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# Design and Fabrication of Temperature and Humidity Stabilizer on Low Voltage Distribution Panel with PLC-Based Fuzzy Method to Prevent Excessive Temperature and Humidity on The Panel

Anggara Trisna Nugraha<sup>1</sup>, Reza Fardiyan As'ad<sup>1</sup>, and Adianto<sup>1</sup>, Vugar Hacimahmud Abdullayev<sup>2</sup>

<sup>1</sup> Marine Electrical Engineering, Shipbuilding Institute of Polytechnic Surabaya, Surabaya 60111, Indonesia

<sup>2</sup> Azerbaijan State Oil and Industry University,

Corresponding author: Anggara Trisna Nugraha (e-mail: [anggaranugraha@ppns.ac.id](mailto:anggaranugraha@ppns.ac.id)).

**ABSTRACT** Distribution Panel is equipment that functions to receive electrical energy from PLN and subsequently distributes, as well as controls the distribution of electrical energy through the main and branch panel circuits to branch Distribution Panel or directly through the final load circuit. One of the problems with the Distribution Panel is the occurrence of fluctuating voltage changes and disturbances caused by condensation due to high humidity values. Based on previous research, the solution to minimize this problem is by optimizing the temperature and humidity on the Distribution Panel. So, in this research, we examine the effect of fan and heater control on the temperature and humidity of the Distribution Panel. The aim of this research is to fabrication the prototype that can be prevent the presence of excess temperature and humidity that does not meet applicable standards. So that it is expected to minimize the occurrence of hazards due to excessive temperature and humidity. In this research, it was found that the fan control using the fuzzy method can change the temperature of the panel room from 42.06°C to 32.82°C in a period of 440 seconds. However, the fan control with simple logic can only change the temperature of the panel room which is all 42.22°C to 35.05°C in 440 seconds. So it can be concluded that the fan control with the fuzzy method can reduce the temperature faster than the fan control with simple logic. Based on the graph on the panel room temperature stability test, it was found that the level of temperature stability in the room could be better controlled with fan control with the fuzzy method than using fan control with simple logic. Heater control system can reduce humidity levels from 95.14%RH to 55.25%RH within 160 seconds.

**INDEX TERMS:** Distribution Panel, Temperature, Humidity, Fuzzy Method.

## I. INTRODUCTION

Distribution Panel is equipment that functions to receive electrical energy from PLN and then distributes [1]. As well as controls the distribution of electrical energy through the main and branch panel circuits to branch Distribution Panel or directly through the final load circuit in the form of several light points and equipment sockets electricity in the building [2]. The sharing device itself consists of various components such as circuit breakers, conducting cables, and measuring instruments [2]. The heat source in the Splitting Device usually comes from components that exceed the load capacity [3]. The heat that occurs can produce sparks on the

components [4]. In addition to hot temperatures, panel humidity can pose a hazard, high humidity can cause condensation. If the moisture hits the electrical components it can cause a short circuit [5].

According to data in a study who checked the Low Voltage Sharing Connection Device, it was found that there was a change in the contact resistance value when the temperature rose [6]. Where at 28°C the resistance value of each contact R, S, T, is 130μΩ; 169; 151μΩ and at 29°C the resistance value of each contact R, S, T, is 127.3μΩ; 163.9μΩ ; 164.5μΩ [6]. Based on research, one way to optimize the temperature and humidity values on a panel is to use a fan and heater [7]. In a

study conducted Amelia et al using a fan to control the temperature on the photovoltaic panel, in this study the air exhaled by the fan will absorb the heat in the panel and dissipate the heat [8]. Then, the other study has research on controlling the thermoelectric model heater, the control uses the PID method to maintain the temperature and humidity according to the set point [9]. Another study has research about monitoring the electric power that flows, it is necessary to have a monitoring system to monitor the performance of electrical devices and to do trouble shooting [10]. Research conducted by Shahgholian et al uses the fuzzy method to control the speed of the dc motor so that the speed of the dc motor is adjusted to the needs and can also reduce the use of electrical energy [11].

