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PLC Greenhouse Automatic Temperature Control Using Fuzzy Logic Method to Optimize Pakcoy Growth

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ABSTRACT

Vegetables are a good food, especially to meet the needs of vitamins and dietary fiber. However, in urban areas, there is very little land to develop vegetable farming. Hydroponic vertical planting system can be a solution. Pakcoy plants have growth that only takes 40 to 45 days to reach the ideal harvest age. The use of a greenhouse is also suitable for better pest control. However, the greenhouse has the characteristic of storing heat that it absorbs up to 5 degrees Celsius hotter than the outside temperature. The use of greenhouses with temperature control can accelerate the growth of vegetables. Based on this problem, making temperature regulation very necessary, the way is to adjust the rotation speed of the cooling fan using the fuzzy logic method so that the main goal is to save energy and air with a lower temperature can be flowed. The use of this hydroponic greenhouse module is proven to be able to maintain the temperature not much higher than the outside temperature. Comparison of fuzzy logic output values using Matlab software and fuzzy logic output values using PLC has an average error value of 0.27% for fan 1 and 0.35% for fan 2. The performance of the fuzzy logic method used can also be said to be good with an average response time of 61.8 seconds. With the performance of the system, the environment of the greenhouse can be suitable for the plant to grow optimally.

I. Introduction

Food for humans is a basic need that must be met to be able to sustain life and carry out life and life. Food is also the main source of nutrition for humans. Recently, the trend of eating food in the form of vegetables has become a hot topic of discussion, especially during this pandemic. Previously there was also a film called "The Game Changer" which influenced many people to finally decide to become a vegan. Vegan or vegetarian is the practice of not eating meat or its derivatives (Ruby, 2012). According to data from the Central Statistics Agency (BPS) of East Java Province in 2019. Vegetable crop production is dominated by districts that have a high level of elevation, so that from a temperature perspective, the area is very suitable for growing vegetables. In areas with low elevations, the average temperature is higher. Meanwhile, the air temperature in East Java can reach 35.9 degrees Celsius (BPS, 2017).

In addition, problems in the agricultural sector are indeed systematic problems because they involve narrow or small agricultural land. The national average of agricultural land ownership is 0.25 to 0.3 hectares per farm family (Nurcepatan and Irfan, 2020). Hydroponics is a system of growing in water media, without using soil (Untung Prastio, 2015). This system is very suitable to be applied in urban areas that lack agricultural land. Greenhouses are commonly used to overcome problems in outdoor planting, such as pests and weather problems. However, the greenhouse itself has a problem, namely during the dry season the temperature inside the greenhouse can be higher than the air temperature outside, so that it has an impact on plant growth and high evaporation (Nurcepatan and Irfan, 2020). For this reason, a good air circulation system is needed to keep the temperature in the greenhouse from overheating. Pakcoy (Brassica Rapa) is a vegetable that is commonly grown in hydroponic systems. Pakcoy is usually harvested at the age of 30-35 days after planting (Heru and Agus, 2014). The temperature of this vegetable maintenance ranges from 20 to 35 degrees Celsius, but this plant will be optimal at a temperature of 20 to 25 degrees Celsius (Chiska et al., 2020). In terms of control, the

use of PLC as a controller has advantages, especially when the device is to be developed on an industrial scale because the Siemens S7-1200 PLC is already an industry standard controller. For that the researcher will take the title in this final project is "Prototype Hydroponic Greenhouse Module With Fuzzy Logic Method as PLC-Based Automatic Temperature Control"

II. Methods

A. PLC Siemens S7-1200

Programmable Logic Controller (PLC) is basically an electronic device that functions as a controller of the logic state (ON or OFF status) of other devices connected to the PLC and the arrangement scheme can be changed (programmed). Generally PLC programming is done by a software running on a computer (PC). Examples of PLC applications are traffic light settings, factory machine work settings and others.

There are three main parts of a PLC namely input, controller and output. The input section is used to read the device from the outside, either digital signals such as switches or analog signals such as temperature sensors and others. The output section is generally an open collector transistor, triac, SSR or mechanical relay to control external devices. Generally, a PLC is equipped with communication devices to connect with external devices such as PCs, touch screen HMIs and others (Bakhtiar, A, 2020). This PLC has 14 digital input pins, 8 digital output pins and 2 analog input pins. This PLC uses 120-220V AC power as its main source.

B. Esp32

Esp32 is a microcontroller introduced by Espressif System which is the successor of the ESP8266 microcontroller. In this microcontroller, there is already a WiFi module in the chip, so it is very supportive for creating Internet of Things application systems. Esp32 can be programmed using a variety of environments such as the Arduino IDE. The specifications of the Esp32 are as follows (Espressif, 2019).

