Investigation of Solar Cell Factors Using Fuzzy Set Technique

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Abstract: Fuzzy set technique has been used to demonstrate the physical factors of a silicon solar cell. The physical parameters of a solar cell are calculated experimentally in outdoor measurement and the obtained values are compared with those obtained theoretically. The comparison results showed a good agreement using these two methods.

Keywords: Fuzzy set technique, commercial solar cell, physical parameters, outdoor measurement.

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1. Introduction

The spacecraft's sent to the nearby solar system rely on photovoltaic panels to supply electricity via solar radiation. As far as the distant planets are concerned, solar radiation is weak so that the required electrical energy is not obtained, so that radioisotope thermal generators are used in those areas far from the sun. Solar panels are used on probes and spacecraft for two important purposes: Production of energy for measuring and exploration devices, providing the necessary heat for its operation or cooling, Power generation for the operation of the rocket motor or the electric motor of the probe, sometimes called a solar-electric propulsion. The so-called interest rate is a characteristic that gives the ratio of the energy generated to the weight. This figure represents the maximum energy in the service of the spacecraft relative to the weight of the vehicle, including solar panels. In order to increase the energy generated per kilogram, solar panels working on spacecraft use solar panels in which photovoltaic cells are stacked to cover 100% of their sun-exposed surfaces. The circular solar wafer, which covers only about 90% of the surface, is not used. The global idea of space electricity generation technology is summarized. It will be composed of solar cells installed in a satellite orbiting Earth, and the energy generated will be transformed into microwaves that are transmitted to the earth to be converted back into electrical energy again. The important problem in celestial mechanics to solve Kepler's orbit based on three-body problem is called Kepler and Barker equations[1-8]. Many materials can be used to fabricate the cells[9-16]. Depending on the material used with the fabrication of solar cell there are several kinds of photovoltaic cells inorganic and organic solar cells[17-23].

When the surface of the cell is exposed to the solar spectrum, the photons that increase the energy gap contribute to the release of silicon electrons. The excess energy is dissipated in the form of heat and an equivalent circuit as shown in **Figure 1** can represent the solar cell. Source I_L is the result of the electrons' irritation due to solar radiation and the current I_s is represents the saturation current of the diode crystal and R_L represents the load resistance of the circuit.

The ideal features of the solar cell can be described as $I-V$ with the following relationship

$$I = I_D \times \left(exp^{\frac{qV}{kT}} - 1\right) - I_L$$

$$V_{oc} = \frac{qV}{kT} \times \ln\left(\frac{I_L}{I_D} + 1\right) = \frac{qV}{kT} \ln\left(\frac{I_L}{I_D}\right)$$

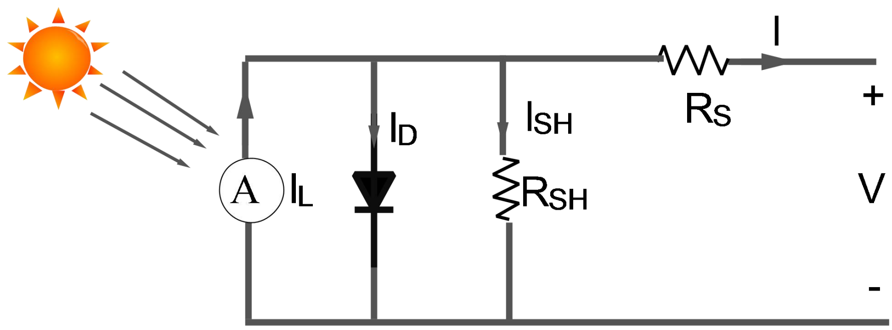

Figure 1. Schematic diagram of electrical circuit of a solar cell.

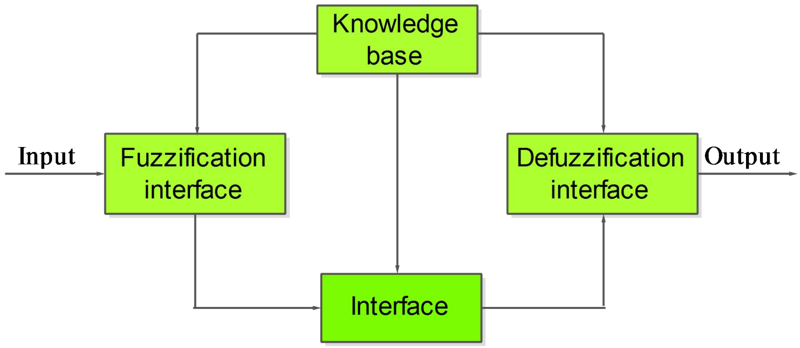

Figure 2. Fuzzy logic system

Thus, based on the Eq. 2, and for a specific value of I_L, we see that V_{oc} is increasing logarithmically with the decrease of the reverse saturation current I_D.

