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Measuring the Solar Cell Parameters Using Fuzzy Set Technique

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Abstract: This work studies the application of fuzzy set (FS) and fuzzy logic (FC) methods to determine the optimal operating point of solar cell. The physical parameters of the solar cell have been measured practically using silicon solar cell. The important parameters of the silicon cell are compared with each other using fuzzy set comparison method (FSCM) based on (I-V) characteristic curves of the voltage of photovoltaic cell and the maximum power resulting from the cell; which is a simple method for the measurement. The results of the simulation method show that, the fuzzy set comparison method (FSCM) is better measuring these parameters.

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1. Introduction

At present; photovoltaic cell provide the most important long time energy supply for satellites and space vehicles; have been successfully employed in small-scale terrestrial applications. Three-body problem is the major equation to solve the problem of the Kepler's orbit by means of the equations of Kepler and Barker equations[1-8]. The pioneer candidate for acquisition power from the sun is the photovoltaic cells, because it converts sunlight in direct way to electricity with high quantum efficiency with low operation cost and free of pollution. Two conditions must exist if we talk about materials that can transfer light into electricity. For first condition, it should have the ability to absorb the incident light from the lower to higher levels of energy[9-12]. For the second condition, it should contain internal electric field to accelerate the electrons into special direction to generate electrical current. Many materials have been used to improve the quantum efficiency of the PV cells[13-18]. There are many types of photovoltaic cells inorganic and organic solar cells[19-28]. For any solar cell devices the best important thing is the current-voltage characterization of the solar cell, an example for an equivalent electric circuit is shown in **Figure 1**. The most important part of this circuit is the current and voltage difference at the front and back contact by means of voltmeter and ammeter on can measure these important parameters (V and I) of the cell, respectively. In addition, the light intensity of the source is an important parameter for the current value measurements with the resistance as a load of the circuit.

In this research, a fuzzy set theory has been used to obtain the predicted (maximum and minimum values) of a physical parameters of a photovoltaic cell (output) in outdoor measurements, and compare all the input parameters with the output parameters using this theory. This method is used for several applications; a control command is obtained as a crisp value.

1.1 Important Parameters of Solar Cell

Based on the form of the electric circuit for solar cells;

the resistance as a load is particularly chosen to the output energy as it be maximum. $(I - V)$ curve extremely influences the performing energy output. Demonstrating current voltage plot, someone should 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[30].

$$\eta = \frac{P_m}{P_{in}} \times 100\% = \frac{P_m}{E \times \times A} \times 100\% \qquad 2$$

where P_{in},: intensity of the arriving photons (mW/cm^2), and A: area of a solar cell (cm^2) and the arriving photons P_{in} merging Eqs. 1and 2 yields[31]

$$\eta = \frac{V_{oc} \times I_{sc} \times FF}{E \times A} \times 100\% \qquad 3$$

The Eq. 3 obtains the efficiency based on the variables; fill factor, open voltage circuit, and short circuit current 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}.

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

1.2 Fuzzy Set Method[32-38]

The two basic components of fuzzy systems are utilize another factor called Fill Factor FF to gets the maximum output energy P_m based on V_{oc} and I_{sc}[29].

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

fuzzy sets and operations on fuzzy sets. Fuzzy logic defines rules, based on combinations of fuzzy sets by these operations. This section is based on the basic works of Zadeh.

In general, a fuzzy rule can be represented by a fuzzy expression $R = A \to B$, R can be viewed as a fuzzy set with a two-dimensional membership function

$$\mu_R(x,y) = f(\mu_A(x), \mu_B(y))$$

where: the function f, called the fuzzy implication function, performs the task of transforming the membership degrees of x in A and y in B into those of (x,y) in $A \times B$, and f is a min operator and product operator.

Crisp sets: given a universe of discourse$X = \{x\}$, a crisp (conventional) set A is defined by enumerating all elements $x \epsilon X$

$$A = \{x_1, x_2, x_3, x_n$$

That belong to A the membership can be expressed by a function $f_A$mapping x on a binary value

$$f_A: X \to \{0, 1\}, f_A = \begin{cases} 1 \; if \; x \epsilon A \\ 0 \; if \; x \notin A \end{cases}$$

Thus, an arbitrary x either belongs to A, or it does not, partial membership is not allowed. For two sets A and B, combinations can be defined by the following operations

$$A \cup B = \{x/x \epsilon A \; or \; x \epsilon B, \; A \cap B = \{x/x \epsilon A \; and \; x \epsilon B\},$$
$$\bar{A} = \{x/x \notin A \; and \; x \epsilon X\}$$

