Automatic hydroponic nutrient mixing for hydroponic NFT and fertigation

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Abstract. This paper aims to create hydroponic nutrient mixing system automatically for circulation hydroponic system like NFT (Nutrient Film Technique) and for non-circulation hydroponic system such as drip irrigation system. System continuously sense nutrient concentration and pH level with EC (Electrical Conductivity) sensor and pH sensor. This data will process by ESP32 Wi-Fi microcontroller for monitoring and control dosing pump to maintain nutrient solution EC and pH with the predefined target. In non-circulated hydroponic, nutrition and water will flow into the irrigation system, to control humidity level in plant media, system use soil moisture level sensor. System use IoT cloud Blynk for easy user control and monitoring, user can use application in their smartphone. Test result shows system can increase the EC value from current condition 0.7 to target 3 within ±9 minutes and can maintain the EC value.

Keywords: ESP32, NFT, Fertigation, EC, pH.

1. Introduction
Currently there is a problem where population growth in the world continues to increase while agricultural land also continues to grow every year. According to the FAO (Food and Agriculture Organization) in 2050 farmers need to increase income by up to 70% to meet the food needs needed [1]. Agriculture 4.0 is a revolution in agriculture using modern technology. Agriculture 4.0 doesn’t use modern technology only for the development of innovation but also to solve problems related to current agriculture [2]. Vertical farming is a process of planting where plants are stacked using stacking racks to overcome the problem of the limited area of planting needed. In the vertical farming system that is carried out indoors the plant's light requirements are provided by artificial light with the aim to increase the growth rate of the plants [3]. In a study entitled Sensitivity of Seven Diverse Species to Blue and Green Light: Interactions with Photon Flux, the results show that the color adjustment of light can be used to increase the efficiency of plant growth [4].

NFT (Nutrient Film Technique) is an advanced technique of hydroponics in which the nutrient mixture that has reached the outlet is taken for reuse. Addition of water, nutritional elements, adjusting the pH level and EC (Electrical Conductivity), filtering, and sterilization need to be done so that the nutrient mixture can be reused [5]. Another nutrient delivery method commonly used is fertigation. Fertigation is a combination of the two words, they are fertilizer and irrigation. Fertigation is the process of adding nutrients to the irrigation flow that is used to water plants [6]. The output from fertigation usually uses a dripper so that nutrition output is constant and not excessive [7].
In hydroponic techniques because planting process doesn’t use soil as planting media, nutrients that are usually present in the soil need to be given manually to the path of irrigation system [8]. Nutrient levels needed by plants in water can be measured using EC (Electrical Conductivity). EC measurements in solutions can be done using sensors. In the non-circulated planting method the EC control only considers the amount of material used by the system, meanwhile in the circulated system the removal of residual nutrients will affect the nutritional control system that used [9].

2. System Design

There are two systems used, which are circulated (NFT system) and non-circulated (Fertigation system). Both NFT (Nutrient Film Technique) system and the Fertigation system use vertical farming planting method to grow plants. Nutrition in the NFT system is carried out by titrating nutrient fluids into a nutrient mixing container. Water from the tub will keep rotating through the netpot filled with rockwool that have plant seeds on it (close loop). Meanwhile the distribution of nutrients in the fertigation system is done by titrating nutrient fluids into a nutrient mixing container and directly channeled using the drip method to the cocopeat that contained plant seeds (open loop).

The NFT system monitors water temperature, ambient temperature and humidity around the area of plant growth, the level of light intensity, and the value of electrical conductivity (EC) in the mixing tank. Lighting in the NFT system is divided into two types, they are Full Spectrum LED and White LED with the purpose to see the effect of light on the process of plant growth. There is a scheduler system that can automatically turn on and turn off the lights according to a predetermined schedule. The automatic EC compounding system also has the feature of selecting nutrients for fruit and vegetable crops. All features in the NFT system are owned by the fertigation system, but there are additional features of soil moisture sensors in the fertigation system that are useful for automatic watering and maintaining the soil moisture conditions of the growing media. When the soil moisture condition of the growing media is below the threshold start to watering, the system will begin to water gradually until the moisture condition of the planting medium has reached the threshold stop watering.

