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

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Abstract:

Obtaining information about a solar cell's properties is necessary in order to assess its performance and to maximise the amount of output power that can be extracted from it. We describe a computationally based binary-coded genetic algorithm (GA) for extracting the parameters (I0, Iph, and n) from a single diode model. The binary-coded genetic algorithm (GA) is based on the principle of least squares (GA). This feature is responsible for determining the current-voltage (I-V) characteristic of a photovoltaic cell. The approach was created in LabVIEW, which served as the programming environment. Application of the programming tool to the I-V curve derived from the literature, with previously published data used to validate the results. values. The values of parameters calculated by GA are in great agreement with the values of these parameters that have previously been published. Solar cells consisting of silicon and plastic are used in this application. It was used to extract characteristics for an experimental I-V characteristic of a 4 × 4 cm2 polycrystalline silicon solar cell, which was tested under a range of environmental circumstances after the programme had been validated. 900 watts per square metre Compared to the experimental I-V characteristic, the GA-derived I-V characteristic is quite comparable in all areas.

INTRODUCTION

The globe is on the lookout for alternative energy sources to meet the world's growing energy demand, and solar photovoltaics (SPV) energy conversion plays a significant part in this search. For a solar photovoltaic (SPV) plant to function at its optimum capacity, it is necessary to understand the specific parameters of the solar cell or module. The total performance and conversion efficiency of the solar cell, on the other hand, are directly related.A variety of physical characteristics, such as photocurrent (Iph), series resistance (Rs), and shunt resistance, influence the outcome (Rsh),The saturation current (I0) and the ideality factor of the diode (n).As a result, reliable estimate of such factors is necessary.Not only is it necessary to do an appraisal of the situation, but it is also necessary.not only to increase cell performance, but also to improve the design and fabricationThe cell's procedure and quality control are both addressed in [1].There are a variety of ways, such as polynomial curve fitting.There have been reports in the literature on the extraction of cell parameters using various methods including the Lambert W function [3, particle swarm optimization [4, and pattern search optimization [5]. In this study, a computationally based binary-coded algorithm is presented.The use of GA is used to retrieve cell parameters from a cell.based on an I-V characteristic that was determined empiricallyLabVIEW (laboratory virtual instrument) is used to develop the software for GA to gather cell parameters.as a programming environment (engineering workbench, version-10)tool. The characteristics of silicon and plastic solar cells are discussed.The results achieved by using the suggested GA are determined to be satisfactory.conformity to that which has been reported in the literature [3, 4]I-V characteristics of a commercial polycrystalline semiconductor [Figure 8].The silicon solar cell produced by GA is likewise in excellent condition.accord with the I-V characteristic obtained experimentally.

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THEORY

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

Here, I denotes the output current, Iph indicates the photocurrent, I0 indicates the saturation current, Rs denotes the series resistance, Rsh denotes the shunt resistance, n indicates the ideality factor, and kB denotes the bandwidth.The Boltzmann constant is equal to 1, and the temperature is equal to T. Direct The extraction of parameters from eq. (1) is restricted by the nonlinear I-V relationship and the transcendental character of current.An equation for a solar cell may be found here. Alternative procedures, such as the Newton-Raphson method [6], may be used to determine the parameters.Previously, the Least Squares approach [7] and the least squares method [6] were used.The I-V properties of silicon and germanium are investigated in this paper.The data reported in the literature [3, 8] was used to create plastic solar cells, which were then tested. Making use of the GA that was retrieved.

The values of Iph, I0, and n were derived from the synthesised I-V characteristic, and the value of I was computed for a set of different values of V using the Newton-Raphson technique for each of the different values of V. ThisThe I-V characteristic was then utilised to determine the validity of the hypothesis.as well as the robustness of the current approachIn order to derive Iph, I0, and n from the experimental I-V characteristic of a commercial polycrystalline silicon solar cell, we must first determine the I-V characteristic of the commercial polycrystalline silicon solar cell.The values of Rs and Rsh were calculated by performing linear regression on chosen points on the I-V characteristic around the centre of the curve.The conditions of an open circuit and a short circuit are described below.

The value of dV/dI at a short circuit may be calculated using eq. (1).

The value of Rsh is determined by the condition (i.e. I Isc and V 0).

$$\frac{dV}{dI} = R_{sh} + R_s \approx R_{sh} \qquad (2)$$

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

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

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

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.

SOLAR CELL PARAMTERS EXTRACTION

In many ways, Darwin's idea of natural selection and natural evolution served as an inspiration for the Genetic Algorithm. The procedures of GA are designed to increase the fitness of a population.Selection, crossover, and mutation are all examples of natural selection. In this piece of art, thea collection of parameters that are unknown (i.e. solar cell parameters)a cell's X coordinates are specified as X (0, Iph, and n). These unidentified parameters are the members (i.e., the people) of the

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group.The population and were retrieved using continuous evolution using GA, which was used to extract the data. Initially, a significant number of people (Npop) were present.Sets of solar cell parameters (for example, X I0, Iph, and n) are discussed.a random number generator The software then calculates the current value.based on the Newton-Raphson technique for each and every randomly selectedUsing eq., we constructed a set of solar cell parameters for each of the experimental voltages (1).Then there are the computed currents.when they are compared to experimental values at each genetic stageIteration is necessary in order to determine the suitability of the answer.The parameters that lead to greater fitness were identified.picked by the selection operator and then crossed across by the crossover operatorin addition to the mutation operator in order to boost fitnessIn this study, an elimination procedure and a random-point generator are used.As a selection, crossover and single bit-flipping were utilised, respectively.Operators for crossover and mutation are defined as follows: In our examples, the fitness function is defined as follows:

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

Where I exp(Vi) and I cal(Vi) are the experimental and calculated current values at Vi, respectively, and p is the total number of current measurements at Vi.In the I-V characteristics, there are voltage steps. According to the eq (4),Better fitness is represented by a lower value of the fitness function.agreement between the fitted I-V characteristic and the synthetic I-V characteristicThe I-V characteristic is the same as the experimental one.

