SSRG International Journal of Electronics and Communication Engineering Volume 6 Issue 6, 5-9, June 2019
ISSN: 2348 – 8549 /doi:10.14445/23488549/IJECE-V6I6P102 © 2019 Seventh Sense Research Group®

Modeling of a Solar Cell considering Single-Diode Equivalent Circuit Using Matlab/Simulink

Mr.Kyaw Thu[#1], Mr.Yin Maung Maung[#2], Ms.Than Than Win[#3]
Myin Gyan Degree College, Myanmar
[#1]Department of Physics,
[#2]Department of Physics, University of Yangon, Myanmar
[#3]Department of Physics, Pinlon University, Myanmar

Abstract

This paper focuses on a circuit-based simulation model for a PV cell to adequately assess temperature dependence, solar radiation change, and diode ideality factor. This research work introduces the simple method of mathematical modeling and simulation of current-voltage characteristics for photovoltaic cells. This modeling aims to estimate the nonlinear I-V model of a photovoltaic cell to apply the simulation for the researcher students easily. So this paper indicates the parameters for the nonlinear I-V equations based on only the data such as open-circuit voltage, short circuit current, voltage, and current at maximum power point for voltage and current at the normal condition or the standard test condition which are obtained from manufacturer's datasheet.

Keywords: *Photovoltaic energy, solar cells, modeling, simulation, Matlab*

I. INTRODUCTION

In recent years, significant photovoltaic (PV) deployment has occurred, particularly in Germany, Spain, and Japan [1]. Also, PV energy is expected to become an important player in the coming years in Myanmar since it is one of the Asian countries with the highest levels of solar radiation. Sunshine in mainland Myanmar varies between 1800 and 3100 hours per year, so it has a huge potential for solar energy exploitation.

At present, the tenth-largest PV power plant in the world is in Portugal, with an installed capacity of 46 MW. The aim is to reach 1500 MW of installed capacity by 2020, multiplying tenfold the existing capacity [2].

A PV system allows the direct conversion of sunlight into electricity. The main device of a PV system consists of series or parallel solar cells. PV systems may be grouped to form panels or arrays. Power electronic converters usually require processing the electricity from the PV module. These converters may be used to regulate to control the power flow in grid-connected or off-grid connected systems for the voltage and current at the load and the maximum power point tracking (MPPT) of the device [3]. The solar cell is basically a solid-state junction diode exposed to light. Solar cells are made of several types of semiconductors using different manufacturing processes [4]. The solar radiation to electrical energy produced by a solar cell instant depends on its intrinsic properties and the incoming solar radiation at any time and everywhere [5].

The irradiance is composed of photons of different energies, and some are absorbed in the p-n junction. Photons with energies lower than the solar cell bandgap are useless and generate no voltage or electric current. The photons energy is dissipated as heat energy in the solar cell [6]. A single-diode PV cell model was considered in this paper, including the effect of the series resistance. This paper may be used the equivalent circuit of a solar cell with its parameters as a tool to simulate in order to consider the solar radiation and temperature change, the I-V characteristics of PV cell.

This document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

II. MODELLING OF IDEAL SOLAR CELL

When sunlight strikes the surface of a solar cell, some of the photons are energetic enough to free electrons from the N-type semiconductor. The separation of the charges gives rise to a terminal voltage. When connected to an external circuit, a current flows as long as sunlight illuminates the solar cell. In the dark, the I-V characteristics of a solar cell have an exponential characteristic similar to that of a diode [7]. To maximize the extracted output power from a PV power plant with the help of MPPT control, the understanding and modeling of PV cells are needful [8].

The ideal equivalent circuit of a solar cell is a current source in parallel with a single-diode. The configuration of the simulated ideal solar cell with a single-diode is shown in Fig.1.

