Modeling and Simulation of PV Cell using One-diode model

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Abstract- The focus of this paper is on one diode photovoltaic cell model. The theory as well as the construction and working of photovoltaic cells using single diode method are also presented. Simulation studies are carried out with different temperatures & irradiations. Based on this study a conclusion is drawn with comparison with ideal diode.

General Terms- In recent years, significant photovoltaic (PV) deployment has occurred, particularly in Germany, Spain and Japan [1]. Also, PV energy is going to become an important source in coming years in Portugal, as it has highest source of sunshine radiation in Europe.

Presently the tenth largest PV power plant in the world is in Moura, Portugal, which has an installed capacity of 46 MW and aims to reach 1500 MW of installed capacity by 2020, as stated by the Portuguese National Strategy ENE 2020, multiplying tenfold the existing capacity [2]. The solar cells are basically made of semiconductors which are manufactured using different process [4]. The intrinsic properties and the incoming solar radiation are responsible for the type of electric energy produced [5].

The solar radiation is composed of photons of different energies, and some are absorbed at the *p-n* junction. Photons with energies lower than the band gap of the solar cell are useless and generate no voltage or electric current. Photons with energy superior to the band gap generate electricity, but only the energy corresponding to the band gap is used. The remainder of energy is dissipated as heat in the body of the solar cell [6].

Keywords- PV cell, solar cell, one diode model

I. Introduction

A PV system directly converts sunlight into electricity. Solar cell is the main device of a PV system which is grouped to form panels or arrays. To process electricity from PV devices power electronic converters are required. These converters may be used to regulate the voltage and current at the load, to control the power flow in grid-connected systems, and for the maximum power point tracking (MPPT) of the device [3].

In this paper we have considered one diode PV cell. The effect of the series resistance is also included in this. The equivalent circuit of a solar cell with its parameters as a tool to simulate in order to consider the irradiance and temperature change, the I-V characteristics of PV cell is also used in this paper.

II. Modeling and Simulation

As mentioned above the solar cells are semiconductor with a p-n junction fabricated in a thin wafer or layer of semiconductors. When exposed to light a photo current proportional to the solar radiation is generated, if the photon energy is greater than the band gap. In the dark, the I-V characteristics of a solar cell have an exponential characteristic similar to that of a diode [7].

A detailed approach to PV cell modeling based on a mathematical description of the equivalent electrical circuit of a PV cell. Three models are used for modeling of the PV cell module or array. In comparison the most commonly used configuration is the one-diode model that represents the electrical behavior of the p-n junction.

The simplest model of a PV cell is shown as an equivalent circuit below that consists of an ideal current source in parallel with an ideal diode is known as ideal equivalent circuit of PV cell. The current source represents the current generated by photons and its output is constant under constant temperature and constant incident radiation of light

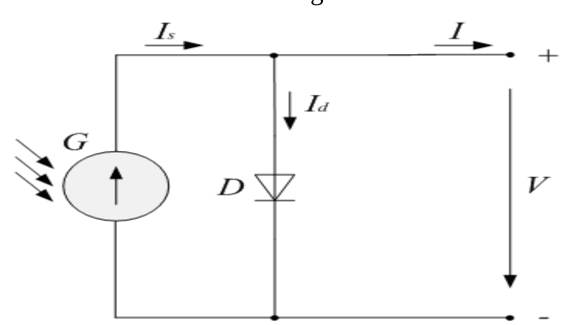

Fig.1 Ideal solar cell with one-diode.

Where G is the solar irradiance, I_s is the photo generated current, I_d is the diode current, I is the output current, and V is the terminal voltage.

The I-V characteristic of the ideal solar cell with one-diode model is given by:-

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

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

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

$$I_{SC} = I = I_s \quad \text{for } V = 0 \quad \text{............. (2)}$$

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

$$V = V_{oc} = \frac{mkT}{q} ln\left(1 + \frac{I_{sc}}{I_0}\right) \quad \text{For } I = 0 \quad \text{........ (3)}$$

The output power is given by:-

$$P = V\left[I_{sc} - I_0\left(e^{\frac{qV}{mkT}} - 1\right)\right] \quad \text{............. (4)}$$

