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Fuzzy Set Technique Application: The Solar Cell

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ABSTRACT

The fuzzy set technique has been used in order to investigate PV parameters in this paper. These parameters are determined in the laboratory practically. Then, the fuzzy set technique is applied in order to examined and analyzed the optimal data of PV parameters theoretically. The results of the parameters obtained are compared which is a simple technique for the calculations. The results showed that the proposed technique is very suitable and accurate for the investigation.

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1. Introduction

Photovoltaic cells allow us to use the energy of sunlight to provide electrical energy. With this, the sun becomes a never-ending battery. That is, it provides an important, clean, and renewable source of energy as an alternative to polluting fossil fuels (such as coal). This is the fastest growing field in the world, with the amount of PV energy being

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doubled every year. The solar cells are designed to work in sunlight, while photovoltaic cells can use any light source to generate electrical current. The first photoelectric cell made to secure energy for satellites. The Russians used them for their Sputnik 3 satellite in 1957. Some materials that produce small electricity when displayed to the sunlight discovered in 1839 by the French scientist Edmund Bequerel. The discovery of Einstein 1 in 1905 was the basis for all photovoltaic technology; this technique can be used in space Aero-physics or celestial mechanics. One of some well-known applications for using numerical analysis in order to solve non-linear equations is satellite orbits [1-15]. These cells are made of a special substance called semisynthetic carrier 2. Silicon is one of the most popular materials used as semiconductors, as a thin layer of silicon is treated to form an electric field that has a positive charge on one half of the carrier and a negative charge on the other end [16-25]. The photoelectric cell material absorbs the light rays, as these rays collide with the free electrons of silicon (the electrons of the surface layer of the silicon atom) causing their release. These electrons are picked up to generate electrical current upon completion of the circuit by connecting two conductors to the positive and negative ends and by this we can take advantage of the generated current [26-36]. This process is the same as the principle of connecting two wires to the positive and negative terminals of the savings poles. Many algorithms can be used with the equation of solar cell [37-47].

The fuzzy set theory [48] has been utilized to order to get the solar cell parameters in indoor measurements in this paper. First, the basic parameters of a silicon solar cell were measured practically in the laboratory. Second, the fuzzy set method is applied for PV parameters calculations. The results showed that the fuzzy set method is very suitable for comparing the optimal values of the photovoltaic cell parameters. The PV physical parameters using a fuzzy set method has been investigated and analyzed.

2. PV Parameters

Corresponding to the electric circuit of PV cell, I-V curve highly effects the performing the output of the energy. Investigating I-V curve, and depending on the parameters P_m, V_{oc}, and I_{sc} the fill factor of the cell can be calculated [49-63].

$$FF = P_m/V_{oc}I_{sc} = V_m I_m/V_{oc}I_{sc} \tag{1}$$

where P_m: maximum power, I_{sc}: short-circuit current and V_{oc}: open-circuit voltage. If the FF (high) this mean the cell have maximum output power, whereas if FF is (low) this means it has minimum output power. The efficiency η of the PV cell has been calculated by the following equation [52-54].

$$\eta = (P_m/P_{in}) \times 100\% = (P_m/E \times A) \times 100\% \tag{2}$$

where: A: area of a PV cell (cm^2) and P_{in},: photon's intensity (mW/cm^2).

By substituting Eq. 1 in Eq. 2 yields [55-56]

$$\eta = (V_{oc} \times I_{sc} \times FF/E \times A) \times 100\% \tag{3}$$

The efficiency of the PV cell denoted by η which can be calculated corresponding to different parameters for example short circuit current, open voltage circuit and fill factor. By demonstrating I-V curve, these parameters can be obtained.

3. Fuzzy Set Theory

The relation $R = A \rightarrow B$, R performed by the fuzzy is sighted as a fuzzy set with a 2-D membership function

$$\mu_R(x, y) = f((x), \mu_B(y)) \tag{4}$$

where: the fuzzy implication function is defined by the function f, implements the function of converting the membership degrees of and y in B and x in A into (x, y) in A × B, the min operator and product operator is f [48].

4. Results and Discussion

Table 1 present the values of the photovoltaic's cell parameters have been demonstrated practically by O. A. Sultan et al. The parameters (T, J_{sc}, V_{oc}) as an input and the parameters (R_m, J_m, V_m, FF, η_m, τ, R_s, R_{sh}) as an output, where: τ, R_{sh}, R_s, J_m and J_{sc}: minority carrier lifetime, shunt resistance, series resistance, maximum current density and short-circuit current density. The class of membership function, which characterized by a function $\mu_{\tilde{A}}(t) = \frac{1}{(\sqrt{t})^{1/9}}$ for solar cell parameters as shown in Figs. 1-10.

Table 1 - solar sell parameters with the effect of temperature.

