IPTEK, The Journal of Engineering, Vol. 11, No. 3, 2025 (eISSN: 2807-5064)

DESIGN AND IMPLEMENTATION OF ELECTRICAL SISTEMS FOR BREAD DOUGH DEVELOPMENT PROOFER TECHNOLOGYS BASED ON MICROCONTROLLER WITH PID CONTROL FOR DONUT DOUGH

Ika Silviana W[a], Muhammad Syaiful Hakim[a], Bambang Sampurno[a], Hendro Nurhadi[a], Mashuri[a*]

[a]*Industrial Mechanical Engineering, Sepuluh Nopember Institute of Technology, Surabaya 60117, Indonesia*
[*]*Corresponding author: mashuri@its.ac.id*

Abstract

The proofing process is an essential step in bread-making, where the dough is allowed to rest for the gas content to develop and form a soft structure. However, many small-scale bread producers still rely on manual methods for proofing, leading to unstable temperature and humidity levels and longer production times. This study focuses on developing an electrical system for a bread proofer that can stabilize temperature and humidity during the proofing process. The system includes an Arduino Mega microcontroller with a DHT22 sensor for real-time temperature and humidity detection, an I2C LCD for monitoring, and a potentiometer for setting the desired temperature and humidity values. To achieve stability, a PID control system is used. The results show that the system can stabilize at a temperature of 40.10oC and humidity at 80-90RH for approximately 38.4 minutes. This electrical system offers an effective solution for optimizing the proofing process in bread production.

Keywords: Proofing; Arduino Mega; Temperature; Humidity; DHT22

1. Introduction

The development of technology in the bread industry is growing rapidly in Indonesia because bread is one of the food substitutes for rice that is in demand by many Indonesians. Changes in people's fast-paced lifestyle patterns have made processed foods that are ready to eat but highly nutritious much sought after. Most processed food products that are sought after are dry foods whose ingredients use a lot of flour[1].This is supported by data published by the Central Bureau of Statistics (BPS), the Average Consumption and Expenditure per Capita per Week by Type of Food in urban areas (IDR), September 2023 for the sweet bread category is 1,083 pieces, March 2023 for the sweet bread category is 1,057 pieces[2]. In the process of making bread dough there is a proofing process. In the proofing process bacteria and yeast will produce gas so that the dough can expand[3]. This proofing process can be done using a proofer, proofer is a proofer used to place the dough that will rise. The required temperature is 38-40°C with humidity around 80-90RH[4]. The use of low fermentation temperatures slows down the fermentation process[5], which is reflected in lower gas production. Increasing temperature also causes a decrease in relative humidity (RH), which makes the surface structure of the bread harder[4]. Temperature and proofing time greatly influenced the volume of dough expansion[5], [6].

The development of bread proofer technology has been carried out by Sukma Drastiawati et al.[7] by using an LPG cylinder as a heat source without using a microcontroller[8]. Meanwhile Muslimin has made a bread proofer technology using Arduino Mega as a microcontroller and SHT11 sensor to detect temperature and humidity[9]. This proofer technology uses heat energy from LPG gas that heats the water reservoir to increase the temperature and humidity in the bread proofer[10]. Meanwhile Buwarda & Sidehabi has made a bread proofer technology that can be used in the bread proofing process. This proofer technology uses an Arduino nano microcontroller and a DHT11 sensor as a sensor to detect temperature and humidity in the bread proofer[11]. Meanwhile Kun Suharno has made a bread proofer technology using a thermostat as a temperature and humidity regulator in the bread proofer technology. This proofer technology which is developed in this research uses the heat source which is generated only from the heater dipped in a pot of water and real time temperature detection using the sensor on the thermostat[12].

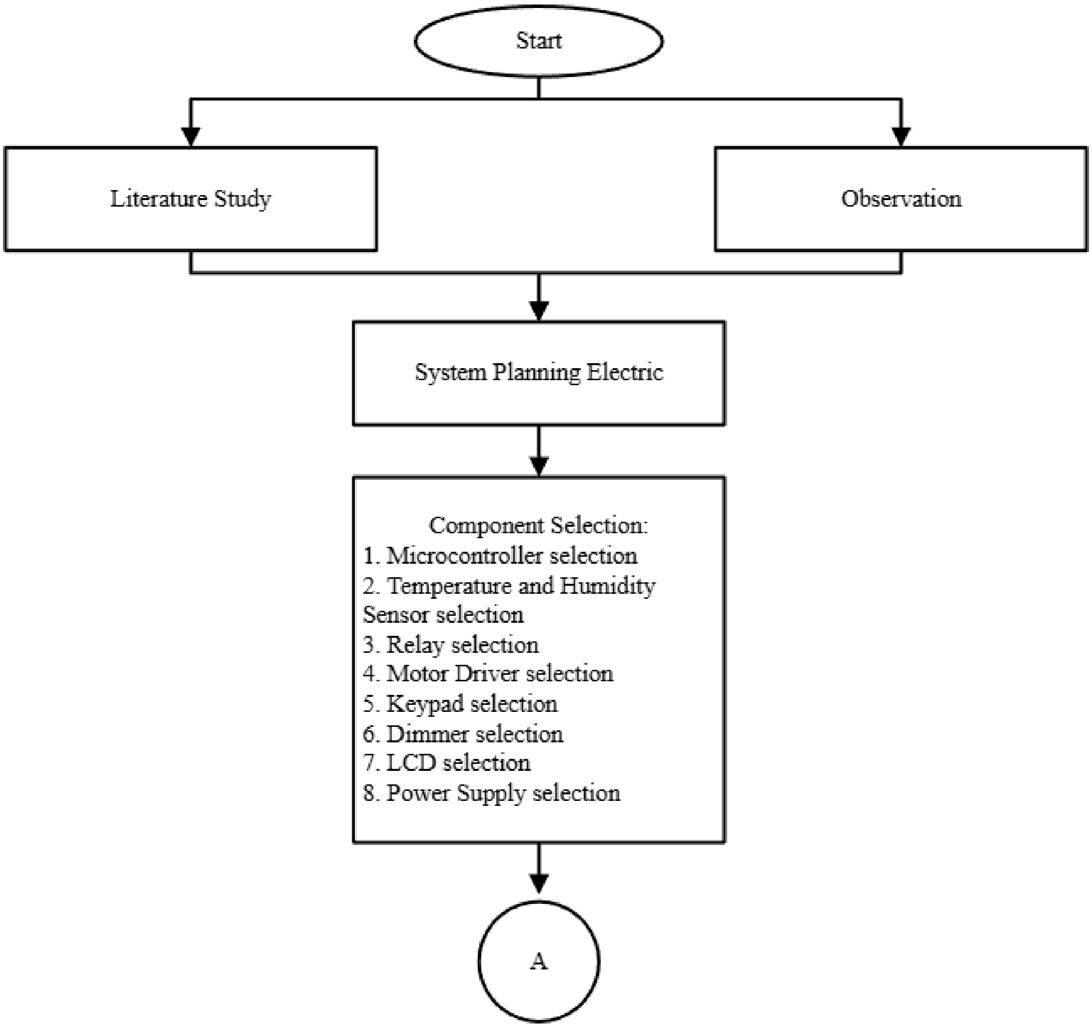
Based on the problems mentioned before, through this research an electrical system is designed for the bread proofer technology to optimize the proofing process by stabilizing the temperature and humidity of the proofing proofer until it reaches the set point using a heater and water heater. In this research, the object used is donut dough. The proofing process on donuts requires 2 stages of proofing. The first proofing of donut dough takes about 30 minutes and the second proofing for donut dough takes 10-15 minutes[13]. The use of the Arduino Mega microcontroller functions to regulate temperature and humidity stability. The use of the DHT22 sensor is used to detect temperature and humidity[14] in the bread proofer in real time. This bread proofer will also be equipped with a potentiometer, which aims to make the temperature and humidity set point values change easily for the user as needed. For the control system of this electrical system, it also uses a PID control system to stabilize the temperature because The PID controller is a feedback controller PID controllers are proven to provide good control performance despite having simple algorithms that are easy to understand[15], [16] and the PID control system can stabilize both parameters automatically[17].

