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Comparing Temperature and Humidity Control Using PID and Fuzzy Logic in a Climatic Chamber

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ABSTRACT The presence of a thermohygrometer is important in some places, especially in hospitals and climate room equipment. A climate chamber is an enclosed space or isolated environment, which will provide the environmental conditions of relative humidity and temperature. In accordance with the Decree of the Minister of Health of the Republic of Indonesia. Certain rooms such as rooms in hospitals require special attention to environmental conditions, such as the surgical process that occurs in the operating room. A thermohygrometer is a tool used to monitor room conditions. The thermoygrometer used must be able to trace the measurement results using certain media. A climate chamber is a device that provides the desired climate regardless of the external environment. The purpose of this study was to analyze the comparison of PID and Fuzzy Logic temperature control systems on the Climatic Chamber (Fuzzy Logic System) device which plays a role in the process of measuring room temperature and humidity in the field. The method used in this study was to compare directly with a previously calibrated thermohygrometer. The measurement results at 25°C have a response time of 7 minutes 30 seconds and an overshoot of 0.1°C, at a temperature of 30°C has a response time of 5 minutes 15 seconds and an overshoot of 0.1°C, at a temperature of 35°C has a response time of 5 minutes 30 seconds and 0.2°C overshoot. At 50%RH Humidity has a response time of 13 minutes 30 seconds, at 60%RH Humidity has a 12 minute response time, At 70%RH Humidity has a 6 minute response time. The measurement results show that fuzzy logic control has more advantages than PID control. Fuzzy logic control has a faster response time to setpoint than PID control and fuzzy logic control has smaller overshoot compared to PID control.

INDEX TERMS Thermohygrometer, Climatic Chamber, Humidity, Temparature, Fuzzy Logic, PID

I. INTRODUCTION

In many applications, data from temperature and humidity measurements are an important part of decision making [1][2][3]. The presence of a thermohygrometer is important in several places, especially in hospitals and climatic chamber devices[4]. In accordance with the Decree of the Minister of Health of the Republic of Indonesia Number 1204/MENKES/SK/X2004, certain rooms, such as operating rooms, need special attention due to the nature of the work that takes place in these rooms, such as the surgical process that occurs in the operating room[5]. Climatic chamber is a closed closed space or isolated environment, which will provide environmental conditions of relative humidity and temperature[6][7]. Climatic chamber apparatus of isolated chamber, temperature control equipment, humidity control equipment and light emitting device. Accuracy of climate control is very important in every field of use of climatic chamber tools [6][8]. In this case, the climatic chamber can also be applied to a thermohygrometer measuring instrument [9][10]. Thermohygrometer is a tool that serves to measure the temperature and humidity of the room[11][12]. So it is very important to ensure the feasibility of the thermohygrometer[13][14][15]. There are several systems that can be used to analyze the feasibility of this thermohygrometer, one of the suitable methods is fuzzy logic. Fuzzy logic has many advantages, namely it can control complex, non-linear systems, and systems that are difficult to represent mathematically. Fuzzy logic is easy to understand, flexible, tolerant of inaccurate data, able to build and apply expert experience directly without training, can work with conventional control techniques[16][17]. One of the applications of FLC is that it is used to control the temperature of the climatic chamber. The room temperature control system is designed to maintain the temperature in a room in accordance with the reference [18][19]. In the current study, the application of the fuzzy logic system method on the thermohygrometer tool will be applied to the climatic chamber tool. The sensor that will be used is the DHT22 sensor. This sensor is a temperature and humidity sensor from Aosong Electronic which consists of two parts, namely a capacitive humidity sensor and a thermistor[4][20][21]. Several previous studies have not measured the feasibility of a thermohygrometer[16][22][23],], so in this study an analysis of the right and appropriate method or system will be carried out to determine the feasibility of a thermohygrometer that plays a role in the process of measuring the temperature and humidity of the climatic device chambers[24].

