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RE-ENGINEERING THE SOLAR DRYER SISTEM WITH SURAM's FUZZY RULE

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Abstract

Solar drying systems have progressed quite rapidly with their utilization, both in terms of technical and algorithmic. At first the drying system only paid attention to the achievable drying temperature, but along with advances in technology the drying system has been able to meet industrial needs, namely to produce drying products that are ready to be re-engineered into daily necessities.

Utilization of artificial intelligent in the solar drying system is realized by using the SURAM's Fuzzy Rule has taken into account 8 parameters in the form of drying temperature, dryer humidity, ambient temperature, ambient humidity, solar energy, moisture content of the material being dried and wind speed according to the location of the solar drying process. Even in the industrial world, it comes to the type of material to be dried, such as coffee, chocolate, tea, tobacco, and wood.

The process will take place by using an operational table in the form of a look up table on the actuator, namely how long the damper, sprayer and heater work according to the material drying schedule.

Keywords: SURAM's Fuzzy Rule, look up table, drying schedule;

I. Introduction

The drying process system that utilizes solar energy in early 1988 was intended only to get the maximum drying temperature possible, by engineering the collector in the dryer [1]. Along with developments in the wood drying process using a drying schedule that depends on the moisture content of the wood, the condition of the kiln at dry temperature and humidity. The controllers used to control the actuators are heater, sprayer and damper, each process used is carried out with optimal control in terms of time and energy as well as stability in the wood drying schedule. The main energy source is solar energy from the collector and alternative energy sources by heating. The amount of solar energy based on the intensity of the sun and alternative energy by heating is electricity consumption [2]. The maximum utilization of solar energy in the wood drying process is the goal of the control system. It depends on the amount of solar energy and changes as well as the temperature of the environment. The responsibility for changes in solar energy in the environmental temperature and humidity variables is the main objective of the control system. This control process is expected to maximize the use of solar energy and minimize the consumption of electrical energy.

The wood drying process depends on the drying schedule, which is used to track the set points for drying temperature and humidity. The drying temperature and humidity conditions in the schedule are different for each step of the wood drying schedule. The control variable for wood drying from the kiln process is the temperature and humidity of the air in the chamber which depends on the moisture content of the wood. It is necessary to control the actuator system for the heater, sprayer and damper, every time the process used is carried out optimally from time and effort and the actuator works in real data conditions. The SURAM's Fuzzy Rule was applied to the drying schedule of Albizia wood and the modification of the membership function in the range [0,5, 1] [3].

The current reengineering of SURAM's Fuzzy Rule has taken into account the effect of wind speed on the location of the drying process, namely at high and low wind speeds. The effect of this wind speed is expressed in the active time of the actuator on. The solar-powered coffee drying process has taken into account the wind speed carried out in the village of Saloon Dolok, Samosir Island.[4]. The reengineering of SURAM's Fuzzy Rule is quite good in following the coffee drying process schedule and producing coffee water content less than 10%. The next design is to re-engineer this solar drying system to be able to follow the drying schedule according to the type of material being dried including chocolate, tobacco and tea as a plantation product in Indonesia.

The reengineering of the use of solar dryers is presented in Figure 1.

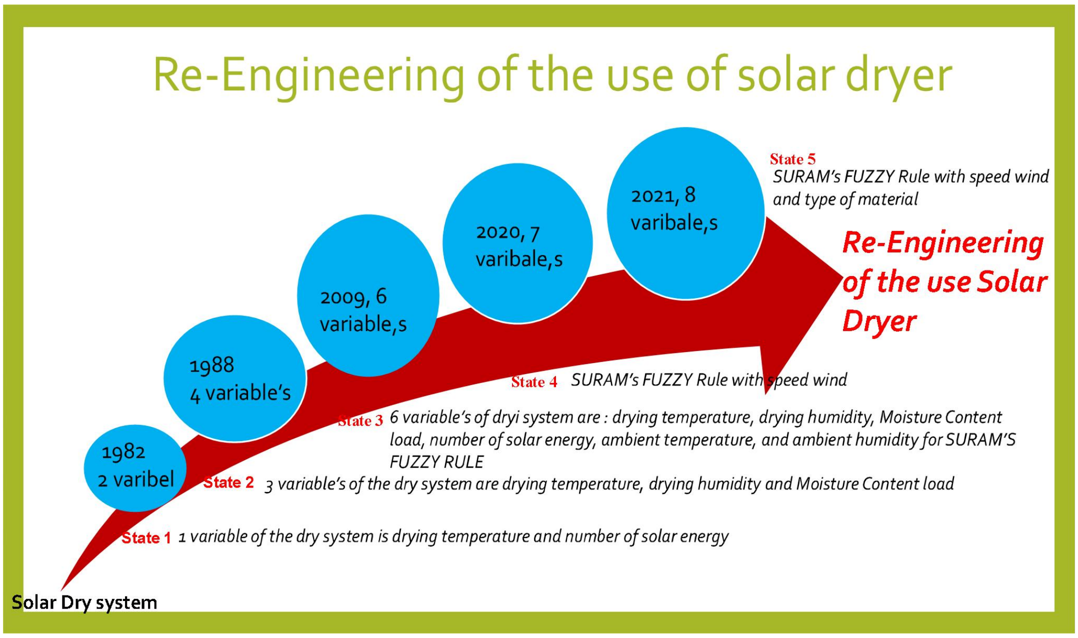

Figure 1. Re-Engineering of the solar dryer base number of parameter's

II. Drying Process and Prototype of solar dryer

In general, the control variables of the solar energy drying process kiln are temperature and humidity to adjust the drying schedule variables. The drying schedule is a drying cycle and has several stages of processes to produce a standard moisture content of the dried material. Each level of the process carried out is set in such a way as to variable temperature and humidity according to the drying schedule of the material and becomes a set point. In this way, the actuator control system (heater, sprayer and damper) will become a means of regulating the condition of the drying chamber so that it can maximize the goal of efficiency in the shortest possible time.

II.1. Drying Process

The drying process begins with measuring the moisture content of the material in such a way that it is adjusted to the drying schedule that is the reference. The drying chamber is set according to the desired temperature and humidity. So according to the existing conditions in the form of solar energy, the drying process is adjusted to the amount of heat collected by the collector to be forwarded to the drying chamber.

