Pergamon

Renewable Energy, Vol. 10, No. 2/3, pp. 125–128, 1997

0960–1481/97 $15.00+0.00
PII: S0960–1481(96)00049–3

Algorithm for Extraction of Solar Cell Parameters from I-V Curve Using Double Exponential Model.

C. L. Garrido-Alzar
Laboratorio Nacional de Investigaciones Fotovoltaicas,
DIEES-IMRE,Universidad de La Habana,
San Lázaro y L, 10400 Vedado, Cuba.

Abstract. Here we present a simple algorithm to perform extraction of solar cell parameters such as photogenerated current (I_L), series resistence (R_S), parallel resistence (R_P), diode factor (a), and saturation currents (I_{01} and I_{02}). We based our computations on double exponential model. Results agree well with PC-1D modeled data, and show that solar cell parameters depend on temperarure and illumination level.

1 INTRODUCTION

The use of double exponential model for extracting solar cell parameters, knowing data from I-V curve, is a difficult problem mainly because of trascendental nature of current dependency on voltage and quantity of involved parameters. Surely, for this reason many authors prefer to use single exponential model to analyze solar cell performance [1, 2].

In fact solar cell parameters obtained using single exponential model have good degree of accuracy as has been reported. However, with double exponential model we can get insight into the relation between physical phenomena that take place in a solar cell and its parameters.

Our purpose is to present an iteration algorithm throug which we can determine solar cell parameters, using double exponential model. In this paper we study n/p silicon monocrystalline solar cells at different temperatures and illumination levels. Our computations were made with the progam MATHEMATICA.

2 PROCEDURE FOR EXTRACTION OF SOLAR CELL PARAMETERS

As we know to study solar cell performance exist several models. One of them is the double exponential model

$$I = I_{01}(\exp[(V - R_S I)/V_T] - 1) + I_{02}(\exp[(V - R_S I)/(aV_T)] - 1) + \frac{V - R_S I}{R_P} - I_L \qquad (1)$$

for a solar cell under illumination, where V_T is the thermal voltage. In this work as parameters we take the photogenerated current I_L, series resistence R_S, parallel resistence R_P, diode factor a, and saturation currents I_{01} and I_{02}. Determination of this parameters is a difficult problem using (1), but throug the algorithm presented here we can solve it in a simple way.

The algorithm is quite simple: firstly, we must set the zero order approximation for a and R_S, and then solve the following set of equations to find I_L, I_{01}, I_{02}, and R_P

$$I_i = I_{01}(\exp[(V_i - R_S I_i)/V_T] - 1) + I_{02}(\exp[(V_i - R_S I_i)/(aV_T)] - 1) + \frac{V_i - R_S I_i}{R_P} - I_L \qquad (2)$$

where $i = 1, 2, 3, 4$.

The next step is to compute a using the value of the open circuit voltage V_{OC} and expression $a = V_{OC}/(V_T b)$ where

$$b = \ln[(I_L + I02 - I_{01}(\exp[V_{OC}/V_T] - 1) - V_{OC}/R_P)/I_{02}] \qquad (3)$$

Finally, we find root of (4) to determine R_S

$$I_5 = I_{01}(\exp[(V_5 - R_S I_5)/V_T] - 1) + I_{02}(\exp[(V_5 - R_S I_5)/(aV_T)] - 1) + \frac{V_5 - R_S I_5}{R_P} - I_L \qquad (4)$$

Now the above steps are repeated until, for example, value of a satisfies the desired precision. If we use MATHEMATICA to compute solar cell parameters, we can achieve this job saving time and efforts. But, we must point out that care must be taken when choosing I_i and V_i ($i = 1, 2, 3, 4, 5$), to ensure the convergence of methods employed by this software.

Our light I-V curves were obtained theoretically using the program PC-1D. We modeled n/p silicon monocrystalline solar cells with the following material and device properties: intrinsic carrier concentration (n_i) equal to 1.45 10^{10} cm^{-3}, we take N_S=2.0 10^{20} cm^{-3} for emitter surface concentration, Erfc doping profile, coated and 0.85 textured front surface, AM1.5G solar spectrum, base width of $300\mu m$ and base doping concentration (N_A) equal to 8.836 10^{16} cm^{-3}. Here we study three solar cells of different areas: SC1 2 cm^2, SC2 4 cm^2, and SC3 24 cm^2. Determination of parameters for SC1 was made for different temperature and illumination conditions.

