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Parameter Calculation of PV Module by Simulation and Computation

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ABSTRACT: The photovoltaic module is typically represented by an equivalent circuit whose parameters are calculated using the experimental current-voltage (I-V) characteristic. The precise determination of these parameters remains a challenge for researchers, which led to adiversification in models and numerical methods used for its computation. In the present study the model has been studied by two mathematical methods. One method of computation is based on simulated Newton-Raphson iteration method and another is computation (mathematical) method. Newton-Raphson iteration method is solved by MATLAB simulation. Two diode model with series and parallel resistance is considered for the calculation of five parameters of selected module 125Wp/12V/SN80. Parametric calculation of I_o ,I_{pv}, R_s, R_{sh} and A is the objective of this work. The simulation results for the 125Wp/12V SN80moduleareconfronted withthoseofthemanufacturer and to the computation method.

KEYWORDS:PV array, simulation, irradiance, saturation current, photovoltaic current

I.INTRODUCTION

Energy demand is increasing in the world at fast rate. To cope up with increased demand, newer methods of energy production are being implemented. Renewable energy sources are the prime one in these technologies. Solar power and wind power are capturing the world highly as compared to other form of energy sources.

Renewable energy sources are preferred due to its non-pollutant qualities, compared to fossils fuels. Solar energy is one of the best available promising renewable power source, among the available renewable energy sources. Solar energy is getting more popularity with its characteristics advantages such as easy erection and instant generation. Again it is getting more popularity due to the benefits provided by Government.

The major constituent of solar system is its panels, which is the transforming source of sunrays power into electrical power. Panels are the costly items in the components of solar system. So the accurate design of panel is essential for its optimum use, before its installation. This can be done by simulation technique. The simulation requires the PV cell modeling which confirm thenonlinear current-voltage (I-V) and power-voltage (P-V) characteristics of solar cell.

There are various PV cell modules studied by researchers in the literature. One of the simplest is one diode model. [1] In broad sense this model is derived by three parameters: Short Circuit Current (I_{sc}), Open Circuit Voltage (V_{oc}), and Diode Ideality Factor (A). When the parameter series resistance (R_s) is added in this model, the accuracy of model gets improved. One drawback of this model is that it is not capable of temperature (T) variation handling. Parameter shunt resistance (R_{sh}) significantly improves the model efficiency. [2] This model is having a drawback of reduced accuracy under low irradiance (G) level, especially at open circuit voltage (V_{oc}). Additional diode design is added to the model for the recombination loss in the depletion region of the cell of solar module. [3] This is two diode model. This model has more parameters to calculate. This model gives more accuracy because this model is more practical especially under low voltages.

The main task is to design a two diode model with higher accuracy. Some difficulties regarding the computation of parameters for higher accuracy is that, it is getting costlier from the computation point of view, as there occur additional coefficients during the computation. Again there occur the difficulties in determination of initial value of the parameters of two diode model. Some software tools are available in market such as PV-Spice, PV-Design-Pro, SolarPro, PV-Cad and PV-Syst etc. for simulation purpose. These software tools are expensive and major drawback is that they are of no use to interface the PV arrays with power converters. The MATLAB simulink model by K. Ishaque*et al*. [4] is quiet better for computation.

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For explaining a photovoltaic model, drawing equivalent circuit is the basic method. Its parameters are calculated from the knowledge of current-voltage (I-V) characteristics. It is typical task to determine accurate values of parameters. In order to get accurate results, various numerical methods are used for the model. In this paper attempt is made to calculate five parameters of model. MATLAB simulation is carried for the module 125Wp/12V/SN80. The results are confronted with data sheet provided by manufacturer. Conclusions are drawn by tallying the results of the mathematical methods adopted.

