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PREDICTION OF AMBIENT CONDITION FOR HIGH EFFICIENCY OF SOLAR PANEL USING FUZZY LOGIC CONTROLLER

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ABSTRACT

The rise in energy crisis required clean and suitable energy resources with higher efficiency. Due to large availability of the solar light, energy generation from solar energy is considered as one of the most suitable energy generation method. However, certain environmental factors affect the efficiency of the solar energy generation from solar panel using photo-voltaic effect. In this work, a parametric estimation is carried out using a fuzzy rule-based system to study the impact of various environmental factors including temperature, humidity and wind velocity on the output solar PV efficiency. All the factors equally impact the efficiency of the solar panel resulting in affecting the efficiency of the solar panel. The simulated and calculated results are compared which shows error less than 1%, which shows the accuracy of the soft computing technique (fuzzy rule based system).

Keywords: Temperature; Fuzzy Logic; Solar Energy; Photo-voltaic Effect

Introduction:

Prevailing energy crises across the globe require urgent and cost-effective energy solutions [1-3]. The high environmental impact and high import cost of conventional energy resources, make them a non-suitable choice to generate clean energy [4]. Energy generation through renewable means includes technologies like solar, wind, biomass and hydro energy are considered as suitable alternatives to conventional energy generation techniques due to their clean and cost-effective energy generation [5, 6]. Sun energy is used to generate electricity in the solar panel under the photovoltaic effect [7-9]. Solar energy is the name for energy that comes from the sun. The energy derived from sunlight that solar cells use to generate direct current electricity. Solar cells employ a wide variety of semiconducting components. Semiconductors are substances that become electrically conductive when exposed to heat or light. However, at low temperatures, they function as insulators [10, 11].

When light photons hit the cell, the energy is transferred to the atoms of the material. Based on the high energy of the photon, the electron from the outermost shell of the material is removed which results in the generation of a free electron and a hole (deficiency of electron). The generated free electron acts an electric charge providing the output circuit is a closed circuit with an external load [12, 13]. The most common and suitable semiconductor solar cell material is silicon.

When maximum light strikes on the silicon solar panel, the solar panel generates maximum electron hole pair resulting in large amount of energy generation. The output open circuit voltage and short circuit current generated as a result of the flow of electron generated by the solar panel are considered as the vital parameters to predict the output efficiency of the solar panel [14, 15].

Several different environmental and operational factors are associated with the efficiency of the solar panel. These includes the solar light irradiation that strikes the solar panel, weather conditions (warm and cold weather) as well as other environmental factors like dust and wind [16-19]. Hasan et al theoretically predicted the impact of several environmental and operational factor on the performance of the solar cell [20]. Different parameters including temperature and dust impact solar panel on different levels based on the change from the ambient parameters [21-23]. However, the prediction of the parametric estimation is for the solar panel is required to properly design the panels.

For the parametric estimations, various different tools has been used in literature [24-26]. To accurately map the energy systems, soft computing approaches like fuzzy logic, neural networks, and evolutionary algorithms are being used in energy modelling [27]. Fuzzy logic tool has been used in energy modelling as well as solar cell efficiency prediction based on different operational parameters. In this work, fuzzy rule based system has been used in order to predict the impact of various different environmental factors on the solar cell power conversion efficiency.

Fuzzy Analysis

MATLAB fuzzy logic MAMDANI model has been used in this work for the parametric estimation of the solar cell output based on various input environmental factors. These factors includes temperature, humidity and wind velocity. These factors are taken as input and the solar PV efficiency is taken as output. The impact of the input environmental parameters is studied in this work on the output solar PV efficiency as shown in the Fuzzy interface controller (FIS) in fig. 1.

