IOT-BASED HUMIDITY CONTROL SYSTEM FOR ELECTROSPINNING

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Abstract

In recent years, electrospinning has become the most common and most widely used nanofiber manufacturing method. One parameter affecting the manufacturing process is the humidity parameter, which affects the morphology. The control tools that have been developed have not been equipped with a remote control and monitoring system. This research aims to develop a humidity control system that can be controlled and monitored remotely and is equipped with data recapitulation. This research used methods from literature studies on humidity control systems, manufacture and assembly of hardware and software, calibration, and performance tests. A humidity control device is produced using a NodeMCU microcontroller connected to the IoT-based Blynk application. This can be controlled and monitored manually with an LCD and Keypad or by using a handphone through the Blynk application, and the humidity value can be recapitulated with Google Sheets in real-time. The sensor used for reading this humidity value is a DHT 22 sensor which has an accuracy value of 99.72% and a precision of 98.81% for 45%-95% humidity. This IoT-based humidity control system device can automate the process of controlling, monitoring, and recapitulating humidity data in real-time.

Keywords: Electrospinning, Humidity, Humidity Control System, Internet of Things, Blynk, DHT22.

INTRODUCTION

In recent years, electrospinning has been the most common and most widely used nanofiber manufacturing method [1]. Its simple process makes electrospinning widely used for making nanofibers with various polymers. Actually, besides the electrospinning technique, there are also several methods of making nanofiber, such as the Mixing and Milling Method [2], Chemical Vapor Deposition (CVD) Method [3], Plasma Enhanced CVD (PECVD) [3], Atomic Layer Deposition (ALD) Method [4].

The basic principle of this method revolves around the static charge generated due to the stretching of polymer fibres that repel each other, resulting in the formation of fibres [1]. The nanofiber manufacturing process applies the electrospinning technique, which is an efficient nanofiber manufacturing technique that utilizes the influence of an electric field to produce a jet of polymer solution with an electric charge. Polymer nanofibers can be formed due to the simultaneous evaporation process of the solvent

[5]. Electrospinning is one method of forming fibers by emitting electric charge from a polymer solution or liquid. Formhals have patented this technique in 1934 [6].

Reviewing the existing literature, to obtain variations in the characteristics of nanofibers, one of the independent variables can be given by varying the air humidity [7]. This air humidity setting regulates the water vapor in the chamber due to the evaporation process of the emitted polymer solution. Developments related to humidity control system research began with controlling humidity in the chamber using a salt bath to maintain normal humidity values in the 75% humidity range [8]. Subsequently, this humidity control system underwent development, where relative humidity (RH) conditions were regulated using dry silica and ultrasonic humidifiers (Air-O-Swiss, Switzerland) [9]. In these systems, the process of increasing humidity is carried out by ultrasonic humidifiers, but this is not accurate enough, so dry silica is added as a counterweight. The chamber is also equipped

with a ventilator, which provides faster achievement of a balanced homogeneous atmosphere in the chamber.

Furthermore, there are research updates on humidity control using blue silica-gel and water spray [10]. Then Anggoro et al. developed a humidity control system consisting of an air pump, relay module, Arduino Uno, silica gel, push button, and resistor. The push button is used to adjust the humidity level [11]. There are two push buttons: one to raise the humidity and another to lower it. And the air pump will suck in the environmental air and collect it with the help of silica gel.

However, previous research still has weaknesses, including the inability to remotely control and monitor humidity control systems. To control and monitor humidity, it must be within a close radius. The data recapitulation system has not been completed in real-time. In addition, using silica gel as a moisture reducer also has disadvantages, namely the need to replace silica gel periodically with a new one.

Therefore, this research aims to design a humidity control system that can be adjusted automatically based on the Internet of Things (IoT), allowing the control and monitoring process to be carried out remotely. Therefore, a humidity control system uses a NodeMCU microcontroller connected to the Blynk application. The system can be controlled and monitored manually using LCD and keypad, and it can be monitored via handphone with the help of the Blynk application, which will send real-time humidity values and allow for remote control. The recapitulation process is done with the help of Google Sheets, which will send real-time humidity data. The operation of the humidity control system requires a good internet network to avoid delays in sending data from the device so that the system performs well.