NOMENCLATURE

I_d	DiodeCurrent, *Ampere*
I_s	DiodeSaturation Current, *Ampere*
I_{ph}	Photocurrent, *Ampere*
I_o	Reverse Saturation Current, *Ampere*
q	Electron Charge, $1.60217646*10^{-19}$ *C*
k	BoltzmannConstant, $1.3806503*10^{-23}$ *J/K*
T	CellTemperature, *Kelvin*
A	DiodeFactor
R_s	SeriesResistance, *Ohm*
R_{sh}	ShuntResistance, *Ohm*
N	NumberofCellsin Series
V_{oc}	OpenCircuit Voltage, *Volt*
I_{sc}	ShortCircuit Current, *Amp*
V_{mpp}	Voltageatthe Pointof Max .Power, *Volt*
I_{mpp}	Currentatthe Pointof Max. Power, *Amp*
I_{pv}	Output Current, *Amp*
I_{sh}	Shunt Current, *Amp*
V_{pv}	Output Voltage, *Volt*
G	Solar Irradiation, *Watt/ Meter*^{2}

Lot of work is done by researchers, on the mathematical methods of parameter calculation. SabanYilmaz*et al.* [5] presented the double diode model with the help of MATLAB for the characteristics of solar radiation (G) at 1000 w/m^2 and temperature (T) 25^{o}C. Dominique Bonkoungou*et al.* [6] studied the single and double diode model for five parameters. The parameters are compared between datasheet values and values obtained from Newton-Raphson iteration method. Aneek Islam *et al.* [7] presented the two diode model characteristics for parameter calculation by efficient iteration method. The characteristics curves obtained are matched with data sheet of manufacturer. T. Skocil *et al.* [8] presented the two diode cell mathematical modeling.

II.MODELLING OF PHOTOVOLTAIC MODULE

Solar cell is basically a PN junction fabricated in a thin wafer or layer of semiconductors. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. [9]When solar cells are exposed to sunlight, photons with energy greater than the band-gap energy of the semiconductor are absorbed and create some electron-hole pair proportional to the incident irradiation. Under the influence of the internal electric fields of the p-n junction, these carriers are swept apart and create a photocurrent which is directly proportional to solar irradiation. [10] Naturally, PV system exhibits a nonlinear current-voltage (I-V) and power-voltage (P-V) characteristics which vary with the radiant intensity (G) and cell temperature (T).

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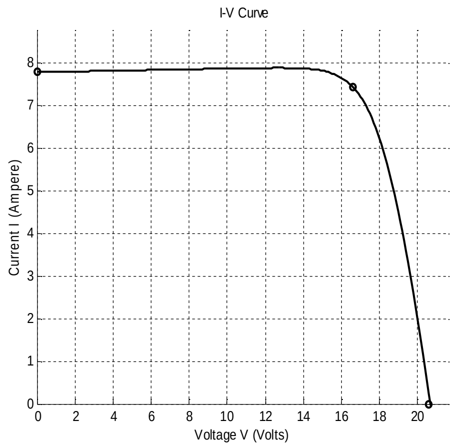
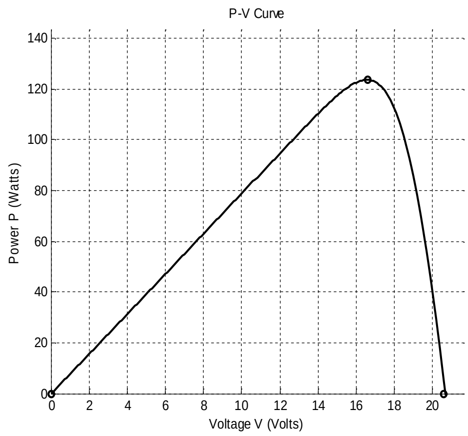


(a) I-V Curve at T = 25°C, G= 1000w/m^2



(b) P-V Curve at T = 25°C, G= 1000w/m^2

Fig.1: Simulated Characteristics of PV Module 125Wp/12V/SN80

The nonlinear nature of PV systems is apparent from Fig.1. The nonlinear characteristics of PV module 125Wp/12V/SN80 indicate that array current and power depends on the array terminal operating voltage. [11]

Below is given the step by step approach for the design of two diode model, two diodes (D_1, D_2) connected in parallel, resistance connected in series (R_s) and resistance connected in parallel (R_{sh}). This is the general mathematical model developed by considering the split up of current by Kirchhoff's law. This mathematical model can be applied to any two diode PV module for study purpose.