The hot air produced will evaporate the water on the surface of the material, through a number of processes including capillarity, vapor diffusion, bound water diffusion, combined vapor diffusion and bound water diffusion and at temperatures over 100 degrees Celsius mass flow. The diffusion process increases with increasing temperature and it is therefore possible to increase the rate of movement of water inside the board to the surface of the board, assuming there is a lower concentration of diffuse molecules on the surface of the board, simply by increasing the temperature inside the kiln. The loss of water from the surface of the material to the air is by evaporation. Evaporation is temperature dependent and depends on the relative humidity of the air surrounding the material. If hot dry air is used for drying, the surface layer of the material being dried can dry quickly and cause hardening. To avoid excessive evaporation from the surface of the material, the air in the kiln must be kept relatively moist. Therefore, kiln drying involves careful control of the temperature and humidity of the air inside the kiln. Air circulation as in air drying also plays an important role in humidity control as it ensures that the air in contact with the material is constantly updated thereby preventing a stagnant layer of moist air from occurring.

II.2. Prototyping Kiln Solar dryer

The prototype of the solar dryer uses a tool to measure solar energy with a pyranometer type MS-801 Chino, maximum voltage +50 mVDC, which has conversion data from the Meteorology and Geophysics Agency. This tool is equipped with 3 actuators, namely damper, spayer and heater. Details of this dryer prototype are presented in Figure 2.

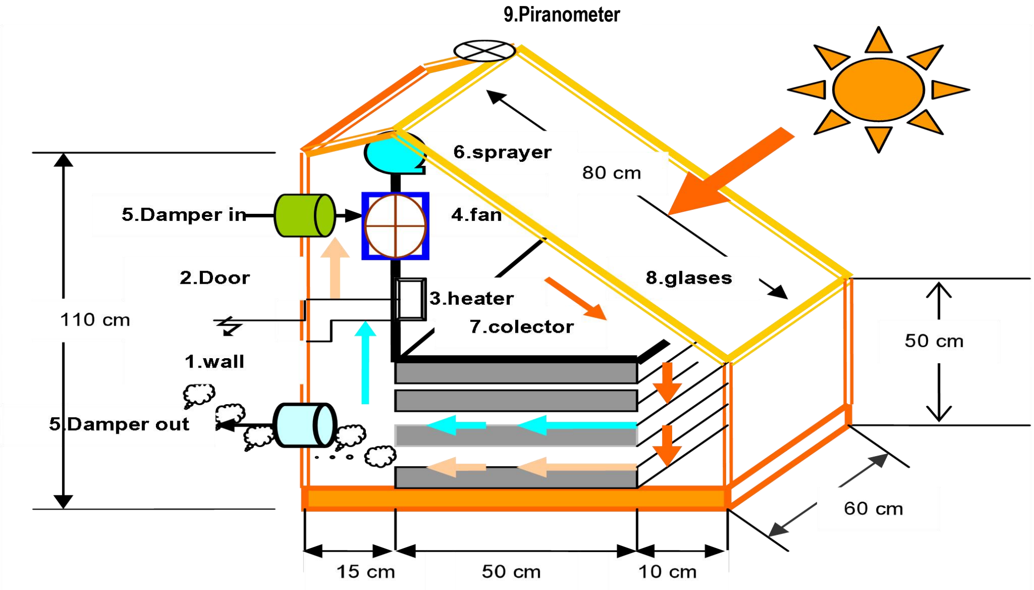

Figure 2. Detailed design of Solar Dryer Prototyping

The most important part of a dehumidifying kiln is the heat pump. The air in the kiln passes through the material and absorbs moisture from the material. Part of that air circulates through a heat pump where the water vapor is condensed and drained out of the room. The heated dry air returns to the kiln chamber. The consumption of electrical energy is minimized, only for the exchange of air in/out by the damper, and the air circulation in the kiln by the fan.

The automatic control unit has a built-in program for drying all types of materials regardless of the initial moisture content. It controls the drying process automatically, so the presence of an operator is not required during drying. The energy consumption is greater only on the first day during the heating stage when the electric heater is turned on until the working temperature is reached. Then, during the drying stage this heater rarely turns on. If the air in the chamber is saturated, the device for the heat exchanger, the air circulation is activated in the form of a damper. If the air in the chamber is saturated, the device for the heat exchanger, the air circulation is activated in the form of a damper. And if the air in the chamber is too dry and saturated, the sprayer works according to the desired time to spray water in steam.

III. SURAM's FUZZY RULE (SFR)

The algorithm of the SURAM's FUZZY RULE is designed in such a way that the automatic control unit has a built-in program for drying system. For the drying process control system takes place automatically, so the presence of the operator is not required during drying. The greater energy consumption is generally only on the first day during the heating stage when the electric heater is turned on until the working temperature is reached..

The input variable in the measurement of ambient temperature as an input parameter is carried out by the SHT11 sensor as shown in Figure 3. and the flowchart of the fuzzy rule algorithm is illustrated in Figure 4. In Table 1. it is explained that the input of the drying chamber is adjusted to the schedule. That way the kiln becomes integrated with an automatic system using electric heating. This option is also suitable for large capacity furnaces and in cases where the power supply is unstable (large voltage or current oscillations or frequent power outages during the winter period). Drying in this case is done in a conventional way, when during the day the electrical energy is only used for the flow fan.

