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EXPERIMENTAL INVESTIGATIONS OF A DOUBLE CONDENSING SOLAR STILL USING FUZZY LOGIC

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ABSTRACT
The performance of solar still is dependent on a number of transient variables. Artificial intelligence has the capability of simulating complex systems. The rule based approach of fuzzy models makes it handy for analysis. This paper presents the fuzzy logic modelling of a double condensing solar still. Using available fuzzy rules a fuzzy logic model is formed by connecting the changes in solar radiation intensity and chamber temperature to the yield of distilled water. Simulation results are in good agreement with those obtained using experiments for different values of solar radiation and chamber temperature
Key Words: *solar still, fuzzy logic*

I.INTRODUCTION

Solar still is a devise used for distillation of brackish water using solar radiation [5]. A double condensing solar still shown in Fig.1 is capable of yielding at least 30% more distillate than a single condensing still [1]. Solar energy passing into the still heats the basin water as well as the water held in the wicks. Predominantly the wick water evaporates only to condense on the underside of the glass and below the plate on which the wicks are placed. The gentle slope of these surfaces directs the condensate to collection troughs, which in turn delivers the water to the collection bottle. About 3.5 litres of distilled water was obtained per square meter per day. The least and maximum yields collected from the experimental solar still were 255 and 280ml/h respectively. The experimental data shown on Table 1 were recorded between 10am and 4pm on a clear sunny day in March.

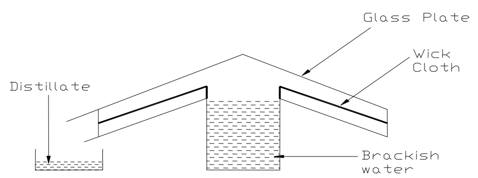


Fig.1 Double condensing solar still

Solar radiation is dynamic in nature due to changes in the solar system over time. A number of uncertainties prevail in such a system in terms of solar radiation, wind velocity, absorption by the wick cloth, chamber temperature, yield, etc. Fuzzy logic allows reasoning with the uncertain facts to infer new facts, with degree of certainty associated with each fact [2]. It is an approach to manage uncertainty. The dynamic behaviour of a fuzzy system is characterized by a set of linguistic fuzzy rules based on the knowledge and experience of a human expert within that domain. A cost effective solar still has been modeled by fuzzy logic [4]. The present work formulates the same for the double condensing solar still using fuzzy logic rule-based reasoning system.

II. PRELUDE TO FUZZY LOGIC MODELING

The first step in the modeling is called fuzzification, which defines linguistic variables, term and membership functions. The second step is called fuzzy rule inference whereby some sets of fuzzy logic operators and production rules are defined. The most common rule is called IF-THEN rule which can be used to formulate the conditional statements that comprise fuzzy logic.The final step in modeling is defuzzification process. The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. The aggregate of fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. In other words, fuzzy logic maps an input space to an output space through a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is not important. The rules refer to the variables and the adjectives that describe those variables. Before building a system that will interpret the rules, all the variables and the adjectives should be defined. To mention about how hot the chamber water is, a range should be defined. Also it should be mentioned about what is meant by linguistics such as high, medium low etc. Thus fuzzy inferencing or fuzzy modeling is a method that interprets the values in the input vector and based on some set of rules, assigns values to the output vector. A membership function is a curve that defines how each point in the input space is mapped to a membership value between 0 and 1. III. Fuzzy logic modeling of double condensing solar still

The two types of fuzzy inference systems are the Mamdani-type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined. Mamdani-type inference expects the output membership functions to be fuzzy sets and is used in this paper. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. Fig.2 shows the conceptual fuzzy logic model of the solar still and Fig.3 shows the designed fuzzy logic model of the same. It is possible and efficient too, to use a single spike as the output membership functions rather than a distributed fuzzy set.