The first model is the 'Two Diode Ideal Model' in which two diodes D_1 and D_2 are connected in parallel. This model is shown in the Fig. 2. The next model is 'Two Diode Model with Series Resistance', in which resistance (R_s) is connected in series towards output side. This model is shown in the Fig. 3. Next model is 'Two Diode Model with Series and Shunt Resistance', in which series resistance (R_s) and shunt resistance (R_{sh}) is connected in series and parallel respectively at output side. This model is shown in the Fig. 4.

1. Two Diode Ideal Model:

Two diodes PV cell equivalent circuit is shown in Fig 2. This is the ideal model of two diodes. It represents the simplest form of model. In this model five parameters can be calculated. Along the five parameters, first two parameters are saturation current I_{s1}, I_{s2} for the diode D_1 and diode D_2 respectively. Third and fourth parameter is ideality factor A_1 and A_2 of first diode D_1 and second diode D_2respectively. Fifth parameter is photovoltaic current I_{ph}. The ideality factor A_1 and A_2 are the functions of voltage across the devices. At high voltage, when the recombination in the device is dominated by the surfaces and the bulk regions, the ideality factor is close to one. However at lower voltages, recombination in the junction dominates and the ideality factor approaches to two. The junction

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recombination is modeled by adding a second diode D_2 in parallel with the first diode D_1 and setting the ideality factor A_2 typically to two.

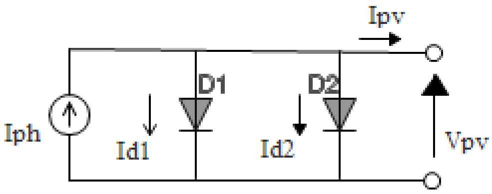

Fig. 2: Circuit Diagram for Two Diode Ideal Model

Theory of Kirchhoff's law is used to derive characteristic equation of this model.

$I_{pv} = I_{ph} – I_{d1} – I_{d2}$ .... (1)

Current of first diode is

$$I_{d1} = I_{s1}\{\exp\left(\frac{q*Vpv}{A1*K*T}\right) - 1\} \quad (2)$$

Current of second diode is

$$I_{d2} = I_{s2}\{\exp\left(\frac{q*Vpv}{A2*K*T}\right) - 1\} \quad (3)$$

Output current I_{pv} is given by following equation

$$I_{pv} = I_{ph} - I_{s1}\left\{\exp\left(\frac{q*Vpv}{A1*K*T}\right) - 1\right\} - I_{s2}\left\{\exp\left(\frac{q*Vpv}{A2*K*T}\right) - 1\right\}$$
…….. (4)

Equations (2), (3) and (4) give the diode current I_{d1}, I_{d2} and output current I_{pv}. Ideality factor for diode D_1 is one and for diode D_2 is two. For the same PN junction temperature (T) and irradiance (G), the short circuit current (I_{sc}) is having highest value, which is generated by PV cell. At the same time, open circuit voltage (V_{oc}) is having highest value at the PV cell terminals. [12] [13] It is given by $I_{sc} = I_{pv} = I_{ph}$ for $V_{pv} = 0$.

2. Two Diode Model with Series Resistance:

Model with resistanceconnected in series (R_s) is shown in Fig. 3, in two diode model. Here six parameters are to determine. Along these six parameters, first two are saturation currents I_{s1} and I_{s2} flowing from the diodes D_1 and D_2respectively. The two diodes D_1 and D_2 are connected in parallel having saturation current I_{s1} and I_{s2}, two idealityfactor for two diodes A_1 and A_2, photo current I_{ph} generated by current source, which is dependent on the solar radiation (G) and the series resistance (R_s).

