needed. Other issues are with the water changes. If the reservoir's pH or nutrient levels get out of balance a water change is necessary.

Until recently many researchers have carried out several experiments related to aeroponics monitoring and control. Their findings and suggestions are reviewed here. Previous work by Laksono et al. [10] focused on designing and implementating wireless sensor and actuator network (WSAN) for the control, monitoring and conditioning of aeroponic growing chamber inside greenhouse. They suggest that data transmission should be the main concern of WSAN especially when the data is transmitted to users. Using short message service (SMS) was applicable for the purpose but its inefficency in terms of cost. They suggest that these results are taken into account through utilizing more efficient data transmission method from the growing chamber to server such as GSM/GPRS/3G modem.

Table I summarized the reference/guidelines for WSAN deployment in agriculture application.

TABLE 1
BASIC REQUIREMENT OF WSAN DEPLOYMENT ON AEROPONICS [6, 7, 8, 9]

No.	Parameter	Common Value
1.	Nutrient Delivery	Mist/Aerosol/Droplet
2.	Growing Medium	None
3.	Desirable pH Nutrient Solution	pH value 5.5 – 6.5.
4.	Cycle Timer Interval	For younger or new plants: 1 min ON, 5 min OFF For mature or older plants: 1 min ON, 15 min OFF
5.	Temperature	Generally the temperature is 22 °C-28 °C
6.	Light	Root area inside growing chamber need dark condition

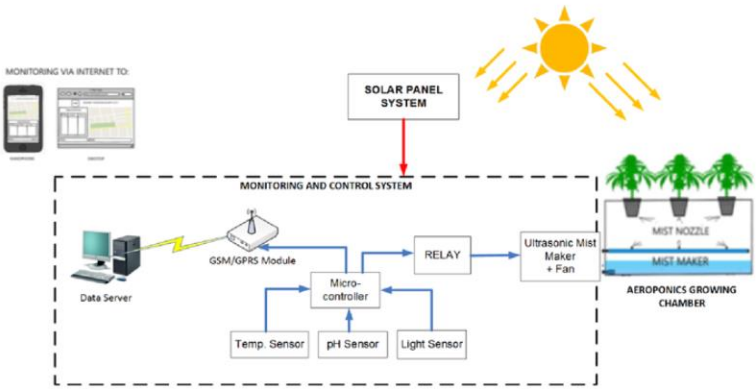

Fig. 2 System Block Diagram.

This paper presents an alternative method for monitoring and montrolling aeroponics agriculture using Wireless Sensor and Actuator Network. This work aims to extend the information from growing chamber to the end users via GSM/GPRS. The rest of this paper is organized as follows. In section II, we proposed the design of wireless sensor and actuator network. In section III, we present a result and discussion. Finally, the conclusion of this work is given in section IV.

II. Proposed Wireless Sensor and Actuator Network

The general concept of the proposed system is shown on Fig. 1. The system is consisted in 2 parts, namely monitoring & control system and solar panel system.

A. Aeroponics Monitoring and Control System

Aeroponics monitoring and control system is shown in Fig.2 This system shall enable automation for the related actuators with a user-defined settings. The coverage of sensor nodes for agricultural application must be dense (i.e. 1 sensor/m^2) [11]. Sensors (pH, temperature, and light) measurements will be transmitted to server and displayed on a website to allow online monitoring.

The system consists of sensors, microcontroller, actuators and communication module, which monitor and control several parameters on growing chamber : temperature, water pH, and light intensity. The sensors that was used in this research are LM35 (temperature sensor), pH sensor, and LDR (light intensity sensor). This microcontroler is programmed using Arduino IDE. On the actuator, there are two relay, that activate Ultrasonic Mist Maker and Fan on specific cycle time.

To obtain temperature data, LM35 sensor was used. This sensor is connected to signal conditioning circuit as shown in Fig.3.

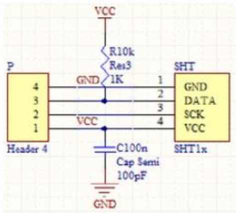

Fig. 3 Temperature sensor schematic diagram.

For pH levels data acquisition from the nutrition tank, a pH sensor, Lutron PE-03 (Fig.4) is used. The output of this sensor is connected to a signal conditioning circuit (Fig.5) that amplify the output signal while transmitting it to the ADC pin of the microcontroller.

Fig. 4 pH Sensor.

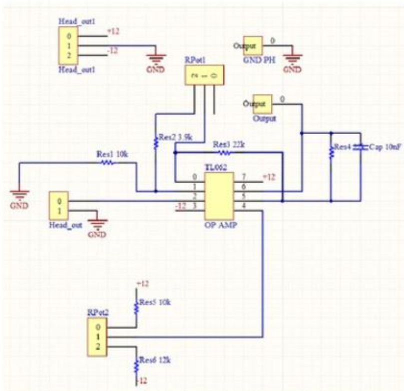

Fig. 5 pH sensor signal conditioning circuit design.

