ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 12, June 2013

Comparative Study of Methods of Determine Amorphous Silicon Solar Cell Parameters

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Abstract -The parameters of atypical solar cell represented by an equivalent circuit can be obtained using the experimental current voltage characteristics I-V. This paper presents a comparative study of three methods for determining solar cell parameters of the single diode lumped circuit model. The methods are the simplified explicit method, iterative method and analytical five point method. These parameters values were extracted using these different methods from experimental I-V characteristics of an amorphous silicon cells.

Key words: **Characteristic, Parameters, Photovoltaic, Methods, Solar Cell.**

I. INTRODUCTION

Electricity production by renewable energy sources is actually promoted in many countries worldwide and is considered a strategic objective for the new Year's. Many founding programmes also support project that provide potential utilities with access to renewable energy solutions and increase familiarity with renewable energy technologies. The production of photovoltaic electricity has known in recent years an increasing of interest by a production throughout the world. This increase was accompanied by a revitalization of researches considered for the optimization of the energy given by solar cells. Thus, the modelling of these solar cells is a vital importance for the quality control and evaluation of the performance of the solar cells. Several researchers [1, 2, and 3] proposed methods to devise ways for identifying the parameters that describe the non-linear electrical model of solar cells. The knowledge of characteristic of a solar cell is a prerequisite for designing and dimensioning a PV power supply. This allows the development of new high –performances conversion systems balancing system- components and permitting the evaluation of the behaviour of the entire system in various conditions. The objective of this work is to compare three different methods to extract the solar cells parameters from experimental I-V characteristics of a solar cell.

II. THEORY AND ANALYSIS

At a given illumination, the current-voltage relation for a solar cell is given by:

$$I = I_L - I_0\left[\exp\left[q\frac{(V+IR_s)}{N_s AKT}\right] - 1\right] \quad (1)$$

From equation (1) the four unknown parameters in this model are the photocurrent I_L, the saturation current I_0, ideality factor A and the series resistance R_s. These parameters are determined from measurements of the I-V characteristics at reference values of solar radiation $300W/m^2$ and ambient temperature $28°C$, which is given directly by the manufacture.

From the I-v characterisation curve, the three prominent couples of points are;(0,I_s),(V_{0s},0) and (Vm,Im). These points can be employed to determine the unknown parameter as follows;

$$Isc = I_L - I_0\left[\exp\left(q\frac{IscRs}{NsAkt}\right) - 1\right] \quad (2)$$

$$0 = I_L - I_0\left[\exp\left(q\frac{Voc}{NsAkt}\right) - 1\right] \quad (3)$$

$$I_m = I_L - I_0\exp\left[\left(q\frac{Vm + \mathrm{Im}\,Rs}{NsAkt}\right) - 1\right] \quad (4)$$

III. THE ANALYTICAL FIVE POINT METHOD

Using this method the characteristic parameters of the solar cell are computed from the value of the open circuit voltage V_{OC}, the short circuit current I_{sc}, the voltage at maximum point I_m, the slope at open circuit point R_{s0}, and the slope at short circuit point R_{Sho} measured from the I-V characteristic. The following expressions are derived [4]

$$R_{Sh} = R_{sh0} = \frac{dv}{dI}\Big|_{I=I_{sc}} \quad (5)$$

$$n^I = \frac{BA}{B+C} \quad (6)$$

Where

$$A = V_m + R_{s0}I_m - V_{OC} \quad (7)$$

$$B = \ln\left(I_{sc} - \frac{V_m}{R_{Sho}} - I_m\right)\ln\left(I_{sc} - \frac{V_{OC}}{R_{sh}}\right) \quad (8)$$

$$C = \frac{I_m}{I_{SC} - \frac{V_{OC}}{R_{sho}}}. \quad (9)$$

$$I_s = \left(I_{sc} - \frac{V_{oc}}{R_{sh}}\right)\exp\left(-\beta\frac{V_{co}}{n^I}\right) \quad (10)$$

$$I_{ph} = I_{sc}\left(1 + \frac{R_s}{R_{sh}}\right) + I_s\left(esp\beta\frac{I_{sc}R_s}{n^I} - 1\right). \quad (11)$$

$$\text{Where } R_{so} = \frac{-dv}{dI}\Big|_{V=V_{oc}} \quad (12)$$

R_{so} and R_{Sho} are obtained from the measured characteristic by a single linear fit. We have slightly modified the expression of the ideality factor and is given by

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$n = 10n^I$

IV. ITERATIVE METHOD

Using this method, iterative methods as the bisection in the interval $[0, R_{s\ max}]$, where $R_{s\ max}$ is the maximum possible value of series resistance [1,5] The value of ideality factor is close to 1 for $R_{s\ max}$ so to determine its value we replace A=1 in equation 10 to yield equation (11)

$$R_s = \frac{\frac{N_s AKT}{q}\ln\left(1-\frac{I_m}{I_{sc}}\right)+V_{oc}-V_m}{I_m}$$

