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PI Control Method Design for Temperature and Humidity Control System in Insulator Test Chamber

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Abstract*—Chamber insulation test on the Electric Energy Conversion and Power System Laboratory Electrical Engineering University of Diponegoro used bulbs as heater and Ultrasonic Mist Maker as a humidifier in simulating a tropical climate but its operation isn't automatic and takes a long time to raise the temperature. Therefore, an automation system and appropriate control method are needed to solve this problem. In this work, a temperature and humidity control system was designed using the Proportional Integral (PI) control method utilizing the DHT22 sensor and the Atmega328p microcontroller as the center of control. PI controller used as a temperature control with the parameter obtained through the Ziegler Nichols 1 tuning method. (Kp = 187.65 and Ti = 63.27). While the humidity control used the On-Off control method. The PI control method tested on 3 reference variations, at 29°C, rose to 33°C, and dropped to 31°C was able to produce a stable system response according to the reference given. Then when given a disturbance, the temperature can return to the reference and steady within 257 seconds. On-Off control as humidity control also able to produce a system response that matches the reference even though it is still oscillating.*

Keywords: Insulator test chamber, DHT22 Sensor, Microcontroller Atmega328p, PI control method

1. INTRODUCTION

Indonesia was a country that has a tropical climate because it is located on the equator which is at the 230 27 'LU to 230 27' LS boundary. This condition is characterized by high rainfall (1960 - 3185 mm), air temperature 20ºC - 35ºC but can reach 38ºC in the dry season, and relatively high air humidity between 50 - 98% RH. These conditions certainly greatly affect the performance of insulators, especially outdoor insulators such as reduce breakdown voltage and durability.

The outdoor insulator tested with direct installation or tested in an insulator test chamber[1]. Temperature and humidity conditioning to simulate the tropical climate is done by bulbs or another heater and using a steam generator or a humidifier[2]. Then the insulator test chamber can simulate the tropical climatic conditions[3].

The insulator test chamber in the Electrical Energy Conversion Laboratory and the Electrical Engineering Power System of Diponegoro University utilizes bulbs to produce heat and Ultrasonic Mist Maker as a humidifier. The hygrometer DHT22 sensor is used to measure the temperature and humidity in the insulator test chamber[4]. But the use of bulbs as heater and Ultrasonic Mist Maker has not been automatic (using switch) and requires a long time to raise the temperature. There are various methods to control the temperature and humidity of the room, including using a pump, silica gel or thermoelectric cooler. Generally-the operation of these devices uses the ON-OFF method [6]. One disadvantage of this method is the occurrence of oscillation. Therefore, the automation system is needed to operate the insulator test chamber so that the temperature and humidity can be controlled according to the reference[9].

The control method used also varies depends on the needs of the plant. Proportional Integral (PI) control method is widely applied because it can control temperature changes to match the setpoint and has a fast response. So in this study, a temperature and humidity control system was designed in the test chamber using PI control. The temperature and humidity range set in the insulator test chamber is at 25ºC - 37ºC and 50 - 98% RH

2 MATERIAL AND METHODE

2.1 Hardware Design

Fig. 1 presents a block diagram selected in this study.The isolator test chamber uses a DHT22 sensor, heater box, Ultrasonic Mist Maker, ATMega328p microcontroller, driver heater, relay, Liquid Crystal Display (LCD), and keypad and the required power supply. A heater box as a heat generator is placed inside the insulator test chamber. A box to place Ultrasonic Mist Maker was placed outside the chamber as a producer of water vapor. Water hose used to channel the water vapor into the chamber through a hole on the side of the chamber. The box for the control circuit also placed outside the chamber equipped with an LCD to display temperature and humidity measurement and a keypad to enter the setpoint of temperature and humidity value[13],[14].

