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Simulation of IoT-Based Temperature and Humidity Conditioning System in Screen House

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ABSTRACT

Nowadays, various problems have arisen in agricultural sector. One of which is the decline in productivity of farmers' crops up to 40% which is caused by non-optimal environmental conditions during the plant growth process. This is certainly a challenge for Indonesian farmers to be able to continue in supplying the country's needs for high quality agricultural products. The challenges faced by Indonesian farmers do not only come from the environmental conditions of plant growth, but the development of Industry 4.0 technology also plays an important role in the development of agricultural sector in Indonesia. In order to adapt to these technological changes, a solution is needed in the form of an integrated agricultural equipment with Industry 4.0 technologies such as the Internet of Things (IoT). One of which is creating an IoT-based control and monitoring system that will be applied to the screen house. In this research, an IoT-based temperature and humidity conditioning system was designed in the screen house. The system design is modeled and tested through simulation on Vensim software. Based on the simulation results of system design, the screen house internal temperature can be controlled or maintained in the optimal temperature range for tomato plant growth, which is 18–24°C with an offside value of ±0.5°C. The heating capacity or heating rate required in this system is 10°C/hour. The cooling capacity or cooling rate generated to compensate the influence of external temperature and heating effect on the screen house internal temperature is 1–1.8°C/hour. The heating and cooling rate values generated in this research are still need to be converted into fan and pump PWM values to be implemented in a fan- pad evaporative cooling system.

KEYWORDS

Temperature
Humidity
Screen house
Internet of things
Fan-pad evaporative cooling

INTRODUCTION

Agriculture is one of the main sectors that need more attention for Indonesia as an agricultural country with the majority of population making a living in this sector. The productivity and quality of Indonesian farmers' crops certainly make an important contribution to the availability of agricultural products for the state. Nowadays, various problems have arisen in agricultural sector, one of which is the decline in productivity of farmers' crops up to 40% of the total crop

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yields required by the state. Optimizing environmental condition that is still lack during the plant growth process is one of the main factors causing the decline in crop productivity.

The productivity of Indonesian farmers' crops which is decreasing due to environmental conditions that are not optimal for plant growth must be addressed as soon as possible. In addition to internal agricultural problems related to crop quality, Indonesian farmers also face challenge from the development of advanced agricultural technology. In order to adapt to these technological changes, a solution is needed in the form of an integrated agricultural equipment with Industry 4.0 technologies such as the Internet of Things (IoT). One of which is creating an IoT-based control and monitoring system that will be applied to the screen house. The selection of screen house as the research object is based on its characteristics that can protect plants from pests and diseases, as well as the screen house microclimate that is relatively easy to control and monitor.

Screen house is a building with walls/screens that made of nets, and a roof that made of plastic [1]. The main benefit of having a screen house is to protect plants from insects that cause pests and plant diseases without changing the environmental conditions in the screen house significantly. Optimal plant growth in the screen house is not only influenced by the internal conditions of the screen house, but also by climatic conditions outside the screen house which tend to be difficult to control.

The climatic condition in Indonesia, which is fluctuate, is certainly one of the factors that causing farmers' failure in planting and harvesting periods [2]. The inaccuracy of farmers' prediction in planting and harvesting has caused many Indonesian farmers to suffer losses due to crop failure. In other words, the productivity of farmers' crops has decreased significantly. Based on the air conditioning concept, this problem can be overcome by adjusting the environmental conditions according to the growth needs of each type of plant. In this case, the environmental parameters that can be adjusted are the temperature and humidity in the screen house.

Agriculture research that focuses on the utilization and improvement of screen house conditions has been carried out by many researchers over the world. These studies are not only limited to the screen house functionality for different types of plants, but also the innovation in technology application for controlling the microclimate in plant growing rooms. One of the technology applications that is widely used in screen house microclimate conditioning is the heating technology application. Therefore, the reference sources related to the heating technology applications will be very easy to find to be used as a reference in controlling the temperature and humidity in screen house. On the other hand, research related to the application of cooling technology in screen house is still quite small, so it is still rare to do and to be used especially in summer period.

The use of screen house in plant cultivation to prevent insect exposure that cause pests and plant diseases has been widely developed, especially in tropical countries. The climatic conditions where the screen house is located, such as temperature, humidity, sun exposure, and wind speed greatly affect the growth of plants in it. Although the screen house is one of the promising technologies in creating climatic conditions for plant growth that are almost the same as the ambient environment, overheating is still often occurs in the screen house. The overheating conditions can be prevented by optimizing the heating and cooling processes in the screen house.