In 2015, Andrea Uribe et al conducted a study on controlled intelligent control applied to the climatic chamber[9]. In this study, we will discuss the design and implementation of temperature control using fuzzy logic in a controlled environment. The results were compared descriptively and through the calculation of several performance measures, with those obtained from the classical PID control applied in the previous work. The results in this study show that fuzzy logic allows for better and more efficient control of temperature variables in this controlled environmental space, because it uses heuristic steps to improve process results. Although the PID controller achieves a precise temperature response, the results show that the fuzzy logic controller performs much better and smoother, taking into account parameters such as overshoot, rise time, completion time, and performance measures [9] In 2016, Mirna Maricela Martínez Flores et[25] al conducted research on the development and implementation of control algorithms, which improve the performance of climate-room cooling systems without compromising their performance in terms of accuracy and recovery. The measurement results of the cooling system performance coefficient (COP) concluded that Design 1 has a lower COP in the cooling system. It also concludes that the control algorithm that creates a lower pressure ratio and greater control in superheat is the one with the greatest scale in saving energy consumption. This can be seen when the algorithm used in Design 3 The control algorithm using the electric valve pressure regulator in the evaporator (EPR) has a big advantage over the control algorithm that does not use it, therefore it is recommended to encourage the use of EPR in the climatic chamber control algorithm. In 2020 Sahand Darehshouri et[8] simulate an environmental chambers are used for a variety of experiments in multiple disciplines but are often prohibitively expensive. In this study, we developed an environmental chamber that allows reliable regulation of temperature and relative humidity in a range typical for warm climatic conditions. As we have only used consumer products, which are readily available off the shelf, the device is affordable (<€900) and easy to replicate. The presented chamber has inner dimensions of 1,790 × 970 × 520 mm (height × width × depth). It is heated with two infrared lamps, and for moistening, an ultrasonic mister is used. Air dehumidification and cooling down to ambient temperature are realized with inflowing compressed laboratory air. Additionally, we installed a Peltier element cooling system to enable temperatures below the ambient laboratory temperature. The chamber works in a temperature and humidity range of 15–50 °C and 10–95%.

In 2017, Faisal Wahab et al conducted research on the design and prototype of fuzzy logic control for temperature control of the climatic chamber. In this paper, we will design FLC for air conditioning systems and realize it in the form of a prototype for simplicity of design. This system has an input of room temperature and the number of people in the room, while the output is the cooling rate of the room. Testing this system is done by comparing the results of the controller output through the Fuzzy Logic Toolbox simulation available in MATLAB[26]. The two prototype units were designed with different input sensors for comparison. The results showed that the first and second system prototypes were able to control the temperature of the climatic chamber with an average error of 1.31% and 4.06%, respectively, when compared to the MATLAB simulation[18]. In 2018, Ema Utami et al conducted research on the design of the temperature and humidity control system server room using fuzzy logic based on a microcontroller[16]. This study proposes the design of a server room temperature and humidity control system using fuzzy logic based on a Wemos D1 microcontroller as a remote control infrared transmitter to control the temperature and mode settings of the Air Conditioner to control the temperature and humidity of the server room. Microcontroller-based fuzzy logic for controlling the temperature and humidity of the server room has been successfully designed and successfully implemented into the microcontroller with the results of simulation testing using matlab obtained values that match the results on the microcontroller with an average output deviation of 0.03500 AC Temperature Set and AC average Mode Set the output deviation to 0.01225. system

II. METHODHOLOGY

Research and manufacture of this module using a pre-experimental research method with the type of research "One Group Post Test Design", the authors provide treatment by making a series of temperature sensors and humidifiers using a DHT22 sensor and Fuzzy Logic and PID analysis[27]. Fuzzy logic is logic that represents fuzzy values, uncertainties or degrees of truth. Fuzzy logic is the development of boolean logic which has values 0 and 1. In fuzzy logic, the membership values are between 0 and 1. In this study, the Tsukamoto method of inference was used. The fuzzy system consists of 3 basic fuzzy rules, namely fuzzification, inference, and defuzzification. Fuzzification is a process of changing system inputs that have crips values into fuzzy variables using membership functions stored in the knowledge base. Inference is a process of converting fuzzy input into fuzzy output by following the rules (if-then) that have been defined in the fuzzy knowledge base.