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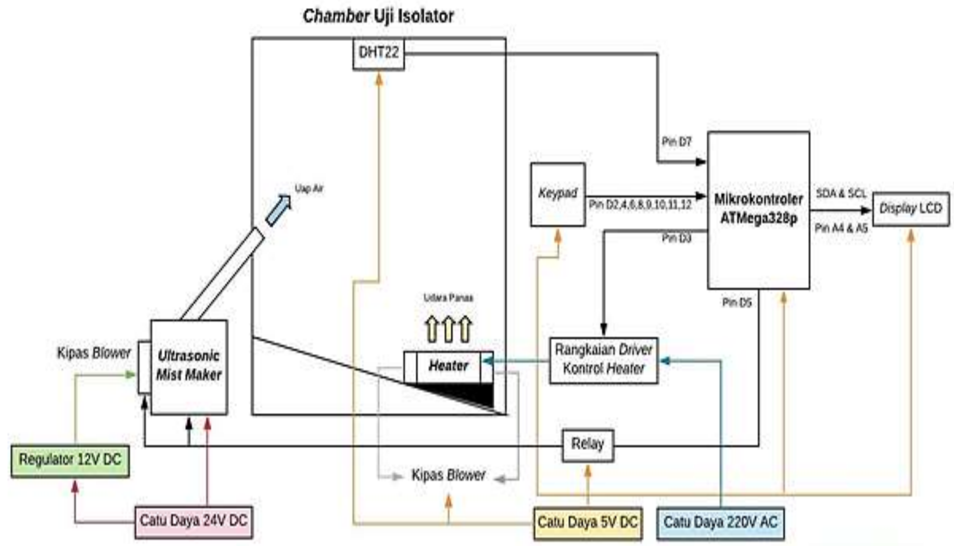

Fig 1. Block diagram of hardware design

2.2 PI Control Design

Block diagram of this procedure is presented in Fig.2. PI control used in the isolator test chamber can control the temperature in the range of 25ºC- 37ºC. Tuning of PI parameters (Kp and Ti) through the bump test experiment by sending a signal u (step) using a potentiometer. The bump test experiment on PI control design was done by sending changes in the value of u in the form of pulse values from 0% to 25% through a potentiometer. The actual temperature measured in the isolator test chamber was 26.6°C. The value change of control action u was done when the temperature of the insulator test chamber reached a steady-state (PV0) then the value of u is increased to 25%. After the temperature response reached a steady-state (PV1), PI control parameters can be determined used Ziegler Nichols formula[12][13].

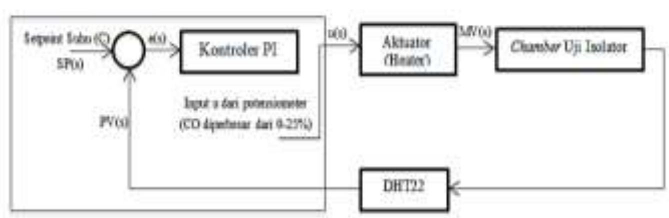

Fig 2. Block diagram of bumptest experiment

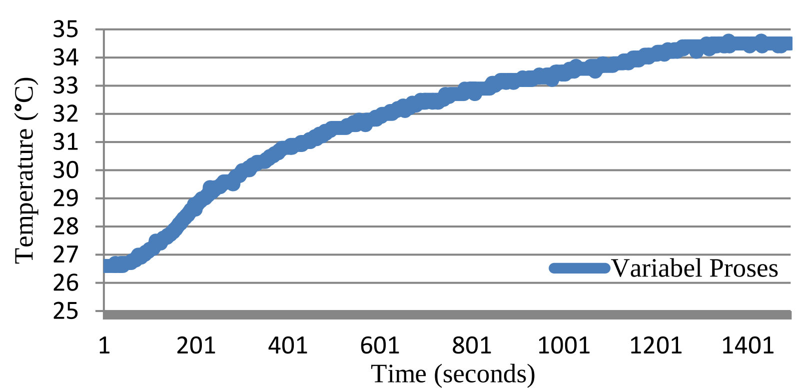

Fig 3. The result of bumptest experiment

Based on Figure 3, it can be seen that the process output is stable (achieving a steady state when given a change in u value) so that the process model used is a self-regulating model or FOPDT model. The FOPDT model parameters can be determined with the following steps [12]:

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1. L (Time of transportation delay) = 19 seconds.
2. T (Processing time) = 489 seconds.
3. K (Process static gain) = 0,1234 seconds.