T (°C)	J_{sc} (mA/cm²)	V_{oc} (V)	R_m (Ω)	J_m (mA/cm²)	V_m (V)	FF	η_m (%)	τ (μs)	R_s (kΩ)	R_{sh} (kΩ)
5	3.52	2.1	5	3.38	1.2	0.55	5.9	-	0.26	4.5
14	4.86	2.2	5	3.52	1.35	0.44	6.9	15.6	0.18	10
30	4..6	1.97	5	4	1.1	0.48	6.4	18.5	0.11	3.9
50	4.8	1.8	5	3.4	1.2	0.47	5.9	23.1	0.12	1.8
60	4.4	1.75	5	3.75	0.82	0.39	4.45	26	1	1.2
70	4.5	1.76	5	3.9	0.85	0.41	4.8	29.5	1	1.25

By applying Eq. 4, the result of solar cell parameters for the relation between the temperature T fuzzy set operators, one can see the following Figs. 2-11.

Figure 1 shows the temperature fuzzy set versus maximum short circuit current density fill factor fuzzy set.

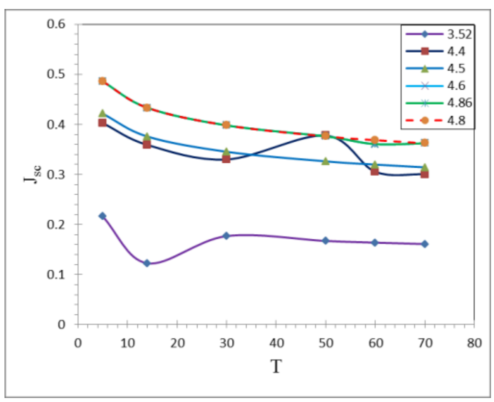

Fig. 1 – Temperature fuzzy set versus maximum short circuit current density fill factor fuzzy set.

Figure 2 shows the temperature fuzzy set versus open circuit voltage fuzzy set.

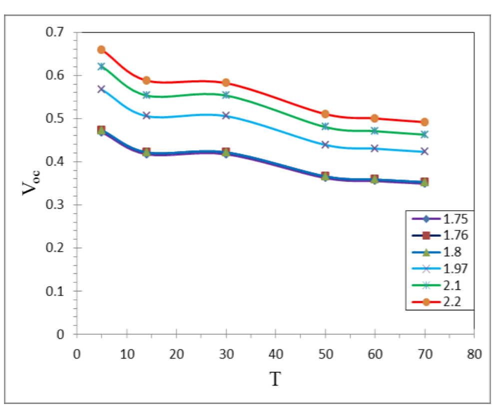

Fig. 2 – Temperature fuzzy set versus open circuit voltage fuzzy set.

Figure 3 shows the temperature fuzzy set versus maximum resistance fuzzy set.

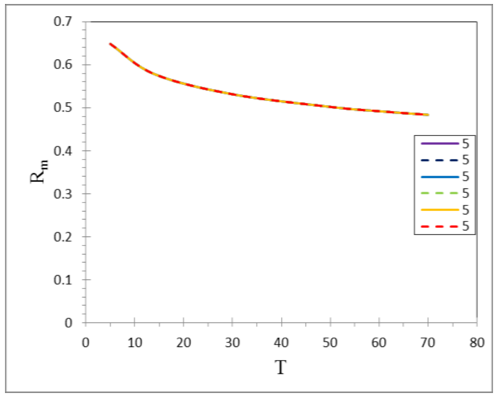

Fig. 3 – Temperature fuzzy set versus maximum resistance fuzzy set.

Figure 4 shows the temperature fuzzy set versus maximum current density fuzzy set.

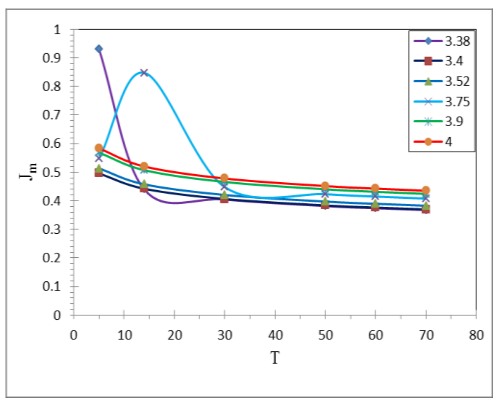

Fig. 4 – Temperature fuzzy set versus maximum current density fuzzy set.

Figure 5 shows the temperature fuzzy set versus maximum voltage fuzzy set.

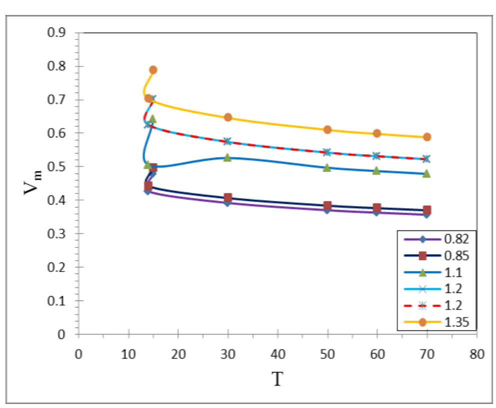

Fig. 5 – Temperature fuzzy set versus maximum voltage fuzzy set.

