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Single Slope Single Basin Solar Still Using Fuzzy Logic

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Abstract:*Solar energy is a non-conventional source of energy widely used in many areas like electricity, cooking, transportation, electronic devices etc. Seventy five percent of Globe is cover with water but drinking water is serious problem in developing countries. To resolve shortage of potable water, planning commission as well as government of under developed countries made efforts in so many ways. Awareness programs to "Save Water" by Government in collaboration with NGOs are running. Nowa day's Single Basin Solar Still is a very simple device used for converting waste water into potable water. There are so many modifications made by researchers to improve the efficiency and capacity of this device. The aim of this paper is to study the effect of various parameters on Performance of single slope single Basin solar still using Fuzzy logic. In this paper an attempt has been made to predict the effect of parameters solar radiation and water temperature (as input) on Distillated yield and instantaneous efficiency (as output) using George Viot's Fuzzy Cruise Controller.*

Keywords: *Fuzzy Controller, Solar Still, Cruise Controller, MATLAB*

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I. Introduction

Solar still is a simple solar device that is used to converting available saline water in drinkingwatersolar still is used in areas where drinking water is unavailable. Shortage for potable water exists in many countries. Solar still is the only efficient solution for water problem in hot climatic conditional areas where there is scarceness of water and electrical energy.

Single slope single basin solar stillconsists of outer and inner enclosure made of plywood with dimension of 1.3 x 1.3 m and 1.25 x 1.25m. The gap between the enclosures is filled with glass wool having the thermal conductivity of 0.0038 W/mK (unit of thermal conductivity). The height of the back wall is 0.03m and front wall of 0.10m. The glass cover of thickness 4 mm is used as the condensing surface and the slope of the glass cover are fixed as 11° which is equal to the latitude of the location. The still is made vapor tight with the help of metal putty. The j-shaped drainage channel is fixed near the front wall to collect the distillate yield and the output trickled down to the measuring jar. The basin of the still is made of G.I. sheet and a thin copper sheet is pasted in the basin and painted black to absorb more solar radiation. A special arrangement has been made to pour saline water drop by drop in the basin to maintain least water depth. The arrangement is made of heat resistant pipes with drip button fixed at regular intervals of 0.10m horizontally in the basin. The basin temperature, saline water temperature, condensing cover temperature of the still has been measured by fixing copper constantan thermocouples which has been calibrated initially. Solar radiation intensity and ambient temperature have been measured with solar radiation monitor and digital thermometer.

Rajanarthini et. al [4]. Worked on Double Slope Wick – Type Solar Still Fuzzy Set, in this paper an attempt has been made to predict the effect of different parameters on the productivity of a double slope wick - type solar still by using fuzzy set technique. From this study it has been found that the various parameter that influence the performance of active and passive solar stills. The result of the study has induced to give the highest priority for the enhancement of the still production.

Shanmugan, [1] discussed on Fuzzy logic modeling of floating cum tilted – wick solar still. In this research article fuzzy logic modeling and simulation of a floating cum tilted – wick solar still has been developed it makes transparent to qualitative interpretation and analysis. Different fuzzy rules have been developed based on general analogy applied between the changes in solar radiation intensity, yield of distillate output subsequent change in the weak and glass temperature of the still.

KalidasaMurgavel et. al. [3] workedon, Progress in improving the effectiveness of the single basin passive solar still, authors review the work different researchers on effectiveness of the single basin passive solar still and compare their performances. They also suggested method for improving the effectiveness for different solar radiation conditions.

Panchal [5] made study on, Effect of different parameter on double slope solarstillproductivity. In his study author observe that single basin solar still which is earlier used for converting available brackish or waste water into potable water is not popularly used because of its low productivity. The aim of his study is to find the effect of various parameters on performance of double slope solar still by using water depth inside the solar still, sprinkler and various dies. Author proved that black die will increase the effective output of the solar still, sprinkler increase the condensation rate and lower depth of water level increase the productivity of solar still. He observes that effective parameters on performance of solar still. Black die is a good parameter to increase the distilled output of solar still and decrease in water depth can increase the productivity of solar still is proved by experiment.