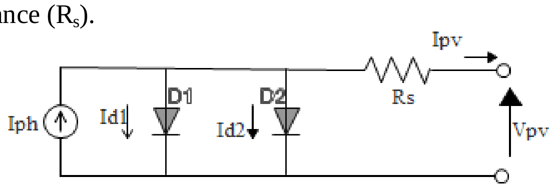

Fig. 3:Circuit Diagram for Two Diode Model with Series Resistance

According to Kirchhoff's law, output current (I_{pv}) is given by

$I_{pv} = I_{ph} – I_{d1} – I_{d2}$…….. (5)

Current from first diode D_1,

$$I_{d1} = I_{s1}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A1*K*T}\right) - 1\right\} \quad (6)$$

Current from second diode D_2,

$$I_{d2} = I_{s2}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A2*K*T}\right) - 1\right\} \quad (7)$$

Output current I_{pv} is given by,

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$$I_{pv} = I_{ph} - I_{s1}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A1*K*T}\right) - 1\right\} - I_{s2}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A2*K*T}\right) - 1\right\}\ldots\ldots \quad (8)$$

Output power is given as,

$$P = V_{pv} * I_{pv} \quad \ldots\ldots\ldots \quad (9)$$

$$P = V_{pv}\{I_{ph} - I_{s1}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A1*K*T}\right) - 1\right\} - I_{s2}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A2*K*T}\right) - 1\right\}\}\ldots\ldots \quad (10)$$

Equation No. 6 and 7 give the diode current I_{d1} and I_{d2} for diode D_1 and diode D_2 respectively. Output current I_{pv} is given by equation No. 8.

3. Two Diode Model with Series and Shunt Resistance:

Two diode model comprising resistance connected in series (R_s) and shuntresistance (R_{sh})connected in parallel is shown in Fig. 4. Two diodes D_1 and $D_2$are connected in parallel, having saturation current I_{s1} and I_{s2}, and having the diode factor A_1 and A_2 respectively, Photocurrent (I_{ph}) generated by current source which is dependent on solar radiation (G). Resistance(R_s) is connected in series and resistance (R_{sh}) is connected in parallel.

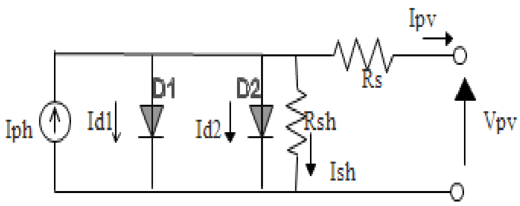

Fig. 4:Circuit Diagram for Two Diode Model with Series and Shunt Resistance

According to Kirchhoff's law, output current (I_{pv})is given by,

$$I_{pv} = I_{ph} - I_{d1} - I_{d2} - I_{sh}\ldots\ldots \quad (11)$$

Current from first diode D_1,

$$I_{d1} = I_{s1}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A1*K*T}\right) - 1\right\}\ldots\ldots \quad (12)$$

Current from second diode D_2,

$$I_{d2} = I_{s2}\left\{\exp\left(\frac{q(Vpv+Rs*Ipv)}{A2*K*T}\right) - 1\right\} \quad \ldots\ldots\ldots \quad (13)$$

The shunt current is given by

$$I_{sh} = \frac{Vpv+R_s*Ipv}{R_{sh}}\ldots\ldots \quad (14)$$

Output current (I_{pv}) of the solar cell with double diode $D_1$and diode D_2 with series R_s and shunt R_{sh}resistance is given as,

$$I_{pv} = I_{ph} - I_{s1}\left\{\exp\left(\frac{q(Vpv + Rs * Ipv)}{A1 * K * T}\right) - 1\right\} - I_{s2}\left\{\exp\left(\frac{q(Vpv + Rs * Ipv)}{A2 * K * T}\right) - 1\right\} - \frac{Vpv + R_s * Ipv}{R_{sh}} \ldots\ldots\ldots \quad (15)$$

The output power P is given by,

$$P = V_{pv} * I_{pv}\ldots\ldots\ldots \quad (16)$$

$$P = V_{pv} * \{I_{ph} - I_{s1}\left\{\exp\left(\frac{q(Vpv + Rs * Ipv)}{A1 * K * T}\right) - 1\right\} - I_{s2}\left\{\exp\left(\frac{q(Vpv + Rs * Ipv)}{A2 * K * T}\right) - 1\right\} - \frac{Vpv + R_s * Ipv}{R_{sh}}\} \ldots\ldots\ldots \quad (17)$$

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Equation No. 12 and 13 give the saturation current I_{s1} and I_{s2} from the diode D_1 and diode D_2 respectively. Current I_{sh} flowing from the shunt resistance R_{sh} is given by the Equation No. 14. The output current I_{pv} is given by the Equation No. 15.

