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Solar Cell Parameters Extraction from a Current-Voltage Characteristic Using Genetic Algorithm

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The determination of solar cell parameters is very important for the evaluation of the cell performance as well as to extract maximum possible output power from the cell. In this paper, we propose a computational based binary-coded genetic algorithm (GA) to extract the parameters (I0, Iph and n) for a single diode model of solar cell from its current-voltage (I-V) characteristic. The algorithm was implemented using LabVIEW as a programming tool and validated by applying it to the I-V curve synthesized from the literature using reported values. The values of parameters obtained by GA are in good agreement with those of the reported values for silicon and plastic solar cells. change to “After the validation of the program, it was used to extract parameters for an experimental I-V characteristic of 4×4 cm^2 polycrystalline silicon solar cell measured under 900 W/m. The I-V characteristic obtained using GA shows excellent match with the experimental one.

Keywords: Solar cell, Genetic algorithm.

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1. INTRODUCTION

The world is running after alternative energy sources to cater today’s high energy demand, where the solar photovoltaics (SPV) energy conversion plays an important role. To operate SPV plant at its maximum possible capacity, it is essential to know about the exact parameters of a solar cell/module. However, the overall performance and conversion efficiency of solar cell is directly affected by various physical parameters such as photocurrent (I_{ph}), series resistance (R_s), shunt resistance (R_{sh}), saturation current (I_0) and diode ideality factor (n). Therefore, an accurate estimation of such parameters is always required not only to carry out the evaluation of cell performance but also to improve the design, fabricate process and quality control of the cell [1].

Various methods such as, polynomial curve fitting [2], Lambert *W* function [3], particle swarm optimization [4], and pattern search optimization [5] are reported in the literature for the extraction of cell parameters. In this paper, a computational based binary-coded GA is employed for the extraction of cell parameters from an experimentally measured I-V characteristic. The program for GA to obtain cell parameters is developed using LabVIEW (laboratory virtual instrument engineering workbench, version-10) as a programming tool. The parameters of silicon and plastic solar cells obtained using proposed GA are found to be in good agreement with that of reported in the literatures [3, 8]. I-V characteristic of a commercial polycrystalline silicon solar cell obtained using GA is also in good agreement with its experimental I-V characteristic.

2. THEORY

The I-V relation of solar cell for a single diode model is given by

$$I = I_{ph} - I_0\left[\frac{q(V+IR_s)}{nk_BT} - 1\right] - \frac{V+IR_s}{R_{sh}} \tag{1}$$

Where, I is the output current, I_{ph} is the photocurrent, I_0 is the saturation current, R_s is the series resistance, R_{sh} is the shunt resistance, n is the ideality factor, k_B is the Boltzmann constant and T is the temperature. Direct parameters extraction from eq. (1) is limited by the nonlinear I-V relation and transcendental nature of current equation for a solar cell. To find the parameters, alternate techniques such as Newton-Raphson method [6] and Least Square method [7] have been used previously.

In this work, the I-V characteristics of silicon and plastic solar cells were synthesized from the data reported in the literature [3, 8]. Using the GA extracted values of I_{ph}, I_0 and n from the synthesized I-V characteristic, the value of I was calculated for the set of different values of V using Newton-Raphson method. This I-V characteristic was then used to check the validity and robustness of the present approach.

To obtain I_{ph}, I_0 and n from the experimental I-V characteristic of a commercial poly crystalline silicon solar cell, the values of R_s and R_{sh} were obtained using linear regression of selected points on I-V characteristic near the open circuit and short circuit condition, respectively.

From the eq. (1),the value of dV/dI at short circuit condition (i.e. $I = I_{sc}$ and $V = 0$) gives the value of R_{sh}

$$\frac{dV}{dI} = R_{sh} + R_s \approx R_{sh} \tag{2}$$

And at open circuit condition (i.e. $I = 0$ and $V = V_{oc}$

$$\frac{dV}{dI} = \frac{nk_BTq^{-1}}{I_{sc} + I - V/R_{sh} + nk_BT/(qR_{sh}) + (I + I_{sc})R_s/R_{sh}} +$$

$$+R_s \approx \frac{nk_BTq^{-1}}{I_{sc} + I - V/R_{sh}} + R_s \tag{3}$$

Thus, the value of R_s is derived from the plot of dV/dI as a function of $q^{-1}(I_{sc} + I - V/R_{sh})^{-1}k_BT$ by taking the intercept on y-axis.

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3. SOLAR CELL PARAMTERS EXTRACTION

Genetic Algorithm is essentially inspired by Darwin's theory of natural selection and natural evolution. In GA, the fitness of a population is improved by the processes of selection, crossover and mutation. In this work, the set of unknown parameters (i.e. solar cell parameters) are defined as $X = (I_0,\ I_{ph}$ and $n)$ for a cell. These unknown parameters are the members (i.e. individuals) of population and were extracted using continuous evolution through GA. Initially, a large population (N_{pop}) of sets of solar cell parameters (i.e. $X = I_0,\ I_{ph}$ and n) are created randomly. Then, the program calculates current based on Newton-Raphson method for each randomly generated set of solar cell parameters for each experimental voltage using eq.(1).Then, calculated currents are compared with experimental values at every genetic iteration in order to evaluate the fitness of the solution. The set of parameters corresponds to better fitness were selected by selection operator and followed by crossover and mutation operator in order to improve the fitness.