C. DHT22 Sensor

The DHT22 is a humidity sensor that can also read temperature. There are 2 types of this sensor in the market, namely DHT22 with PCB breakout and without PCB breakout. Both have the same 3 pins, namely VCC, A0 and GND. While the DHT22 without a PCB breakout has an additional pin, the NC pin. The advantage of this sensor when compared to DHT11 is that it has a better level of accuracy. DHT11 has a tolerance level of 5% for its humidity reading and ±2°C for its temperature reading. Meanwhile, DHT22 has a tolerance level of 2-5% for humidity readings and ±0.5°C for temperature readings (Adafruit, 2018).

D. Turbidity Sensor

This turbidity sensor is a water turbidity sensor. The working principle of this sensor is to use light which is then emitted to detect particles dissolved in water by reading light transmission and particle scattering rates. This sensor can produce an analog signal output of 0 - 4.5V. The more particles there are in the liquid, the lower the output voltage of this sensor (DFRobot. 2017).

E. HCSR-04

This sensor is a sensor that uses ultrasonic waves to detect the distance from an object to this sensor. Ultrasonic waves emitted will then bounce when there are objects in front of them. In measuring distance (cm), the speed of sound is multiplied by the time when ultrasonic waves are emitted and when ultrasonic waves are received. Travel time must be divided by 2 because the waves travel back and forth. If written in the formula, then Distance(cm)=(0.034(cm/μs)× Time(μs))/2.

F. Cooling Fan

This cooling fan aims to blow wind to cool the air temperature inside the greenhouse. The faster the fan spins, the cooler the temperature will be. This fan works in the voltage range of 10.0 - 13.2V DC. While the working current is 0.08A with a maximum rotation speed of 1800 RPM.

G. Mosfet Module

Mosfet (Metal Oxide Semiconductor Field Effect Transistor) is a semiconductor device that is widely used as a switch and as a signal amplifier in electronic devices. This Mosfet Module is an IC that has been assembled to make it easier to install wiring. The function of this mosfet is to increase both the voltage and current that the controller cannot supply. How to use this module is to set the PWM signal input (Pulse Width Modulation) then this module will output a voltage based on the PWM input signal.

H. WiFi Router

Router is hardware that is used to connect several networks, be it the same network or different networks. Routing is the process of sending data packets over a network from one device to another. This router is used as a data bridge between PLC to HMI and also PLC to Arduino.

I. Water pump

This water pump is a device that functions to pump water and the main driver is a Volt motor. This motor functions to convert electrical energy from the source into kinetic energy in the form of rotation. The rotation generated from the motor is then used to pump water through the blades inside the pump. In this study, 2 types of pumps were used, namely AC pumps and DC pumps

J. Fuzzy Logic Method

The Sugeno fuzzy logic control method to be used as data processing. The author uses 4 variables consisting of 2 input variables in the form of the difference value of 2 temperature sensors inside the module with sensors outside the module and 2 output variables in the form of 2 fans or fan speeds. The fuzzification aims to convert numerical data into a member variable of a fuzzy set. In the process of fuzzification in this final project, the author uses a triangular shape of 4 pieces on both sensors.

a. Normal : [0 1.5 3]
b. Warm : [1.5 3 4.5]
c. Hot : [3 4.5 6]
d. Very Hot : [4.5 6 7.5]

The Rule Base is used as the basis for processing the inference block. This rule consists of the rules of the input that are interconnected with the output. The following is the rule base used by the author:

r1 = if sensor1 is normal and sensor2 is normal then fan1 is slow and fan2 is slow.
r2 = if sensor1 is warm and sensor2 is normal then fan1 is medium and fan2 is slow.
r3 = if sensor1 is hot and sensor2 is normal then fan1 is fast and fan2 is slow
r4 = if sensor1 is normal and sensor2 is warm then fan1 is slow and fan2 is medium.
r5 = if sensor1 is normal and sensor2 is hot then fan1 is slow and fan2 is fast.
r6 = if sensor1 is warm and sensor2 is warm then fan1 is medium and fan2 is medium.
r7 = if sensor1 is normal and sensor2 is normal then fan1 is fast and fan2 is medium.
r8 = if sensor1 is normal and sensor2 is normal then fan1 is max and fan2 is medium.
r9 = if sensor1 is normal and sensor2 is normal then fan1 is medium and fan2 is fast.
r10 = if sensor1 is normal and sensor2 is normal then fan1 is medium and fan2 is max.
r11 = if sensor1 is normal and sensor2 is normal then fan1 is fast and fan2 is fast.
r12 = if sensor1 is normal and sensor2 is normal then fan1 max and fan2 fast.
r13 = if sensor1 is normal and sensor2 is normal then fan1 is fast and fan2 is max.
r14 = if sensor1 is normal and sensor2 is normal then fan1 max and fan2 max.