Shanmugam et al. [2] discussed on Fuzzy logic modeling of single slope single basin solar still, in this paper author developed the thermal analysis of single slope single basin solar still with fuzzy logic modeling and simulation. Experimental observation for his study Experimental observation have been carried out on 9 May 2012 in Dhanalakshmi college of EngineeringChennaiTamilnadu. Qualitative interpretation and different fuzzy rule have beendeveloped based on general analogy applied between change solar radiation intensity, yield of distilled output Mamdani model has been used to predict a distillate output for the same day.

In this paper we use experimental observation of Shanmugan et al [2] to predict distillate output and Instantaneous Efficiency. We apply G.V. Cruise Controller for fuzzification by giving membership value to linguistic term Low, Normal, High. Our work provides output Distilled Yield and Instantaneous Efficiency of solar still for two inputs namely Solar Radiation and Water Temperature. Section 2. Material and Methods the fuzzy cruise controller and rule base with basic concepts used in this paper. Section 3. Results and Discussion explain the solution of problem taken by Shanmugan et al [2] by replacing only two variable inputs Solar Radiation I(t) and Water Temperature (T_w) with Speed Difference and Acceleration in G -V Cruise Controller respectively obtain output, Instantaneous Distillates(D) and Instantaneous Efficiency (I_e) similar to Throttle Control.

II. Materials and Method

2.1Fuzzy set: If χ is a collection of objects universe of discourse , then fuzzy set denoted by$\tilde{A}$ is a set of ordered pairs$(x, u_{\tilde{A}}(x)|\forall x \in X\}$ where$u_{\tilde{A}}(x)$ is called the membership function or grade belongingness of x in $\tilde{A}$.

2.2Fuzzy Logic: Fuzzy logic is a form of many-valued logic in which the truth values of variables may be [0,1]. It is employed to handle the concept of partial truth, where the truth value may range between completely true and false. By contrast, in crisp logic, the truth values of variables may be the either true or false.

2.3Fuzzy Rule Based System: Fuzzy linguistic description is formal representation of system model through IF – THAN rules. They encode knowledge about system in statement of the form.
IF (set of conditions) are satisfied THEN (a set of subsequent) can be inferred.

2.4Fuzzification and Defuzzification: Fuzzificationis process of making a quantity fuzzy by membership functionand defuzzification is the reverse process of fuzzification i.e. Conversion of fuzzy quantity into single crisp value. There are following methods used for defuzzification.

a) Center of sums Method
b) Mean of Maxima Method
c) Center of Maxima Method
d) Weighted Average Method
e) Center of Gravity Method is one of the popular method which used widely for defuzzification

2.6Greg Viot's Fuzzy Cruise Systems: G –V controller is used to maintain a vehicle at a desired speed this system consists of two fuzzy inputs namely speed difference and acceleration and one fuzzy output, namely throttle control. it is shown in figure2.1.