Additionally, the following rules have to be satisfied

$$A \cap \bar{A} = \emptyset, \text{ and } A \cup \bar{A} = X$$

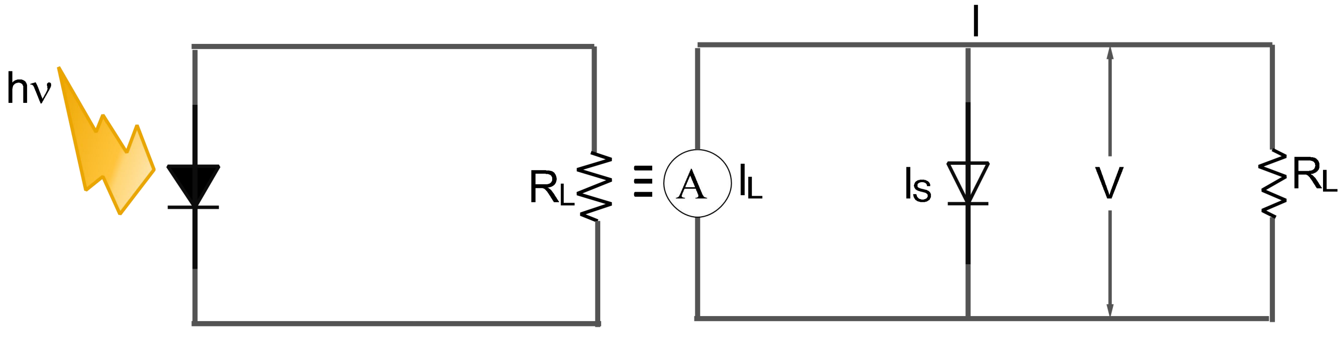


Figure 1. Simple electrical circuit of a photovoltaic cell.

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.

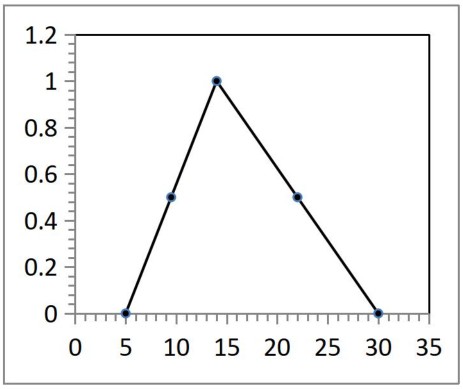
3. Results and Discussion

The following data in **Table 1** was performed using a commercial silicon solar cell with an active area of 44 cm^2 under illumination power density of 69 mW/cm^2, which corresponds to AM1.5 conditions. The test was achieved when the cell loaded by decade box of resistors.

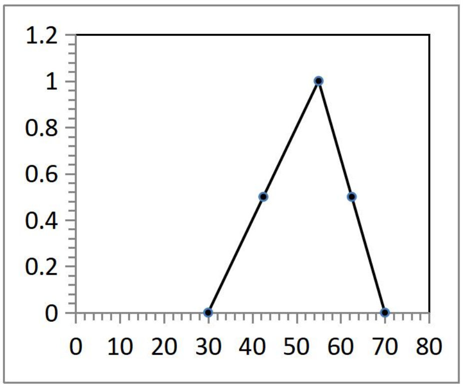
The Input parameters are (T, J_{sc} , V_{oc}) and the Output parameters are (R_m, J_m, V_m, FF, η_m, τ, R_s, R_{sh}) Where: J_{sc} is the open-circuit current density, J_m is maximum current density, R_s is series resistance, R_{sh} is shunt resistance, and τ is minority carrier lifetime.

T (°C)	J_{sc} (mA/cm^2)	V_{oc} (V)	R_m (Ω)	J_m (mA/cm^2)	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	3	4	1.1	0.48	6.4	18.5	0.11	3.9
50	4.8	1.8	3	3.4	1.2	0.47	5.9	23.1	0.12	1.8
60	4.4	1.75	2	3.75	0.82	0.39	4.45	26	1.0	1.2
70	4.5	1.76	2	3.9	0.85	0.41	4.8	29.5	1.0	1.25

Table 1. The effect of temperature on the solar sell parameters[21].

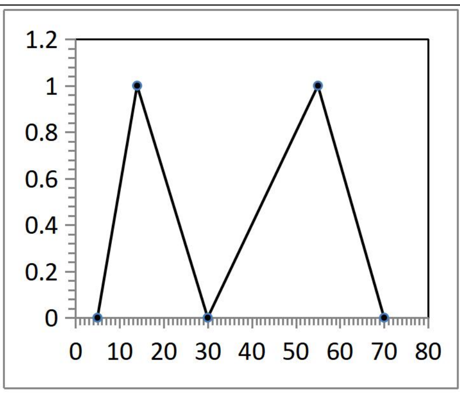


1-A (T vs. R_{sh}, R_s, V_m, η_m)-(H) (T=5,14,30)

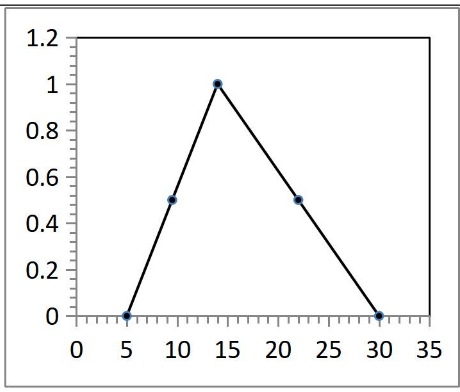


1-B (T vs. R_{sh}, R_s, V_m, η_m)-(L)-T=30,50,60,70)

