Greenhouse Conditioning using Internet of Things and Solar Panel

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Abstract— *The conditioning in a greenhouse is one of the efforts in the development of biotechnology-based plant products, thus enabling the growth of a plant to be controlled. In the current era of the industrial revolution 4.0, control technology leads to the use of information and communication technology. Internet of Things based devices can be used to build control systems. One of the most popular IoT devices today is the ESP8266, a microcontroller module that can connect to WiFi and TCP / IP. In the other side, the abundant sunlight is a potential use as an alternative sources of electrical energy to conditioning of greenhouse. In this research, the development of the solar energy as source of power of electrical energy in greenhouses and contolled using internet of thing is the main problem.*

Keywords— ***greenhouse, internet of things, solar energy, conditioning, control.***

I. INTRODUCTION

As a country with a tropical climate, Indonesia has a fairly high fertility rate. But fertility is not enough, it is necessary to develop agriculture by utilizing biotechnology, especially in order to increase agricultural production. The use of biotechnology is also needed, because with the increasingly rapid developments in the industrial sector, the area of agricultural land in Indonesia is also getting smaller. The shrinking of agricultural land is also caused by the large number of land changes to residential areas.

One of the biotechnologies that have developed quite rapidly is the use of a greenhouse. A greenhouse is a building made of glass or polyethylene which plays an important role in protecting the survival of plants. The gases contained in the greenhouse, such as carbon dioxide and methane and water vapors are conditioned in a balanced condition, so that they can withstand the sun's heat energy which affects the conditions or temperature therein.

Greenhouse also has weather engineering capabilities, which include temperature, watering duration and air circulation (Alwi, 2011). Sometimes unpredictable weather changes and limited land have led to the choice of greenhouse technology as an alternative solution to these problems (Abbas et al, 2015).

Conditioning in the greenhouse is also an effort to develop plant products through biotechnology so that the growth of a plant can be controlled to accelerate plant growth. However, so far, control in greenhouses is generally still done manually or in traditional ways, so that the effectiveness of growth in plants is lacking. Therefore, an automatic control system is needed in the greenhouse to make it easier to use the greenhouse.

In the current era of the Industrial Revolution 4.0, control technology (automatic control) leads to the use of ICT (information and communication technology). The control system is connected to the internet so that observation data storage, control decisions, and monitoring can be carried out through cloud computing. This allows the owner / operator to access the control system via a mobile device such as a smartphone, tablet or laptop.

Is an IoT (Internet of Things) based device that can be used to build an ICT-based control system? One of the most popular IoT devices today is the ESP8266, a microcontroller module that can connect to Wi-Fi and TCP / IP connections. As a microcontroller, this device has a processor, memory, input / output lines, and can be programmed according to the needs of the application.

In addition, the existing greenhouses still use conventional sources of electricity (PLN), which sources come from coal, fuel oil, natural gas, and others. Dependence on conventional energy sources of course has a bad impact, such as the increasing demand for energy is not accompanied by availability in nature. So that efforts to use renewable energy from alternative energy sources need to be pursued. Indonesia is a country that is exposed to the sun all year round, so the potential for solar energy is enormous as an alternative energy. Therefore, the development of the potential for solar energy as an alternative energy source must be done properly.

Conditioning a greenhouse that is in accordance with what is expected will be able to increase agricultural productivity and it is hoped that plants will continue to produce throughout the year without depending on the season. Automatic control will also make it easier for farmers to apply the availability of water, nutrients and light intensity needed by plants and is expected to be able to control plants from various kinds of pest and disease attacks.

The availability of abundant sunlight is a potential use of alternative sources of electrical energy. Therefore, the development of the potential for solar energy as a solar power plant which is a provider of electrical energy in greenhouses needs to be investigated. So it is hoped that the Greenhouse can have its own energy supply without depending on electrical energy.

II. MATERIAL AND METHOD

2.1 Operational Design

The greenhouse control system is intended to maintain the temperature and humidity (RH) of the room at the desired level. Temperature and RH are detected by special sensors that can be read by the system. The desired level can be adjusted by inputting numbers on the interface in the form of a computer screen (laptop, tablet, or smartphone).

The system then sends a digital signal to the relay which functions to switch (turn ON and OFF) the space cooling actuator and humidifier actuator devices.