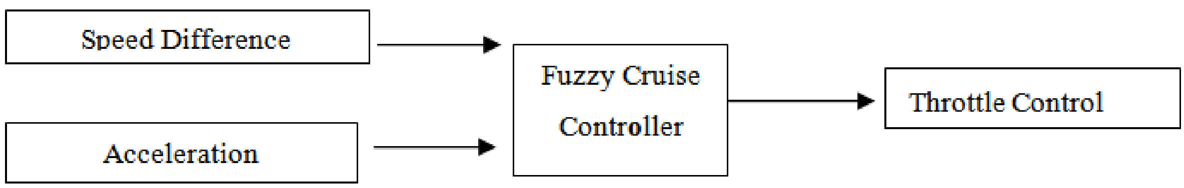

Fig: 2.1

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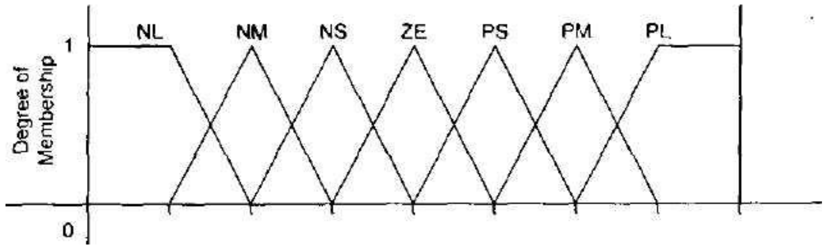
Fuzzy set considered in G- V Cruise Controller for two input variable and output is given in figure 2.2 Where ZE = Zero, PS, PM, PL are positively small, medium and large respectively also NS, NM and NL represent negatively small, medium and large respectively.



31 63 95 127 159 191 223 255

Fig: 2.2

Degree of Membership for fuzzy set of input and output is calculated by membership Function given below

$$\text{Degree of membership} = \begin{cases} = 0 \quad \text{if (Delta} < 0\text{)or (Delta } \leq 0\text{)} \\ = \min\begin{pmatrix}\text{Delta } 1 * \text{slope } 1 \\ \text{Delta } 2 * \text{slope } 2\end{pmatrix} \text{ otherwise} \end{cases}$$

Where Delta 1 = x - point 1, Delta 2 = point 2 – x

Rule base consider in this controller are given in Table 2.1

Table 2.1 Rule base in G-V Cruise controller

Rule l	If (speed difference is NL) and (acceleration is ZE) then (throttle control is PL)
Rule 2	If (speed difference is ZE) and (acceleration is NL) then (throttle control is PL)
Rule 3	If (speed difference is NM) and (acceleration is ZE) then (throttle control is PM)
Rule 4	If (speed difference is NS) and (acceleration is PS) then (throttle control is PS)
Rule 5	If (speed difference is PS) and (acceleration is NS) then (throttle control is NS)
Rule 6	If (speed difference is PL) and (acceleration is ZE) then (throttle control is NL)
Rule 7	If (speed difference is ZE) and (acceleration is NS) then (throttle control is PS)
Rule 8	If (speed difference is ZE) and (acceleration is NM) then (throttle control is PM)

2.7 **Single Basin Solar Still:** A simple device that used to convert available saline water in drinking water. Schematic Photograph of thesolar still is set at Research Center of Physics, Dhanalakshmi College Engineering, Chennai, Tamilnadu, India. See figure 2.3

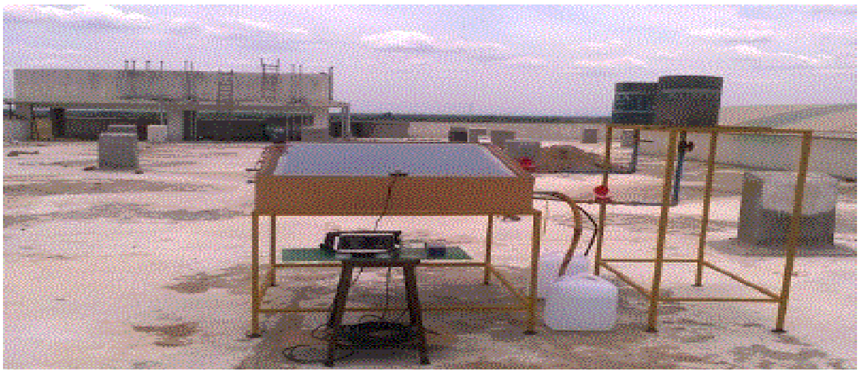


Fig 2.3

III. Results and Discussion

Using above mention devicefigure 2.3 Shanmugan[2] carried out an experiment from, 6:00AM to 6:00 AM 24hrs duration (9th May 2012). The amount of the distillate yields, and instantaneous efficiency derived using different values of solar radiation intensity and Water temperaturein the observation table 3.1.