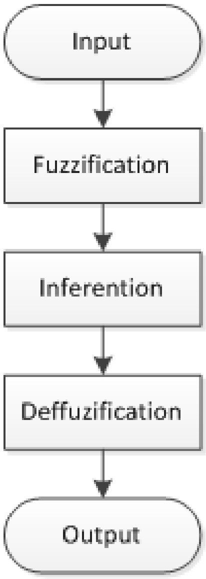

FIGURE 1. The model flowchart

Defuzzification is a process of converting the results of the inference stage into crips-valued output using a predefined membership function

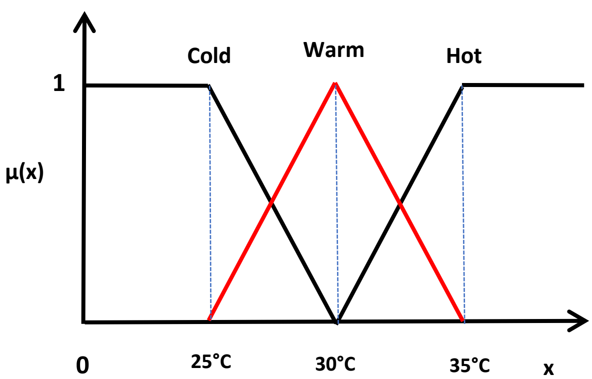

FIGURE 2. Membership function of 0-35 °C

$$\mu_{Cold(x)}=\begin{cases} 0; x \geq 30°C \\ \dfrac{30°C - x}{30°C - 25°C}; 25°C \leq x \leq 30°C \\ 1; x \leq 25°C \end{cases}$$

$$\mu_{Warm(x)}=\begin{cases} 0; x \leq 25°C \text{ or } x \geq 35°C \\ \dfrac{x - 30°C}{30°C - 25°C}; 25°C \leq x \leq 30°C \\ \dfrac{35°C - x}{35°C - 30°C}; 30°C \leq x \leq 35°C \end{cases}$$

$$\mu_{Hot(x)}=\begin{cases} 0; x \leq 30°C \\ \dfrac{x - 30°C}{35°C - 30°C}; 30°C \leq x \leq 35°C \\ 1; x \geq 35°C \end{cases}$$

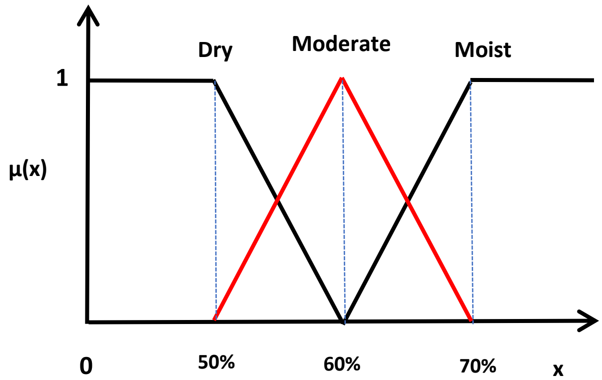

FIGURE 3. Membership function of 0-70 %

$$\mu_{Dry(x)}=\begin{cases} 0; x \geq 60 \\ \dfrac{60 - x}{60 - 50}; 50 \leq x \leq 60 \\ 1; x \leq 50 \end{cases}$$

$$\mu_{Moderate(x)}=\begin{cases} 0; x \leq 50 \text{ or } x \geq 70 \\ \dfrac{x - 60}{60 - 50}; 50 \leq x \leq 60 \\ \dfrac{70 - x}{70 - 60}; 60 \leq x \leq 70 \end{cases}$$

$$\mu_{Moist(x)}=\begin{cases} 0; x \leq 60 \\ \dfrac{x - 60}{70 - 60}; 60 \leq x \leq 70 \\ 1; x \geq 70 \end{cases}$$

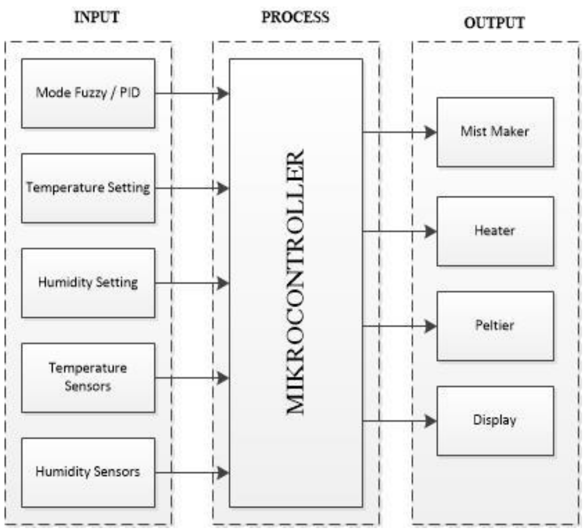

FIGURE 4. The diagram block of the proposed method

When the tool is turned on, first select the Fuzzy or PID mode. Then setting the temperature if the temperature setting is low then the peltier and fan are on while if the temperature setting is high then the heater is on. The second step is setting the humidity. If the humidity setting is low then the heater is on, while if the humidity setting is high then the mist maker is on. Then the output of the temperature and humidity sensors will be processed in the microcontroller and displayed on the nextion display[30][31][32][33].