The control system is planned to use a hybrid electric power source, namely solar power (using solar panels / photo-voltaic) and the electricity grid. For this reason, a control is needed to switch sources automatically based on the ability of the solar panel unit at any time (depending on the brightness of the sun). This capability is detected by a voltage sensor that is read by the system. If the voltage from the solar panels is less than required, the control system will switch to the PLN network using a relay / contactor.

In general, the control system receives information from the sensor in the form of temperature, RH, and voltage. The system also has a set point regarding the three parameters which are input by the operator. If the temperature exceeds the set point, the cooling actuator must be ON. Conversely, if the temperature is below the set point, the coolant must be OFF. Humidifier ON if RH is less than set point, and OFF if above set point. If the voltage generated by the solar panels is less than required, the power source must be switched to the power grid, conversely, if the solar panel voltage is sufficient, the power must be switched back to the solar panels.

The control system is designed to be able to communicate with computer devices (laptop/tablet/smartphone) via a wireless/WiFi network with internet protocol (IP). Therefore, it will be possible for the control system to be monitored and controlled remotely via the internet (Internet of Things/IoT system).

2.2 System Design

Based on the working principles that have been formulated in the operational design, a system design can be made as shown in Fig. 1. Broadly speaking, the components of the control system consist of (1) sensors, (2) IoT-based Microcontollers, (3) Programs, (4) Actuators, (5) Power supply, (6) Internet, (7) User interfaces, (8) Solar Panel and Power source.

The sensor functions as a detector for the amount of temperature, RH, and voltage that produces information that can be read by the microcontroller. The temperature and RH sensors are a single unit of the DHT22 type sensor. This sensor directly sends digital data that can be read directly by the microcontroller in the form of calibrated temperature and RH values. Voltage is detected using a voltage divider circuit to avoid voltage above the supply voltage from the microcontroller (3.3 V). The output voltage is then connected to the microcontroller ADC input to be converted into a digital value.