Fig.1 NFT System Block Diagram
2.1. System Flow Diagram

Fig. 2 Fertigation System BlockDiagram

Fig. 3 NFT System Flow Diagram
When the system starts running, the system will initialize the necessary variables, such as input/output pin configuration, addressing each I2C module, and Wi-Fi connection. Then the system will access the configuration data contained in the EEPROM (Electrically Erasable Programmable Read-Only Memory). After accessing configuration data in the EEPROM, the system reads from the environment around the device. Humidity reading using the DHT22 sensor, visible light reading using the TSL2561 sensor, the value of EC in the water in the mixing container using the EC sensor, and the temperature of the water in the mixing container using the DS18S20 sensor. Then the system will check whether Blynk is connected to the server or not. If connected, the results of readings from all sensors and configurations on ESP32 will be sent to the Blynk cloud. Then the system will run the scheduler system. In this section the user can configure the scheduler to set the start and stop time of the lights. The last part of the NFT system is automatic EC control. Nutritional configuration, setting the target EC value, and setting the ON/OFF condition of dosing pump can be done in this section.

Fig.4 Fertigation System Flow Diagram

Just like in the NFT system, when the system starts, it will initialize the necessary variables, such as the configuration of input/output pins, addressing each I2C module, and configure Wi-Fi connection. Then the system will access the configuration data contained in the EEPROM. After accessing configuration data in the EEPROM, the system reads from the environment around the device. Humidity reading using the DHT22 sensor, visible light reading using the TSL2561 sensor, the value of EC in water in the mixing container using the EC sensor, the value of soil moisture in the planting media, and the temperature of the water in the mixing container using the DS18S20 sensor. The fertigation system has a feature for automatic watering on the planting media used. This feature can do watering to add and maintain moisture levels from the soil media used automatically.
2.2. Sensor Experiment (DHT22 Humidity and Temperature Sensor, DS18B20 Water Temperature Sensor, EC Sensor)

DHT22 Temperature and humidity sensor experiment performed by recording output value from sensor, and then compare it with commercial temperature and humidity sensor output. The experiment taken in two room condition where the second room is colder than the first one. For DS18B20 water temperature sensor experiment, 300mL water used to read the temperature and then compare the output with EC&TDS meter also pH meter temperature reading. In addition also conducted an experiment to see the time required by DS18B20 sensor to achieve stability in measurement of water temperature. Lastly for EC sensor first is the experiment to find coefficient value to change sensor output unit from voltage to EC. After that there also experiment to find the result of EC sensor output in system and compare it with commercial EC sensor output.

2.3. Scheduler System Experiment

The experiment is done by setting several times for scheduler to turns ON and OFF. The time during experiment continuously printed in monitor, and when scheduler do action notification will also be printed in monitor.

2.4. Automatic EC Control System Experiment

In this experiment the target EC value is set to 3 mS/cm. At the beginning the nutrient mixing container is only filled with plain water. The EC value in container is recorded every minute until the EC target is reached and also reaches its stability.

2.5. Fertigation Dripper Output Experiment

This experiment is done by collecting and calculate the output water from dripper with several condition, they are when both dripper line is on, when dripper line A is on and line B is off, lastly when dripper line A is off and line B is on. The experiment conducted several times with different duration with range from 5 to 300 seconds.

3. Experimental Result and Discussion

The following Figure 5 below is the results of DHT22 sensor experiment, the difference of output obtained error is 6.7%.

![Fig. 5 Graph of Temperature Reading in First Room](image-url)
Meanwhile in second experiment result that can be seen in figure 6, DHT22 error increasing to 12.2%. So it can be concluded that DHT22 reading errors increase in colder room.

The following Figure 7 below is the results of humidity reading from DHT22 sensors and compared to commercial humidity sensor. The difference obtained is quite big, there is 18% error which is due to the experiment have been done in open space.

The following figure 8 below is the results of humidity data reading between DS18B20 sensor, EC&TDS meter, and pH meter. The output value difference for each sensor has a relatively equal amount, then for this case DS18B20 sensor will use correction factor to make the reading result approaching to target reading.
For the time of DS18B20 sensor reach stability can be seen in figure 9.
The following figure 10 below is the result of relation between voltage and EC.

![Graph of Relation Between Voltage and EC](image)

**Fig. 10 Graph of Relation Between Voltage and EC**

After getting the relation then we use gradient formula to find the coefficient to change EC sensor output value from voltage to EC.

\[
m = \frac{EC_{\text{max}} - EC_{\text{min}}}{Voltage_{\text{max}} - Voltage_{\text{min}}}
\]

\[
m = \frac{5.023 - 0.692}{2.23 - 2.85} = \left( \frac{-4.331}{0.63} \right)
\]

And from here we can find the coefficient value using gradient equation formula.

\[
Voltage = EC \left( \frac{-4.331}{0.63} \right) + 2.94
\]

\[
EC = (Voltage - 2.94) \left( \frac{0.63}{4.331} \right)
\]

Next experiment is to see the result of EC sensor reading with proper EC value as output compared to commercial EC&TDS meter. The result can be seen in figure 11 below. The difference is so small, so it can be concluded EC sensor can be used in system.