METHOD

This research methodology uses the experimental method. This research aims to create an IoT-based humidity controller that can be set remotely using Blynk or close range using a keypad and monitored in real-time using LCD and Blynk as electrospinning support, as shown in Figure 1.
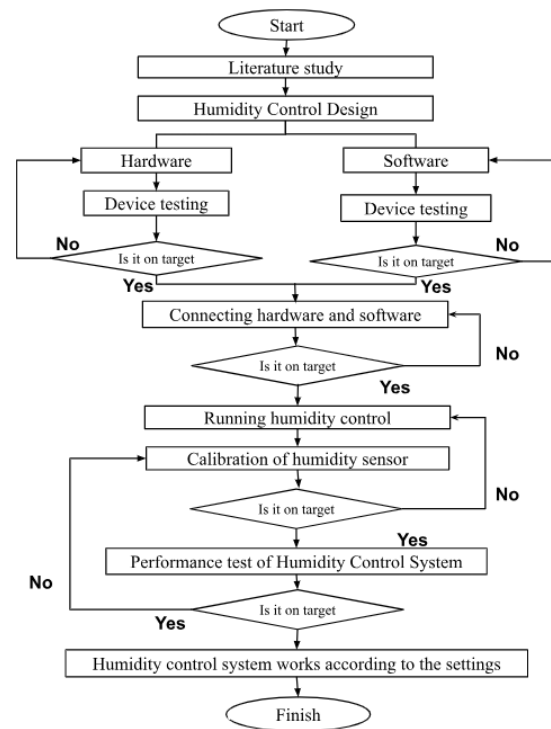

Figure 1. Research Methodology

Research Material

The tools and materials used to manufacture IoT-based humidity control devices, such as electrospinning support, are shown in Table 1.

Table 1. The Tools and Materials

Name	Qty
Fan 12 V	1
Peltier	1
Cold sink	1
Heatsink	1
Cables	Desired
Modul diffuser	1
Sensor DHT22	1
NodeMCU	1
V3 ESP8266	1
Modul Relay 2 Channel	1
Keypad matrix 4x4	1
LCD I2C	1
NodeMcu Base ESP8266	1
Kabel Micro USB	1
Jumper	Desired
Adaptor	1
Paper Tape	1
Arduino IDE	1
Google sheets	1

Humidity Control System Hardware Design

The hardware design of the humidity control system is divided into three main components, which are in the design of the

system containing the increasing and decreasing humidity system shown in Figure 2 in the circuit design describing the pin configuration and the controller's design. The controller and monitoring design is in the form of a box, as shown in Figure 3. A monitoring system uses a 12C LCD, and a controlling system uses a keypad; the circuit design is shown in Figure 4.
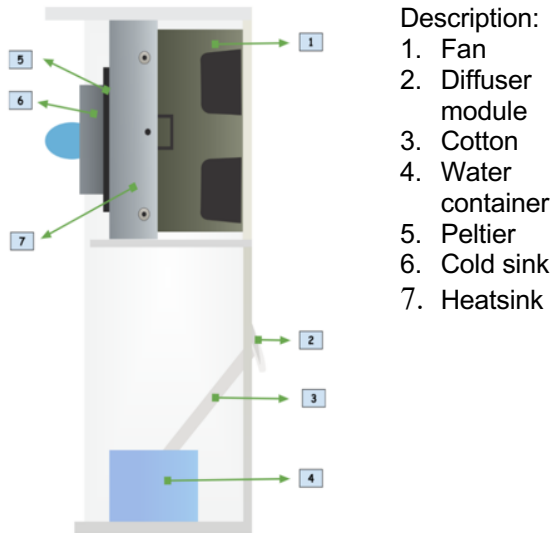

Description:
1. Fan
2. Diffuser module
3. Cotton
4. Water container
5. Peltier
6. Cold sink
7. Heatsink

Figure 2. Humidity Control System

Description :
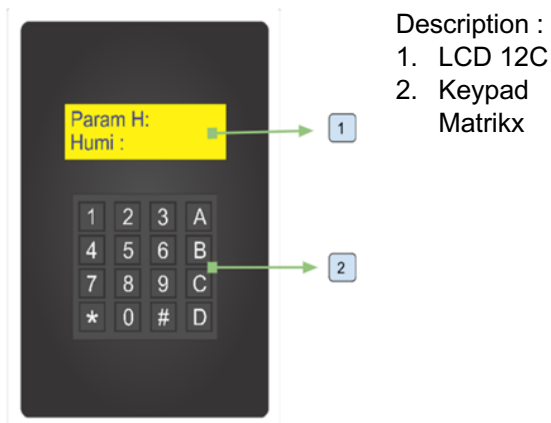1. LCD 12C
2. Keypad Matrikx

