Nutrient Feeding Automation System in Hydroponic Cultivation Using NodeMCU Based on PID Controller

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Abstract: Hydroponic system is the cultivation of plants without soil and using only nutrient solutions in water. The concentration of these nutrients needs to be adjusted before being given to plants. If the nutrients given are too concentrated, the plants will die or wilt, on the contrary if the concentration is low, the plants will lack nutrients. The automation system for regulating nutrient concentrations in this study is based on a PID controller using nodeMCU. The setpoint is the reference nutrient concentration value which is compared with the current concentration output measured by the sensor to get an error. If the error is positive, it indicates that the plant is on the verge of nutrient deficiency so that the nutrient solution valve needs to be opened to increase the concentration of the solution. On the other hand, if the error is negative it means that the concentration of the solution exceeds the value it should have, so the water valve needs to be opened to reduce the concentration that occurs. The test results show that the PID controller with Kp=0.8, Ki=0.5, and Kd=0.5 gives a fairly good response and a relatively smaller average error of 3.92.

1 INTRODUCTION

There are number of studies have been carried out in relation with control hydroponic plants, including the design of a hydroponic plant automation system through regulating temperature and humidity, electrical conductivity, pH, and lighting using sensors and microcontrollers (Pache, Dudhe, & Dharaskar, 2022) as well as temperature and level regulation (Azhari, Simanjuntak, Hakim, & Sabar, 2022) (Chaiwongsai, 2019).

Control algorithms are used in the regulation of hydroponic plants to obtain better performance, including which uses the PID method to adjust pH of solution (Hadiatna, Dzulfahmi, & Nataliana, 2020). Another control method is Fuzzy Logic Controller to adjust nutrient concentration (Nurmahaludin, Cahyono, & Riadi, 2020) and to regulate the electrical conductivity and pH of hydroponic plants (Dela Vega, Gonzaga, & Gan Lim, 2021).

The next development is the regulation of providing nutrition to hydroponic plants wirelessly where Arduino is connected to Wi-Fi (Tembe, Khan, & Acharekar, 2018) (Sihombing, Karina, Tarigan, & Syarif, 2018) and an Ethernet module by connecting to a microcontroller (Haq, Suwardiyanto, & Raya Jember, 2018). Even though the control has been done remotely, the settings are still done on-off where the microcontroller will turn on or turn off the actuator (pumping machine) when the control objective has been achieved.

In this study, the PID control algorithm is used where the resulting error will be processed proportional, integral, and derivative. The valve opening process depends on the servo motor movement based on the PID controller output value so that the desired density is achieved faster than the on-off method. The control process is carried out wirelessly using NodeMCU via an android device.

The control process is basically an attempt to keep output (response) at the desired value of one or more variables. Control system also aims to obtain good performance from the controlled variables. Closed loop control block diagram is shown in Figure 1. Plant is a controlled system in this case is the concentration of the hydroponic solution.

Process begins by giving a set point in the form of the desired nutrient concentration value, then measure the current output using the TDS sensor. The results obtained are compared with the set point to find errors that occur.

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$$e(t) = SP - PV \quad (1)$$

where e(t) is error at time t, SP is set point, and PV is present sensor's measured output.

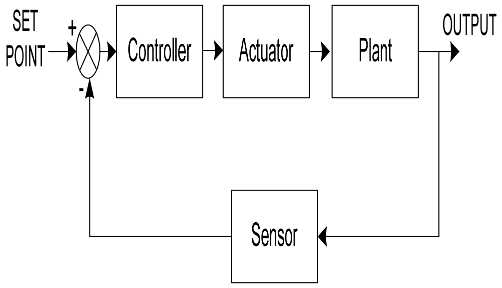

Figure 1: Block diagram of closed loop control system.

Controller will provide an action based on the control algorithm used. If using a PID controller, the resulting error will be processed proportionally (P), integral (I), and derivative (D) as follows:

a. Proportional Controller (P):

$$P = K_p\, e(t) \quad (2)$$

b. Integral Controller (I):

$$I = K_i \int e(t) \quad (3)$$

c. Derivative Controller (D):

$$D = K_d \frac{\partial e(t)}{\partial t} \quad (4)$$

2 METHODS

The design of the nutrient concentration control system in order to obtain the nutrient concentration in accordance with the reference value for each type of hydroponic plant is shown in Figure 2. To adjust the solution concentration, a PID control algorithm is used which will adjust the servo openings in the nutrient and water valve. After the concentration of the solution required by the plant is reached, the hydroponic plants are watered.

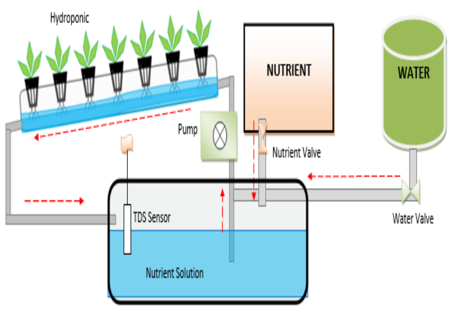

Figure 2: System design for nutrient concentration control.