Figure 2 and Figure 3. Membership of T vs R_{sh}, R_s, V_m, η_m and (T vs. R_{sh}, R_s, V_m, η_m) at various values of T



AB (T vs. R_{sh}, R_s, V_m, η_m)-(H& L)-(T=5,14,30,50,60,70)



1-C (T vs. J_m)-(H)-(T=5,14,30)

Figure 4 and Figure 5. Membership of T vs R_{sh}, R_s, V_m, η_m and (T vs. J_m) at various values of T

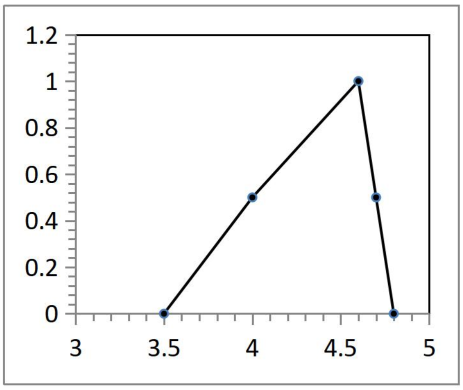
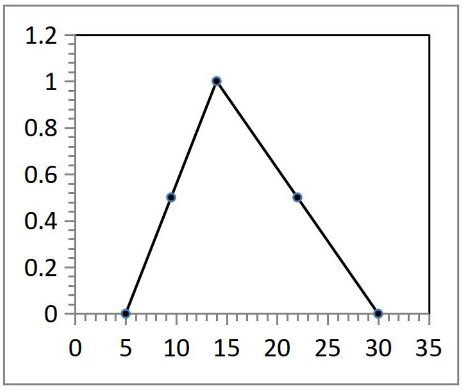
	
(J_{sc} vs. V_m, J_m, τ, R_s, R_{sh})-(H)-(T=5,14,30)-L	(T vs. J_m)-(H)-(T=5,14,30)

Figure 5 and Figure 6. Membership of J_{sc} vs V_m, J_m,τ,R_s,R_{sh} and (T vs. J_m) at various values of T

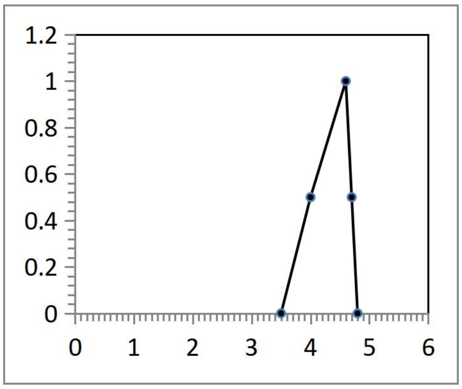
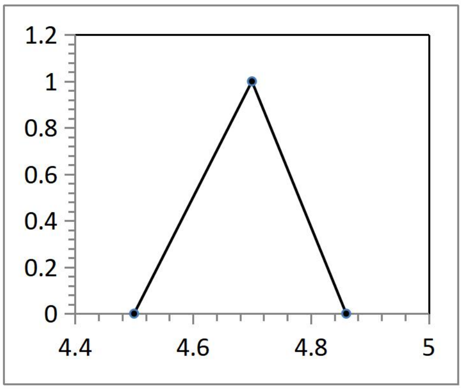
	
(J_{sc} vs. V_m, J_m, τ, R_s, R_{sh})-(H)-(T=5,14,30)-L	(T vs. J_m)-(H)-(T=5,14,30)

Figure 7 and Figure 8. Membership of J_{sc} vs V_m, J_m,τ,R_s,R_{sh} and (T vs. J_m) at various values of T

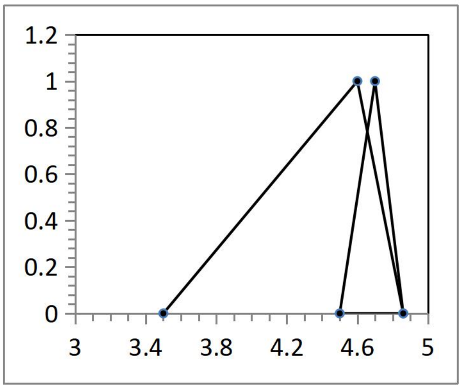
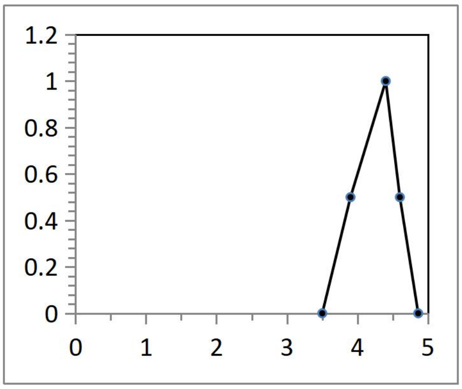
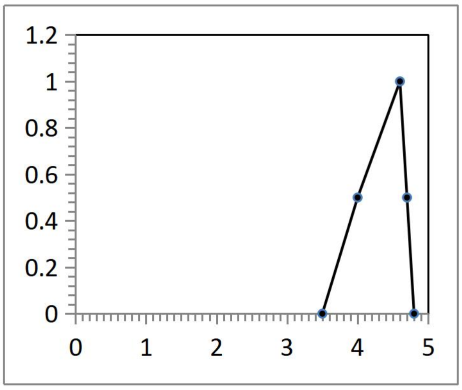
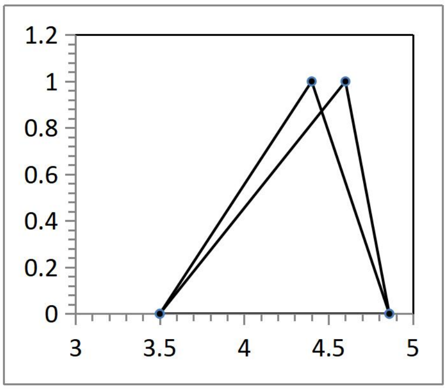
	