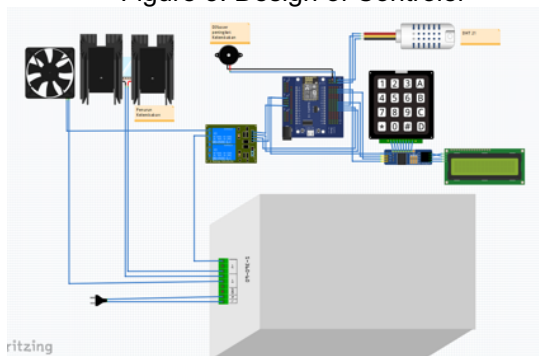Figure 3. Design of Controler

Figure 4. 3D Design of Humidity Control System

Humidity Control System Software Design

At this stage, the software design using the Arduino IDE to write the code to be uploaded to the NodeMCU begins with uploading the code via a laptop. This process aims to check the condition of the NodeMCU port, upload the code, and test the performance of the NodeMCU. After a successful upload, the LCD will be turned on, and the text will be displayed as written in the uploaded code. If the LCD does not light up or the text does not appear, this indicates a problem with either the code or the cable connected to the LCD or possibly damage to the NodeMCU port.

After the NodeMCU programming is successful, proceed with activating the Blynk application. By setting the display device that shows the humidity value and humidity parameters. So that it is easier to monitor the humidity in the chamber in real-time and also to control remotely using a handphone. In operating this application, paying attention to the internet connection is necessary because if the internet network is terrible, it can cause delays in the monitoring process. Continued for the next stage, namely Google Sheet programming, the software used to collect data in real-time. This aims to facilitate the processing of moisture data when needed.

Calibration

Calibration is the process of evaluating and establishing the accuracy of a measuring instrument by comparing it to a standardized instrument. Calibration can also be defined as a process designed to improve measuring instruments' accuracy and precision. Calibrating the measuring instrument will help enhance its precision by reducing the measurement uncertainty that can interfere with the consistency of the results.

1. Accuracy Analysis

Accuracy is the conformity between an analysis's results and a measurement's true value [12]. The value of the analysis results is an estimate of the true value by considering the uncertainty value [13]. A measurement system's accuracy needs to be determined to determine the level of closeness of quantity measurements to the actual value [14]. Knowing the accuracy of the measurement can ensure that the measurement is valid and objective. Generally, accuracy is expressed in the form of error values in the measurement process. The error and accuracy formulas are shown in equations (1) and (2) [14], [15] as follows:

$$Error\,(\%) = \left| \frac{Y - \bar{X}_n}{Y} \right| \times 100\% \qquad (1)$$

$$Accuracy\,(\%) = 100\% - Error \qquad (2)$$

Where Y_n denotes the theoretical or actual value and X_n denotes the measured or observed value.

2. Precision Analysis

Precision is the ability of a measuring instrument to give the same results from repeated measurements in the same way [16]. Precision is used to show how close the difference in value is when repeating measurements [17]. Instrument precision can be determined by calculating the standard deviation (SD). SD measures how clustered each data point is around the mean. The SD value is calculated with the equation (3).

$$SD = \frac{1}{\sqrt{n}} = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1}} \qquad (3)$$

Where SD is the standard deviation, X_i is the individual data, $\bar{X}$ is the average, and n is the total data. Then, the precision results are reported using equation (5) [18].

$$\%RSD = \frac{SD}{\bar{X}} \times 100\% \qquad (4)$$

$$Precision = 100\% - \%RSD \qquad (5)$$

Relative standard deviation (RSD), also called Coefficient of Variation (CV), is a measure of dispersion that is relative (independent of the unit of measure used), so RSD can be used to compare the density of two groups. Based on the measurement results, it can be calculated how much the measurement precision results on the device. Precision results show how close an examination result is if it is repeated. The precision results on the device are calculated based on the coefficient of variation. The coefficient of variation is a measure of dispersion that is relative (does not depend on the unit of measure used), so the coefficient of variation can be used to compare the density of two groups of data. The coefficient of variation equation is used to convert the standard deviation value into a percentage value. A good coefficient of variation is less than equal to 2% [19].

Performance Test

Performance testing is the process of testing a device to test its speed, stability, capability, and reliability under a specific workload. In addition to validating the DHT22 sensor, a qualitative analysis is also needed to see the running capability of the humidity control system, such as controlling and monitoring humidity using the Blynk application, keypad, and LCD applied to the chamber.