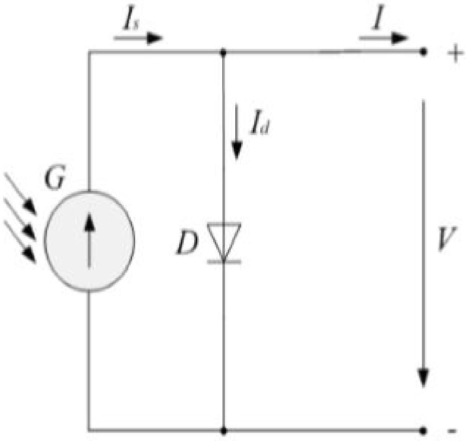

Fig.1: Ideal solar cell with single-diode

In Fig.1, G is the solar radiance, I_S is the photocurrent, I_d is the diode current, I is the output current, and V is the terminal voltage. The I-V characteristics of the ideal solar cell with a single diode are given by:

$$I = I_S - I_0\left(e^{\frac{qV}{mkT}} - 1\right) \quad (1)$$

Where I_0 is the diode reverse bias saturation current, q is the electron charge, N is the diode ideality factor, k is the Boltzmann's constant, and T is the cell temperature.

A solar cell can at least be characterized by the short circuit current I_{SC}, the open-circuit voltage V_{OC}, and the diode ideality factor 'N'.

For the same irradiance and p-n junction temperature conditions, the short circuit current I_{SC} is the greatest value of the current generated by the cell. The short circuit current I_{SC} is given by:

$$I_{SC} = I = I_S \quad for\ V = 0 \quad (2)$$

For the same irradiance and p-n junction temperature conditions, the open-circuit voltage V_{OC} is the greatest value of the voltage at the cell terminals [7]. The open-circuit voltage V_{OC} is given by:

$$V = V_{OC} = \frac{NkT}{q}\ln\left(1 + \frac{I_{SC}}{I_0}\right) \text{ for } I = 0 \, (3)$$

The output power is given by:

$$P = V\left[I_{SC} - I_0\left(e^{\frac{qV}{NkT}} - 1\right)\right] \quad (4)$$

III. SOLAR CELL WITH SERIES RESISTANCE

The model may be introduced by adding a series resistance. The configuration of the simulated solar cell with single-diode and series resistance is shown in Fig.2.

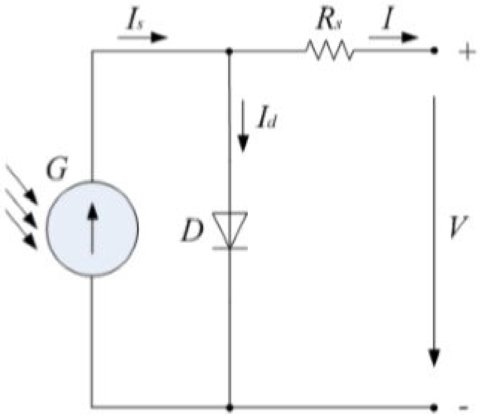

Fig.2: Solar cell with single-diode and series resistance

The I-V characteristics of the solar cell with single-diode and series resistance are given by:

$$I = I_S - I_0\left[e^{\frac{q(V+R_S I)}{NkT}} - 1\right] \quad (5)$$

For the same solar radiation and p-n junction temperature conditions, the inclusion of series resistance in the model may be implied the use of a recurrent equation to determine the output current in the function of the terminal voltage. The Newton–Raphson method is converged more rapidly and for both positive and negative currents [7].

The short circuit current I_{SC} is given by:

$$I_{SC} = I = I_S - I_0\left[e^{\frac{q(R_S I_{SC})}{NkT}} - 1\right] \quad \text{for } V = 0$$

(6)

Normally the series resistance is very small and negligible in computing (6). Hence, it is used (2) as a good approximation of (6). The open-circuit voltage V_{OC} is given by:

$$V = V_{OC} = \frac{NkT}{q}\ln\left(1 + \frac{I_{SC}}{I_0}\right) \quad \text{for } I = 0$$

(7)

The output power is given by:

$$P = V\left[I_{SC} - I_0\left(e^{\frac{q(V+R_S I)}{NkT}} - 1\right)\right] \quad (8)$$

The diode saturation current at the operating-cell temperature is given by:

$$I_0 = I_0^*\left(\frac{T_C}{T^*}\right)^3 e^{\frac{\varepsilon q}{Nk}\left(\frac{1}{T^*} - \frac{1}{T_C}\right)} \quad (9)$$

Where I_0^* is the diode saturation current at reference condition, T_C is the p-n junction cell temperature, T^* is the cell p-n junction temperature at reference condition, and ε is the bandgap.

