Modeling and Simulation of PV Cell based on two-diode model

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ABSTRACT

The focus of this paper is on two diode photovoltaic cell model. The theory as well as the construction and working of photovoltaic cells using two diode methods are also presented. This model has good accuracy at low irradiation level which allows for a more accurate prediction of PV cell system performance. Simulation studies are carried out with MATLAB simulink at different temperatures & irradiances. Based on this study a conclusion is drawn with comparison with point taken directly from data sheet & curve published by manufacturer, show excellent correspondence to the model.

Keywords: ***PV cell, Solar cell, Two diode model, Simulation***.

General Terms

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

Presently the tenth largest PV power plant commissioned in the world is in Moura, Portugal, which has an installed total capacity of 46 MW and aims to reach capacity of 1500 MW till 2020, as stated by the Portuguese National Strategy ENE 2020, multiplying tenfold the existing capacity [2].

The solar cells are basically made of semiconductor materials which are manufactured using different technique [4].

Electric energy produced by the PV cell is fully dependent on the intrinsic properties of semiconductor materials and the incoming solar radiation [5].

The solar radiation is composed of photons of different energy levels, and some are absorbed at the *p-n* junction. Photons with energy lower than the band-gap of the solar cell are useless and not contribute for generating voltage or electric current. Photons with energy superior to the band gap only contributes for generating electricity, but only the energy corresponding to the band gap is used. The remainder of energy is dissipated as heating the body of the solar cell [6].

1. INTRODUCTION

A PV system use to converts solar energy to the electrical energy through radiation of sun light. Solar / PV cell is the main device of a PV / Solar system which are grouped in series or parallel or combination of series & parallel to form solar panels or arrays. Power electronic converters are used to process electricity from PV devices. 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].

The accuracy of a simulation is affects by the PV cell modeling, which require the estimation of the non linear I-V & P-V characteristics curve [8]. The efficient simulation of PV/solar system should following two criteria: (1)It should be simple & fast & able to accurately predict the I-V & P-V characteristics curve even such partial shading. (2)It should be comprehensive tool for develop and validate PV/ solar system design includes power converters & the MPPT controls. Presently existing software packages like PV-Spice, PV-DesignPro, SolarPro, PVcad and PV-syst are available in the market that are expensive, unnecessarily complex and accurse problem with the interfacing of the PV array with power converters [9].

2. 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 partial light the I-V characteristics of a solar cell have an exponential characteristic similarly to that of a diode [7].

2.1 Modeling:

A detailed approach to PV cell modeling based on a mathematical description of the equivalent electrical circuit of a PV/solar cell. The PV cell model BPSX150 is used to modeling of the PV cell module or array.

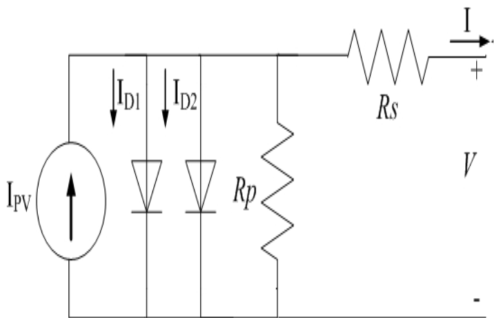

Fig.1 two diode model of PV/solar cell

A basic model of two diode PV/solar cell is shown in Fig.1.

Output current of PV/solar cell given by:

$$I = I_{PV} - I_{01}\left[\exp\left(\frac{V + IR_S}{a_1 V_{T1}}\right) - 1\right] - I_{02}\left[\exp\left(\frac{V + IR_S}{a_2 V_{T2}}\right) - 1\right] - \left(\frac{V + IR_S}{R_p}\right) \quad \ldots..(\mathbf{1})$$

Where I_{01} & I_{02} are the reverse saturation current of diode 1 & 2, V_{T1} & V_{T2} are their thermal voltage of respective diodes, and the diode ideality constant is represented by a_1 & a_2 respectively. In equation (1) term I_{02} represent recombination loss in the depletion region as explained in [10].

