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DESIGN OF RICE DRYER AUTOMATION SYSTEM USING FUZZY MIMO METHOD

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Abstract – Rice is one of the most important cultivated plants in human civilization. One of the most important post-harvest processes is drying. Therefore, we need a drying process with an artificial heat source that can be adjusted to achieve a constant heat according to the temperature characteristics of the rice. By applying the Fuzzy-MIMO control system, rice drying is expected to work quickly without damaging the rice foam. Fuzzy-MIMO system is translated into a rule based on the fuzzy algorithm that has been created. The fuzzy-MIMO method used is the Sugeno method with input temperature errors and humidity errors and outputs in the form of heat and wind gusts. The temperature sensor used has an error factor of 3.61%. The expected control system is a heating system and a motor to regulate the wind gusts in the drying chamber. The total drying time produced is 240 seconds with a moisture content of 15.2%. Drying time is influenced by the initial moisture content of rice.

Keywords: Fuzzy-MIMO; Heater; Moisturizer; Rice; Temperature

I. INTRODUCTION

Rice is one of the most important cultivated plants in human civilization. Along with the increasing Indonesian population, of course, it must be balanced with the increasing number of food needs as well. Good handling of food crops is one thing that needs to be considered to overcome the number of food needs [1]. The water content of harvested rice from paddy fields is generally still quite high, around 20-23%. At this level of moisture content, rice is not safe to store because rice seeds can grow back into seeds. For the rice to be stored safely, it needs to be dried until it reaches a balanced moisture content of 14%. Therefore, we need a drying process with an artificial heat source that can be adjusted to achieve constant heat.

There are several drying methods carried out by other researchers, one of which is grain drying using the husk (rice husk) burning method. The rice drying method with the husk method is considered less effective. In addition, the problems faced by these farmer entrepreneurs are high rainfall and an erratic rainy season, which affects time efficiency and poor grain quality.

Based on these conditions, it is necessary to take innovative steps to make a grain dryer that has good benefits including not requiring a lot of labor, faster time efficiency, not depending on climate, and not producing emission gases that can pollute the environment. The existence of a microcontroller-based grain dryer can provide technical assistance to farmer entrepreneurs. This tool is designed as innovative as possible which has advantages over the previous methods. The final moisture content of grain can reach a minimum number in one drying, the resulting temperature is in the range of 40ºC to 70ºC. Temperature control can be automatic by using built-in temperature and humidity sensors.

II. METHODS

Tools Design

This grain drying system consists of constituent devices, namely mechanical devices, electronic devices, and software. All the constituents are combined so that the dryer can work semi-automatically.

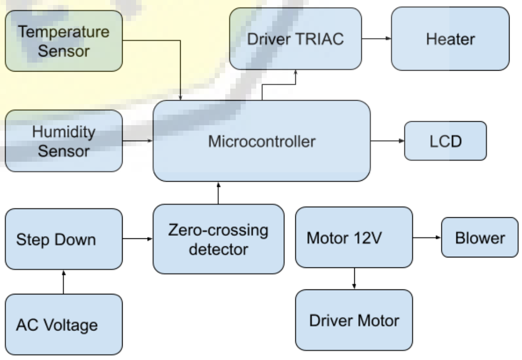


Figure 1. Block Diagram

Creating a controlled grain dryer, this system is added with electronic devices, namely temperature, humidity sensors, microcontrollers, and DC motors [9]. Temperature and humidity sensors are placed in the dryer tube. The temperature and humidity data obtained from the sensors are then processed using a microcontroller to produce control actions [7]. The control action in question is the actuator movement of the control system, namely the heater and blower. The temperature and humidity in the system can be observed through the LCD (Liquid Crystal Display).

Hardware Tools

This electronic design consists of several important circuits in the grain drying system, including the minimum AVR system using an LCD, zero-crossing detector, and the TRIAC BTA12 isolation driver circuit.

1. BTA12. TRIAC Isolation Driver Circuit

This isolation driver circuit functions as a separator between the control circuit voltages in the form of voltage low to the power circuit voltage in the form of high voltage AC. In this study, one MOC3021 optocoupler was used in a series. This optocoupler signal will then be forwarded to the TRIAC gate [8].