In this research, the temperature and humidity conditioning for screen house will be carried out using an Evaporative Cooler (EC). EC is a cooling system that uses the principle of evaporative cooling, in which the air conditioning process is carried out by using water as a cooling medium and adding humidity to the airflow [3]. The advantages of EC compared to the other cooling systems are it can be more energy efficient, and its implementation is quite simple. However, this system has a weakness, namely the increase in air humidity, so it is only suitable for use in areas with low humidity and high temperature [4]. One of efforts to reduce the increase in air humidity when using EC in screen house is by providing new air circulation into the screen house through the room/ventilation window openings.

Research related to the control and monitoring system in screen house has been done by the author. However, the media and method of screen house microclimate conditioning were very different from this research. The evapotranspiration process was the main factor that affect the screen house microclimate conditioning in previous research. The screen house conditioning media used was irrigation system that is operated on a scheduled basis. Meanwhile, the IoT technology used in this research is not much different from the IoT technology that has been applied by the author in previous research, namely the integration of agricultural equipment with IoT technology that allows users to control and monitor the screen house microclimate condition remotely through an application on user smartphone.

LITERATURE REVIEW

The screen house temperature and humidity conditioning system in this research was designed and simulated with environmental conditions that represent Indonesia as a tropical country. In general, the architectural configuration of screen house in tropical countries such as Indonesia, Africa and South America resembles the tunnel type in Figure 1 [5]. The distance from screen house base (concrete slab) to the highest point of semi-cylindrical building is 3 meters. The length of tunnel type screen house usually reaches 20 to 32 meters. The tunnel type screen house can be completely covered with a screen or a rain-protective plastic material such as Polyethylene or Teflon. This screen house is also equipped with a 1x2 meter zip lock door which is completely covered with screen.

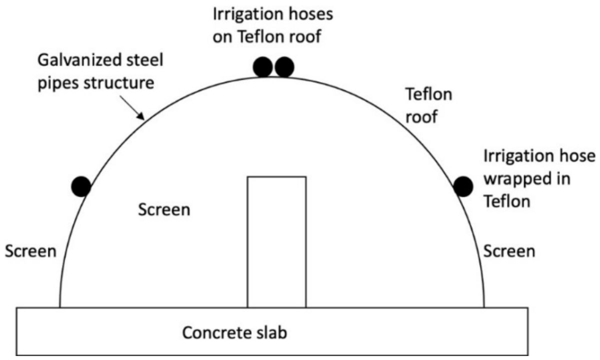

Figure 1. Architectural Configuration of Screen House

The plant that is assumed to be cultivated in this screen house is tomato (Lycopercisum esculentum Mill.), which is one of the high production level commodities in Indonesia. Tomato plants are categorized as the day-natural vegetable which its growth is not affected by the length of irradiation or the length of the day. Tomato plants ideally grow in cold, dry weather and highlands (1000 – 1250 masl) [6]. The optimum temperature for tomato plant growth is 18-24°C with a minimum temperature of 14°C and a maximum temperature of 26 °C (Nasir, 1999). In this research, the optimum temperature of tomato plant growth is used as a specification for the screen house internal temperature which must be maintained or controlled by a temperature conditioning system. The optimum humidity value for tomato plant growth is 80% [7].

The environmental climatic conditions that will be simulated in this research are in the form of an average hourly temperature in Bandung city. The selection of Bandung City as the research location was based on the plan to build a screen house in this city for further research. So that the system design process carried out in this research is adjusted to the real climatic conditions where the screen house will be made later. The average hourly temperature and humidity in Bandung City based on data from The Weather Channel can be seen in Table 1.

Table 1. The Average Hourly Temperature and Humidity in Bandung City

Hour	Temperature (°C)	Humidity (%)	Hour	Temperature (°C)	Humidity (%)
00.00	23	98	12.00	30	75
01.00	23	100	13.00	29	76
02.00	23	99	14.00	29	79
03.00	23	100	15.00	28	81
04.00	23	100	16.00	27	83
05.00	23	100	17.00	26	86
06.00	23	100	18.00	25	89
07.00	24	96	19.00	25	92
08.00	26	90	20.00	24	94
09.00	27	84	21.00	24	95
10.00	29	77	22.00	23	97
11.00	29	75	23.00	23	98