RESULTS AND DISCUSSION

Result of The Humidity Control System Design

The display of the humidity control system device can be shown in Figure 6, Figure 7, and Figure 7, and the display of the humidity controlling and monitoring device using Blynk and Keypad can be shown in Figure 9 and Figure **9**. The Google Sheet display for recapitulating humidity values can be shown in Figure **10**.

1. The Hardware Display of The Humidity Control System

Figure 5. View Tool Appearance

Figure 6. Side View Tool Design

Figure 7. Design of The Tool Inside

The picture above shows a humidity control device mounted on a semi-vacuum box. The humidity-reducing part is composed of a 12V DC fan and a peltier. A diffuser module is used to increase the humidity. The chamber used is a semi-vacuum box with dimensions of 48 cm x 31 cm x 27 cm. The DHT22 sensor is installed in the center of the chamber, with a position between the humidity-decreasing and increasing devices. The humidity increase and decrease device is activated with a relay that will automatically turn on or turn off the device according to the humidity parameters that have been set.

2. **Control and Monitor Display of Humidity Control System**
   a) **Remote Control and Monitor**
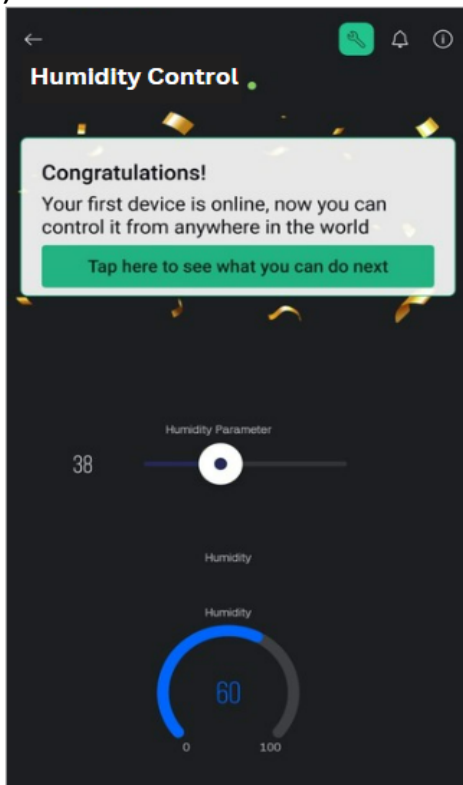
Figure 8. Control and Monitor display Humidity Control System on Blynk Application

b) **Close-Range Control and Monitor**

The humidity control system device that has been made has two devices for controlling and monitoring humidity data in the chamber. Remote controlling and monitoring can be done using the Blynk application, and for close controlling and monitoring activities can be done using the Keypad and LCD mounted on the control box. Users can easily use this to operate the humidity control system.
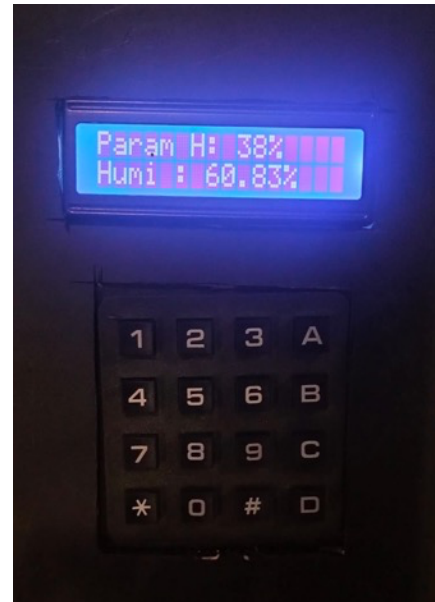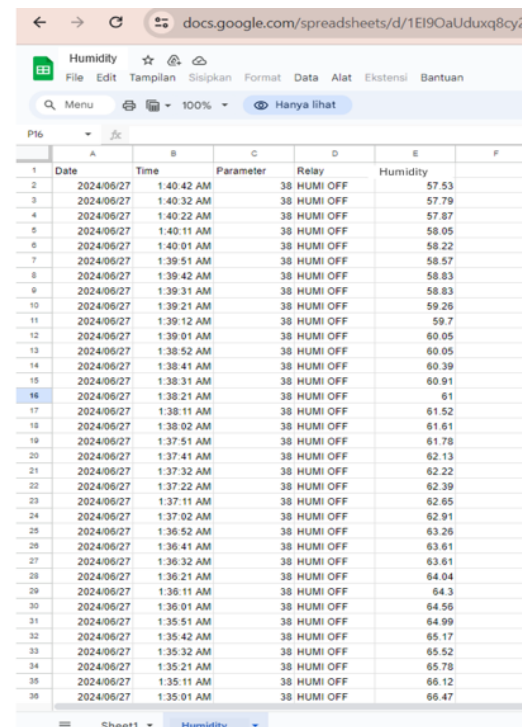