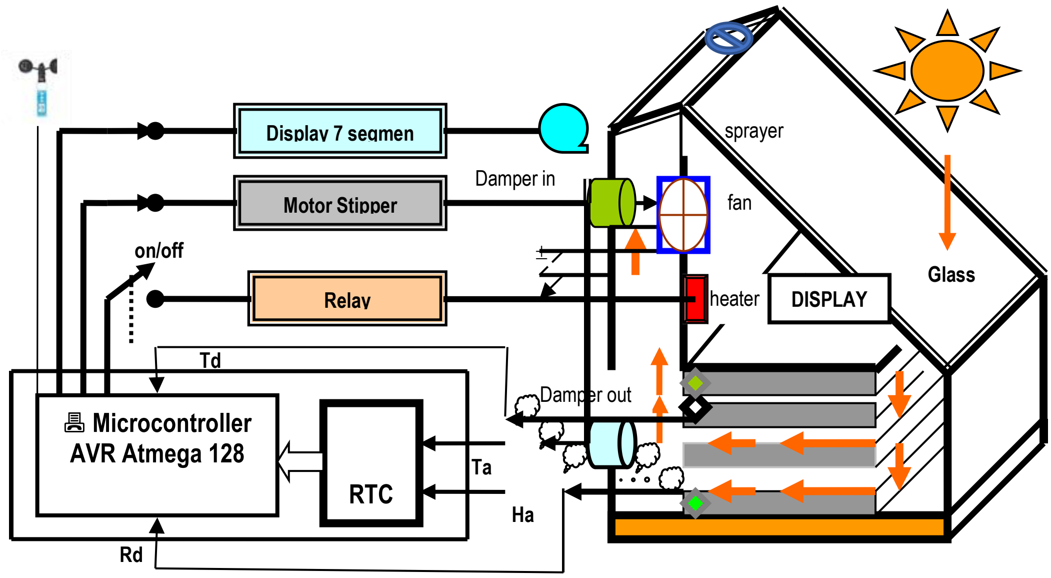

Figure.3. Automatic control system for coffee drying kiln prototype

Microcontroller AVR Atmega 128 has a capacity a big amount 128k flash, 53 pin I/O, 6 channel PWM and 8 channel 10-bit ADC; then to be used for application system control complex. Microcontroller AVR Atmega 128 is a microcontroller AVR Atmel 8 bit family, with specifications are

• 128 Kb Flash PEROM

• 4Kb EEPROM

• 4Kb SRAM

• On-chip Analog Comparator

• 8 Channel 10 bit ADC

• 2 8 bit PWM

• 6 PWM with programmable resolution (2-16 bit)

• Dual Programmable UART

• SPI Interface

• Programmable Watchdog with On Chip Oscillator

• Adjustable VREF ADC

• 53 bit I/O

• Power On Reset and Programmable Brown out detection

• Internal Calibrated RC Oscillator

• The pocket included the ISP cable, CD and RS232 cable

Anemometer

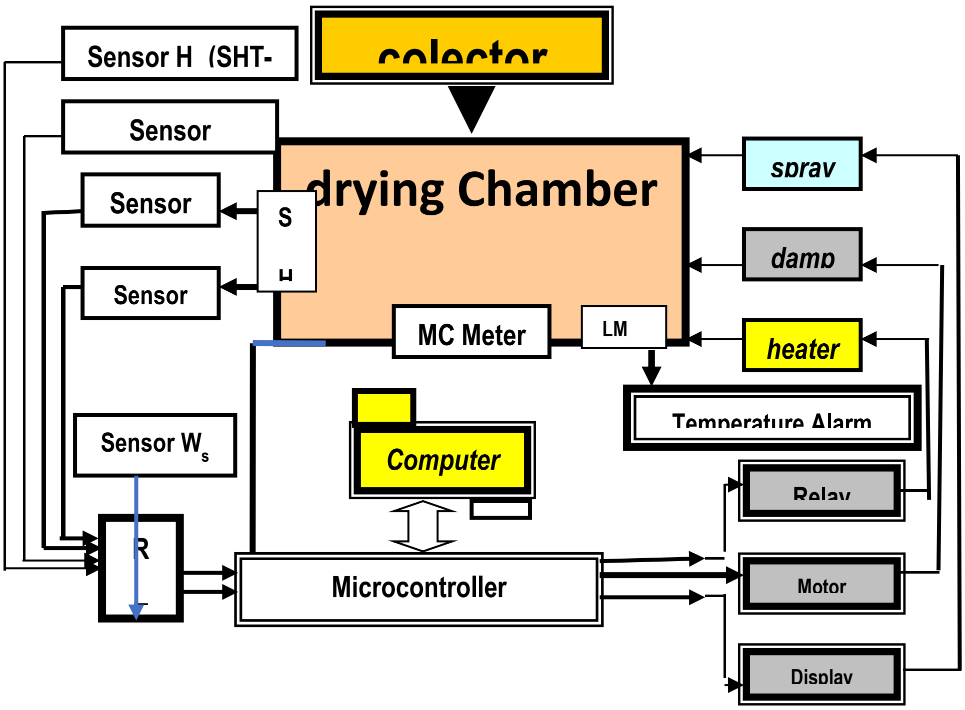

Figure 4. Schematic of the control system for the application of the fuzzy rule algorithm

The input parameters used for the fuzzy rule gloomy are shown in Table 1 . There are 5 parameters used, namely: drying temperature Td, drying chamber humidity Rd, ambient temperature Ta, ambient humidity Ha, and wind speed v. In particular, wind speed is a special consideration because it has 2 alternatives, namely above 2.8 m/s and below, thus adjusting for the use of the 16 output parameters according to Table 2 and Table 3.

Tabel 1. Parameter Input

No.	**Parameter's**	**Range**	**Describe**
1.	Temperature Drying Td	0 – 150 ^{0}C	
2.	Temperature Ambient Ta	0 – 150 ^{0}C	Weather
3.	Humidity Drying Rd	0 – 100 %	
4.	Humidity Ambient Ha	0 – 100 %	Conditions of air
5.	Wind speed Wd	0 – 10 m/s	

The higher the wind speed, the more energy is lost, and vice versa. So that the rules obtained will be different at high wind speeds and low wind speeds. This of course will affect the length of time the actuator works, where in terms of heating time the greater but the active damper time will be smaller, but for the sprayer it will remain. The effect of this wind speed can be seen in table 1 and table 2, how significant is the energy conversion required to increase the temperature of the drying chamber when the wind speed is high compared to the low wind speed. Each stage of the coffee drying schedule, the difference in solar radiation needs reaches 100 watt/m^2.