(J_{sc} vs. V_m, J_m, τ, R_s, R_{sh})-(H)-(T=5,14,30.50.60,70)-H H	(J_{sc} vs. R_m)-(H)-(T=5,14,30)-L

Figure 9 and Figure 10. Membership of J_{sc} vs Vm, Jm,τ,R_s,R_{sh} and (J_{sc} vs. R_m) at various values of T

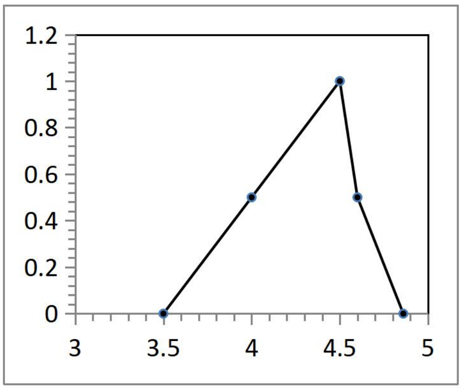


(J_{sc} vs. R_m)-(H)-(T=5,14,30)-L

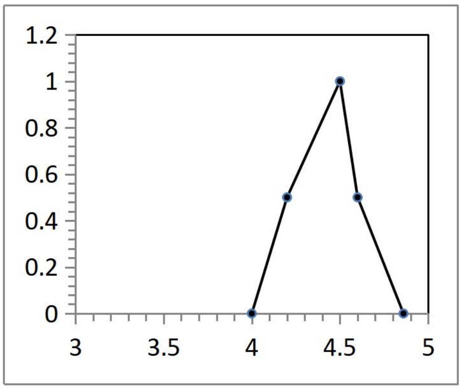


(J_{sc} vs. R_m)-(H)-(T=5,14)-H H

Figure 11 and Figure 12. Membership of J_{sc} vs Vm, Jm,τ,R_s,R_{sh} and (J_{sc} vs. R_m) at various values of T

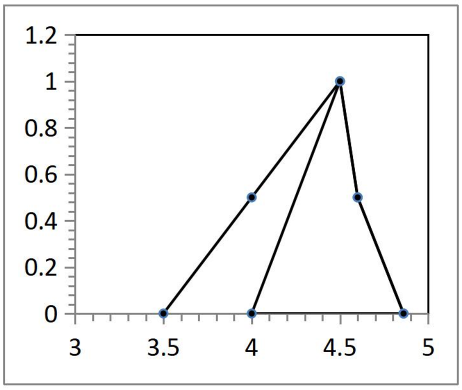


(J_{sc} vs. J_m)-(H)-(T=5,14,30,50,60,70)-H

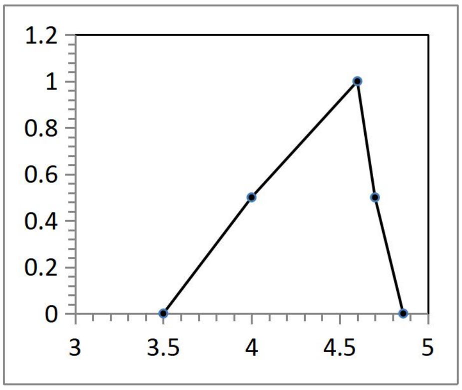


(J_{sc} vs. J_m)-(H)-(T=5,14,30)-H

Figure 13 and Figure 14. Membership of (J_{sc} vs. J_m) and (J_{sc} vs. J_m) H at various values of T