Then the model of the isolator test chamber can be obtained from the equation:

$$G(s) = \frac{K}{Ts+1}.e^{-LS} \tag{1}$$

The response function of this system is :

$$G(s) = \frac{0{,}1234}{489s+1}.e^{-19S} \tag{2}$$

Based on the three parameters above, PI parameter values can be determined using the Ziegler Nichols 1 tuning method as follows:

1. $Kp = \frac{0.9T}{K.L}$
   $= \dfrac{0{,}9 \ x \ 489}{0{,}1234 \ x \ 19}$
   $= 187{,}6509$

2. $Ti \ = 3{,}33x \ L$
   $= 3{,}33 \text{ x } 19$
   $= 63{,}27$

2.3 Software Design

The Flowchart of PI Control Design is presented in Figure 4. Software used to apply the equation of the PI control method in a discrete region into the program so that it can be processed by the Atmega328P microcontroller to control the temperature of the insulator test chamber[14].

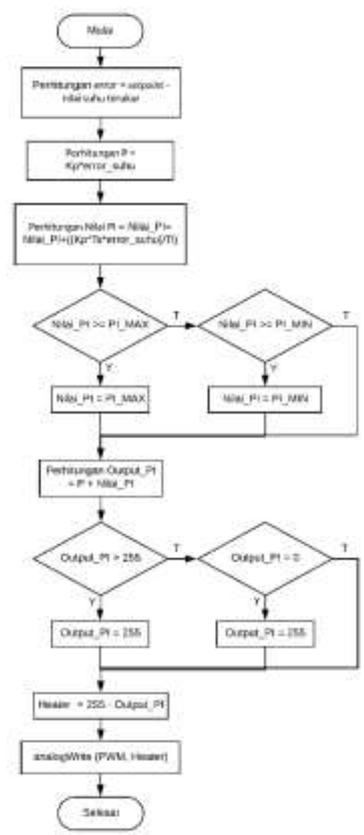

Fig 4. Flowchart of PI Control Design

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3. RESULT AND DISCUSSION

The PI control method can be used for temperature control in this study was tested on 3 reference variations and disturbance test. While On-Off Control was used in humidity control tested on 3 reference value.

3.1 *Temperature Testing*

Tests were carried out to determine the ability of PI control in temperature control used in this research. The reference given in these test are 29ºC, then rise up to 33ºC, down to 31ºC, and disturbance test at 29ºC. The result of the test is showed in Figure 5,6, 7, and 8.

The temperature reference given in the test is 29ºC and the actual temperature in the insulator test chamber is 26,5ºC. The response system is presented in Figure 5.

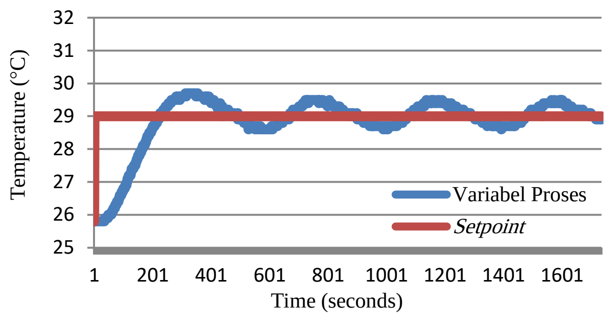

Fig 5. System response to fixed temperature testing

When the control system is turned on, the heater start work to heat the room. In the chamber, the fan spread heat to all directions. When the difference between the reference temperature and the room (error) decreases, the control signal will reduce the heater power. When the error value is zero or negative, the control signal would turn off the heater. However, the heating element still produced heat and spread to the surroundings, so the room temperature will continue to rise so that oscillation symptoms was occur.