The purpose of this research is to get an electrical system that can stabilize temperature and humidity and get a control system whose temperature and humidity set point values can be inputted and changed easily, so that later the bread proofer will be more flexible in its use and the proofing process can be done automatically. Another goal of this research is to obtain system performance data in achieving temperature and humidity set point values and system stability in maintaining temperature and humidity in a bread proofer.

2. Method

This chapter will discuss the research methodology which includes the stages in completing the research as a whole process. The completion of this research is depicted in a flow diagram as shown in the image below:

2.1. Illustrations



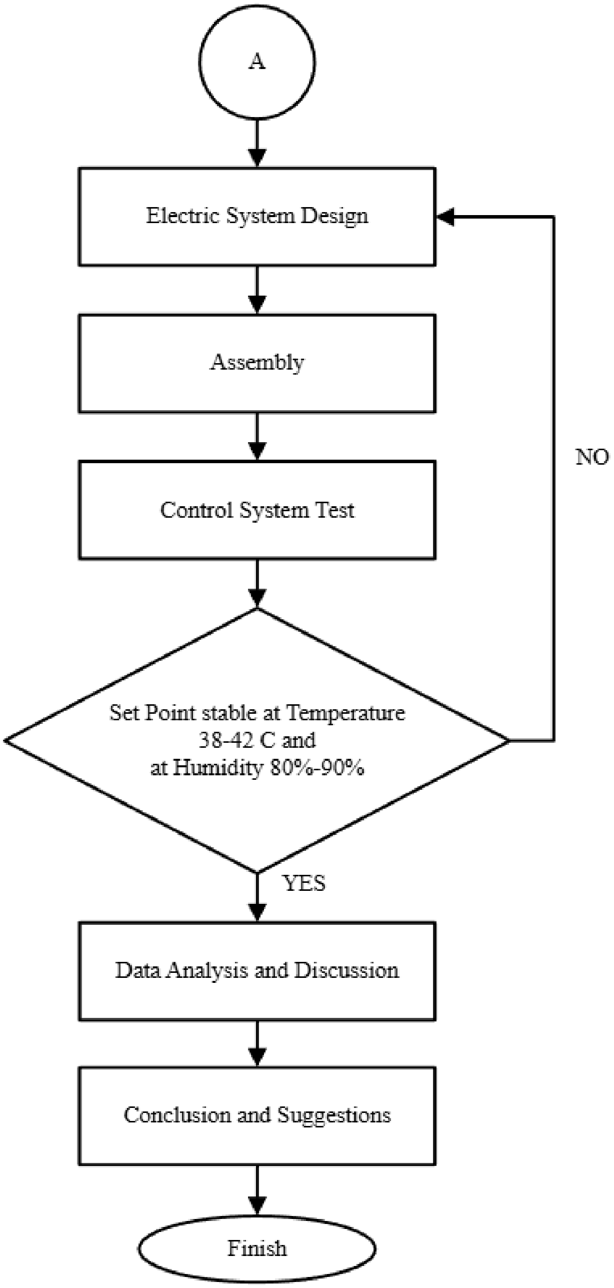


Figure 1. Research flowchart

A Observes

At this stage, the process of observing partners and looking for problems is experienced. In this case the object sample is UMKM in the field of bakery in the Tambakasri village, Tajinan sub-district, Malang district, East Java. Data collection techniques at this stage were obtained from interviews with partners. The questions asked were how long the process of developing bread dough manually and what factors affect the bread development process.

B System planning

In this research, the input is the reading value of the temperature and humidity sensor DHT22, because DHT22 sensors have more accurate readings than DHT11 sensors[14]. The controller used is Arduino Mega because the Arduino Mega itself rarely experiences errors compared to other microcontrollers and the Arduino microcontroller can work with 10-bit or 1023[18] and the pins or features on the Arduino Mega are sufficient for programming and system needs. The actuator in this study is a heater that functions to increase the humidity value in the proofing room, the exhaust fan functions to reduce the humidity value in the proofing room, and the lamp functions to increase the temperature value in the proofing room. The working system of the proofer are two processes that run simultaneously, namely the temperature stabilization process and the humidity stabilization process.

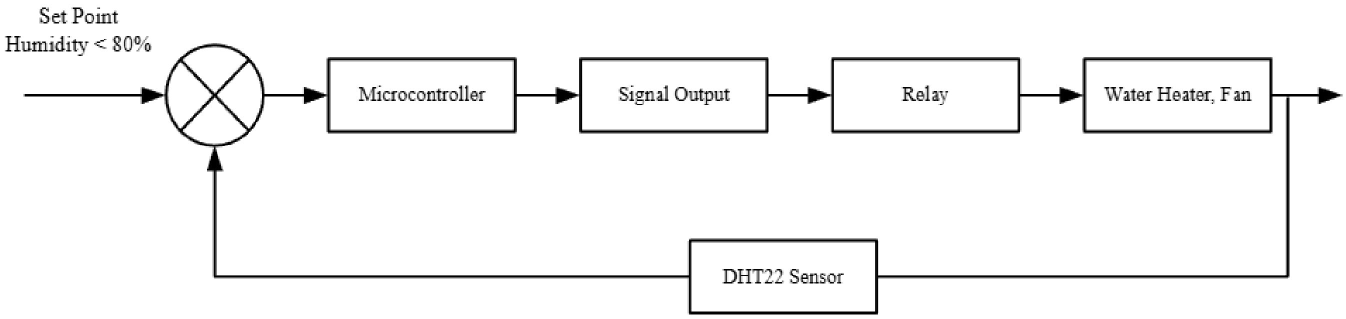


Figure 2. Block diagram of humidity stabilization

Figure 2 shows the humidity stabilization process. When the DHT22 humidity sensor reading < 80RH, the system will trigger the SSR relay to turn on the water heater. When the DHT22 humidity sensor reading >90RH, the system will trigger the SSR relay to turn off the water heater and trigger the relay to turn on the exhaust fan.

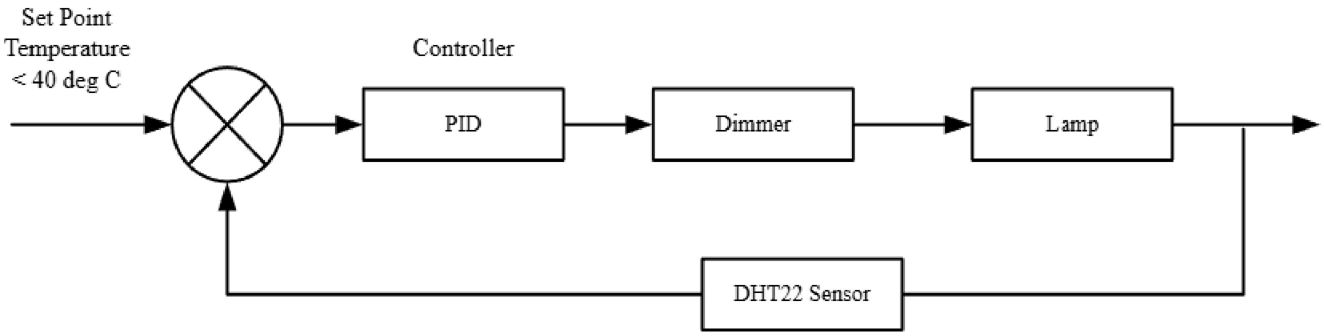


Figure 3. Block diagram of temperature stabilization

Figure 3 shows the temperature stabilization process. When the DHT22 sensor temperature reading < 40ºC then the system will trigger the dimmer so that the heat emission generated by the incandescent lamp occurs and the temperature increases, if the temperature > 40ºC then the system will trigger the dimmer to reduce the light intensity of the incandescent lamp so that the temperature can be stabilized in the proofing room and this temperature stabilization process uses a PID control system.

