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Characteristics of Solar Cell Outdoor Measurements Using Fuzzy Logic Method

Mohammed RASHEED[1*], Mohammed Abdelhadi Sarhan[2]
[1] Applied Sciences Department, University of Technology-Baghdad- Iraq
[2] College of Science, Department of Mathematics, Al-Mustansiriyah University-Baghdad- Iraq
*Corresponding Author:rasheed.mohammed40@yahoo.com or 10606@uotechnology.edu.iq

Abstract: In this paper proposes a fuzzy logic Simulink in order to calculate a maximum output parameters of solar cell, for each index, three functions describing membership to the fuzzy subsets favorable, the temperature (temp.), open circuit voltage (V_{oc}) and short circuit currant (I_{sc}) have been defined. A fuzzy logic calculates the modules according to both the degree of membership of the indices to the subsets (L), (M), (H) and a set of decision rules. Then the modules are aggregated into the indicator parameter output of solar cell is presented.

Keywords: Photovoltaic cell; temperature; fuzzy logic technique; solar cell parameters; outdoor, Matlab simulink
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1. Introduction

Photovoltaic (PV) points to a clean energy technology, which utilizes a solar cell panel to give release electrons when uncovered to a light, performing in the producing of electricity. Photovoltaic is commonly pointed to term as "PV", solar energy is the popular expression for this technology, PV cells or solar power panels or Photovoltaic cells are utilized to harness the power from the sun, A PV apparatus is a semi-conductor cell which, when uncovered to sunlight, transforms the sun's light into an electricity[1,2]. A suitable introduction of a photovoltaic effect which regards for all of its utilizes is the immediate diversion of rays into electrical current, such as an inflow of electric current or voltage decline. The expression photovoltaic cell is utilized to depict an apparatus, which transforms the power of the rays into electricity for the objectives of performance work. Equivalents with the expression solar cell are utilized as the fallen rays hail from the sun. In other apparatus, called as photodiodes and sometimes photodetectors meaning rays by the photovoltaic effect and the rays is not transformed into power in order to do the work. Practically, a description photovoltaic in photovoltaic technology; the name photovoltaic are usually utilized to point to the transformation of light into applicable electric power, like in solar cells or photovoltaic cells[3,4]. Now days; many materials have been used with fabrication of the solar cells to enhanced its quantum efficiency which is the main important physical parameter of PV cells. For example; indium tin oxide (ITO), zinc oxide (ZnO), niobium doped titanium dioxide (TiO_2:Nb), aluminum doped zinc oxide (AZO), nickel oxide (NiO), Bismuth trioxide (Bi_2O_3), which are used in rigid and flexible electronics[5-9]. There are many types of solar cell such as silicon, inorganic and organic solar cells[10-13]. For more applications of solar cell in space based on nonlinear equation [14-22].

In this paper a simple fuzzy logic valuation system have been used to prophesy the maximum output physical parameters of silicon solar cell. The practical results approaching in this article using Matlab Simulink program.

2. The equivalent Electrical Circuit of a Photovoltaic Cell

A material transform light into electricity, it should accept two conditions. Firstly, it requires the ability to imbibe incident light within the upgrading of photons to higher level of energy. Secondly, it requires consist of an inner electric field to hastens the upgraded electrons in a special direction, performing in an electric current. A photovoltaic cell is any A material transform light into electricity, it should accept two conditions. Firstly, it requires the ability to imbibe incident light within the upgrading of photons to higher level of energy. Secondly, it requires consist of an inner electric apparatus, as uncovered to rays that, raises electric charge to inflow in an electrical circuit with a resistance as a load. An example for an electric circuit is presented in **Figure 1**.

The electric current and the voltage difference towards the back and front contacting the circuit can be calculated using instruments such as a ammeter and voltmeter respectively.

The electric current values based on the arriving light density. Also, the electric current based on the load of the electric circuit.

