IoT-Based Flow Control System Using Node MCU with PI Controller CHR Tuning Method

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Abstract. In community life, the availability of clean water has been decreasing with the decrease in water quality of community consumption. This is obtained from reality and surveys in several villages. Compared with the results of reports from the National Statistics Agency, the province is very volatile and tends to increase every year. In this event, there is an imbalance between the report and reality so sometimes the community can not do anything. it is better if the community or everyone should control the use of clean water. This is an effort to stabilize the availability of clean water in the community. The objective of this study is to provide solutions to tackle those problems by controlling the water flow through a smartphone. Therefore, the consumers who get less water distribution for their daily needs will decrease. The method used to regulate the water flow rate is PI control with the Chien Hrones Reswick (CHR) tuning method. The results show that the Chien Hrones Reswick method produces a better and faster response to achieve a stable condition. Furthermore, when the system is given a disturbance, the response from the sensor can reach a stable condition. Moreover, when the setpoint is changed, the response from the sensor can still follow the setpoint changes and can achieve a good and fast steady state.

Keywords: Chien Hrones Reswick · IoT · Turning Method

1 Introduction

Water is a basic necessity for mankind. Water availability and quality are the top priorities for living well on this earth. Drinking water is good for consumption and should include tasteless, odourless, colourless and without heavy metals [1]. Water is needed in all human lifespan ranging from low scale to high scale industries because in the industrial production process it must use at least running water but the water flow must be well controlled and monitored. Therefore, the entire production process in the industry is very measurable and beneficial [2]. Now, modern industrial technology reaches generation 4.0, which is all internet-based system control, although not all are implemented [3–5].

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In this case, we make a literature study to solve a few existing problems where water flow stability can be regulated, monitored, and maintained [6].

In the literature, there are many control methods used to control or maintain the variable at the reference value or set point such as the PI controller [7] adaptive control [8] sliding mode control [9] and model predictive control [10] Proportional Integral control to obtain a good stability response using the Chien Hrones Reswick (CHR) tuning method is utilized in this study. To obtain a better system response, with a speed rise time and minimum overshoot, the NodeMCU v3 is used as a controller. Then, a valve with a servo motor is used as an actuator, and pipe is the main plant of our system. In this paper, the design of proportional-integral controllers by using Chien Hrones Reswick based on the Internet of Think (IoT) is discussed. In section II, the control method design is defined. Then, the architecture of our design is provided in section III. Section IV discusses the results and discussions. Finally, the conclusions of this paper are presented in section V.

2 Control Method

2.1 PI Controller

The most dominant PI controller architecture is the ideal PI controller presented as follows

$$G_c(s) = K_c\left(1 + \frac{1}{\tau_i s}\right) \tag{1}$$

where K_c states proportional reinforcement (change in output that causes changes in input) and τ_i represents integral time. Both K_c and τ_i can be set. Integral time controls integral control actions and changes in K_c values resulted from proportional and integral control actions. τ_i shows how many times the reset or repeat times are proportionally repeated [11].

For cancelling error of steady state in the response, the PI controller is employed in many applications but this controller has drawbacks regarding the response speed and the stability of the system. If there is no issue with the speed, this controller is good to implement. Moreover, the controller doesn't have a prediction for future errors so the controller cannot cancel the oscillation and reduce the rise time.

2.2 The Tuning Method of Chien Hrones Reswick (CHR)

The tuning method of Chien Hrones Reswick (CHR) is modification of the Ziegler-Nichols method [12]. In 1952, Chien Hrones Reswick constructed this tuning method. The method offers a good technique for selecting a compensator to process control applications. In industrial applications, the parameters of that controller are selected based on CHR criteria as shown in Fig. 1.

The CHR method utilizes the open loop of the Ziegler Niclos (ZN) method that uses step response to determine the values of K, L, and T. Table 1 provides the parameters of the controller proposed by Chien, Hrones and Reswick.

