Design of climate control system using microcontrollers for smart greenhouse

Tony K. Hariadi[1], Syaiful Anwar[1], Slamet Riyadi[2], Nafi Ananda Utama[3], Indira Prabasari[3]

[1] Dept. of Electrical Engineering, Universitas Muhammadiyah Yogyakarta
[2] Dept. of Information Technology, Universitas Muhammadiyah Yogyakarta
[3] Dept. of Agrotechnology, Universitas Muhammadiyah Yogyakarta

ABSTRACT

The research aimed to use simple microcontroller circuitry to control temperature, humidity and showering inside a greenhouse. A 3x2x2m (LxWxH) green house was built and installed with Air Conditioner (AC) 0.5pK, heater, sprinkle and 8-watt tube lamp. Green house condition without climate controller was recorded and showed that the highest temperature inside was between 25^{o}C and 42^{o}C meanwhile temperature outside was between 23^{o}C and 38^{o}C. To observe different condition, the system was set to minimum temperature and the result was between 20^{o}C to 28^{o}C on the inside, while outside temperature was between 20oC to 38oC. The last experiment was setting the controller at a designated condition and revealed that it was successful to maintain the temperature between 25oC to 30oC while outside temperature was between 20^{o}C to 42^{o}C. During the experiment humidity inside the green house was able to maintain between 75%-93% while outside humidity fluctuated between 53%-93%. The data indicated that the design was able to control the green house climate.

Keywords: green house control, plant productivity control, microcontroller design

INTRODUCTION

Greenhouse climate control is needed in in any region to accomodate plant growth requirement. (Montero, J.I., van Henten, E.J., Son, J.E. and Castilla, N. 2011). The main variables that need to be adjusted in a greenhouse are temperature, air humidity, and light intencity. The other treatments to the plants in the greenhouse are watering, fertilization, and eradication of pests and diseases.(Shipp, L., Johansen, N., Vänninen, I. and Jacobson, R. 2011). Greenhouse is also usefull to protect plant from pest such us parasite and predators. (M. Mackauer. 1980). Opit (1995) mentioned that predator-prey relationship were affected by hygrothermal condition.

The control of environment variables like temperature, humidity, and light in the greenhouse generally was done manually by the workers. With the development of electronics technologies, it is possible to do the control of those variables automatically and continuously. Another adjustment that also needed beside the adjusment of temperature, humidity, and light is the watering system automatically. The treatment for the plants such as climate adjusment and nutrition is different in each planting age. Therefore the climate control in the greenhouse is better adjusted in such a way that will meet the requirement of the plants in accordance with their age. (Bucklin, R.A. 2002). Maintaining and controlling suitable greenhouse environment is very important after finding suitable location

The objective of this research and design was to create an integrated control system of temperature, humidity, light, and watering in the greenhouse.

The primary needs of the plants to live and thrive normally that come from the outside of their bodies are the sunlight, nutrient, and water. Therefore, those three are called as the essential factors for the life of the plants.

Part of the sunlight that can be seen by the human eye is having a wavelength of 400 to 700 nm. This part of sunlight is converted by the plants into the chemical energy in the process of photosynthesis, so that it is called as the light of photosynthesis, or Photosynthetically Active Radiation (PAR), (Kania, Stephen, Gene Giacomelli. 2002)

The growth of plants is also affected so much by the humidity. If the humidity of the environtment is outside the limit, then the growth of the plants will be impaired. Each group of the plants require different humidity for optimal growth. For most plants, the relative humidity required is about 80%.

The temperature of the air influence the plants life activities, ie on the photosynthesis process, respiration, transpiration, growth, pollination, conception, and miscarriage of fruit. The size of this effect is related to other factors such as humidity, water availability, and the plant types. The average temperature require for the plants activities ranges between 15^0C to 40^0C (Mardjuki, Aspamo. 1990)

The structure of a greenhouse must be able to withstand the load caused by rain, wind, and its use as a crutch for the plants. Greenhouse must also be able to pass on sunlight to the plants maximally. Particular greenhouse, especially in the tropics, requires the handling of the cooling system to get rid of the excessive heat. (Budiyanto, Gunawan. 2001). Here are some examples of greenhouse structures such as the construction of ridge and furrow, the structures are easy to maintain and in warm climates. Issues appearing on such structures is poor air circulation if it is built on a large scale, and the drain loads are big on the roof connection between the buildings. The construction of sawtooth is a construction that is inexpensive, well ventilated and cool, so that will have problems heating, especially in cold areas. The construction of quonset is a design that is simple, inexpensive, and capable of absorbing light to the maximum. However, such construction is less able to accommodate the growth of plant height, especially in the corners, and have problem in the ventilation system. The construction with skeleton resembling the letter A (A Frame) or horses (Gable Truss) is a construction that is easily constructed but require more building materials than other types of construction, and more blocking light toward the plants.