RESULTS AND DISCUSSION

The system design model that is simulated in Vensim simulator can be seen in Figure 2. The initial temperature of internal screen house is assumed to be 25°C, with the external temperature value using daily average temperature data in Bandung City. Basically, the air conditioning system consists of heating, cooling, adding water vapor (humidifying), and reducing water vapor (dehumidifying) processes [8]. The temperature conditioning system in this research is designed to be able in keeping screen house internal temperature within the expected temperature range, without turning the heater on and off continuously. To be able to do this, the control system must have a buffer range so that the heater will only turn on when the temperature is below the lower limit of the buffer range, and it will turn off when the temperature rises to exceed the upper limit of the temperature buffer range. If the internal temperature is in the expected temperature range, then the heater will stay on when it's on, and stay off when it's off.

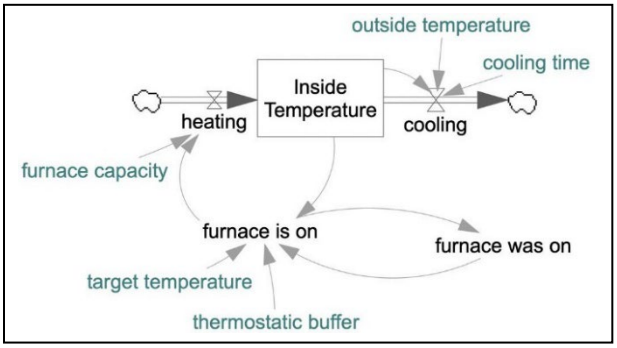

Figure 2. The System Design Model in Vensim Software

Tomato plants to be cultivated in a screen house have the optimum temperature to growth in the range of 18–24°C. In order to control the screen house internal temperature, a temperature setpoint value of 21°C can be set with a buffer range of ±3°C, so that the heater will turn on when the temperature sensor (thermostat) detects the screen house temperature below 21-3=18°C and turns off when the screen house temperature rises above 21+3=24°C. The heating capacity as the maximum value of heater to heat the screen house in this system is assumed to be 10°C/hour. The heat rate value that is quite high was chosen to compensate the heating process duration, hence it can save energy.

Meanwhile, for the cooling process, a comparison will be made between the internal temperature and the external ambient temperature of the screen house. If the heater is off, then the cooling effect is represented as the difference between internal and external temperature over the cooling time [9]. Cooling time is the time required for current temperature value to be closer to the target temperature. The cooling time value in this study is assumed to be 8 hours. The simulation results of internal temperature, heating rate and cooling rate in the screen house can be seen in Figure 3.

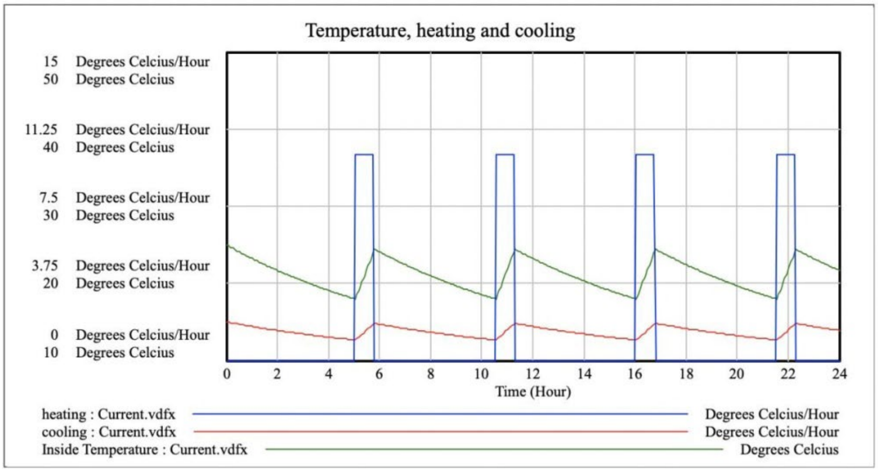

Figure 3. The Simulation Result of Screen House Microclimate Conditioning System

Based on the simulation result above, it can be seen that the screen house internal temperature (green graph) is strongly influenced by the heating (blue graph) and cooling (red graph) processes that occur in it. The oscillations on the internal temperature graph are caused by the heating and cooling processes which continue to occur alternately for 24 hours of system operation. At the initial process, the heater is set to be in the OFF-condition while the cooler is in the ON-condition according to the system specifications. This is done to make sure the internal temperature does not continue to rise beyond the upper range limit along with the increase of external temperature. As a result, the value of internal temperature will decrease along with the cooling process with a decreasing cooling rate as well.