2.1 System Design

Figure 3 shows the hardware design and online network. The main controller in system is the NodeMCU microcontroller based on the ESP8266 module.

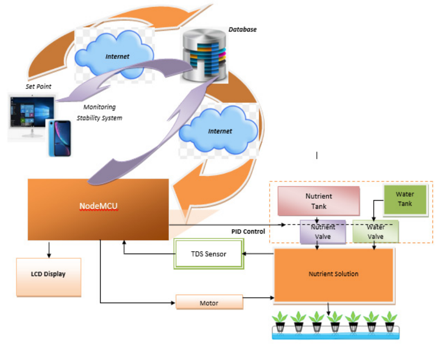

Figure 3: Hardware and network design.

The process of adjusting the concentration of the nutrient solution is shown in the flow chart as shown in Figure 4.

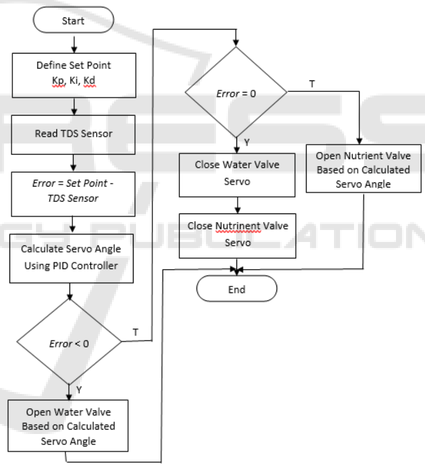

Figure 4: Control process flowchart.

2.2 Schematic Circuit

The schematic of electronic circuit is shown in Figure 5. Schematic has the following pin out configuration:

1. The TDS sensor will be connected to the analog pin A0 of the NodeMCU microcontroller. The sensor probe is placed in a tub of nutrient solution that flows into the hydroponic NFT.
2. RTC and LCD use serial I2C, each of which for SDA data is connected to the D1 pin of the NodeMCU Microcontroller. Meanwhile, the SCL leg is connected to the D2 pin of the NodeMCU Microcontroller.

3. Temperature and humidity sensors are connected to the D0 pin of the NodeMCU microcontroller
4. Solid State Relay to drive the stirrer motor in the NFT nutrient circulation basin and the main nutrient solution reservoir A and B, gets a trigger from pins D3 and D4 of the NodeMCU microcontroller.
5. Servo motor is used to rotate the water valve and the main nutrient valve solution A and B connected to the D5 and D6 pins of the NodeMCU microcontroller.

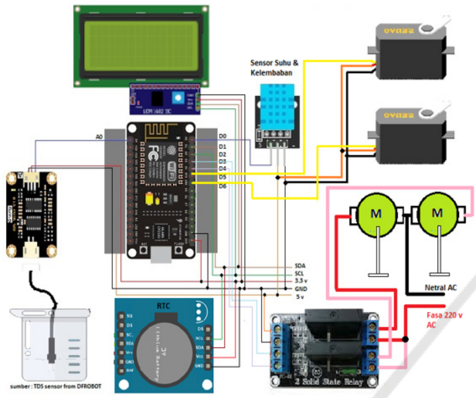

Figure 5: Electronic circuit schematic.

2.3 PID Control Algorithm Design

The nutrient solution concentration control system with PID control as shown in Figure 6 is as follows:

1. The system input (set point) is the desired reference value, in this case the concentration value of the hydroponic plant nutrient solution.
2. The system output is the current value of the nutrient solution concentration measured using the TDS (Total Dissolved Solids) sensor.
3. The output value is then compared with the set point to calculate the error.
4. The output of the PID controller will adjust the angle of the servo motor to open the nutrient solution or water valve.
5. If the error value is positive, it indicates that the plant is approaching the threshold of excess nutrients. So the controller will drive the servo motor to open the water valve.
6. On the contrary, if the error value is negative, it indicates that the plant is starting to approach the threshold of nutrient deficiency so that the nutrient solution valve needs to be opened through servo motor movement.
7. System response data (output) is sent to the database via the internet by the microcontroller. These responses can be accessed and displayed via the web for monitoring and analysis of system transient responses.

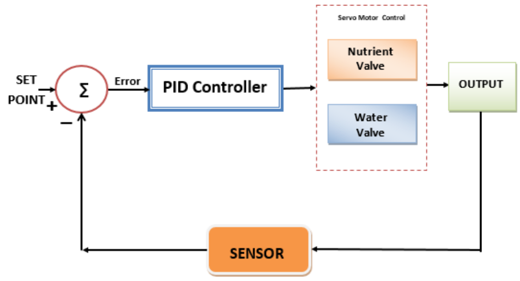

Figure 6: Nutrient concentration control system block diagram.

3 RESULT AND DISCUSSION

Node-MCU microcontroller will retrieve data from the database in the form of a reference value for the concentration of the desired plant nutrient solution.

3.1 Determine Set Point

The data is a set point that can be selected online via a gadget or computer based on the type of plant. Display of plant type selection as shown in Figure 7. In Figure 7 there are two types of plants to be selected. The selection is based on the type of hydroponic plants. For example lettuce will be selected then after the submit button is clicked, the nutrient density value data from the database will be sent to the NodeMCU as a set point is an error that will be processed by the microcontroller using the PID controller.