IV. Design Membership Functions

Design of membership function for variables in fuzzy logic implemented to map of typical of triangle and trapezium as of a drying schedule as shown in Figure 5. It's needed to implemented control system of wood drying chamber. Fuzzification of Membership Function in range [**0.5, 1**], and for weather (Temperature of Ambient Ta) with variable M: over-cloudy; B: cloudy; CB: bright-cloud; C: clear; SC : clearest

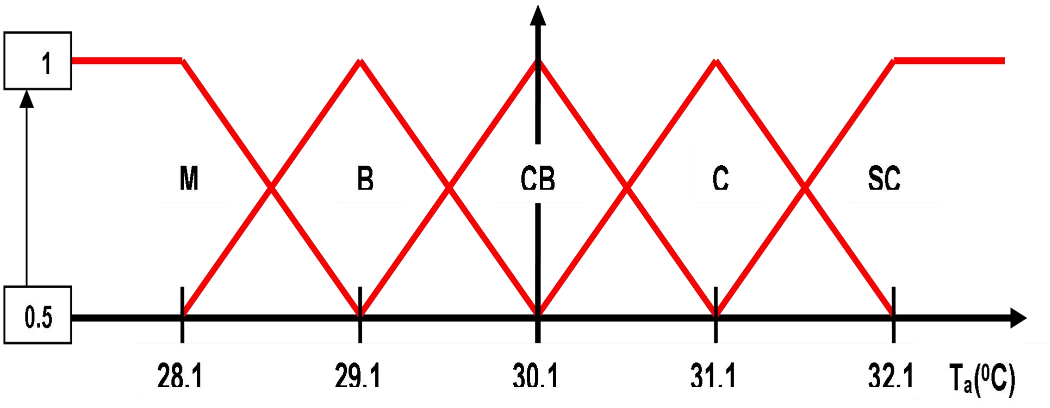

Figure. 5. Membership Function of temperature ambient

Change of temperature ambient design shown in figure 6. with: -H = - High, -M = -Medium, -S = - Small, Z = Zero, S = Small, M = Medium, H = High.

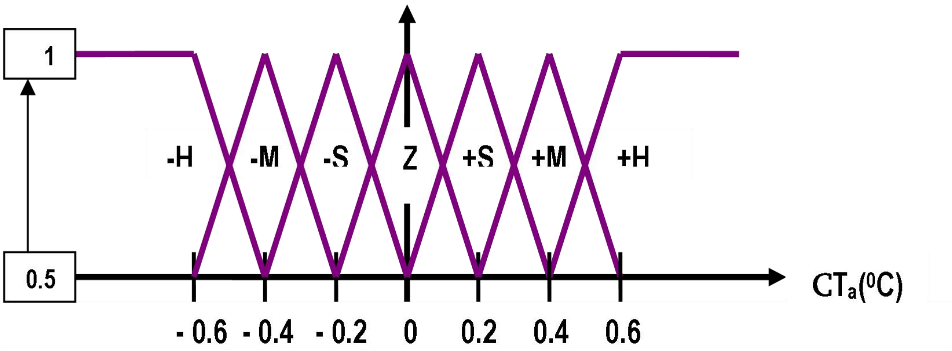

Figure. 6. Membership Function for change of temperature ambient

Computation process of variable change of temperature ambient are given eq.1. with n $\rightarrow$ 0 s/d ~

$$\mathbf{CTa\ [(n+1)T] = Ta[(n+1)T] - Ta[nT]} \qquad \mathbf{(1)}$$

Representative of weather is variable temperature ambient and this change used to maximize and to hoist responsibility of membership Function. Fuzzification of Membership Function in range [**0.5, 1**], and for conditions of air (Humidity of Ambient Ta) for set point temperature drying (Td) and Humidity drying (Rd) describe by Figure 7. with variable : P : Hot; AP : Rather-Hot; H : Swarm; S: Fresh; D : Cold.

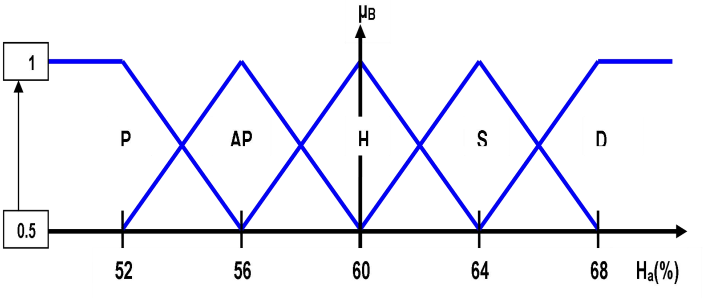

Figure. 7. Membership Function of humidity ambient

Change of humidity ambient design shown in Figure 8. with: -H = - High, -M = -Medium, -S = - Small, Z = Zero, S = Small, M = Medium, H = High. Computation Process of variable change of humidity ambient are given eq.2. with n $\rightarrow$ 0 to $\sim$

$$\mathbf{CHa\ [(n+1)T] = Ha[(n+1)T] - Ha[nT]} \qquad \mathbf{(2)}$$

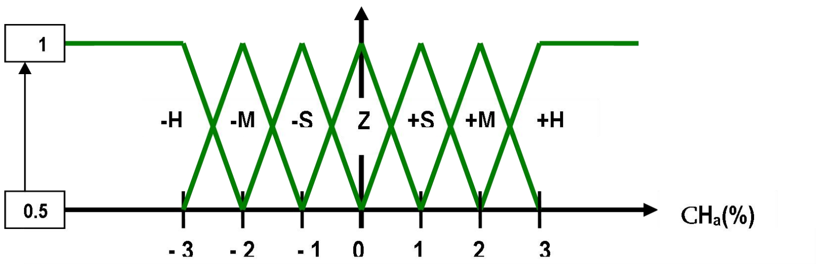

Figure. 8. Membership Function for change of humidity ambient.

Representative of conditions of air in variable humidity ambient and this change used to maximum of membership Function, with appropriate rule in a table look-up scheme, shown Table 2 and Tabel 3.

Tabel 2. Parameter ouput at implemented the SURAM's Fuzzy Rule algorithm for wind speed low

No.	**Rule**	**Actuator**			**Conditions**
		Heater	**Damper**	**Sprayer**	
1.	SUR-AM – 1	off	off	S	Lowering Drying Temperature Td and suddenly increasing Drying Chamber Humidity Rd [Heating Process]
2.	SUR-AM – 2	H	off	off	Increase Drying Temperature suddenly and decrease Drying Chamber Humidity Rd.