3 RESULTS

Once obtained illuminated I-V curves from PC-1D, we proceed to compute the solar cell parameters. Table 1 shows the computed parameters of SC1, SC2, and SC3 cells under 1 sun of illumination at 298 K degree. The value of short circuit current I_{SC} and V_{OC} given by our computations and PC-1D are presented in table 2, where one sees that both values (PC-1D and calculated) are very close. In Fig. 1 we show the illuminated I-V curves, where we plot (1) (straight line I-V curve) using the above determined parameters for each solar cell. As can be seen from Fig. 1, there is a good correspondence between PC-1D data and computed data points, having the better correspondence for SC3, which indicates that parameters of this cell where determined with better precision.

In table 3 we present the determined parameters of SC1 under different temperatures and illumination levels. Here we appreciate that diode factor a indeed decreases with temperature as has

Cell	*Area*, cm^2	J_L, $mA\ cm^{-2}$	J_{01}, $A\ cm^{-2}$	J_{02}, $A\ cm^{-2}$	a	R_S, $m\Omega$	R_P, Ω
SC1	2.0	30.736	$1.235E-11$	$5.744E-7$	2.138	145.088	35403.80
SC2	$2*2$	30.749	$0.524E-12$	$2.136E-8$	1.579	312.404	2614.49
SC3	$4*6$	30.737	$0.548E-12$	$2.608E-8$	1.801	1.942	2441.25

Table 1: Computed parameters for SC1, SC2, and SC3 cells under 1 sun at 298^oK.

Cell	*PC-1D*		*Computed*	
	I_{SC}, mA	V_{OC}, mV	I_{SC}, mA	V_{OC}, mV
SC1	-61.47	544.5	-61.472	544.526
SC2	-122.90	580.1	-123.001	580.000
SC3	-737.70	617.5	-738.100	617.580

Table 2: I_{SC} and V_{OC} values of SC1, SC2, and SC3 cells.

been reported before [1, 3]. Another important fact is the dependence of solar cell parameters on illumination level. Table 4 shows I_{SC} and V_{OC} values in these cases. The light I-V curves of SC1 when we use different temperature and illumination conditions, are plotted in Fig. 2. Again one observes agreetment betweeen PC-1D and computed data.

4 CONCLUSIONS

Our results, figures and tables presented in this paper, show that agreetment exists between PC-1D data and computed data. This fact indicates that the algorithm here given to determine solar cell parameters, can yields the values of such parameters with good degree of accuracy. On the other hand this values agree well with those reported before by other authors. If we use MATHEMATICA, with our algorithm this parameters are computed in a simple and quick manner, showing that this software can be a very useful tool to perform calculations of solar cell parameters.

REFERENCES

[1] S.K.Sharma, K.B.Samuel, A.Agarwal, N.Srinivasamurthy, and B.L.Agrawal, "Temperature dependence of solar cell diode factor-experimental verification", *6th Photovoltaic Science*

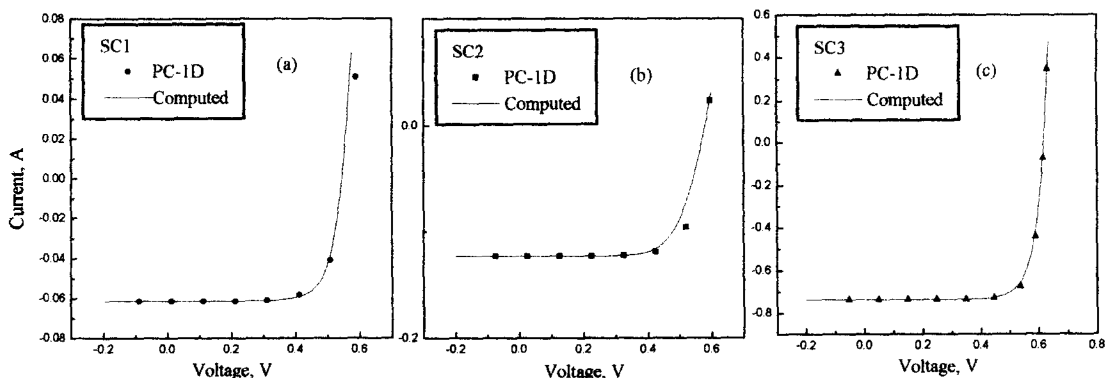

Figure 1: Light I-V curves of SC1, SC2, and SC3 cells.

