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# PH Control System In Hydroponic Dutch Bucket System Chili Plant Using PI Control Method

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***Abstract***— *Dutch Bucket System for chili plants is a method of cultivating chili plants with a hydroponic system that utilizes a supply of nutritious water directly into a bucket (bucket). One of the parameters that affect the environment of chili plants is the degree of acidity (pH) dissolved in water as a growing medium. Where is, a suitable pH for chili growth is 6.0. The pH must always be maintained so that chili can grow properly. Therefore, we need a control system that manages the pH automatically. In designing this hydroponic system, the PI control method will control the pH parameters. The obtained results of the control system are an overshoot value of 2.79% and 7.83% when conditions areabove the set-point and below the set-point.*

**Keywords— *Ducth Bucket System, Chili Plant, PI Control***

## 1. INTRODUCTION

In general, chilies are cultivated using a planting medium in the form of soil, which is currently decreasing in availability. Then the cultivation of chili plants was developed using a hydroponic system. The hydroponic system is a cultivation system without using soil media with a more controlled living environment so that the results obtained are maximized[1]. From the existing hydroponic system, it is unfortunate that the chili plant's environment is still controlled manually by a farmer. One of the parameters that affect the environment of chili plants is the degree of acidity (pH) dissolved in water as a planting medium. Where is the good pH for the growth of chili, namely 6.0 – 6.5[2]. This pH must always be maintained so that chilies can grow properly. Therefore we need a control system that can control the pH automatically.

In designing this hydroponic system parameters such as pH will be controlled automatically using the PI control method. The simplicity of the structure and control parameters that are easy to tune are the reasons for using PI as a control method in this system [3]. It is intended that people can implement this system independently because it is relatively easy and simple to operate. In addition, this hydroponic system uses the Dutch Bucket System (DBS) method as a planting technique. DBS is a method in a hydroponic system that utilizes a continuous supply of nutritious water into a bucket, which will then flow back through a pipe with the help of a pump

## 2. SYSTEM DESIGN

### 2.1 System Block Diagram

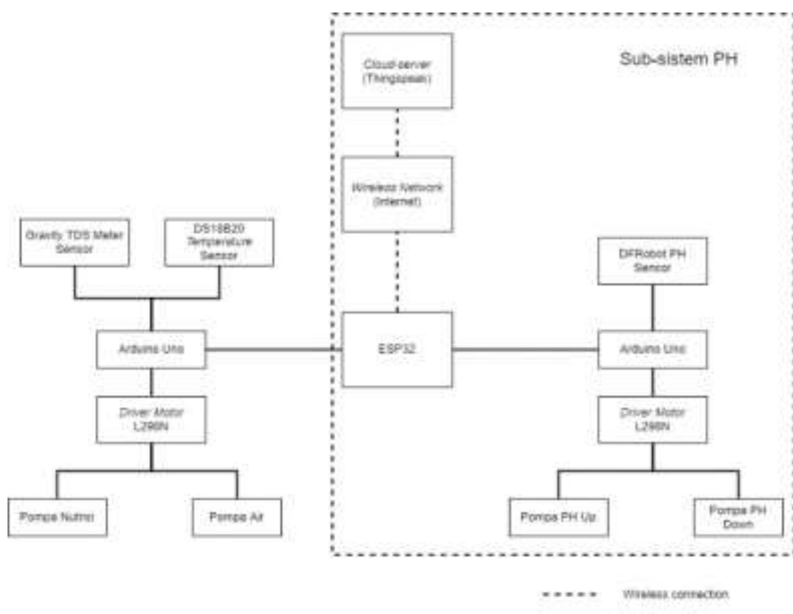



Fig 1. Water PH Control System Block Diagram and Nutritiong Monitoring

Overall, the control system for hydroponic DBS chili plants is shown for nutrient levels and water pH. Where the two parameters mutually influence each other. Balanced water pH levels will help plants absorb nutrients in their growth and development more easily. Then a control system was created is shown in Figure 1