To predict the amount of distillate output and instantaneous efficiency, using G -V Cruise Controller by considering Solar Radiation and Water Temperature as fuzzy input and Distilled Yield,Instantaneous Efficiencyas fuzzy output shown in figure 3.1(a), 3.1(b) respectively.

Table 3.1: Experimental Observations on 9 th May 2012.

Basin Temp. (^{0}C)	Water Temp (^{0}C)	Glass Temp (^{0}C)	Solar Radiation (W/m^2)	Distilled water yield	Instantaneous Efficiency (%)
				Experimental	Experimental
43	41	37	426	0.058	16.87
45	44	41	467	0.082	23.14
51	46	44	627	0.124	30.16
52	48	46	784	0.254	41.23
55	50	49	844	0.280	42.36
60	54	49	892	0.340	47.81
62	59	53	997	0.384	52.35
67	59	58	1076	0.476	59.48
71	65	63	1089	0.570	69.74
76	70	67	1089	0.610	74.85
72	65	64	1010	0.512	69.74
67	62	58	974	0.490	63.14
63	56	53	855	0.420	56.57
60	53	49	839	0.374	51.26
53	46	44	724	0.314	46.54
51	46	43	611	0.276	42.65
47	44	39	499	0.252	39.87

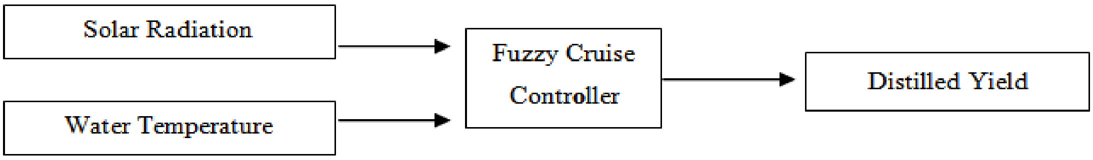


Fig: 3.1(a)

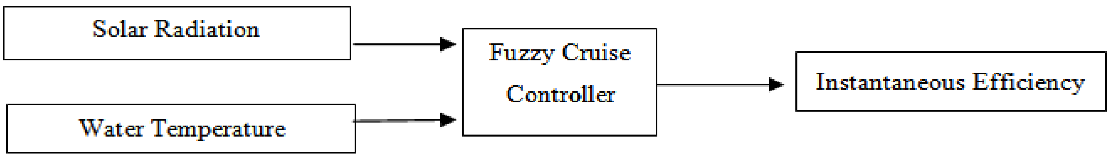


Fig: 3.1(b)

In observation table 3.1 we divide input variable in three linguistic terms Low Normal and High as given table 3.2.

Table 3.2

S.No	Linguistic Terms	Input Range		Output Range	
		I (t)	T_w	D	I(e)
1	Low	426 – 757.5	41-55.5	0.058-0.334	16.87-45.86
2	Normal	591.75-923.25	48.25-62.75	0.196-0.472	31.365-60.355
3	High	757.5 -1089	55.5-70	0.334-0.610	45.86-74.85

Denoting membership function μ_L, μ_N, μ_H to linguistic terms Low Normal and High, for input and output are given in table 3.3(a), (b), (c),(d) respectively.

3.3(a) Input Solar Radiation I(t)

$\mu_L(x) = \begin{cases} 0 & \text{when } x \le 426 \\ \frac{(x-426)}{165.75} & \text{when } 426 \le x \le 591.75 \\ \frac{757.5-x}{165.75} & \text{when } 591.75 \le x \le 757.5 \\ 1 & x = 591.75 \end{cases}$	$\mu_N(x) = \begin{cases} 0 & \text{when } x \le 591.75 \\ \frac{(x-591.75)}{165.75} & \text{when } 591.75 \le x \le 757.5 \\ \frac{923.25-x}{165.75} & \text{when} 757.75 \le x \le 923.25 \\ 1 & x = 757.5 \end{cases}$	$\mu_H(x) = \begin{cases} 0 & \text{when } x \le 757.5 \\ \frac{(x-757.5)}{165.75} & \text{when } 757.5 \le x \le 923.25 \\ \frac{(1089-x)}{165.75} & \text{when } 923.25 \le x \le 1089 \\ 1 & x = 923.25 \end{cases}$