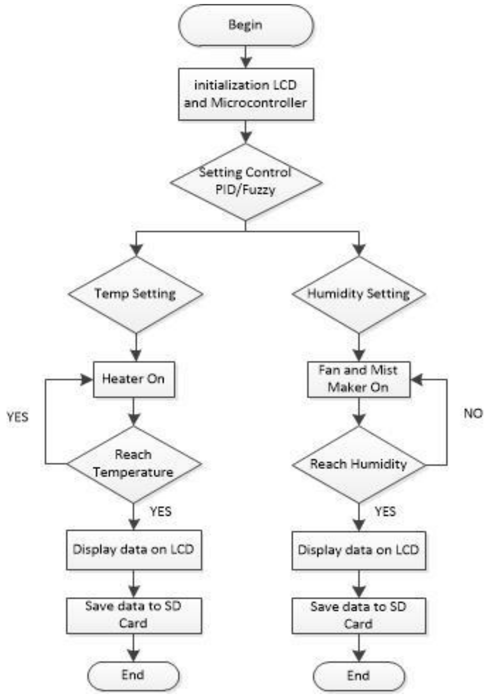

FIGURE 5. The flowchart of the proposed method

The tool starts to operate, will start the LCD and microcontroller initialization process. Then the user selects the temperature and humidity settings using PID or Fuzzy Logic. Then the user selects the temperature and humidity settings. When the temperature is set, the heater will turn on, when the temperature setting has been reached, the temperature data will be displayed on the LCD nextion, then it will be stored on the SD Card. Likewise, when the humidity is set, the mist maker and fan will work. When the humidity setting has been reached, the data will be displayed on the nextion LCD and then will be stored on the available SD Card.

III. RESULT

The results of this study were compared with a thermohygrometer by direct comparison between the display module and the comparison tool used. The thermohygrometer used as a comparison is the HTC-2 Size of HTC-2 is 9cm X 11cm X 2cm . with battery power 2600-2800mAh. HTC-2 weight is 500gram.

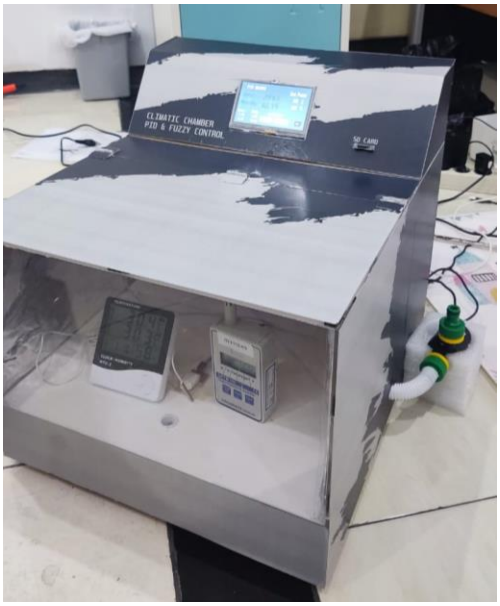

FIGURE 6. Module Results

Comparisons were made by comparing the measurement values of the tool module with the HTC-2. The test was carried out 6 times on the data at the temperature setting point, namely, 30°C, 35°C and the humidity setting 60% RH, 70% RH[34].

FIGURE 7. Testing the DHT22 temperature sensor using the HTC-2

TABLE 1
Results of Fuzzy Logic control temperature measurement at 25°C (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	24.9	25	-0.1	0.4
X2	24.9	25.1	-0.2	0.4
X3	24.9	25.1	-0.2	0.4
X4	24.9	25.1	-0.2	0.4
X5	24.9	25	-0.1	0.4
X6	24.9	25.1	-0.1	0.4
Average			-0.17	0.40
STDEV			0.05	0.00

from 6x data collection at a temperature setting of 25 °C, the highest error value was obtained, namely 0.2 °C with an error value of 0.4%.