For find greater accuracy by this model it required to find the several parameters like I_{PV}, I_{01}, I_{02}, R_P, R_S, a_1 & a_2. Researchers find that a_1=1 & a_2=2 will simplify the solution. Shockley-read-hall recombination in the space charge layer of the photodiode approximation is near to this value of a_1 & a_2[11].

The equation for the PV current can be written in form of temperature & irradiation will be:

$$I_{PV} = \left(I_{PV_{STC}} + K_1 \Delta T\right)\frac{G}{G_{STC}} \quad \ldots\ldots(2)$$

$I_{PV_{STC}}$ (taken in ampere) is the light generated current under standard test conditions (STC), $\Delta T = T - T_{STC}$ (taken in Kelvin, T_{STC}=25^{0}C). Surface irradiation of the cell denoted by G & G_{STC}=1000W/m^2 is the irradiation under STC. The short circuit current shown by k_1 & normally it is provided by the manufacturer.

The diode saturation current given by:

$$I_0 = I_{0STC}\left(\frac{T_{STC}}{T}\right)^3 exp\left[\frac{qE_g}{ak}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right] \quad \ldots\ldots(3)$$

Where E_g the band gap energy of semiconductor material & I_{0STC} is the nominal saturation current.

To more simplify the model, both of the reverse saturation currents I_{01} & I_{02} will be equal in magnitude.

$$I_{01} = I_{02} = \left(\frac{I_{0STC} + K_1 \Delta T}{\exp\left[\frac{V_{0STC} + K_V \Delta T}{\left[\frac{a_1 + a_2}{p}\right] V_T}\right] - 1}\right) \quad \ldots\ldots(4)$$

It is seen that if $a_2 \geq 1.2$, the I-V curve of proposed model & practical model have best match. Let assume $(a_1+a_2)/p=1$ and a_1=1, it follows that the variable p will be chosen to be greater than 2. The expression for I_{01} & I_{02} modifies to:

$$I_{01} = I_{02} = \left(\frac{I_{0STC} + K_1 \Delta T}{\exp\left[\frac{V_{oc,n} + K_V \Delta T}{V_T}\right] - 1}\right) \ldots\ldots\ldots(5)$$

The two parameter R_P & R_S remains unknown that can be find by any standard iteration method. When we finding value of R_P that time also simultaneously iteratively increasing value of R_S. The formula is:

$$R_P = \frac{V_{mp}(V_{mp} + I_m R_S)}{V_{mp}(I_{PV} - I_{d1} - I_{d2}) - P_{max,E}} \quad \ldots\ldots\ldots(6)$$

Where

$$I_{d1} = I_{01}\left[\exp\left(\frac{V + IR_S}{a_1 V_{T1}}\right) - 1\right] \ldots\ldots(7)$$

and

$$I_{d2} = I_{02}\left[\exp\left(\frac{V + IR_S}{a_2 V_{T2}}\right) - 1\right] \ldots\ldots(8)$$

The initial condition for both resistances will be:

$$R_{so} = 0\,, \quad R_{P0} = \frac{V_{mp}}{I_{scn} - I_{mp}} - \frac{V_{ocn} - V_{mp}}{I_{mp}} \ldots\ldots(9)$$

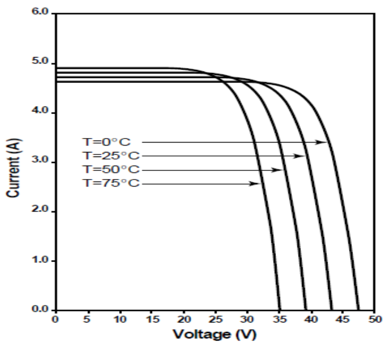

Fig.1: Standard I-V characteristic of BPSX150 solar cell

The manufacturer data will be be strictly recommended for value of I_{sc}, P_{mp} (V_{mp}, I_{mp}) and v_{oc}.