3.3(b) Input Water Temperature: (T_w)

$\mu_L(x)=\begin{cases} 0 & \text{when } x \le 41 \\ \frac{(x-41)}{7.25} & \text{when } 41 \le x \le 48.25 \\ \frac{(55.5-x)}{7.25} & \text{when } 48.25 \le x \le 55.5 \\ 1 & x = 48.25 \end{cases}$	$\mu_N(x)=\begin{cases} 0 & \text{when } x \le 48.25 \\ \frac{(x-48.25)}{7.25} & \text{when } 48.25 \le x \le 55.5 \\ \frac{(62.75-x)}{7.25} & \text{when } 55.5 \le x \le 62.75 \\ 1 & x = 55.5 \end{cases}$	$\mu_H(x)=\begin{cases} 0 & \text{when } x \le 55.5 \\ \frac{(x-55.5)}{7.25} & \text{when } 55.5 \le x \le 62.75 \\ \frac{(70-x)}{7.25} & \text{when } 62.75 \le x \le 70 \\ 1 & x = 62.75 \end{cases}$

3.3(c) Output Distilled Water Yield: (D)

$\mu_L(x)=\begin{cases} 0 & \text{when } x \le 0.058 \\ \frac{(x-0.058)}{0.138} & \text{when } 0.058 \le x \le 0.196 \\ \frac{(0.334-x)}{0.138} & \text{when } 0.0196 \le x \le 0.334 \\ 1 & x = 0.196 \end{cases}$	$\mu_N(x)=\begin{cases} 0 & \text{when } x \le 0.196 \\ \frac{(x-0.196)}{0.138} & \text{when } 0.196 \le x \le 0.334 \\ \frac{(0.472-x)}{0.138} & \text{when } 0.334 \le x \le 0.472 \\ 1 & x = 0.334 \end{cases}$	$\mu_H(x)=\begin{cases} 0 & \text{when } x \le 0.334 \\ \frac{(x-0.334)}{0.138} & \text{when } 0.334 \le x \le 0.472 \\ \frac{(0.610-x)}{0.138} & \text{when } 0.472 \le x \le 0.610 \\ 1 & x = 0.472 \end{cases}$

3.3(d) Output Instantaneous efficiency: I(e)

$\mu_L(x)=\begin{cases} 0 & \text{when } x \le 16.87 \\ \frac{(x-16.87)}{14.495} & \text{when } 16.87 \le x \le 31.365 \\ \frac{(45.86-x)}{14.495} & \text{when } 31.365 \le x \le 45.86 \\ 1 & x = 31.365 \end{cases}$	$\mu_N(x)=\begin{cases} 0 & \text{when } x \le 31.365 \\ \frac{(x-31.365)}{14.495} & \text{when } 31.365 \le x \le 45.86 \\ \frac{(60.355-x)}{14.495} & \text{when } 45.86 \le x \le 60.355 \\ 1 & x = 45.86 \end{cases}$	$\mu_H(x)=\begin{cases} 0 & \text{when } x \le 45.86 \\ \frac{(x-45.8)}{14.495} & \text{when } 45.86 \le x \le 60.355 \\ \frac{(74.85-x)}{144.95} & \text{when } 60.355 \le x \le 74.85 \\ 1 & x = 60.355 \end{cases}$

3.1Fuzzy sets for input and output are given in figure 3.2(a),(b), (c),(d) respectively