MATERIALS AND METHODS

Tom Schmidt (2015) has written that a basic green house structure was 2x6 or 2x4. This research built 3x2x2m (LxWxH) green house was built and installed with Air Conditioner (AC) 0.5pK, heater, sprinkle and 8-watt tube lamp. The system should be able to sense the temperature and humidity and control temperature, humidity, radiation, and watering. The system was designed to

- sense the temperature and humidity in the greenhouse as the input of control process of temperature and humidity, and can perform the control based on the sensing
- be able to serve watering and irradiation that are scheduled.

Meanwhile, to support the interactivity between the system and user, and to increase the reliability of the system, it takes the following functions:

- The system can display information as temperature, humidity, time, and date.
- Users can enter the control settings with ease.
- The system is able to maintain a setting variable if the primary power source of the system is disconnected, and reusing the variable when the main power source is reconnected, without the need to reset the settings.
- Time and date of the system is always up to date, although the primary power source is cut off.

The hardware was built consist of two parts, the electronic part as a sensing and processing unit of sensed data, and the greenhouse as the executing unit of control

command. Electronic parts include a sensor, microcontroller, viewer, and interface of the control command of the greenhouse.

The software was based on a plot or algorithm processes required. This algorithm will determine the scenario of the action to be performed by the system in response to input from sensors and boundaries, which has been set previously. The greenhouse control in this study was using priority-based scenarios of action. The scenarios of action, briefly, shown in Table 1.

Table 1. Greenhouse control scenario

		Active control driver			
		AC	Heater	Lamp	Watering can
Treatment	Cooling	1	0	x	x
	Heating	0	1	x	x
	Humidity	x	x	x	Set.1.a
	Humidity decrease	x	x	x	Set.1.b
	Irradiating	x	x	1	x
	Watering	x	x	x	1

Description of Table 1:

- 1 = On, 0 = Off, x = not affected
- Handling of humidity carried by the watering area of the greenhouse
  - Set 1: humidity setting set to On
    a : additional watering unscheduled
    b : elimination of watering (on schedule)
  - Set 0 : humidity setting set to Off, which means watering will run only on schedules

Device Implementation

After the controller system passed, the next test was perform the implementation. The implementation of the device was done in a mini greenhouse with the size of 2m x 3m x 2.2m with fiber wall. The controller driver consist of window type AC with the magnitude of 0.5 pk, heater, sprinklers, and 8 watt TL lamp. The observation of control results carried out on four parameters, namely observation of temperature, humidity control, timely watering, and timeliness of irradiation.

ANALYSIS AND DISSCUSION

Temperature Control

The observations of temperatur control performed in three days. On the first day, the greenhouse was left without control, on the second day the control was done to obtain the lowest temperature, and on the third day the control was done on a certain temperature. The observation of temperature control can be seen in figure 1, 2, and 3.

Figure 2 indicates that without control the temperature inside the greenhouse in the daylight became higher than the temperature outside the greenhouse. While at night (dawn/early morning) the difference of temperature inside and outside the greenhouse was getting smaller.

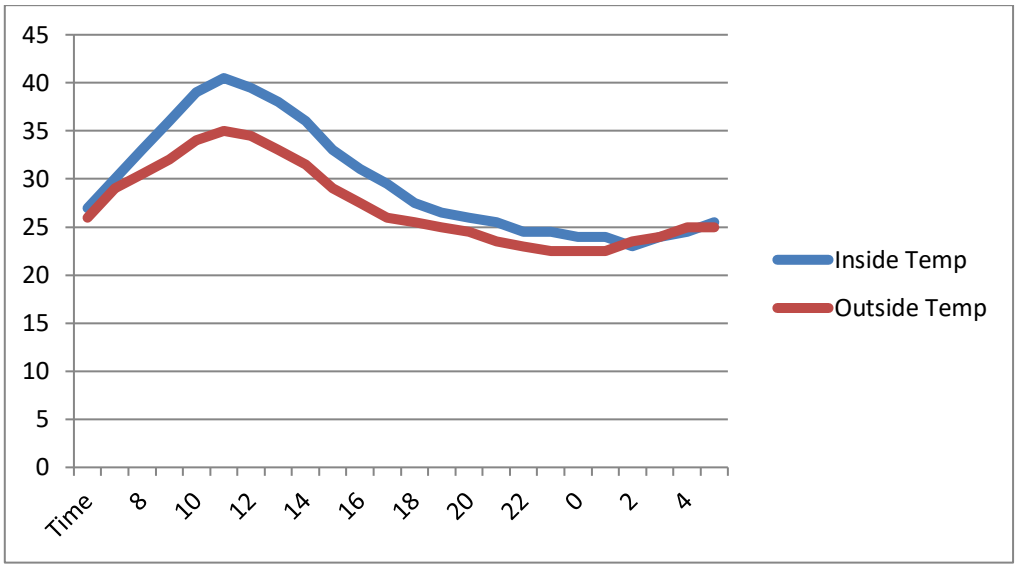

Figure 1. Diferrence of outside and insided greenhouse without temperature control