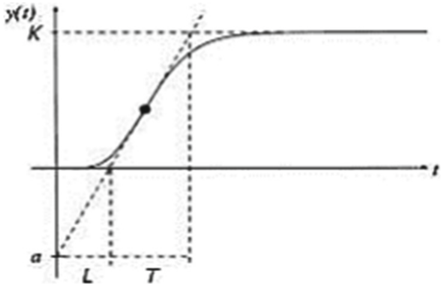

Fig. 1. Step Response of CHR criteria.

Table 1. CHR Method.

Regulator – 20% Overshoot			
Controller	K_c	τ_i	τ_d
P	0.7 T/L	-	-
PI	0.7 T/L	2.3 L	-
PID	1.2 T/L	2 L	0.42 L

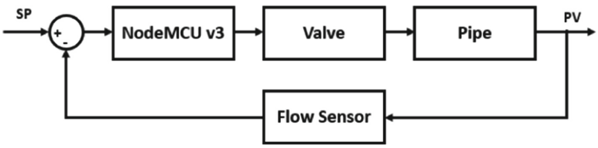

Fig. 2. The Block Diagram of the System.

3 Water Control Flow

The concept of designing and manufacturing tools is divided into two stages. The first stage is to design and manufacture the hardware and the second stage is to design and manufacture the software. The design and manufacture of hardware include circuit block diagrams and a series of tools. Meanwhile, software design includes system flow diagrams. Figure 2 is a block diagram of the system.

Block diagram consists of input devices, data processing devices and output devices. The input device consists of a water flow sensor that functions as an input sensor to calculate water flow and a button as input to set the system limit. Data processing device consisting of NodeMCU as the main brain of the system in processing input data and output devices in the form of a servo motor as a driving motor to open and close taps.

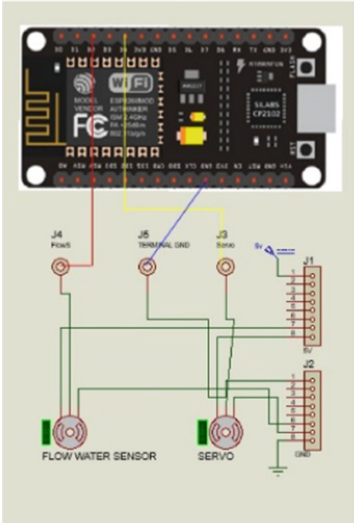

Fig. 3. The Block Diagram of the System.

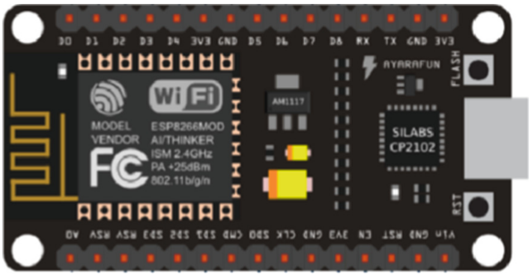

Fig. 4. NodeMCU v3

3.1 The Overall Design of the System

The system consists of components combined into one unit. The components include NodeMCU as the controller, servo motor as the actuator, and YSF201 as the flow sensor. Figure 3 is the entire system architecture of the system.

3.2 Node MCU v3

Nodemcu is an open-source IoT platform kit developed by using the programming language Lua to help the maker in making IoT products. Nodemcu has a sized board that is very small which is 4.83cm long, 2.54cm wide, and weighing 7 g. Moreover, NodeMCU has a relative price affordable. Furthermore, the size is small and the price of this board is affordable while it is equipped with wifi features and firmware that is of a natural open source [13]. Figure 4 provides the hardware of NodeMCU v3.

Table 2. Ports Function of NodeMCU v3.

Port arduino	Function
D2	Port for sensor
D4	Port for motor servo
GND	Port for Ground

Tabel 2 indicates the use of NodeMCU Ports, The sensor used in this work is port D4 and port D2 is the output port for the controller motor servo. The other output port is port GND to connect the external power supply with NodeMCU.