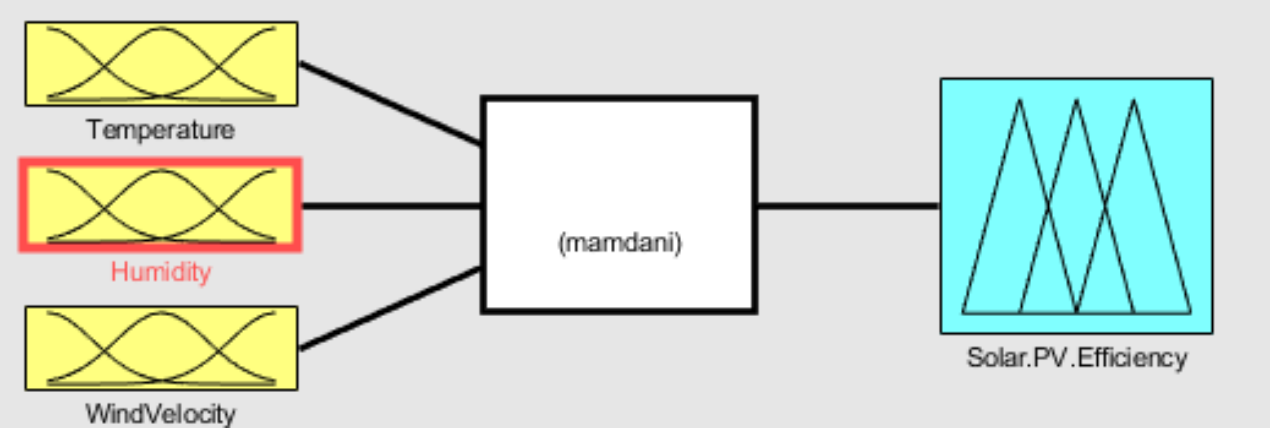

Fig. 1: FIS of the environmental factors impacting solar panel and its solar PV efficiency as output

The ranges and the membership function for the input and output are then defined in the membership function editor. The input membership functions and ranges are shown in fig. 2. For the input temperature, the range is taken from 10 to 60 ^{o}C. The membership function for the input temperature is taken as low temperature, medium and high temperature as shown in figure 2 (a). The input relative humidity is taken in percentage from 1-100%. The membership functions for

the input are taken as less humidity, medium and high humidity as shown in figure 2 (b). The third input wind velocity as shown in figure 2 (c) is taken in range of 0 to 20 m/s of wind with the membership function of low, medium and high wind conditions.