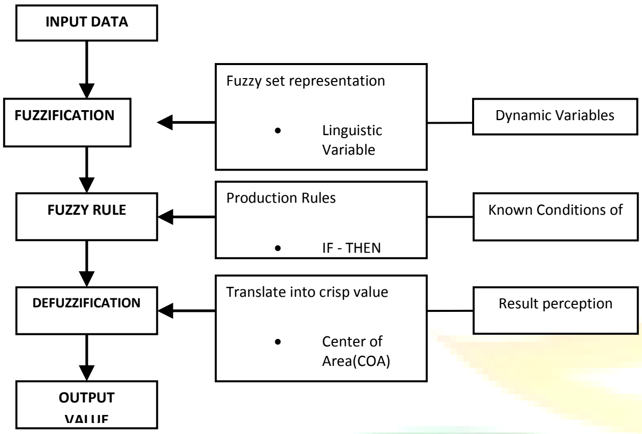


Fig.2 Conceptual Fuzzy Logic Model of the Solar Still

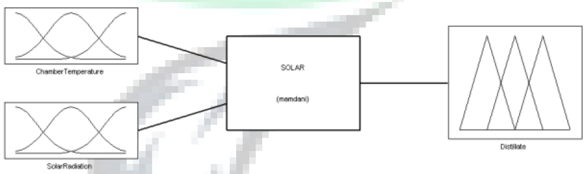
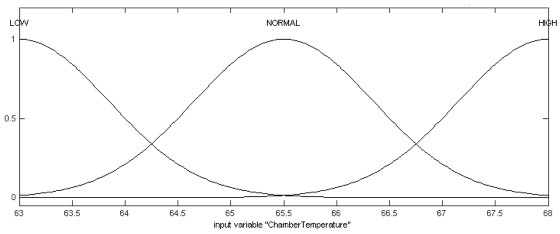
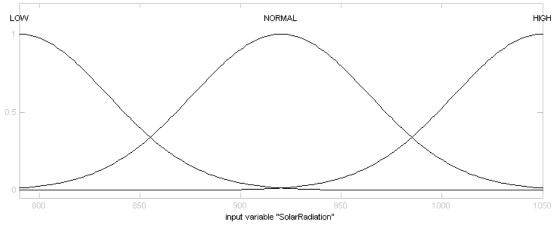


Fig.3 Designed fuzzy logic model of the solar still

III.I MEMBERSHIP FUNCTIONS

The following three dynamic variables are considered as the membership functions: solar radiation intensity(R), chamber temperature (T) of the still, and the distillate yield (D) collected per hour. Solar radiation intensity is a transient quantity and varies continuously. These variations influence the chamber temperature and hence the distillate yield. The evaporation of water also affects the chamber temperature. The solar still acts as a fuzzy system and fuzzy logic is applied to it through the membership functions. From the experimental results of the solar still, the observed range of solar radiation intensity was from 790 to 1050 W/m2 and the range of chamber temperature was from 65.3 to 67.8◦ C. The minimum and maximum distillate collected was 255 and 280ml/h, respectively. The patterns of membership functions for the three variables generated based on these ranges of experimental values are shown in Fig 4.





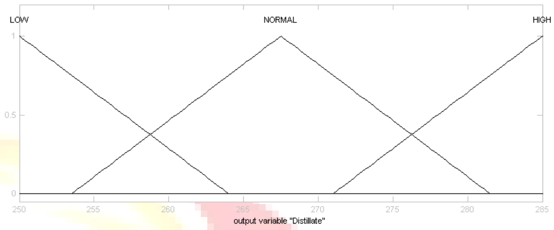


Fig. 4 Membership functions

III.II. FUZZY RULES

Individual parameters can identify two isolated cases [4]:High solar radiation intensity indicating high distillate yield normally associated with the more heating chances of the still, and High chamber temperature accompanied with normal solar radiation intensity indicating low distillate yield due to continuous heating of the still without much loss of heat by evaporation. In addition, the following cases also be identified:

(i) Low chamber temperature and low solar radiation indicating low yield, as the still needs further heating for meaningful evaporation;

(ii) Normal chamber temperature and low solar radiation intensity indicating low yield, as the evaporation process is not in progress;

iii) Normal chamber temperature and high solar radiation indicating normal yield, because of the ongoing and progressing heating of the still.