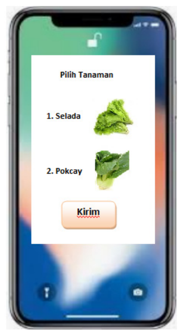

Figure 7: Web based hydroponic plant selection display.

The mechanism for using web based program is as follows:

1. Activate the WiFi access point that will connect to NodeMCU microcontroller.
2. Turn on the hardware device for the nutrition system for hydroponic plants.

3. After a few moments, setpoint value, TDS sensor, temperature, humidity and time display will appear on the LCD.
4. Open the internet web address and then enter the username and password as shown in Figure 8.

Figure 8: Menu login.

5. Selecting planting time setup menu as shown in Figure 9.

Figure 9: Main menu display.

6. Determination of set point starts from the setup menu for planting date and time on the website.
7. Return to the main menu to enter the TDS Data menu, to display TDS data, temperature and humidity. Set point value will be sent to the NodeMCU microcontroller via the internet as shown in Figure 7 as before.
8. TDS Graph menu provides system response in reaching a predetermined set point.

3.2 PID Controller Simulation Results

PID controller testing aims to determine the effect of the values of Kp, Ki, and Kd on the system response and the resulting error. Figure 10 provides test results with values of Kp=0.8, Ki=0.3, and Kd=0.2, where the value of the concentration of the solution from the TDS sensor readings are taken for each sampling time.

Response of the system to the set point is shown in Figure 5.13, with a set point value of 600 ppm. While the resulting error which is the difference between the set point and the output is given in Figure 11. The average error value of the test is 6.95.

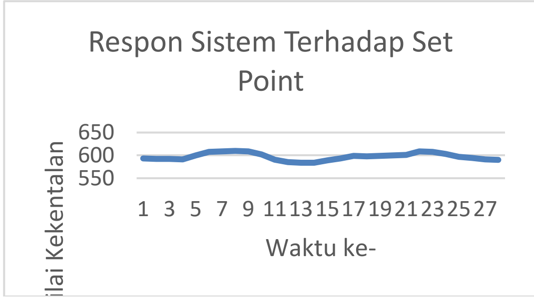

Figure 10: System response for Kp=0.8, Ki=0.3, Kd=0.2.

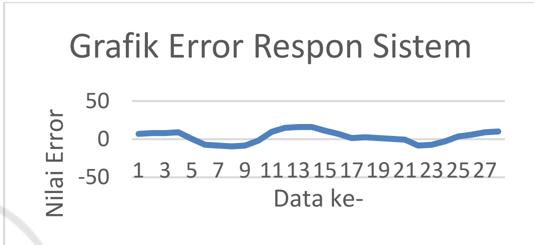

Figure 11: System error for Kp=0.8, Ki=0.3, and Kd=0.2.

Figure 12 is the result of testing using a PID controller with Kp=0.8, Ki=0.5, Kd=0.5 and a set point of 600 ppm. Average error value of the test is 3.92 as shown in figure 13.

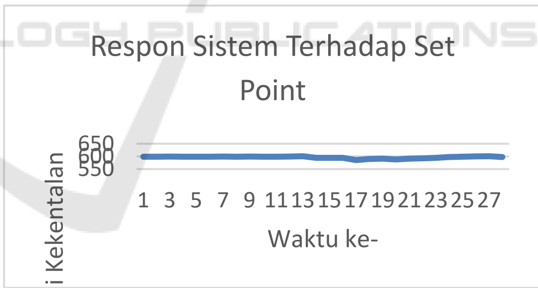

Figure 12: System response for Kp=0.8, Ki=0.5, Kd=0.5.

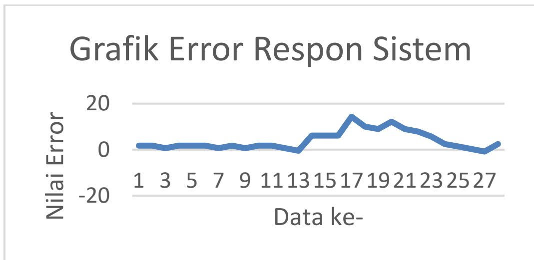

Figure 13: System error for Kp=0.8, Ki=0.5, and Kd=0.5.

Based on the simulation results, the PID controller values with Kp=0.8, Ki=0.5, and Kd=0.5 gave a smaller average error and a better response. This is because integral controller will reduce the steady state error and the derivative controller is useful for reducing the overshoot that occurs. So that by increasing the values of Ki and Kd compared to the initial value will give better results.

4 CONCLUSIONS

Control the concentration of nutrient solution for hydroponic plants using a PID controller where the output of the controller will regulate the opening of servo motor in the nutrient and water tank valve.

The test results show that the PID controller with Kp = 0.8, Ki = 0.5, and Kd = 0.5 gives a fairly good response and a relatively smaller average error of 3.92.

Improvement of system response and mean error in this test is done by increasing the constant of integral controller (Ki) and derivative controller (Kd).

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