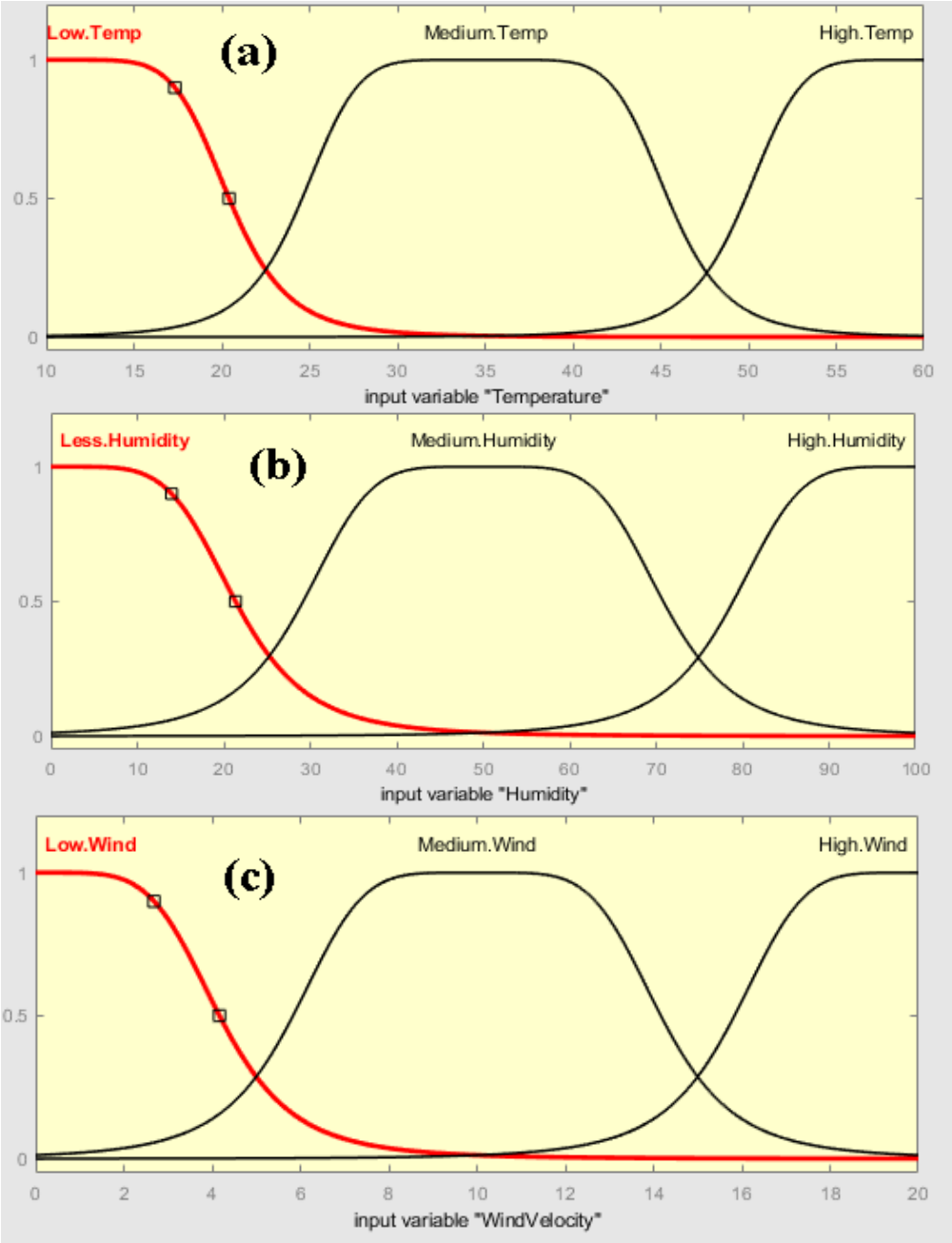

Fig. 2: Input membership functions (a) Temperature (b) Humidity (c) Wind velocity

The output Solar PV efficiency is taken in range of 0 to 25% which is the nominal efficiency of the mono-crystalline solar cell. The membership functions taken for the output solar PV efficiency includes Low, Medium and High as shown in figure 3.

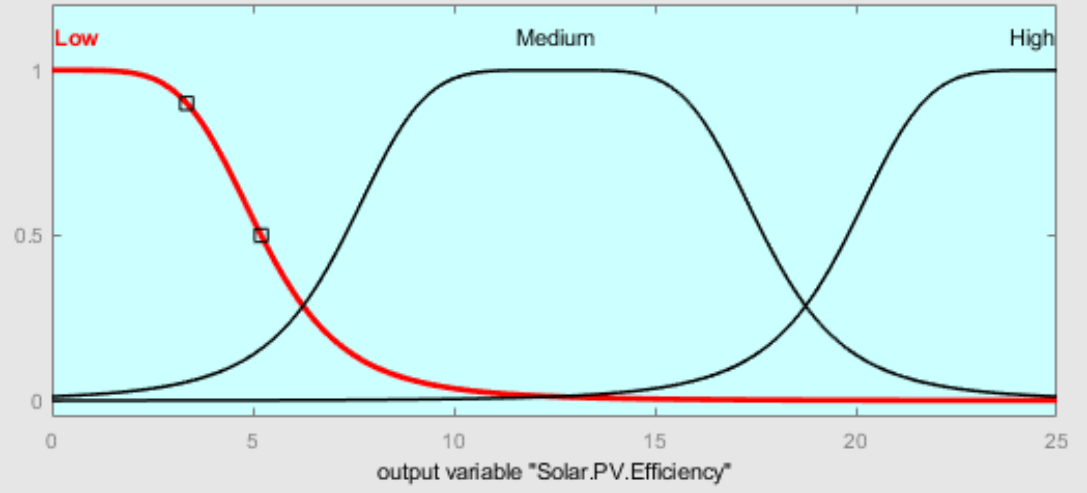

Fig. 3: Output membership functions and ranges for Solar PV efficiency.