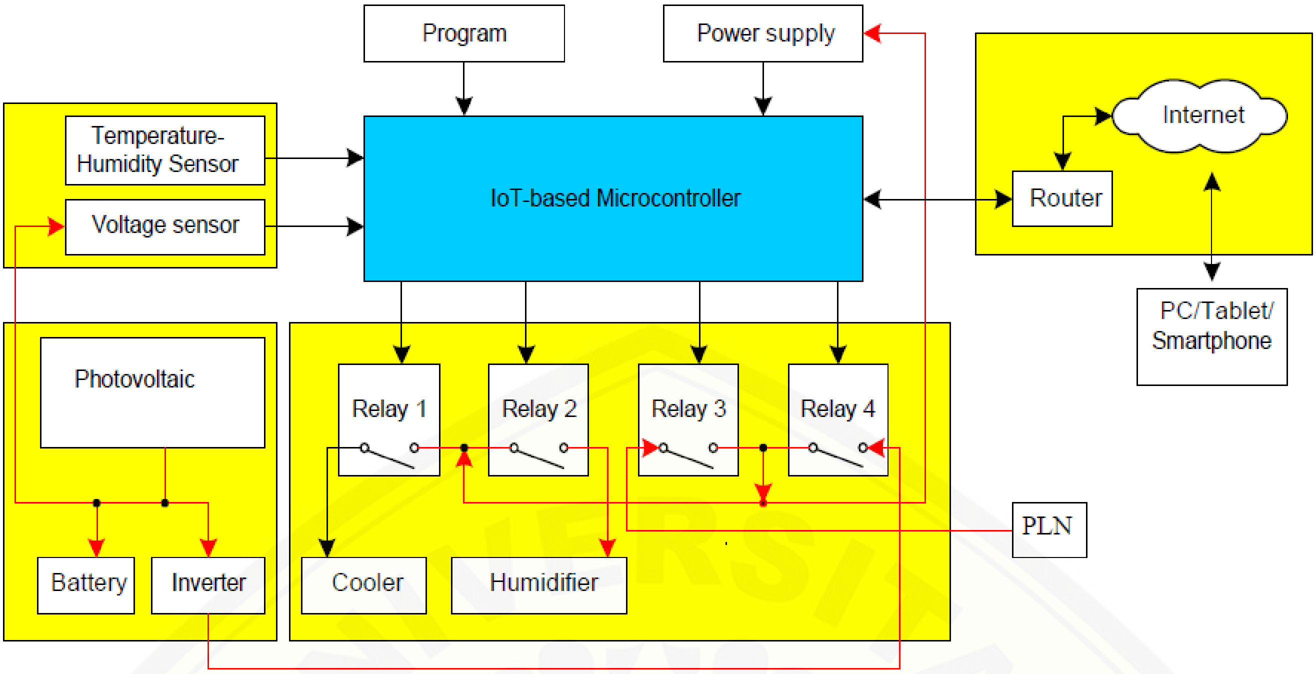


FIGURE 1: System design of the greenhouse control system

The microcontroller is the brain of this control system. The main function of this component is to process the information read / received to decide the operation of the actuator when to ON and when to OFF. Decision making is based on the comparison of the actual value obtained from the sensor with the set point value inputted by the user / operator.

In addition, this unit facilitates connection to the internet network via WiFi media. By using a PC / Smartphone device, the user / operator can access the interface via a web browser at a recognized IP-address. The control web display and the control algorithm are determined through the preparation of the microcontroller program. The program is a sequence of instructions stored in the microcontroller memory which will be executed every time the microcontroller is turned on. The program is structured using a microcontroller programming language, namely ESP8266 Basic (Molinari, 2015). The functions of this microcontroller program include reading sensors, reading set points, displaying temperature, RH and voltage values, displaying control functions on the web, sending digital signals to relays, and others.

Actuators are electrically powered devices that can affect parameters such as temperature and RH. The temperature actuator functions as an air conditioner such as a fan or evaporative cooler. While RH can be increased with an actuator in the form of a humidifier or sprayer. The actuator that can move the power source line is a relay or contactor.

A power supply or power supply is a unit that provides the DC voltage required by electronic circuits. This unit is an adapter that converts AC 220V to 5V DC voltage.

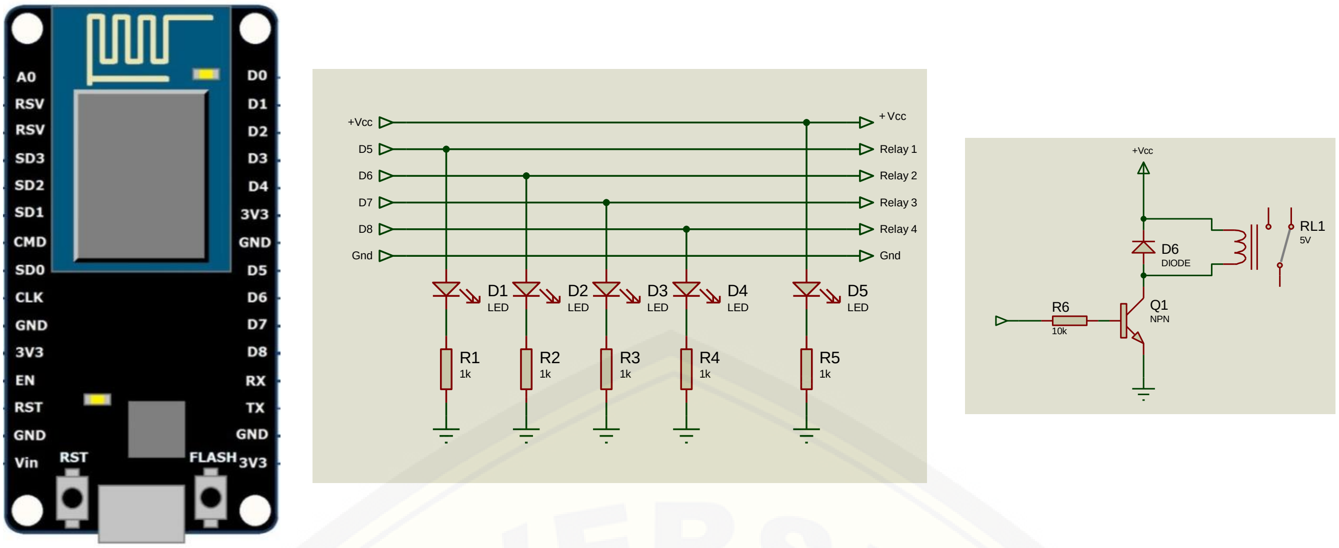
This unit is a wireless router connected to the internet network. The function of this unit is to connect the microcontroller to the internet by providing an IP address to the microcontroller device, so that it can be accessed via that IP address.