Figure 9. Control and Monitor display Humidity Control System on the LCD

3. **Spreadsheet Display for Collecting Data from Humidity Control System**

Figure 10. Humidity Data View on Google sheet

Data collection from the humidity control system device is done with the help of Google Sheets, which will help recap some data, including date, time, humidity parameters,

humidity values, and relay conditions. By using Google Sheets, the incoming data will be recorded automatically, facilitating the process of monitoring and processing humidity data.

Results of DHT22 Sensor Calibration

Data collection for this research begins with the DHT22 sensor calibration step. This sensor calibration process aims to adjust the value read from the sensor used with a standardized humidity measuring instrument. So that the calibration process can minimize the risk of measurement errors, ensure the accuracy of the data obtained, and ensure the reliability of the sensor used.

The data in this study were collected from the calibration of the DHT22 humidity sensor. The data collection technique used for humidity calibration compares the value read on the

DHT22 with the data listed on Elitech RC-4HC. The results are shown in Table 2.

1. Data Before Calibration of DHT22 Humidity Sensor with Elitech RC-4HC

After that, the data that has been obtained (Table 2) is processed into a graph to get the linear regression equation. The data graph before calibration is shown in Figure 11. The data from the graph shows the regression equation y = 0.8637x + 7.6699, where the x-axis is humidity using DHT22 and the y-axis is humidity using Elitech RC-4HC. From the experimental data above, it can be seen that there is an error of 3.79 %, so the accuracy value is 96.21%, and the precision value is 99.71%. Then, calibration is carried out by entering the regression formula obtained into the Arduino IDE coding.

Table 2. Data Before Calibration

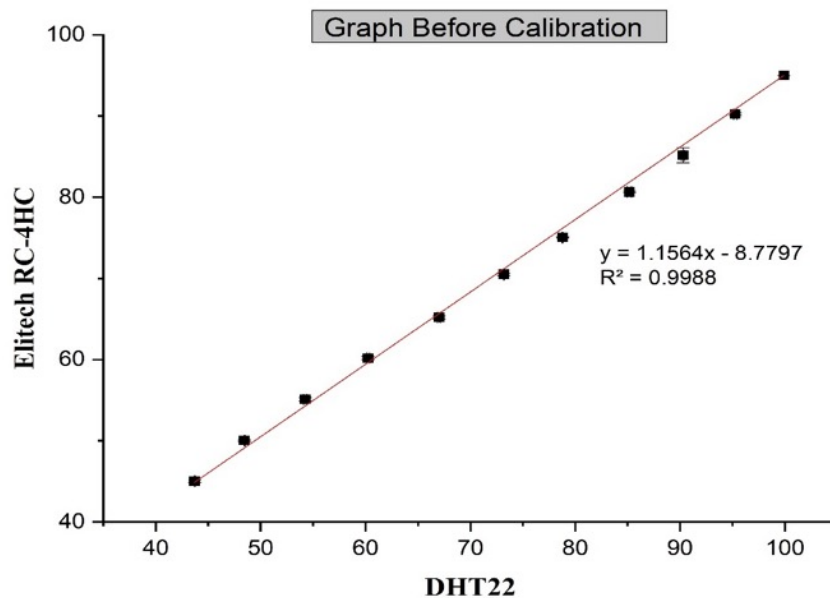| No	RH (%)	Elitech $\bar{X}$(%)	SD (%)	DHT 22 $\bar{X}$ (%)	SD	Precision (%)	Error (%)	Accuracy (%)
1	45	45,02	0.04	43.70	0.15	99.66	2.93	97.07
2	50	50.03	0.05	48.45	0.11	99.78	3.16	96.84
3	55	55.09	0.17	54.26	0.20	99.63	1.51	98.49
4	60	60.17	0.13	60.24	0.19	99.69	0.12	99.88
5	65	65.19	0.14	67.01	0.20	99.71	2.79	97.21
6	70	70.51	0.03	73.20	0.16	99.79	3.82	96.18
7	75	75.05	0.05	78.80	0.08	99.90	5.00	95.00
8	80	80.66	0.17	85.17	0.13	99.85	5.59	94.41
9	85	85.17	0.13	90.29	0.93	98.97	6.01	93.99
10	90	90.24	0.16	95.26	0.17	99.82	5.56	94.44
11	95	95	0.00	99.9	0.00	100.00	5.16	94.84
		Average (%)				99.71	3.79	96.21