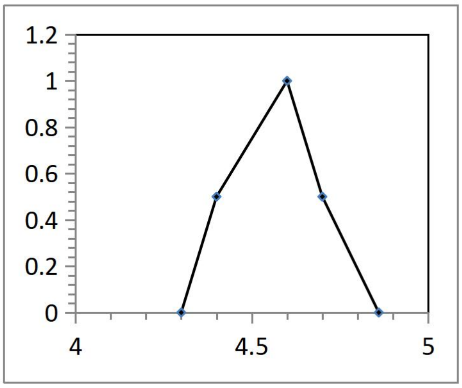


(J_{sc} vs. J_m)-(H)-(T=5,14,30,50,60,70)-H H

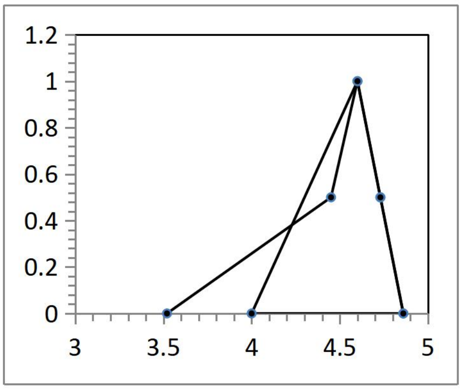


(J_{sc} vs. FF)-(H)-(T=5,14,30)-H

Figure 15 and Figure 16. membership of (J_{sc} vs. J_m) and (J_{sc} vs. FF)-(H) at various values of T

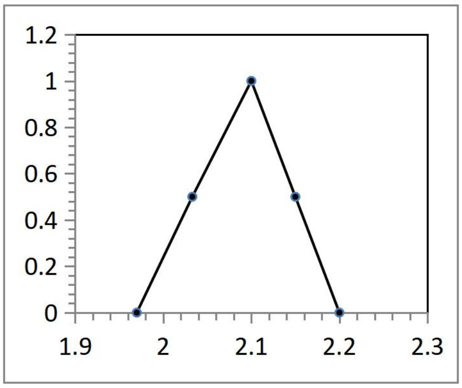


(J_{sc} vs. FF)-(H)-(T=5,30,60)-H

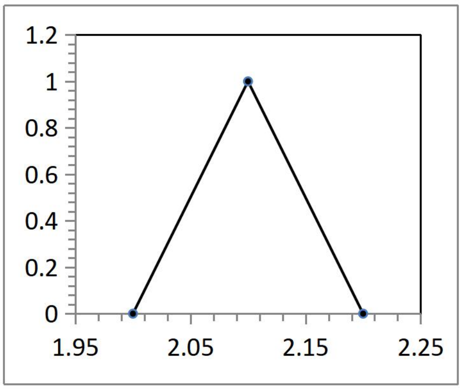


(J_{sc} vs. FF)-(H)-(T=5,14,30,50,60,70)-HH

Figure 17 and Figure 18. Membership of (J_{sc} vs. FF)-(H) and (J_{sc} vs. FF) at various values of T

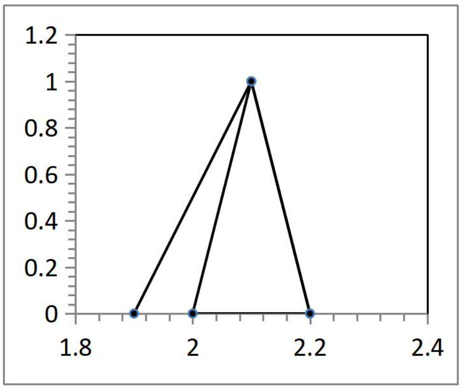


(V_{oc} vs. R_m)-(H)-(T=5,14,30)-H

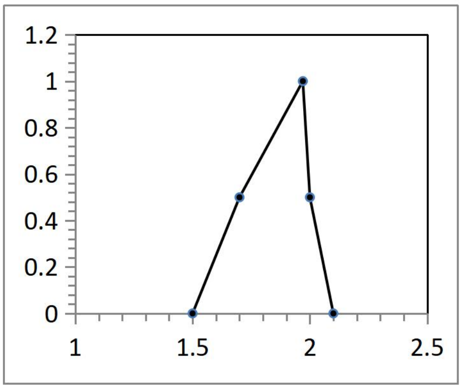


(V_{oc} vs. R_m)-(H)-(T=5,14)-H

Figure 19 and Figure 20. Membership of (V_{oc} vs. R_m) and (V_{oc} vs. R_m)-(H) at various values of T

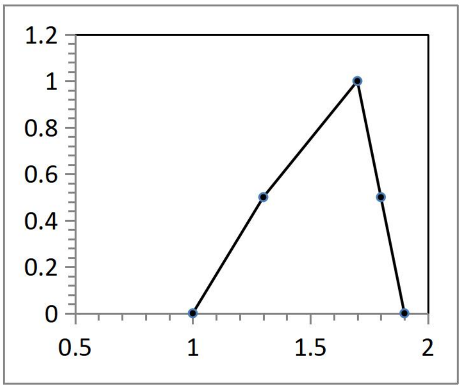


(V_{oc} vs. R_m)-(H)-(T=5,14,30,60,70)-HH

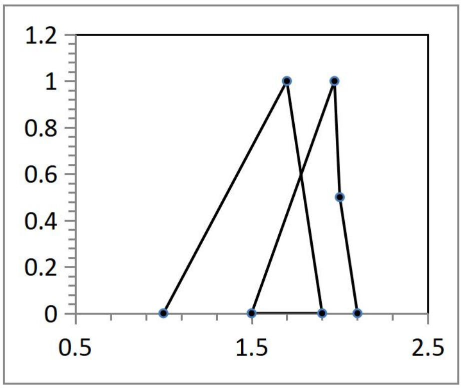


(V_{oc} vs. J_m)-(H)-(T=5,30,60)-H

Figure 21 and Figure 22. Membership of (V_{oc} vs. R_m) and (V_{oc} vs. J_m)-(H) at various values of T