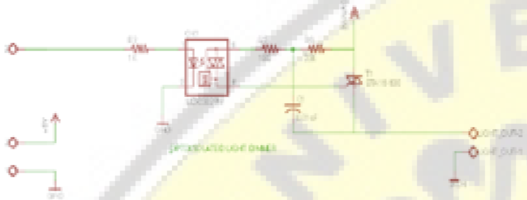


Figure 2. A driver circuit and isolation

2. Zero crossing detector

The zero-crossing detector circuit is a circuit that functions to detect the phase change of the voltage at the grid voltage. This circuit is needed to indicate when the Triac gate will be triggered. The result of this circuit is in the form of high pulses that coincide at the time of changing the phase of the grid voltage, namely when the voltage reaches zero volts precision, so it is called a zero detector or zero detector.

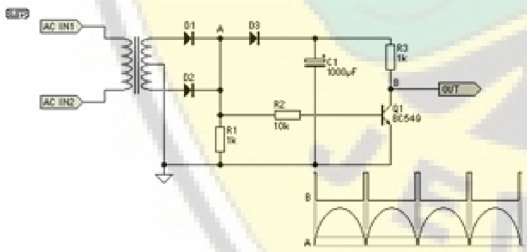


Figure 3. Zero-Crossing Detector

The transistor used is BC549 which is an NPN type transistor. The resulting pulses will be used as a reference by the microcontroller for generating PWM signals to the Triac.

In this zero-crossing detector circuit, a CT (center tap) type transformer is needed in its assembly with a working voltage of 6 volts.

Mechanical Designs

This grain drying system uses a cylindrical conveyor mechanical model in which there are threads as the path of the grain so that the drying is evenly distributed.

Figure 4. Mechanical design with conveyor model.

This grain dryer is driven by a 12v DC motor which is coupled directly to the drying cylinder. The materials used to make this mechanical drying system are iron and zinc as well as other supporting devices.

Figure 5. Cylindrical conveyor driving motor.

Software Design

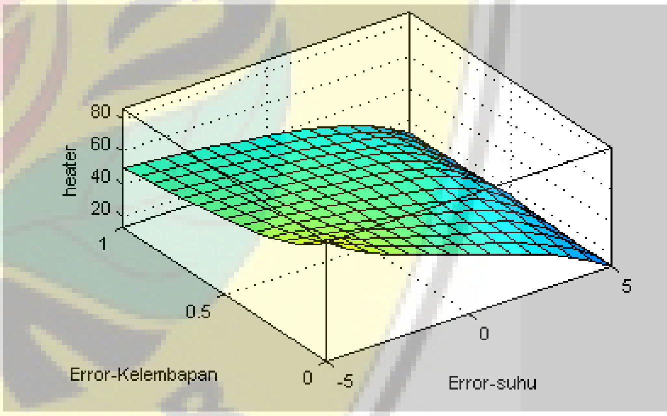


Figure 6. fuzzy system

Software design is presented in Figure 8. The system with this fuzzy method consists of several processes, namely [2]:

1. Fuzzification System

This process works to convert an analog quantity (crisp input) into fuzzy input. Fuzzification has the role of transforming a firm number obtained from a measurement into an estimate of subjective values, or it can be defined as a mapping from an input space to a fuzzy set in real input speech. For this purpose, a fuzzy operator is needed.

The system that I use uses a triangular curve representation fuzzification. The triangular curve is a combination of 2 lines (linear).

2. Rule Base

This process serves to find a fuzzy output value from fuzzy input. The process is a fuzzy input value that comes from the fuzzification process and is then entered into a rule that has been created to be used as a fuzzy output. This is the main part of fuzzy because this is where the system will be smart or not. If you are not smart in setting the rules (the rule base) then the system to be controlled will be chaotic.

Rule base of grain drying system

a) If the temperature is low the humidity is wet then the heater is high
b) If the temperature is low, the humidity is dry, the heating is low
c) If the temperature is high and the humidity is wet then the heater is high
d) If the temperature is high and the humidity is wet then the heater is low.