III.COMPUTATION METHOD TO DETERMINE UNKNOWN PARAMETER

In most cases for specific values of series (R_s) and shunt (R_{sh}) resistance, the major impact of parasitic resistance is to reduce the fill factor**.**[14] Both the magnitude and impact of series (R_s) and shunt (R_{sh}) resistance depend on the structure of the solar cell, at the operating point of the solar cell.[15] So, necessary approach for accurate determination of parameters is done.The five parameters I_{pv}, I_o, A, R_s, R_{sh} for the model with series (R_s) and shunt (R_{sh})resistance, are obtained simultaneously by solving the equations in MATLAB using the iterative method like Newton-Raphson iteration method, which solve system of nonlinear equations. And again all these five parameters are calculated by mathematical equations derived from the two diode model connected with series (R_s) and shunt (R_{sh})resistance. For notational convenience, the following equations can be defined,

$R_{so} = \frac{dV}{dI}$ where $V = V_{oc}$ …….. (18)

$R_{sho} = \frac{dV}{dI}$ where $I = I_{sc}$…….. (19)

Where,
R_{so} =Series resistance at the standard temperature condition i.e. 25 ^oC.
R_{sho} = Shunt resistance at the standard temperature condition i.e. 25 ^oC.
V = Output voltage of two diode model with series and shunt resistance.
I = Output current of two diode model with series and shunt resistance.
R_{so} and R_{sho} can be obtained experimentally from the I-V curves.

Thermal voltage (V_t) of a PV module having *Ns* cells connected in series is given by the formula

$Vt = \frac{Ns*k*T}{q}$Volt, …………. . (20)

where k is Boltzman constant, *q* is electron charge, *T* is the temperature of PN junction. [6]

Five parameters R_{sh}, I_o,I_{pv}, A and R_s are calculated from following equations.

Shunt resistance (R_{sh}) is given by the following equations

$R_{sh} = R_{sho}$…….. (21)

$Rsh = \frac{Isc*Rs}{Ipv - Io*\left[exp\left(\frac{Isc*Rs}{A*Vt}\right) - 1\right] - Isc}$Ohm….. (22)

Reverse saturation current (I_o) is given by,

$Io = \left(Isc - \frac{Voc}{Rsh}\right) exp\left(-\frac{Voc}{A*Vt}\right)$…….. (23)

Output current (I_{pv}) is given by,

$$Ipv = Isc * \left(1 + \frac{Rs}{Rsh}\right) + Io\left(exp\left(\frac{Isc * Rs}{A * Vt}\right) - 1\right)$$

……… (24)

Diode ideality factor (A) is given by,

$A = \frac{Voc}{Vt*\ln\left(1 + \frac{Isc}{Io}\right)}$……… (25)

Series resistance (R_s) is calculated by using the following equation,

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$$-\frac{Impp}{Vmpp} = -Io * \left[\frac{1}{Vt}\left(1-\frac{Impp}{Vmpp} * Rs\right) e\left(\frac{Vmpp+Impp*Rs}{A*Vt}\right)\right] - \frac{1}{Rsh}\left(1 - \frac{Impp}{Vmpp} * Rs\right) \quad \ldots\ldots\ldots\ldots \quad (26)$$