3.	SUR-AM – 3	H	D_3	off	To increase the temperature of the Drying Chamber Td and to hold the Humidity of the Drying Chamber Rd.
4.	SUR-AM – 4	H	D_2	S	Increasing Drying Temperature and Lowering Humidity Dryer Chamber Rd.
5.	SUR-AM – 5	H_1	D_3	off	To lower Drying Temperature Td and to maintain Drying Chamber Humidity Rd
6.	SUR-AM – 6	H_2	off	S	To lower the Drying Temperature Td and to lower the Drying Chamber Humidity Rd
7.	SUR-AM – 7	off	off	off	To maintain Drying Temperature Td and Drying Chamber Humidity Rd
8.	SUR-AM – 8	H	D_1	off	To maintain Drying Temperature Td and Adjust Drying Chamber Humidity Rd with Ambien Humidity Ha [Equalizing Process]

Note: D_1 : Damper ON : 3 minute H : Heater ON : 15 minute

D_2 : Damper ON : 2 minute H_1 : Heater ON : 10 minute

D_3 : Damper ON : 1 minute H_2 : Heater ON : 5 minute

S : Sprayer ON : 1 minute

Tabel 3. Parameter ouput at implemented the SURAM's Fuzzy Rule algorithm for wind speed high.

No.	**Rule**	**Actuator**			**Conditions**
		Heater	**Damper**	**Sprayer**	
1.	SUR-AM – 1	off	off	2S	Lowering Drying Temperature Td and suddenly increasing Drying Chamber Humidity Rd [Heating Process]
2.	SUR-AM – 2	2H	off	off	Increase Drying Temperature suddenly and decrease Drying Chamber Humidity Rd.
3.	SUR-AM – 3	2H	$0.5D_3$	off	To increase the temperature of the Drying Chamber Td and to hold the Humidity of the Drying Chamber Rd.
4.	SUR-AM – 4	2H	$0.5D_2$	2S	Increasing Drying Temperature and Lowering Humidity Dryer Chamber Rd.
5.	SUR-AM – 5	$2H_1$	$0.5D_3$	off	To lower Drying Temperature Td and to maintain Drying Chamber Humidity Rd
6.	SUR-AM – 6	$2H_2$	off	2S	To lower the Drying Temperature Td and to lower the Drying Chamber Humidity Rd
7.	SUR-AM – 7	off	off	off	To maintain Drying Temperature Td and Drying

					Chamber Humidity Rd
8.	SUR-AM – 8	2H	0.5D1	off	To maintain Drying Temperature Td and Adjust Drying Chamber Humidity Rd with Ambien Humidity Ha [Equalizing Process]

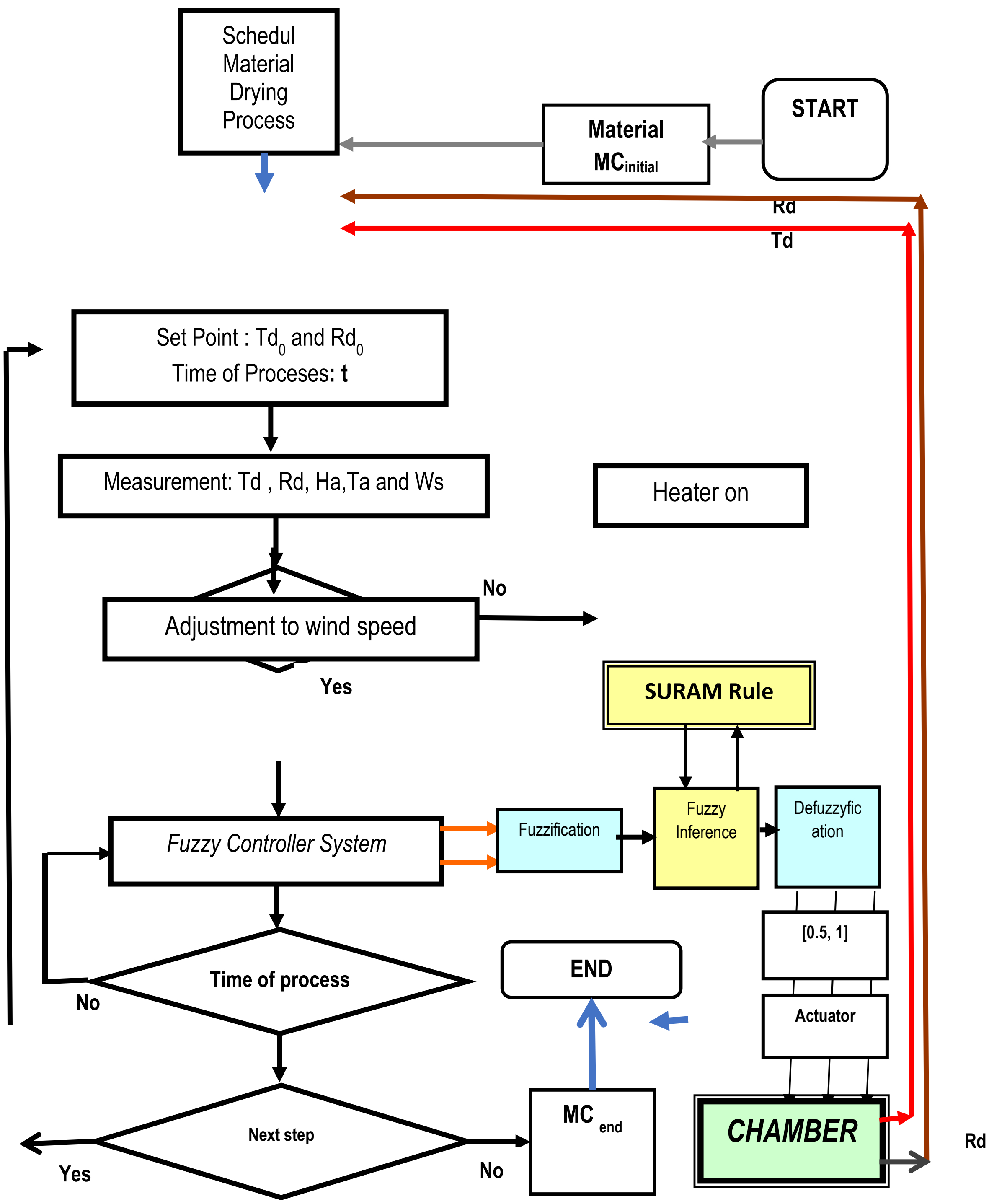

Figure 9. Flowchart Algorithm of SURAM's FUZZY RULE

Flowchart Algorithm of SFR for dryer is presented in Figure 9, starting with inputting the Moisture Content of of the material to be dried. With this moisture content value, it is adjusted to the drying schedule to get the initial value of the temperature of the Tdo coffee drying room and the initial humidity of the Rdo drying chamber. The sensor reads the required parameters including chamber drying Temperature Td, chamber humidity Rd, Ambien Temperature Ta, Ambien Humidity Ha, and wind speed at that time.

