QUID 2017, pp. 1040-1043, Special Issue N°1- ISSN: 1692-343X, Medellín-Colombia

OPTIMIZATION OF EXPONENTIAL DOUBLE-DIODE MODEL FOR PHOTOVOLTAIC SOLAR CELLS USING GA-PSO ALGORITHM

(Recibido el 16-06-2017. Aprobado el 07-09-2017)

Vahdat Nazerian
University of Mazandaran,
Assistant Professor, Department of electrical engineering, Babolsar, Iran

Sogand Babaei
University of Mazandaran,
BS student, Department of software engineering, *Babolsar, Iran*

Resumen: En este trabajo se presenta un circuito eléctrico equivalente basado en el efecto fotovoltaico (PV) con estudios sobre la simulación del sistema de energía solar. Este modelo consiste en dos diodos exponenciales que ilustran cómo se comportan las células solares para generar electricidad. Mediante el uso del software MATLAB, realizamos simulaciones. Nuestro objetivo es calcular el valor mínimo de error para los parámetros desconocidos del modelo, que se logra utilizando el cuadrado medio de errores (RMSE). Con respecto al modelo ofrecido, que pretendemos investigar con el algoritmo GA-PSO sugerido, obtenemos el valor mínimo de error (RMSE) después de alcanzar parámetros desconocidos y luego compararemos los resultados con otros métodos. Por lo tanto, se puede demostrar que el algoritmo propuesto con un valor RMSE de 2,02 proporciona un resultado óptimo. De acuerdo con los cálculos calculados, el tiempo de ejecución de este algoritmo para cada cálculo es de aproximadamente 1 minuto y 30 segundos, mientras que el tiempo total del algoritmo se calculará de acuerdo con los valores de los parámetros y la frecuencia de repetición. Con el progreso del proceso de cálculo esta vez sale a 3 minutos y 30 segundos.

Palabras clave: Efecto fotovoltaico, Células solares, Modelo exponencial de doble diodo, Algoritmo GA-PSO, Cuadratura media de errores (RMSE)

Abstract: In this paper, an equivalent electrical circuit based on the photovoltaic effect (PV) is presented with studies on the simulation of the solar energy system. This model consists of exponential double diodes illustrates how solar cells behave in order to generate electricity. By using the MATLAB software, we performed simulations. Our goal is to calculate the minimum error value for the unknown parameters of the model, which is attained by using root mean square of errors (RMSE). Regarding to the offered model, which we intend to investigate with the suggested GA-PSO algorithm, we obtain the minimum error value (RMSE) after achieving unknown parameters and then we will compare the results with other methods. Therefore, it can be shown that the proposed algorithm with a RMSE value of 2.02 provides an optimal result**.**

Citar, estilo APA: Nazerian, V., & Babaei, S. (2017). Optimization of exponential double-diode model for photovoltaic solar cells using ga-pso algorithm**.** *Revista QUID (Special Issue)*, 1040-1043.

According to the computed calculations, the runtime of this algorithm for each calculation is approximately 1 minute and 30 seconds, while the total time of the algorithm will be figured according to the parameter values and the frequency of repetition. With the progress of the calculation process this time comes out to 3 minutes and 30 seconds.
Keywords: Photovoltaic Effect, Solar Cells, Exponential Double-diode Model, GA-PSO Algorithm, Root Mean Square of Errors (RMSE)

1. INTRODUCTION

The sun is the biggest renewable energy source on the earth. If only 1% of the world's deserts are equipped with thermal power plants, that is enough to produce world-wide annual demand for electricity. For every 1 kw of solar energy, the production of 6 kg of pollutant is prevented, which is equivalent to an average of 5,270 kg annually, resulting from burning 21,222 Liters of diesel fuel. The efficiency of these cells has been improved from 6% to 22% over the past 60 years. With the exordium of nanotechnology in the production of solar cells, the efficiency of these cells has increased drastically (Hyvarinen, 2003). There are two ways to use solar energy: direct use of sunlight and convert it to electricity through photovoltaic cells and direct use of solar energy and convert it to other energies (power plant applications).

The economic benefits of using solar energy include no need for fuel, easy to install and connected at any location, low cost utilization, long-term economic savings, free energy source and creation of culture. Recently, photovoltaic arrays have been used in many applications such as battery chargers, solar water pumping systems, network connected PV systems, solar hybrid vehicles, and satellite systems. In all solar energy systems, efficient simulations of photovoltaic panels are required before any testing approvals (Dondi, 2008), (Campbell, 2007).

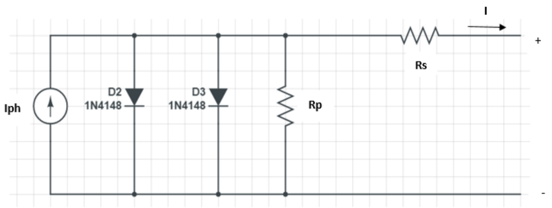

Figure. 1. Double-diode circuit model

This circuit model has a light-dependent current source, two exponential diodes, series resistance and parallel resistance (Nazerian, 2017).The amount of current source is directly proportional to the light emitted on the photovoltaic cell, which changes as a linear coefficient with light intensity. Due to the semiconductor junction in photovoltaic cells, this circuit also uses two diodes and two resistors for the modeling.