Light sensor is used to obtain light intensity measurements. It works based on a principal that it will generate current which will be proportional to the received light intensity. This sensor is also needed to be connected to signal conditioning circuit (Fig.6) before connected to microcontroller.

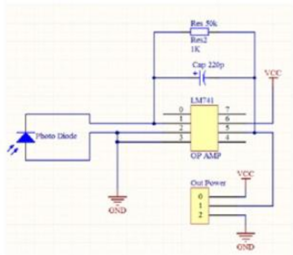

Fig. 6. Light intensity sensor signal conditioning circuit design.

Control system (Fig 7) is designed to maintain the timing how the actuator work. The timing cycle is shown in Fig. 8 and described as follow.

1. Mist maker will be turned on for a 2 minutes and turned off for 10 minutes.
2. Fan will be turned on when mist maker is activated to blown the water moisture.

The ON / OFF time intervals are set on microcontroller timer. The timer intervals are need to be adjusted accordingly. For instance if the condition in a very dry area the OFF time needs to be reduced. In a place of wet or humid area the OFF time may need to be increased. As a rule of thumb, the OFF time should be set a few minutes before the plants show signs of drying out. The ON time isn't as critical because the excess water is returned back to the reservoir. In other words the critical part is not drowning the roots, but rather the roots drying out.

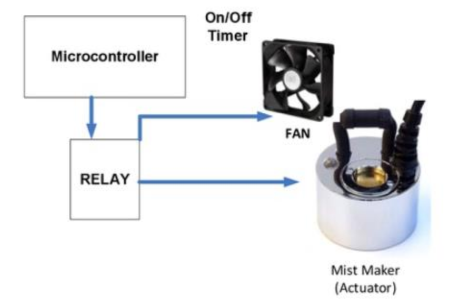

Fig. 7. Actuator subsystem design.

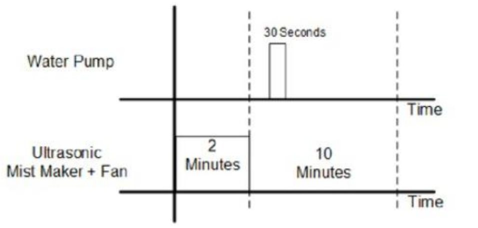

Fig. 8. Actuator cycle

Figure 9 shows the flowchart that used for the software of Monitoring System. The server send signal 1 or 2 then in sequentially receive data from Hydroponics system and power plant unit. The data that was received on server are temperature, water level, pH water, light intensity, current and voltage.

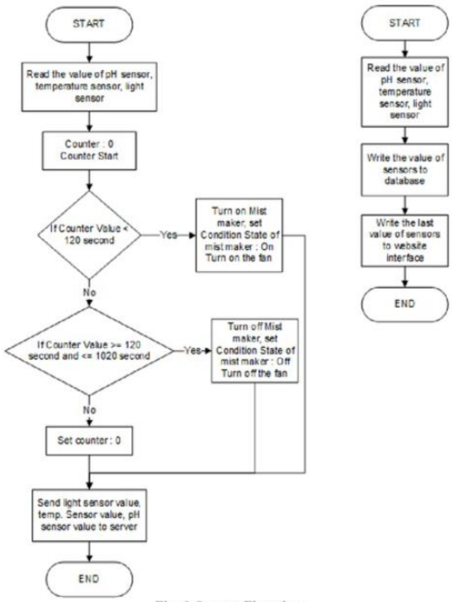

Fig. 9 System Flowchart.

B. Server System

For data storing and displaying, a there must be a PC based server where the monitored data will be displayed. End users may connect directly with the server through internet using web browsers to the WSAN. The connection between end users and server is established through GSM/GPRS.

C. Solar Panel System.

Solar Panel System (Fig. 9) consists of Solar Panel, Solar Charge Controller, Battery, and DC-to-AC inverter.

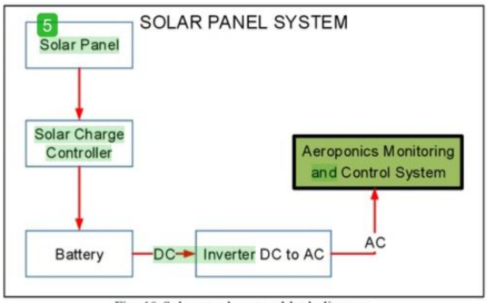

Fig. 10 Solar panel system block diagram.

This module convert light energy from the sun to electricity. Solar charge controller regulates the solar panel output to charge the battery. The inverter is used to convert from DC to AC.

III. RESULT AND DISCUSSION

A. Hardware Result

Fig. 11 shows the aeroponics system is deployed. *Chili* (*Capsicum frutescens*) is used as test plant's experiment (Fig.12). Solar panel system can be seen in Fig.12.

Fig. 11. System implementation.

Fig. 12. Plant for experiment.

Fig. 13. Solar panel system implementation.

