

Design and Simulation of Solar PV Model Using Matlab/Simulink

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Abstract— Solar radiant energy accounts for most of the usable renewable energy on this earth. Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductor that exhibit the photovoltaic effect. In this paper presents a method of modeling and simulation of photovoltaic arrays in MATLAB using solar cell block from SimElectronics library. The method is used to implement and determine the characteristic of a particular photovoltaic cell panel and to study the influence of different values of solar radiation at different temperatures concerning performance of photovoltaic cells. This model it can be used for build a photovoltaic circuit model for any photovoltaic array. All modules which form the photovoltaic system model are individually modeled and validated in Simulink

Keywords: Modeling, Solar cell, photovoltaic array, Simulation, MATLAB/Simulink

1 INTRODUCTION

Photovoltaic (PV) and renewable energy sources (RES) have experimented a great development in recent years [1], mainly because of the growing concern about climate change and the oil price increase, which has led many countries to adopt new regulations to promote this kind of energy. Photovoltaic cells are very low exploitation costs (free fuel), limited maintenance requirements, reliable, silent and easy to install. In addition, in some stand-alone applications photovoltaic cells are certainly convenient in comparison with other energy sources, especially in those places that are not accessible, which is unprofitable to install traditional power lines [2].

2. MODEL OF SOLAR CELL

Any photovoltaic model is based on diode behavior, which gives to photovoltaic cell its exponential characteristic. The solar cell can be modeled with three modeling systems [3]. The first possibility of modeling can be done with instruments which can implement any differential equation or algebraic relationship of a highly complex mathematical model. Another possibility is given by Simscape™, which allows direct modeling using physical components of the electric field (resistors, capacitors, diodes) to implement exactly the same mathematical equation. A modeling system more complex than those described above is performed using SimElectronics advanced component library, which contains a block called Solar Cell. The solar cell from MATLAB 8.5.0. (R2015a) is a solar current source, which includes solar induced current and temperature dependence [4].

2.1 Solar - induced current

Solar cell block is formed from a single solar cell as a resistance R_s connected in series with a parallel combination of a current source, two exponential two diodes and a parallel Resistor R_p [4], [5]. The output current source I is given by equation (1):

$$I = I_{ph} - I_{s1} \cdot \left(e^{\frac{V + I \cdot R_s}{N_1 \cdot V_t}} - 1 \right) - I_{s2} \cdot \left(e^{\frac{V + I \cdot R_s}{N_2 \cdot V_t}} - 1 \right) - \frac{V + I \cdot R_s}{R_p} \quad (1)$$

Where I_{ph} is solar-induced current: $I_{ph} = I_{pho} \cdot I_r / I_{ro}$, where I_r is irradiance in W/m^2 which fall on the cell surface; I_{pho} is measured solar generated current for the irradiance I_{ro} ; I_{s1} is the saturation current of the first diode; I_{s2} is the saturation current of the second diode; $V_t = kT / q$ is the thermal voltage, depend on temperature of the device T , k is the Boltzmann constant and q is the elementary charge of the electron; N_1 is the quality factor (the emission coefficient for the diode) of the first diode; N_2 is the quality factor (the emission coefficient for the diode) of the second diode; V is the voltage at the terminals of the solar cell.[8]

This block allows choosing one of two models: a model with 8 parameters in which the previous equation describes the output current, and a model with 5 parameters if for this equation is applied the following simplifying assumptions: the impedance of the parallel resistor is infinite and the saturation current of the second diode is zero. The model with 5 parameters allows optimization of this block according to the equivalent circuit model parameters or by short circuit current and open circuit voltage [3].

2.2. Temperature dependence.

Several solar cell parameters (the solar-induced current I_{ph} , the saturation current of the first diode I_{s1} , the saturation current of the second diode I_{s2} , the series resistance R_s and the parallel

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resistance R_p) depend on temperature. Photovoltaic cell temperature is specified by value of the fixed circuit temperature parameter, TFIXED [4]. Between the solar-induced current I_{ph} and temperature of solar cell T [4-8] appears the relation 2:

$$I_{ph}(t) = I_{ph} \cdot (1 + TIPH1 \cdot (T - T_{meas})) \tag{2}$$

Where : $TIPH1$ is the first temperature coefficient for I_{ph} ; T_{meas} is the parameter extraction temperature.

3. MODEL OF PHOTOVOLTAIC ARRAY

3.1. Model for plotting the characteristics of PV module.

In the model (Figure 1) represents a PV cell array connected to a variable resistor. This resistor has an input ramp which just varies resistance linearly in closed circuit until it reaches the 30th steps. Inside the array subsystem are 8 rows of photovoltaic solar cells connected in series, formed by 8 solar cells of SimElectronics® library (Fig. 2). This structure can be built in any configurations by connecting multiple strings of solar cells in series or in parallel [3,8].