1) The design criteria of the electrical system for the bread dough proofer are as follows:
   a) This system can be used for proofing bread dough.
   b) The system can display the Temperature set point input menu on the I2C LCD display.
   c) The system can display the Humidity set point input menu on the I2C LCD display.
   d) The set point value can be changed using a potentiometer.
   e) The set point value can be input using the Push button.
   f) The system can display the temperature inside the bread proofer on the I2C LCD display.
   g) The system can display the humidity inside the proofer on the I2C LCD display.
   h) The system can stabilize the humidity.
   i) The system can stabilize the temperature.
   j) The system can turn the water heater on and off to stabilize the humidity.
   k) The system can adjust the intensity of bright lights to stabilize the temperature.

   l) The system can turn the fan on and off.
   m) The system can turn on the exhaust fan when the humidity exceeds the set point.
2) As for the Parameter Design design of the electrical system in the bread dough proofer technology is as follows:
   a) The Power System for this proofer uses a power source that comes from PLN.
   b) The microcontroller used is the Arduino Mega.
   c) The input set point value can run on the system.
3) As for the Experiment Design of the electrical system in the bread dough proofer technology is as follows:
   a) DHT 22 Sensor Calibration
      Calibration is used so that data readings are accurate so that the data that becomes input to the microcontroller is valid and the decisions taken by the microcontroller are correct. The calibration process is carried out by comparing the temperature and humidity read by the DHT22 sensor[19] with the HTC 1 Temperature Humidity Meter Digital Hygrothermograph Thermometer.
   b) PID tuning
      PID tuning is done to get the value of Kp, Ki, Kd so that temperature stability can be maintained in the range of 38 - 42 °C.
   c) Data collection is carried out from the proofer on until the set point value of temperature and humidity is reached and stabilized.
   d) The research was conducted at UMKM RASTAR which is located in the Regency. Malang.

C Component selection

The selection of components is supported by the theory obtained from literature studies and observations so that components are obtained that are in accordance with system specifications that can run as planned. The components used are Microcontroller, Temperature and Humidity Sensor, Relay, Motor driver, Keypad, Dimmer, LCD, and Power Supply.

D Electric system planning

The design of the Proofer Electrical System programming focuses on creating algorithms that can stabilize temperature and humidity for precise control and monitoring of accurate temperature and humidity. The system uses a modular approach for flexibility and scalability in its implementation, integrating controllers, sensors and actuators. Utilizing technology in programming and data communication within the system, this system design aims to produce a reliable and adaptive system. The wiring of the Proofer Electrical System is shown in Figure 4.

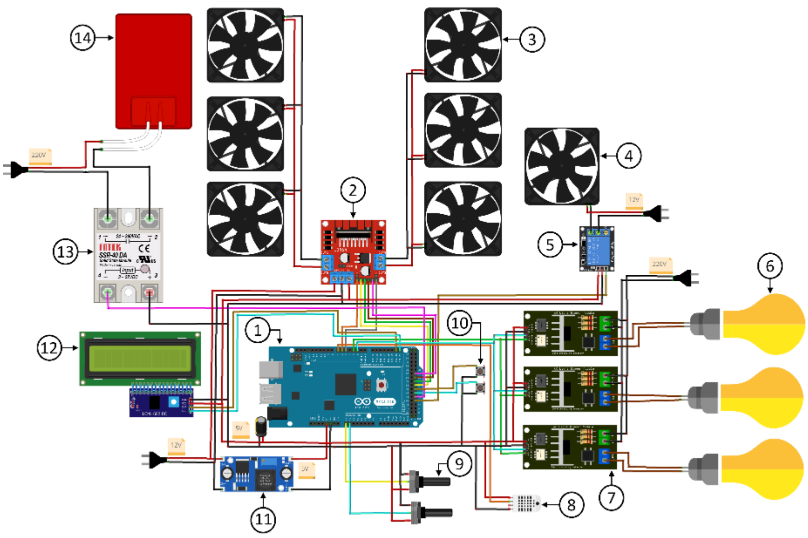


Figure 4. Wiring system

1.	Arduino Mega	6.	Lamp	11.	Stepdown
2.	Modul L298N	7.	AC Light Dimmer	12.	LCD I2C
3.	Fan Centrifugal	8.	Sensor DHT22	13.	Relay SSR
4.	Fan Exhaust	9.	Potentiometers	14.	Water heater
5.	Relay	10.	Push Button		

E Assembly

System design in the research of Microcontroller-based Bread Dough Proofer Electrical System includes a comprehensive process to develop an integrated and efficient system, which enables humidity stabilization, temperature stabilization, accurate data collection, and precise monitoring during the proofing process. This involves harmonious integration between hardware and software, as well as thorough testing to ensure optimal performance.

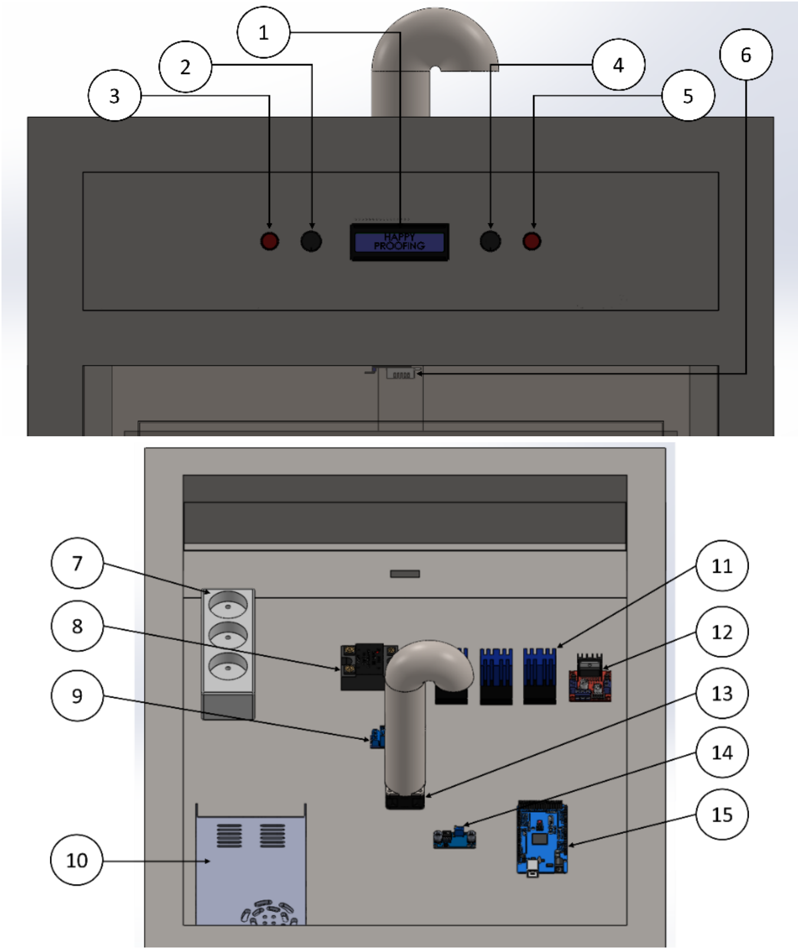


Figure 5. Placement of electrical components

1.	LCD I2C 16x2	6.	DHT22	11.	AC Light Dimmer
2.	Humidity Potentiometers	7.	Socket Outlet	12.	Module L298N
3.	Push Button System	8.	Relay SSR	13.	Fan Exhaust
4.	Temperature Potentiometers	9.	Relay	14.	Stepdown
5.	Menu Push Button	10.	Power Supply	15	Arduino Mega

Figure 5 shows the placement of the components used in the electrical system of the bread dough proofer technology. Later the electrical system on top of the proofer technology will be closed.