In this system design , the focus is more on a system that is able to maintain the degree of acidity (pH) of water as a growing medium for hydroponic chili plants, namely at pH 6.0. In addition, the system is designed to be able to monitor changes in pH that occur via a web-server directly. The block diagram of the design of the pH control and monitoring system is shown in Figure 2

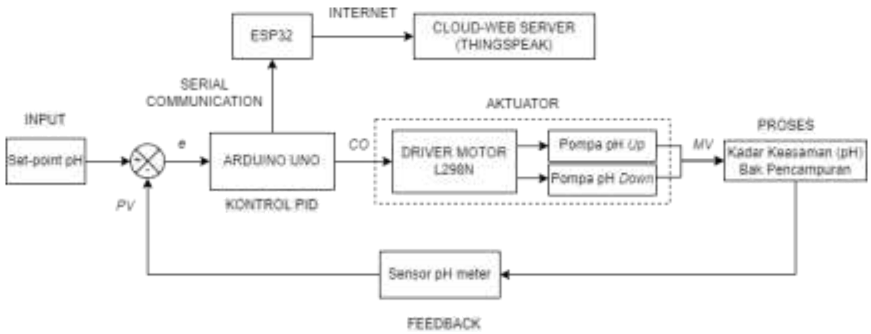



Fig 2. Control System Block Diagram and Water PH monitoring

## 2.2 Design of PI Control Methods

The first step in designing the PI control method is to test the system's open loop response. Open loop system response test was carried out by mixing the buffer solution into a 30 liter capacity mixing container with a constant PWM motor value, then observing changes in the readable system response. The acid/base buffer solution used is a mixture of 50 ml of weak acid/base and 2 liters of water. This mixed solution will be flowed by a motor with a PWM 80 to a mixing container filled with water, and a pH meter sensor SEN0161-V2 has been installed in it to take pH readings dissolved in water. The results of the pH sensor readings will be plotted in graphical form and an approach will be made using the IPDT (Integrating Plus Dead Time) method to find the mathematical modeling.

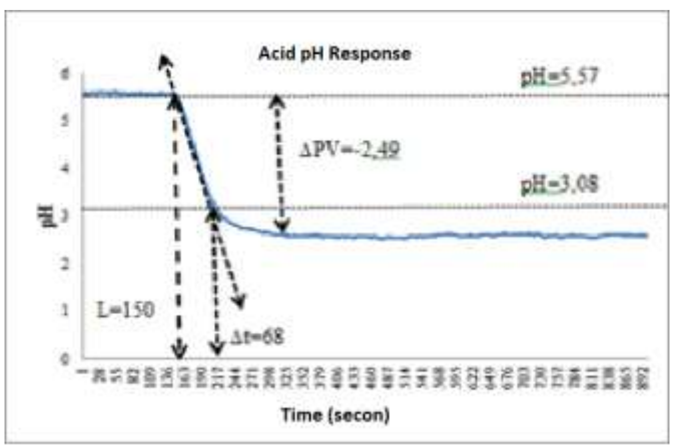



Fig 3. Acid PH System Response Graph

From the tests that have been carried out, the response of the system is obtained as shown in Figure 3. It can be analyzed that the pH value of the system has decreased from 5.57 to 3.08. In addition, IPDT parameters can be determined through equations (1) and (2), namely:

1. *Gain integrating* proses (K*)

$$K^* = \frac{\Delta PV/_{\Delta t}}{\Delta CO} = \frac{3.08-5.57/_{68}}{80-0} = -0,000457721 \quad (1)$$

2. Process Transport delay (L)

$$L=150 \text{ s} \quad (2)$$

From the tests that have been carried out, the response of the alkaline pH system was obtained as shown in Figure 4. It can be analyzed that the system has an increase in the pH value from 5.59 to 8.6. In addition, the IPDT parameters can be determined using equations (3) and (4) :

