RESEARCHERID
THOMSON REUTERS

[*Emeksiz* et al., 4(6): June, 2017*] ISSN: 234-5197
Impact Factor: 2.715

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

OPTIMIZATION OF PV MODULE WITH SINGLE-DIODE MODEL FOR TOKAT REGION

Cem Emeksiz*[1], Akif Akbulut[2], Zafer Dogan[3], Mehmet Akar[4]
[*]Gaziosmanpasa University, Faculty of Natural Sciences and Engineering, Electric-Electronic Engineering Department, Tokat/TURKEY
[*] cem.emeksiz[AT]gop.edu.tr

DOI: 10.5281/zenodo.802328

Keywords: Solar energy, Photovoltaic effect, Characteristics of PV cell, Single diode model

Abstract
In this study single diode model of photovoltaic cell is is simulated with using all cell parameters for Tokat Region in TURKEY. Retscreen software and matlab were used to determine model parameters. Simulation studies were carried out with different irradiations and temperatures in Tokat Region. The output power, voltage and current characteristics of PV model are analyzied especially with taking the effect of temperature and irradiance. Komaes 140W PV module is referenced to analyze the presented model. Also Euclidean distance, Manhattan distance and Minskowski distance methods are used to determine distance from maximum panel power.

Introduction
Over the last decades, renewable energy sources has been most popular and credible for humankind. Because fossil fuels cause pollution and limited sources [1]. So, solar energy, wind energy, biomass etc. become most popular in alternative energy sources. In that context, solar energy is inexhaustible, renewable and non-polluting. Therefore it can be used in different energy applications [2]. But solar energy has less energy contribution than other energy sources. Because it has low efficiency and high cost [3]. Our country has a position of having second highest potential of solar energy in Europe. However, Turkey is falling behind of many of European countries in terms using its potential. Nevertheless, due to the new regulations put in place in last years, benefiting from solar energy has begun to be chosen in Turkey as well, for producing electricity. That is why, today, Energy Ministry of Turkey encourages setting up Solar Power Plants and it is permitted to produce electricity up to 500kW without licence.

Solar cell is the main part of PV systems and these systems directly produce the electiric from sun. Cells are suitable to be connected to power electronic systems and loads [4]. Efficiency is very important for photovoltaic systems. Thereby maximum power point tracking control is prefered in many PV systems. PV system parameters also have an important role and the circuit based model is needed for modelling for the PV cell [5]. Generally non-linear I-V curve is used for modeling of PV module. Many researchers used single-diode model to characterize the PV module as the current source in parallel to a diode [6-8]. The single diode model use a series resistance for good performance.These models are known to as Rs-models [9-10]. Also many researchers have used this model that includes a shunt resistance (Rsh) for right approach [11-13]. On the other hand the second model is two-diode model of a solar cell. Difference between Rs model and two-diode model is a second diode. But especially Rs model is commanly prefered . Because this model is very simple and to determine parameters of cell is easy [14-17].

In literature; Celik et.al., have used analytical models that are used four- and five-parameter for current of photovoltaic module [9]. For PV panel behavior Neural network revised under realistic weather conditions [19]. Ghani et.al., have studied numerical solition about series and shunt resistances [20]. PV cell's dynamic resistance is calculated using I-V characteristics in Ref [21]. Zagrouba et.al., calculated the electrical parameters using genetic algorithms [22]. Ishibashi et.al., offered a new approach using a single I-V curve to derive cell parameters [23].

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

In this study; single diode model is preferenced to determine unknown parameters of solar cell and focused on distances from the maximum panel power according to meteorological data of Tokat. Numerical analysis showed a 40% loss of maximum panel power.

Mathematical Model of A Solar Cell

One-Diode model is shown in Fig.1 where represents series and parallel resistance, espectively. I_L light current (A), I_D ideal diode current (A), Ish shunt resistance current, I cell's current.