Table No. 1: Data Sheet of Selected PV Module 125Wp/12V/SN80

SN	Description	Details
1	Operator	SGTIPDC
2	Product ID	125WP/12V SN80
3	Current Temp Coefficient (mA/^{o}C)	2.000
4	Voltage Temp Coefficient (mV/^{o}C)	-2.0000
5	Model Area (cm^2)	9620.00
6	Sensor Temperature^{o}C	28.7
7	Irradiance (mW/cm^2)	0.0992
8	I_{sc}(A)	7.7828
9	V_{oc}(V)	20.6813
10	P_{mp}(W)	123.6398
11	I_{mp}(A)	7.4577
12	V_{mp}(V)	16.5788
13	Fill Factor	76.81
14	Module Efficiency (%)	12.96
15	Estimated Shunt Resistance (Ohm)	29.4783
16	Estimated Series Resistance (Ohm)	0.1252

IV.SIMULATED AND COMPUTATIONAL RESULTS

Following are the resultsobtained bysimulated Newton-Raphsoniteration method for the PV module 125Wp/12V/SN80.

Part A:Results by Simulation

SN	Parameter	Value
1	Rp_{min}	50.445899*Ohm*
2	Rp	-116.356401*Ohm*
3	Rs_{max}	0.550103*Ohm*
4	R_s	0.200000*Ohm*
5	A_1	1.000000
6	A_2	1.200000
7	T	25.000000^o*C*
8	G	1000.000000W/M^2
9	$P_{max,m}$	123.634096 (model)*Watt*
10	$P_{max,e}$	123.639717 (expt.)*Watt*
11	Tolerance	0.001000
12	P_{error}	-0.005620
13	I_{pv}	7.782800*Ampere*
14	I_{sc}	7.797061 *Ampere*
15	V_{oc}	20.600000*Volt*
16	V_{mp}	16.600000*Volt*
17	I_{mp}	7.447837*Ampere*
18	$I_{o1}=I_{o2}$	1.515007e-09*Ampere*

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Following are the resultsobtained by computation (mathematical) for the PV module 125Wp/12V/SN80.

Part B:Results by Computational Method

Parameter	Obtained Result
I_0	238.931 x 10 $^{-9}$Amp
I_{pv}	7.8159 Amp
R_s	0.1627 Ohm
R_{sh}	29.4385 Ohm
A	1.3

V. COMPARISON OF PARAMETRIC VALUES

Table No. 2: Comparative Chart for Results ofPVModule 125Wp/12V/SN80

Parameter	Actual Data of PV Module	By Simulation	By Computation
I_0	---	1.515007 e-09 Amp	238.931 x 10 $^{-9}$Amp
I_{pv}	---	7.782800 Amp	7.8159 Amp
R_s	0.1252 Ohm	0.550103 Ohm	0.1627 Ohm
R_{sh}	29.4783 Ohm	50.445899 Ohm	29.4385 Ohm
A	---	1.2	1.3

Table No. 2 shows the comparison of parametric values obtained by Newton-Raphson iteration method, used for solving nonlinear equations of PV module 125Wp/12V/SN80 and by computation, for the five parameters I_{pv}, I_o, A, R_s and R_{sh}. This set of parameter is compared with original manufacturer data. It is seen that values of shunt resistance (R_{sh}) and series resistance (R_s)are well matched with the manufacturer data and by computation method.

VI.CONCLUSION

The model for five parameter I_0, I_{pv}, R_s, R_{sh} and A is presented and parameters are obtained by computation and simulation methods. Simulation technique is used to draw the open circuit I-V and P-V characteristics of PV module125Wp/12V/SN80. The result obtainedby Newton-Raphson iteration method of solving nonlinear equations of PV module in MATLAB simulink and parameters computed are compared with manufacturers data.

Based on the methods used for parameter determination i.e. simulation and computation, and the results obtained by these two techniques, when compared with manufacturer data pertaining to these parameters, following broad conclusion can be drawn:

1. Computation by mathematical method requires long time as compared to simulation method.
2. As simulation method is based on computer programming, it requires software which is costly means.
3. Very less time is required for obtaining results by simulation than computation.
4. Simulation is having its own limitations for obtaining results, due to designing consideration of programming.
5. Certain constants are to be strictly assumed for computation of results mathematically.
6. There is slight deviation in some results obtained by simulation and computation, compared to manufacturers data, due to assumptions considered for the respective method.