Based on the existing problems, the author wants to make a final project of a prototype for connecting panel performance stabilizers based on PLC using the Fuzzy Sugeno method. The system can control temperature and humidity, so that the temperature and humidity on the connecting panel can be optimal. The aim of this research is to fabrication the prototype that can be prevent the presence of excess temperature and humidity that does not meet applicable standards. So that it is expected to minimize the occurrence of hazards due to excessive temperature and humidity.

## II. MATERIALS AND METHOD

### A. MATERIAL

#### 1. Electrical Distribution Equipment

Connecting Equipment For a general term encompassing switching devices and their combinations with related control, measuring, protective and regulating equipment [12]. As well as assemblies of such devices and equipment with their interconnections, accessories, enclosures and supporting structures, intended principally for use in the generation, transmission, distribution and conversion of electrical energy [13]. While the Sharing and Control Connection Equipment is electrical equipment intended to be connected to an electrical circuit for the purpose of carrying out one or more of the following functions: protection, control, isolation, switching of switchgear and controlgear [6].

Connecting equipment for one of them is the connecting panel for [14]. The switchgear panel is the connecting equipment for the service area in the form of a panel or a combination of panels, made of conductive or non-conductive materials mounted on a frame equipped with electrical equipment such as switches, cables and rails as well as protective equipment [15].

#### 2. Temperature and Humidity Standards on Low Voltage Electrical Distribution Equipment

Electronic devices have a temperature capacity that needs attention. Because if the temperature is too high, it can cause a fire [16]. Then in solar PV, excess heat can also reduce the power generated by solar PV [17]. Temperature can also affect the efficiency of electrical equipment [18]. It can be stated that

temperature increase causes the visible drop in the efficiency of electricity production [18]. The automation system can also be disrupted if the temperature controller overheats [19]. On medium voltage devices, temperature and humidity can cause black out [20].

Based on SPLN D3.020-1:2019 in the number section regarding service conditions that normal service conditions are as follows [21]:

- 1) Inner pair;
- 2) The ambient air temperature does not exceed 40°C and its average temperature for 24 hours does not exceed 35°C;
- 3) The average relative humidity measured for 24 hours does not exceed 95% and the average relative humidity measured for one month does not exceed 90%;
- 4) The height of the installation site does not exceed 1000 meters above sea level.

According to PUIL 2011 the current delivered by each conductor for a continuous period during normal operation must be such that the appropriate temperature limits are specified in TABLE 1 [13].

TABLE 1

Maximum operating temperature for this type of insulation.

No.	Insulation Type	Temperature Limit (°C)
1.	Polyvinyl chloride (PVC)	70
2.	Crosslinked polyethylene (XLPE) and ethylene propylene rubber (EPR)	90
3.	Mineral (PVC covered or plain touchable)	70
4.	Minerals (plain can't be touched and not in contact with combustible materials)	105

#### 3. PLC

PLC is a digital electronic device with memory and can be programmed to store instructions that carry out specification functions such as logic, sequences, timing, arithmetic and counting to control a machine in industry [22]. In executing the program, it takes a scan time for the execution cycle. This scan time consists of several processes, namely reading input, processing programs and issuing outputs [23]. The input process is the process of reading the input module used [24]. The program process is a PLC process in processing input data according to the program created [25]. The process of issuing output in the PLC process in issuing data to be issued to the PLC. And all these processes are issued sequentially and will always be repeated.

#### 4. SHT20 Sensor

The SHT20 humidity and temperature sensor from Sensirion has set the industry standard in terms of form factor and

intelligence [26]. The SHT20 sensor contains a capacitive-type humidity sensor, a bandgap-type temperature sensor, and dedicated analog and digital integrated circuits – all on a single CMOSens® chip [27]. SHT20 sensor readings in humidity level readings are in the range 0 – 100 %RH with an accuracy level of  $\pm 3.0$  %RH (Sensirion AG, 2014). While in reading the temperature value is in the range of -40 – 125 °C with an accuracy level of  $\pm 0.3$  °C [27].