Figure 6 shows the temperature fuzzy set versus fill factor fuzzy set.

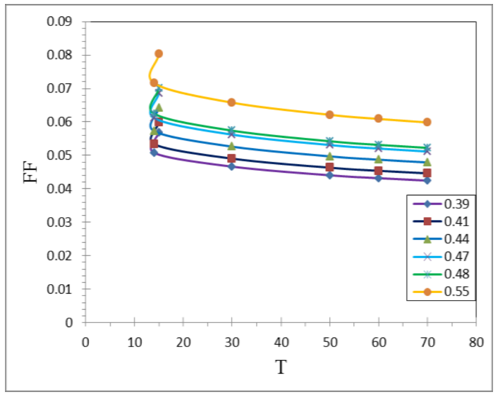

Fig. 6 – Temperature fuzzy set versus fill factor fuzzy set.

Figure 7 shows the temperature fuzzy set versus efficiency fuzzy set.

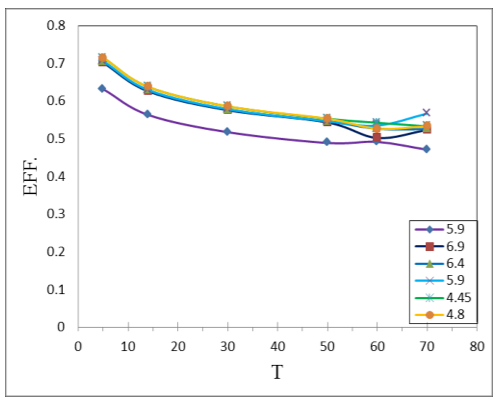

Fig. 7 – Temperature fuzzy set versus efficiency fuzzy set.

Figure 8 shows the temperature fuzzy set versus lifetime fuzzy set.

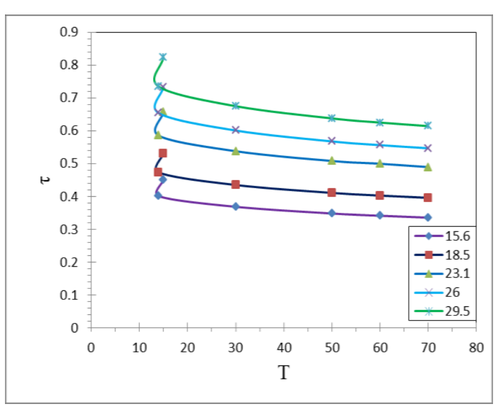

Fig. 8 – Temperature fuzzy set versus lifetime fuzzy set.

Figure 9 shows the temperature fuzzy set versus series resistance fuzzy set.

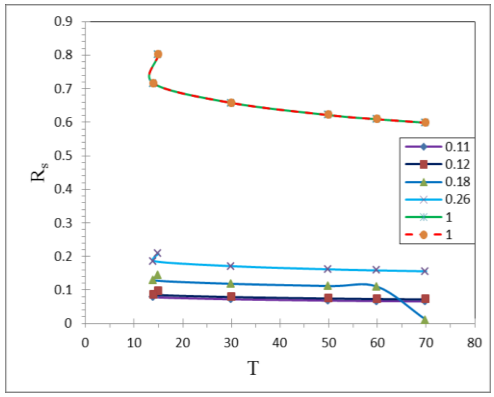

Fig. 9 – Temperature fuzzy set versus series resistance fuzzy set.

Figure 10 shows the temperature fuzzy set versus shunt resistance fuzzy set.

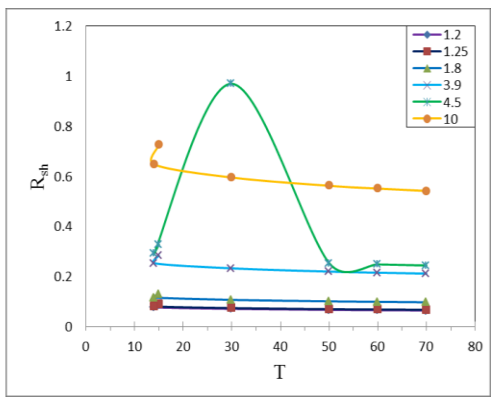

Fig. 10 – Temperature fuzzy set versus shunt resistance fuzzy set

5. Conclusion

This paper present the most important parameters of PV cell by means of fuzzy set theory. Various values of temperatures and efficiencies have been used in this paper. By comparison with solar thermal systems, the PV cell gives a attractive ways for direct conversion of light into electricity with low maintenance and a high reliability and as compared with solar thermal systems. The results obtained proved that fuzzy set method is very suitable and effective with the use of solar cell.

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