3. Solar Cell Parameters

Depending on the shape of the electric circuit for solar cells, the resistance as a load is particularly chosen to the output energy, as it is maximum. The form of the I-V curve extremely influences the performing energy output. Demonstrating the form of the I-V curve, someone should utilize another factor called Fill Factor FF to gets the maximum output energy P_m with open circuit voltage V_{oc} and short circuit voltage I_{sc}[26].

$$FF = \frac{P_m}{V_{oc}I_{sc}} = \frac{V_m I_m}{V_{oc}I_{sc}} \qquad 1$$

where P_m: maximum power, V_{oc}: open circuit voltage, I_{sc}: short circuit current. Increases a maximum power output means; higher FF. then, it is possible to demonstrate the efficiency η of the solar cell which is described the ratio of output photons to the incident photons[27].

$$\eta = \frac{V_m I_m}{T_l A} \qquad 2$$

where T_l,: intensity of the arriving photons (mW/cm^2), and A: area of a solar cell (cm^2) and the arriving photons W_l. merging Eqs. 1and 2 yields[28

$$\eta = \frac{FF\, V_{oc}I_{sc}}{T_l A} \qquad 3$$

The Eq. 3 obtains the efficiency based on the variables, fill factor, open voltage circuit and short circuit current, which are utilized to demonstrate a solar cell. The value of the physical parameters acquired using investigating the solar cell I-V curve. Using variable voltage, calculating current, the resistance as a load is mainly changed from zero when the highest short circuit current inflow I_{sc} to infinity, gets the highest open voltage circuit V_{oc}.

4. The Fuzzy Logic Technique

It performs practices of the human and priorities through a membership functions and the rules of fuzzy. Fuzzy logic application to problems of a maximum output parameter in systems is extremely charming. It is not easy for a system to obtain perfect information of the solar cell inputs; it should have a decision depend on imperfect statistics. Basically; a fuzzy network contains many blocks, known as, fuzzy knowledge base, fuzzification, defuzzification and decision making[29]. **Figure 2** shows the structure of a type Fuzzy logic set. In the step one the inputs should be taken and calculate the degree to which they belong to each of the suitable fuzzy sets through membership functions. The input is usually a numerical value between 0 and 1. Some fuzzy rules are specified, which determine the Behavior of the system. This rule-base together with a simple implication method composes the inference engine[30-32].

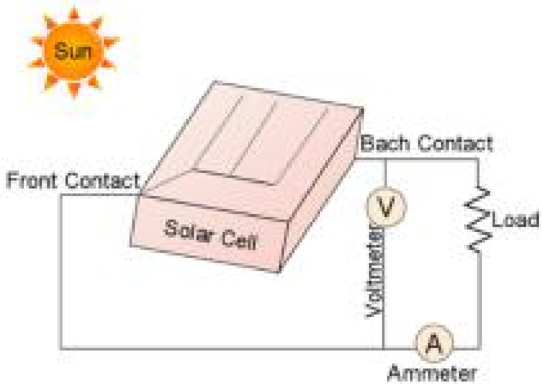


Figure 1. simple duplicated electrical circuit of a photovoltaic cell allows the production of usable power.

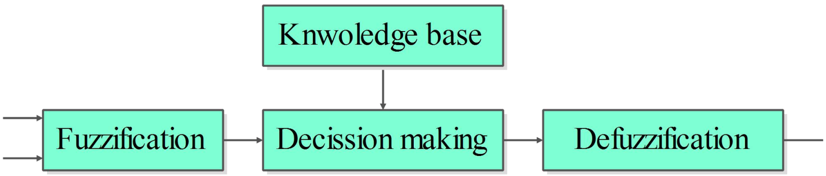
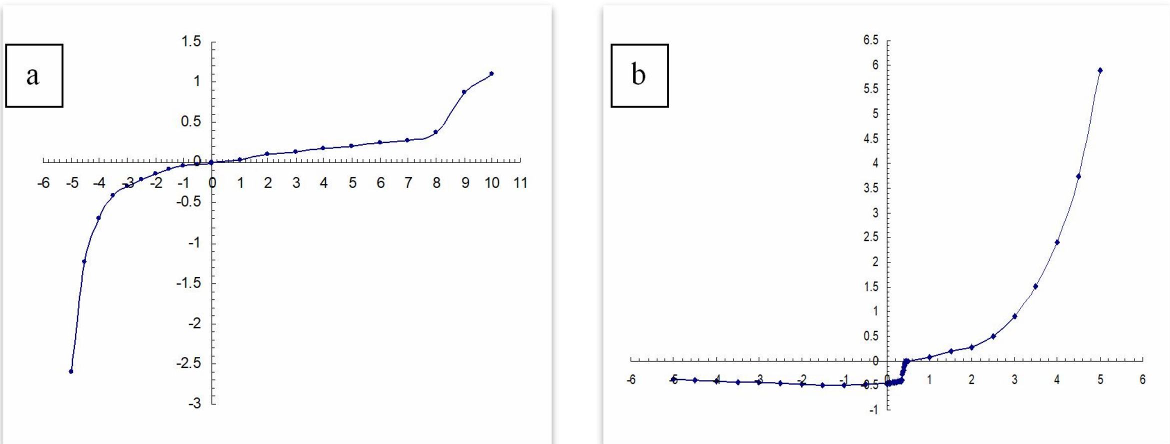