4. DISCUSSION OF RESULTS AND CONCLUSIONS

Figures 1 and 2 show the synthetic and fitted I-V curves, respectively.silicon solar cell features and properties of a plastic solar cellGA is used in the cell and vice versa. Tables 1 and 2 provide examples ofthe reference parameters and the parameters derived from GAfor solar cells made of silicon and for solar cells made of plastic,

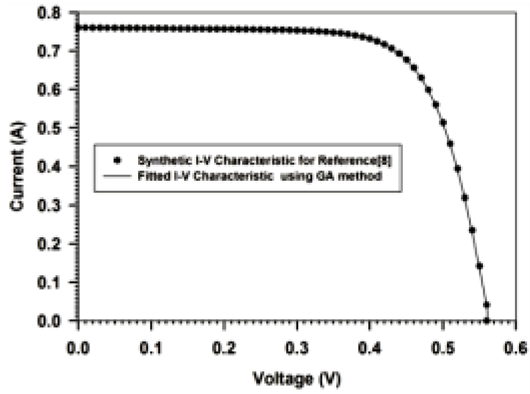

Fig. 1 – Synthetic and fitted I-V characteristic of silicon solar cell

According to the figures 1 and 2, it can be seen that the synthetic I-V characteristics precisely overlap the fitted IV characteristics produced using GA (as shown in the figures). It is also found that the parameters recovered by GA are extremely similar to the findings provided in references [3, 8] as indicated in the references section.Tables 1 and 2 show the performance of the silicon solar cell and polymers, respectively.the solar cell, and so on

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Table 1 – Parameters from Ref. [8] and extracted using GA with Rs 0.0364 and Rsh 53.76

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

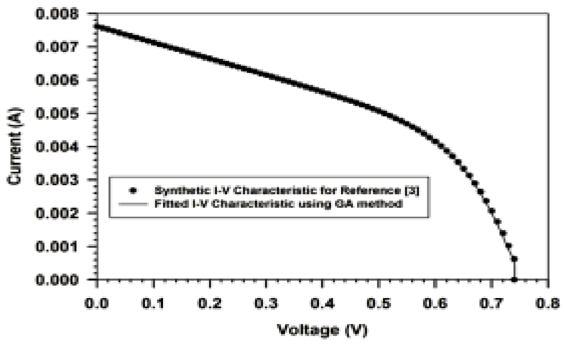

Fig. 2 – Synthetic and fitted I-V characteristic of Plastic solar cell

Table 2 – Parameters from Ref. [3] and extracted using GA with Rs 8.59 and Rsh 197.24

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

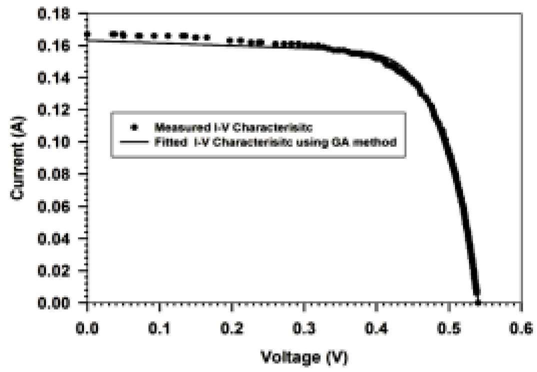

Figure 3 shows the I-V parameters of a commercial polycrystalline silicon solar cell, both experimentally and theoretically.

GA is also used to extract parameters from observed I-V characteristics for a commercial polycrystalline silicon solar cell, as shown in Fig. 3. This is an additional test. TheA 16 cm2 cell was used, and the illuminated I-V characteristic was evaluated under high light intensity (900 W/m2) at room temperature.35 degrees Celsius is the temperature. The GA-extracted data is shown in Table 3.The following are the parameters for a polycrystalline silicon solar cell. It is the case

Table 3 – GA-extracted parameters for polycrystalline silicon solar cell with fixed parameters Rs = 0.3214 Ohm and Rsh = 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

It was determined that the measured I-V characteristic is a good match with the fitted I-V characteristic. However, it is also seen that the fitted I-V characteristic is somewhat out of whack with the observed I-V characteristic.based on the measured characteristic in the vicinity of the short circuitcurrent. In this case, it may be attributable to the fact that the values of Rs and Rsh were calculated using linear regression.a method that may be somewhat off from the actual values of R and Rsh

Conclusion

The extraction of cell parameters for both synthetic and measured I-V characteristics using a GA-based technique has been shown to be effective. The findings acquired by the use of GAhad found themselves to be in excellent accord with the stated findings andResults that can be measured As a result, it is clear that GA-basedThe software may prove to be a beneficial tool in the extraction of the solar cell.characteristics in order to assess the overall performance of the systemsolar photovoltaic (PV) cells The series resistance and shunt resistance were calculated from the experimental data using the formulasThe linear regression approach is used in this case. These criteria, on the other handIt is possible that the calculated numbers will differ somewhat from the real ones. ThisTo overcome this constraint, the algorithm must be improved in order to extract all solar cell properties, including Rs.Regarding the use of genetic evolution by Rsh.

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