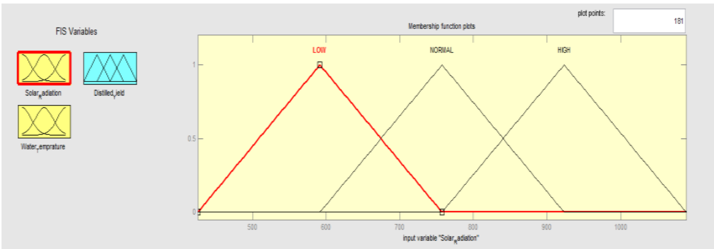


Fig 3.2(a)Solar Radiation I(t)

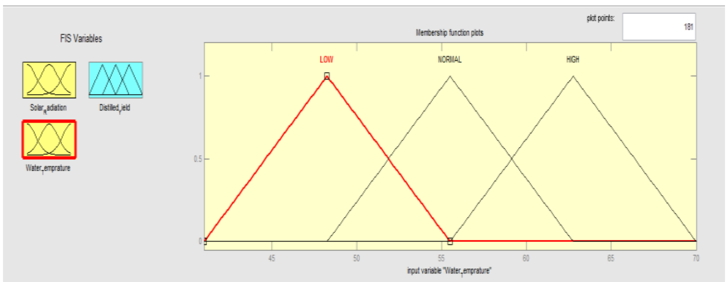


Fig3.2 (b): Water Temperature (T_w)

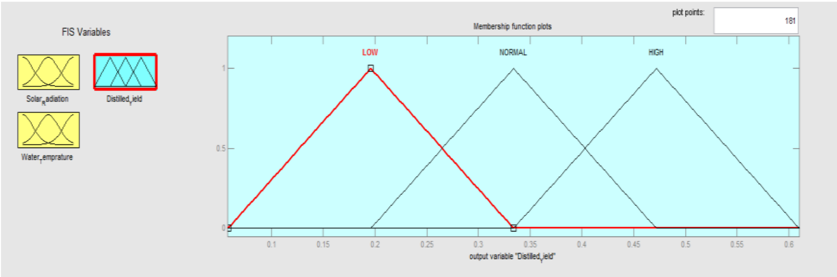


Fig3.2(c) Distilled water yield (D)

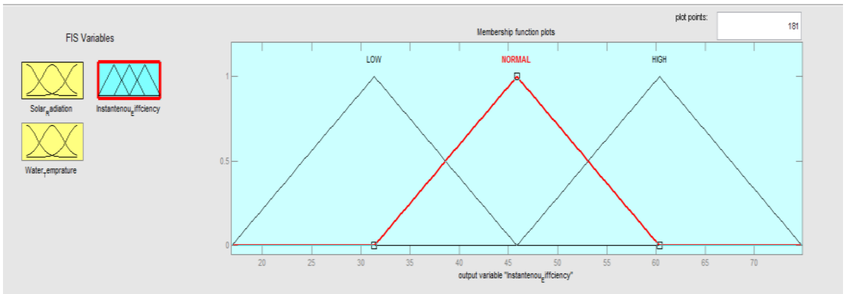


Fig 3.2(d): Instantaneous efficiency I(e)

3.2 Fuzzy rule framed in which our study considered as given below

(a)Fuzzy Rulesfor distillated yield (D)

Rule 1	IF (Solar radiation is Low) AND (Water temperature is Low) THEN (Distillated Yield is Low)
Rule 2	IF (Solar radiation is Low) AND (Water temperature is Normal) THEN (Distillated Yield is Low)
Rule 3	IF (Solar radiation is Low) AND (Water temperature is High) THEN (Distillated Yield is Low)
Rule 4	IF (Solar radiation is Normal) AND (Water temperature is Normal) THEN (Distillated Yield is Normal)
Rule 5	IF (Solar radiation is Normal) AND (Water temperature is Low) THEN (Distillated Yield is Normal)
Rule 6	IF (Solar radiation is Normal) AND (Water temperature is High) THEN (Distillated Yield is Normal)
Rule 7	IF (Solar radiation is High) AND (Water temperature is Low) THEN (Distillated Yield is Low)
Rule 8	IF (Solar radiation is High) AND (Water temperature is Normal) THEN (Distillated Yield is Normal)
Rule 9	IF (Solar radiation is High) AND (Water temperature is High) THEN (Distillated Yield is High)