Figure 2. Structure of a fuzzy logic set.

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		5.27	3.64	1.27	0.556	6.43	5	0.05	5.81
14	4.86	2.2		5	3.52	1.35	0.44	6.9	15.6	0.18	10
30	4.6	1.97		2.9	3.66	1.25	0.557	4.09	14.5	0.05	2
50	4.8	1.8		2.92	3.66	1.25	0.29	6.36	14.6	0.05	2
60	4.4	1.75		2.92	3.66	1.25	0.29	6.36	14.6	0.05	2
70	4.5	1.76		2.9	3.69	1.3	0.29	6.23	14.3	0.05	2.01

Table 1. The experimental parameters of PV cell [33]



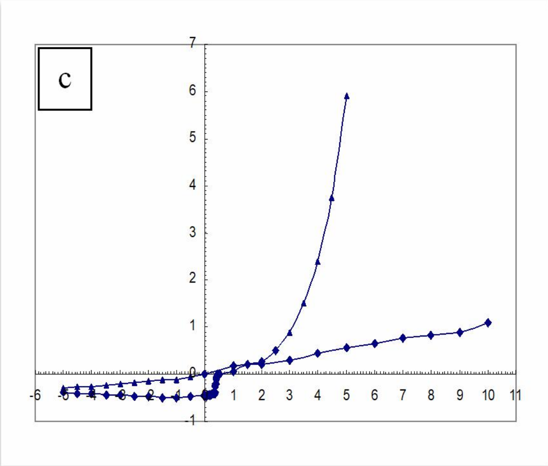


Figure 3. a, b and c the I-V curve of the solar cell based on the effects of the photocurrent.

5. Experimental Detials

Table 1 presents the actual results of a silicon solar cell, the photovoltaic cell operating is the 4th quadrant of the I-V shape, in this part the voltage is positive and the electric current is negative, thus, the negative sign refers to the direction a according to a reference of the system only. If $V = 0$ and $I = 0$; when V is (+Ve), I is proportion with V exponentially, if V (-Ve), I is a constant value and small, j is (-) sign.

Figure 3a-Figure 3c presents the I-V curve based on the influence of the photocurrent which is not a function of the voltage and temperature.

Fuzzy Logic Technique is utilized to obtain the maximum values of PV parameter of a photovoltaic cell in this paper. Using this technique, the fuzzy logic input variables, temp., I_{sc}, V_{oc}. The fuzzy logic (inputs and outputs) are described by three lingual parameters: L (LOW), M (MEDIUM), and H (HIGH), Table 2 shows the classification of input data and their fuzzy sets in this study. Input parameters is (T, J_{sc} , V_{oc}) and the output parameters is (R_m, J_m, V_m, FF, η_m, τ, R_s, R_{sh}) where J_{sc}: the open-circuit current density. J_{sc}: the open-circuit current density, J_m: maximum current density, R_s: series resistance, R_{sh} : shunt resistance, τ : minority carrier lifetime.

Fuzzy logic membership functions I_{sc}, V_{oc} and T (°C) are shown in **Figure 4- Figure 6**. Triangle membership function boundaries subsets are chosen and expressed based on the rules of the fuzzy to indicates the state of each physical parameters.

IF Temp is low l & I_{sc} is medium & V_{oc} is high then Rm is high & J_m is high & V_m is high & F.F is high & Eff is high & T is med & R_s is low & R_{sh} is high. Defuzzucation process where we get the value of one to distinguish and detect the uncertain and inaccurate values and show it naturally. Here, represents the value of output as shown in **Figure 7**.