Figure 11. Graph Comparing DHT22 with Elitech RC-4HC Before Calibration

Table 3. Data After Calibration

No	RH (%)	Elitech		DHT 22			Error (%)	Accuracy (%)
		$\bar{X}$ (%)	SD (%)	$\bar{X}$ (%)	SD (%)	Precision (%)		
1	45	45.26	0.18	45.56	0.20	99.56	0.66	99.34
2	50	50.24	0.05	50.16	0.09	99.82	0.15	99.85
3	55	55.11	0.13	55.15	0.10	99.82	0.07	99.93
4	60	60.72	0.09	60.69	0.06	99.90	0.06	99.94
5	65	65.69	0.10	65.80	0.05	99.92	0.16	99.84
6	70	70.13	0.14	70.19	0.15	99.78	0.08	99.92
7	75	75.41	0.03	75.40	0.03	99.97	0.01	99.99
8	80	80.24	0.21	80.55	0.30	99.63	0.38	99.62
9	85	85.42	0.27	85.65	0.22	99.75	0.27	99.73
10	90	90.56	0.26	90.37	0.24	99.73	0.21	99.79
11	95	95	0.00	94	0.00	100.00	1.05	98.95
	Average (%)					99.81	0.28	99.72

2. Data After Calibration of DHT22 Humidity Sensor with Elitech RC-4HC

The results of the calculation of accuracy and error on DHT22 as a humidity meter after adding regression values to the coding are shown in Table 3.

After calibration, it was found that the error value became smaller from the initial value of 3.79% to 0.28%, so the accuracy value increased from 96.21% to 99.72%. It was also found that the RSD value decreased from 0.29% to 0.19%, so the precision value increased from 99.71% to 99.81%. The RSD value is smaller than 2%. Based on theory, a good RSD value is less than equal to 2%, and the average RSD value obtained after calibration is 0.19%. Therefore, the data obtained has proven to be good.

After calibration, the data is processed in graphical form to determine the linear regression equation. The data graph after calibration is shown in Figure 12.

Based on the graph of the results of data processing, the measurement result is $R^2 = 0,9996$. This shows that the calibration results on DHT22 have a high level of linearity. From the graph before and after calibration, it is found that the intercept data decreases from 8.7797 to 0.6967. The intercept value shows the point where a curve intersects the y-axis. In addition, if the gradient value is close to 1, then the slope of the curve will be straight up, forming an angle of $45°$ to the x-axis. The difference between the gradient and 1 before calibration and after calibration decreases from 0.1564 to 0.0103. It can be concluded that the curve has a high level of linearity. The intercept value gets closer to 0, the gradient value gets closer to 1, and the x value gets closer to the y value.
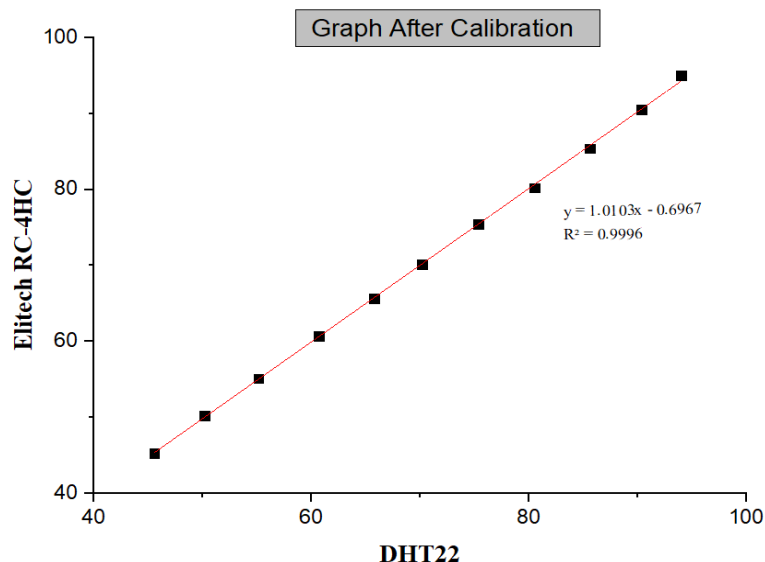

Figure 12. Graph Comparing DHT22 with Elitech RC-4HC After Calibration

Working Principle Controlling of Humidity Control System

Performance testing is testing a device to determine its speed, stability, capabilities, and reliability under a specific workload. In addition, performance testing is used to test the workability of the humidity control system as a humidity controller and monitor.

