SALAGA Journal
Vol. 03, No. 01, June 2025, pp. 6~10
ISSN: 3032-2677
DOI: 10.70124/salaga.v3i1.1815

Temperature and Humidity Control in a Small-Scale Greenhouse in a Tropical Climate

Tisha Aditya A. Jamaluddin[1], Sitti Nur Faridah*[2], Muhammad Tahir Sapsal[2], Andini Dani Achmad[3], and Reskyanto Ari[2]
[1]National Research and Innovation Agency, Energy Conversion and Conservation Research Centre, South Tangerang Banten, Indonesia.
[2]Department of Agricultural Technology, Faculty of Agriculture. Hasanuddin University, Makassar, Indonesia
[3]Department of Electrical Engineering, Faculty of Engineering. Hasanuddin University, Makassar, Indonesia

Article Info

Article history:

Received 04 23, 2025
Revised 05 07, 2025
Accepted 05 11, 2025

Keywords:

Arduino
Greenhouse
IoT
Microclimate control

ABSTRACT

Global climate change has increased fluctuations in temperature and humidity, threatening the sustainability of the agricultural sector. This research aimed to develop an Internet of Things (IoT)-based microclimate control system for greenhouses using Arduino and the Thingspeak platform. The system was designed as a closed-loop using an ESP-32 as the control center, a DHT-22 sensor for data acquisition, and Solid-State Relay (SSR) actuators to control the blower, heater, and misting pump. Testing was conducted in a greenhouse with an area of 3 m² and a height of 2.3 meters. The results showed that the system could maintain a temperature of 27–36°C (external deviation: 29–48°C) and humidity of 85–90% (external deviation: 47–100%) with low overshoot, namely 1.18% (temperature) and 1.49% (humidity), and a settling time of under 4 minutes. The steady-state error was within the tolerance limit (maximum 5%). However, the system experienced a data loss of 26.04% and an average transmission delay of 16.5 seconds due to network instability at the test location. Nevertheless, the system proved effective in maintaining an optimal microclimate for small-scale plant growth.

Corresponding Author(s):

Sitti Nur Faridah
Faculty of Agriculture, Hasanuddin University
Jl. Perintis Kemerdekaan KM.10, 90245, Tamalanrea, Makassar, Sulawesi Selatan, Indonesia
Email: faridah_sn@agri.unhas.ac.id

1. INTRODUCTION

Global climate change has had a direct impact on the agricultural sector. The uncertain climate, with increasing fluctuations in temperature and air humidity, has a major impact on the sustainability of agricultural cultivation. Greenhouses are increasingly favored due to their potential to significantly enhance food production by controlling environmental parameters to ensure optimal plant growth (Chen et al., 2025). Even well-controlled environments can yield better results (Salinas et al., 2021). The greenhouse building is equipped with a translucent roof structure, which has the function of manipulating environmental conditions (microclimate) so that the plants inside can develop optimally (Eduard et al., 2022; Furqon et al., 2022).

Technological advancements have positively impacted plant cultivation, significantly improving yields through the application of previously developed methods, such as irrigation supply according to plant needs (Ali et al., 2024) which the integration of control technology can simplify its implementation. In the form of smart greenhouses equipped with control systems, these systems can regulate the temperature and humidity within the greenhouse. The sensor system works to determine the levels of humidity and temperature, and adjustments are made to ensure that the levels meet the needs of the plants (Rianti & Prastyo, 2022).

A control system is a system or process whose output (final result) is determined by a predetermined set point. There are two types of control systems that are usually applied, namely open control systems (open loop) and closed control systems (closed loop). A closed loop control system allows for feedback to be given based on sensor readings over a preset set point. In a closed loop circuit system, the error signal is intended to be the result of the difference between the input signal and the feedback signal, which will then be fed to the control component

(Laksono et al., 2011). Besides that, the development of Internet of Things (IoT) technology, which is connected to the internet network can access information remotely. The development of IoT makes connectivity between users and controlled objects easier. The current application of IoT has reached various fields, including household environments, offices and agriculture (Amaral et al., 2011; Fadil et al., 2023).

2. MATERIALS AND METHODS

The material used in this research was a laptop with Proteus software, Fritzing software, Microsoft Excel and Sketchup software, solder, box machine, platform monitoring Thingspeak, reservoir, misting 3 mm, hose 7 mm, pump DC, sensor DHT-22, power supply 5 V, Solid State Relay (SSR) type DD and DA, LCD 20X4 equipped with I2C, ESP-32, jumper cables, blower and lamp as a heater.