The user interface unit is a mobile device such as a laptop, tablet or smartphone. The function of this unit is as an interface device between the user / operator and the control system. Applications used are web browsers such as Mozilla, Chrome, and so on.

The source of electricity used in the greenhouse control system functions as a power source for the power supply and actuator unit. The source of electricity comes from the solar panel unit and the electricity network that works in a hybrid manner.

2.3 Electronic Circuit

The electronic circuit consists of the ESP8266 microcontroller circuit module, a series of indicator lights, and a relay-board circuit module. Schematic diagrams of electronic circuits are presented in Figures 2(a), 2(b), and 2(c). The electronic circuit is arranged based on the schematic diagram above. Between circuits connected by jumpers and connectors.



(a) **(b)** **(c)**

FIGURE 2(a): NodeMCU version of the ESP8266 microcontroller module, 2(b): Schematic diagram of indicator lights, and 2(c): Schematic diagram of a 1 channel relay circuit

2.4 Software Development

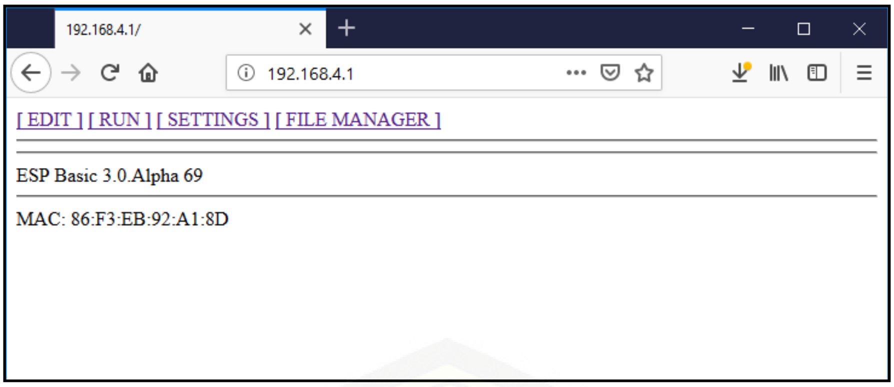
The microcontroller program is prepared in BASIC language using the ESP8266 BASIC compiler based on hardware design and control algorithms. The programming step begins by uploading (flash) the BASIC firmware to the ESP8266 microcontroller as follows:

1) Installing the ESP_Basic_Flasher application on a PC computer;
2) connecting the ESP8266 microcontroller module (NodeMCU) using a USB cable;
3) run the ESP_Basic_Flasher application program (see Fig. 3(a));
4) enter the parameter COM Port number and memory size (Flash Size);
5) click Firmware Flash;
6) wait a while for the flashing process to complete;

The next step is to connect the PC WiFi with the SSID emitted by the NodeMCU device. Default SSID name contains MAC ADDRESS. Furthermore, using a browser opens the web with the URL address: http://198.162.4.1/ so that a display like Fig.3 (b) is obtained. From this figure, information about the mac address of the device is obtained.

To write / compile a program click "EDIT" and a page will be displayed with the provided writing area (Fig. 3(c)). Press "Save" to save the program, and click "RUN" to run the program.

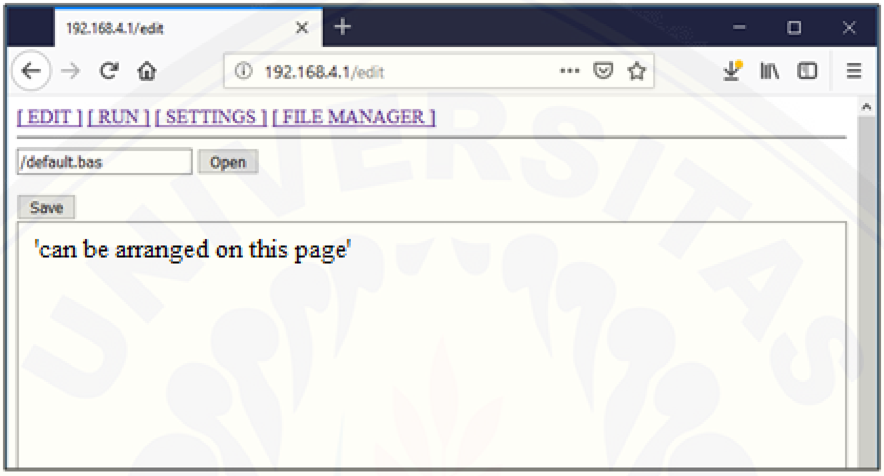
(a)