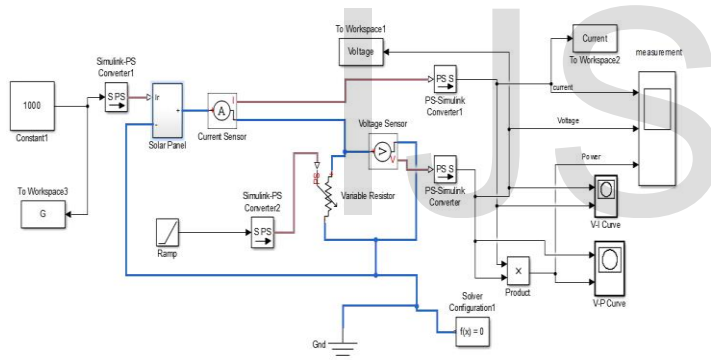


Fig. 1. The Simulink model for photovoltaic arrays.

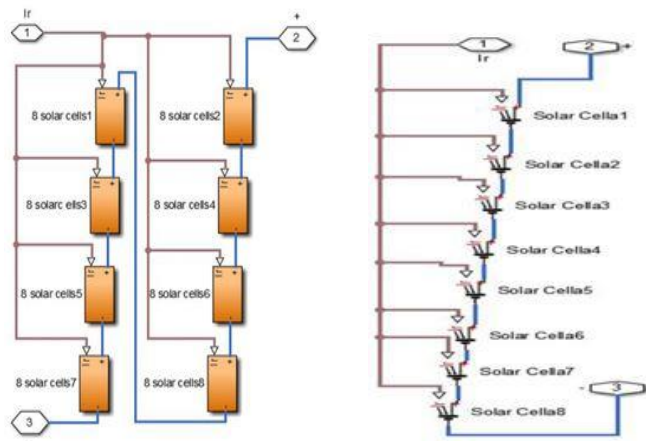


Fig. 2. Connection of solar cells in PV panel subsystem.

The advantage of using of this high level of implementation is to create a simple equivalent circuit, which have much more

complex parameters, including the effect of temperature in the device which is very important for behavior of this type of system. The photovoltaic panel model is validated by simulating at a value of irradiance of $1000W/m^2$ and a temperature of $25^\circ C$.

The parameters of a single solar cell

Parameter	Value
Short-circuit current [A]	$I_{sc} = 7.34$
Open-circuit current [V]	$V_{oc} = 0.6$
Quality factor	$N = 1.5$
Series resistance [Ω]	$R_s = 0$
First order temperature coefficient for I_{ph} [1/K]	$TIPH1 = 0$
Temperature exponent for I_s	$TXIS1 = 3$
Temperature exponent for R_s	$TRS1 = 0$
Parameter extraction temperature [$^\circ C$]	$T_{meas} = 25$
Fixed circuit temperature [$^\circ C$]	$TFIXED = 25$

In Fig. 3 are shown the current, voltage and power which are obtained at output of PV array. These are the curves of current, voltage and power versus time. When the resistance varies, the current and voltage vary depending on the voltage-time relationship which gives the power curve

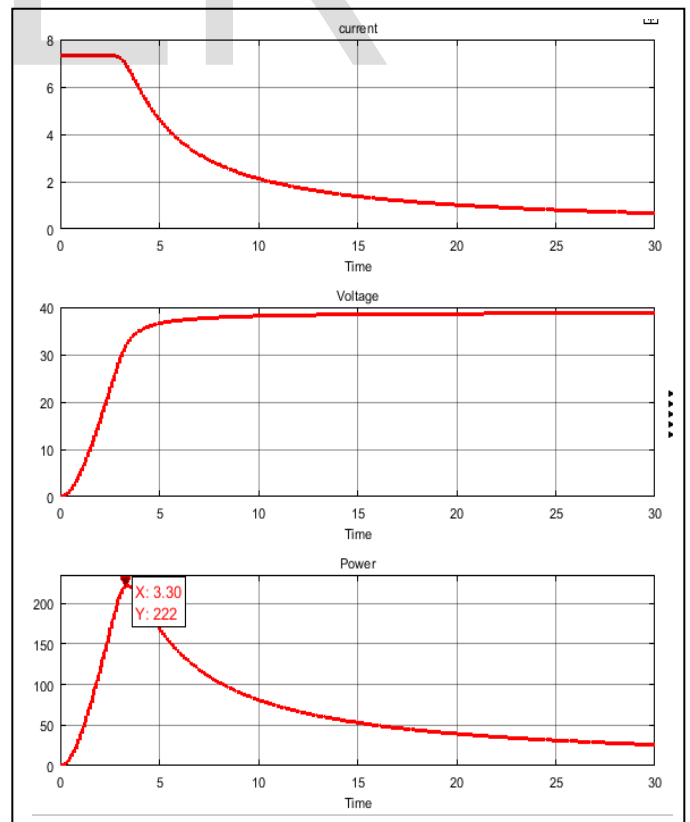


Fig. 3. Current, voltage and power curves for PV array.

The characteristics of V-I and V-P of the photovoltaic array is given in Fig. 4 and Fig. 5. The V-I curve represent the standard behavior of the photovoltaic cell and photovoltaic array respectively. In the middle of this characteristic is the maximum power point. This point is very critical for this kind of system for maximum power extraction from the photovoltaic array. Result that the main objective is to try operating around of this maximum point in order to make the photovoltaic cells to work at maximum efficiency.