2.1 Solar Cell with Series Resistance:-

For more accurate result the model adding a series resistance. The configuration of the simulated solar cell with one-diode and series resistance is shown in Figure 2

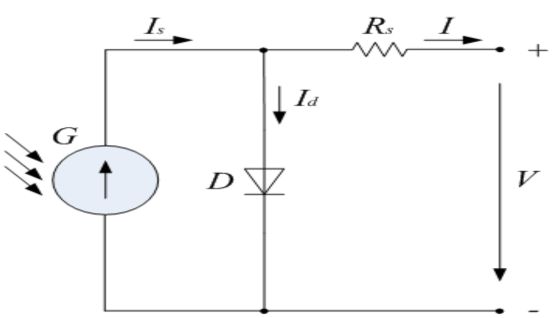

Fig. 2. Solar cell with single-diode and series resistance.

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

$$I = I_s - I_0\left[e^{\frac{q(V+IR_s)}{mkT}} - 1\right] \quad \text{................(5)}$$

For the same irradiance and p-n junction temperature conditions, the effect of a series resistance in the PV model implies the use of a recurrent equation to determine the output current in function of the terminal voltage. The Newton-Raphson method converges more rapidly and for both positive and negative currents. The short circuit current I_{SC} is given by:-

$$I_{SC} = I = I_s - I_0\left[e^{\frac{q(R_s I_{SC})}{mkT}} - 1\right] \quad for\ V = 0 \quad \text{...... (6)}$$

The series resistance is small and negligible, the open circuit voltage V_{oc} is given by:-

$$V = V_{oc} = \frac{mkT}{q} ln\left(1 + \frac{I_{sc}}{I_0}\right) \quad \text{for } I = 0 \quad \text{..... (7)}$$

The output power is given by:-

$$P = V\left[I_{sc} - I_0\left[e^{\frac{q(V+IR_s)}{mkT}} - 1\right]\right] \quad \text{............. (8)}$$

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

$$I_0 = I_0^*\left(\frac{T_c}{T^*}\right)^3 e^{\frac{\varepsilon q}{mk}\left(\frac{1}{T^*} - \frac{1}{T_c}\right)} \quad \text{............. (9)}$$

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 band gap.

III. SIMULATION RESULTS

For simulation result the mathematical models for the ideal solar cell and the solar cell with series resistance were implemented in Matlab/Simulink. We use the BP SX 150S PV module. The electrical parameter for BP SX 150S PV module is given by:-

Electrical Characteristics data of PV module
Maximum Power (P_{max}) = 150W
Voltage at Pmax (V_{mp}) = 34.5V
Current at Pmax (I_{mp}) = 4.35A
Open-circuit voltage (V_{oc}) = 43.5V
Short-circuit current (I_{sc}) = 4.75A
Temperature coefficient of I_{sc} = 0.065 ± 0.015 % / °C
Temperature coefficient of V_{oc} = -160 ± 20 mV/ °C
Temperature coefficient of power = -0.5 ± 0.05 % / °C
NOCT = 47 ± 2 °C

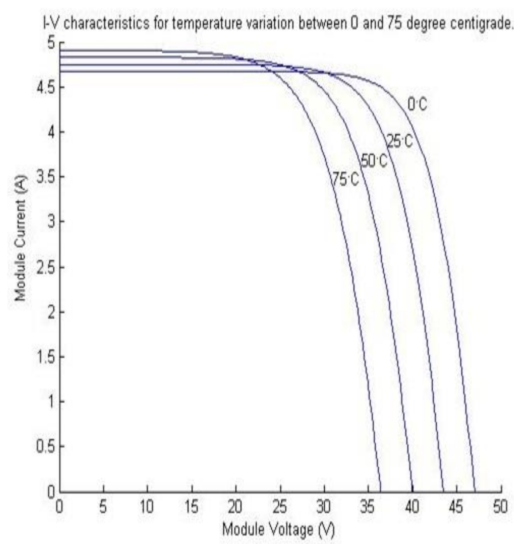

Fig:-(a) I-V characteristic for the temperature variation between 0 and 75°C.