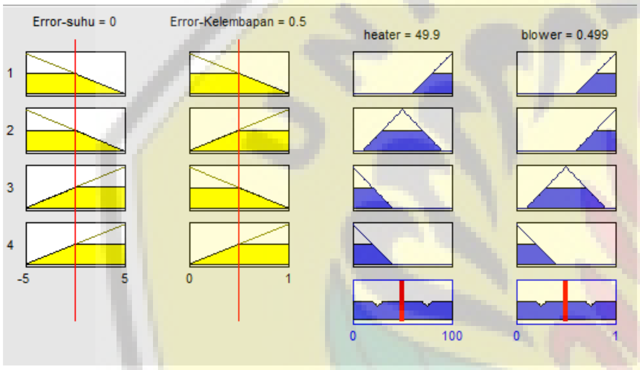


Figure 7. Rule base system

3. Deffuzification

Defuzzification is the process of converting each result from reading the fuzzification value into the actual value. To determine the ignition strength (fire strength) in this study used Min. The defuzzification value will later be used as a heating reference. To find the total Z value, the following equation is used [2]:

$$z = \frac{(a1 \times a2) + (a2 \times Z2) + (a3 \times Z3) + (a4 \times Z4)}{A1 + A1 + A3 + A4}$$

The following is a flow diagram of the program algorithm design:

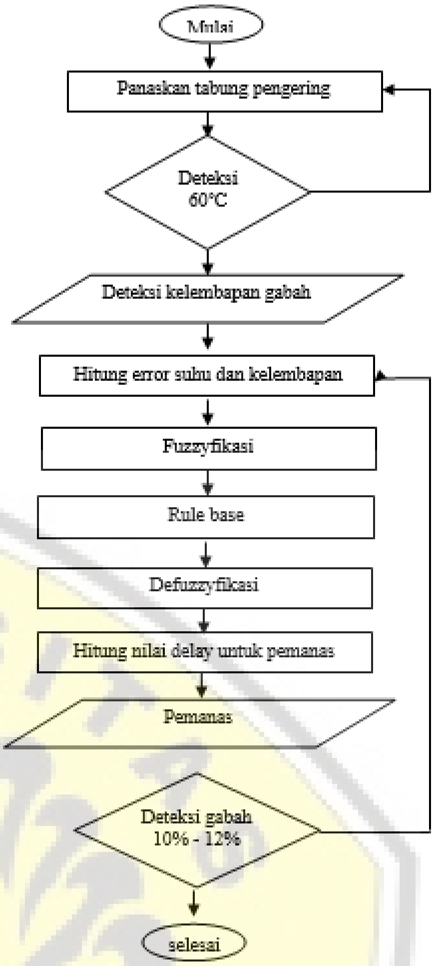


Figure 8. Software Flowchart

III. RESULT AND DISCUSSION

TIP3055. Current Amplifier Power Supply Circuit

The signal processing circuit gets a voltage of 12 volts because in this circuit there is a microphone that requires a voltage to turn it on, where the higher the voltage, the better. The power supply on the microcontroller and the reference voltage for the pins on the ADC is 5 volts, but the reference voltage and the microcontroller power supply are separated. This is because the reference voltage is fixed and is not affected by the microcontroller voltage. The results of the power supply test are shown in table 1.

Table 1. Testing the Power Supply Circuit

No.	Voltage Target (Volt)	Rated Voltage	*Error* (%)	Output Target
1.	5 Volt	4,97	0,6	system power supply
2.	5 Volt	4,97	0,6	Sensor power supply SHT11
3.	5 Volt	5,03	0,6	Sensor power supply DHT11

Testing the power supply circuit to generate power for the system went well because after testing only the largest error percentage was 0.6%.

Minimum System Circuit AVR Microcontroller

This minimum system test aims to find out the microcontroller system can work as desired. This test is carried out by entering the program which is then displayed on the LCD on the input and output ports on the microcontroller system as well as measuring the power supply voltage.

The equipment used in testing this minimum system is an AVO meter and a voltage source from a ± 8 Volt DC power supply.

The following describes the minimum system test conditions when connected to an LCD;

1) If the PA port is connected to the LCD, the LCD can display the results of the program that has been created and entered on the microcontroller.
2) If the PB port is connected to the LCD, the LCD can display the results of the program that has been created and entered on the microcontroller.
3) 3) If the PC port is connected to the LCD, the LCD can display the results of the program that has been created and entered on the microcontroller.
4) The PD port displays an LCD, then the LCD can display the results of the program created and entered on the microcontroller. The following is a list of programs to check ports on the microcontroller using the LCD:

Input Circuit

1) SHT11 Sensor To get the temperature and humidity values, the SHT11 reading data needs to be converted first before being displayed on the LCD by using the formula [6]:

$$RH = (Dataread \times 0.0405) - (Dataread \times dataread \times 0.0000028) - 4:$$

$$Temp = (Data\ read - 4000)/100$$

Table 2. Data from the SHT11. temperature sensor test results

No	Sensor	Thermometer	Error Percent
1	27	27	0
2	29,45	30	3,61
3	43	43	0
4	48	47	2,12
5	65	65	0

From the results of the temperature test in table 2, it can be observed that the accuracy of temperature readings by the SHT11 sensor has the largest percent error, which is 3.61%.