##### 5. MLX90614 Sensor

The MLX90614 temperature sensor is an infrared thermometer for temperature measurement without touching objects [28]. The sensor consists of an infrared based temperature sensitive detector chip and signal conditioning ASSP which is integrated with the TO-39 [29]. This sensor is supported by a low noise amplifier, 17 bit ADC, DSP unit and a thermometer that has high accuracy and resolution [28]. The thermometer is calibrated with digital output from PWM and SMBus. As a 10-bit PWM, it will show temperature changes which will be measured continuously with a temperature range of -40°C to 120°C and object range from -70°C to -380°C [29].

##### 6. Motor Driver L298N

Motor Driver L298N is a dual motor driver module or has 2 outputs. So the motor driver type can control 2 motors at once up to 2A [30]. The L298N motor driver can also be connected with simple manual switches, TTL logic gates, relays, etc [30]. This module is also equipped with a power LED indicator, an on-board +5V regulator, and a protection diode [31].

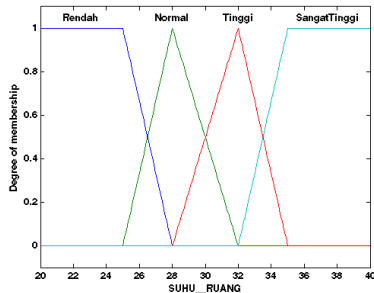


FIGURE 1. Panel Room Temperature Input Membership Function

## B. METHOD

### 1. Fuzzy Sugeno Methods

#### a. Fuzzification

Fuzzification is used to map crisp values into fuzzy sets through a membership function [31]. Fuzzy input parameters. Panel room temperature is divided into 4 (four) linguistic values, namely Low, Normal, High and Very High with the respective membership functions shown in Figure 5. Meanwhile, the input parameters for Conducting Cable Temperature are divided into 4 (four) linguistic values, namely Low, Normal, High and Very High with their respective membership functions shown in FIGURE 1. Based on the Membership Function in Figure 1, the formula for each Membership Function is as follows:

#### 1) $\mu$ Low Temperature (x)

$$\mu(x; 20, 20, 25, 28) = \begin{cases} 1 & x < 25 \\ \frac{28 - x}{28 - 25} & 25 \leq x \leq 28 \\ 0 & x > 28 \end{cases}$$

#### 2) $\mu$ Normal Temperature (x)

$$\mu(x; 25, 28, 32) = \begin{cases} 0 & x < 25 \\ \frac{x - 25}{28 - 25} & 25 \leq x \leq 28 \\ \frac{32 - x}{32 - 28} & 28 \leq x \leq 32 \\ 0 & x > 32 \end{cases}$$

#### 3) $\mu$ High Temperature (x)

$$\mu(x; 28, 32, 35) = \begin{cases} 0 & x < 28 \\ \frac{x - 28}{32 - 28} & 28 \leq x \leq 32 \\ \frac{35 - x}{35 - 32} & 32 \leq x \leq 35 \\ 0 & x > 35 \end{cases}$$

#### 4) $\mu$ Very High Temperature (x)

$$\mu(x; 32, 35, 40, 40) = \begin{cases} 0 & x < 32 \\ \frac{x - 32}{35 - 32} & 32 \leq x \leq 35 \\ 1 & x > 35 \end{cases}$$

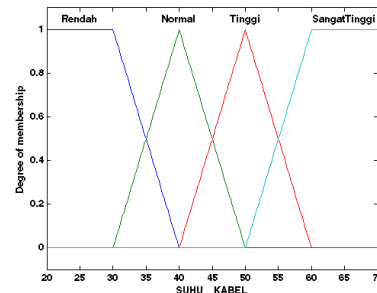


FIGURE 2. Cable Temperature Input Membership Function

Based on the Membership Function in Figure 2, the formula for each Membership Function is as follows:

#### 1) $\mu$ Low Temperature (x)

$$\mu(x; 20, 20, 30, 40) = \begin{cases} 1 & x < 30 \\ \frac{40 - x}{40 - 30} & 30 \leq x \leq 40 \\ 0 & x > 40 \end{cases}$$

#### 2) $\mu$ Normal Temperature (x)

$$\mu(x; 30, 40, 50) = \begin{cases} 0 & x < 30 \\ \frac{x - 30}{40 - 30} & 30 \leq x \leq 40 \\ \frac{50 - x}{50 - 40} & 40 \leq x \leq 50 \\ 0 & x > 50 \end{cases}$$

#### 3) $\mu$ High Temperature (x)

$$\mu(x; 40, 50, 60) = \begin{cases} 0 & x < 40 \\ \frac{x - 40}{50 - 40} & 40 \leq x \leq 50 \\ \frac{60 - x}{60 - 50} & 50 \leq x \leq 60 \\ 0 & x > 60 \end{cases}$$

4)  $\mu$  Very High Temperature (x)

$$\mu(x; 50, 60, 70, 70) = \begin{cases} 0 & x < 50 \\ \frac{x - 50}{60 - 50} & 50 \leq x \leq 60 \\ 1 & x > 60 \end{cases}$$

b. Inference (Rule-Base)

Fuzzy rules are used to map several possible outputs resulting from the combination of parameters entered. Fuzzy rules used in this FIS design are as many as sixteen rules as stated in TABLE 2.

TABLE 2

FIS Rules for Intake Fan and Exhaust Fan Control

No.	Input		Output	
	Panel Room Temperatur	Cable Temperature	RPM Intake Fan	RPM Exhaust Fan
1.	Low	Low	Slow	Slow
2.	Low	Normal	Normal	Slow
3.	Low	High	Normal	Normal
4.	Low	Very High	Fast	Normal
5.	Normal	Low	Slow	Normal
6.	Normal	Normal	Normal	Normal
7.	Normal	High	Fast	Normal
8.	Normal	Very High	Very Fast	Fast
9.	High	Low	Normal	Fast
10.	High	Normal	Fast	Fast
11.	High	High	Fast	Fast
12.	High	Very High	Very Fast	Very Fast
13.	Very High	Low	Fast	Very Fast
14.	Very High	Normal	Fast	Very Fast
15.	Very High	High	Very Fast	Very Fast
16.	Very High	Very High	Very Fast	Very Fast

c. Defuzzification

The results of processing from the fuzzy algorithm will be read by the controller which will be used as a reference for controlling the intake fan and exhaust fan. Output membership functions can be seen in TABLE 3 and TABLE 4.

TABLE 3

Intake Fan RPM Output Membership Function

No	RPM Intake Fan	Set Category
1.	575 RPM	Slow
2.	1150 RPM	Normal
3.	1725 RPM	Fast
4.	2300 RPM	Very Fast

TABLE 4

Exhaust Fan RPM Output Membership Function

No	RPM Exhaust Fan	Set Category
1.	575 RPM	Slow
2.	1150 RPM	Normal
3.	1725 RPM	Fast
4.	2300 RPM	Very Fast

### C. CALCULATION ANALYSIS

To find out the results of the fuzzy output, it is necessary to have a value for the panel room temperature and the temperature of the conductor cable. Then it is obtained from one of the test samples, namely the value of room temperature = 38.2°C and cable temperature = 33.9°C. So the results of the fuzzy methods are as follows.