3.3 Water Flow Sensor Planning

This system is built using water flow sensor model YF-S201 with a working range of 1–30 L/min and water pressure $\leq$ 1.75 Mpa [14]. Figure 5 is a schematic circuit of the water flow sensor. This project will employ the water flow sensor to continuously detect the water flow rate through the main pipe. The readings outputted by the sensor will be sent to the controller on NodeMCU v3.

3.4 Blynk App

Blynk is an application for mobile OS such as iOS and Android that provide the controller for Arduino modules, Raspberry Pi, ESP8266, WEMOS D1, and similar modules via the Internet [15]. This application is a creativity container for creating graphical interfaces for projects that will be implemented only with the drag and drop widget method.

Its use is very easy to manage everything and can be done in less than 5 min. Blynk is not bound to a particular board or module. From this application platform, we can control anything from a distance, wherever we are and at any time. With a mobile connected to the internet as well as with a stable connection, this is what is called the Internet of Things (IoT) system (Fig. 6).

4 Result and Discussion

In this chapter, we will discuss the results of sensor testing carried out by comparing the results of measurements between Arduino on the LCD and a measuring cup measuring 500 ml. The result of measuring the flow sensor is presented in Table 3.

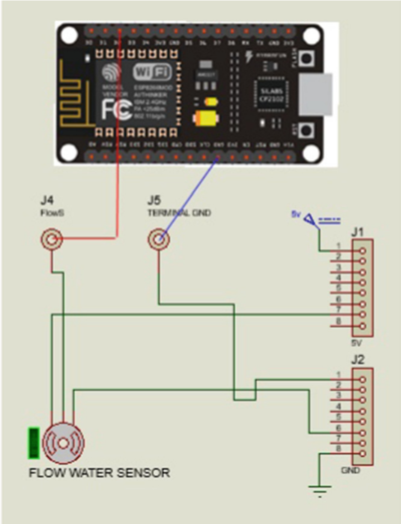

Fig. 5. Water Flow Sensor Network

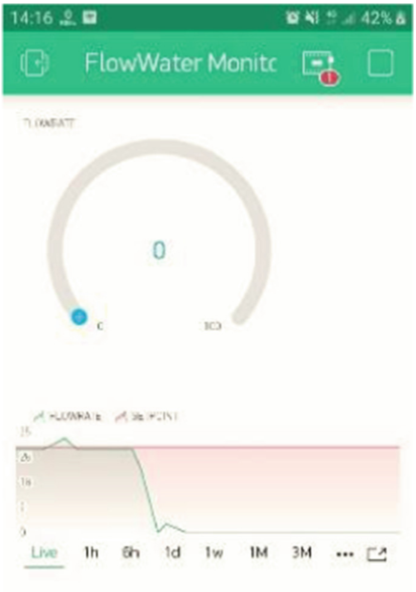

Fig. 6. UI Blynk Application

Based on the data above, there are shortcomings in the water flow sensor because this tool does not have 100% accuracy, and there are errors or measurement inaccuracies [16]. The percentage of errors is calculated as follows.

Table 3. Measuring Flow Sensor.

Nu	Cup Measure (L)	LCD (L)	Difference
1	0.5	0.525	25
2	0.5	0.521	21
3	0.5	0.513	13
4	0.5	0.508	08
5	0.5	0.506	06

- *Total Difference: 73*
- *Total Trials: 5*

$$Average\ Difference = \frac{Total\ Difference}{Total\ Trials} \tag{2}$$

using Eq. (1) the average difference is 73/5=14.6, then to calculate the error percentage is formulated using Eq. (2)

$$Error\ Precentage = \frac{Average\ Difference}{500} \times 100\% \tag{3}$$

The result of (3) is $14.6/500*100\% = 2.92\%$. From the calculation of the percentage of errors obtained the percentage error rate of 2.92%.