When the internal temperature reaches the lower limit of the optimal temperature range for tomato plant growth, which is 18°C, the heater will turn ON with a heating rate value according to system specifications, which is 10°C/hour. The change in heating status from OFF to ON is accompanied by an increase in the cooling rate so that the internal temperature will not continue to rise beyond the upper limit of optimal temperature range for tomato plant growth. When the internal temperature has reached the upper limit of the optimal temperature range value, the heater will be turned OFF and the cooling rate of the cooler will be reduced so that the internal temperature value can be maintained in the optimal temperature range. The screen house internal temperature value can be seen more clearly in Figure 4.

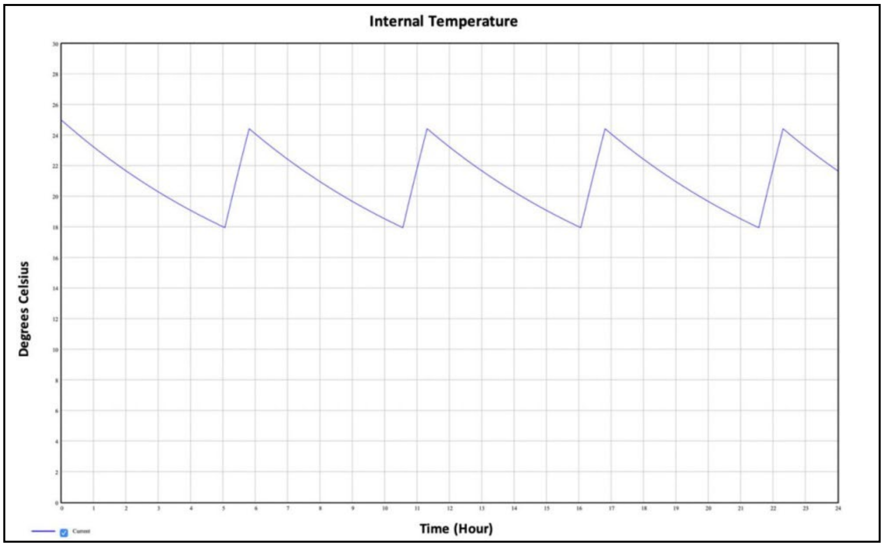

Figure 4. The Screen House Internal Temperature Value

In Figure 4 above, it can be seen that the screen house internal temperature is always within the expected temperature range of 18– 24°C, with an offside value of ±0.5°C. The offside value that occurs at the upper limit of internal temperature range is probably caused by the selection of cooling time that is too large, so that the resulting cooling rate unable to compensate the external temperature changes accurately. For more details, the cooling rate value can be seen in Figure 5.

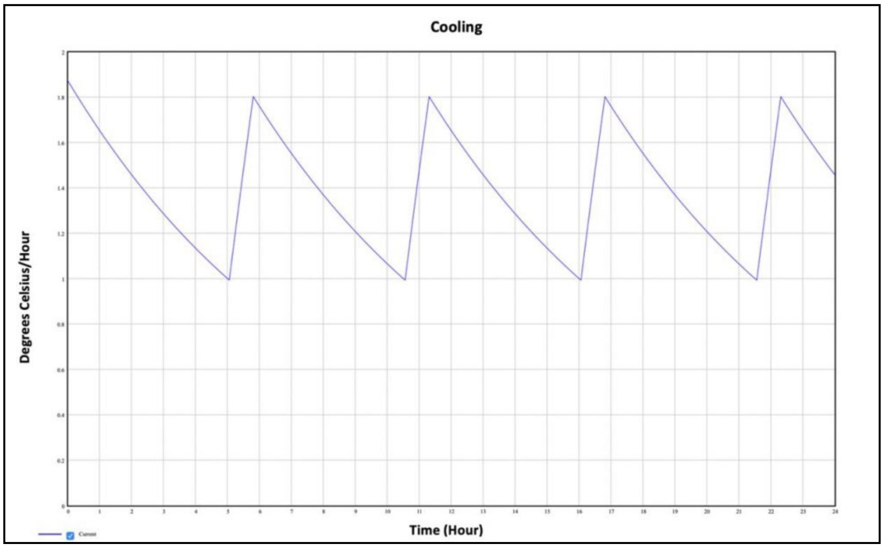

Figure 5. The Cooling Rate Value

In Figure 5 above, it can be seen that the decrease in cooling rate value occurs when the heater is in the OFF-condition. Meanwhile, the increase in cooling rate value occurs when the heater is ON to prevent the internal temperature from continuing to rise beyond the maximum of optimal temperature range. When the system is first turned on, the value of cooling rate is