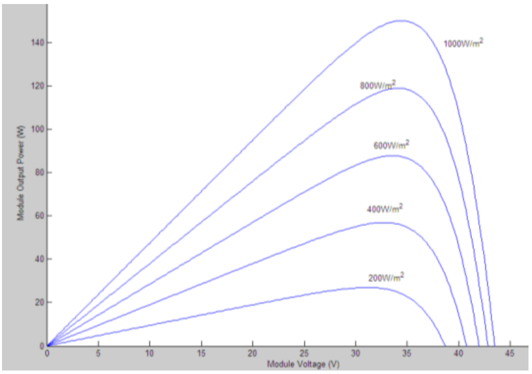

Fig:- (b) P-V characteristics for various condition of solar irradiation

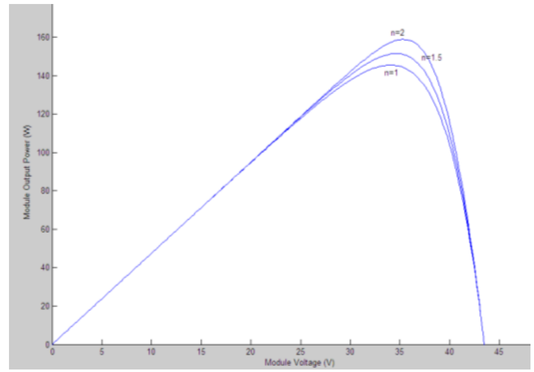

Fig:- (e) P-V characteristics for a diode ideality factor variation between 1 and 2.

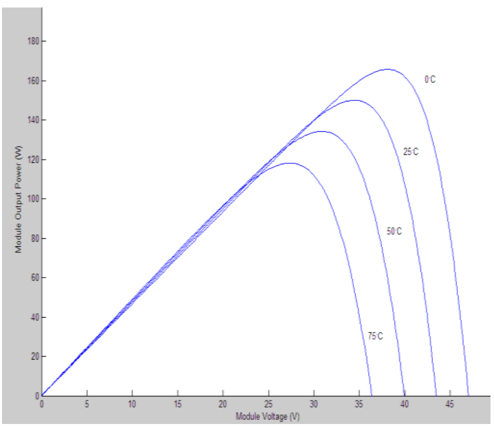

Fig:- (c) P-V characteristics for temperature between 0 and 75^{0}C

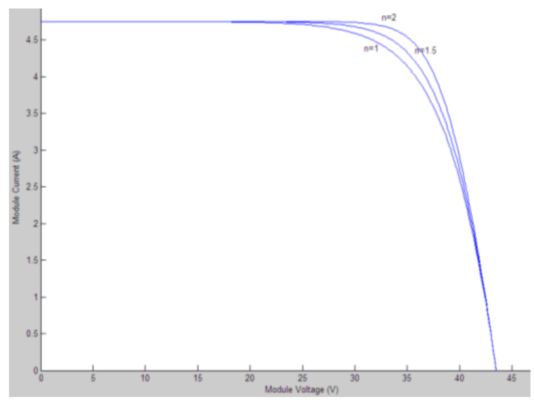

Fig:- (f) I-V characteristics for a diode ideality factor variation between 1 and 2.

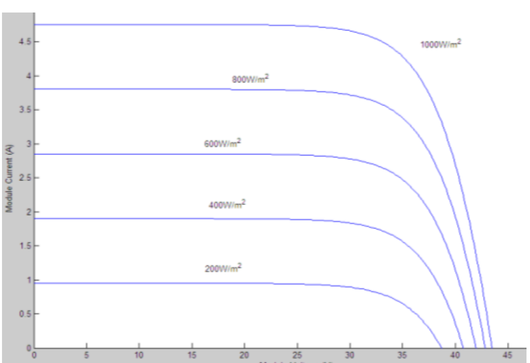

Fig:-(d) I-V characteristic for various conditions of solar irradiation.

IV. CONCLUSION

The behavior of ideal solar cell model and the behavior of the solar cell with series resistance model are studied in this paper. Included effects are: temperature dependence, solar radiation change, and diode ideality factor and series resistance influence. The solar cell with series resistance model offers a more realistic behavior for the photovoltaic systems. Particularly, this model is to be considered in panels with series cells, because the series resistance is proportional to the number of solar cells in the panel.

Modeling of photovoltaic modules are not difficult, of realize than when is known the model of photovoltaic cell. Also have been demonstrated that the temperature and the solar irradiation influenced suggestive the system performance.

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