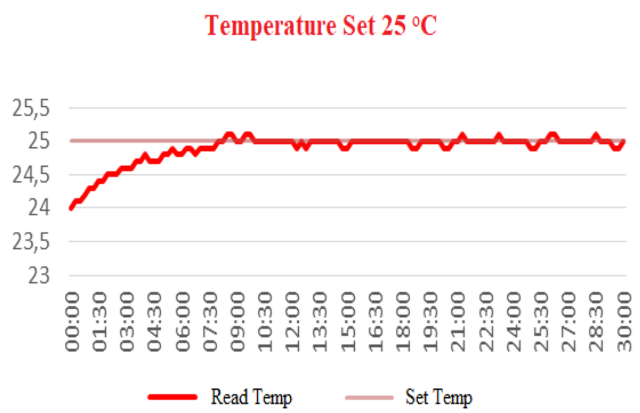

FIGURE 8. Results of Fuzzy Logic Control temperature measurement at 25°C.

From the graph of temperature measurement using the Fuzzy Logic control above, the results obtained at a temperature setting of 25 °C obtained data for the rise time from 24 °C in 7 minutes 30 seconds, then an overshoot of 0.1 °C occurred, the overshoot occurred for 1 minute. Steady state in the Fuzzy Logic control oscillates at the lowest temperature point of 24.9 °C and the highest point of 25.1 °C with a temperature deviation of 0.4 °C.

TABLE 2
Results of Fuzzy Logic control temperature measurement at 30°C (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	29.9	30.1	-0.2	0.3
X2	30	30.2	-0.2	0
X3	30.1	30.2	-0.1	0.3
X4	30	30.1	-0.1	0
X5	29.9	30.2	-0.3	0.3
X6	29.9	30.0	-0.1	0.3
Average			-0.17	0.11
STDEV			0.08	0.27

from 6x data collection at a temperature setting of 30 °C, the highest error value was obtained, namely 0.2 °C with an error value of 0.3%.

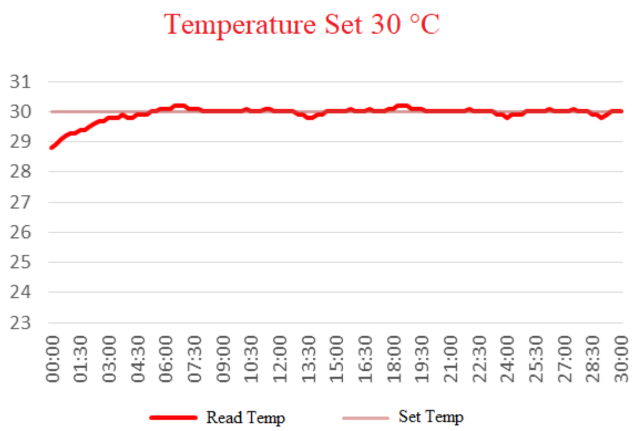

FIGURE 9. Results of Fuzzy Logic Control temperature measurement at 30°C.

From the graph of temperature measurement using the Fuzzy Logic control above, the results obtained at a temperature setting of 30 °C obtained data for the rise time from 29 °C in 5 minutes 15 seconds, then an overshoot of 0.1 °C occurred, an overshoot occurred for 2 minutes. Steady state in the Fuzzy Logic control oscillates at the lowest temperature point of 29.8 °C and the highest point of 30.1 °C with a temperature deviation of 0.3 °C.

TABLE 3
Results of Fuzzy Logic control temperature measurement at 35°C (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	35.1	35.2	-0.1	-0.3
X2	35.1	35.2	-0.1	-0.3
X3	34.9	35.1	-0.2	0.3
X4	35	35.2	-0.2	0
X5	34.9	35.1	-0.2	0.3
X6	35	35.2	-0.2	0
Average			-0.17	0
STDEV			0.05	0.26

From 6x data collection at a setting temperature of 35°C, the highest error value was obtained, namely -0.2°C with an error value of 0.3%.