It is noted that by selecting an appropriate load, of about 80% of the an external power can be obtained as an amount $(I_{sc} \times V_{oc})$. I_{sc} represents the short circuit current of the solar cell and is equal to I_L while V_{oc} represents the open circuit volt of the solar cell and we see that the shaded area in the Figure of $I - V$ curve is the maximum power rectangle, Also, the amounts I_m and V_m which represents the maximum (current and voltage) of the solar cell respectively, when equipped with the maximum power P_m[24]

$$P_m = V_m I_m = V_m J_m \quad 3$$

The conversion efficiency of the solar cell is determined by the following relationship[25]

$$\eta = \frac{P_m}{P_{in}} \times 100\% = \frac{V_m I_m}{P_{in}} = \frac{FF \times I_L \times V_{oc}}{E \times A} \times 100\% \qquad 4$$

where P_m is the incident power on the solar cell and FF is known as a fill factor[26,28].

It is noted the maximum efficiency is not determined by a specific energy gap accurately, but the maximum efficiency occurs on the values distributed from them, so it can be considered semiconductors whose energy gap ranges between (1-2) eV as materials suitable for the preparation of solar cells.

There are several factors leading to the decline of the efficiency of the ideal solar cell and one of these factors is the resistance R_s resulting from the loss of the ohmic contact of the front surface and the fall of the external power to 30% of its maximum value when there is a series resistance of 5 Ω only.

This paper will focus on determination the physical parameters of the photovoltaic cell and examine these parameters using fuzzy set mathematical method.

Figure 2 presents the fuzzy logic system[29,30]

According to **Figure 2** the design of fuzzy logic system, have four main components, first the fuzzification interface, which transforms input crisp values into fuzzy values. Second the knowledge base, which contains knowledge of the application domain and the goals. Third, the decision-making logic that performs interface for fuzzy control actions. Fourth, the defuzzification interface.

In the traditional group, the element is either a member of the group or not a member of the group. In the fuzzy group, the element has membership scores in that group. For example, if U is a set and S is a subset of U and μ_s a function gives each element of group U a class of belonging to group S, if element x belongs to group S, thus $\mu_s = 1$, if element x does not belong to group S, thus $\mu_s = 0$ the membership function in this case is defined as follows

$$\mu_s: U \rightarrow \{0, 1\}$$

In the fuzzy group, element x can belong to the S group. Thus, the degree of belonging to group S, or the element x does not belong to the S group, its degree of belonging may belong to the S group to a certain extent. In this case, the membership function is defined as follows

$$\mu_s: U \rightarrow [0, 1]$$

This means that the membership function in the Classic group takes only one of the 0 or 1 values, while in fuzzy logic the membership function takes any degree of the period $[0, 1]$.

In this research, a fuzzy set technique has been utilized to get the examined (minimum and maximum values) of a photovoltaic cell (output) factors in outdoor measurements, and compare the data with the output parameters using experimental values. This method is important, simple, and utilized for many fields of applications.

2. Experimental Method

In this research, the method including fuzzy set method has been utilizrd to determine PV physical parameters and conversion efficiency evolutionary algorithms were brefiely described and compared the mathematical results with those obtained by experimental one.

