Fuzzy Logic Modeling of Single Slope Single Basin Solar Still

S. Shanmugan\textsuperscript{a} and G. Krishnamoorthi\textsuperscript{b}

\textsuperscript{a}Assistant Professor, Research Center of Physics, Dhanalakshmi College of Engineering, Manimangalam, Tambaram, Chennai–601 301, Tamilnadu, India. E-mail: s.shanmugam1982@gmail.com

\textsuperscript{b}Assistant Professor, Department of Physics, Excel College of Engineering and Technology, Pallakapalayam, Sankari west, Namakkal–637303, Tamilnadu, India. E-mail: gdkrishnaphysics625@gmail.com

Abstract

A present work aims at the thermals analysis with fuzzy logic modeling and simulation of a single slope single basin solar still has been developed. The still is transparent to qualitative interpretation and different fuzzy rule have been developed based on general analogy applied between the change in solar radiation intensity, yield of distillate output and subsequent changes in the basin liner, water and glass temperatures of the still. The still has provided with a dripping arrangement to pour saline water drop by drop in the basin. The experimental from the modeling and simulation for different values of solar radiation and water temperature are incorporated. These are good agreement between the experimental ones.

Keywords: Solar Still, Fuzzy Logic, Distillation.

Introduction

As the solar radiation has dynamic nature due to its continuous variation over time there is a lot of uncertainty prevails in the solar thermal system devices in terms of amount of absorption, temperature, performance etc., which work under the influence. Engelbrecht has coined a fuzzy logic to manage uncertain facts to inter new facts with a degree of certainty associated with each fact [1]. In the transportation area, many
expert systems were designed for predicting the tractive performance of the vehicle. Because of its importance, Fuzzy Logic techniques were proposed for power demand prediction [5]-[7]. Fuzzy Logic has been applied successfully to a large number of expert applications. This work presents the model of FLS, comprising the control rules and term sets of variable with their relates fuzzy sets, in which classical set theory is extended to handle partial memberships, enabling to express vague human concepts using fuzzy sets [8]. Jigeesh has made a preliminary work to simulate a solar water desalination using fuzzy logic rule based reasoning system [2].

Materials and methods

Fuzzy Rule-Based Single Slope Single basin Solar Still

Fuzzy rule based reasoning system consists of three components which will perform a specific task in the reasoning process (i.e.) fuzzification process, internecine and defuzzification. The fuzzification process predicts a fuzzy representation of non fuzzy input values by applying membership function associated with each fuzzy set in the rule input space. The process of mapping the fuzzified inputs into the rule base and to provide a fuzzified output to each rule in inferencing. Defuzzification process converts the output of the fuzzy rules into a scalar or non-fuzzy value.

Membership Function

Here four dynamic variables have been considered. Solar Radiation Intensity I(t), water temperature (T_w), Instantaneous distillate (D) and Instantaneous efficiency (I_e) per hour. The solar radiation intensity varies continuously these variation influence the water temperature and thereby the distillated yield and instantaneous efficiency. Hence, the four variables have been treated as the dynamic one and the new designed still as a fuzzy system and fuzzy logic has been proposed to that system. From the experimental results of the proposed system, the observed range of solar radiation intensity from 426 to 1089W/m^2 and the range of water temperature were from 41 to 70 °C for basin temperature from 43 to 76 °C, presently. The mass of the output a single slope single basin solar still was 0.340kg/m^230minutes and Instantaneous efficiency (I_e) 12 to 57%, respectively. Since the water temperature has been taken as one of the dynamic variables instead of taking basin surface temperature. Based on these range of experimental results, the patterns of membership function for the four variables have been generated and are depicted in the figure 1.
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Radiation (W/m²) I(t)

Solar Radiation W/m².

Temperature (°C)

Instantaneous distillate (D)
Instantaneous efficiency ($I_e$)

**Figure 1**: Membership functions.

**Mamdani's Method**

Mamdani's method is the most commonly used in applications, due to its simple structure of 'min-max' operations. We will go through each one of the steps of the method with the help of the example shown in the motivation section.

**Mamdani controller**

A Mamdani controller is usually used as a feedback controller. Since the rule base represents a static mapping between the antecedent and the consequent variables, external dynamic filters must be used to obtain the desired dynamic behavior of the controller figure 2.