ESP Basic 3.0.Alpha 69

MAC: 86:F3:EB:92:A1:8D

(b)



/default.bas

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'can be arranged on this page'
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(c)

FIGURE 3: (a) Flasher ESP8266 Basic Interface, 3(b) Web programming interface, 3(c) Program writing area

Apart from being based on a series of hardware and control algorithms, program design also refers to the web appearance, component layout, aesthetics and others. Some of the required web components include a button, textbox, text, dropdown, and so on. Button is used to switch ON / OFF of each actuator when set in manual mode. Text and text-boxes are used to display measurement values and input set points. Dropdown is used to select "Manual" and "Auto" mode options for each actuator. The “Manual” mode will allow control of the actuator by clicking the ON or OFF button. While the "Auto" mode automatically turns on or off based on the set point value and actual parameters.

The program simulation is carried out by observing the changes in the indicator light which is connected to the NodeMCU module when the ON / OFF button is clicked. Sensors are also installed on the module, then observed the display of temperature, RH and voltage values provided on the web. The choice of “Manual” and “Auto” mode is also tested on each actuator which is simulated with an indicator light. If an error occurs and the function mismatches, then the program will be repaired immediately until a solution is found.

2.5 Calibration

Calibration is carried out to obtain the appropriate measurement value. In this study, three parameters were measured, namely temperature, RH and voltage. As previously described, temperature and RH were measured using a calibrated DHT22 sensor. Therefore, only voltage measurements will be calibrated in this study. While the temperature and RH will be compared with the measurement results with a thermohygrometer to get the average deviation which is the absolute value of the difference.

Voltage calibration is intended so that the voltage value displayed on the control web is the actual value in volts. Voltage measurement in this system involves a conversion process from an analog to digital quantity (ADC) where the ADC output value is the conversion value of a 10-bit binary number (0 - 1023). This is in accordance with the ADC characteristics of the ESP8266 microcontroller, which has an output of 10 bits (Espressif System, 2015).

The calibration stage is to provide input to the ADC pin (A0) of the NodeMCU module in the form of an analog voltage ranging from 0 Volts to a maximum that can produce an output of 1023. To generate an analog voltage, a multi-turn potentiometer is used which is assembled as a voltage divider. Furthermore, by turning the potentiometer gradually the ADC input voltage varies. Each voltage variation is measured with a voltmeter and the ADC output is recorded on the web.

The data pairs obtained are then processed with linear regression techniques to produce an equation for the relationship between the ADC output value and the voltage. This equation will then be used to convert the ADC value into the voltage value displayed on the web.

III. RESULT AND DISCUSSION

3.1 Hardware

The hardware design consists of: a microcontroller module, relay unit, DHT22 sensor, power supply, and voltage sensor. This design can be seen in Fig. 4 below. The microcontroller module uses NodeMCU, a type of module based on the ESP8266 which is widely sold in the on-line shop market. This module has several GPIO (general purpose input output) lines that can be used to family digital "1" or "0" signals. In this design, four GPIO lines are used to drive the relay and indicator lights, namely D5, D6, D7, and D8. Line D5 for Fan, D6 for humidifier, D7 for mains power source (solar panels or PLN), and D8 reserved for irrigation pumps.

The microcontroller module is powered by 5 V via the micro-USB connector from the power supply or HP charger. A PC power bank and USB port can also be used for this purpose.

The indicator light board consists of 5 red LEDs. The five LEDs respectively from top to bottom (Figure 4.1) are used as indicators: Relay 1, Relay 2, Relay 3, Relay 4, and Power-on. This board is equipped with a male connector which is used to connect the 4 channel relay board.