#### 1. Fuzzification

Input Panel Room Temperature

- 1)  $\mu$  Low Temperature (x) = 0
- 2)  $\mu$  Normal Temperature (x) = 0
- 3)  $\mu$  High Temperature (x) = 0
- 4)  $\mu$  Very High Temperature (x) = 1

Input Cable Temperature

- 1)  $\mu$  Low Temperature (x) =  $\frac{40-33,9}{40-30} = 0,61$
- 2)  $\mu$  Normal Temperature (x) =  $\frac{33,9-30}{40-30} = 0,39$
- 3)  $\mu$  High Temperature (x) = 0
- 4)  $\mu$  Very High Temperature (x) = 0

#### 2. Inference

1. Rule 1 =  $\min(\mu \text{ Low Temperature } (38,2), \mu \text{ Low Temperature } (33,9))$   
 $= \min(0, 0,61)$   
 $= 0$
2. Rule 2 =  $\min(\mu \text{ Low Temperature } (38,2), \mu \text{ Normal Temperature } (33,9))$   
 $= \min(0, 0,39)$   
 $= 0$
3. Rule 3 =  $\min(\mu \text{ Low Temperature } (38,2), \mu \text{ High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
4. Rule 4 =  $\min(\mu \text{ Low Temperature } (38,2), \mu \text{ Very High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
5. Rule 5 =  $\min(\mu \text{ Normal Temperature } (38,2), \mu \text{ Low Temperature } (33,9))$   
 $= \min(0, 0,61)$   
 $= 0$
6. Rule 6 =  $\min(\mu \text{ Normal Temperature } (38,2), \mu \text{ Normal Temperature } (33,9))$   
 $= \min(0, 0,39)$   
 $= 0$

7. *Rule 7* =  $\min(\mu \text{ Normal Temperature } (38,2), \mu \text{ High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
8. *Rule 8* =  $\min(\mu \text{ Normal Temperature } (38,2), \mu \text{ Very High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
9. *Rule 9* =  $\min(\mu \text{ High Temperature } (38,2), \mu \text{ Low Temperature } (33,9))$   
 $= \min(0, 0,61)$   
 $= 0$
10. *Rule 10* =  $\min(\mu \text{ High Temperature } (38,2), \mu \text{ Normal Temperature } (33,9))$   
 $= \min(0, 0,39)$   
 $= 0$
11. *Rule 11* =  $\min(\mu \text{ High Temperature } (38,2), \mu \text{ High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
12. *Rule 12* =  $\min(\mu \text{ High Temperature } (38,2), \mu \text{ Very High Temperature } (33,9))$   
 $= \min(0, 0)$   
 $= 0$
13. *Rule 13* =  $\min(\mu \text{ Very High Temperature } (38,2), \mu \text{ Low Temperature } (33,9))$   
 $= \min(1, 0,61)$   
 $= 0,61$
14. *Rule 14* =  $\min(\mu \text{ Very High Temperature } (38,2), \mu \text{ Normal Temperature } (33,9))$   
 $= \min(1, 0,39)$   
 $= 0,39$
15. *Rule 15* =  $\min(\mu \text{ Very High Temperature } (38,2), \mu \text{ Tinggi } (33,9))$   
 $= \min(1, 0)$   
 $= 0$
16. *Rule 16* =  $\min(\mu \text{ Very High Temperature } (38,2), \mu \text{ Very High Temperature } (33,9))$   
 $= \min(1, 0)$   
 $= 0$

### 3. Defuzzification

$$\text{RPM Intake Fan} = \frac{(0,61 \times 1725) + (0,39 \times 1725)}{(0,61 + 0,39)}$$

$$= 1725 \text{ RPM}$$

$$\text{RPM Exhaust Fan} = \frac{(0,61 \times 1725) + (0,39 \times 1725)}{(0,61 + 0,39)}$$

$$= 2300 \text{ RPM}$$

## III. RESULTS

In this study, several tests were carried out, namely the effect of fan control on the decrease in panel temperature, the effect of fan control on the stability of the panel temperature, and the effect of heater control on decreasing humidity levels.