3. Results and Discussion

Figures 2, **3**, and **4** present the experimental data of a silicon solar cell in outdoor measurement[17]. **Figure 1** presents maximum resistance and voltage values against temperature under 100 mW/cm^2 illumination power density which corresponds to AM1.5 conditions. **Figure 2** presents the fill factor and conversion efficiency values of the cell with respect to temperature; while **Figure 3** presents the series and shunt resistance values against temperature

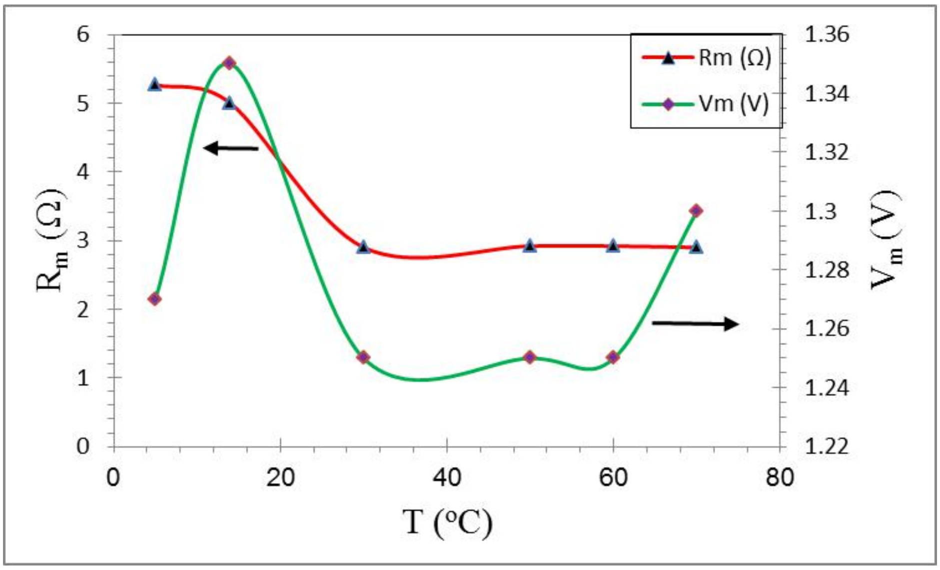

Figure 2. Maximum resistance and voltage against temperature.

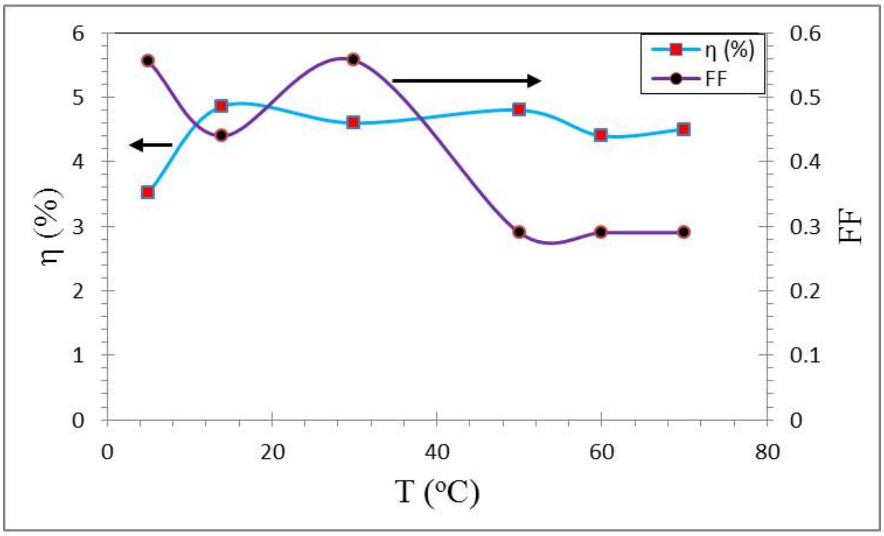

Figure 3. Maximum efficiency and fill factor against temperature.