.

2. THE ELECTRICAL CIRCUIT MODEL AND RELATED EQUATIONS

A. Exponential double-diode circuit

The equivalent circuit based on the double-diode model of solar cell is shown in Fig. 1.

B. Mathematical equations

According to the model presented in Fig. 1, the current of the first and second diodes, parallel resistance, photovoltaic current source and the output current of the array are given by the equations (1) to (5) below, respectively.

$$I_{D1} = I_{S1} * [(e^{\frac{\frac{V}{N_S} + R_S * I}{A_1 * V_T}}) - 1] \quad (1)$$

$$I_{D2} = I_{S2} * [(e^{\frac{\frac{V}{N_S} + R_S * I}{A_2 * V_T}}) - 1] \quad (2)$$

$$I_{sh} = \frac{\frac{V}{N_S} + R_S * I}{R_P} \quad (3)$$

$$I_{ph} = I_{D1} + I_{D2} + I_p + I \quad (4)$$

$$I + I_{S1} * [(e^{\frac{\frac{V}{N_S} + R_S * I}{A_1 * V_T}}) – 1] + I_{S2} * [(e^{\frac{\frac{V}{N_S} + R_S * I}{A_2 * V_T}}) – 1] + \frac{\frac{V}{N_S} + R_S * I}{R_P} - I_{ph} = 0 \quad (5)$$

Where I_D is diode current, I_S is reverse saturation current, V is output voltage of solar array, V_T is thermal voltage, A is ideality factor of diode, I_{ph} is photovoltaic current source, I is output current of solar array, R_s is series resistance, R_{sh} is parallel resistance (Salam, 2010), (Villalva, 2009).

Using equation (5), we are supposed to find a set of values for unknown model parameters A_1, A_2, I_{S1}, I_{S1}, I_{ph}, R_P and R_S in such a way that the equation is just a function of I and V, so that the I-V characteristic fits on the experimental I-V curve of the photovoltaic array with measured values of Table 1.

Table 1. Measured Values

I_{sc}	V_{oc}	I_{mp}	V_{mp}	N_s
3.11	21.3	2.88	17	36

Where the measured values of the PV array are defined as follows:

N_s: The number of photovoltaic cells in series
V_{oc}: Open circuit voltage
I_{sc}: Short circuit current
I_{mp}: Current of maximum power
V_{mp}: Voltage of maximum power

In this case, by altering V from 0 to V_{oc} in equation (5), we will have different current (I), so that the results obtained from the circuit model matches properly with experimental values of Table 1. The maximum conformity of the values is our goal in this paper. So, the error function of RMSE is defined below as equation (6).

$$RMSE=\sqrt[2]{\frac{1}{5}*(I_{sca}-I_{sc})^2+(V_{oca}-V_{oc})^2+\left(I_{mpa}-I_{mp}\right)^2+\left(V_{mpa}-V_{mp}\right)^2+\left(P_{mpa}-P_{mp}\right)^2} \quad (6)$$

Where the RMSE is the root mean square of errors and we should minimize the error value to obtain the unknown parameters of the model.
Ideally, the 7 model parameters are defined using the proposed optimization algorithm so that the same values of Table 1 could be extracted from the equation (5) to obtain the optimal possible state.

3. Proposed GA-PSO Algorithm

This algorithm combines the genetic algorithm and the PSO. The genetic algorithm uses Darwinian selective principles to find the effective formula to forecast or pattern matching. The genetic algorithms are often a good option for regression-based prediction techniques. The flowchart of GA-PSO algorithm is shown in Fig. 2, which was used in this paper.

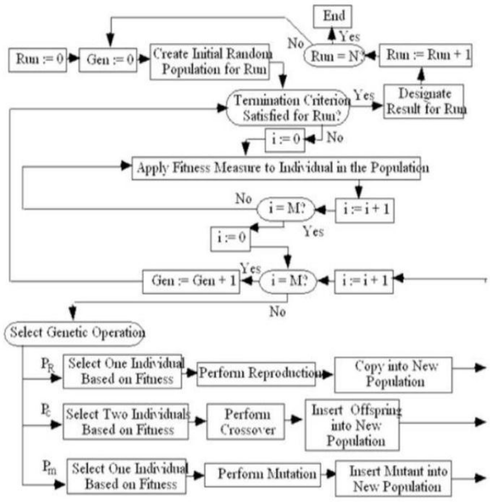

Fig. 2. The Flowchart of GA-PSO algorithm

4. RESULTS AND DISCUSSION

By specifying the range of each model parameter, GA-PSO algorithm gives the optimal output using MATLAB programming as shown in Table 2.