The defuzzification process uses the weight average calculation method. The output membership function as shown in Figure 13 for both fans is the same, namely:

Slow = 9
Medium = 10
Fast = 11
Very fast = 12

III. Results And Discussion

A. Fuzzy Method Test

Testing on the fuzzy logic method is carried out by comparing the output data from the function block with the results of training carried out with Matlab software. The first step is to test the output value using Matlab. Figure 1 is the Testing Using Matlab.

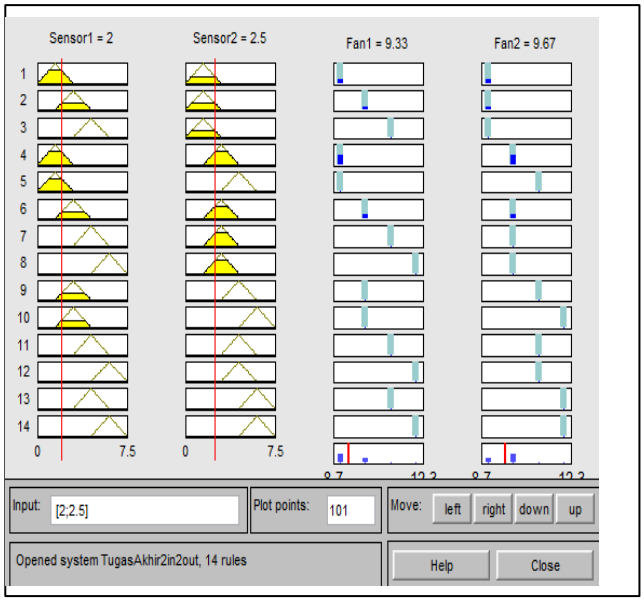

Figure 1. Testing Using Matlab

In Figure 2 Testing Method On FB PLC; the test is given a sensor value of 1 = 2 and sensor 2 = 2.5 shows the output of fan 1 = 9.33 and fan 2 = 9.67.

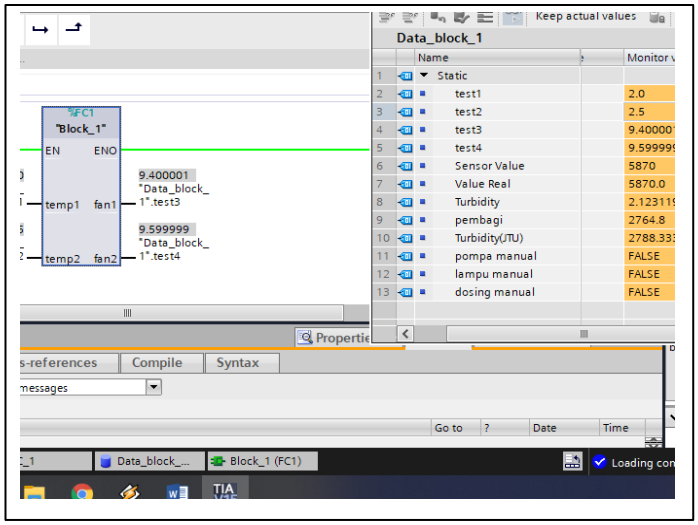

Figure 2. Testing Method On FB PLC

Table 1 shows the results of testing the fuzzy logic method that has been made on the function block. It was found that the output value on fan 1 was 9.4 and fan 2 value was 9.59 in testing the value of sensor 1 of 2 and sensor 2 of 2.5.

Table 1. Fuzzy Logic Method Testing Data

No	S1	S2	Matlab Fan1	Matlab Fan2	PLC Fan1	PLC Fan2
1	1	1	9	9	9	9
2	2	2.5	9.33	9.67	9.33	9.59
3	3.5	3	10.33	10.0	10.33	10.0
4	4	4.5	10.7	11.0	10.66	11.0
5	2	5	9.43	11.1	9.33	11.0
6	2.33	2.93	9.55	9.95	9.54	9.91

Table 2. Percentage of Error Value Fuzzy Logic Method

Num	Matlab Fan1	Matlab Fan2	PLC Fan1	PLC Fan2	Error Fan1	Error Fan2
1	9	9	9	9	0%	0%
2	9.33	9.67	9.33	9.59	0.75%	0.82%
3	10.33	10.0	10.33	10.0	0.29%	0%
4	10.7	11.0	10.66	11.0	0.37%	0%
5	9.43	11.1	9.33	11.0	0.11%	0.9%
6	9.55	9.95	9.54	9.91	0.1%	0.4%
			Avg	error	0.27%	0.35%

In Table 2 it is found that the average error on fan 1 is 0.27% and on fan 2 is 0.35%. Based on the error value, it can be said that the fuzzy logic controller method used has worked well.