F System testing

A Tuning PID

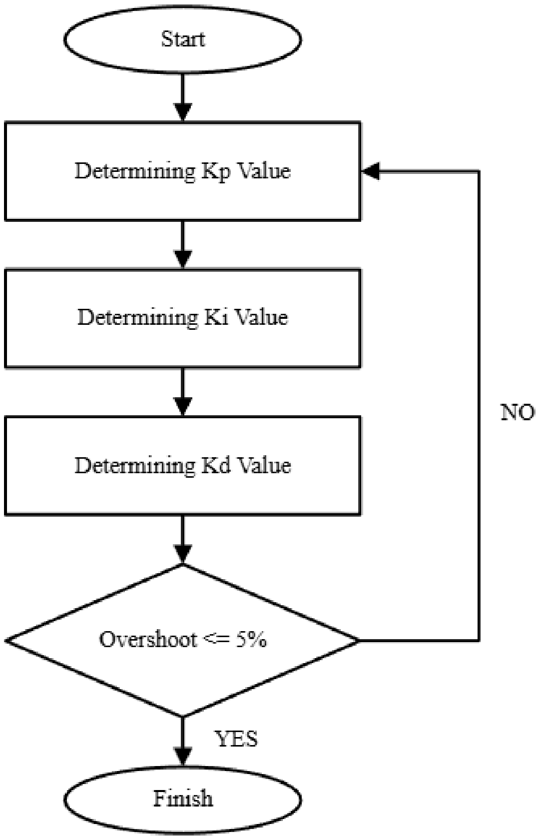


Figure 6. Flowchart tuning PID

Figure 6 shows the stages of the PID tuning process in the electrical system of the proofer. Testing is done by determining the value of Kp, Ki, Kd on the PID control system. In implementing the PID control system, it is necessary to adjust the values of Kp, Ki and Kd, so that the resulting output response signal is as desired, therefore the tuning process is carried out[20]. This test starts with determining the Kp value until it reaches the set point value. After that, determine the value of Ki to eliminate the steady state error of the system response. Next, determine the value of Kd to improve stability and accelerate the transient response of the system. After getting a system response that has Overshoot on the system <= 5% and a stable steady state with a set point of 40°C, then the tuning process has been completed and the values of Kp, Ki, and Kd are entered in the overall system program.

B Temperature and humidity stability

The stability testing of temperature and humidity, the system is tested by combining the temperature stabilization program with the PID control system and humidity stabilization. This test is done to see the results of temperature and humidity stabilization. The results that will be discussed will be the time to achieve temperature and humidity stability, temperature and humidity stability.

3. Results and Discussion

This section discusses the testing and analysis of the electrical system of the bread dough proofer planned in the previous section.

3.1. Calibration

DHT22 sensor calibration is used to calibrate the temperature and humidity readings of the DHT22 sensor so that the readings are accurate. This calibration is done by comparing the DHT22 temperature and humidity readings and the HTC-1 temperature and humidity readings.

Table 1. Temperature readings of DHT22 and HTC-1

Temperature		
DHT22 (°C)	**HTC-1 (°C)**	**Error (%)**
32,65	31,17	4,75
35,52	33,33	6,57
37,65	35,23	6,87
39,47	37,03	6,59
41,47	39,03	6,25
43,48	41,00	6,05
Error Average		6,18

Table 1 shows the results of the DHT22 and HTC-1 temperature readings. From the table it can be concluded that the DHT22 temperature reading still has a high error value, with an average error of 6.18% and an accuracy of 93.82%. From the results of the DHT22 and HTC-1 Temperature readings, it can be concluded that the sensor must be calibrated. The calibration method used is the linear regression method. The regression method chosen was the linear regression method due to its relative simplicity, yet effectiveness in correcting measurement inaccuracies[21]. Data from the calibration process is displayed in graphical form in Figure 7.

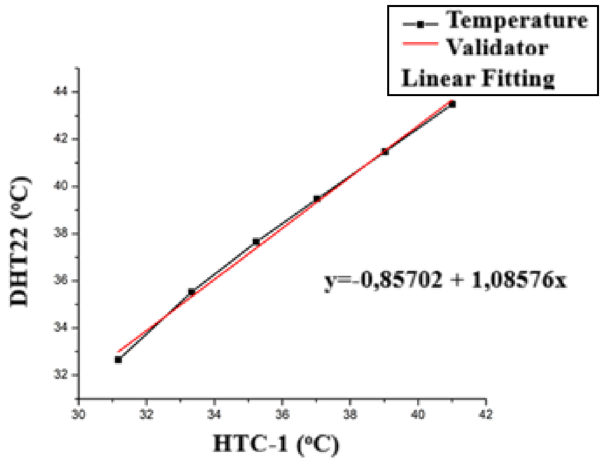


Figure 7. Temperature DHT22 regression graph

Figure 7 shows that the equation for the gradient value in reading the Temperature value is y = a + bx, where the values of a and b are obtained from the calculation, so that the equation below is obtained.

$$y = -0.85702 + 1.08576x$$

After getting the equation for the gradient value of the linear regression, this equation is then entered into the temperature reading program in the Arduino IDE.

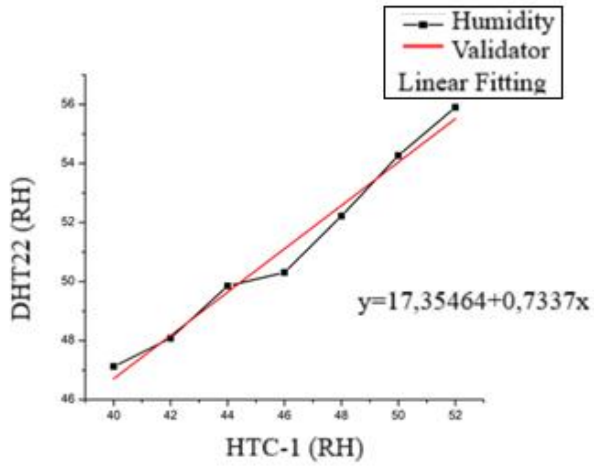


Figure 8. Humidity DHT22 regression graph

Figure 8 shows that the equation for the gradient value of the Humidity value reading is y = a + bx, where the values of a and b are obtained from the calculation, so that the equation below is obtained.

$$y = 17.35464 + 0.73375x$$

After getting the equation for the gradient value of the linear regression, this equation is then entered into the humidity reading program in the Arduino IDE.

3.2. Validation

```
float temperatureRead() {
  double suhu = dht.readTemperature();
  double temperature = -0,85702 + 1,08576 * suhu;
  return temperature;
  delay(100);
}
//------------------ Pembacaan Temperature DHT22
```

Figure 9. Program for DHT22 temperature reading

```
float humidityRead() {
  double kelembapan = dht.readHumidity();
  double humidity = 17,35464 + 0,73375 * kelembapan;
  return humidity;
  delay(100);
}
//------------------ Pembacaan Humidity DHT22
```

Figure 10. Program for DHT22 humidity reading

After inputting the equation obtained from the linear regression graph in the DHT22 Temperature and Humidity sensor reading program on the Arduino IDE as shown in Figure 9 and Figure 10, then the next process is the validation process of the DHT22 sensor reading with HTC-1. The sensor readings on the Arduino IDE serial monitor will be compared with the HTC-1 validator. The results of this reading will produce an average error value and the accuracy of the DHT22 sensor reading after calibration.