Short Circuit Current Classification			
Range (mA/cm^2)	0 - 2	1.5 - 4	3.5-6
Type of Membership Parameters	LOW (L)	Medium (M)	High (H)
Open Voltage Circuit Classification			
Range (volt)	0 – 0.6	0.55 – 1.5	1.3 - 2.5
Type of Membership Parameters	LOW (L)	Medium (M)	High (H)
Ambient Temperature Classification			
Range (C°)	0 - 12	10 - 35	32 - 80
Type of Membership Parameters	LOW (L)	Medium (M)	High (H)

Table 2. Input data fuzzy logic (Range of input parameters).

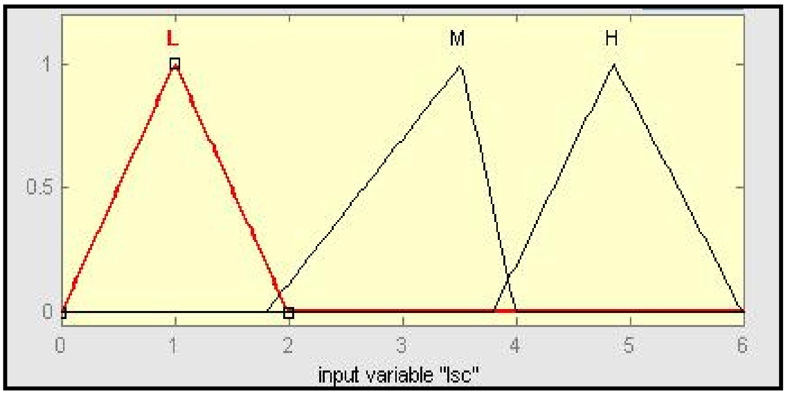


Figure 4. The membership functions of Short circuit current (A).

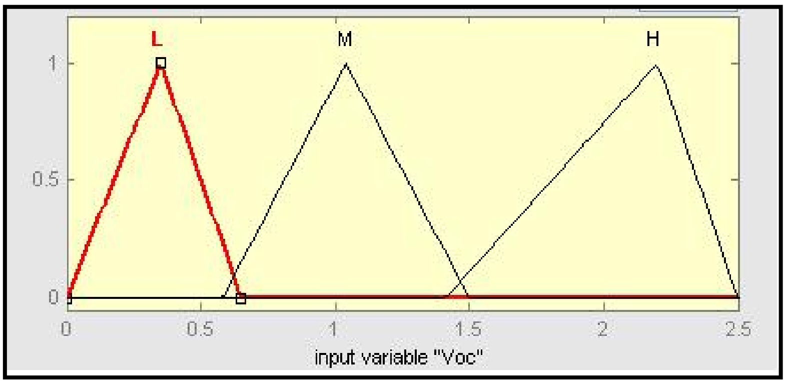


Figure 5. The membership functions of Open circuit voltage (V).

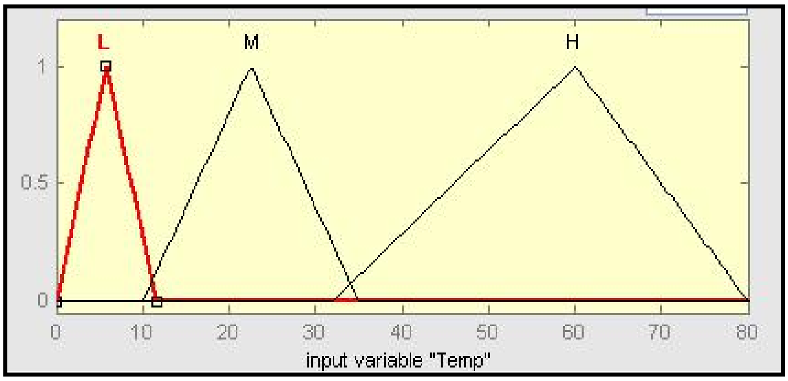


Figure 6. The membership functions of Temperature (°C).