The DHT22 sensor is connected by a 3 line cable to the microcontroller. In its application in miniature greenhouses and real greenhouses, these connector cables can be replaced with lengths of up to 10 m. This sensor will be placed in the middle of the room and put in a special box as a protection. The voltage sensor uses a potentiometer to limit the voltage source that is measured to exceed the ADC capability limit, which is 3.3 volts. This sensor must be calibrated first to get the appropriate voltage value.

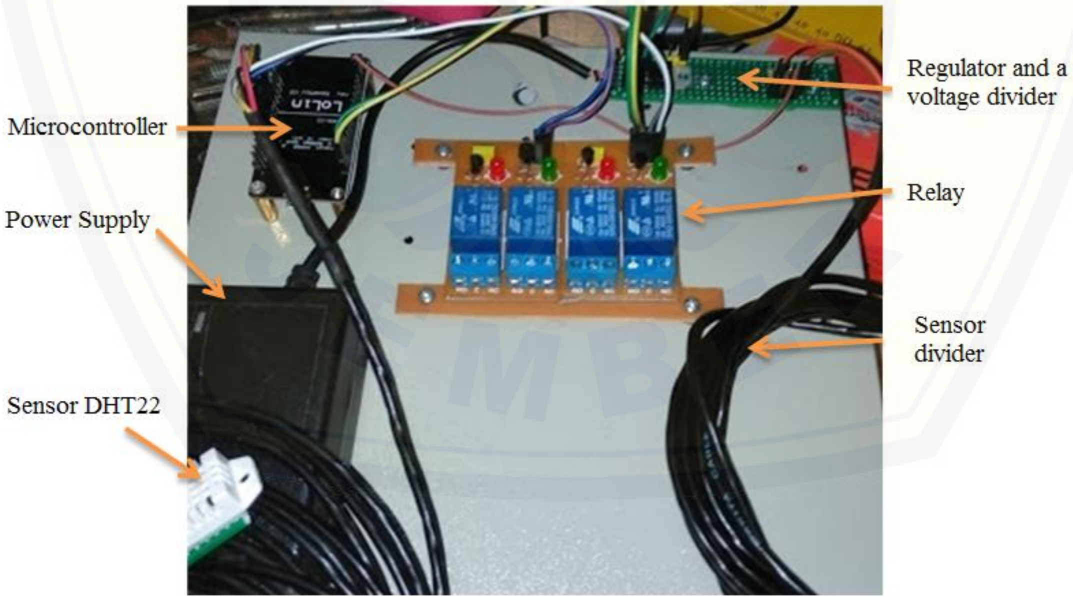
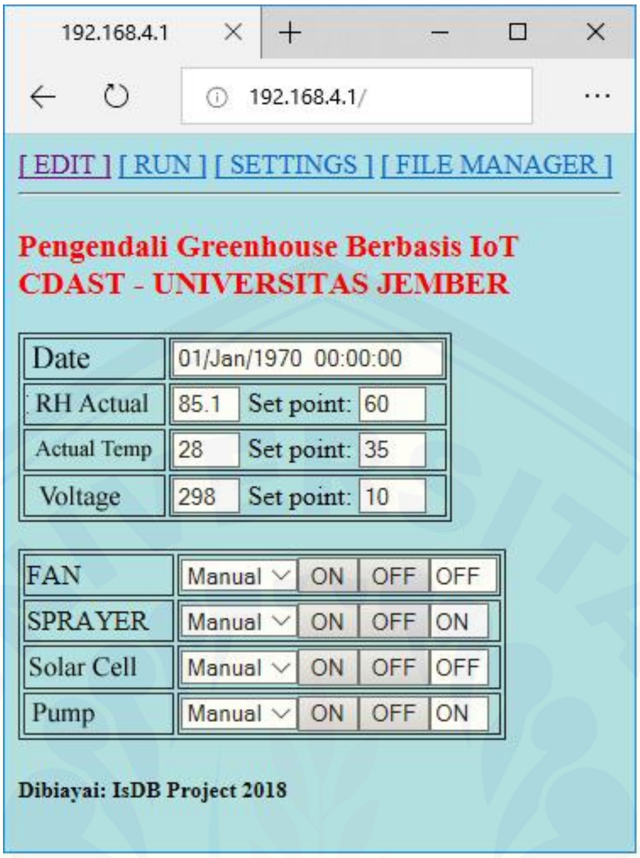


FIGURE 4: The result of the control system design

3.2 Software

The design of the software produces a web-based display of the greenhouse controller program as shown in Fig.5. The web controller can be accessed via a web browser with Android (using a smartphone) or Windows (using a laptop). The device to access must first be connected to WiFi with the SSID name: ESP86: F3: EB: B6: F8: F8 emitted by the ESP8266 module.