Table 3. Temperature reading results of DHT22 and HTC-1 after calibration

Humidity		
DHT22 (ºC)	**HTC-1 (ºC)**	**Error (%)**
69,01	68	1,49
68,01	67	1,51
66,01	66	0,02
65,17	65	0,26
64,24	64	0,37
63,32	63	0,51
62,57	62	0,92
61,69	60	2,82
60,70	59	2,88
59,74	58	3,00
Error Average		1,38

Table 3 shows the results of the DHT22 temperature reading after the calibration process. The average error obtained from the DHT22 temperature reading is 1.56% and the accuracy is 98.44%. From the results of the DHT22 and HTC-1 temperature readings, it can be concluded that the sensor is suitable for use.

Table 4. Humidity reading results of DHT22 and HTC-1 after calibration

Temperature		
DHT22 (ºC)	**HTC-1 (ºC)**	**Error (%)**
30,46	30,60	0,46
30,95	30,90	0,16
31,47	31,30	0,54
32,04	31,70	1,07
32,61	32,10	1,59
33,19	32,60	1,81
33,68	33,10	1,75
34,31	33,5	2,42
34,98	34,00	2,88
35,51	34,50	2,93
Error Average		1,56

Table 4 shows the results of DHT22 humidity readings after the calibration process. The average error obtained from the DHT22 humidity reading is 1.38% and the accuracy is 98.62%. From the reading results of Humidity DHT22 and HTC-1 it can be concluded that the sensor is feasible to use.

3.3. System planning

Figure 11 shows the product of the wiring diagram that has been made. in its application, the PCB board is used as an electrical connecting circuit between the components and the Arduino Mega. The PCB board here was chosen because of its durability and simplicity in the wiring system. The connector on each component on the PCB board uses a socket so that it can be connected properly and is not easily separated.

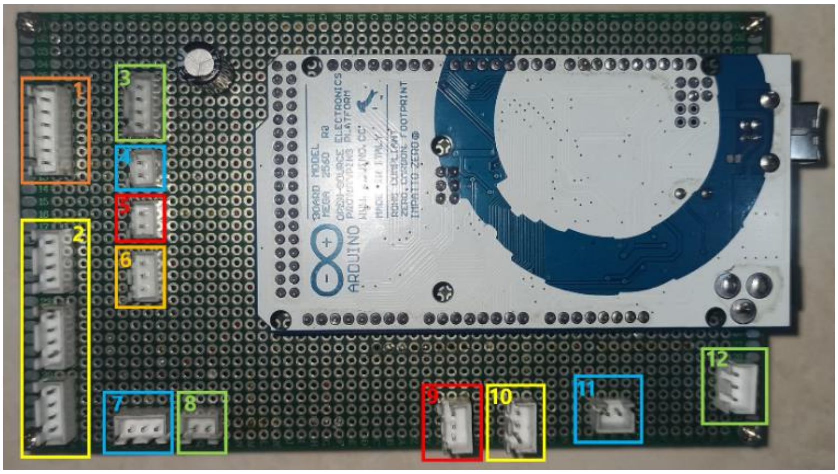


Figure 11. Wiring electrical system (PCB)

Table 5. Pin Arduino Mega

No	Component	Pin
1	Motor Driver L298N	ENA = 6, IN1 = 39, IN2 = 37, ENB = 5, IN3 = 35, IN4 = 33
2	AC Light Dimmer	Output = 3, Zerocross = 2
3	LCD I2C	SDA = 20, SCL = 21
4	Push Button Menu	Pin 43
5	Push Button System	Pin 41
6	Power Module Driver L298N	Pin 5v and gnd
7	Fan Relay	Pin 47
8	Water Heater Relay	Pin 45
9	Temperature Potentiometers	Pin A0
10	Humidity Potentiometers	Pin A1
11	Power Input 5V	Pin 5v and gnd
12	DHT22	Pin 7

Table 5 shows the Arduino Mega pins used in the circuit. The pulse width modulation (PWM) pin on the L298N module functions to adjust the fan speed while on the AC Light Dimmer the PWM pin is used to control the light intensity of the lamp. Pin 2 on the AC Light Dimer is a zero cross pin which is a pin on each microcontroller is different, so must make sure the pin is zero crossed first when using the AC Lamp Dimmer. Pin 5V is used as a power pin on the Arduino so that electricity is more stable.