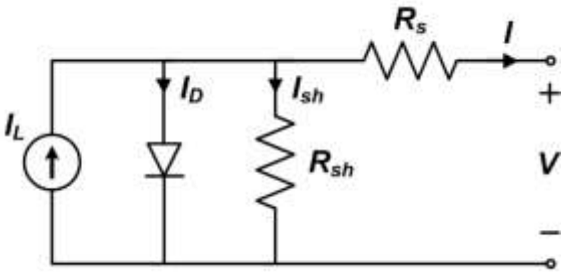

Figure 1 Electrical Device of Solar Cell with One-Diode

Generally to calculate relation between the cell`s current and voltage is used following equation:

$$I = I_L - I_0\left(e^{\frac{(V+R_S I)}{aV_T}} - 1\right) - \frac{V+IR_S}{R_{sh}} \qquad (1)$$

Where;
I_L : Photocurrent (A)
I_0 : Diode Saturation Current (A)
R_s : Series Resistance (Ω)
R_{sh} : Shunt Resistance (Ω)
a : Diode Ideality Factor
V_T : Thermal Voltage equivalent (V)

Cell Parameters And Equations To Determine Cell Parameters

Photocurrent (I_L)

The photocurrent can simply be calculated using Equation 2. This equation is a function of temperature and irradiance values. [24],

$$I_L = \frac{I_{scref}}{G_{T_{cref}}} G_{Tc} - \alpha\left(T_c - T_{cref}\right) \qquad (2)$$

G_{Tc} : Irradiance (W/m^2)
$G_{T_{cref}}$: Reference irradiance (1000 W/m^2)
I_{scref} : Reference condition's short circuit current (A)
α : Curve Fitting Parameter
T_c : Condition Temperature
T_{cref} : Reference Temperature (25 ^{O}C)

$$\alpha = \frac{T_{cref}+273}{T_c+273}\,\alpha_{ref} \quad (3)$$

α_{ref} : The value of α the reference condition (1000W/m^2 and 25 ^{O}C) [25],

$$\alpha_{ref} = \frac{2V_{mpref}-V_{ocref}}{\frac{I_{scref}}{I_{scref}-I_{mpref}}+ln\left(1-\frac{I_{mpref}}{I_{scref}}\right)} \quad (4)$$

V_{mpref} : The Reference Condition's Maximum Power Point Voltage (V)
V_{ocref} : The Reference Condition's Open Circuit Voltage (V)
I_{mpref} : Maximum Power Point Current At The Reference Condition (A)

Diode Saturation Current (I_0)
According to variations in cell temperature to calculate the diode saturation current (I_0) is used the following equation [26];

$$I_0 = \frac{(R_{sh}+R_s)I_{sc}-V_{oc}}{R_{sh}e^{\left(\frac{V_{oc}}{a\,V_T}\right)}} \quad (5)$$

$$V_T = \frac{n_s kT}{q} \quad (6)$$

q : Electron Charge (1.60217646 × 10^{-19} C)
n_s : Series Cells's number
k : Boltzmann Constant (1.3806503 × 10^{-23} J/K)
T : P-N Junction's temperature (K)

Series (R_s) And Shunt Resistances (R_{sh})
Both series and shunt resistances are calculated according to the following equations [26];

$$R_s = \alpha_{ref}ln\left[1-\frac{I_{mpref}}{I_{scref}}\right]+V_{ocref}-V_{mpref} \quad (7)$$

$$R_{sh} = \frac{(V_m-I_mR_S)(V_m-R_S(I_{sc}-I_m)-aV_T)}{(V_m-I_mR_S)(I_{sc}-I_m)-aV_TI_m} \quad (8)$$

Series resistance is small than parallel resistance. Also parallel resistance's value is generally high. Therefore both of them are negligible [27].

Materials and Methods
Komaes KM(P) 140 PV panel is referenced for modeling. Because it is most commonly used in PV technology. Electrical characteristics data of Komaes 140W pv module is shown in Table 1.

Table 1. Electrical characteristics data of Komaes 140W

Electrical Characteristics		
Model	**KM(P) 140**	
Maximum Power	Pmax (W)	140
Maximum Power Voltage	V_m(V)	18.36
Maximum Power Current	I_m(A)	7.65
Open Circuit Voltage	V_{oc}(V)	21.96
Short Circuit Current	I_{sc}(A)	8.17
Cells of Module	Pcs	36(4x9)
Temperature Coefficient of I_{sc}	%/^{O}C	+0.05
Temperature Coefficient of V_{oc}	%/^{O}C	-0.35

In this study; the monthly mean values of solar irradiance and temperature for Tokat Region were obtained using RETScreen Software. RETScreen is most suitable and used software for renewable energy, energy efficiency, energy performance analysis and feasibility analysis. The monthly mean values of solar irradiance and temperature are shown in Table 2.