The SSID name of each ESP8266 device by default takes from its mac-address. The URL address that must be accessed is http://192.168.4.1. Furthermore, obtained a display like Fig. 5.



Pengendali Greenhouse Berbasis IoT
CDAST - UNIVERSITAS JEMBER

Date	01/Jan/1970 00:00:00		
RH Actual	85.1	Set point:	60
Actual Temp	28	Set point:	35
Voltage	298	Set point:	10

FAN	Manual	ON	OFF	OFF
SPRAYER	Manual	ON	OFF	ON
Solar Cell	Manual	ON	OFF	OFF
Pump	Manual	ON	OFF	ON

Dibiayai: IsDB Project 2018

FIGURE 5: Web interface for greenhouse controllers

3.3 Tempereture Measurement Performance

The results of temperature observations at the same object and time using the control unit and digital thermohygrometer are presented in Table 1. Based on the table, the average deviation between measurements using the control unit and the thermohygrometer is 0.5°C.

TABLE 1
TEMPERATURE MEASUREMENT

Unit Control	Thermohigrometer	d	d^2	|d|
28.4	27.8	0.6	0.36	0.6
27.2	26.6	0.6	0.36	0.6
28.6	28.1	0.5	0.25	0.5
26.4	26.8	-0.4	0.16	0.4
28.4	27.8	0.6	0.36	0.6
27.7	27.2	0.5	0.25	0.5
27.8	27.3	0.5	0.25	0.5
27.9	28.4	-0.5	0.25	0.5
29.0	28.5	0.5	0.25	0.5
29.0	28.5	0.5	0.25	0.5
29.0	28.5	0.5	0.25	0.5
28.2	27.8	0.4	0.16	0.4
Avarage				0.5

3.4 Relative Humidity (RH) Measurement Performance

RH is measured using the same sensor, namely DHT22. So this calibration of RH only produces an average deviation between the RH readings by the control unit and the thermohygrometer. The results of RH observations with both tools can be seen in Table 2. The average deviation value was 0.6%.

TABLE 2
RELATIVE HUMIDITY MEASUREMENT

Unit Control	Thermohigrometer	d	d^2	|d|
77.1	78	-0.9	0.81	0.9
85.5	85	0.5	0.25	0.5
76.2	77	-0.8	0.64	0.8
79.9	80	-0.1	0.01	0.1
82.1	82	0.1	0.01	0.1
80.7	82	-1.3	1.69	1.3
79.6	81	-1.4	1.96	1.4
73.8	75	-1.2	1.44	1.2
74.1	74	0.1	0.01	0.1
73.8	74	-0.2	0.04	0.2
74.2	74	0.2	0.04	0.2
75.5	76	-0.5	0.25	0.5
Avarage				0.6

3.5 Solar Panel Performance

In the experiment, the energy from solar panels needed for conditioning the greenhouse is very dynamic. The existence of sunlight intensity which is influenced by the time of day and night and the presence of clouds is very influential in the fulfillment of electrical energy. Meanwhile, the weather outside the greenhouse greatly affects the electrical energy used. To meet the electrical energy from solar panels for a greenhouse, further research is still needed.

3.6 Green House Conditioning

In principle, the greenhouse system has been implemented and is able to provide a good temperature and relative humidity. However, for performance related to plant growth, further research is still needed.

IV. CONCLUSION

In this research, the temperature and humidity control systems in greenhouses with energy from solar panels have been discussed and can be controlled by Internet of Things. The system can provide an ideal environment with controllable temperature and humidity that allows plants to experience perfect growth. This research focuses on the control system structure, hardware, software design, and system control strategy. The control system has a simple hardware structure, is cost-effective, easy to use and maintain, and provides good temperature and humidity stability.

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