![Graph of EC Value Comparison](image)

**Fig. 11 Graph of EC Value Comparison**
The following table 1 below is the result of scheduler experiment result. There is no delay in scheduler system used in system.

Table 1 Scheduler Test Result

| No | Time Configuration Scheduler Turned ON (hh:mm:ss) | Time Delay Scheduler Turned ON (s) | Time Configuration Scheduler Turned OFF (hh:mm:ss) | Time Delay Scheduler Turned OFF (s) |
|----|-------------------------------------------------|---------------------------------|-----------------------------------------------|---------------------------------|
| 1  | 12:03:00                                        | 0                               | 12:04:00                                      | 0                               |
| 2  | 12:10:00                                        | 0                               | 12:12:00                                      | 0                               |
| 3  | 12:15:00                                        | 0                               | 12:20:00                                      | 0                               |
| 4  | 12:24:00                                        | 0                               | 13:00:00                                      | 0                               |
| 5  | 14:42:00                                        | 0                               | 16:00:00                                      | 0                               |
|    | Average (second)                                | 0                               | Average (second)                              | 0                               |

Figure 12 below is the result of automatic EC control system experiment. Can be seen that EC target is achieved in 10 minutes and the system continue to stabilize the EC value in mixing container.

The following Table 2 below is the result of output from dripper from experiment. Dripper can maintain the output to fertigation system even when one line is closed and when both line is open.
Table 2 Compounding Nutrient Table

| Salt Type | A Open, B Closed | A Closed, B Open | A Open, B Open |
|-----------|-----------------|-----------------|----------------|
|           | Line A (t)      | Line B (t)      | Line A (t)      | Line B (t)      |
| 5         | 0.03            | 0.024           | 0.032           | 0.026           |
| 10        | 0.042           | 0.051           | 0.045           | 0.052           |
| 15        | 0.083           | 0.062           | 0.062           | 0.062           |
| 20        | 0.091           | 0.091           | 0.091           | 0.085           |
| 25        | 0.097           | 0.105           | 0.098           | 0.115           |
| 30        | 0.1             | 0.11            | 0.11            | 0.11            |
| 35        | 0.131           | 0.152           | 0.128           | 0.152           |
| 40        | 0.155           | 0.17            | 0.147           | 0.177           |
| 45        | 0.192           | 0.178           | 0.151           | 0.19            |
| 50        | 0.211           | 0.211           | 0.204           | 0.211           |
| 55        | 0.235           | 0.224           | 0.221           | 0.23            |
| 60        | 0.25            | 0.23            | 0.21            | 0.25            |
| 65        | 0.268           | 0.282           | 0.258           | 0.288           |
| 70        | 0.307           | 0.31            | 0.289           | 0.299           |
| 80        | 0.342           | 0.355           | 0.322           | 0.345           |
| 90        | 0.376           | 0.381           | 0.384           | 0.372           |
| 100       | 0.42            | 0.394           | 0.43            | 0.412           |
| 120       | 0.52            | 0.5             | 0.47            | 0.51            |
| 180       | 0.8             | 0.79            | 0.78            | 0.82            |
| 300       | 1.3             | 1.3             | 1.3             | 1.4             |
| Total Rate rata LPM | 0.258 | 0.000 | 0.000 | 0.258 | 0.251 | 0.265 |

4. Conclusion

DHT22 sensor has an accuracy of 93.3% in room with temperature about 26°C, and the accuracy fall into 87.8% in colder room with temperature about 19°C. Humidity reading from DHT22 has an accuracy of 82% when used in open room. Water temperature sensor DS18B20 has an accuracy of 96.9% for reading and need time more than 11 seconds to reach stability in reading. Scheduler system that used doesn’t have delay for ON and OFF time. EC sensor in experiment has an accuracy of 96.3% for measuring solution with EC range from 1 to 5. Automatic EC control system need 10 minutes to reach the EC target from 0.8 to 3. Dripper in fertigation system can maintain the output to system with average value of 0.258 LPM.

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