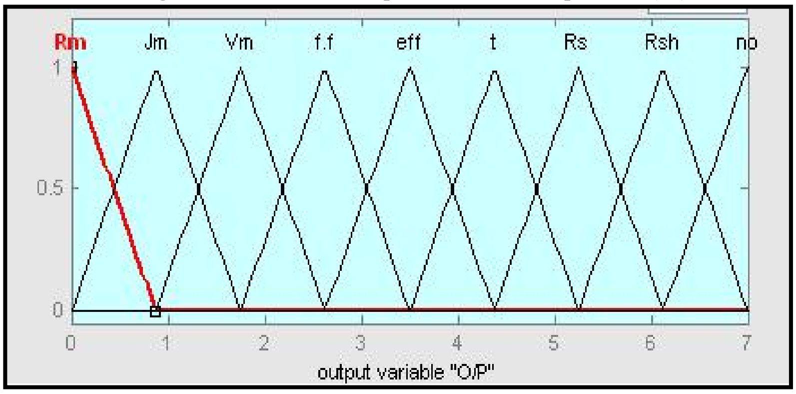


Figure 7. the output variables.

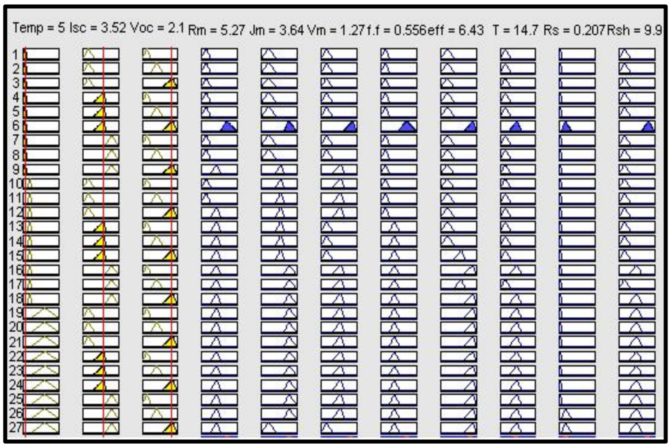


Figure 8. Interface module (the rules viewer).

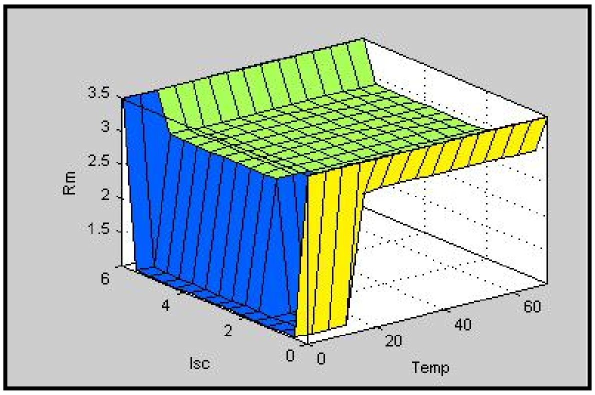


Figure 9. The value of Maximum resistance**.**

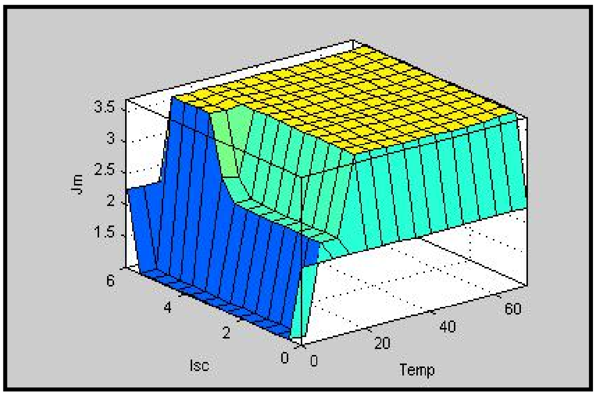


Figure 10. The value of Maximum current density.

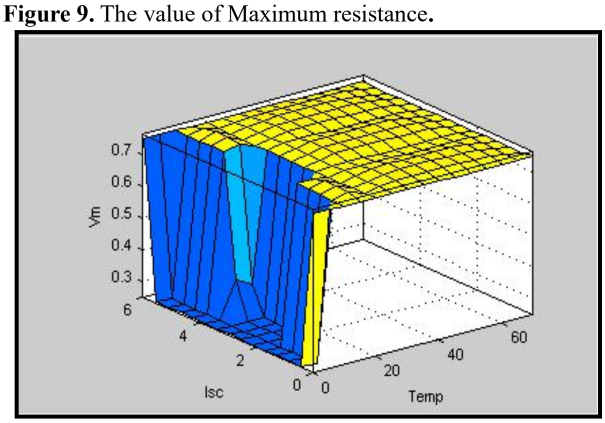


Figure 11. The value of Maximum voltage.