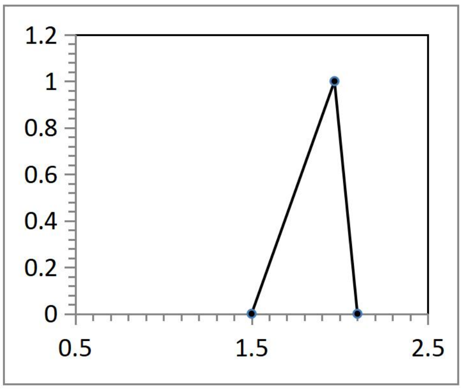


(V_{oc} vs. J_m)-(H)-(T=5,30,70)-H

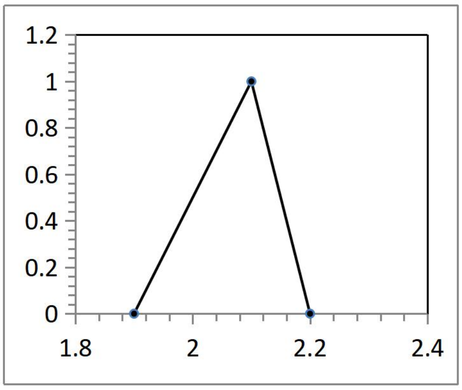


(V_{oc} vs. J_m)-(H)-(T=5,30,70)-HH

Figure 23 and Figure 24. Membership of (V_{oc} vs. J_m) and (V_{oc} vs. J_m)-(H) at various values of T

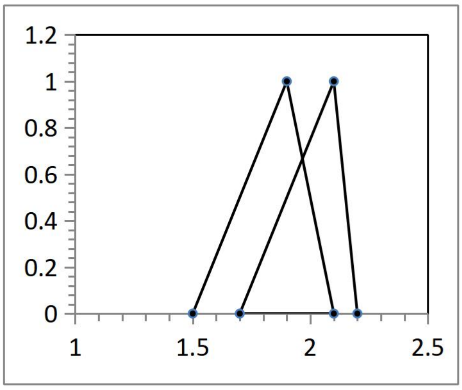


(V_{oc} vs. FF)-(T=5,30,70)-H

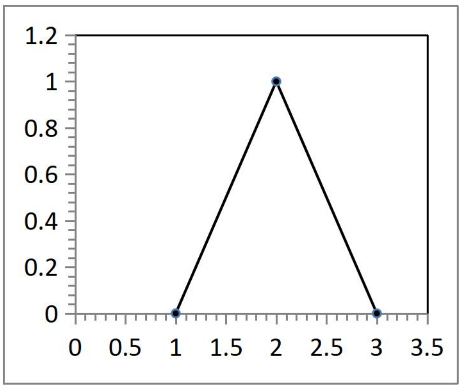


(V_{oc} vs. FF)-(T=5,14,60)-H

Figure 25 and Figure 26. Membership of (V_{oc} vs. FF) and (V_{oc} vs. FF)-H at various values of T



(V_{oc} vs. FF)-(T=5,30)-HH



(V_{oc} vs. V_m, η_m, τ, R_s, R_{sh})-(T=5,14,30)-L

Figure 27 and Figure 28. Membership of (V_{oc} vs. FF) and (V_{oc} vs. V_m, η_m, τ, R_s, R_{sh}) at various values of T.

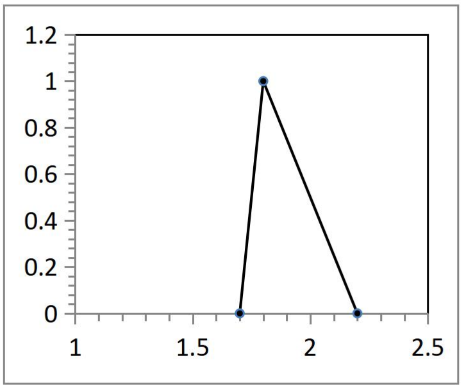
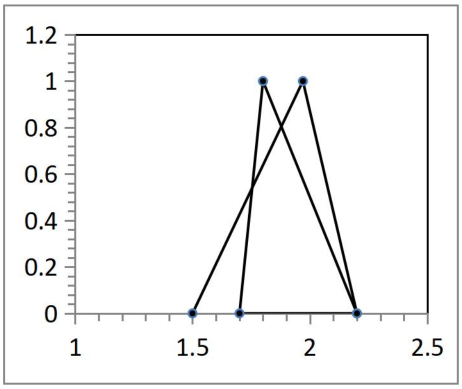
	
(V_{oc} vs. V_m, η_m, τ, R_s, R_{sh})-(T=14,50,60)-L	(V_{oc} vs.V_m, η_m, τ, R_s, R_{sh})-(T=5,14,30,50,60,70)-L L

Figure 29 and Figure 30. Membership of (V_{oc} vs. V_m, η_m, τ, R_s, R_{sh}) and (V_{oc} vs.V_m, η_m, τ, R_s, R_{sh})-L at various values of T.