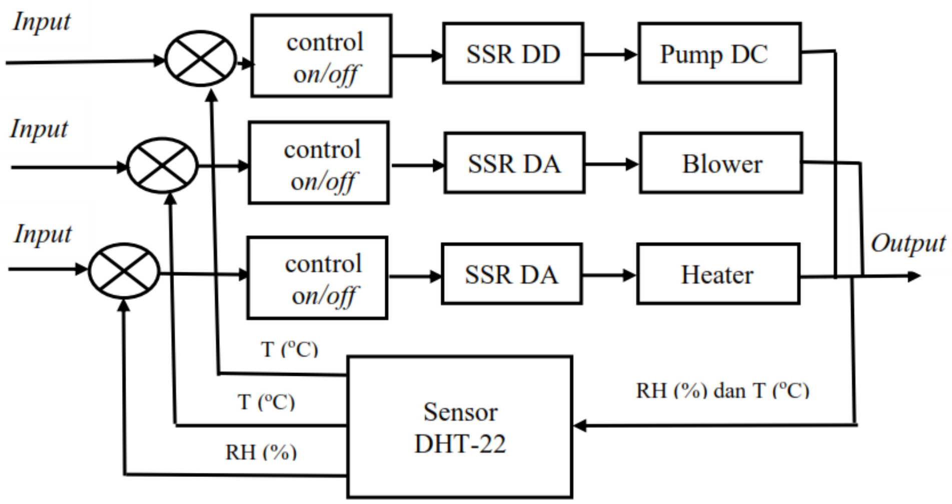


Figure 1. Closed loop system for temperature and humidity control

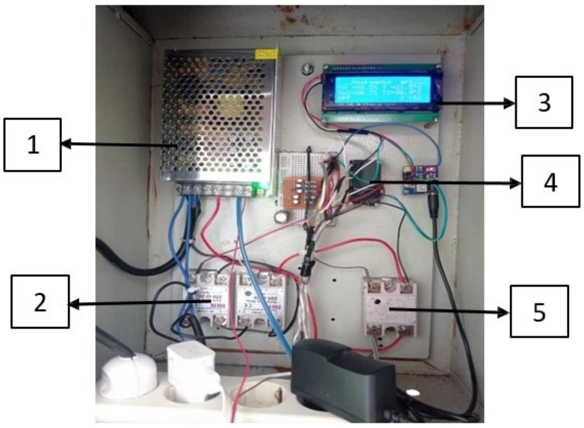
The closed loop control system was designed to control temperature and humidity in the greenhouse. The system can control greenhouse conditions by adjusting temperature and humidity using blowers, heaters, and misting. Closed-loop systems utilized sensors to read temperature and humidity levels. The input for the sensor used pins D2, D5, D15, and the LCD used pins D21, D22. The output for the blower used pin D14, the heater used pin D27 and the DC pump used pin D28. There were 3 actuator systems, namely DD type Solid State Relay (SSR) for the DC pump and 2 DA type SSRs for the blower and heater, and an ESP-32 microcontroller. The selection of actuators, such as SSRs and the ESP-32 controller was due to their affordability and proven effectiveness in remote control and data acquisition (Ayusari et al., 2024; Fadil et al., 2023).

This research utilized an on-off control system, maintaining air humidity levels required for horticultural plants at around 80-90%. The IoT platform used is Thingspeak, which monitors field data and conveys it to users. To transmit sensor data to the Thingspeak platform, an internet connection was required.

3. RESULTS AND DISCUSSION

The control system produced in this research was assembled with various constituent components that were related to each other. (Prabowo, 2018) mentioned that a control system is a system consisting of several components that are interconnected with each other. This system used an ESP-32 as a control center and a DHT-22 sensor, which can measure the temperature and humidity levels on the green simultaneously with digital output values. Using an SSR (Solid State Relay), which functions to connect and disconnect electrical currents. The DA type SSR was used for the actuator of the blower and heater, while the DD type SSR was used for the actuator of the misting pump. LCD as a monitor to read temperature and humidity values. The results of the control system design are presented in Figure 2.