A Programming

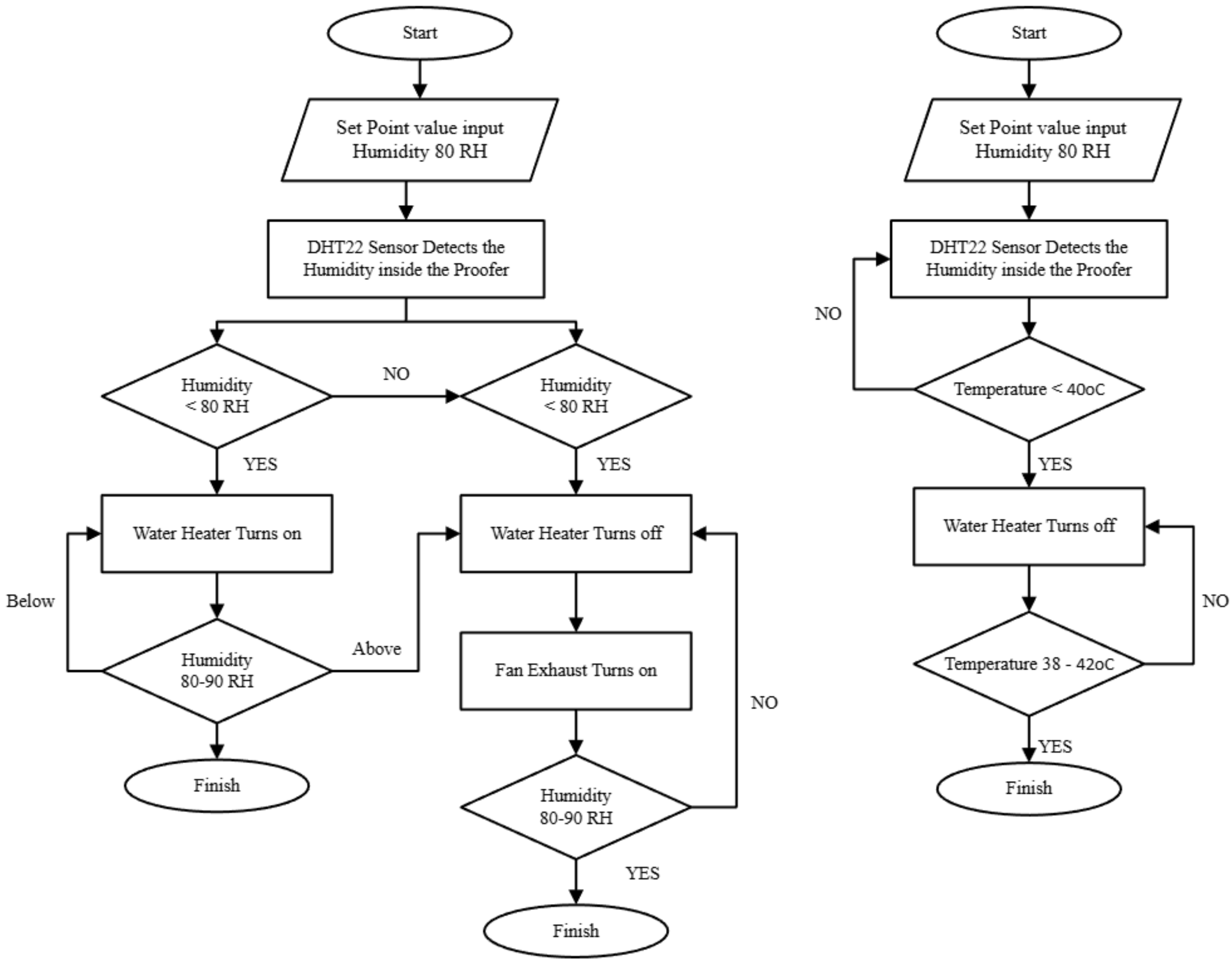


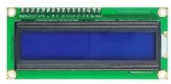
Figure 12. Device working system

Figure 12 shows the working system of temperature and humidity stabilization in the bread dough proofer. Measurement of temperature and humidity is done by utilizing the DHT22 sensor which provides data in the form of analog signals. Furthermore, the results of the DHT22 temperature and humidity readings are used to trigger the system and displayed on the LCD to monitor the proofing process and to stabilize the temperature and humidity in the proofing room. As a result, the system can stabilize the temperature and humidity in the proofing room as well as the display on the LCD screen.

B Component selection

The selection of components in the electrical system of the bread dough proofer is based on the most appropriate technical specifications for each component such as microcontroller, temperature and humidity sensor, relay, motor driver, keypad, dimmer, lcd, and power supply. Produce optimal temperature and humidity stabilization as shown in Table 6. The following are the components used in the electrical system of the bread dough proofer.

Table 6. Product of component used

Need	Components		Description	Need	Components		Description
Microcontroller		**Arduino Mega**	controller for the electrical system of the bread dough proofer and system control center	Keypad		**Potentiometers 10k ohm**	set the temperature and humidity set point values
Temperature and Humidity Sensor		**DHT22**	detects temperature and humidity in the proofing room	LCD		**I2C 16x2**	display menu and monitor temperature and humidity
Dimmer		***AC Light Dimmer***	Adjust the light intensity of the lamp	Driver Motor		**Module L298N**	adjust the speed of the fan in the proofing room
Relay		**Relay 5v DC**	Disconnect and connect exhaust fan power	Power Supply		**Power Supply 12V 10A**	supply power to the electrical system components of the bread dough proofer
Relay SSR		***Relay SSR Autonics***	Disconnect and connect Water Heater power				

C System assembly

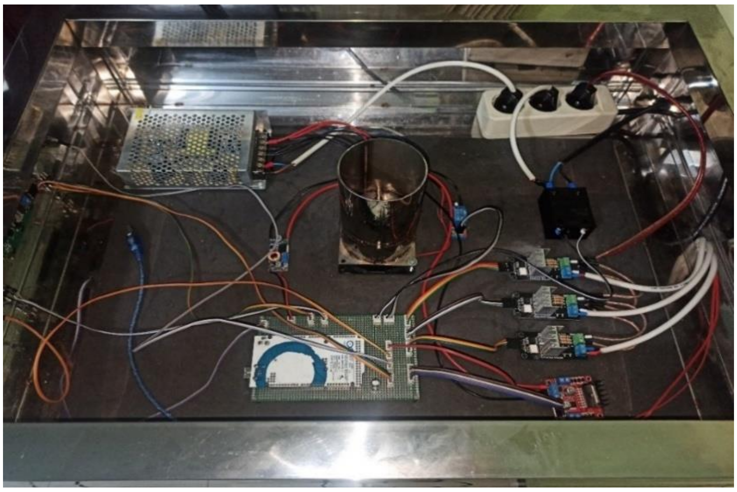


Figure 13. Electrical system

At this stage, the electrical system assembly is carried out which has been assembled with the mechanical system of the proofer technology. The result of the designs that were made at the research planning stage as shown in Figure 13. The electrical system and components are assembled into one unit. After the assembly process, the PID tuning process is carried out on the electrical system.

D System testing

Testing the electrical system of the bread dough proofer uses several tests to ensure accuracy and reliability. These tests include:

1) Tuning PID

The tuning process is carried out to obtain the optimal system response according to the system requirements. The tuning process is done by changing the Kp value to increase the speed of the system response[22]. The effect of Ki value is to reduce the steady state error[23]. The effect of the Kd value is to reduce the speed of error change, reduce oscillations and improve system stability[24].

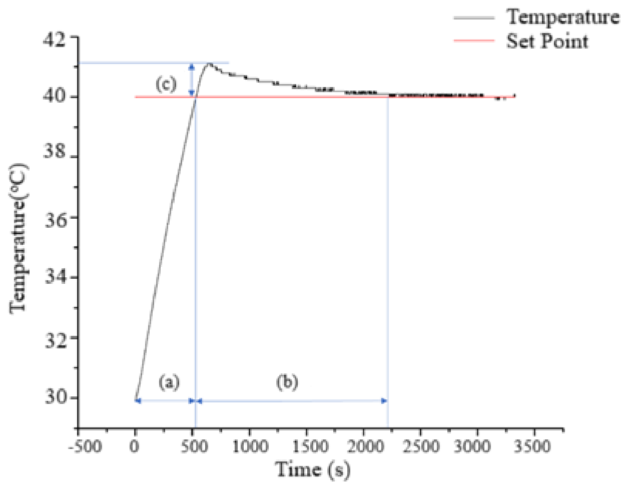


Figure 14. PID system response of bread dough proofer (a) rising time, (b) settling time, (c) overshoot

When doing the tuning process with the value of Kp = 50, Ki = 1, Kd = 1. The system response from the above constants gets a stable system response at a set point of 40 ºC. The system response of this constant has a fairly large overshot of 41.10 ºC. The rising time of this PID system response takes 528 seconds or 8.8 minutes to reach the temperature set point of 40ºC, where the initial temperature when the proofer is turned on is 30ºC. Rising time of the PID system response as shown in Figure 14. Settling time on the system response takes 2238 seconds or 37.13 minutes, the system reaches steady state. After getting the system response as shown in Figure 14, the re-tuning process is carried out because of the large overshot in the system response.

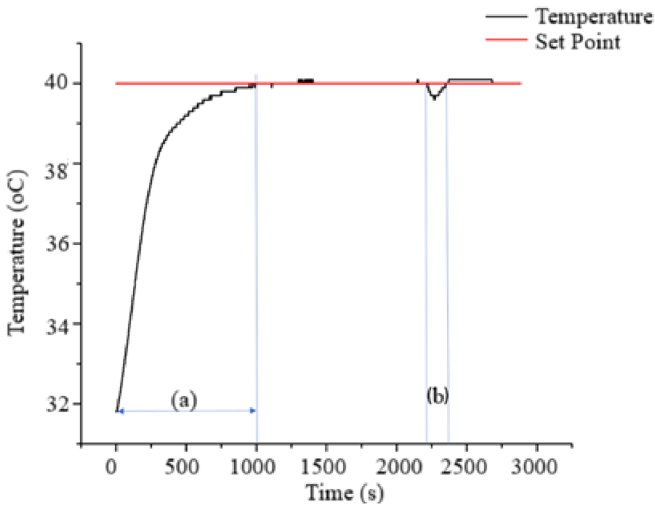


Figure 15. PID system response of bread dough proofer (a)rising time, (b)disturbance

After doing the tuning process and getting the system response as shown in Figure 14, re-tuning is done by lowering the Kp value to 30, the value of Kp = 30, Ki = 1, Kd = 1. The system response of the constant Kp = 30, Ki = 1, Kd = 1 can be shown in Figure 15. The system response of the above constants gets a stable system response at a set point of 40ºC. Rising time of the PID system response takes 1000 seconds or 16.6 minutes to reach the temperature set point of 40ºC, where the initial temperature when the proofer is turned on is 32ºC. Rising time of the PID system response can be shown in Figure 15. The overshot of the PID system response when it has reached the set point is 0.10ºC. After the system runs for 2250 seconds or 37.5 minutes the system is given a disturbance by opening the door of the proofer and the response decreases from the steady state. After the disturbance, the system response stabilized back to the set point of 40ºC. This slow response system was chosen because the process of increasing the humidity in the proofer technology takes a long time and the overshot value of this response is small, namely 0.10ºC.