Based on the results of testing to the fixed reference in Figure 5 it can be seen that the PI control is able to reach and maintain the output temperature according to the 29ºC reference with a transient response for delay time (Td) is 129 seconds, rise time (Tr) is 223 seconds, time peak (Tp) is 313 seconds, settling time (Ts) is 529 seconds, and the maximum overshoot (Mp) produced is 0.408%.

The temperature reference given in this test rised to 33ºC from the actual temperature in the insulator test chamber was 29ºC. The response system is presented in Figure 6.

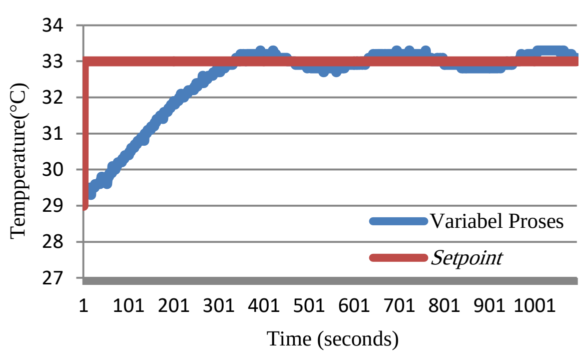

Fig 6. System response to step up temperature reference

Based on the results of the test in Figure 6 it can be seen that the PI control is able to reach and maintain the output temperature according to the 33ºC reference with a transient response response for delay time (Td) of 159 seconds, rise time (Tr) of 333 seconds, time peak (Tp) is 393 seconds, settling time (Ts) is 533 seconds, and the maximum overshoot (Mp) produced is 0,262%. In this testing, Oscilation value reduced abaut a half of previous testing.

The temperature reference given in the test was changed to 31ºC and the actual temperature in the insulator test chamber is 33ºC. The response system is presented in Figure 7.

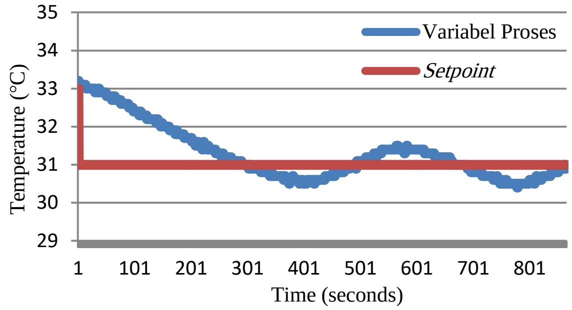

Fig 7. System response to step down temperature reference

Based on the results of the test in Figure 7 it can be seen that the PI control is able to reach and maintain the output temperature according to the 31ºC reference with a transient response response for delay time (Td) of 147 seconds, rise time (Tr) of 287 seconds, time peak (Tp) is 375seconds, settling time (Ts) is 551 seconds, and the maximum overshoot (Mp) produced is 0,336%.

The testing was done by opening half of the door of the insulator test chamber for approximately 15 minutes when the system has reached a stable state at temperature 29ºC. This test aims to determine the ability of PI control in maintain chamber temperature responding to the disturbance .

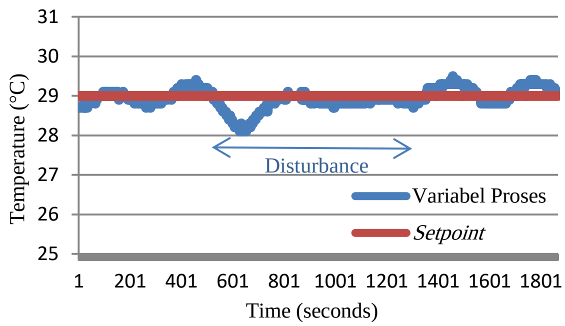

Fig 8. System response to temperature reference testing with disturbance

Based on the results of the test with disturbance in Figure 8 it can be seen that the disturbance is given at 525 seconds for approximately 15 minutes. The system response is unstable and the temperature decreases far from the 29ºC reference with the lowest temperature being 28.1ºC at the 628th seconds. The temperature then gradually rises again in seconds to 654 seconds. The temperature increase continued and even reached a reference temperature of 29ºC in the 782 seconds to 867 seconds but dropped back and did not reach the reference temperature of 29ºC anymore. Then at the 1326th seconds, the door closes again and the temperature rises until it reached a reference.