(13)

$$R_{s\ max} = \frac{1}{I_m}\left[\frac{N_s KT}{q}\ln\left(1-\frac{I_m}{I_{sc}}\right)+V_{oc}-V_m\right]$$

(14)

The variation of different parameters in versus of the variation of solar radiation or ambient temperatures for the method expressed as:

For the short circuit current and open circuit voltage

$$I_{sc} = I_{sc.ref}\frac{S}{S_{ref}} + \mu I_{sc}(T - T_{ref}) \quad (15)$$

$$V_{oc} = V_{oc.ref} + V_t \ln\left(\frac{S}{S_{ref}}\right) + \mu V_{oc}(T - T_{ref}) \quad (16)$$

where $V_t = \frac{N_s AKT}{q}$ (17)

The variation in the ideality factor is given by

$$\frac{A}{A_{ref}} = \frac{T}{T_{ref}} \quad (18)$$

and

$$I_0 = I_{0\ ref}\left(\frac{T}{T_{ref}}\right)^3 exp\left[q\frac{E_{gap}}{KA}\left(\frac{1}{T_{ref}}-\frac{1}{T}\right)\right] \quad (19)$$

At the last the variation of the current and voltage at the maximum power point are described by

$$V_m = V_{m\ ref} + V_t \ln\left[\frac{S}{S_{ref}}\right] + \mu V_{oc}(T - T_{ref}) \quad (20)$$

$$I_m = I_{m\ ref}\frac{S}{S_{ref}} + \mu I_{sc}(T - T_{ref}) \quad (21)$$

V. SIMPLIFIED EXPLICIT METHOD

This method considers as a first approximation $I_L = I_{sc}$ after simplification of equation (2),(3) and (4)

$$I_{sc} = I_L \quad (21)$$

$$0 = I_L - I_0\left[\exp\left(q\frac{V_{oc}}{N_s AKT}\right)\right] \quad (22)$$

(23)

$$I_m = I_L - I_0\left[\exp\left(q\frac{V_m + I_m R_s}{N_s AKT}\right)\right] \quad (24)$$

From 18 & 19 saturation current can be deduced as

$$I_o = I_{sc}\left[\exp\left(-\frac{q}{N_s AKT}V_{oc}\right)\right] \quad (25)$$

And from this equation (1) becomes

$$I = I_{sc}\left[1 - \exp\left[q\frac{V - V_{oc} + IR_s}{N_s AKT}\right]\right] \quad (26)$$

The equation at the point of maximum power at it turn becomes

$$I_m = I_{sc}\left[1 - \exp\left[q\frac{V_m - V_{oc} + I_m R_s}{N_s AKT}\right]\right] \quad (27)$$

From this equation, the value of series resistance can be deduced as

$$R_s = \frac{\frac{N_s AKT}{q}\ln\left(1-\frac{I_m}{I_{sc}}\right)+V_{oc}-V_m}{I_m} \quad (28)$$

The last parameter to be determined is the ideality factor A, by exploiting the fact that the derivative of maximum power is zero

$$\frac{dP}{dV} = 0 = \frac{\delta I}{\delta V}V + I\frac{\delta V}{\delta V} \quad (29)$$

From equation (1) we find that

$$A = \frac{q(2V_m - V_{oc})}{N_s KT\left[\frac{I_{sc}}{I_{sc}-I_m}+\ln\left(1-\frac{I_m}{I_{sc}}\right)\right]} \quad (30)$$

VI. RESULTS AND DISCUSIION

The parameters obtained using the different methods or the amorphous silicon solar cells are given in Table 1.

Table 1: Values of Parameters Extracted Using Different Methods for Solar Cells

Parameters	Simplified Explicit Method	Iterative Method	Analytical Five Point Method
Series Resistance (Rs)	0.016	0.014	0.011
Photocurrent (Ip)	0.546	0.531	0.545
Saturation Current (Is)	0.122	0.340	0.280
Shunt Conductance (Cs)	0.006	0.034	0.028

Moreso, from the results obtained at standard test conditions using data provided by the manufacturer the behaviour of the solar cell was estimated for the different ambient temperatures. The results given by simulation in the Matlab environment are compared with those of the experiment. It is observed from figure 1 and 2 that the results given by the different methods are in agreement with the experiment results of the current voltage I-V in the standard test condition. It is seen that the exact ness of estimated results for the different temperatures is Varied from one method to another, were the analytical five point method is more influenced by the variation of ambient temperature compared to other two methods.

VII. CONCLUSION

We have compared three methods to obtain amorphous silicon solar cells parameters; the methods and analytical five point methods are analytical five point method, iterative method and the simplified explicit method. The simplified explicit method gives parameters values that are very close to those obtained by iterative method. The analytical five point method seems faster and simpler, the uncertainties prevailing in measuring the open circuit voltage and the short circuit current, locating the maximum power point and in graphical determining the two slope, impede an accurate solution for the parameters and thus a constructed fit may not represent accurately the I-V characteristics over its whole range. By comparing the results of the three methods with those of experimentation we concluded that the iterative method and the simplified explicit method are the less influenced by the ambient temperature variation and therefore are more accurate.

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