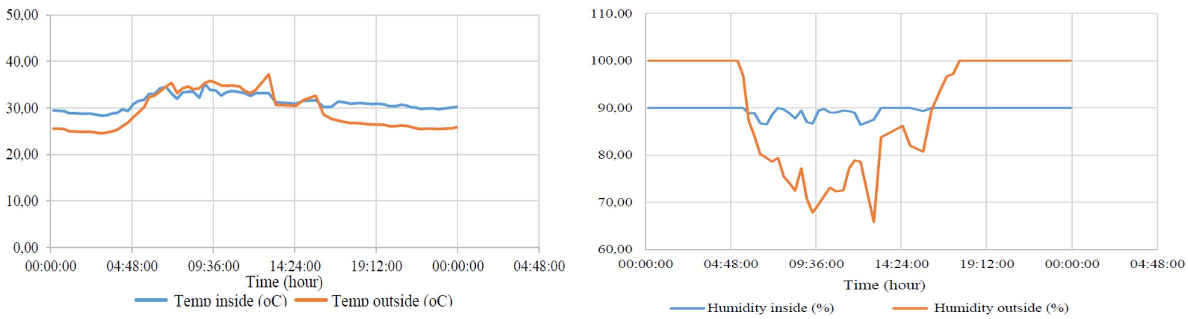
Air temperature and humidity are important factors for plant growth and development. Air humidity that is too low will cause a high transpiration rate, resulting in water loss in plants, and conversely, high humidity will result in decreased nutrient absorption (Abidin et al., 2024; Nurnasari & Djumadi, 2010). Greenhouses were designed to manipulate the microclimate. Climate change causes unstable environmental conditions, so efforts were needed to maintain these conditions in accordance with plant needs.



Information:
1. Power supply
2. Solid state relay type DA
3. LCD 20 X4
4. ESP-32
5. Solid state relay type DD

Figure 2. Temperature and humidity control system design

The control system was applied to a greenhouse with an area of 3 m^2 and a height of 2.3 m. The test results showed that the system can maintain temperature and humidity in the greenhouse. As seen in Figure 3, the temperature inside the greenhouse ranged from 27 to 36°C, while the ambient temperature ranged from 29 to 48°C. Likewise, humidity in the greenhouse ranged from 85 - 90%, while environmental conditions were more fluctuating, with the highest humidity reaching 100% and the lowest being 47%. On-off control worked based on sensor data, after the sensor read the RH conditions, the blower or light will turn on or off. The on/off control worked based on the error value. If the error value was more than the set point, the actuator will turn on, and if the error value was less than the set point, the actuator will turn off (Asmaleni et al., 2020)



(a) (b)

Figure 3. (a) Temperature and (b) humidity inside and outside the greenhouse

Steady state is a condition where the output value of the system enters a stable condition according to the input value; and the condition before steady state is called the transient state or transition (Sari, 2013). Therefore, transient response testing was carried out to determine overshoot and settling time. The control system worked according to design. The blower and heater, as well as the misting pump adjusted the temperature and humidity according to the setting point (38^{0}C and 80% respectively).

Figure 4 showed the settling time for temperature was less than 3 minutes, and humidity was less than 4 minutes. The amount of overshoot and settling time depended on the length of the process. Ogata (1995) mentioned that there is no provision for a best value, thus the temperature and humidity control in the greenhouse had met the design requirements.

Based on the results of the steady state response testing, it can be seen that the designed control was stable and the error level was within the tolerance limit, i.e. 1.18% for temperature and 1.49% for humidity. The error level tolerance limit was in the range of 5% above the set point and 2% below the set point. Ogata (1997) mentioned that the tolerance limit for steady state error values in a linear closed loop system is 2-5% of the value range used. However, it should be noted that the system was capable of controlling a space of 3 m² with a height of 2.3 meters. For larger spaces, adjustments are necessary, particularly regarding actuator response time, which may be longer due to increased load and distance, potentially affecting efficiency. Additionally, temperature and humidity distribution must be considered, as larger spaces will have more varied conditions.