The rules and the dependency of the input on the output are then selected by defining the rules. The rules depends on the number of input and membership functions. For this work, the number of rules defined are 27 which are based on literature and human decision making. On the basis of the rules the 2D and 3D graphs are analyzed and the results are studied.

Result and Discussion

2D graph between input temperature and output solar PV efficiency is shown in figure 4. The graphs shows that at low temperature and high temperature the solar PV efficiency decrease. At low temperature, the light irradiation is low mainly due to clouds and fog. At high temperature, the electron generated in the solar panel collides with each other resulting in recombination as well as delay in electron to reach the external circuit.

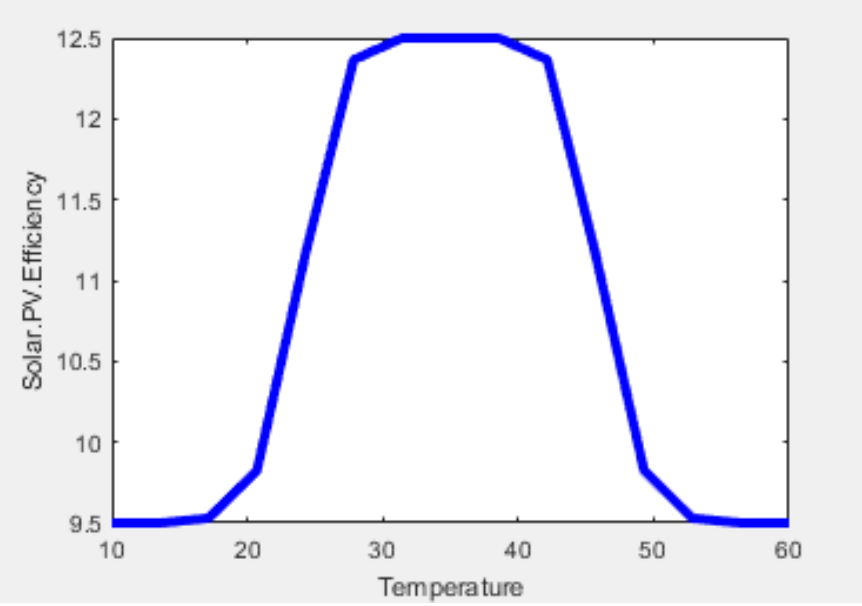

Fig. 4: Temperature and its impact on the solar PV output efficiency

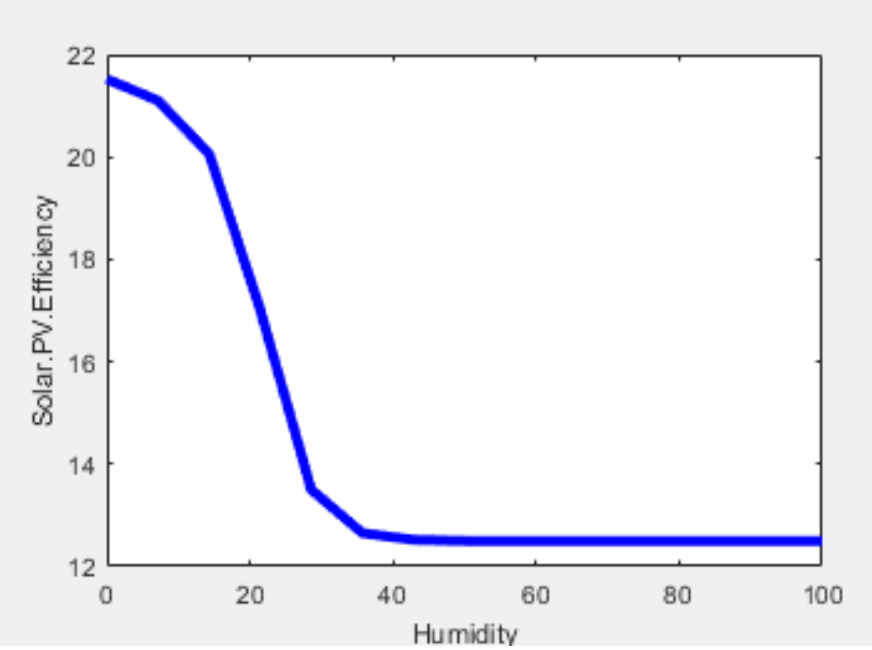

Fig. 5: Humidity and its impact on the solar PV output efficiency