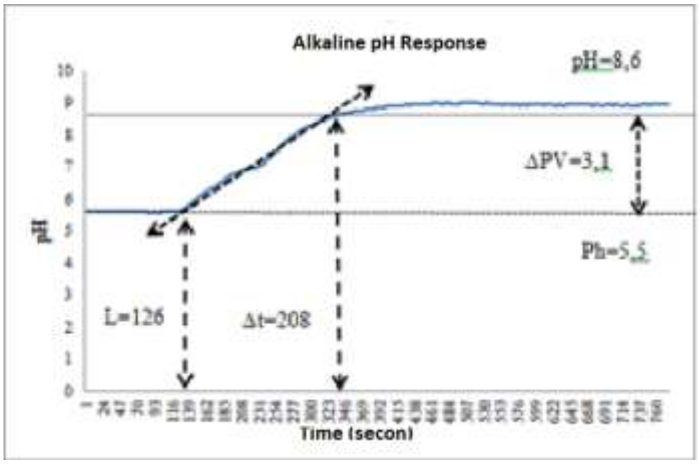



Fig 4. Alkaline PH System Response Graph

1. *Gain integrating* proses (K*)

$$K^* = \frac{\Delta PV/_{\Delta t}}{\Delta CO} = \frac{8,6-5,59/_{208}}{80-0} = 0,000180889 \quad (3)$$

2. Process Transport delay (L)

$$L = 126 \text{ s} \quad (4)$$

The formula for determining Kp and Ki values based on the Ziegler-Nichols 1 method is shown in Table 1

Table 1 Tuning PI Ziegler Nichols 1 Method

| Kontrol | Kp | Ti |
|---|---|---|
| P | $\frac{0,78}{L.K^*}$ | - |
| PI | $\frac{0,9}{L.K^*}$ | 3,3L |

From equations (3) and (4) it is possible to calculate the PI tuning parameters based on the formula in Table 1. The following calculations for the parameter values Kp and Ki are shown in equations (5) and (7).

$$K_p = \frac{0,9}{L.K^*} = \frac{0,9}{150 \times 0,000457721} = 13,10843373 \quad (5)$$

$$T_i = 3,3.L = 3,3 \times 150 = 495 \quad (6)$$

$$K_i = \frac{Kp}{T_i} = \frac{13,10843373}{495} = 0,026481684 \quad (7)$$

From equations (4) and (5) it is possible to calculate the PI tuning parameters based on the formula in Table 1. The following calculations for the parameter values Kp and Ki are shown in equations (8) and (10).

$$K_p = \frac{0,9}{L.K^*} = \frac{0,9}{126 \times 0,000180889} = 39,48742288 \quad (8)$$

$$T_i = 3,3.L = 3,3 \times 126 = 415,8 \quad (9)$$

$$K_i = \frac{Kp}{T_i} = \frac{39,48742288}{415,8} = 0,094967347 \quad (10)$$

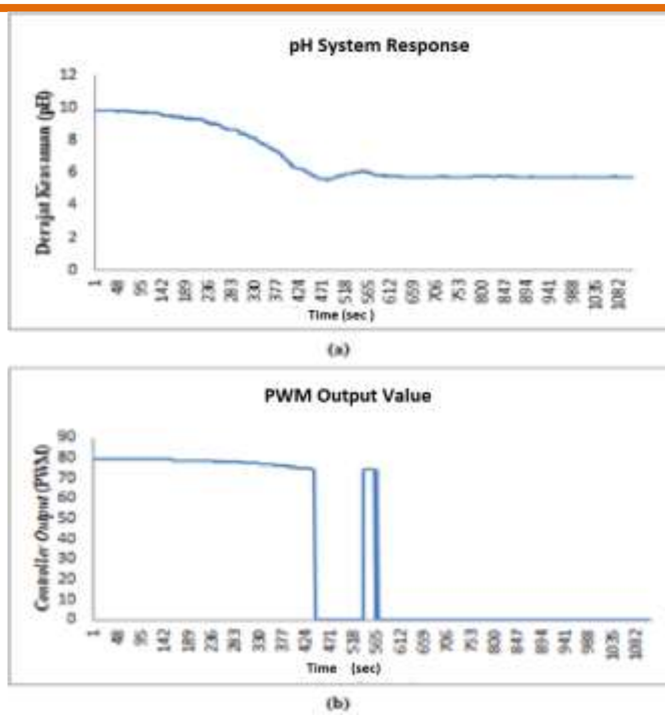



Fig 5. System Response with PI Control Above Setpoint Conditions
a. pH Value b. PWM Output