### 1. Effect of fan control on decreasing panel temperature

This test is carried out to find out how effective the fan control is in lowering the temperature inside the panel. The

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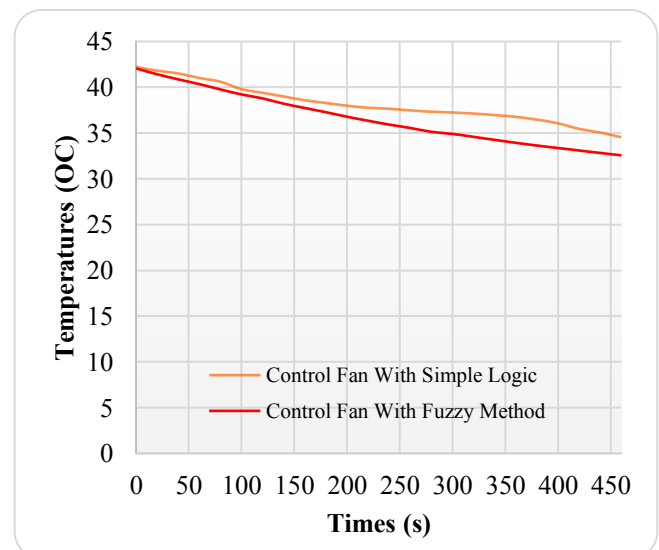
test is carried out by modifying the panel temperature until it reaches a temperature of 42°C until the panel room temperature becomes less than 35°C. Fan control system is divided into fan control system with simple logic and fan control system with fuzzy method. The data from this test is attached in [TABLE 5](#).

**TABLE 5**

**Fan Control System Data On Panel Reducing Temperature**

Time (s)	Panel room temperature with simple logic (C)	Panel room temperature with fuzzy control (C)	Difference temperature (C)
0	42.22	40.86	1.36
20	41.81	40.34	1.47
40	41.51	39.76	1.75
60	41.01	39.21	1.8
80	40.6	38.78	1.82
100	39.79	38.2	1.59
120	39.39	37.73	1.66
140	38.99	37.27	1.72
160	38.58	36.78	1.8
180	38.28	36.34	1.94
200	37.98	35.92	2.06
220	37.76	35.55	2.21
240	37.65	35.13	2.52
260	37.47	34.9	2.57
280	37.33	34.58	2.75
300	37.24	34.25	2.99
320	37.12	33.93	3.19
340	36.96	33.63	3.33
360	36.76	33.36	3.4
380	36.46	33.09	3.37
400	36.06	32.82	3.24
420	35.45	32.56	2.89
440	35.05	32.28	2.77
460	34.54	31.05	3.49

The test results data in [TABLE 5](#) can be illustrated in a graph according to [FIGURE 3](#). This graphic illustration is aimed at seeing more clearly the effect of fan control with simple logic and fan control with the fuzzy method on changes in temperature in the panel room.



**FIGURE 3. Panel Room Temperature Decrease Against Time Comparison Chart**



Based on the FIGURE 3, it can be seen that the temperature of the panel with the control system using the fuzzy method decreases faster than the temperature of the panel with a control system using simple logic. This is evidenced by the temperature of the panel with the control system using the fuzzy method which was originally 42.06°C to 32.82°C in a period of 440 seconds. Meanwhile, the panel temperature with a control system using simple logic in a period of 440 seconds can only reduce the temperature of the panel room from 42.22°C to 35.05°C.

## 2. Effect of fan control on the stability of the panel temperature

This test is carried out to find out how effective the fan control is in maintaining the temperature in the room so that the temperature inside the panel can reach a level of stability. The test is carried out by heating the panel room temperature with an initial temperature of 29.18°C. The panel will be heated for 300 seconds or 5 minutes. Fan control system is divided into fan control system with simple logic and fan control system with fuzzy method. The data from this test is attached in TABLE 7 and TABLE 8.