Table 3 and Figure 2 show the result of performance on minimum temperature. During the day, the cooler was able to lower the temperature in the greenhouse so as to 28 ° C. While at night, the temperature in the greenhouse could not be reduced significantly, lower than the temperature outside the greenhouse, for the AC cooling components was covered by ice crystals make it unable to draw the air in the greenhouse.

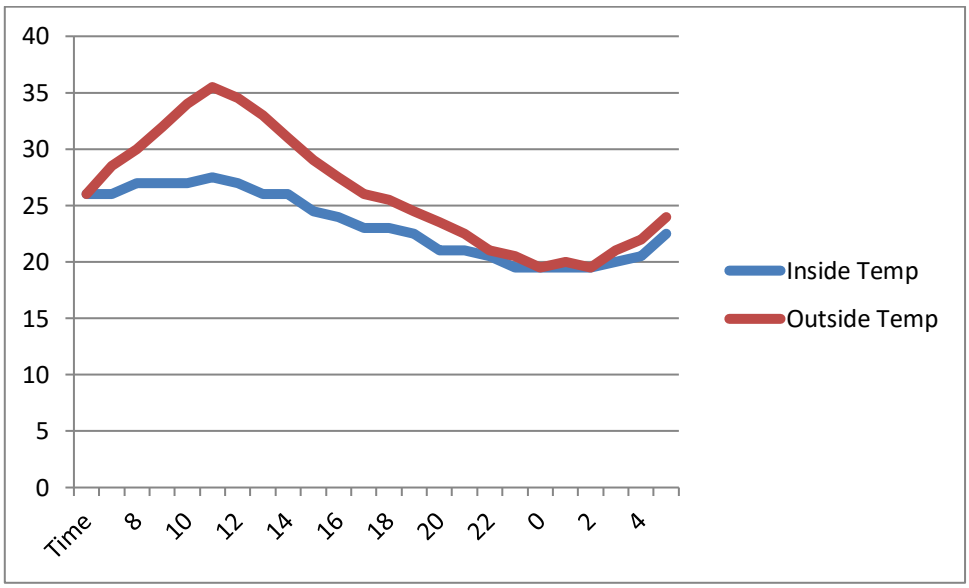

Figure 2. Diferrence of outside and insided greenhouse with temperature control set to minimum

Table 4 and Figure 3 show the examples of control result on certain temperatures. The device was set to reach temperatures between 20° C to 30° C. During the daylight, the temperature inside the greenhouse is able to be lowered to 30° C, and at night the temperature could be maintained above 20° C.

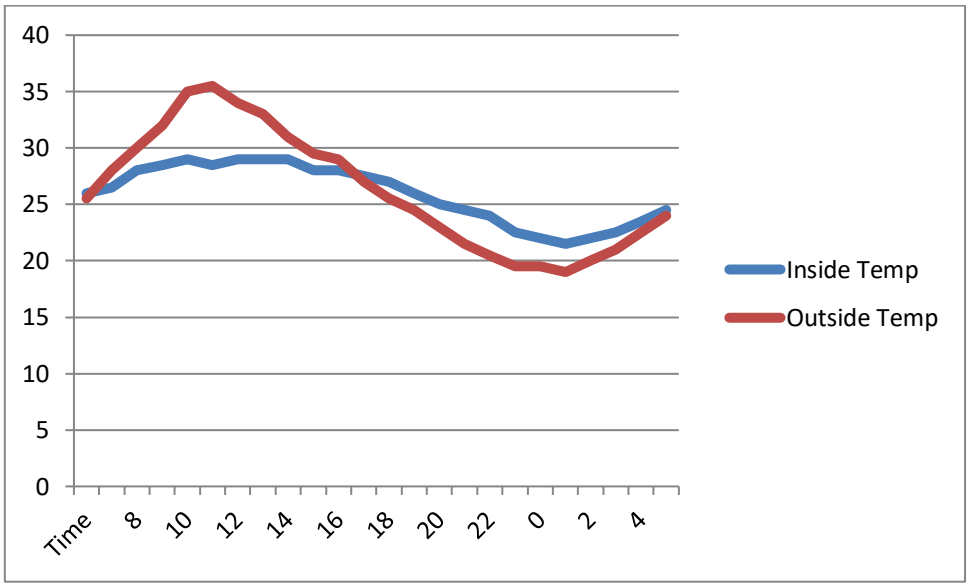

Figure 3. Diferrence of outside and insided greenhouse with temperature control set between 20-30 C