(b) Fuzzy Rulesfor Instantaneous efficiency I (e)

Rule 1	IF (Solar radiation is Low) AND (Water temperature is Low) THEN (instantaneous efficiency is Low)
Rule 2	IF (Solar radiation is Low) AND (Water temperature is Normal) THEN (instantaneous efficiency is Low)
Rule 3	IF (Solar radiation is Low) AND (Water temperature is High) THEN (Distillated Yield is Low)
Rule 4	IF (Solar radiation is Normal) AND (Water temperature is Normal) THEN (Instantaneous efficiency is Normal)
Rule 5	adiation is Normal) AND (Water temperature is Low) THEN (Instantaneous efficiency is Normal)
Rule 6	IF (Solar radiation is Normal) AND (Water temperature is High) THEN (Instantaneous efficiency is Normal)
Rule 7	IF (Solar radiation is High) AND (Water temperature is Low) THEN (Instantaneous efficiency is Low)
Rule 8	IF (Solar radiation is High) AND (Water temperature is Normal) THEN (Instantaneous efficiency is Normal)
Rule 9	IF (Solar radiation is High) AND (Water temperature is High) THEN (Instantaneous efficiency is High)

3.3 Three dimensional graphs between output Distilled Yield and Instantaneous efficiency though the MATLAB. In figure 3.3 (a), (b)respectively

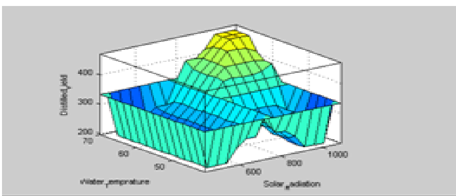


Fig: 3.3(a)

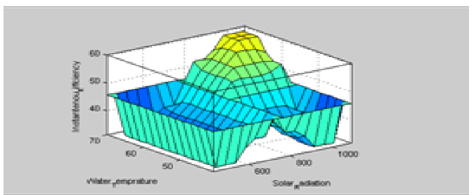


Fig: 3.3(b)

3.4 Casestudy: In above experiment by considering input value Watertemperature 55^0 C and normalized solar radiation is 758 W/m^2 we obtained output distillated yield = 0.334 and Instantaneous efficiency = 45.9 in figure 3.4(a), (b) respectively.

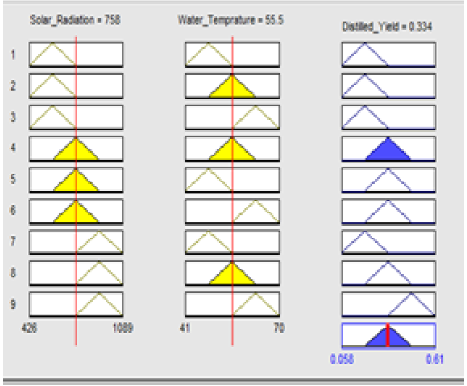


Fig: 3.4(a)

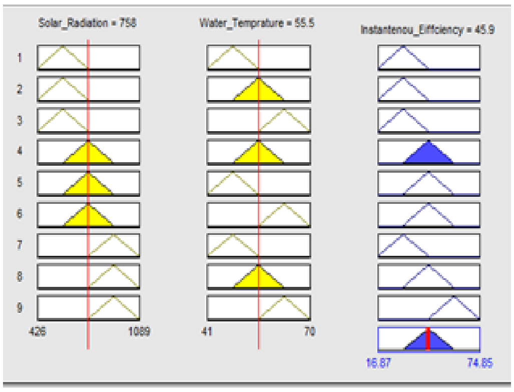


Fig: 3.4 (b)

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