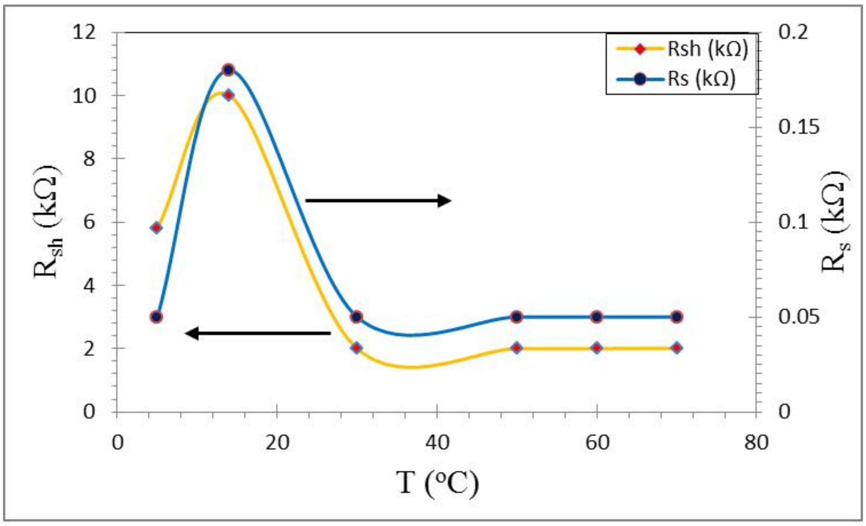

Figure 4. Series and shunt resistance against temperature

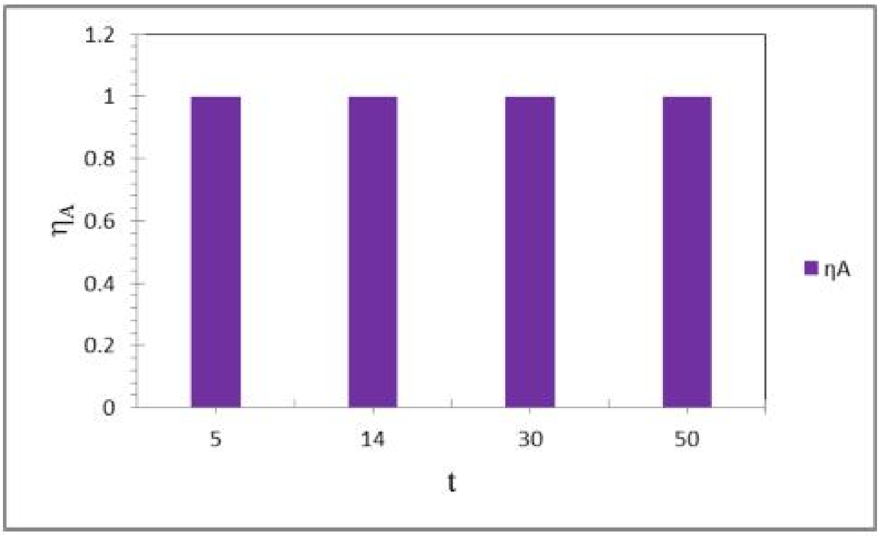

Figure 5. Graphical representation of crisp set.

Using fuzzy set theory, the physical factors of a solar cell (R_m, J_m, V_m, FF, η_m, τ, R_s, R_{sc}) have been calculated and the relation betw een the conversion efficiency are shown in **Figure 5**-**Figure 8**.

4. Conclusion

The important factors of a silicon solar cell have been measured experimentally using a commercial cell with specific active area. In addition, fuzzy set technique has been employed to determine these factors of a solar cell. The obtained results are in good agreement as compared the two methods with each other's.