## 3. TEST RESULT AND ANALYSIS

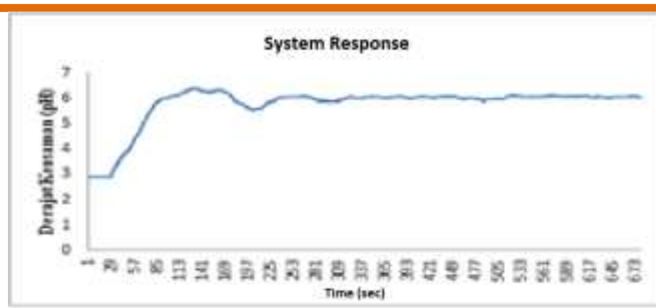
### 3.1 PI Control Testing on Conditions Above Setpoint

This test uses Kp = 13.10843373 and Ki = 0.026481684 to control the pH value of water according to a setpoint of 6.00. The initial condition of the pH reading is 9.81. The resulting error value is 3.81. This value will be sent to the Arduino Uno and processed to produce a PWM control signal. The control signal will be sent to the acid pump motor to supply how much acid buffer liquid into the container until the reading reaches the setpoint value. The results of testing the response of the PI control method in conditions above the setpoint are shown in Figure 5 (a) and (b).

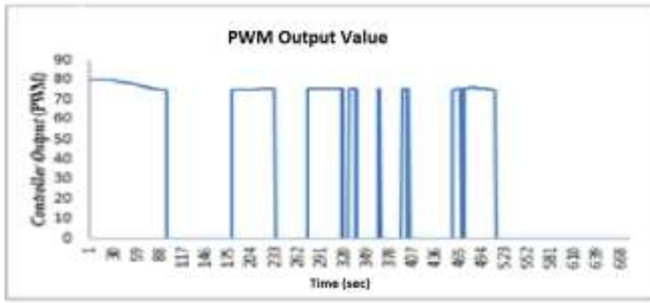
From the tests that have been carried out, the system response is shown in Figure 5 (a), it can be analyzed that the system has a delay time (Td) of 348 seconds, a rise time (Tr) of 254 seconds, a settling time (Ts) of 636 seconds, the overshoot value is 2.79% and the time peak value (Tp) at the second 478. Overshoot on system response occurs due to delays in process transportation (L). This causes when the actual pH has reached the setpoint, but the value has not been read on the sensor, so the pump will continue to pump and an overshoot will occur. Whereas in Figure 5 (b), it can be seen that when the pH is at a value ≤6, the PWM output value at the acid pump will be 0.

### 3.2 PI Control Testing on Conditions Below Setpoint

This test uses Kp = 39.48742288 and Ki = 0.094967347 to control the pH value of water according to a setpoint of 6.00. The initial condition of the pH reading is 2.88. The resulting error value is 3.12. This value will be sent to the Arduino Uno and processed to produce a PWM control signal. The control signal will be sent to the base pump motor to supply how much alkaline buffer liquid into the container until the reading reaches the setpoint value. The results of testing the response of the PI control method under the setpoint conditions are shown in Figure 6 (a) and (b).