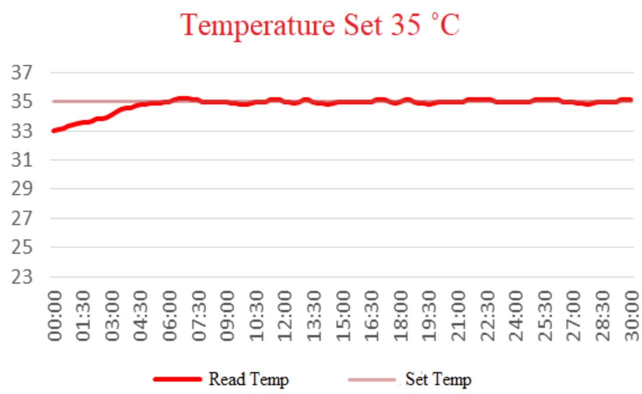

FIGURE 10. **Results of Fuzzy Logic Control temperature measurement at 35°C**

TABLE 4

Results of Fuzzy Logic control humidity measurement at 50 %RH (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	49.8	52	-2.2	-4.2
X2	49.9	53	-3.1	-5.8
X3	49.9	53	-3.1	-5.8
X4	49.8	53	-3.2	-6.0
X5	49.8	52	-2.2	-4.2
X6	49.9	52	-2.1	-4.0
Average			-2.65	-5.04
STDEV			0.53	0.96

From the graph of temperature measurements using the Fuzzy Logic control above, the results obtained at a temperature setting of 35 °C obtained data for the rise time from 33 °C in 5 minutes 30 seconds, then an overshoot of 0.2 °C occurred, the overshoot occurred for 1 minute. Steady state in the Fuzzy Logic control oscillates at the lowest temperature point of 34.8 °C and the highest point of 35.2 °C with a temperature deviation of 0.3 °C. Then the results on the humidity parameters generated by the author are as follows. From 6x data collection at a humidity setting of 50% RH, the highest error value was obtained compared to the comparison tool, which was -3.2% RH with an error value of 6%

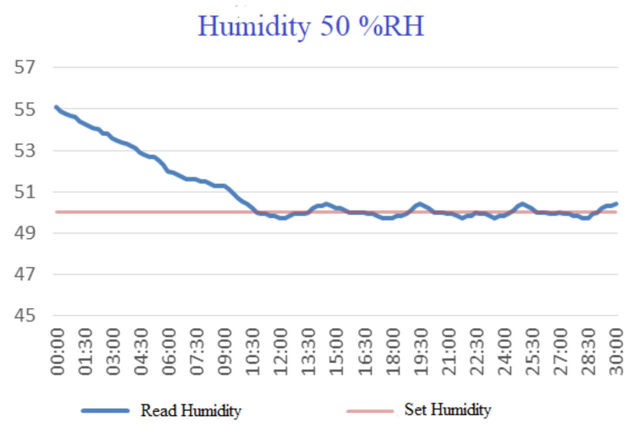

FIGURE 11. **Results of Fuzzy Logic Control humidity measurement at 50 % RH**

At a humidity setting of 50% RH with fuzzy logic control, it takes about 13 minutes 30 seconds to reach a stable humidity with the initial humidity being at 55% RH. Steady state on the fuzzy logic control oscillates at the lowest humidity point which is 49.7% RH and the highest point is 50.4% RH with a humidity deviation of 0.53% RH.

TABLE 5

Results of Fuzzy Logic control humidity measurement at 60 %RH (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	59.9	63	-3.1	-4.9
X2	59.9	64	-4.1	-6.4
X3	59.9	64	-4.1	-6.4
X4	59.8	64	-4.2	-6.6
X5	59.8	64	-4.2	-6.6
X6	59.9	63	-3.1	-4.9
Average			-3.30	-5.96
STDEV			0.54	0.81

From 6x data collection at a humidity setting of 60% RH, the highest error value was obtained compared to the comparison tool, which was -4.2% RH with an error value of 6.6% RH.