Table 2. The results of missing parameters with GA-PSO algorithm

	A2	A1	I_{s2}	I_{s1}	I_{ph}	R_p	R_s
Range of missing parameters	2.5-1	2.5-1	10^{-7} - 10^{-10}	10^{-7} - 10^{-10}	1.5Is- Is	1000-100	0.1-0.001
Result	1.54	1.13	$6.82*10^{-8}$	$1.01*10^{-8}$	4.45	916.07	0.04

According to the results of the parameters from Table 2, the minimum error value (RMSE) of the algorithm is 2.02. Fig. 3 and Fig. 4 show the I-V and P-V characteristics of the solar array using GA-PSO algorithm, respectively.

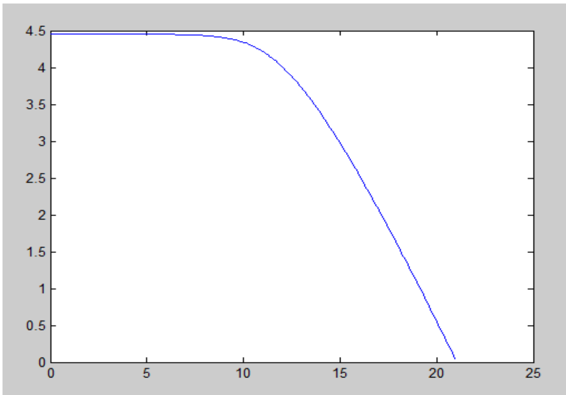

Figure 3. I-V characteristic using GA-PSO algorithm

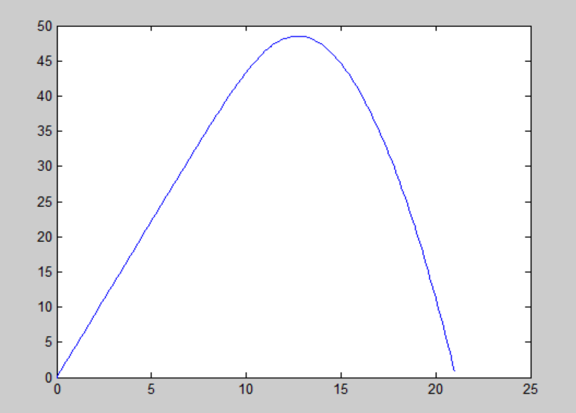

Figure 4. P-V characteristic using GA-PSO algorithm

The calculation time for each round of this algorithm at the beginning of the program is 1 minute and 30 seconds. By program progressing and aggravating, the calculation time also reaches to 3 minute and 30 seconds. However, it is necessary to expand the domain of the parameters in order to obtain better result, the frequency of repetition and the duration of the entire program will increase. For the values rather reasonable in this algorithm, it takes about 12 hours on the PC systems. Finally, the RMSE value of this algorithm is equal to 2.02. Due to the calculation time, the error value obtained from GA-PSO algorithm is appropriate, which seems to be used in optimization of model parameters as well.

5. CONCLUSION

In this paper, exponential double-diode model of PV solar panels was presented to optimize the electrical equivalent circuit parameters. Regarding to the model examined by the proposed GA-PSO algorithm, the minimum error value (RMSE) for the unknown parameters is 2.02, which its calculated time takes along about 1 minute and 30 seconds. The results of the optimization can forecast the I-V and P-V characteristics of the PV arrays obtained from experimental measurements as well. Comparing the results of the GA-PSO algorithm shows the accuracy of the proposed model and algorithm for optimizing PV in various conditions.

6. REFERENCES

J. Hyvarinen, J. Karila, "New analysis method for crystalline silicon cells", *Proc. 3rd World Conf. Photovoltaic Energy Convers.*, pp. 1521-1524, 2003.

D. Dondi, A. Bertacchini, D. Brunelli, L. Larcher, L. Benini, "Modeling and optimization of a solar energy harvester system for self-powered wireless sensor networks", IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2759-2766, Jul. 2008.

A. Chatterjee, A. Keyhani, D. Kapoor, "Identification of photovoltaic source models", IEEE Trans. Energy Convers., vol. 26, no. 3, pp. 883-889, Sep. 2011.

R. C. Campbell, "A circuit-based photovoltaic array model for power system studies", *Proc. 39th North Amer. Power Symp.*, pp. 97-101, 2007.

V. Nazerian, M. Alahgholi, “Modelling of photovoltaic solar panels using linear-piece multi-diode equivalent circuit model”, 4th international conference on electrical & computer engineering, Tehran, Iran, 12 Jan. 2017.

V. Nazerian, Kh. G. Firuzjah, S. Gholamzadeh, M. H. Dizaj, “Simulation of photovoltaic solar cells using MATLAB/Simulink”, International conference on the new horizons in the basic and technical sciences and engineering, Tehran, Iran, 4 March 2017.

Z. Salam, K. Ishaque, H. Taheri, "An improved two-diode Photovoltaic (PV) model for PV system", Proc. Joint Int. Conf. PEDES, pp. 1-5, 2010.

M. G. Villalva, J. R. Gazoli, E. R. Filho, "Comprehensive approach to modeling and simulation of photovoltaic arrays", *IEEE Trans. Power Electron.*, vol. 24, no. 5, pp. 1198-1208, May 2009.