IV. SIMULATION AND MODELLING RESULTS

The models for the ideal solar cell and the solar cell with series resistance were implemented in Matlab/Simulink. The I-V characteristics for various irradiance conditions and N=1.5, considering the ideal solar cell, are shown in Fig.3.

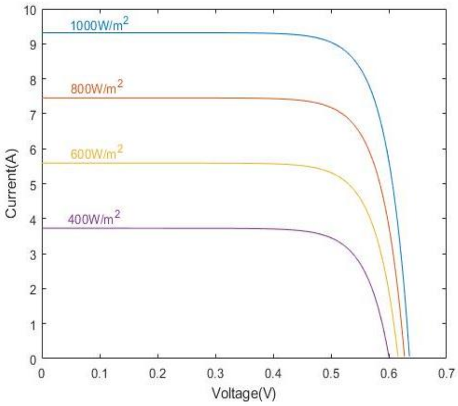

Fig.3: I-V characteristics for various conditions of solar radiation

The I-V characteristics for a diode ideality factor variation between 1 and 1.9, considering the ideal solar cell, are shown in Fig.4.

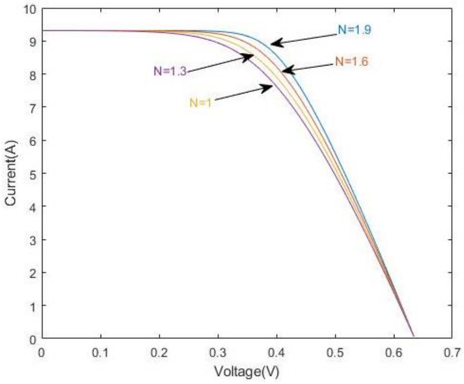

Fig.4: I-V characteristics for a diode ideality variation between 1 and 1.9

The I-V characteristics for a temperature variation between 0 and 100 ºC and N=1.5, considering the ideal solar cell, are shown in Fig.5.

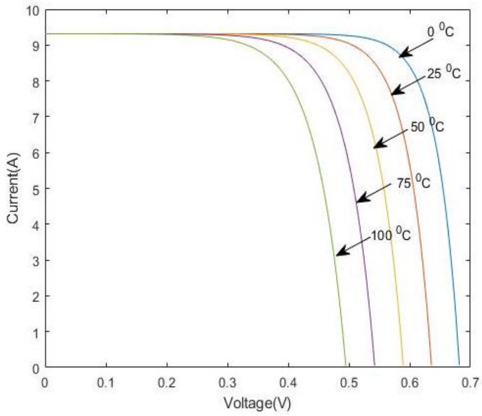

Fig.5: I-V characteristics for the temperature variation between 0 and 100 ºC.

The P-V characteristics for the temperature variation between 0 and 100 ºC and N=1.5, considering the ideal solar cell, are shown in Fig.6.

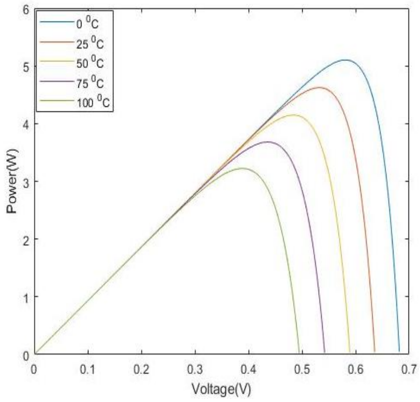

Fig.6: P-V characteristics for the temperature variation between 0 and 100 ºC.