3.2 *Humidity Testing*

Tests were carried out to determine the ability of the On-Off control in humidity control used in this research. The reference given in this test is 80%, 85%, and 90%. The result of the test is presented in Figure 9, 10, and 11.

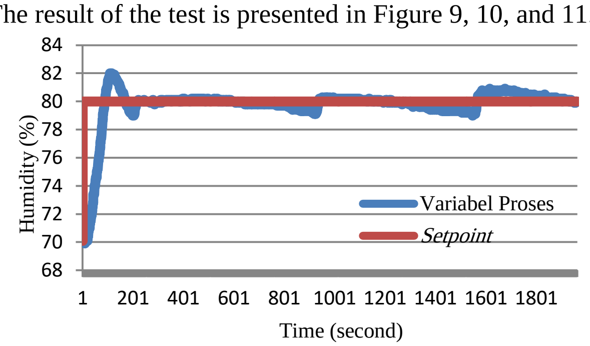

Fig 9. System response to fixed humidity testing at 80%

This humidity test was carried out in 1963 seconds or about 33 minutes. Based on the results of the test in Figure 9 it can be seen that the On-Off control is able to reach and maintain the desired setpoint value which is at 80% humidity.

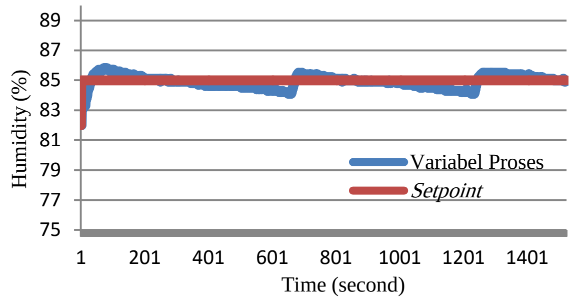

Fig 10. System response to fixed humidity testing at 85%

This humidity test was carried out for 1524 seconds or about 26 minutes. Based on the results of the test in Figure 10 it can be seen that the On-Off control is able to reach and maintain the desired setpoint value which is at 85% humidity.

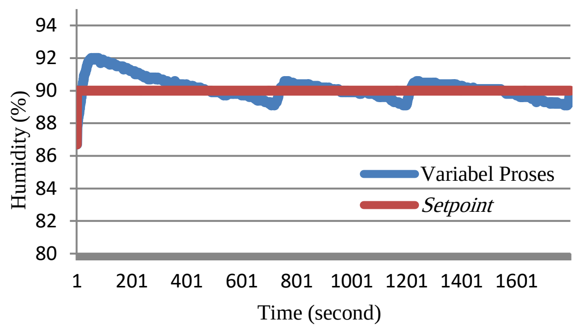

Fig 11. System response to fixed humidity testing at 90%

This humidity test was carried out for 1797 seconds or about 30 minutes. Figure 11 shows that the On-Off control is able to reach and maintain the desired setpoint value which is at 90% humidity.

When the chamber humidity below the reference, the controller orders the ultrasonic mist maker to work changed water into steam and spread it throughout the room so that the humidity will increase. When the chamber humidity is equal or higher than the reference value, the PI controller will turn off the ultrasonic mist maker, so that the humidity does not increase.

4. CONCLUSION

Based on experiments and analysis of results, it can be concluded that the temperature and humidity control systems in the isolator test chamber using the PI control method have been successfully realized. All PI control tests used the parameters Kp = 187.65 and Ti = 63.27. The results of tuning using the Ziegler Nichols 1 method have a good performance because it is able to achieve and maintain the reference given in several variations and can overcome the disturbance given. On-Off control for humidity control also works well in achieving and maintaining a given reference.

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