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:

\[ I = I_L - I_0 \left[ \exp \left( \frac{q (V + IR_S)}{N_s A k T} \right) - 1 \right] ^{(1)} \]

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/m² 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: \((0, I_{sc}), (V_{oc}, 0)\) and \((V_m, I_m)\). These points can be employed to determine the unknown parameter as follows:

\[ I_{sc} = I_L - I_0 \left[ \exp \left( \frac{q I_{sc} R_s}{N_s A k T} \right) - 1 \right] ^{(2)} \]

\[ 0 = I_L - I_0 \left[ \exp \left( \frac{V_{oc}}{N_s A k T} \right) - 1 \right] ^{(3)} \]

\[ I_{m} = I_L - I_0 \left[ \exp \left( \frac{V_m + I_m R_s}{N_s A k T} \right) - 1 \right] ^{(4)} \]

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\( R_{so} \), and the slope at short circuit point\( R_{sh} \) measured from the I-V characteristic. The following expressions are derived [4]

\[ R_{sh} = R_{sh0} = \frac{dI}{dv} \bigg|_{v=V_{sc}} ^{(5)} \]

\[ n^l = \frac{EA}{B+C} \]

\[ A = V_m + R_{so} I_m - V_{oc} ^{(7)} \]

\[ B = \ln \left( \frac{I_{sc}}{I_m} - \frac{I_m}{R_{sh0}} - I_m \right) \ln \left( \frac{I_{sc}}{R_{sh0}} - V_{oc} \right) ^{(8)} \]

\[ C = \frac{I_m}{R_{so} - V_{sc}} \]

\[ I_s = \left( I_{sc} - \frac{V_{oc}}{R_{sh}} \right) \exp \left( -\beta \frac{V_{oc}}{n} \right) ^{(10)} \]

\[ I_{ph} = I_{sc} \left( 1 + \frac{R_s}{R_{sh}} \right) + I_s \left( \alpha s p \beta \frac{I_{sc} R_s}{n^l} - 1 \right) \]

Where \( R_{so} = -\frac{dv}{di} \bigg|_{v=V_{oc}} ^{(12)} \)

\( R_{so} \) and\( R_{sh0} \) 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
IV. ITERATIVE METHOD

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

\[
R_s = \frac{N_S A K T}{q} \ln \left( 1 - \frac{I_m}{I_{sc}} \right) + \frac{V_{oc} - V_m}{l_m}
\]

(13)

\[
R_{s\text{ max}} = \frac{1}{I_m} \left[ \frac{N_S A K T}{q} \ln \left( 1 - \frac{I_m}{I_{sc}} \right) + V_{oc} - V_m \right]
\]

(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

\[
I_{sc} = I_{sc\text{ ref}} \frac{S}{S_{\text{ref}}} + \mu I_{sc} (T - T_{\text{ref}})
\]

(15)

\[
V_{oc} = V_{oc\text{ ref}} + \nu \ln \left( \frac{S}{S_{\text{ref}}} \right) + \mu V_{oc} (T - T_{\text{ref}})
\]

(16)

where \(V_t = \frac{N_S A K T}{q}\)

(17)

The variation in the ideality factor is given by

\[
\Delta_i = \frac{r}{T_{\text{ref}}}
\]

(18)

and

\[
I_0 = I_{0\text{ ref}} \left( \frac{T}{T_{\text{ref}}} \right)^3 \exp \left[ q \frac{E_g}{kT} \left( \frac{1}{T_{\text{ref}}} - \frac{1}{t} \right) \right]
\]

(19)

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

\[
I_m = I_{m\text{ ref}} \frac{S}{S_{\text{ref}}} + \mu I_{sc} (T - T_{\text{ref}})
\]

(20)

\[
I_{sc} = I_{sc\text{ ref}} \frac{S}{S_{\text{ref}}} + \mu I_{sc} (T - T_{\text{ref}})
\]

(21)

V. SIMPLIFIED EXPPLICIT METHOD

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

\[
I_{sc} = I_L
\]

(21)

\[
0 = I_L - I_0 \left[ \exp \left( q \frac{V_{oc}}{N_S A K T} \right) \right]
\]

(22)

\[
I_m = I_L - I_0 \left[ \exp \left( q \frac{V_m + I_m R_s}{N_S A K T} \right) \right]
\]

(23)

From 18 & 19 saturation current can be deduced as

\[
I_o = I_{sc} \left[ \exp \left( -\frac{q}{N_S A K T} V_{oc} \right) \right]
\]

(25)

And from this equation (1) becomes

\[
I = I_{sc} [1 - \exp \left( \frac{q}{N_S A K T} \frac{V_m}{V_{oc} + I_m R_s} \right)]
\]

(26)

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

\[
I_m = I_{sc} [1 - \exp \left( \frac{q}{N_S A K T} \frac{V_m - V_{oc} + I_m R_s}{I_m} \right)]
\]

(27)

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

\[
R_s = \frac{N_S A K T}{q} \ln \left( 1 - \frac{I_m}{I_{sc}} \right) + \frac{V_{oc} - V_m}{l_m}
\]

(28)

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

\[
\frac{dP}{dV} = 0 = \frac{dI}{dV} + \frac{dV}{dV}
\]

(29)

From equation (1) we find that

\[
A = \frac{q(2V_m - V_{oc})}{N_S A K T} \left( I_{sc\text{ ref}} - I_0 \right) + \ln \left( 1 - \frac{I_m}{I_{sc\text{ ref}}} \right)
\]

(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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Simplified Explicit Method</th>
<th>Iterative Method</th>
<th>Analytical Five Point Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series Resistance</td>
<td>0.016</td>
<td>0.014</td>
<td>0.011</td>
</tr>
<tr>
<td>Photocurrent (Ip)</td>
<td>0.546</td>
<td>0.531</td>
<td>0.545</td>
</tr>
<tr>
<td>Saturation Current</td>
<td>0.122</td>
<td>0.340</td>
<td>0.280</td>
</tr>
<tr>
<td>Shunt Conductance</td>
<td>0.006</td>
<td>0.034</td>
<td>0.028</td>
</tr>
</tbody>
</table>

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.

REFERENCES