This test stage is carried out after calibrating the DHT22 humidity sensor. It was found that DHT22 has an accuracy of 99.72% and a precision level of 99.81% for a humidity range of 45%-95%. Then, the device performance test is carried out to determine whether the device can control the humidity in the semi-vacuum chamber as expected.

The first step that must be taken is to prepare all the necessities first. The DHT22 humidity sensor is placed in a semi-vacuum chamber, while the Elitech RC-4HC is placed outside the chamber. This is done to prove that the humidity control system can reduce the humidity in the chamber compared to the humidity in the open space. Next, the Elitech RC-4HC is connected to ElitechLog and the Blynk application is connected to the internet network. Only after the humidity control system device and humidity sensor are turned on are the humidity parameters set using the Blynk/Keypad application at 80% humidity to increase the humidity in the chamber, which initially had 65% humidity. In this condition, the diffuser module device will be turned on by a relay to increase humidity and the humidity increase device will be deactivated. Wait a few moments until the chamber has humidity according to the parameter settings. When the humidity in the chamber shows a humidity value of 80%, monitoring is carried out to maintain humidity for 10 minutes. Only then is the humidity control system device set at 50% humidity to activate the humidity reduction device. In this condition, the fan and Peltier will be turned on by a relay to reduce humidity, and the diffuser module will be turned off. Wait a few moments until the chamber has humidity according to the set parameters. After the device works as expected, the data is processed using the Excel application from the Google Sheets and ElitechLog.

The working control system of the humidity control system is tested for performance divided into three conditions. The results of the plotting can be seen in Figure 13.

In the first state, it indicates that the device is in the condition of raising the humidity in the chamber from normal humidity to RH 80%. So, the relay turns on the diffuser module. In the second condition, it indicates that the device is maintaining 80% humidity, so in this condition, the humidity control system automatically turns off. When the humidity is more than 80%, the humidity control activates the fan and Peltier to lower the humidity and the diffuser module to increase the humidity turns off, and vice versa. Then, in the third condition, it shows that the appliance is lowering humidity from 80%RH to 50%RH, so the fan and Peltier are active to reduce humidity.

Then, the performance test was also carried out to maintain humidity at RH 80%, 70%, 60%, and 50%, as shown in Figure 14.
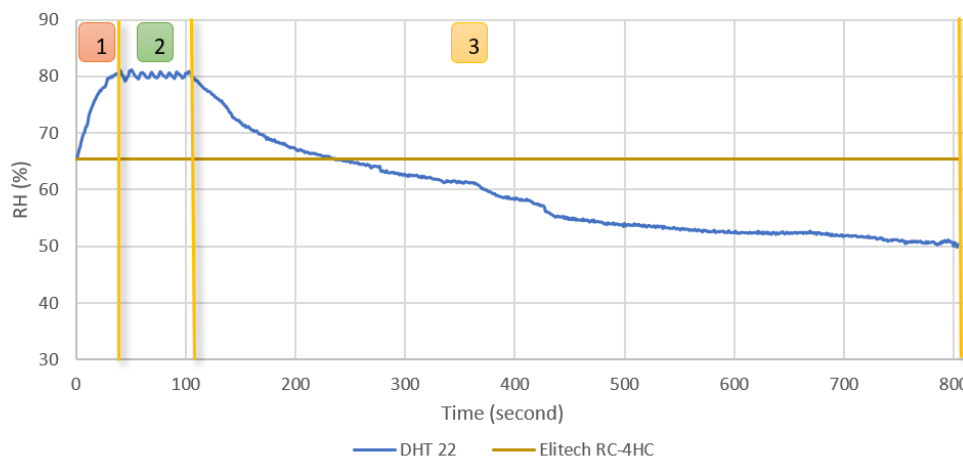
Graph of Performance