2) System stability testing

After PID tuning is done and getting the desired system response. Next, test the PID system on the electrical system of the bread dough proofer to see the temperature stability and humidity stability of the bread dough proofer. The working system of the bread dough proofer stabilizes temperature and humidity simultaneously. The process of testing and data collection is carried out for 2 hours, starting from the proofer being turned on until temperature and humidity stability is achieved.

A Temperature stability

In the PID system response, the bread dough proofer has a rising time of 615 seconds or 10.25 minutes to reach the temperature set point of 40ºC, where the initial temperature when the appliance is turned on is 26ºC. The rising time of the PID system response can be shown in Figure 16. Overshot of the PID system response when it has reached the set point is 0.30ºC. The steady state condition of the temperature stabilization in the proofing room is 40.10ºC, this is likely related to the accuracy of the DHT22 temperature reading of 98.44%. After the system runs for 2459 seconds or 41 minutes the system experiences a disturbance because the humidity increases, and the response increases from the steady state to 40.40ºC. After experiencing a disturbance, the system response stabilized back to the set point of 40.10ºC

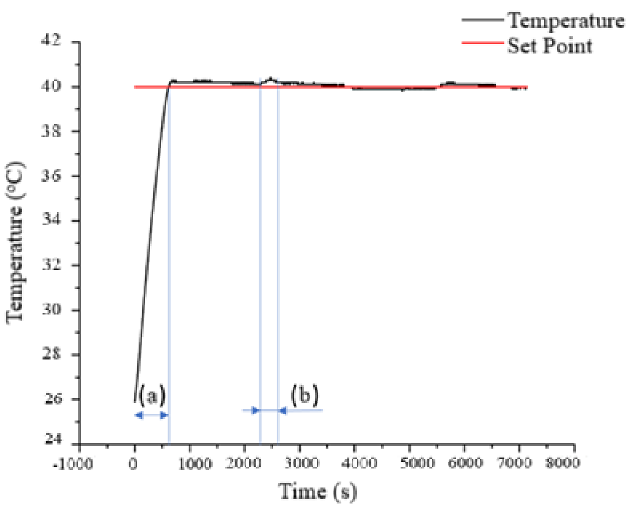


Figure 16. testing the PID system response to temperature stability (a) rising time, (b) disturbance

B Humidity stability

The response of the humidity stabilization system on the bread dough proofer has a rising time of 2,425 seconds or 40.41 minutes to reach a humidity set point of 80RH. The rising time of the humidity stabilization system response can be shown in Figure 17. The rising time of this humidity stabilization has a long time because the water heating process is long enough and requires sufficient pressure so that the water vapor produced can rise to the proofing room through the pipe next to the proofer technology wall. The rising time the humidity in the proofing room decreased at the beginning of the stabilization process, because the temperature stabilization process was carried out and the temperature in the proofing room increased so that the humidity decreased. After the system runs for 2459 seconds or 41 minutes the humidity of the proofing room increases to 93.3RH, in this condition the exhaust fan turns on to remove excess moisture in the proofing room. This excess moisture is caused by water vapor that continues to spread in the proofing room even though the heater has been turned off. After the humidity reaches 90RH the exhaust fan turns off and the humidity stabilizes from 90 - 80RH for 2,304 seconds or 38.4 minutes. After the humidity is below 80RH, the heater will turn on again to increase the humidity for 758 seconds or 12.63 minutes, this heating time is faster than the initial heating process due to the hot water temperature, so that the pressure generated by boiling water is reached faster and water vapor can spread to the proofing room.

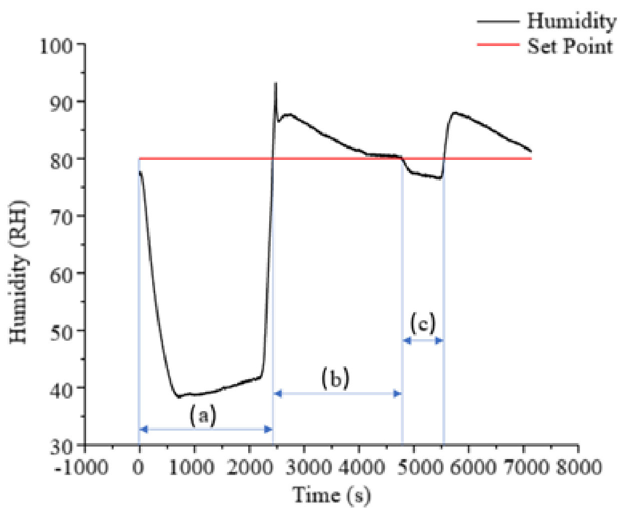


Figure 17. Humidity stability testing (a) rising time, (b) proofing condition, (c) reheating

4. Conclusions

From the planning process to the system design in the electrical system of the bread dough proofer, it can be concluded that:

1. The electrical system used in this research combines controllers, sensors, and actuators. The sensor used in this system is DHT22 to read temperature and humidity. Furthermore, the sensor reading results are displayed on the 16X2 I2C LCD display. The actuators used in this system include a heater to increase the humidity value in the proofing room by producing steam, an exhaust fan to reduce the humidity value by removing steam into the free air, and an incandescent lamp to increase the temperature in the proofing room by emitting light whose intensity is regulated by the controller. The controller uses Arduino Mega which functions to coordinate the sensor readings and give commands to the actuators to stabilize the temperature and humidity in the proofer chamber.
2. The stability of temperature and humidity is coordinated by the controller based on the results of sensor readings and actuator work. If the humidity < 80RH then the system will trigger the SSR relay so that the water heater will turn on, if the humidity > 90RH then the system will trigger the relay to turn on the exhaust fan to remove the water vapor in the proofing room and the heater is turned off. If the temperature < 40oC then the system will trigger the dimmer so that the heat emission generated by the incandescent lamp occurs and the temperature increases, if the temperature > 40oC then the system will trigger the dimmer to reduce the light intensity of the incandescent lamp so that the temperature can be stabilized in the proofing room and this temperature stabilization process uses a PID control system.
3. Temperature and humidity stability performance of the proofer system can stabilize the temperature at a temperature of 40.10oC and humidity in the range of 80 - 90RH for 38.4 minutes.

Acknowledgment

Research grant from ITS with contract number No: 897/PKS/ITS/2024. Laboratory of Mechatronics, Department of Industrial Mechanical Engineering, Faculty of Vocations, Sepuluh Nopember Institute of Technology.

References

[1] B. L. Sanyoto, Andreyanto, Mashuri, L. Rusdiyana, And D. Shidqul Aziz, "Rancang Bangun Mesin Penepung Biji Sorgum Sebagai Alternatif Bahan Baku Tepung Terigu Dalam Produk Olahan Makanan Dengan Kekasaran 100 Mesh," *Jurnal Amori*, Vol. 2, 2021.