B. HMI Testing

In Figure 3 shows that the UV lamp is purple with an automatic running condition because the manual switch of the lamp is not on. The water pump turns off with an automatic running condition because the pump's manual switch is not on. The top and bottom fans are both running with a voltage of 9.0 V. Sensor 1 reads 29.3 ºC, sensor 2 reads 29.7 oC and sensor 3 reads 29.2 ºC. Water Level reading 75%. The turbidity level of the water is 2158 ppm.

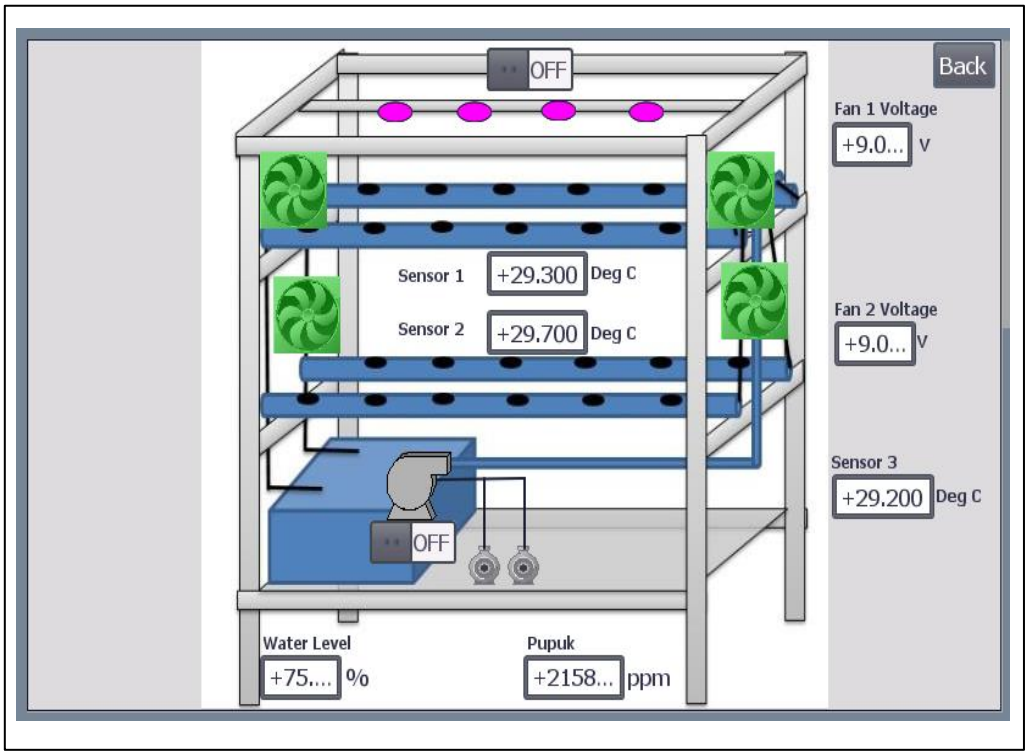

Figure 3. HMI Test

C. Overall System Test

In testing this system involves all the devices used both software and hardware. This test is done by calculating the time response needed to reach the temperature value inside is close to the temperature outside the tool. From the test data in Table 3, it is found that the average response time is 61.8 seconds. The difference in the response time value is caused by the presence of noise around the system. In addition, there is also a delay between communication from the ESP32 and the PLC.

Table 3. System Test Data

Num	Inside Sensor 1	Inside Sensor 2	Outside Sensor	Time Response Fuzzy (s)
1	33.8	33.6	30.2	76
2	33.3	33.1	30.1	65
3	33.4	33.1	30.2	64
4	33.3	33.2	30.1	67
5	32.7	32.5	30.0	53
6	32.5	32.4	30.0	56
7	32.5	32.4	29.9	52
			Average Time Response	61.8

IV. Conclusion

In the application of 2 fan speed control using the fuzzy logic method with 2 temperature sensor inputs, 2 outputs, 4 membership functions and 14 rules can work well. Comparison of fuzzy logic output values using Matlab software and fuzzy logic output values using PLC has an average error value of 0.27% for fan 1 and 0.35% for fan 2. The method applied also has an average response time value of 61.8 seconds.

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