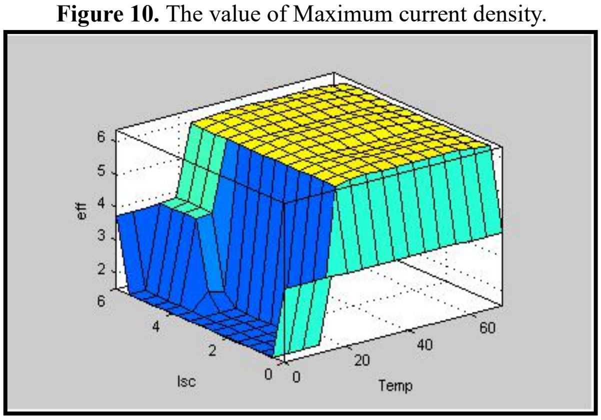


Figure 12 . The value of Maximum efficiency.

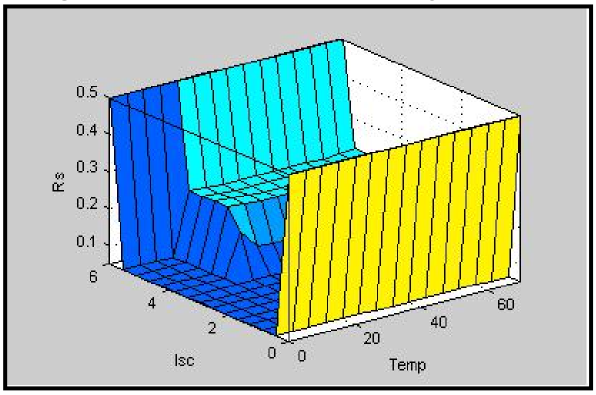


Figure 13. The value of R_s**.**

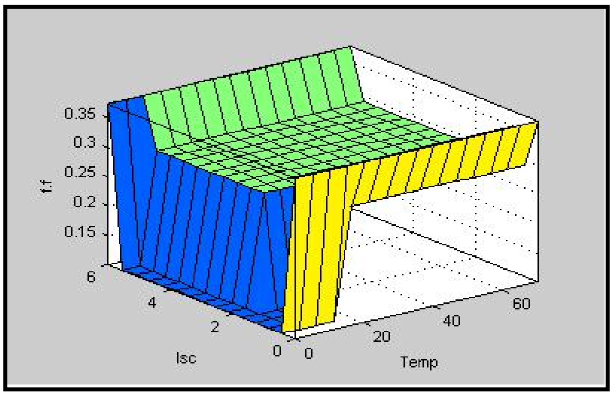


Figure 14. The value of FF.

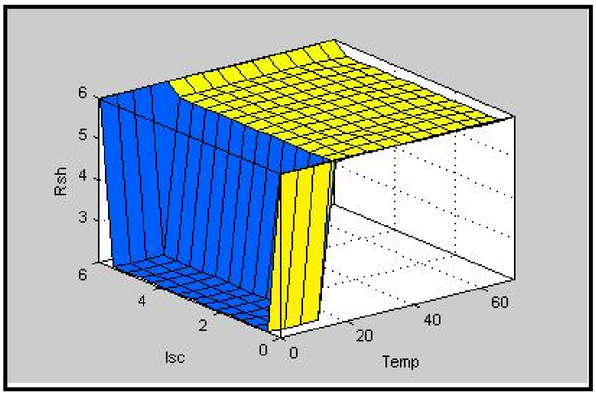


Figure 15. The value of R_{sh}

6. Result and Discussion

When using fuzzy logic to detect and distinguish the uncertain and inaccurate values, and confirmed in normal values, we obtain the optimal results for R_m, J_m, V_m, FF, T, R_s, $R_{sh}$and efficiency, as shown in **Figure 8.** The maximum values (outputs) for physical parameters of solar cell are shown in **Figure 10-Figure 15**.

7. Conclusions

The present work describes the concept of utilizing an easy fuzzy prediction network to estimate the maximum output parameter for the solar cell. The experimental results presented in this research. Simply and obviously characterize the efficiency of the fuzzy logic for the effective solar cell and confirming the concept approaching here extremely general which utilized to different types of solar cell. The fuzzy set rules use as an adaptive, thus the fuzzy set parameters are acquainted with a network over time.

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