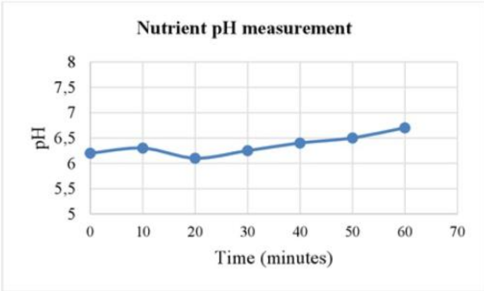

Fig. 14. pH sensor experiment result.

B. *Experimental Result*

After implementation, a test is conducted to test functionality of the system's components.

1) Temperature Sensor Test Result

The result from temperature and humidity sensor experiment indicate that the temperature sensor. A testing in order to validate and calibrate the readings of the sensor was done by implementing other digital temperature reader which has a known tolerance and reliability, Lutron HT-3005.

TABLE II. TEMPERATURE AND HUMIDITY TEST RESULTS

Parameter	Designed circuit	Reference unit Lutron HT-3005
Temperature	28.5	27.1

2) pH Meter Test Result

A pH meter is tested using nutrient water mixture for aeroponics. The result on Table III and Fig.14 shows that in 1 hour, the pH level reading is consistent between 6.2 – 6.7 (neutral value). This results indicate that the sensor works consistently for aeroponics application.

TABLE III. PH METER TEST RESULT

Waktu (menit)	pH
0	6.2
10	6.3
20	6.1
30	6.25
40	6.4
50	6.5
60	6.7

3) Light Intensity Sensor Test Result

Light sensor is tested was done by correlating the changes in the input with the readings obtained through a multimeter.

TABLE IV.
Light intensity sensor test results.

Condition	Output voltage
Light is lit	4.05V
Light sensor is covered	2.55V
Light is turned off	1.89V

This test results have been used to calibrate the sensor to obtain calculation and correlation between the voltage and light intensity.

4) Actuator Test Result

This test is conducted to obtain the information about the performance of actuator (mist maker and fan). Tabel V and Fig. 15 shows that within 7 hours the water and nutrient mixture decreased only 5 litre (± 0.7 L/hour) (see Table V and Fig.15). The result indicate that by using aeroponics system, nutrient usage is very efficient.

TABLE V. ACTUATOR AND TANK CAPACITY RESULT

Time (Hour)	**Tank Capacity (litre)**
1	40
2	39.5
3	37
4	36.8
5	36
6	35.8
7	35.2

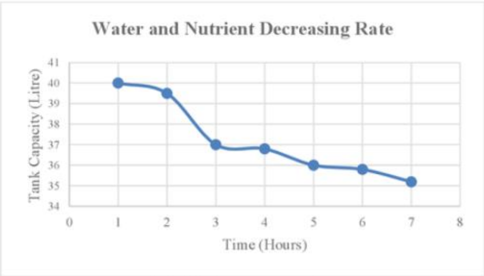

Fig. 15. Actuator test result.

5) *Wireless Network Result*

Data transmission to internet using GSM/GPRS module was done by sending data packets from the microcontroller to the server. This data transmission was scheduled once in every minute, each data packets containing data obtained from the sensors. The website is hosted on *Geeknesia* and can be accessed and displayed using web-browser (Fig. 16). The website provides the information about temperature, light intensity, pH level, and actuator activation status.

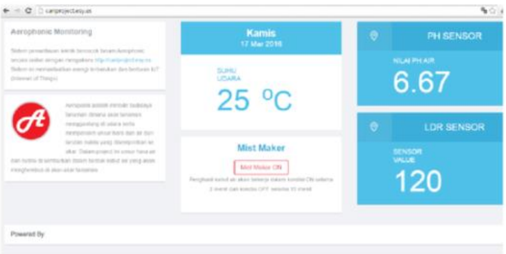

Fig. 16 System information is displayed on website

From the testing table II, III, IV and V, we give some analysis:

1. For the light intensity, the average of light intensity is 497. The system is ran accordance to the design, where the system will continously display the sensor's value.
2. The average water temperature is 25.46°C. The system ran accordance to the design, where the fan will turn to ON state if the water temperature more than 28°C and will still in ON state until the water temperature below 22°C.
4. The level of acidity (pH) in the water reservoir is on level 6.43, which is in good pH value for plant growth.

IV. Conclusion

This paper successfully presented an alternative method for monitoring and controlling aeroponics agriculture system using WSAN. Firstly, the system can monitor environment condition using sensor data. Secondly, the system is programmed to automated actuator activation on specific time period. Thirdly, the data from sensor to server via internet using GPRS and can be accessed on website.

V. Future Works

For future works, there are several improvement that can be done in this system such as :

1. Camera installation for visual monitoring.
2. Water cooling system for stabilizing nutrient's temperature.
3. Humidity sensor installation for monitoring the water moisture.

ACKNOWLEDGEMENTS

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