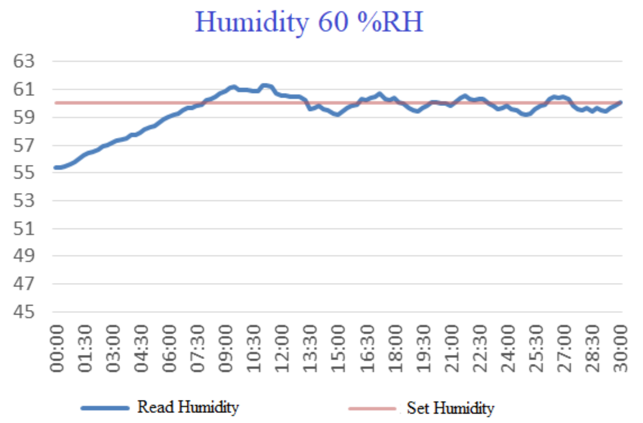

FIGURE 11. **Results of Fuzzy Logic Control humidity measurement at 60 % RH**

At a humidity setting of 60% RH with fuzzy logic control, it takes about 12 minutes to reach a stable humidity with the initial humidity being at 55% RH. Steady state on the fuzzy logic control oscillates at the lowest humidity point which is 59.2% RH and the highest point is 60.7% RH with a humidity deviation of 0.54% RH.

TABLE 6
Results of Fuzzy Logic control humidity measurement at 70 %RH (A is proposed method, and B is calibrator)

Data-i	A	B	Error	% Error
X1	70	74	-4	-5.4
X2	70	74	-4	-5.4
X3	69.9	75	-5.1	-6.8
X4	69.9	75	-5.1	-6.8
X5	70	75	-5	-6.7
X6	69.9	74	-4.1	-5.5
Average			-4.55	-6.10
STDEV			0.57	0.72

From 6x data collection at a humidity setting of 70% RH, the highest error value was obtained compared to the comparison tool, which was -5.1% RH with an error value of 6.8% RH

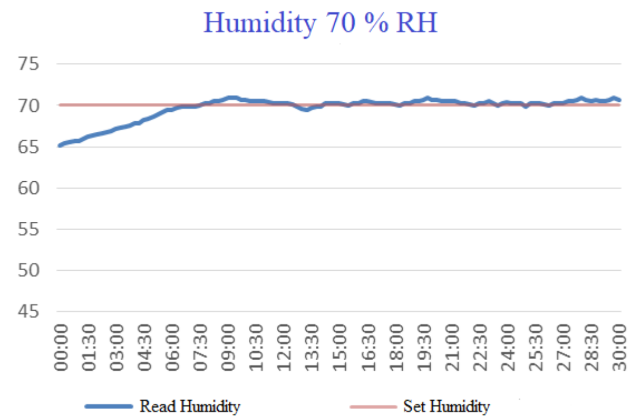

FIGURE 12. **Results of Fuzzy Logic Control humidity measurement at 70 % RH**

At the PID control humidity setting of 70% RH, it takes about 6 minutes to reach a stable humidity with the initial humidity at 65% RH. Steady state on fuzzy logic control oscillates at the lowest humidity point which is 69.5% RH and the highest point is 70.5% RH with a humidity deviation of 0.57% RH

IV. DISCUSSION

The purpose of this study is to compare PID and Fuzzy control systems on temperature and humidity parameters[35], which one is suitable for the needs of the climatic chamber. Comparisons were made from data measurement with comparison tools, comparison of rise time, steady state error to overshoot of the two controls made. From the results of data collection for the two controls, each character has different results, in achieving response time, the Fuzzy control is superior because it reaches the setting temperature faster than the PID control, as well as the graph results in terms of temperature stability and temperature changes, Fuzzy control is still superior when observing. Then based on the observation of the overshoot data, it was found that the PID control overshoot value was higher than the fuzzy control.

TABLE 7
Results Comparison of response time to steady state

Control	Temp Setting	Time required
PID	25°	4 minutes 30 seconds
	30°	17 minutes 30 seconds
	35°	18 minutes
FUZZY	25°	4 minutes
	30°	12 minutes
	35°	12 minutes 45 seconds

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From the results of data collection in the table above, it is known that to reach the temperature setting the Fuzzy control is faster than the PID control.

TABLE 8
Results Comparison of overshoot values

Control	Temp Setting	Display Temp	Overshoot
PID	25°	25.4	0.4
	30°	30.4	0.4
	35°	35.4	0.4
FUZZY	25°	25.1	0.1
	30°	30.1	0.1
	35°	35.1	0.1

From the results of data collection, it is known that the PID control has an average overshoot of 0.4 °C at all temperature setting points, while for fuzzy control it has an average overshoot of 0.1 °C at all temperature setting points.