Table 2. The monthly mean values of solar irradiance and temperature

Month	**Solar Irradiance (kWh/M^2/g)**	**Temperature (^{O}C)**
January	1.85	-0.4
February	2.60	0.0
March	3.64	3.9
April	4.52	9.6
May	5.62	13.3
June	6.53	16.4
July	6.48	18.7
August	5.77	18.8
September	4.69	16.0
October	3.19	11.8
November	2.14	5.9
December	1.54	1.3
Mean value of yearly	4.05	9.7

In the single diode model, to solve nonlinear I-V equation, electrical and thermal values of PV panel using datasheet, location variables, defining constants, finding series and parallel resistances were used and I–V characteristic curves are achieved. According to months I–V characteristic curves are shown in Fig. 2.

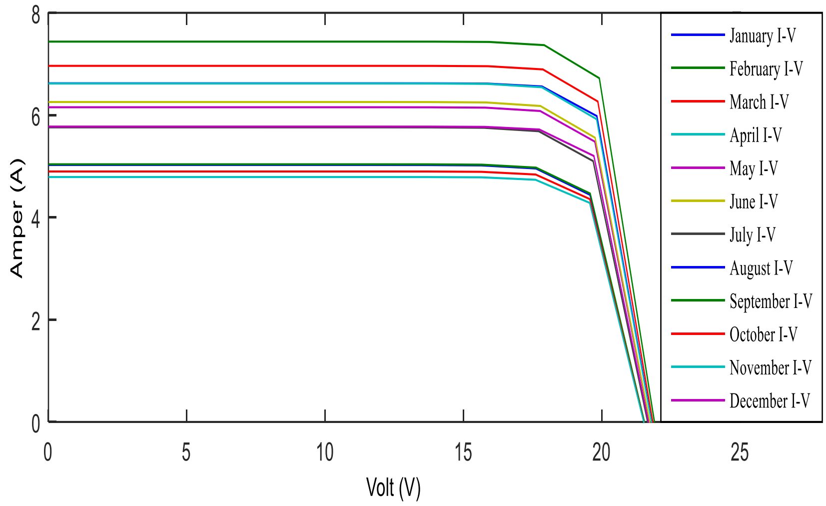

Figure 2 I-V Characteristics According to Months

The maximum power of the panel was calculated for each month in Fig. 3.

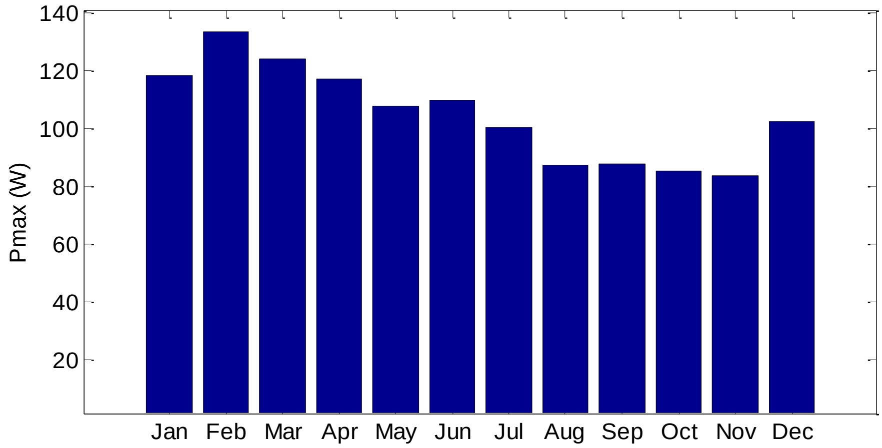

Figure 3 The Maximum Power of The Panel for Eeach Month

The maximum power of panel was selected as reference is 140W. The distance of power for each month from the maximum panel power was calculated by 3 methods. These are Euclidean distance, Manhattan distance and Minskowski distance. These methods are widely used in clustering methods of data mining.

Euclidean distance
It is the most commonly used distance measure in practice. Euclidean distance is an application of pythagorean theorem in two dimensional space.Euclidean space becomes a metric space.