(a)




(b)

Fig 6. System Response with PI Control Below Setpoint Conditions
a. pH Value b. PWM Output

From the tests that have been carried out, the system response is shown in Figure 6 (a), it can be analyzed that the system has a Td of 59 seconds, a Tr of 48 seconds, a Ts of 235 seconds, an overshoot value of 7.83% and a Tp value in seconds to-204. There is an overshoot in the system response, caused by a delay in the process transportation (L). This causes when the actual pH has reached the set point, but the value has not been read on the sensor, so the pump will continue to pump and an overshoot will occur. Whereas in Figure 6(b), it can be seen that when the pH is at a value ≥6, the PWM output value at the base pump will be 0.

### 3.3 PI Control Testing with Disturbance

This test uses Kp = 13.10843373 and Ki = 0.026481684 to control the pH value of water according to a set-point of 6.00. The initial condition for reading the pH is 5.9 (steady state). Then 30 ml of KOH base liquid was given into the mixing container so that the reading became 9.28. The resulting error value is 3.38. This value will be sent to the Arduino Uno and processed to produce a PWM control signal. The control signal will be sent to the acid pump motor to supply how much acid buffer liquid into the container until the reading reaches the setpoint value. The results of testing the response of the PI control method when given a base disturbance are shown in Figure 7 (a) and (b).

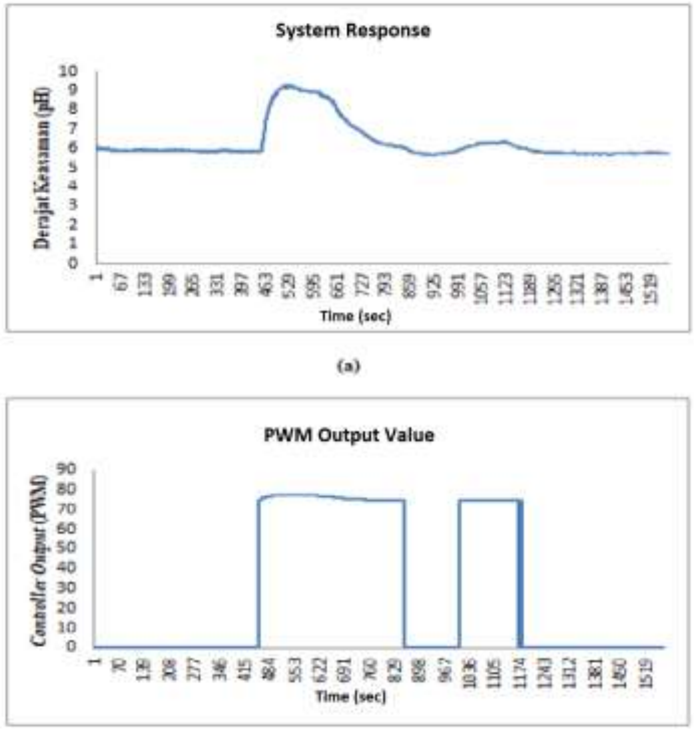



Fig 7. System Response with PI with Disturbance
a. pH Value b. PWM Output

## 4. Conclusion

From the response of the system with PI control in the conditions above the setpoint has a Td of 348 seconds, a Tr of 254 seconds, a Ts of 636, an overshoot value of 2.79% and a Tp value of 478 seconds. From the response of the system with PI control under the setpoint conditions, it has a Td of 59 seconds, a Tr of 48 seconds, a Ts of 235 seconds, an overshoot value of 7.83% and a Tp value of 204 seconds.

From the response of the system with PI control when given 30 ml of alkaline disturbance in the 454th second in water with a steady pH of 5.9 it rose to 9.28. So that the resulting error is 57.28%. The system response experienced an overshoot of 10.8% with the Tp value at 1117 seconds. And the system reaches its steady state again at the 1263th second or 809 seconds after being disturbed. From the response of the system with PI control when given 30 ml of acid disturbance in the 308th second in water with a steady pH of 6.1 it decreased to 3.42. So that the resulting error is 43.93%. The system response experienced an overshoot of 9.71% with the Tp value at 643 seconds. And the system reaches its steady state again at the 666th second or 358 seconds after being disturbed.

## 5. Acknowledgment (Heading 5)

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