1.9°C/hour. Then along with the decrease of internal temperature due to cooling effect, the cooling rate value will decrease until it reaches its minimum value of 1°C/hour. When the cooling rate is in its minimum value, the internal temperature has also reached the minimum value for the optimal temperature range, so the heater will turn ON to prevent excessive internal temperature drops. As long as the heater is ON, the cooling rate value will continue to increase until it reaches its maximum value of 1.8°C/hour. At this maximum cooling rate value, the internal temperature has also reached the maximum value of the optimal temperature range, so that the heater will turn OFF and the cooling rate will be decrease in order to keep the screen house internal temperature in optimal temperature range that has been set.

The heating process can be seen more clearly in Figure 6. During the 24 hours of system operational time, 4 heating processes have been occurred. The heating capacity for each cycle is the same, which is 10°C/hour according to the system specifications. The heating duration for each cycle is also the same, namely ± 50 minutes, which is quite short for heating process. Based on the simulation results related to the heating process, it can be seen that the specified heating capacity is appropriate and able to compensate the effect of external temperature fluctuation on the screen house internal temperature.

In this research, the system is designed to be equipped with a fan-pad evaporative cooling system. Meanwhile, the simulation results obtained are still in the form of heating and cooling process mechanism accompanied by the certain heating and cooling rates to control the screen house internal temperature. So that to be implemented in the fan-pad system, it is necessary to convert the heating and cooling rate values into PWM values to control the fan and pump in the fan-pad evaporative cooling system. Similar conditions also applied to the humidity control process in the screen house. This is the problem limitation in this study, and will be used as the further research. As for the Internet of Things (IoT), it will be implemented by using a cloud server to store temperature and humidity readings in the screen house, as well as displaying this data via smartphone to make it easier for users to control the screen house microclimate conditions.

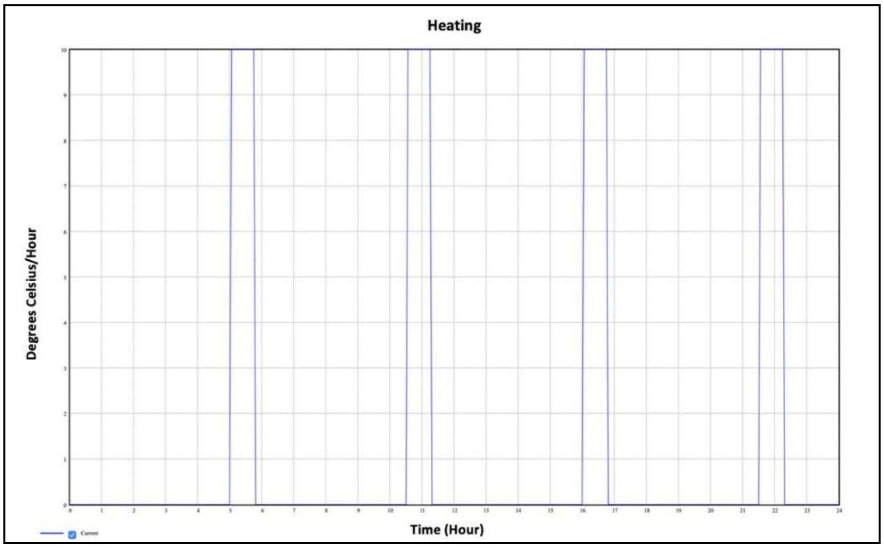

Figure 6. The Heating Rate Value

CONCLUSION

Based on the simulation results that have been carried out in this research, it can be concluded several things as follows.

1) The screen house temperature and humidity control system has been successfully designed and simulated on Vensim software.
2) The screen house internal temperature can be controlled or maintained within the optimal temperature range for tomato plant growth, which is 18-24^{o}C with an offside value of ±0.5^{o}C.
3) The heating capacity or heating rate required in this system is 10 oC/hour.
4) The cooling capacity or cooling rate produced to compensate the influence of external temperature and heating effect on the screen house internal temperature is 1–1.8 °C/hour.
5) The heating and cooling rate values generated in this research are still need to be converted into fan and pump PWM values to be implemented in a fan-pad evaporative cooling system.

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