From the results of the humidity test on the SHT11 sensor in table 3, it can be observed that the accuracy of the sensor is that the sensor readings are close to the measurement results using a Rice Moisture measuring instrument with the largest percent error of 14.28%.

Table 3. SHT11. humidity sensor test results data

No	Sensor	Moustrizer Meter	Erorr persen
1	13	11	18,08
2	16	14	14,28
3	18	20	10

2) Sensor DHT11

Table 4. DHT11. temperature sensor test results data

No	Sensor	Thermometer	Error Percent
1	13	11	18,08
2	16	14	14,28
3	18	20	10

From the temperature test data in table 4, it can be observed that the accuracy of the temperature reading by the DHT11 sensor has the largest percent error, which is 3.61%.

Table 5. DHT11 . humidity sensor test results data

No	sensor	*Moustrizer Meter*	Erorr persen
1	13	11	18,08
2	16	14	14,28
3	18	20	10

From the results of the humidity test on the SHT11 sensor in table 5, it can be observed that the accuracy of the sensor is that the sensor readings are close to the measurement results using a Rice Moisture measuring instrument with the largest percent error of 14.28%.

From the test results of the SHT11 and DHT11 input sensors in table 4.2 and table 4.4, it can be observed that the DHT11 sensor has less precise temperature data than SHT11.

d) Zero-Crossing Detector Test

This test aims to determine the functioning of the zero-crossing detector circuit (phase detection). The test is carried out using an analog oscilloscope. Before testing the oscilloscope must be calibrated first.

After the calibration process is complete, the test is carried out by placing the red probe channel 1 on the collector leg of the transistor while the black probe is connected to the ground. Channel 2 is used as a reference for the sine voltage signal from the grid. Because the grid voltage is greater than the capacity of the oscilloscope, the channel 2 probe can be placed on the grid voltage transformer by a transformer with an output voltage of 6 volts so it is safer.

Combining the display from channel 1 which is a zero-crossing detector pulse signal with channel 2 which is a grid voltage signal, it will appear when the sine signal intersects with zero, zero-cross gives a high signal as output. And the output of phase detection can be seen in Figure.

Figure 9. Phase Detection

The waveform of a single-phase AC voltage and the output waveform of the phase detection circuit is shown in Figure 9 where if the AC waveform (output of the CT transformer) is at the zero-crossing position, this circuit will detect that position with a high condition [8]. Conversely, when the AC wave is in a value position, it will be in a low condition.

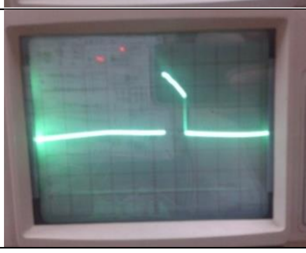
e) Testing the TRIAC BTA12 Driver and Isolation Circuit.

Testing the TRIAC driver circuit shows that this circuit can become a switch according to the angle of ignition. In testing the TRIAC driver circuit, testing was carried out with a load voltage divider circuit and lamp. From the TRIAC ignition angle test, the test results are in the form of a TRIAC triggering waveform and a voltage waveform at the load according to the ignition angle (180° - 0°).

Figure 10. TRIAC Driver Circuit Testing

From the results of testing the TRIAC driver circuit, the TRIAC can delay the supply voltage on the incandescent lamp load so that it can be stated that this TRIAC driver circuit can work and is in good condition. The data for the test results for the TRIAC driver circuit is shown in table 6.

Table 6. Triac Driver Circuit Testing

Ignition	Wave
75˚	
90˚	
125˚	

The experiment uses an ignition angle of 180˚-0˚ because basically, it goes back to the working principle of a zero-crossing detector which reads high conditions when it is at zero crossing. For calculations, 10ms is the result of the AC half-wave (180˚) which is assumed to be an AC wave with a frequency of 50Hz. The following is an experimental picture of the TRIAC driver circuit testing.