If the drying chamber temperature Td is smaller than Td_o, the heater is in the ON position, and if Td is greater than or equal to Tdo, then the wind speed is high or low. Furthermore, it is adjusted to the appropriate rules for treating the drying chamber, through a fuzzy computational process. The process continues if the processing time has not been reached and the process steps are carried out according to the drying schedule. The process will stop when the moisture content of the coffee is reached, or the drying step is complete.

V. Computation of SURAM's Fuzzy Rule

V.1. Look Up Tabel SFR

This SFR is a fuzzy logic-based rule containing weather conditions and air conditions which are implemented in the coffee drying process. Obtained 150 output control rules by utilizing fuzzy logic operators implemented in a solar coffee dryer, the performance of this fuzzy controller will optimize the use of solar energy, to minimize the consumption of electrical energy by the heater, according to wind speed. This control rule is needed to maintain a chamber condition according to the coffee drying schedule. To maximize the use of solar energy, it is necessary to have a control system that is responsive to changes in the amount of solar energy and environmental temperature. SURAM's Fuzzy Rule is able to optimize the use of solar energy and is responsive to changes. This process will provide hope for minimal use of electrical energy and the system will quickly respond to changes in environmental conditions.

The advantage of the SUR-AM Rule is that it reduces the time delay of the actuator response, where to activate the actuator it is not necessary to process the influence of solar energy on the temperature and humidity of the drying chamber and/or the effect on changes in moisture content. This is the intelligence of the fuzzy controller system so that the coffee drying process can be maintained at the expected conditions

For computation of the fuzzy rule suram, it begins by entering the initial value of the water content in MC coffee = 54%. According to the drying schedule, the drying chamber temperature is set at Td_o = 60 ^oC and the humidity in the drying room is Rdo = 65% and wind speed = 1.2 m/s. Furthermore, the measurement data showed that the ambient temperature Ta = 29.2 ^oC, Humidity ambient Ha = 64%. In the next measurement, it was obtained that Ta (n + 1) = 29,6 ^oC and Ha (n + 1) = 64.2%, where measurements are carried out every 5 minutes.

From equation (1), it is found that the change in the ambient temperature value is CTa(n+1) = Ta(n+1) - Ta = 29.6 - 29.2 = 0.4 oC. From Figure 6, it is found that there are two membership values of Ta = 29.2, namely cloudy: B and CB: clear clouds, respectively: μ_B = 0.9 and μ_{CB} = 0.1, according to Figure 3. Similarly, the change is CTa = 0.8 ^oC according to Figure 7, Ha = 64% is at S = Fresh with a membership value of μ_S = 1.0 and the change in humidity CHa = 0.2% is at μ_z = 0.8 and μ_s = 0.2.

From Table 3 it is obtained with conditions B = 0.9 and CB = 0.1 at the position of change + M, then the weather conditions are Claud with membership value = 0.9 and Bright Claud = 0.1. Likewise for the air condition in table 4. stated in the Fresh state with a maximum membership value of 0.8. And the possibilities that occur from each combination of weather conditions and air conditions are stated in Table 4, Table 5, and Table 6.

Tabel 4. Implementation of SURAM's Fuzzy Rule on Condition : Td [(n+1)] < Td0

N0.	IF ……	AND ……	AND weather conditions is	AND air conditions is .	THEN OUTPUT is …
1	T_d [(n+1)] < Td_0	R_d [(n+1)] > Rd_0	Over-Claud	Hot	SUR-AM – 2
2				Rather Hot	SUR-AM – 2
3				Swam	SUR-AM – 2
4				Fresh	SUR-AM – 2
5				Cold	SUR-AM – 2
6			*Claud*	Hot	SUR-AM – 2
7				Rather Hot	SUR-AM – 2
8				Swam	SUR-AM – 2
9				Fresh	SUR-AM – 2

10				Cold	SUR-AM – 2
11			*Bright-Claud*	Hot	SUR-AM – 2
12				Rather Hot	SUR-AM – 2
13				Swam	SUR-AM – 2
14				Fresh	SUR-AM – 2
15				Cold	SUR-AM – 2
16			Clear	Hot	SUR-AM – 3
17				Rather Hot	SUR-AM – 2
18				Swam	SUR-AM – 2
19				Fresh	SUR-AM – 2
20				Cold	SUR-AM – 2
21			clearest	Hot	SUR-AM – 3
22				Rather Hot	SUR-AM – 3
23				Swam	SUR-AM – 2
24				Fresh	SUR-AM – 2
25				Cold	SUR-AM – 2
26		R_d [(n+1)] ≤ Rd_0	Over-Claud	Hot	SUR-AM – 3
27				Rather Hot	SUR-AM – 3
28				Swam	SUR-AM – 3
29				Fresh	SUR-AM – 3
30				Cold	SUR-AM – 3
31			Claud	Hot	SUR-AM – 3
32				Rather Hot	SUR-AM – 3
33				Swam	SUR-AM – 3
34				Fresh	SUR-AM – 3
35				Cold	SUR-AM – 3
36			Bright-Claud	Hot	SUR-AM – 4

37				Rather Hot	SUR-AM – 4
38				Swam	SUR-AM – 3
39				Fresh	SUR-AM – 3
40				Cold	SUR-AM – 3
41			Clear	Hot	SUR-AM – 4
42				Rather Hot	SUR-AM – 4
43				Swam	SUR-AM – 4
44				Fresh	SUR-AM – 3
45				Cold	SUR-AM – 3
46			clearest	Hot	SUR-AM – 4
47				Rather Hot	SUR-AM – 4
48				Swam	SUR-AM – 4
49				Fresh	SUR-AM – 3
50				Cold	SUR-AM – 3