The I-V characteristics for a temperature variation between 0 to 100 ^{0}C and N=1.5, considering the solar cell with series resistance, are shown in Fig.7.

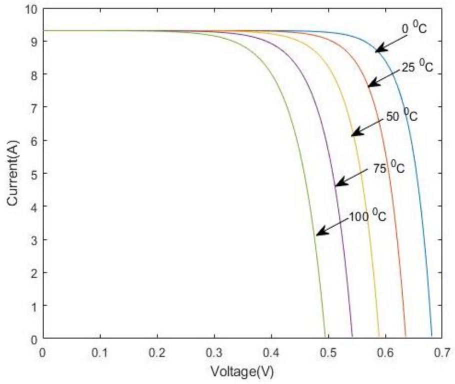

Fig.7: I-V characteristics for various conditions of temperatures (0 to 100 ^{0}C) (considering series resistance).

The I-V characteristics for a diode ideality factor N=1.5, considering the solar cell with a series resistance of R=4mΩ to 20mΩ, are shown in Fig.8.

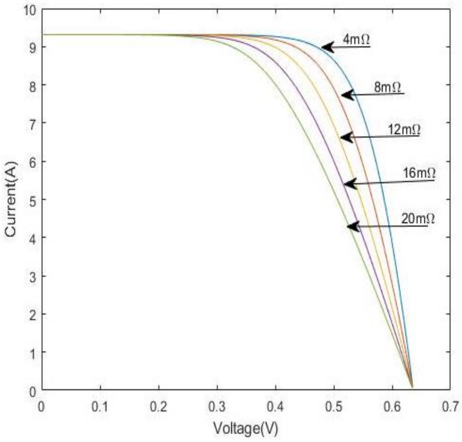

Fig.8: I-V characteristics for a diode ideality factor N=1.5（R=4mΩ to 20mΩ).

The P-V characteristic for a temperature variation between 0 and 100ºC and N=1.5, considering the solar cell with a series resistance of R=0Ω, are shown in Fig.9.

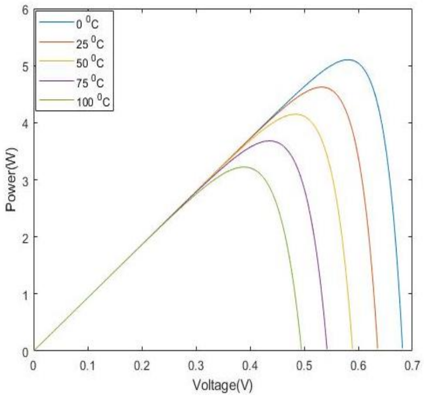

Fig.9: P-V characteristics for the temperature variation between 0 and 100 ºC (considering series resistance).

The P-V characteristics for the series resistance variation between 4mΩ and 20mΩ and N=1.5, considering the solar cell with a temperature of 25ºC, are shown in Fig.10. The P-V characteristics for R_S= 20mΩ are shown in Fig.11.

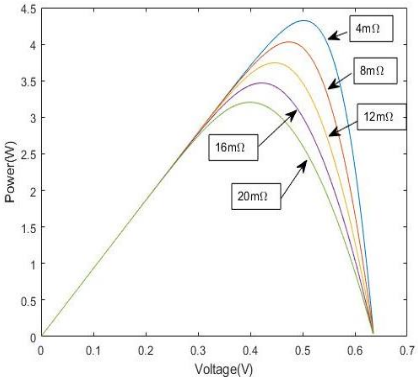

Fig.10: P-V characteristics for the series resistance variation between 4mΩ and 20mΩ (considering temperature 25 ºC).