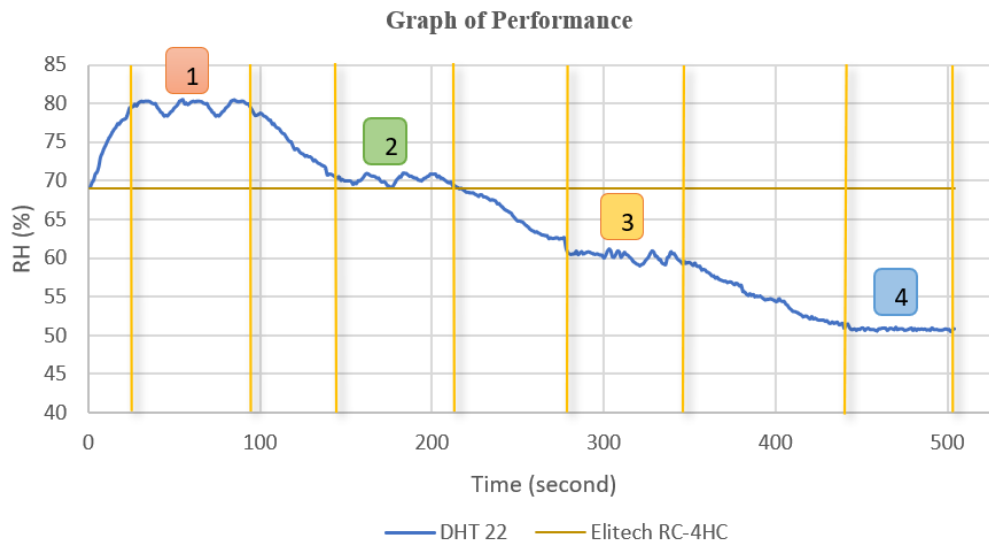Figure 13. Humidity Control System Performance Test Chart

Figure 14. Humidity Control System Performance

From the picture above, the first condition shows the state of the device is maintaining humidity at RH 80%, the second condition shows the state of the device is maintaining humidity at RH 70%, and the third condition shows the state of the device that maintains humidity at RH 60%, and for the fourth condition shows the position of the device that maintains humidity at RH 50%.

The working principle of the humidity control system is that when the Blynk application is connected to the internet network, the relay on the controller will be activated. The on and off of the relay is set based on the input value in "Humidity Parameters," which can be set using the Blink/Keypad application. When the humidity in the chamber wants to be increased, the relay will turn on the circuit connected to the diffuser module which is capable of increasing humidity and deactivating the humidity-increasing circuit. The way these diffuser modules works is to change the water in the cotton fibers into ultra-fine-sized particles with the help of ultrasonic vibrations on the module membrane, which will then change the water particles to look like fog.

Meanwhile, when the humidity in the chamber wants to be lowered, the diffuser module will be turned off by relay, and then the circuit connected to the fan and Peltier will be turned on. In this condition, the water vapor in the chamber will be sucked in by the rotation of the fan and flow out of the chamber. Apart from that, the fan will also distribute warm air because the fan is in contact with the hot side of the Peltier. At that time, slowly water vapor in the chamber will be pulled out of the chamber and captured in the cold sink, which is connected to the cold side of the Peltier so that water vapor sticks to its cold.

The sink will become water droplets which will later fall into the reservoir.

When the humidity value in the chamber matches the "Humidity Parameter" value, the relay will turn off completely. So that the humidity increases and decreases device will turn off simultaneously. This is to maintain humidity in the chamber. Then, if the chamber's humidity increases or decreases, the relay will turn on again and work accordingly.

Based on the performance tests that have been carried out, it is known that the device made is as expected. This can be seen based on the performance test graph. The humidity control system device can increase and decrease humidity and can maintain humidity in the chamber using a relay that is used as an on-off controller in the circuit and has good performance. This is shown through the process of activating and deactivating the humidity increase and decrease device alternately quickly.

CONCLUSION

Based on the above paper, it is known that a humidity control system device has been successfully made which consists of IoT System components, namely the NodeMCU ESP8266 as a microcontroller connected to the Blynk application to control and monitor, but can also control with a keypad and monitor with an LCD. This device uses a DHT22 humidity sensor that has been calibrated using Elitech RC-4HC in the humidity range of 45%-95% for a semi-vacuum chamber. The sensor reading this humidity value has an accuracy value of 99.72% and a precision of 98.81%. It is also equipped with a spreadsheet to collect data from the DHT22 sensor in real-time.

ACKNOWLEDGMENT

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