In addition to the above, more cases could be possible with variable results. Consolidating all these cases the following nine fuzzy logic rules are presented [4]:

Rule 1: If (solar radiation is high) AND (temperature is low), THEN (yield is High).
Rule 2: If (solar radiation is high) AND (temperature is Normal), THEN (yield is Normal).
Rule 3: If (solar radiation is Normal) AND (temperature is low), THEN (yield is Normal).
Rule 4: If (solar radiation is Normal) AND (temperature is Normal), THEN (yield is Normal).
Rule 5: If (solar radiation is High) AND (temperature is High), THEN (yield is High).
Rule 6: If (solar radiation is Normal) AND (temperature is High), THEN (yield is Low).
Rule 7: If (solar radiation is Low) AND (temperature is low), THEN (yield is Low).
Rule 8: If (solar radiation is Low) AND (temperature is Normal), THEN (yield is Low).
Rule 9: If (solar radiation is Low) AND (temperature is High), THEN (yield is Low).

The above rules were fed to the fuzzy logic model and the application was run for different values of solar radiation intensity and the chamber temperature leading to the prediction of distillate yield.Fig.5 shows the membership relations between the input and output variables. Fig.6 shows the solution domain as a three-dimensional graph generated between the three variables.

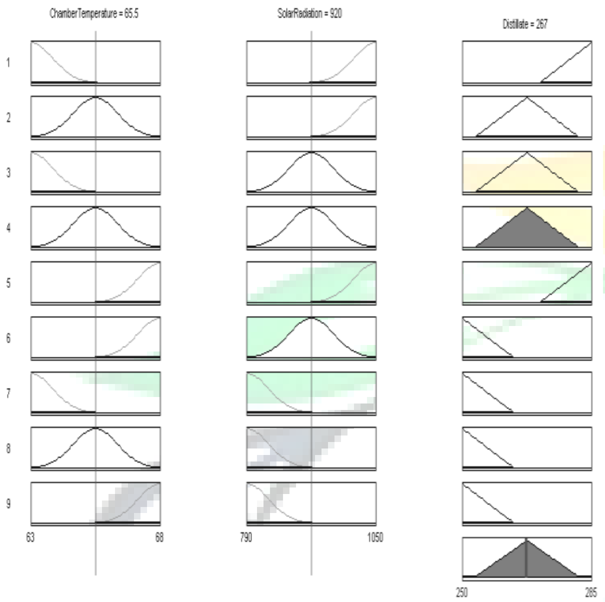


Fig.5. Membership relations between the input and output variables.

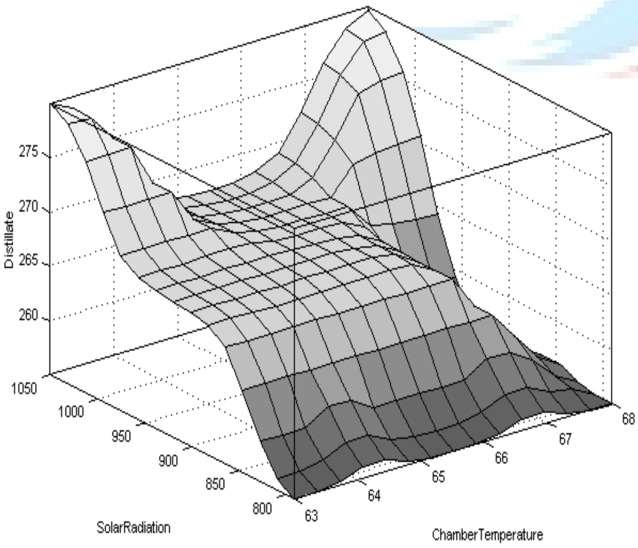


Fig. 6 Solution domain as a three dimensional graph

The experimental results are given in table along with simulation results.

Sl. No	Chamber Temperature (°C)	Solar Radiation (W/m^2)	Distillate Yield(ml/h)		
			From Experiments	From Fuzzy Model	% Deviation
1	65.3	800	255	256	0.3 %
2	64.8	980	275	268	2.54 %
3	63.2	1000	270	274	1.48 %
4	63	1050	265	280	5.66 %
5	67.6	1010	280	275	1.78 %
6	66.4	840	280	261	6.78 %
7	66.1	790	260	255	1.92 %

Table 1.Experimental and simulation results

IV. RESULTS

There is good agreement between experimental and fuzzy results. This indicates that the fuzzy logic model based inferencing system employed in the present work is validated with the experiments. These results provide appreciable scope for the implementation of artificial intelligence in the analysis of solar stills.

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