MODELING OF THE CURRENT-POWER CHARACTERISTICS OF PHOTOVOLTAIC MODULE IN MATLAB / SIMULINK

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Abstract: In this article, a photovoltaic model analysis was carried out to simulate the actual behavior of a photovoltaic module using Matlab - Simulink using the parameters of photovoltaic cells consisting of a single diode, series and shunt resistance. The typical characteristics of a 150W P 36 crystalline solar module were used to evaluate the model. The characteristic curves were obtained from the manufacturer's data sheet, which shows an exact match of the model, and this proves that the module is reliable.

Keywords: *Photovoltaic module, Performance I-V and P-V, photovoltaic (PV), photovoltaic cells, Matlab , photovoltaic module, simulation.*

Introduction

A solar cell is a semiconductor diode exposed to light. Solar cells are made from several types of semiconductors using various manufacturing processes [1]. The electrical energy produced by a solar cell depends on its internal properties and incoming solar radiation [2]. Solar radiation consists of photons of different energies, and some of them are absorbed by p - n -transition. Photons with energies below the band gap of a solar cell are useless and generate neither voltage nor electric current. Photons with energies greater than the band gap generate electricity, but only the energy corresponding to the band gap is used. The rest of the energy is dissipated as heat in the solar cell housing [3]. This article discusses the photocell model with one diode, including the effect of series resistance. The article uses the equivalent circuit of a solar cell with its parameters as a modeling tool to take into account the change in irradiance and temperature, the CVC of the photocell.

2. Simulation

A. Ideal solar cell

As mentioned above, solar cells are semiconductor with p - n transition, made in the form of a thin plate or layer of semiconductors. When exposed to light, a photocurrent is generated that is proportional to solar radiation if the photon energy is greater than the band gap. In the dark, the CVC of a solar cell has an exponential character similar to that of a diode [3]. In order to maximize the extractable power output of a photovoltaic power plant with MPPT control , understanding and modeling the photovoltaic cell is necessary. The ideal solar cell equivalent circuit is a current source connected in parallel with a single diode. The configuration of a simulated ideal single diode solar cell is shown in Figure 1.

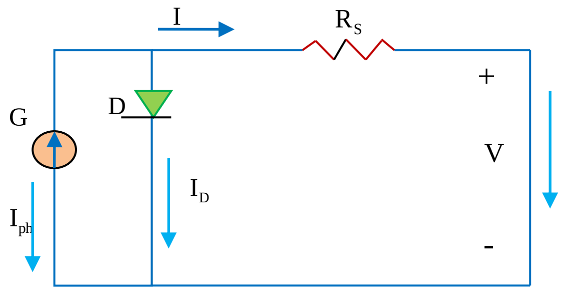

Рис.1. Базовая фотоэлектрическая ячейка

1. Equivalent circuits of photocells

The basic photovoltaic cell is represented by a diode, where In the figure G - solar radiation, I_S — photogenerated current, I_d is the diode current, I is the output current, and V - voltage at the terminals. The diode consists of n -type silicon and p -type silicon doped semiconductor with a resulting space charge layer. Typically, an unirradiated solar cell behaves much the same as a diode. Therefore, a simple diode can describe an equivalent circuit [3]. The semiconductor is temperature sensitive and the current generated by the illumination of the photocell is linear with solar radiation and also with temperature.

Table1. Main parameters of solar cells

PV technology	Ideality factor
Si-Mono	1.2
Si-Poly	1.3
a-Si-H	1.8
a-Si-H	3.3
a-Si-H	5
cdTe	1.5
CTs	1.5
AsGa	1.3

Fig. 1 shows an ideal photovoltaic cell, and one of the simplified and basic modules consists of a single diode connected in parallel to a current source that generates light, the ratio of the output current and voltage is:

$$I = I_{ph} - I_0\left[\exp\left(\frac{V}{n_s}\frac{q}{nk_B T}\right) - 1\right], \quad (1)$$

$$I = I_{ph} - I_S\left[\exp\left(\frac{V + IR_S}{nk_B T}\right) - 1\right] - \frac{V + IR_S}{R_{SH}}. \quad (2)$$

I_{ph} - photocurrent, I_S - diode reverse saturation current, q - electron charge , equal to 1 . 6x10 $^{-19}$ C, V is the voltage across the diode, K is the Boltzmann constant, T is the junction temperature, N is the diode ideality factor (usually 1 to 2), and and are the intrinsic R_{SH} shunt R_S and series resistances of the cell, respectively. Usually the value R_{SH} is very large and the value R_S is very small, so they can be neglected to simplify the analysis [1] ; At the point of maximum power $V = V_{mp}$ and $I = I_{mp}$

$$I = I_{ph} - I_0\left[\exp\left(\frac{V_{mp} + I_{mp}R_S}{n_s V_T}\right) - 1\right] - \frac{V_{mp} + I_{mp}R_S}{R_{SH}}. \quad (3)$$