TABLE 6

Fan Control System Data On Panel Temperature Stabilization

Time (s)	Panel room temperature with simple logic (C)	Panel room temperature with fuzzy control (C)	Difference temperature (C)
0	29.19	29.18	0.01
20	29.9	29.32	0.58
40	30.5	29.48	1.02
60	31.41	29.59	1.82
80	32.32	29.75	2.57
100	33.03	29.88	3.15
120	33.73	30.02	3.71
140	34.54	30.16	4.38
160	35.15	30.28	4.87
180	35.75	30.43	5.32
200	36.26	30.56	5.7
220	36.76	30.72	6.04
240	37.37	30.79	6.58
260	38.08	30.95	7.13
280	38.68	31.08	7.6
300	39.49	31.17	8.32

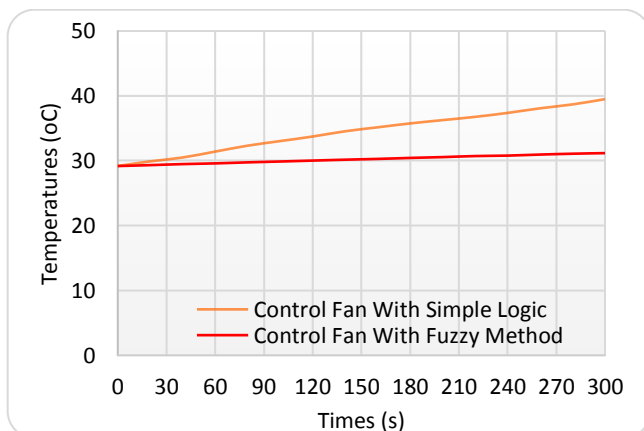


FIGURE 4. Panel Room Temperature Against Time Comparison Chart

The test results data in TABLE 5 can be illustrated in a graph according to FIGURE 4. This graphic illustration is at work knowing the level of temperature stability when there is a change in temperature with a simple logic fan control system and a fuzzy method fan control system. The graph in FIGURE 4 illustrates that fan control using the fuzzy method can stabilize the panel room temperature. This is evidenced by the line graph of the fan control with the fuzzy method stable for 5 minutes in FIGURE 4. This is in contrast to the temperature of the panel room with a simple logic fan control system which continues to increase for 5 minutes.

## 3. Effect of heater control on decreasing humidity levels

This test is conducted to find out how effective the heater control is in reducing the humidity level inside the panel so that the panel humidity level can be controlled according to the set point. This test takes place by increasing the humidity of the panel to 95%RH. After the humidity level is 95%RH, the heater will turn on automatically. At the time of testing the ambient humidity was  $\pm 60\%$  RH. The data from this test is attached in TABLE 9.

TABLE 7

Heater Control System Test Data

Time (s)	Humidity (%RH)	Heater Condition	$\Delta$ Humidity (%RH)
0	95.14	ON	0.00
10	76.25	ON	18.89
20	67.06	ON	9.19
30	63.13	ON	3.93
40	61.00	ON	2.13
50	59.79	ON	1.21
60	58.78	ON	1.01
70	57.77	ON	1.01
80	57.37	ON	0.40
90	56.86	ON	0.51
100	56.36	ON	0.50
110	56.16	ON	0.20
120	55.95	ON	0.21
130	55.65	ON	0.30
140	55.45	ON	0.20
150	55.35	ON	0.10
160	55.25	ON	0.10

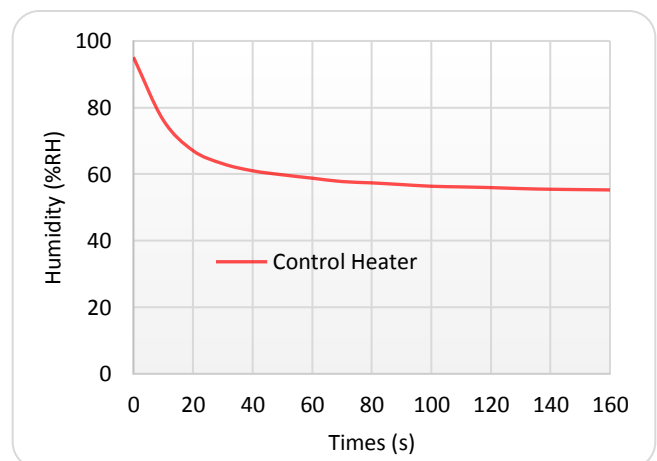


FIGURE 5. Panel Humidity Against Time Comparison Chart

The test results data in TABLE 7 can be illustrated in a graph according to FIGURE 5. This graphic illustration aims to find out how the heater performs in reducing panel humidity. The graph in FIGURE 5 proves that the heater control can reduce the humidity level of the panel from 95.14%RH to 55.25%RH within 160 seconds.