REFERENCES

[1] Glass M. C., 'Improved Solar Array Power Point Model with SPICE Realization of Generalized', IECEC, Vol. 1, pp. 286-291, 1996.
[2] Kajihara A and Harakawa A. T., 'Model of Photovoltaic Cell Circuits Under Partial Shading', ICIT, pp. 866-870,2005.

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ISSN (Online): 2278 – 8875

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(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 4, April 2016

[3] Tan Y. T., Kirschen D. S., and Jenkins N., 'A Model of PV Generation Suitable for Stability Analysis', IEEE Trans. Energy Converts, Vol. 19, No. 4, pp. 748-755, 2004.

[4]KashifIshaque, Zainal Salam‖, 'An Improved ModelingMethod to Determine the Model Parameters of Photovoltaic (PV) ModulesUsing Differential Evaluation (DE)' Solar Energy 85 (2011) pp. 2349-2359.

[5] SabanYilmaz, AlevYilmaz, MahitGiines, HasanRizaOzcahk, 'Two Diode Model Performance Analysis of Photovoltaic Panels', International Journal of Engineering Trends and Technology (IJETT)-Volume4Issue 7–July 2013.

[6] DominiqueBonkoungou, ZacharieKoalaga, DonatienNjomo, 'Modelling and Simulation of Photovoltaic Module Considering Single-diode Equivalent Circuit Model in MATLAB' International Journal of Emerging Technology and Advanced Engineering ISSN 2250-
2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 3- March 2013.

[7]Aneek Islam, MdIqbalBaharChoudhari, 'Simulation of Two-Diode Model Based PV Solar Cell / Array: A Simulink Approach', ISTP Journal of Research in Electrical and Electronics : IOCRSEM – 2014.

[8]T. Skocil, M. P. Donsion, 'Mathematical Modeling and Simulation of Photovoltaic Array', International Conference on Renewable Energies and Power Quality, ICREPQ-08.

[9] R Khezzar, M Zereg, AKhezzar, 'Comparative Study of Mathematical Methods for Parameters Calculation of Current-Voltage Characteristics of Photovoltaic Module', International Conference, Electrical & Electronics Engg, ELECO, 2009, 5-8 Nov, 2009, Print
ISBN 978-1-4244-5106-7.Publisher IEEE.

[10]M. Azzouzi, L. Mazzouz, D. Popescu, 'Matlab-Simulink of Photovoltaic System Based on a Two-Diode Model', ISBN: 978-988-19252-7-5, Proceedings of the World Congress on Engineering, 2014 Vol.I, WCE 2014, July 2-4, 2014, London, U.K.

[11] M. R. AlRashid, K. M. El-Naggar, M.F. AlHajri, 'Parameters Estimation of Double Diode Solar Cell Model', International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol. 7, No. 2, 2013.

[12] B. Alsayid, 'Modelling and Simulation of Photovoltaic Cell/Module/Array with Two Diode Model'. International Journal of Computer Tchnology and Electronics Engineering (UCTEE), Volume 1, Issue 3, 2012.

[13] T. Salmi M. Bouzguenda, A. Gastli, A. Masmoudi, 'MATLAB/Simulink Based Modeling of Solar Photovoltaic Cell'. International Journal of Renewable Energy Research, Volume2, No. 2, 2012.

[14]htpp//www.pveducation.org

[15] N. Hamrouni, M. Jraidi and A. Cherif, Solar Radiation and Ambient Temperature Effects on the Performance of a PV Pumping System.Revue des Energies RenouvelablesCell'.International Journal of Renewable Energy Research, Volume2, No. 2, 2012.

[14] htpp//www.pveducation.org

[15] N. Hamrouni, M. Jraidi and A. Cherif, Solar Radiation and Ambient Temperature Effects on the Performance of a PV Pumping System.Revue des Energies Renouvelables Vol. 11 No 1, pp 95-106, 2008.