**Figure 2**: Fuzzy controller in a closed-loop configuration (top panel) consists of dynamic filters and a static map (middle panel). The static map is formed by the knowledge base, inference mechanism and fuzzification and defuzzification interfaces.
The control protocol is stored in the form of if-then rules in a rule base which is a part of the knowledge base. While the rules are based on qualitative knowledge, the membership functions defining the linguistic terms provide a smooth interface to the numerical process variables and the set-points. The fuzzifier determines the membership degrees of the controller input values in the antecedent fuzzy sets. The inference mechanism combines this information with the knowledge stored in the rules and determines what the output of the rule-based system should be. In general, this output is again a fuzzy set. For control purposes, a crisp control signal is required. The defuzzifier calculates the value of this crisp signal from the fuzzy controller outputs. In figure 2 one can see that the fuzzy mapping is just one part of the fuzzy controller.

Signal processing is required both before and after the fuzzy mapping. The dynamic pre-filter and post-filter process the controller’s inputs and outputs. They typically perform signal scaling and dynamic filtering, e.g., compute the derivative and the integral of the control error or of the control signal.

Illustration of the Design
The photograph of the experimental single slope single basin solar still is shown in the Figure 1a and schematic diagram 1b. The still consists 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. 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.

Experiment has been carried out from 6 am to 6 am of 24h duration with compare ordinary basin type solar still for during summer days at Research Center of Physics, Dhanalakshmi college Engineering, Chennai–601 301 [latitude 13º 04’N, long 80º 17’E], Tamilnadu, India.
Fuzzy Rules
Fuzzy rules have been framed in which more cases coated be possible with variable results:

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)

And similarly
Rule 1a: IF (Solar radiation is Low) AND (Water temperature is Low), THEN (Instantaneous efficiency is Low)
Rule 2a: IF (Solar radiation is Low) AND (Water temperature is Normal), THEN (Instantaneous efficiency is Low)
Rule 3a: IF (Solar radiation is Low) AND (Water temperature is High), THEN (Instantaneous efficiency is Low)
Rule 4a: IF (Solar radiation is Normal) AND (Water temperature is Normal), THEN (Instantaneous efficiency is Normal)
Rule 5a: IF (Solar radiation is Normal) AND (Water temperature is Low), THEN (Instantaneous efficiency is Normal)
Rule 6a: IF (Solar radiation is Normal) AND (Water temperature is High), THEN (Instantaneous efficiency is Normal)
Rule 7a: IF (Solar radiation is High) AND (Water temperature is Low), THEN (Instantaneous efficiency Low)
Rule 8a: IF (Solar radiation is High) AND (Water temperature is Normal), THEN (Instantaneous efficiency is Normal)
Rule 9a: IF (Solar radiation is High) AND (Water temperature is High), THEN (Instantaneous efficiency High)

The above rules were inference and executed for different values of solar intensity, water temperature and hence forth the value of the quantity of the distillate yield and instantaneous efficiency were found.

**Result and Discussion**

Experimental observations have been carried out in typical one of the day (09’ May 2012) in Dhanalakshmi college Engineering, Chennai–601 301, Tamil Nadu, India between 9.00 A.M to 5.00 P.M. Mamdhani model has been used to predict the distillate output for the same day. The amount of the distillate yield and instantaneous efficiency derived using different values of solar intensity and water temperature are also given in table 1. Along with the experimental results for comparison purpose. From the results, three-dimensional graphs were generated between the four variables and depicted in figure 4 and 5. The relative standard deviation has been found between the experimental and simulation results in order to signify the closeness of the trend. It is observed that there is a reasonable agreement between the simulation and experimental results.

**Table 1**: Experimental and simulation results.

<table>
<thead>
<tr>
<th>basin Temper ature (°C)</th>
<th>Water Temper ature (°C)</th>
<th>Glass Temper ature (°C)</th>
<th>Solar Radiatio n (W/m²)</th>
<th>Distilled water yield lit/30 min</th>
<th>Instantaneous Efficiency (%)</th>
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<td>Figure 4: Three-dimensional graphs between instantaneous distillate yield, Temperature of the water and Solar Radiation.</td>
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<td>Figure 5: Three-dimensional graphs between instantaneous efficiency, Temperature of the water and Solar Radiation.</td>
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Conclusion
The concept of fuzzy logic modeling of single slope single basin solar still results pertaining to the theory is quite impressive. It provides not only a meaningful and powerful representation of measuring uncertainties but also with a meaningful representation of fuzzy concepts expressed in languages. Thus a fuzzy mode of the system can be defined mathematically by assuming to each possible individual a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which its individual is similar or compatible with the concept. These results provide enormous scope for the applications of the developed fuzzy system to optimize the still.

Nomenclature
- D - Instantaneous distillate output (L/hr)
- I_e - Instantaneous efficiency (%)
- I_{(t)} - Instantaneous Solar intensity (W/m^2)
- T_w - Instantaneous Water surface temperature (°C)
- T_g - Instantaneous glass temperature (°C)

References