#### IV. DISCUSSION

Based on the graph in FIGURE 3, the panel room temperature can be reduced using a fan control system. In the graph, it can be seen that fan control with the fuzzy method can reduce the temperature of the panel room faster than fan control with simple logic. This is evidenced by the fan control line with the fuzzy method decreasing faster than the fan control line with simple logic in Figure 6. It is also proven based on Table 5 and Table 6 that the fan control using the fuzzy method can change the temperature of the panel room from 42.06°C to 32.82°C in a period of 440 seconds. However, the fan control with simple logic can only change the temperature of the panel room which is all 42.22°C to 35.05°C in 440 seconds. So it can be concluded that the fan control with the fuzzy method can lower the temperature faster than the fan control with simple logic.

Then, based on the graph in FIGURE 4, it can be concluded that the level of temperature stability in the room can be better controlled with fan control using the fuzzy method than using fan control with simple logic. This is evidenced by the fan control line using the fuzzy method in the graph in Figure 7 which is stable and sloping. The straight and sloping line proves that the temperature of the panel room can be stable even though it is influenced by the hot air inside the panel. In contrast to the fan control line with simple logic that continues to rise over time. This proves that the fan control with simple logic cannot stabilize the temperature of the panel room when exposed to hot air. So it can be concluded again that the fan control with the fuzzy method can control the stability of the temperature of the panel room.

In the graph of FIGURE 5, it can be seen that the humidity of the panel decreases with time. This happens because of the influence of the heater control on the panel. When the heater operates, the humidity level will decrease due to the hot air generated by the heater. Then the water vapor will be created through the circulation that occurs due to fan control. Based on the graph, it can also be seen that the humidity of the panel decreases very significantly when the humidity is >60%RH. However, the decrease in humidity slows down when the humidity level is <60%RH. This is because the humidity has reached an ambient humidity value of  $\pm 60\%$  RH. So it can be concluded that the heater control can control the humidity level in the panel.

Based on these data, it can be concluded that the prototype can control the temperature and humidity according to the setpoint adjusted to the applicable standard. So that accidents on electrical equipment caused by excessive temperature and humidity that are not in accordance with

standards can be minimized. Then, the advantages in this prototype can provide a state of stabilization of the panel temperature at a temperature of 32°C. This stabilization state is caused by the fuzzy control method on the fan control. However, the weakness in this prototype is that humidity stabilization has not been achieved because the humidity on the panel can only be controlled but does not reach a stable point.

#### V. CONCLUSION

Fan control with fuzzy method can lower the temperature faster than fan control with simple logic. This is evidenced by the data in TABLE 5 and TABLE 6 and FIGURE 6. The level of temperature stability in the room can be better controlled with fan control with the fuzzy method than using fan control with simple logic. So that the fan control with the fuzzy method can control the stability of the panel room temperature based on the data in TABLE 7 and TABLE 8 and FIGURE 7. The heater control can control the humidity level inside the panel. So that the moisture content in the panel can be stable. This is based on the data in TABLE 6 and TABLE 9 and FIGURE 8.

Based on all these data, it is found that this prototype can control temperature and humidity. So that can be prevent the presence of excess temperature and humidity that does not meet applicable standards. So that it is expected to minimize the occurrence of hazards due to excessive temperature and humidity. However, the weakness of this prototype is that there is still no method of controlling the heater. So suggestions for further research can add a control method to the heater so that humidity can reach the set point quickly and stabilization of the humidity value on the panel can be achieved.

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