T, K	*Intensity, suns*	J_L, $mA\ cm^{-2}$	J_{01}, $A\ cm^{-2}$	J_{02}, $A\ cm^{-2}$	a	R_S, $m\Omega$	R_P, Ω
298	1	30.736	$1.235E-11$	$5.744E-7$	2.138	145.088	35403.80
325	1	31.197	$2.360E-10$	$0.533E-8$	1.162	34.667	15177.0
345	1	31.505	$0.921E-9$	$1.503E-8$	1.142	13.460	17350.2
298	5	153.784	$2.769E-12$	$1.214E-6$	2.344	45.890	30088.0
298	10	307.814	$1.740E-12$	$0.866E-6$	2.205	22.608	4086.30

Table 3: Computed parameters for SC1 under different temperatures and illumination levels.

Temperature, K	Illum. level, suns	*PC-1D*		*Computed*	
		I_{SC}, mA	V_{OC}, mV	I_{SC}, mA	V_{OC}, mV
298	1	−61.47	544.5	−61.472	544.526
345	1	−63.01	521.2	−62.799	521.750
298	5	−307.6	628.4	−307.880	627.866
298	10	−615.6	656.9	−615.840	656.400

Table 4: I_{SC} and V_{OC} values of SC1.

and Engineering Conference, New Delhi, India, Febrary, 1992

[2] C.Protogeropoulos, B.J.Brinkworth, R.H.Marshall, and B.M.Cross, "Evaluation of two theoretical models in simulating the performance of amorphous-silicon solar cells", *10th European Photovoltaic Solar Energy Conference*, Lisbon, Portugal, April, 1991

[3] J.Beier, and K.Bucher, "Comparison of dark and light I-V curves of solar cells", *10th European Photovoltaic Solar Energy Conference*, Lisbon, Portugal, April, 1991

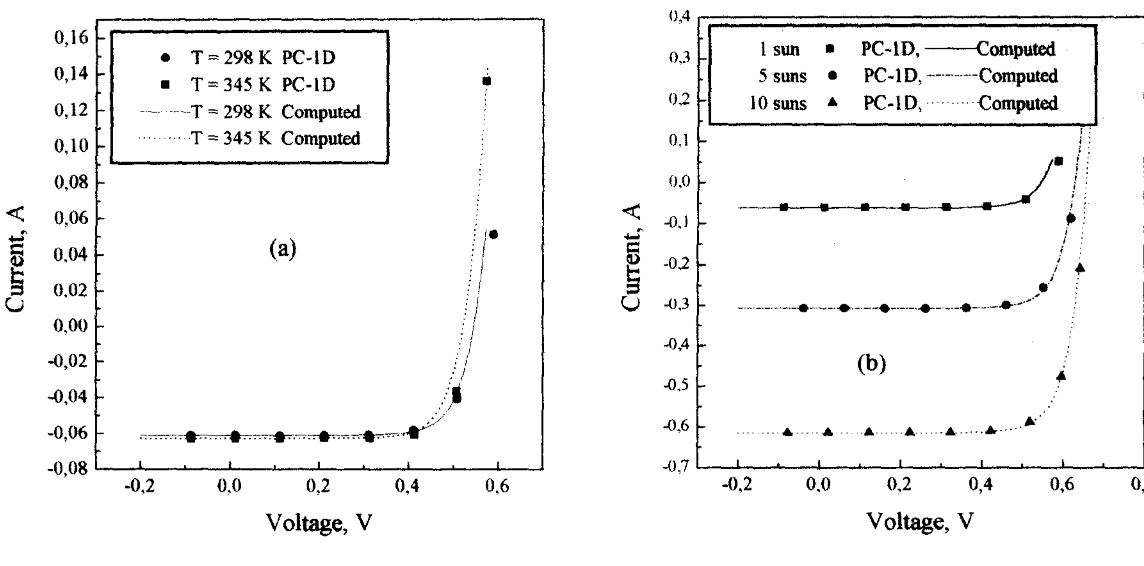

Figure 2: Light I-V curves of SC1 at different temperatures (a) and illumination intensities (b).