2. Modeling photovoltaic devices

The IV characteristic of a photovoltaic module depends on the relationship between current and voltage generated in a typical solar cell. The characteristic IV curve and most of the parameters affecting the characteristics of a photovoltaic cell refer to R_S, R_{SH} as well as from the intensity of the irradiation level and temperature. The generated current I_{ph} of photocells, without taking into account series and parallel resistances, is difficult to determine. The specifications only state the standard short circuit current I_{mp}, which is the maximum current available at the PV module's terminals. A semiconductor is temperature sensitive, and the current generated by the illumination of a photocell is linear with solar radiation and is also temperature V_{oc} dependent I_{SC}. According to the analysis and results obtained, the CVC when changing the resistance of the shunt while maintaining the temperature and irradiation constant at STK 1000 W/m $_2$ and 25 co, respectively. In this case, the influence of the shunt resistance leads to a deviation of the maximum power point by a large amount. The effect is very small and can be neglected in some cases, as shown in Appendix B. Usually the value R_{sh} is very large, so it can be neglected. Determining the parameters R_S and R_{sh} the actual model of a single diode photocell is complex. With more independent parameters, the best fit should be determined iteratively, for example by Newton's method. However, estimating the initial values for R_S and R_{sh} is relatively simple. In standard approaches, R_S the calculation was carried out using (2). But (2) is only applicable if the output curves are provided by the manufacturer. According to the slopes of the I-Vat V_{OS} and, I_{SC} accordingly, we can estimate the series and shunt resistances R_S and R_{SH} The resistance at V_{OC} is at best proportional to the series resistance . However, there are some datasheets that do not give any output curves. Note that (3) can be obtained from (3)

$$I_{mp} = I_{ph} - I_0\left[\exp\left(\frac{V_{mp} + I_{mp}R_S}{n_s V_T}\right) - 1\right] - \frac{V_{mp} + I_{mp}R_S}{R_{sh}}. \tag{4}$$

substitute , estimate the initial value $R_{SH} = \infty$ and change the equation.

$$R_S = \frac{nKN_S T_{rf}}{qI_{mps}} \ln\left(\frac{I_{phs} - I_{mps} + I_{0s}}{I_{0s}}\right) - \frac{V_{mps}}{I_{mps}} \tag{5}$$

By applying the MPP condition and rearranging the obtained terms (4), the minimum value is determined R_{SH}. Therefore, using (4) we have

$$R_{sh,min} = \frac{V_{mp}}{I_{phs} - I_{mp}} - \frac{V_{osc} - V_{mp}}{I_{mp}}. \tag{6}$$

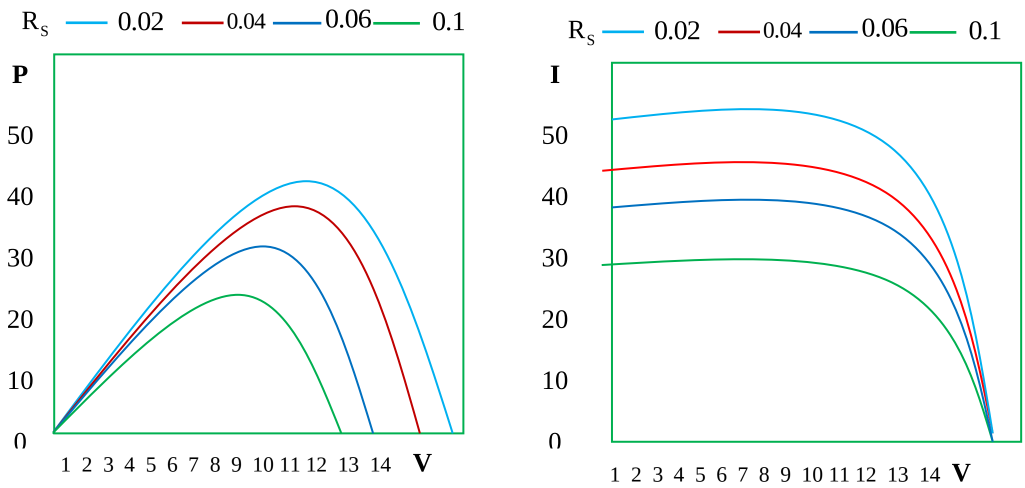

Fig. 2 Variable value of series resistance (0, 0.02 , 0.04 , 0.08 and 0.1) respectively, the figure shows the effect of series resistance leading to deviation of the maximum power point. The effect is small and in some cases it can be neglected.

Matlab/SIMULINK model has been evaluated for the PS - P 36-150 Wp solar panel module The results are shown in fig. 2. I-V and P-V simulation results show a good match in terms of short-circuit current, open-circuit voltage, and maximum power. In this work, for predicting the behavior of a photovoltaic cell under various physical and environmental conditions, the Matlab/SIMULINK model can be considered as an intelligent tool to extract the internal parameters of any solar photovoltaic cell, including the ideal ratio, series, and shunt. Some of these parameters are not always specified by manufacturers.

CONCLUSION

This article presents a mathematical model of a photovoltaic cell. The proposed procedure provides an accurate and valid photocell model. The results of the Matlab model show excellent agreement with the manufacturer's data from the table. This model has been designed so that it can be used to show the effect of temperature, irradiation, shunt and series resistances on IV characteristics. The maximum power output by the photovoltaic module is about 150.04 W at parameters close to the values provided by the manufacturer: I = 8.15 A and V = 18.41 V (table I).

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