4.1 C-H-R Tunning Method

To determine the initial value, the step response method from ZN is used to obtain the K, L, and T values. First, the system is run with set point 3 without using the controller to get the PV graph. From the PV chart, $K = 3.594$, $L = 0.753$, and $T = 0.155$, the values obtained are processed by using the formula in Table 1 as follows:

- $L = 0.753$ and $T = 0.155$. Then,
- Regulator – 20% Overshoot PI
- $\mathrm{Kp} = 0.7\frac{\mathrm{T}}{\mathrm{L}} = 0.7\frac{0.155}{0.753} = 0.144$
- $\mathrm{Ti} = 2.3\mathrm{L} = 2.3 \times 0.753 = 1.732$

So, Value of $\mathrm{Kp} = 0.144$ and $\mathrm{Ti} = \frac{1}{1.732} = 0.577$.

4.2 Implementation Value of CHR to the System

In this study, we conduct some tests to evaluate the performance of the controller. The system testing used in this study is a constant set point, response system with disturbance and response system with set point change. The response output of constant set point, response output with disturbance and response output with set point change are presented in Fig. 7, 8 and 9 respectively.

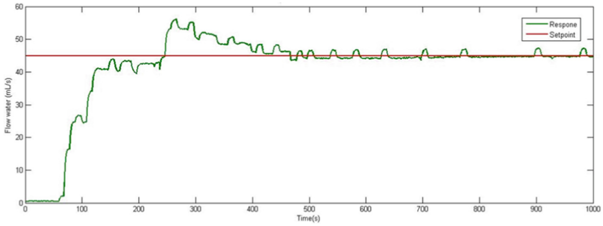

Fig. 7. The output of Flow with a constant set point

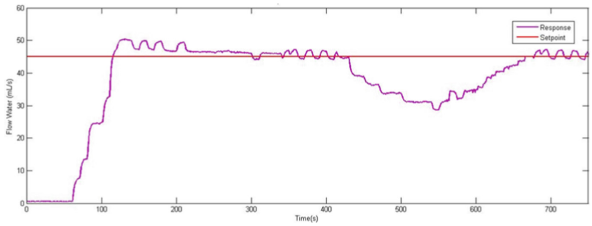

Fig. 8. The output of Flow with disturbance

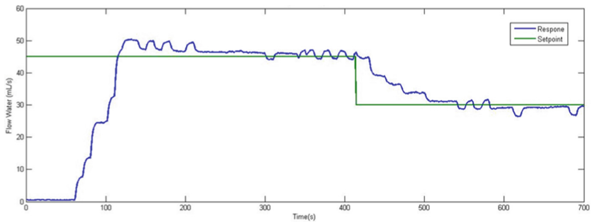

Fig. 9. The output of Flow with set point change

In Fig. 7 the set point of the system is set to 45 mL/s. The output of the flow experiences an overshoot at $t = 200$ s. Then, the output response returns to the set point at $t = 500$ s and remains stable. Moreover, there is a ripple of flow at $t = 600$ s, 700 s because of the characteristic of this variable. In Fig. 8, the disturbance has been added to the system at $t = 400$ s to evaluate the performance of the controller. The result shows that the response can return to the setpoint at $t = 700$ s and the system needs 300 s to make the system back stable. The set point of the output of flow with set point change as shown in Fig. 9 is set to 45 mL/s at the initial condition and is changed to 30 mL/s at $t = 400$ s. It can be seen that the response always follows the set point.

5 Conclusions

This paper discusses the design of PI controls to regulate water flow. This study uses the Integral Proportional method. to determine the value of K_p and τ_i the Chien-Hrones-Reswick tuning method or commonly called the CHR is used. By using the 20% CHR Regulator method, the value of $K_p = 0.144$ and $\tau_i = 0.577$ are obtained. The results show that using the PI controller with the CHR tuning method the output response always follows the set point in all testing systems.

Authors' Contributions. Rifqi Firmansyah and Mustafa M. A. Seedahmed conceived the original idea. All authors discussed and agreed with the main focus and ideas of this paper.

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