Figure 5 shows the impact of humidity on the solar PV efficiency. The graphs depicts that humidity have a clear impact on the solar output owning to the fact that more the humidity more will be loss of irradiation of sunlight due to moisture in the air and on the solar panel. The results in a rapid decrease in the efficiency due to rise in humidity. Figure 6 shows the impact of wind velocity on the solar PV efficiency. The wind velocity reduces the impact of shading, create lighter irradiation to fall on the solar panel thus results in a small rise in the solar PV efficiency as shown in figure 6.

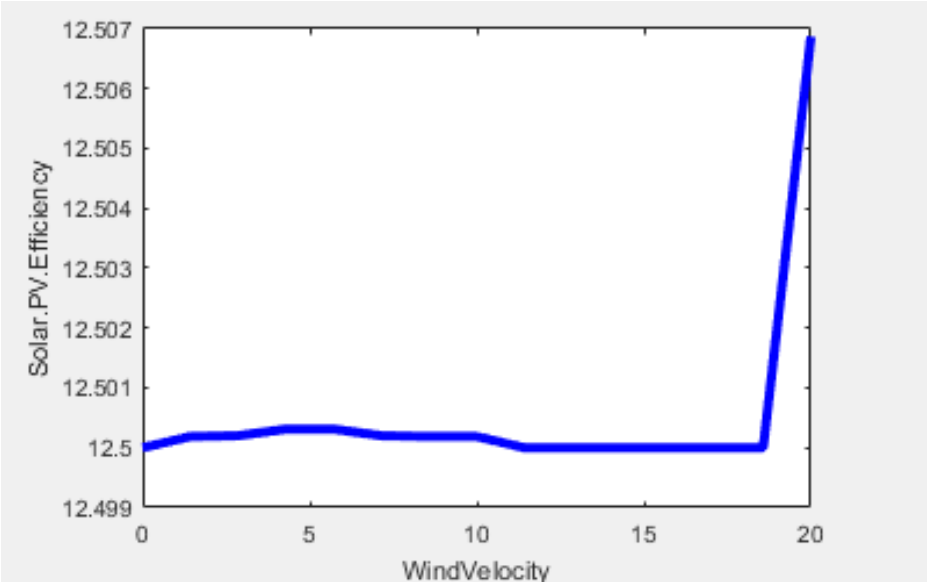

Fig. 6: Wind Velocity and its impact on the solar PV output efficiency.

The rule viewer for the designed system in shown in figure 7. The rule viewer provides the crisp value of the inputs and the crisp output value for the particular input. The crisp output value is then compared with the MAMDANI model calculated value using the MAMDANI model formula as shown in equation 1.

$$\text{MAMDANI Model formula} = \frac{\sum Ri \; x \; Si}{\sum Ri} \text{ x } 100 \qquad (1)$$

Where, Ri is the minimum membership function calculated from the input crisp values and Si is the singleton value of the output.