2.2 Simulation:

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 BPSX150 PV module. The electrical parameter for BPSX150 PV module is given by:-

Maximum power (P_{max}) =150W
Voltage at P_{max} (V_{mp}) = 34.5V
Current at P_{max} (I_{mp}) = 4.35A
Warranted minimum P_{max} =140W
Short-circuit current (I_{sc}) = 4.75A
Open-circuit voltage (V_{oc}) =43.5V
Maximum system voltage =600V
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

After the simulation process we get following characteristics:

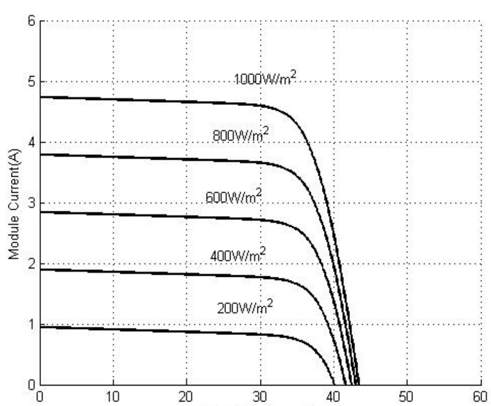

Fig.2: I-V characteristics for various conditions of solar radiations.

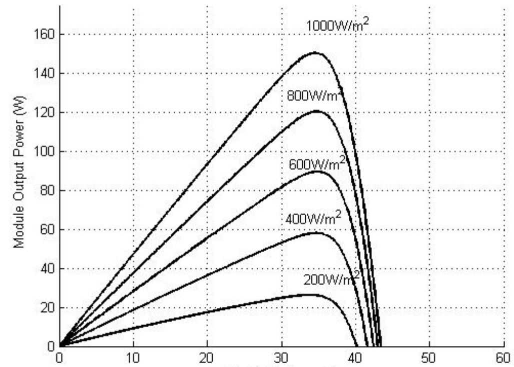

Fig.3: P-V characteristics for various conditions of solar radiations.

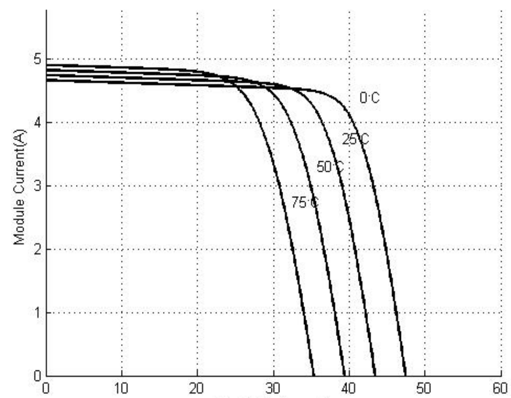

Fig.4: I-V characteristics for temperature variation from 0^0C to 75^0C.

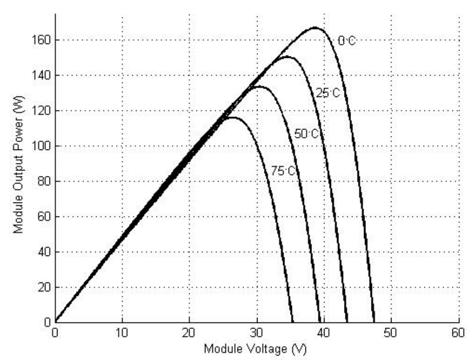

Fig.5: P-V characteristics for temperature variation from 0^0C to 75^0C.

3. CONCLUSION:

The behavior of ideal solar cell model and the behavior of the solar cell with two diode model are studied in this paper. Included effects: temperature dependency, solar radiation changes, and diode ideality factor and series & parallel resistance influence. The two diode solar cell model with series & parallel resistance offers a more realistic behavior for the photovoltaic systems. Particularly, this model is to be compared with standard curve that's provided on manufacturer's website.

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 radiation influenced suggestive the system performance.

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