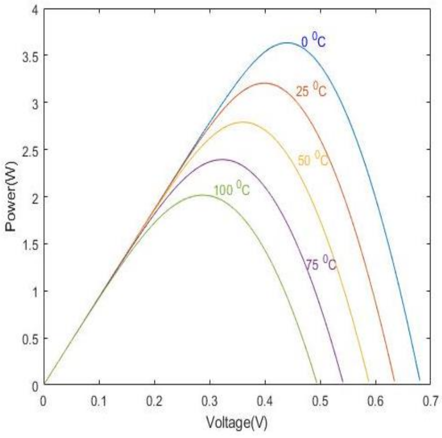

Fig.11: P-V characteristics for the temperature variation between 0 and 100 ºC (Rs=20mΩ)

The I-V characteristics for the Rs variation between 0Ω and 20mΩ are shown in Fig.12. With the change of the temperature, the solar radiation, and the diode ideality factor, the I-V and P-V will change accordingly.

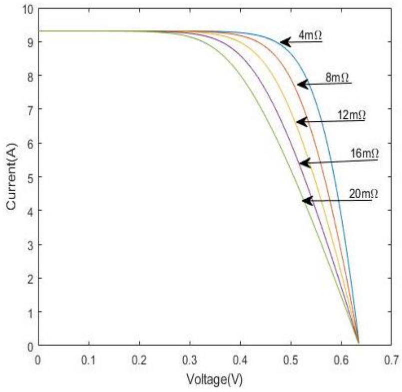

Fig.12: P-V characteristics for the Rs variation.

V. CONCLUSIONS

In this paper, the behavior of the ideal solar cell model and the solar cell's behavior with a series resistance model is studied. This model estimates the effects of temperature dependence, solar radiation change, and diode ideality factor, and series resistance influence. The solar cell with a series resistance model may be offered a more realistic behavior for the photovoltaic systems. In this work, the effect of temperature, series resistance, and diode ideality factor on the P-V characteristics are simulated in Matlab/Simulink. This research work is introduced an improved mathematical model for photovoltaic modules that employ only parameters provided by the manufacturer's solar cell without requiring the use of any numerical methods. The simulation is pointed out in order to validate the manufacturer's solar cell and to compare experimental results.

VI. ACKNOWLEDGMENT

The author would like to thank Professor Dr. Yin Maung Maung, Department of physics, and the University of Yangon for his kind permission to carry out this work.

VII. REFERENCES

[1] F. Spertino and J. S. Akilimali, “Are manufacturing I–V mismatch and reverse currents key factors in large photovoltaic arrays?”, IEEE Transactions on Industrial Electronics, Vol. 56, No. 11, pp. 4520-4531, Nov. 2009.

[2] M. Laranja, “Portuguese National Strategy ENE 2020”. Available: http://www.ccr-norte.pt/norte2020/laranja.pdf

[3] M. G. Villalva, J. R. Gazoli, and E. R. Filho, “Comprehensive approach to modeling and simulation of photovoltaic arrays”, IEEE Transactions on Power Electronics, Vol. 24, No. 5, pp. 1198-1208, May 2009.

[4] A. S. Sedra and K. C. Smith, Microelectronic Circuits. London, U.K.: Oxford Univ. Press, 2006.

[5] M.A. Eltawil, Z. Zhao, “Grid-connected photovoltaic power systems: Technical and potential problems—A review”, Renewable and Sustainable Energy Reviews, Vol. 14, No. 1, pp. 112–129, Jan. 2010.

[6] Kassel,“Photovoltaic systems technology,” Universitat Kassel, Germany, 2003.

[7] G.R. Walker, “Evaluating MPPT topologies using a Matlab PV model”, Journal of Electrical & Electronics Engineering, Vol. 21, No. 1, pp. 49-56, 2001.

[8] J. Yuncong, J.A.A. Qahouq, and I. Batarseh, “Improved solar PV cell Matlab simulation model and comparison”, in Proc. 2010 IEEE International Symposium on Circuits and Systems — ISCAS’10, Tuscaloosa, Alabama, USA,2010.

[9] Balamurugan.R, Vanisha.B, Manimekalai.A, Kavitha.N, Iyappan.S, "Power System Integration of Photovoltaic and Energy Storage" SSRG International Journal of Electrical and Electronics Engineering 5.2 (2018): 18-21.