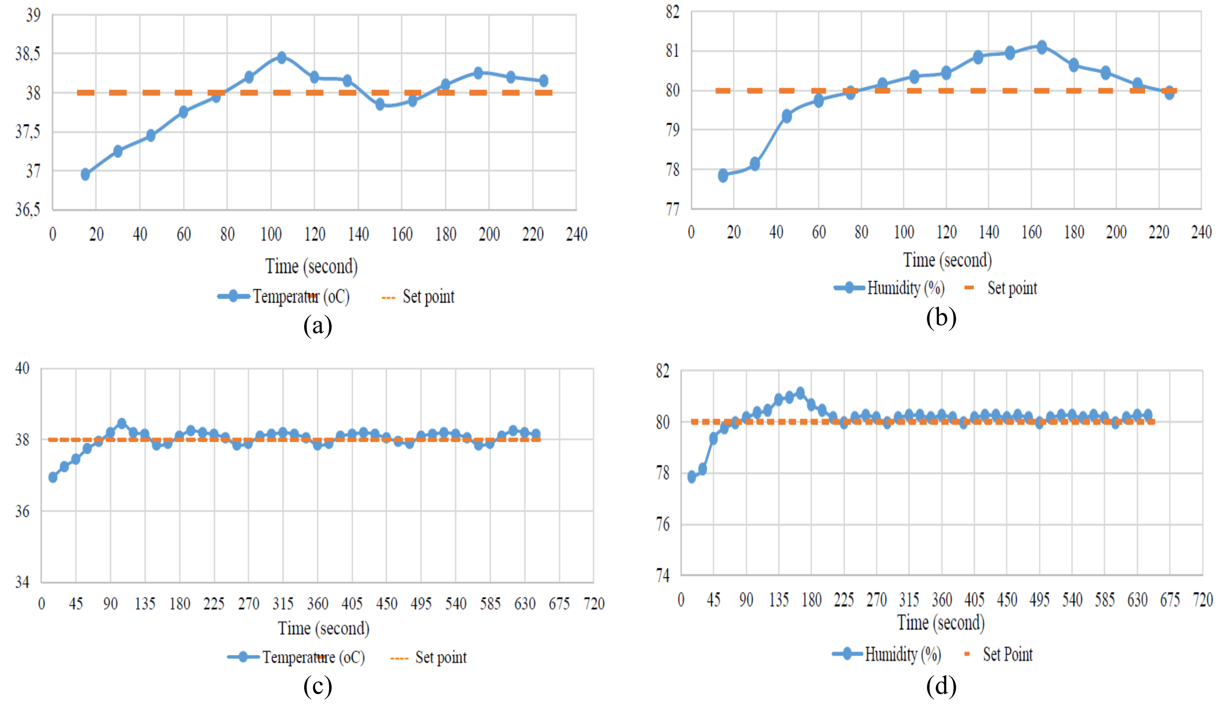


Figure 4. Transient response on (a) temperature (b) humidity and steady state error on (c) temperature and (d) humidity

The data obtained amounted to 497, with 175 missing data points (26.04%) out of the total expected, which was 672 data points. Meanwhile, the average transmission delay was 16.5 seconds. The data transmission delay did not affect the performance of the control system, which operated independently within the microcontroller. Data transmission was solely for monitoring purposes, where the average delay was not significant. However, it was advisable to use a local storage system as a backup, utilizing a memory card module if necessary. Remote monitoring was very helpful in understanding the temperature and humidity conditions in the greenhouse. The varying percentage of lost data can be attributed to unstable network conditions, as the research location was a remote experimental farm far from residential areas, resulting in slow data transmission duration.

Table 1. Monitoring of unreadable and delayed data

Time	Data sent	Data received	Delay (second)	Data lost (%)
Day-1	96	67	16.43	30.21
Day-2	96	72	16.76	25.00
Day-3	96	69	16.45	28.13
Day-4	96	73	16.60	23.96
Day-5	96	73	16.68	23.96
Day-6	96	73	16.70	23.98
Day-7	96	70	16.92	27.08

4. CONCLUSION

A prototype of a temperature and humidity control system that works on-off was produced. The system could control stable temperature and humidity in small scale greenhouse according to the setting point and could be monitored via the Thingspeak platform. Data loss at Thingspeak was 26.04%, and the average delay was 16.5 seconds, due to network instability. Overshoot temperature (1.18%) and humidity (1.49%) were at a settling time of less than 4 minutes. The system controls stabled temperature and humidity with steady state error within tolerance limits (maximum 5%).