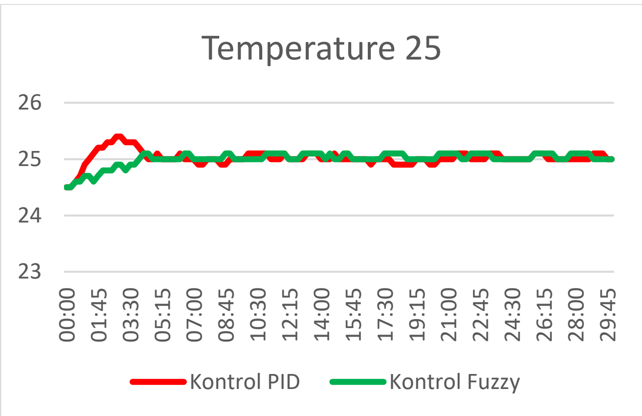

FIGURE 13. **Graph of comparison of controls at a temperature setting of 25°C**

In a graphical comparison between PID and Fuzzy controls, it is found that the time required for the rise time on the PID control is faster, but the Fuzzy control reaches steady state temperature faster, while the PID control takes longer to reach steady state, due to overshoot.

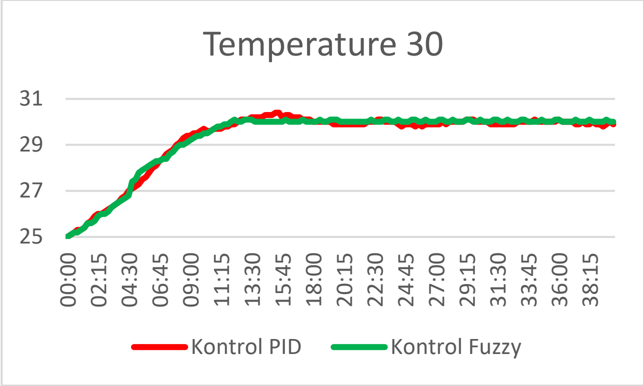

FIGURE 14. **Graph of comparison of controls at a temperature setting of 30°C**

The graphical comparison between PID and Fuzzy controls shows that the time required for rise time is relatively the same, as is the case at 25°C temperature setting, Fuzzy control is achieved faster at steady state temperature, while PID control takes longer to reach steady state, because there is an overshoot

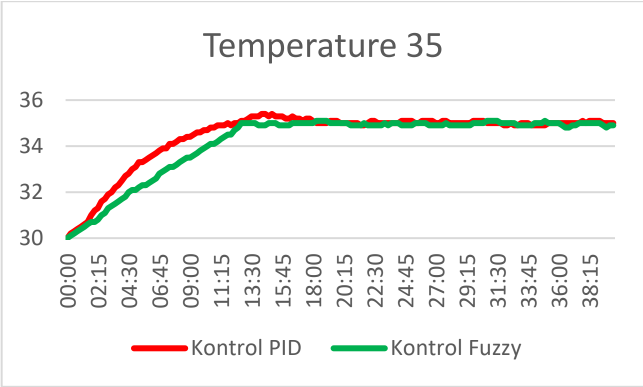

FIGURE 15. **Graph of comparison of controls at a temperature setting of 35°C**

The graphical comparison between PID and Fuzzy controls shows that the time required for the rise time is relatively the same, but at the setting of 35°C, the temperature increase in the fuzzy control is more stable than the PID control, then the same is true for the temperature setting of 25°C and 30° C, Fuzzy control is achieved faster at steady state temperature, while PID control takes longer to reach steady state, due to overshoot.

IV. CONCLUSION

Based on the results of the discussion and the purpose of making the module made by the author, it can be concluded that. The DHT22 sensor can be used for the climatic chamber sensor because it has a small accuracy tolerance, namely in measuring 2% RH humidity, and measuring 0.5 °C temperature and has a scan time of 2 seconds. From the measurement results obtained data that the fuzzy control is more efficient than the PID control in the consumption of response time and time to reach steady state. For the future to be even more efficient in terms of time consumption to reach steady state and have a low overshoot, as well as make the chamber design even better so that it is not interfered with by ambient temperature so that more stable data can be produced on humidity parameters.

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