Tabel 5. Implementation of SURAM's Fuzzy Rule on Condition T_d [(n+1)] = Td_0

N0.	IF ……	AND ……	AND weather conditions is …	AND air conditions is ..	THEN OUTPUT is....
N0.	**IF ……**	**AND ……**	**AND Keadaan Cuaca is ….**	**AND Kondisi Udara is …..**	**THEN OUTPUT is …..**
1.	T_d [(n+1)] = Td_0	R_d [(n+1)] > Rd_0	Over-Claud	Hot	SUR-AM – 2
2				Rather Hot	SUR-AM – 2
3				Swam	SUR-AM – 2
4				Fresh	SUR-AM – 2
5				Cold	SUR-AM – 2
6			Claud	Hot	SUR-AM – 2
7				Rather Hot	SUR-AM – 2

8				Swam	SUR-AM – 2
9				Fresh	SUR-AM – 2
10				Cold	SUR-AM – 2
11			Bright-Claud	Hot	SUR-AM – 3
12				Rather Hot	SUR-AM – 3
13				Swam	SUR-AM – 2
14				Fresh	SUR-AM – 2
15				Cold	SUR-AM – 2
16			Clear	Hot	SUR-AM – 3
17				Rather Hot	SUR-AM – 3
18				Swam	SUR-AM – 3
19				Fresh	SUR-AM – 2
20				Cold	SUR-AM – 2
21			clearest	Hot	SUR-AM – 3
22				Rather Hot	SUR-AM – 3
23				Swam	SUR-AM – 3
24				Fresh	SUR-AM – 2
25				Cold	SUR-AM – 2
26		R_d [(n+1)] ≤ Rd_0	Over-Claud	Hot	SUR-AM – 3
27				Rather Hot	SUR-AM – 3
28				Swam	SUR-AM – 3
29				Fresh	SUR-AM – 3
30				Cold	SUR-AM – 3
31			Claud	Hot	SUR-AM – 3
32				Rather Hot	SUR-AM – 3
33				Swam	SUR-AM – 3
34				Fresh	SUR-AM – 3

35				Cold	SUR-AM – 3
36			Bright-Claud	Hot	SUR-AM – 6
37				Rather Hot	SUR-AM – 6
38				Swam	SUR-AM – 3
39				Fresh	SUR-AM – 3
40				Cold	SUR-AM – 3
41			Clear	Hot	SUR-AM – 6
42				Rather Hot	SUR-AM – 6
43				Swam	SUR-AM – 3
44				Fresh	SUR-AM – 3
45				Cold	SUR-AM – 3
46			clearest	Hot	SUR-AM – 6
47				Rather Hot	SUR-AM – 6
48				Swam	SUR-AM – 6
49				Fresh	SUR-AM – 3
50				Cold	SUR-AM – 3

Tabel 6.. Implementation of SURAM's Fuzzy Rule on Condition : T_d [(n+1)] > Td_0

N0.	IF ……	AND ……	AND weather conditions is …	AND air conditions is …	THEN OUTPUT is ……
1	T_d [(n+1)] >Td_0	R_d [(n+1)] > Rd_0	Over-Claud	Hot	SUR-AM – 2
2				Rather Hot	SUR-AM – 2
3				Swam	SUR-AM – 2
4				Fresh	SUR-AM – 2
5				Cold	SUR-AM – 2
6			Claud	Hot	SUR-AM – 2
7				Rather Hot	SUR-AM – 2

8				Swam	SUR-AM – 2
9				Fresh	SUR-AM – 2
10				Cold	SUR-AM – 2
11			Bright-Claud	Hot	SUR-AM – 5
12				Rather Hot	SUR-AM – 5
13				Swam	SUR-AM – 2
14				Fresh	SUR-AM – 2
15				Cold	SUR-AM – 2
16			Clear	Hot	SUR-AM – 5
17				Rather Hot	SUR-AM – 5
18				Swam	SUR-AM – 5
19				Fresh	SUR-AM – 2
20				Cold	SUR-AM – 2
21			Sangat Cerah	Panas	SUR-AM – 5
22				Agak Panas	SUR-AM – 5
23				Hangat	SUR-AM – 5
24				Sejuk	SUR-AM – 2
25				Dingin	SUR-AM – 2
26		R_d [(n+1)] ≤ Rd_0	Over-Claud	Hot	SUR-AM – 3
27				Rather Hot	SUR-AM – 3
28				Swam	SUR-AM – 3
29				Fresh	SUR-AM – 3
30				Cold	SUR-AM – 3
31			Claud	Hot	SUR-AM – 3
32				Rather Hot	SUR-AM – 3
33				Swam	SUR-AM – 3
34				Fresh	SUR-AM – 3

35				Cold	SUR-AM – 3
36			Bright-Claud	Hot	SUR-AM – 6
37				Rather Hot	SUR-AM – 6
38				Swam	SUR-AM – 6
39				Fresh	SUR-AM – 7
40				Cold	SUR-AM – 7
41			Clear	Hot	SUR-AM – 6
42				Rather Hot	SUR-AM – 6
43				Swam	SUR-AM – 6
44				Fresh	SUR-AM – 7
45				Cold	SUR-AM – 7
46			clearest	Hot	SUR-AM – 6
47				Rather Hot	SUR-AM – 6
48				Swam	SUR-AM – 6
49				Fresh	SUR-AM – 7
50				Cold	SUR-AM – 7

From the computational results it is obtained that the output used is the treatment of the actuator is Rule Suram 2, according to Table 4. Furthermore, from Table 4 that the Rule Suram 2 is Heater ON, Damper OFF, and Sprayer OFF, the meaning is Increase Drying Temperature suddenly and decrease Drying Chamber Humidity Rd. And From equation 1, the required solar energy is: Io = 617+9.7(Tdo-45) (watt/m2) = 617 + 9.7 (60 - 45) = 617 + 145.5 = 762.5 Watt/ m^2.

V.2. Experiment Result

The measurement was carried out in Kampung Salaon-dolok, Samosir Island, North Sumatra, Indonesia, as a coffee-producing area on Monday, April 12, 2021, at: 10.30 WIB. The prototype was prepared for the drying process of 100 kg of coffee with an average moisture content of 54.75%. Initial conditions: Initial temperature: 29.2 ^{o}C and humidity of 64%. The drying process is carried out for 7 full days, so that the drying process is completed on Monday, April 19, 2021 at 7.30 WIB.

Parameter measurement results are presented in Figure 10. namely Coffee Moisture Content, Drying Chamber Temperature, Humidity Chamber, every 5 minutes.