Euclidean distance is the length of the line that is connecting A and B points ($\overline{AB}$). If there are two point in Euclidean as A = (A1, A2,..., An) and B = (B1, B2,..., Bn), distance (d) is calculated by Pythagorean formula.

$$d(A,B) = \sqrt{(A_1 - B_1)^2 + (A_2 - B_2)^2 + \cdots (A_n - B_n)^2} \quad (9)$$

This equation can be updated as equation 10.

$$\mathrm{d(i,j)} = \sqrt{\sum_{i=1}^{p} \left(X_{ik} - X_{Jk}\right)^2} \quad (10)$$

Manhattan distance
This distance is calculated as the sum of absolute distances between observations. The Manhattan distance is calculated as:

$$d(i,j) = |X_{i1} - X_{j1}| + |X_{i1} - X_{j2}| + \cdots \quad (11)$$

Minskowski distance
The Minkowski distance is a metric in a normed vector space. It is the generalization form of Manhattan distance and Euclidean distance. Minskowski distance is calculated as:

$$d(i,j) = \left[|X_{i1} - X_{j1}|^m + |X_{i2} - X_{j2}|^m + \cdots |X_{im} - X_{jm}|^m\right]^{1/m} \quad (12)$$

The results that were obtained according each distance method are shown in Table 3.

Table 3. Distance values from maximum power for each distance method

Months	Euclidean Distance	Manhattan Distance	Minskowski Distance
January	445,895	651,766	199,311
February	361,105	533,913	160,663
March	391,222	573,564	174,029
April	401,174	582,325	178,576
May	432,161	622,071	192,617
June	408,133	585,651	181,766
July	448,138	639,078	199,892
August	538,385	759,781	242,965
September	526,058	741,888	236,821
October	575,231	809,249	261,269
November	618,088	866,046	282,895
December	530,120	759,333	239,895

Discussion and Conclusion

We studied single-diode model of solar cell to determine I-V characteristic. The performance of the PV system under change solar radiation and temperature difference are calculated in this paper. While solar radiation increases, cell's current increases in direct proportion and open circuit voltage comparatively less increases. On the other side while temperature increases, cell's current less increases but open circuit voltage linearly decreases. This situation affects the output power of panel. Especially in November, 60% of output power of panel is decreased was observed in numerical solutions. This situation leads to a loss of about 79 kWh of energy. Three distance methods were used. The maximum distance was calculated with Manhattan Distance Method in November. To study on Physical modeling is very diffucult because of the parameters of the given module. But mathematical model helps to analyse by changing values. Panels can be used more efficiently with the production of custom panels for cities or regions. Also this situation reveals the importance of hybrid systems.

References

[1] I.L. Alboteanu, C.A.Bulucea, and S. Degeratu, "Estimating Solar Irradiation Absorbed by Photovoltaic Panels with Low Concentration Located in Craiova Romania," Sustainability, 2015, 7, 2644-2661; doi:10.3390/su7032644.
[2] M. Abdulkadir, A.S. Samosir, and A.H.M. Yatim, "Modeling and Simulation of a Solar Photovoltaic System, Its Dynamics and Transient Characteristics in LABVIEW," International Journal of Power Electronics and Drive System (IJPEDS) Vol. 3, No. 2, June 2013, pp. 185~192 ISSN: 2088-8694.
[3] P. Sudeepika, and G.M.d Gayaz Khan, "Analysis Of Mathematical Model Of PV Cell Module in Matlab/Simulink Environment," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 3, Issue 3, March 2014.
[4] M.G. Villalva, J.R. Gazoli, and E.R. Filho, "Comprehensive approach to modeling and simulation of photovoltaic arrays," IEEE Trans. Power Electron. 2009,24 (5), 1198–1208.
[5] N. Yıldıran, and E. Tacer, "Identification of photovoltaic cell single diode discrete model parameters based on data sheet values" Solar Energy 127, 2016, 175–183.
[6] R.M. Da Silva, and J.L.M. Fernandes, "Hybrid photovoltaic/thermal (PV/T) solar systems simulation with Simulink/Matlab," Solar Energy, 2010,84: 1985-1996.
[7] I.H. Altas, and A.M. Sharaf, "A Photovoltaic Array Simulation Model for Matlab-Simulink GUI Environment," IEEE, Clean Electrical Power, International Conference on Clean Electrical Power (ICCEP '07), 2007,June 14-16, Ischia, Italy.
[8] R.K. Nem, S. Nema, and G.A. Gnihotri, "MATLAB / simulink based Study of photovoltaic cells / modules / array and their experimental verification," International Journal of Energy and Environment. 1(3): 487-500, 2010.
[9] N. Celik, and N. Acikgoz, "Modeling and experimental verification of the operating current of mono-crystalline photovoltaic modules using four- and five-parameter models," Appl. Energy, vol.84, no.1, 2007, pp.1-15.
[10] W. Xiao, W.G. Dunford, and A.A. Capel, "Novel modeling method for photovoltaic cells," Proc. IEEE 35th Annu. Power Electron. Spec. Conf. (PESC), Vol.3, 2004, pp.1950-1956.
[11] M.G. Villalva, J.R. Gazoli, and E.R. Filho, "Comprehensive approach to modeling and simulation of photovoltaic arrays," IEEE Trans. Power Electron., vol.24, no.5, pp.1198-1208, May. 2009.
[12] C. Carrero, J. Amador, and S.A. Arnaltes, "Single procedure for helping PV designers to select silicon PV module and evaluate the loss resistances," Renewable Energy, vol.32, no.15, 2007, pp.2579-2589.
[13] S. Liu, and R.A. Dougal, "Dynamic multiphysics model for solar array," IEEE Trans. Energy Convers., vol.17, no.2, pp.285-294, Jun. 2004.
[14] S. Chowdhury, G.A.S. Taylor, P. Chowdhury, A.K. Saha, and Y.H. Song, "Modelling, simulation and performance analysis of a PV array in an embedded environment," Proc. 42nd Int.Univ. Power Eng. Conf. (UPEC), 2007, pp.781-785.
[15] J.A. Gow, and C.D. Manning, "Development of a photovoltaic array model for use in simulation studies of solar energy conversion systems," Proc. 6th Int..Conf. Power Electron. Variable Speed Drives., 1996, pp.69-74.