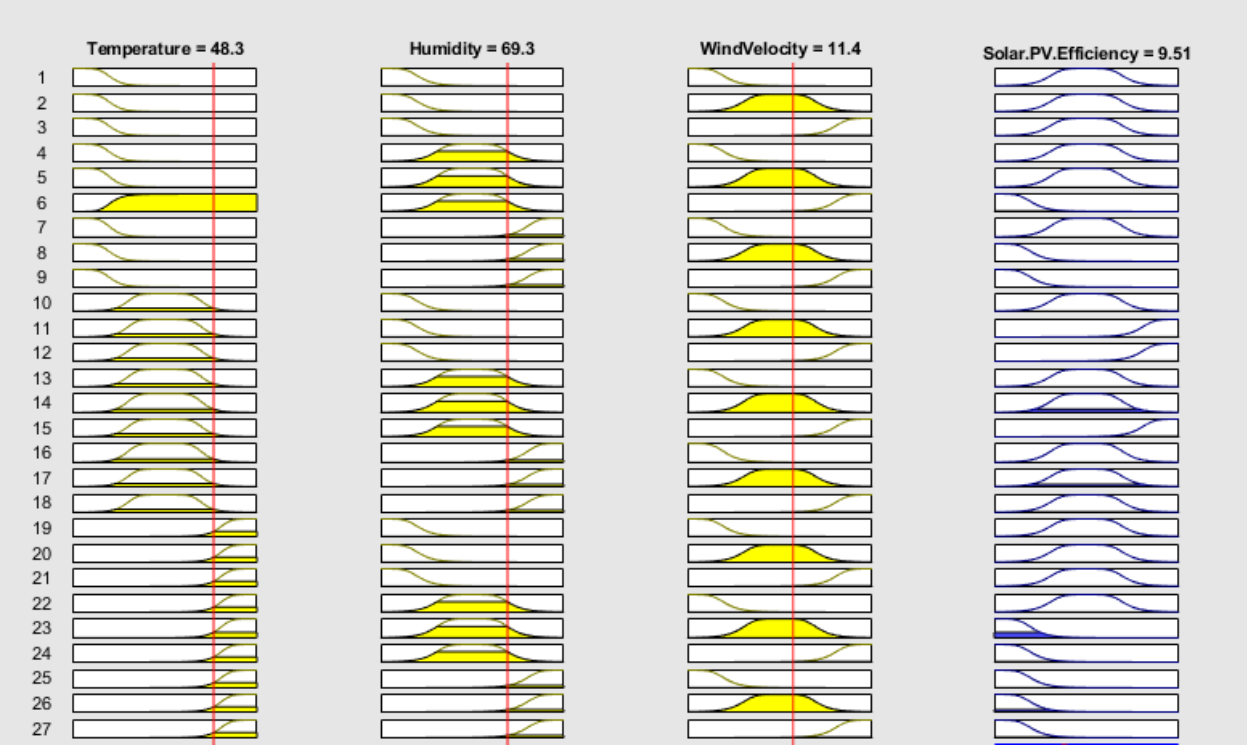

Fig. 7: Rule viewer for the system.

Table 1: Error between the Simulated and calculated values

	Solar PV efficiency
Simulated Value	9.51%
Calculated Value	9.505%
Error	0.5%

The simulated value of the output solar PV efficiency from the rule viewer is 9.51 % and after calculated using the MAMDANI model formula it was 9.505% as shown in table 1. The error between the values are less than 1% which shows the accuracy of the simulated carried out in the Fuzzy rule based system. The studied parameters including temperature, wind velocity and humidity impacts the solar panel output efficiency resulting in decrease in the overall solar cell performance. The work shows that these environmental factors must be considered in order to

properly and efficiently designed solar panel to generate maximum energy to fulfil the growing energy needs.

Conclusion

Solar panels are largely impact by environmental and other factors resulting in decrease in their efficiency. Based on these factors the monitoring and tracking of the parameters and their impact on the output efficiency of the solar panel is required. This work provides a parametric estimation of the impact of environmental factors including temperature, wind velocity and humidity on the output solar PV efficiency using fuzzy rule-based system. The results shows that the low and higher temperature results in decrease in solar cell efficiency mainly due to clouds and high collision between the electrons respectively. Similarly, humidity impacts the solar panel by decreasing the efficiency which the humidity increases. Wind velocity increases the solar PV output efficiency due to reduction in shading and for better light irradiation. The error of less than 1% in between the MAMDANI model calculated and simulated values shows the precision of the simulation.

Author's Contribution: F.Q., predicted and designed the idea of the work; M.A., Carried out the model designing and simulated work and F.A., worked on the acquisition of rules; F.Q and I.J.K., Executed simulated work, data analysis and composed the elementary draft; M.A and F.A., Did the final draft editing and analysis along with grammatical revisions.

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