Based on the test results of the TRIAC ignition angle test data obtained in table 6. In the experiment, the wave area from an ignition angle of 75˚ - 125˚ waveforms has a larger area to be smaller.

f) Analysis and Testing of Fuzzy Logic Implementation

In this drying system, the inputs that are processed to obtain fuzzy values are temperature errors and humidity errors. The temperature error shows how far the current temperature is from the 60oC setpoint, while the humidity setpoint error is 11%. Reading this input is called the quantization process. After the temperature error and humidity error are read, each input is determined by the degree of membership through the mapping of the membership degree values that have been made. Changing the input value in the form of a numeric variable into a fuzzy variable (linguistic variable) is intended so that the input can be processed fuzzy.

The fuzzification program listing is used to find the value. The translation of the above program is that if the humidity error value is more than 4 and the humidity error is less than 5, then the membership degree of the input is 0.9 in the positive set (dfpos1) and 0.1 in the negative set (dfneg1) and so on. The reasoning technique used in this fuzzy control system is the Min method. In the program listing the first rule is written that, if the fuzzification value in the negative2 set is smaller than the fuzzification value in the positive1 set, the fuzzification value in the negative^2 set is used as the (fire strength) value for the first rule. If these conditions are not met, then the value is a positive set.

Table 7. Fuzzy Algorithm Testing

No	Input		Fuzzification			
			ET		EH	
	ET	EH	dfp1	dfn1	dfp2	dfn2
1	5	0	1	0	0,5	0,5
2	10	-5	1	0	0	1
3	8	-10	1	0	0	1
4	-1	2	0,4	0,6	0,7	0,3
5	-5	-8	0	1	0	1

The value of the ignition strength (fire strength) resulting from the selection process based on the rules (rule base) and reasoning techniques with the Min method is still a fuzzy variable (linguistic variable). To be processed into a control action, this value needs to be converted back into a numeric variable through the defuzzification process.

The results of the defuzzification for each input obtained from the results of theoretical and program calculations, there is no percent error value. This is because the fuzzification value of each input has been mapped. So that each input that will be processed fuzzy has a predetermined fuzzification value.

After the defuzzification value is obtained, this value is converted into a control action in the form of heat from nickel which is made in units of degrees Celsius to heat the heating tube. The required heating range is 30-60 degrees centigrade which is represented by a value of 1-10. In the above program, it is written that the defuze value is multiplied by variable 4.

Table 8. Changing the Defuzzification Value into Heating

No.	Input		Defuzzification
	ET	EH	(Z)
1	10	-5	0,5
2	8	-10	0,5
3	-1	2	0,467

The first stage for this rice dryer is the heating process of the dryer tube (heating). The tube is heated until the temperature reaches 60oC. This process takes 8 minutes. After the tube temperature reaches 60oC, the next step is to enter the grain to be dried. Before entering the drying tube, the grain is first checked for moisture content to adjust the temperature. For 1.10 minutes, the temperature of the tube decreases after reaching 60˚C and will turn on again after the temperature is less than 60˚C.

The process of turning the heating element on and off takes ±1 minute. To reach a temperature of 60oC from the time the grain is inserted takes 2 minutes. The total time required for the drying process is 4 minutes to obtain a moisture content of 10% -12%.

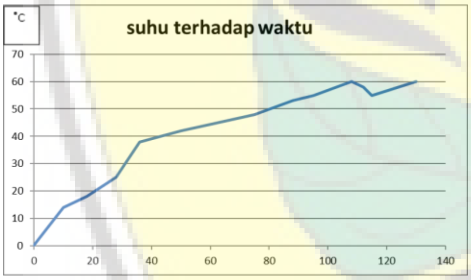


Figure 11. Graph of Change in Temperature with Time

The picture above is the result of a drying experiment carried out with a capacity of 5 kg. The temperature drop in the graph above is when the heater has reached 60˚C then the heating element is off, when the heating element is off the temperature drops to ±5˚C.

IV. CONCLUSION

This grain dryer uses 2 sensor inputs that have the same characteristics but have different effectiveness This tool has a temperature set point of 60˚C to obtain a moisture content of 10-12% of the grain. The percent error of the sensor has an average of 2-5% which is shown in Table 4.2 - 4.5. The time needed to get 10-12% moisture content is ±3 minutes The use of a zero-crossing detector circuit to determine the 0 reference point of the AC voltage. The maximum value generated from the TRIAC BT12 isolation driver is 1ms which has an ignition angle of 18.

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