4. Conclusion

Solar cells offer a potentially attractive means for direct conversion of sunlight into electricity with high reliability and low maintenance as compared with solar thermal systems. The disadvantages are high cost and difficulty of storing large amount of electricity for later use as compared with the relative case of storing heat for later use. The cost of generating electric power with solar calls can be reduced by using concentrator to focus sunlight on to the cell.

References

1. M. S. Rasheed, Approximate Solutions of Barker Equation in Parabolic Orbits, Engineering & Technology Journal, 28(3) (2010) 492-499.
2. M. S. Rasheed, An Improved Algorithm For The Solution of Kepler‘s Equation For An Elliptical Orbit, Engineering & Technology Journal, 28(7) (2010) 1316-1320.
3. M. S. Rasheed, Acceleration of Predictor Corrector Halley Method in Astrophysics Application, International Journal of Emerging Technologies in Computational and Applied Sciences, 1(2) (2012) 91-94.
4. M. S. Rasheed, Fast Procedure for Solving Two-Body Problem in Celestial Mechanic, International Journal of Engineering, Business and Enterprise Applications, 1(2) (2012) 60-63.
5. M. S. Rasheed, Solve the Position to Time Equation for an Object Travelling on a Parabolic Orbit in Celestial Mechanics, DIYALA JOURNAL FOR PURE SCIENCES, 9(4) (2013) 31-38.
6. M. S. Rasheed, Comparison of Starting Values for Implicit Iterative Solutions to Hyperbolic Orbits Equation, International Journal of Software and Web Sciences (IJSWS), 1(2) (2013) 65-71.
7. M. S. Rasheed, On Solving Hyperbolic Trajectory Using New Predictor-Corrector Quadrature Algorithms, Baghdad Science Journal, 11(1) (2014) 186-192.
8. M. S. Rasheed, Modification of Three Order Meth ods for Solving Satellite Orbital Equation in Elliptical Motion, Journal of university of Anbar for Pure science, (2019) in press.
9. M. S. Wrighton, "photoelectrochemical conversion of optical energy to electricity and fuels", Acc, Chem. Res. 12 (1994) 303-310.
10. D. W. Kammer, M. A. Ludington, Am. J. Phys. 45(602) (1977).
11. R. J. Van Overstreem, R. P. Mertens, "Physics Technology and Use of Photovoltaic's, Bristol: Adam Hilger, Ch. 2, (1986).
12. K. Zweibel "Harnessing Solar Power-The Photovoltiac Challenge, New York: Plenum, (1990).
13. M. Rasheed, Régis Barillé, Room temperature deposition of ZnO and Al: ZnO ultrathin films on glass and PET substrates by DC sputtering technique, Optical and Quantum Electronics, 49(5) (2017) 1-14.
14. M. Rasheed, Régis Barillé, Optical constants of DC sputtering derived ITO, TiO2 and TiO2: Nb thin films characterized by spectrophotometry and spectroscopic ellipsometry for optoelectronic devices, Journal of Non-Crystalline Solids, 476 (2017) 1-14.
15. M. Rasheed, R Barillé, Comparison the optical properties for Bi2O3 and NiO ultrathin films deposited on different substrates by DC sputtering technique for transparent electronics, Journal of Alloys and Compounds, 728 (2017) 1186-1198.
16. T. Saidani, M. Zaabat, M. S. Aida, R. Barille, M. Rasheed, Y. Almohamed, Influence of precursor source on sol–gel deposited ZnO thin films properties, Journal of Materials Science: Materials in Electronics, 28(13) (2017) 9252-9257.
17. K. Guergouria A. Boumezoued, R. Barille, D. Rechemc, M. Rasheed M. Zaabata, ZnO nanopowders doped with bismuth oxide, from synthesis to electrical application, Journal of Alloys and Compounds, 791 (2019) 550-558.
18. D. Bouras, A. Mecif, R. Barillé, A. Harabi, M. Rasheed, A. Mahdjoub, M. Zaabat, Cu: ZnO deposited on porous ceramic substrates by a simple thermal method for photocatalytic application, Ceramics International, 44 (17) (2018) 21546-21555.
19. W. Saidi, N. Hfaidh, M. Rasheed, M. Girtan, A.