In this work, an elimination method, random-point crossover and single bit-flipping were used as a selection, crossover and mutation operator respectively. The fitness function in our cases is defined as,

$$F(X) = \left\{ \sum_{i=1}^{p} \left[I^{\exp}(V_i) - I^{cal}(V_i) \right]^2 \right\} \Big/ p \qquad (4)$$

Where, $I^{\exp}(V_i)$ and $I^{cal}(V_i)$ are the experimental and calculated values of current at V_i, p is the total number of voltage steps in the I-V characteristics. From the eq. (4), lower value of the fitness function represents better agreement of fitted I-V characteristic with the synthetic I-V characteristic with that of the experimental.

4. RESULTS AND DISCUSSIONS

Fig. 1 and Fig. 2 show the synthetic and fitted I-V characteristics for a silicon solar cell and plastic solar cell, respectively using GA. Table 1 and Table 2 show the reference parameters and GA-extracted parameters for silicon solar cell and plastic solar cell, respectively.

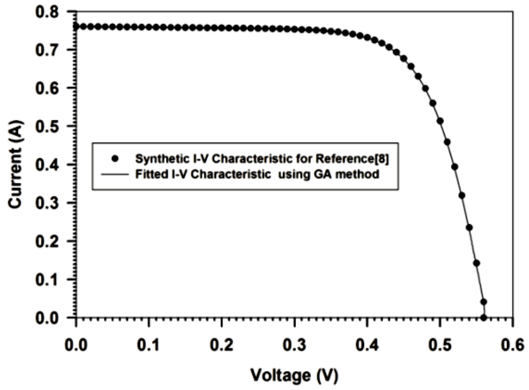

Fig. 1 – Synthetic and fitted I-V characteristic of silicon solar cell

From the Fig. 1 and Fig. 2, it is observed that synthetic I-V characteristics exactly overlap on the fitted I-V characteristics obtained using GA. It is also concluded that the parameters extracted by GA are very close to those reported results in references [3, 8] as listed in Table 1 and Table 2 for the silicon solar cell and plastics solar cell respectively.

Table 1 – Parameters from Ref. [8] and extracted using GA with $R_s = 0.0364\ \Omega$ and $R_{sh} = 53.76\ \Omega$

Silicon solar cell (33 °C)		
Parameters	Ref.[8]	GA extracted values
n	1.4837	1.484
I_0 (μA)	0.3223	0.329
I_{ph} (A)	0.7608	0.761

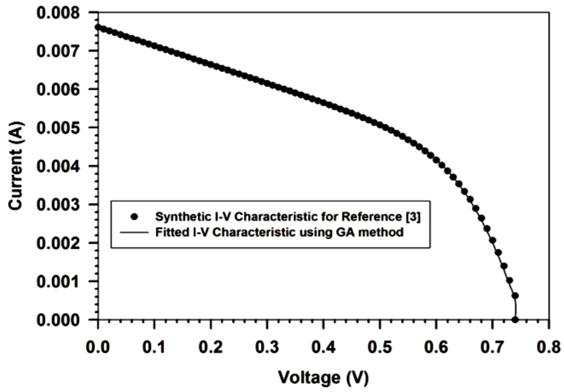

Fig. 2 – Synthetic and fitted I-V characteristic of Plastic solar cell

Table 2 – Parameters from Ref. [3] and extracted using GA with $R_s = 8.59\ \Omega$ and $R_{sh} = 197.24\ \Omega$

Plastic solar cell (27.3 °C)		
Parameters	Ref.[3]	GAextracted values
n	2.31	2.302
I_0 (μA)	0.0136	0.014
I_{ph}(A)	0.00794	0.008

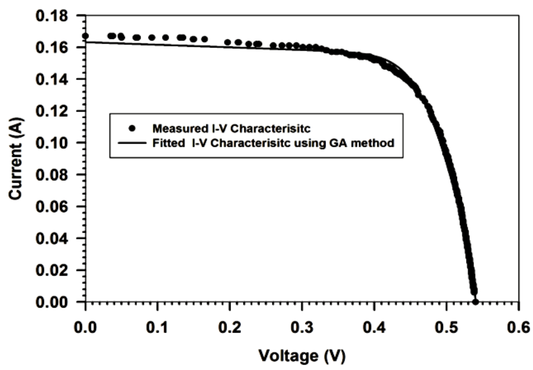

Fig. 3 – Experimental and fitted I-V characteristics of a commercial polycrystalline silicon solar cell

As an additional test, GA is used to extract parameters from measured I-V characteristic for a commercial poly crystalline silicon solar cell as shown in Fig. 3. The area of cell is 16 cm^2 and the illuminated I-V characterristic was measured at the light intensity 900 W/m^2 at temperature 35 °C. Table 3 shows the GA-extracted parameters for a poly crystalline silicon solar cell. It is

Table 3 – GA-extracted parameters for polycrystalline silicon solar cell with fixed parameters R_s = 0.3214 Ohm and R_{sh} = 61.51 Ohm

Poly crystalline silicon solar cell (35 °C)	
Parameters	GA extracted values
n	0.894
I_0 (pA)	8.8338
I_{ph} (A)	0.164

concluded that the measured I-V characteristic gives a good match with fitted I-V. However, It is also observed that the fitted I-V characteristic is slightly mismatched from the measured characteristic near the short-circuit current. This can be attributed to the fact that the values of R_s and R_{sh} were estimated by linear regression approach which could be slightly deviated from the actual values of R_s and R_{sh}.

5. CONCLUSION

GA based approach is successfully used for the extraction of the cell parameters for synthetic and measured I-V characteristics. The obtained results using GA are in good agreement with the reported results and measured results. Thus, it is evident that GA based program can be a useful tool to extract the solar cell parameters in order to evaluate the performance of the solar PV cells. The series resistance and shunt resistance were estimated for the experimental data using linear regression method. However, these parameters may be slightly deviated from the actual values. This limitation requires a further improvement in the algorithm to extract all solar cell parameters including R_s and R_{sh} using genetic evolution.

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