REFERENCES

Abidin, I., Faridah, S. N., Sapsal, M. T., Samsuar, S., & Mubarak, H. (2024). Automation of humidity in the greenhouses for plant cultivation. *BIO Web of Conferences*, *96*. https://doi.org/10.1051/bioconf/20249604004

Ali, M. I., Suhardi, & Haerani. (2024). Effectiveness of the Application of Drip Irrigation In Some Planting Media for Caisim (Barassica juncea L .). *Salaga Journal*, *02*(1), 1–9. https://doi.org/10.70124/salaga.v2i1.1354

Amaral, L. A., Hessel, F. P., Bezerra, E. A., Corrêa, J. C., Longhi, O. B., & Dias, T. F. O. (2011). eCloudRFID – A mobile software framework architecture for pervasive RFID-based applications. *Journal of Network and*

Computer Applications, *34*(3), 972–979. https://doi.org/https://doi.org/10.1016/j.jnca.2010.04.005

Asmaleni, P., Hamdani, D., & Sakti, I. (2020). Pengembangan Sistem Kontrol Kipas Angin Dan Lampu Otomatis Berbasis Saklar Suara Menggunakan Arduino Uno. *Jurnal Kumparan Fisika*, *3*(1), 59–66. https://doi.org/10.33369/jkf.3.1.59-66

Ayusari, Waris, A., & Sapsal, M. T. (2024). Application of Fuzzy Control and IoT Monitoring on Small Scale Biofermentor for Making Virgin Coconut Oil. *Salaga Journal*, *02*(2), 58–64. https://doi.org/10.70124/salaga.v2i2.1776

Chen, S., Liu, A., Tang, F., Hou, P., Lu, Y., & Yuan, P. (2025). A Review of Environmental Control Strategies and Models for Modern Agricultural Greenhouses. *Sensors*, *25*(5). https://doi.org/10.3390/s25051388

Eduard, R., Ruslan, W., Iskandar, I., & Setyanto, D. (2022). Setting Temperature and Humidity with a Misting System in a Pilot Greenhouse at Cisauk-Tangerang, Indonesia. *Applied Sciences (Switzerland)*, *12*(18). https://doi.org/10.3390/app12189192

Fadil, M., Munir, A., & Sapsal, M. T. (2023). On-Off Water Level Control and IoT Monitoring for Aquaponics Systems. *Salaga Journal*, *02*(2), 90–100. https://doi.org/10.70124/salaga.v1i2.1355

Furqon, H., Handarto, H., & Saukat, M. (2022). Uji Kinerja Pengoperasian Sistem Pendinginan Pengabutan pada Greenhouse di Kebun Hidroponik, Fakultas Pertanian, Universitas Padjadjaran. *National Multidisciplinary Sciences*, *1*(2), 109–115. https://doi.org/10.32528/nms.v1i2.61

Laksono, S. K., Triwiyatno, A., & Sumardi. (2011). *Pengaturan sudut fasa berbasis logika fuzzy untuk sistem pengaturan temperatur* [Universitas Diponegoro]. http://eprints.undip.ac.id/25666/

Nurnasari, E., & Djumadi. (2010). Pengaruh Kondisi Ketinggian Tempat Terhadap Produksi dan Mutu Tembakau Temanggung. *Buletin Tanaman Tembakau, Serat & Minyak Industri*, *2*(2), 45–59.

Ogata, K. (1995). *Discrete Time Control Systems* (Second). Prentice Hall.

Ogata, K. (1997). *Modern Control Engineering* (Third). Prentice Hall.

Prabowo, A. H. (2018). *Rancang Bangun Sistem Kendali Otomatis Berbasis Mikrokontroler Untuk Mengendalikan Temperatur Dan Rh Pada Kumbung Jamur Merang (Volvariella Volvaceae L.)*. Universitas Lampung.

Rianti, K. P. K., & Prastyo, Y. (2022). Analisis Penggunaan Sensor Suhu Dan Kelembaban Untuk Monitoring Lingkungan Greenhouse Berbasis Arduino. *Antivirus : Jurnal Ilmiah Teknik Informatika*, *16*(2), 200–210. https://doi.org/10.35457/antivirus.v16i2.2512

Salinas, I., Hueso, J. J., & Cuevas, J. (2021). Active control of greenhouse climate enhances papaya growth and yield at an affordable cost. *Agronomy*, *11*(2). https://doi.org/10.3390/agronomy11020378

Sari, F. Y. (2013). Analisa Steady State Error Sistem Kontrol Linier Invariant Waktu. *Jurnal Matematika UNAND*, *2*(3), 91–97. https://doi.org/10.25077/jmu.2.3.91-97.2013