Megriche, M. E. Maaoui, Effect of B2O3 addition on optical and structural properties of TiO2 as a new blocking layer for multiple dye sensitive solar cell application (DSSC), RSC Advances, 6(73) (2016) 68819-68826.
20. A. AUKŠTUOLIS, M. Girtan, G. A. Mousdis, R. Mallet, M. Socol, M. Rasheed, A. Stanculescu, Measurement of charge carrier mobility in perovskite nanowire films by photo-CELIV method, Proceedings of the Romanian Academy Series a-Mathematics Physics Technical Sciences Information Science, 18(1) (2017) 34-41.
21. O. A. Sultan, K. I. Hassoon, M. S. Rasheed, Deterioration of Silicon Solar Cell Parameter with Ambient Temperature, Al-Mustansiriyah Journal of Science, 14(1) (2003) 25-31.
22. F. S. Tahir, M. S. Rasheed, I. A.l - Hameed, Analysis the Performance of Silicon Solar Cell Parameters with the Ambient Temperature using Fuzzy Logic, Journal of the College of Basic Education 18(75) (2012) 173-183.
23. F. S. Tahir, M. S. Rasheed, Decline in the Performance of Silicon Solar Cell Parameters with the Ambient Temperature in Baghdad, Journal of the College of Basic Education, 18(75) (2012) 95-111.
24. F. Dkhilalli, S. Megdiche, K. Guidara, M. Rasheed, R. Barillé, M. Megdiche, AC conductivity evolution in bulk and grain boundary response of sodium tungstate Na2WO4, Ionics, 24(1) (2018) 169-180.
25. F. Dkhilalli, S. M. Borchani, M. Rasheed, R. Barille, K. Guidara, M. Megdiche, Structural, dielectric, and optical properties of the zinc tungstate ZnWO4 compound, Journal of Materials Science: Materials in Electronics, 29(8) (2018) 6297-6307.
26. F. Dkhilalli, S. M. Borchani, M. Rasheed, R. Barille, S. Shihab, K. Guidara, M. Megdiche, Characterizations and morphology of sodium tungstate particles, Royal Society open science, 5(8) (2018) 1-12.
27. M. Enneffati, B. Louati, K. Guidara, M. Rasheed, R. Barillé, Crystal structure characterization and AC electrical conduction behavior of sodium cadmium orthophosphate, Journal of Materials Science: Materials in Electronics, 29(1) (2018) 171-179.
28. E. Kadri, M. Krichen, R. Mohammed, A. Zouari, K. Khirouni, Electrical transport mechanisms in amorphous silicon/crystalline silicon germanium heterojunction solar cell: impact of passivation layer in conversion efficiency, Optical and Quantum Electronics, 48(12) (2016) 1-15.
29. E. Kadri, O. Messaoudi, M. Krichen, K. Dhahri, M. Rasheed, E. Dhahri, A. Zouari, K. Khirouni, R. Barillé, Optical and electrical properties of SiGe/Si solar cell heterostructures: Ellipsometric study, Journal of Alloys and Compounds, 721 (2017) 779-783.
30. E. Kadri, K. Dhahri, A. Zaafouri, M. Krichen, M. Rasheed, K. Khirouni, R. Barillé, Ac conductivity and dielectric behavior of a−Si: H/c−Si1−yGey/p−Si thin films synthesized by molecular beam epitaxial method, Journal of Alloys and Compounds, 705 (2017) 708-713.
31. M. Winter, Goguen categories: a categorical approach to L-fuzzy relations, Springer. (2007).
32. Mohammed RASHEED, Mohammed Abdelhadi Sarhan, Measuring the Solar Cell Parameters Using Fuzzy Set Technique, Insight-Electronic 1 (1) 2019.
33. Mohammed RASHEED, Mohammed Abdelhadi Sarhan, Solve and Implement the main Equations of Photovoltaic Cell ParametersbUsing Visual Studio Program, Insight-Mathematics 1 (1) 2019.
34. Mohammed RASHEED, Mohammed Abdelhadi Sarhan, Characteristics of Solar Cell Outdoor Measurements Using Fuzzy Logic Method, Insight-Mathematics, 1 (1) 2019.
35. L. A. Zadeh, Fuzzy sets, Information and Control 8(3) (1965) 338–353.
36. D. Dubois, H. Prade, Fuzzy Sets and Systems. Academic Press, New York, (1988).
37. R. Lily Liang, S. L.u, X. Wang, Y. Lu, V. Mandal, D. Patacsil, D. Kumar, FM-test: A Fuzzy-Set-Theory-Based Approach to Differential Gene Expression Data Analysis, BMC Bioinformatics, 7(4): S7. (2006).
38. H. Bandemer, V. Novak, J. Ramik, M. Mares, M. Cerny, J. Nekola, Fuzzy Local Inference in Fuzzy, Bechyne, Czechoslovakia, (1990) 47-48.
39. D. D.H. Prade, "Fuzzy sets and Systems", New York, Academic Press, (1980).
40. G. Klir, V. Clair, B. Yuan, Fuzzy set Theory-Function and Application, Printed Hall PTR, (1997).
41. W. Pedrycz, F. Gomida, An Introduction to Fuzzy sets-Analysis and Design, Printed Hall of India, (1998).