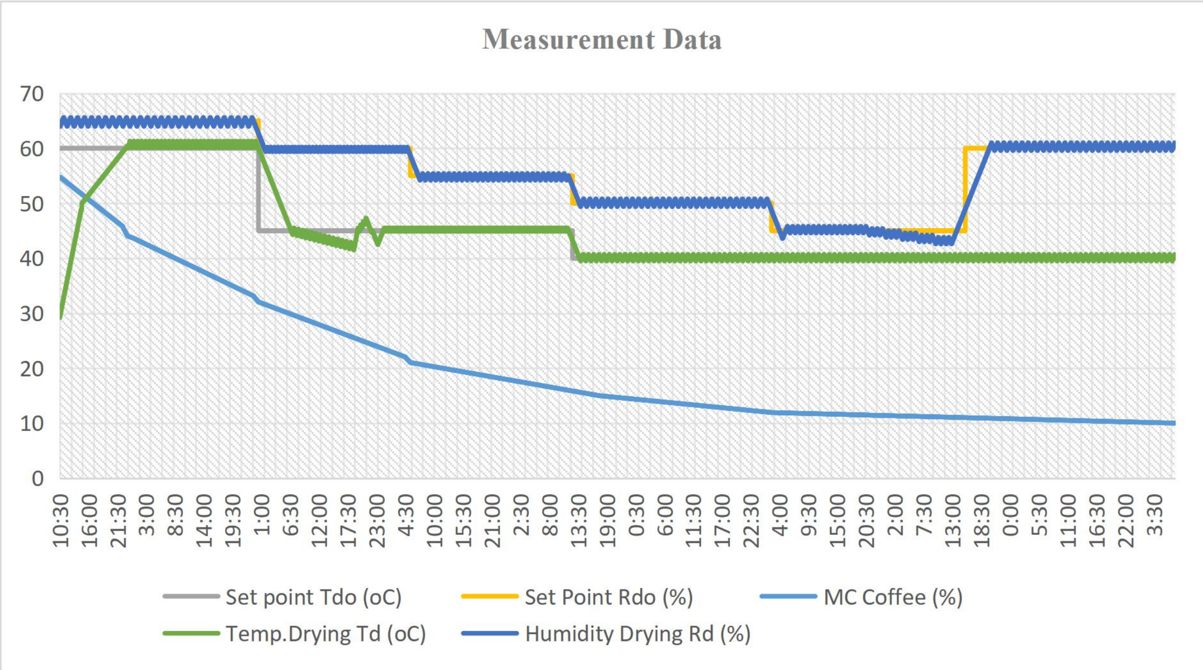

Figure 10. Measurement results: Moisture Content of MC coffee, Temperature Drying, and Humidity Drying on 12 to 19 April 2021

From the measurement results, it is shown that the Fuzzy Rule Suram algorithm is able to follow the coffee drying schedule. It is also shown that the dried coffee reaches the average Moisture content of coffee MC = 10%.

The results of measurements of solar energy in the coffee drying process on 12 to 19 April 2021 are presented in Figure 11, showing that the solar energy used is 40, 86% of the total energy requirement. Solar energy is utilized maximally during the day and at night using a heater using electrical energy. For further development, a solar energy storage system is needed, so that it can be utilized at night.

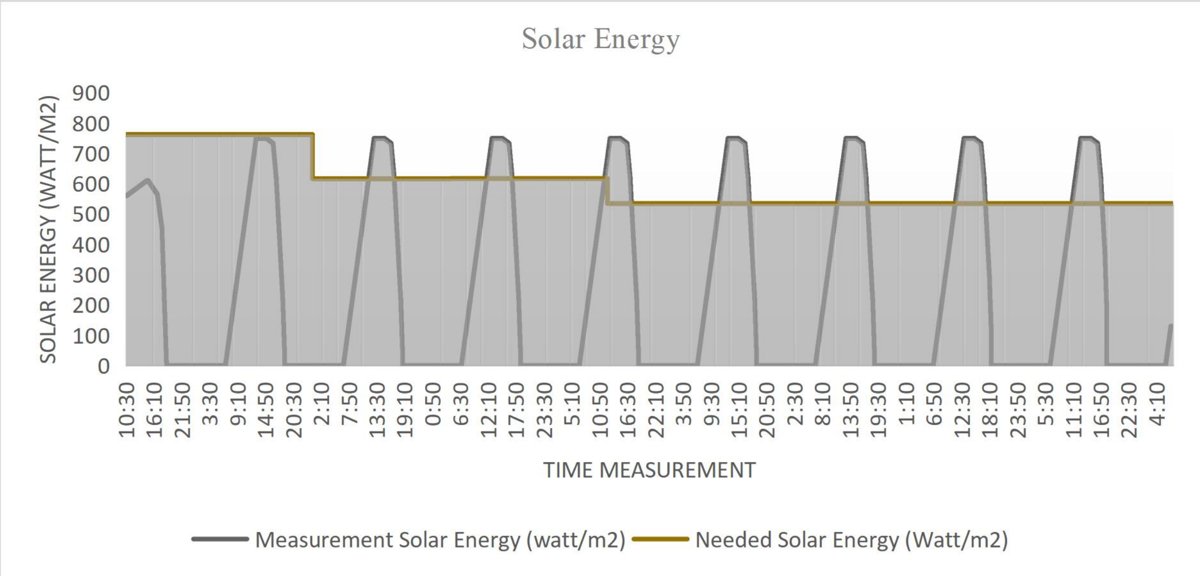

Figure 11. Measurement results of solar energy in the coffee drying process on 12 to 19 April 2021

VI. CONCLUSION

The Fuzzy Rule Suram Algorithm in the coffee drying process is based on fuzzy logic with modified membership functions in the range [0.5, 1] on the parameters of weather conditions and air conditions in the form of ambient temperature and ambient humidity. In the computational process of this algorithm, 16 fuzzy rules to control the output system can be built which consist of 8 rules each for conditions of high wind speed above 2.8 m/s, and low wind speed. There are 3 x 50 treatments for the heater actuator, damper and sprayer, based on the real humidity conditions of the drying room and the humidity according to the drying schedule.

From the results of the implementation on the prototype of this coffee dryer, the utilization of solar energy is 40.86% of the required energy, this is due to the acceleration of the drying process day and night continuously, but can save processing time from 21 days to 7 days.

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