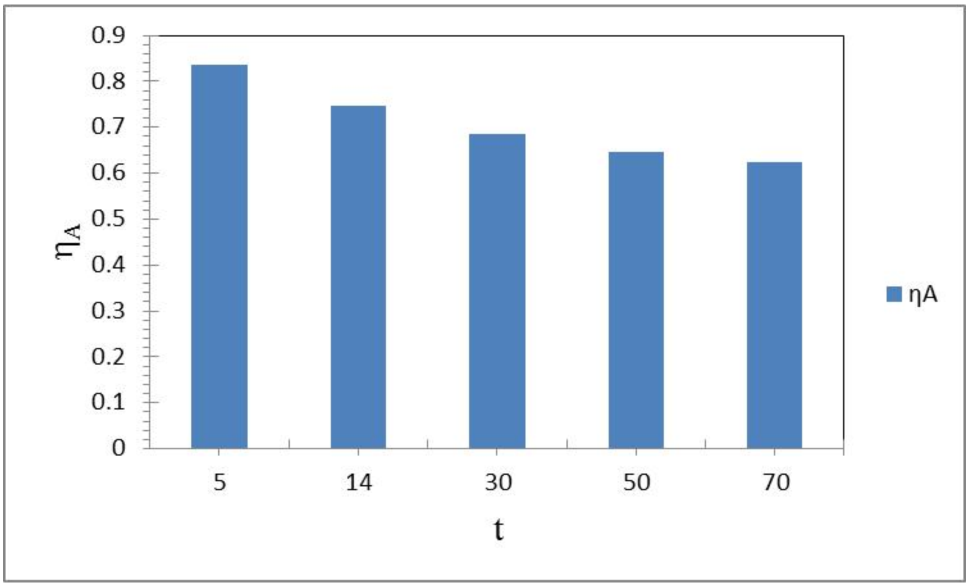

Figure 6. Graphical representation of fuzzy set

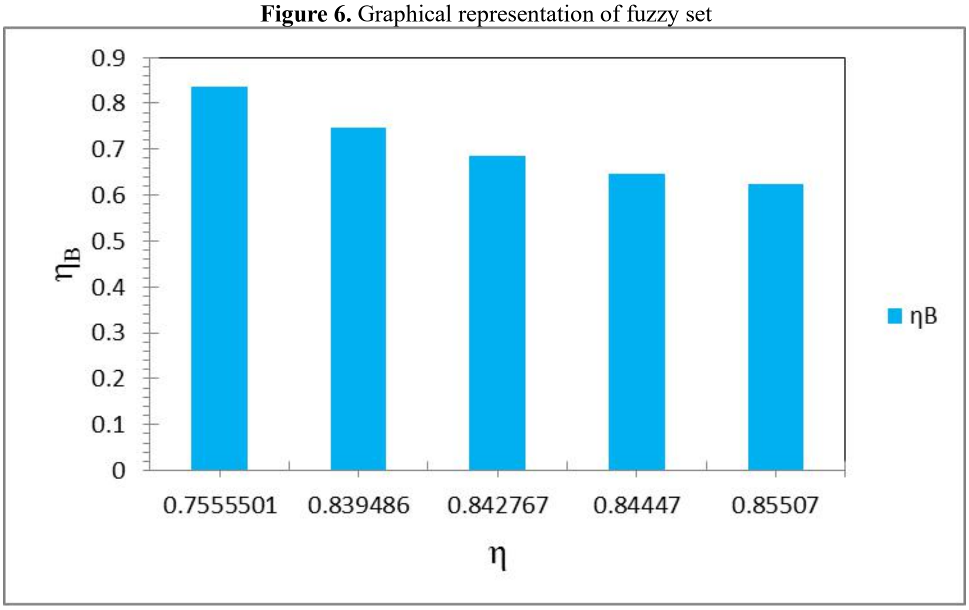

Figure 7. Results of fuzzy interface of the conversion efficiency

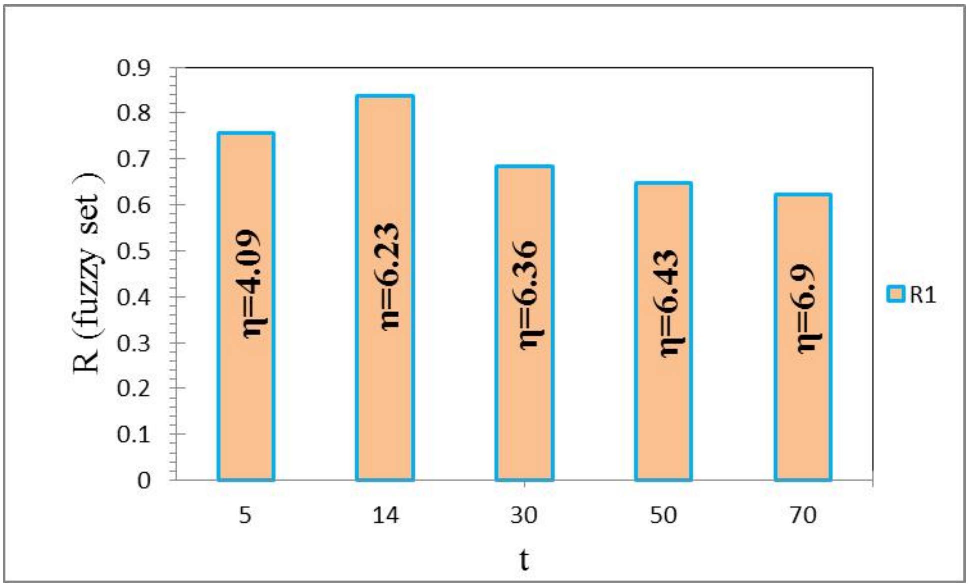

Figure 8. Fuzzy set membership of the efficiency against temperature.

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