Humidity Control

Humidity control algorithm was simply done by watering, when the indoor humidity was lower than desired, and cancel the watering when humidity was over the limit. Therefore testing of this control was carried out on part of the watering schedule by regulating the humidity in the active state (Humid Ctrl = On). Table 5 shows the test results of humidity control.

Table 2. The test result of humidity control

No	Condition	Time	Action	Conclusion
1	Humidity over the limit	Watering schedule available	Not watering	Worked
		Watering schedule unavailable	Not watering	
2	Humidity under the limit	Watering schedule available	Watering	Worked
		Watering schedule unavailable	Watering	

Watering Control

The watering test was done on the timeliness and duration of the watering. In this test the humidity controller was set as disable so as not to disrupt the watering schedule that has been arranged. Table 6 shows the test result of watering control.

Table 3. The test result of watering control

Schedule	Time	08.00	15.00	17.00
	Duration (minutes)	5	5	5
Engaged	Time	08.00	15.00	17.00
	Duration (minutes)	5	5	5
Result		OK	OK	OK

Irradiation Control

As the watering test, the irradiation test was done on timeliness and duration of the irradiation. Table 4 shows the test result of irradiation control.

Table 4. The test result of irradiation control

Schedule	Time	18.00	21.00	23.00	02.00	04.00
	Duration (minutes)	15	15	15	15	15
Engaged	Time	08.00	15.00	17.00	02.00	04.00
	Duration (minutes)	15	15	15	15	15
Result		OK	OK	OK	OK	OK

CONCLUSION

From the result of design and testing device could be concluded that the controlling system of temperature, humidity, and light in the greenhouse that has been built can work well. The test results of the implementation show that:

1. The controller at a designated condition and revealed that it was successful to maintain the temperature between 25^{0}C to 30^{0}C while outside temperature was between 20^{0}C to 42^{0}C.
2. Humidity inside the green house was able to maintain between 75%-93% while outside humidity fluctuated between 53%-93%.

Literature Cited

Bucklin, R.A. 2002. *Florida Greenhouse Design*. One of a series of the Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. http://edis.ifas.ufl.edu/AE016

Budiyanto, Gunawan. 2001. Klimatologi Dasar (Diktat Kuliah). Fakultas Pertanian,Universitas Muhammadiyah Yogyakarta.

George Patrick Opit 1995. PREDATION OF TWO-SPOTTED SPIDER MITES, Tetranycus urticae KOCH (ACARI: TETRANYCHIIDAE) BY THE PREDATORY MIDGE, Feltiella minuta FELT (DIPTERA: CECIDOMYIIDAE). Department of Biological Sciences @George Patrick Opit 1995 SIMON FRASER UNIVERSITY April, 1995

Kania, Stephen, Gene Giacomelli. 2002. *Solar Radiation Availability For Plant Growth In Arizona Controlled Environment Agriculture Systems*. Department of Agricultural and Biosystems Engineering University of Arizona. Tucson, Arizona http://ag.arizona.edu/ceac/research/archive/solarradiation_kania.pdf

M. Mackauer, 1980. Some aspect of quality and quality control of biological control agents during insectary propagation. Proc. V int. Symp. Biol. Contr. Weeds. Brisbane, Australia, 207 - 20

Mardjuki, Aspamo. 1990. Pertanian dan Masalahnya. Yogyakarta: Andi Offset.

Meriam Karlsson. 2014. *Controlling the Greenhouse Environment*. University of Alaska Fairbanks

Montero, J.I., van Henten, E.J., Son, J.E. and Castilla , N. 2011. *GREENHOUSE ENGINEERING: NEW TECHNOLOGIES AND APPROACHES.* Acta Hort. (ISHS) 893:51-63

Shipp, L., Johansen, N., Vänninen, I. and Jacobson, R. 2011. *GREENHOUSE CLIMATE: AN IMPORTANT CONSIDERATION WHEN DEVELOPING PEST MANAGEMENT PROGRAMS FOR GREENHOUSE CROPS*. Acta Hort. (ISHS) 893:133-143

Tom Schmidt, 2015, *Home Greenhouse Controlle Low Cost Greenhouse Automation*, http://www.tschmidt.com