[16] C. Sah, R.N. Noyce, and W. Shockley, “Carrier generation and recombination in p-n junctions and p-n junction characteristics,” Proc. IRE, vol.45, no.9, 1957, pp.1228-1243.
[17] J.A. Gow, C.D. Manning, “Development of a photovoltaic array model for use in power-electronics simulation studies,” IEE Proc. Elect.Power Appl., vol.146, no.2, pp.193-200, 1999.
[18] M. Karamirad, M. Omid, R. Alimardani, H. Mousazadeh, and S.N. Heidari, “ANN based simulation and experimental verification of analytical four- and five-parameters models of PV modules,” Simul. Model. Pract. Theory 34 ,2013, 86e98.
[19] F. Ghani, M. Duke, and J. Carson, “Numerical calculation of series and shunt resistance of a photovoltaic cell using the Lambert W-function experimental evaluation,” Sol. Energy 87, 2013, 246-253.
[20] J. Thongpron, K. Kirtikara, and C. Jivacate, “A method for the determination of dynamic resistance of photovoltaic modules under Illumination,” Sol. Energy Mater. Sol. Cells 90, 2006, 3078-3084.
[21] M. Zagrouba, A. Sellami, M. Bouaicha, and M. Ksouri, “Identification of PV solar cells and modules parameters using the genetic algorithms: application to maximum power extraction,” Sol. Energy 84, 2010, 860-866.
[22] K.I. Ishibashi, Y. Kimura, and M. Niwano, “An extensively valid and stable method for derivation of all parameters of a solar cell from a single current-voltage characteristic,” J. Appl. Phys. 103 (094507), 2008.
[23] Ø. Ulleberg, “Stand-Alone Power Systems for the Future : Optimal Design, Operation, and Control of Solar-Hydrogen Energy Systems,” Ph.D. Thesis, Norwegian University of Science and Technology, Trondheim Norway, 1998.
[24] T. Townsend, “A Method for Estimating the Long-Term Performance of Direct Coupled Photovoltaic Systems,” MS Thesis, University of Wisconsin, 1989.
[25] J. Cubas, S. Pindado, and C. De Manuel, “Explicit Expressions for Solar Panel Equivalent Circuit Parameters Based on Analytical Formulation and the Lambert W-Function” Energies, 2014, 7, 4098-4115.
[26] J. Bikaneria, S.P. Joshi, and A.R. Joshi, “Modeling and Simulation of PV Cell using One-diode model,” International Journal of Scientific and Research Publications, Volume 3, Issue 10, October 2013