[2] Badan Pusat Statistik, *Pengeluaran Untuk Konsumsi Penduduk Indonesia, Maret 2023*, Vol. 27. Badan Pusat Statistik , 2023.

[3] D. Zhang, "Effect Of Proofing On The Rheology And Moisture Distribution Of Corn Starch-Hydroxypropylmethylcellulose Gluten-Free Dough," *Foods*, Vol. 12, No. 4, P. 695, Feb. 2023, Doi: 10.3390/Foods12040695.

[4] T. A. Dendegh, D. I. Gernah, And M. O. Eke, "Investigate The Effects Of Increased Yeast Addition And Proofing Time On The Quality Characteristic Of Bread From Wheat And Cassava Flour," *Asian Food Science Journal*, Vol. 3, No. 4, Pp. 1–10, Aug. 2018, Doi: 10.9734/Afsj/2018/42697.

[5] M. Kostyuchenko, N. Kolotova, I. Tyurina, N. Golubko, And O. Tyurina, "Effect Of Long, Low-Temperature Fermentation On Properties Of Dough And Quality Of Rich Bakery Products Made From Wheat Flour," *Bio Web Conf*, Vol. 64, P. 01011, Jul. 2023, Doi: 10.1051/Bioconf/20236401011.

[6] I. Ikarini, A. Sutrisno, And S. Setyo Yuwono, "Effect Of Batter Method And Proofing Time On Physical And Sensory Characteristics Of Gluten-Free Bread," *Jurnal Teknologi Pertanian*, Feb. 2023.

[7] N. S. Drastiawati, M. Muhaji, N. A. Susanti, And T. W. Wibowo, "Penerapan Mesin Pengembang Adonan Roti (Proofer) Untuk Meningkatkan Produktivitas Ukm Roti Bangkalan," *Jurnal Pengabdian Masyarakat Progresif Humanis Brainstorming*, Vol. 6, No. 2, Pp. 425–433, Apr. 2023, Doi: 10.30591/Japhb.V6i2.4420.

[8] O. E.N., N. R.E., And A. P.U., "Design And Characterization Of A Gas-Powered Baking Oven Fabricated With Local Engineering Materials," *Advanced Journal Of Science, Technology And Engineering*, Vol. 2, No. 1, Pp. 63–77, Nov. 2022, Doi: 10.52589/Ajste-9ccaio1b.

[9] A. N. Hidayati, I. B. P. P. Mahartana, D. N. Serfandi, M. I. Fahmiy, And D. S. Prayogo, "Design And Construction Of Electrical System For Bread Dough Proofer Tool Based On A Microcontroller With Pid Control On Donut Dough," *Techno.Com*, Vol. 24, No. 4, Pp. 1250–1261, Nov. 2025, Doi: 10.62411/Tc.V24i4.14831.

[10] M. Muslimin, "Desain Kontrol Pengembang Adonan Roti Menggunakan Pemanas Gas Elpiji," *Majalah Teknik Industri*, Vol. 26, No. 2, Pp. 8–14, 2018, Accessed: Aug. 29, 2025. [Online]. Available: Https://Journal.Atim.Ac.Id/Index.Php/Majalahteknikindustri/Article/View/4

[11] S. Buwarda And S. S. Tenri Sidehabi, "Mesin Proofer Otomatis Berbasis Mikrokontroller," *Jurnal Ilmiah Ilmu Komputer Fakultas Ilmu Komputer Universitas Al Asyariah Mandar*, Vol. 9, No. 1, Pp. 18–22, Apr. 2023.

[12] A. Ullah, O. B. Kharisma, And I. Santoso, "Fuzzy Logic Implementation To Control Temperature And Humidity In A Bread Proofing Machine," *Indonesian Journal Of Artificial Intelligence And Data Mining*, Vol. 1, No. 2, P. 66, Nov. 2018, Doi: 10.24014/Ijaidm.V1i2.5664.

[13] P. K. Jha, S. Chevallier, J. Cheio, A. Rawson, And A. Le-Bail, "Impact Of Resting Time Between Mixing And Shaping On The Dough Porosity And Final Cell Distribution In Sandwich Bread," *J Food Eng*, Vol. 194, Pp. 15–23, Feb. 2017, Doi: 10.1016/J.Jfoodeng.2016.07.016.

[14] D. Yulizar, S. Soekirno, N. Ananda, M. A. Prabowo, I. F. P. Perdana, And D. Aofany, "Performance Analysis Comparison Of Dht11, Dht22 And Ds18b20 As Temperature Measurement," *Icses*, No. 8, Pp. 37–45, Apr. 2023, Doi: 10.2991/978-94-6463-232-3_5.

[15] P. Bhandari And P. Z. Csurcsia, "Digital Implementation Of The Pid Controller," *Software Impacts*, Vol. 13, Aug. 2022, Doi: 10.1016/J.Simpa.2022.100306.

[16] S. Shafiudin And N. Kholis, "Monitoring System And Temperature Controlling On Pid Based Poultry Hatching Incubator," *Iop Conf Ser Mater Sci Eng*, Vol. 336, P. 012007, Apr. 2018, Doi: 10.1088/1757-899x/336/1/012007.

[17] D. Meana-Llorián, C. González García, B. C. Pelayo G-Bustelo, J. M. Cueva Lovelle, And N. Garcia-Fernandez, "Iofclime: The Fuzzy Logic And The Internet Of Things To Control Indoor Temperature Regarding The Outdoor Ambient Conditions," *Future Generation Computer Systems*, Vol. 76, Pp. 275–284, Nov. 2017, Doi: 10.1016/J.Future.2016.11.020.

[18] A. A. M. Ate, "Design And Implementation Automated Egg Incubator," *Fes Journal Of Engineering Sciences*, Vol. 10, No. 1, Pp. 52–60, Apr. 2021, Doi: 10.52981/Fjes.V10i1.714.

[19] R. A. Koestoer, N. Pancasaputra, I. Roihan, And Harinaldi, "A Simple Calibration Methods Of Relative Humidity Sensor Dht22 For Tropical Climates Based On Arduino Data Acquisition System," 2019, P. 020009. Doi: 10.1063/1.5086556.

[20] I. Adam, H. F. Rozi, S. Khan, Z. Zaharuddin, K. A. Kadir, And A. N. Nurdin, "The Development Of The Fuzzy-Based Infant Incubator," 2019, P. 020101. Doi: 10.1063/1.5118109.

[21] S. Satra, A. Agrawal, S. Gogate, R. Daryapurkar, And N. Mehendale, "Design And Implementation Of Arduino-Based Automatic Irrigation With Moisture Sensor," *Ssrn Electronic Journal*, 2023, Doi: 10.2139/Ssrn.4513859.

[22] R. S. Patil, S. P. Jadhav, And M. D. Patil, "Review Of Intelligent And Nature-Inspired Algorithms-Based Methods For Tuning Pid Controllers In Industrial Applications," *Journal Of Robotics And Control (Jrc)*, Vol. 5, No. 2, Pp. 336–358, Feb. 2024, Doi: 10.18196/Jrc.V5i2.20850.

[23] A. H. F, S. Syahrorini, A. Ahfas, Z. N. F, And A. Z. A, "Line Tracer Robot Navigation System Using Arduino Uno Microntroller With Pid Control," *Academia Open*, Vol. 8, No. 2, Aug. 2023, Doi: 10.21070/Acopen.8.2023.7275.

[24] A. M. Zungeru, M. Mangwala, J. Chuma, B. Gaebolae, And B. Basutli, "Design And Simulation Of An Automatic Room Heater Control System," *Heliyon*, Vol. 4, No. 6, P. E00655, Jun. 2018, Doi: 10.1016/J.Heliyon.2018.E00655.