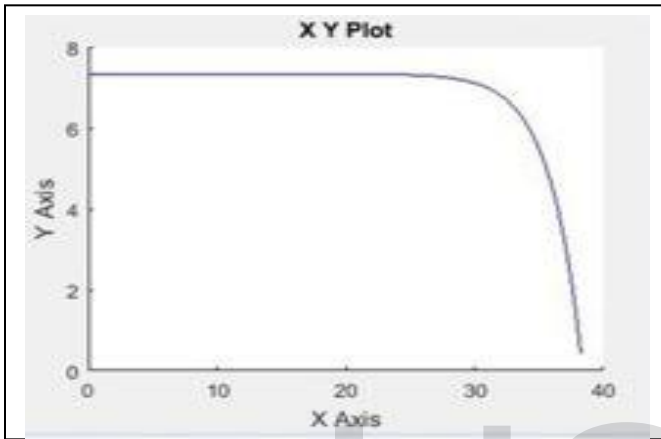


Fig. 4. The V-I characteristics of photovoltaic array

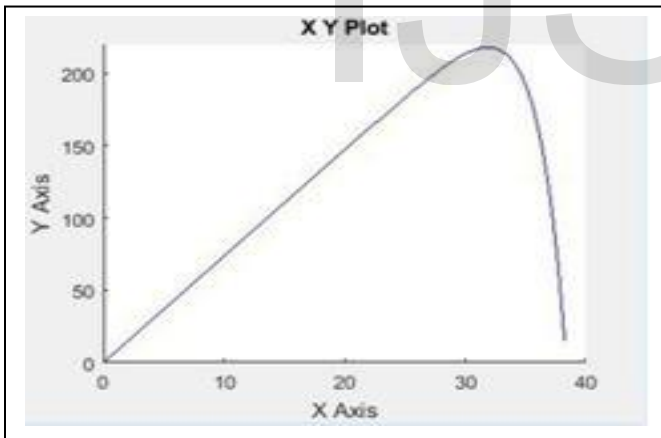


Fig. 5. The V-P characteristics of the photovoltaic array

4. EXPERIMENTAL RESULTS

The V-I curve characteristic for radiation incident on the photovoltaic cells is amended in Fig.6 [7]. If the irradiance decreases, the photovoltaic current generated decreases proportionally to that, and variation of no-load voltage is very small [2].

PV Array VI Curves-data Irradiance effect on PV Array Performance T=25 °C

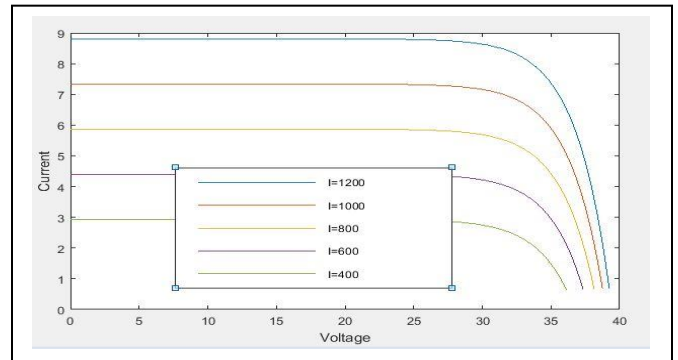


Fig. 6. V-I characteristics for different values of solar radiation at temperature of 25°C.

As shown in Fig.7, when the temperature of module increases the voltage decreases and the produced current remains practically constant. In terms of produced electric power is a reduction in the performance of the photovoltaic panels [2].

Temperature effect on PV Array Performance I=1000 w/m²

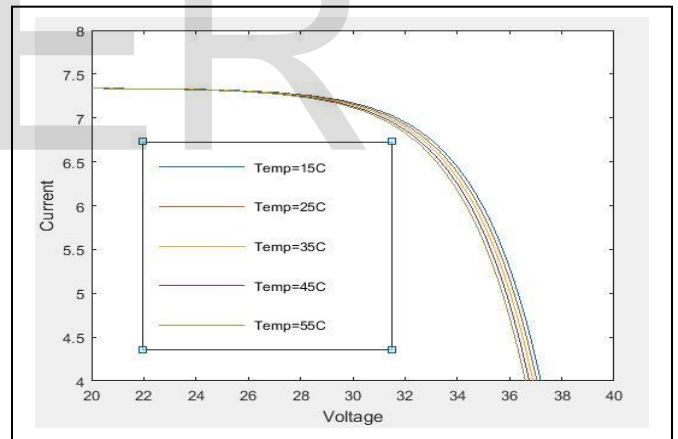


Fig. 7. V-I characteristics for different temperatures.

In Fig. 8 are represented the V-P characteristics of the photovoltaic panel for a level of irradiation of 1000 W /m² and for different temperatures and, respectively in Figure 9 are given the V-P characteristics for different levels of solar radiation at the temperature of 25°C for the photovoltaic panel model shown in Fig. 1

Temperature effect on PV Array Performance $I=1000 \text{ w/m}^2$

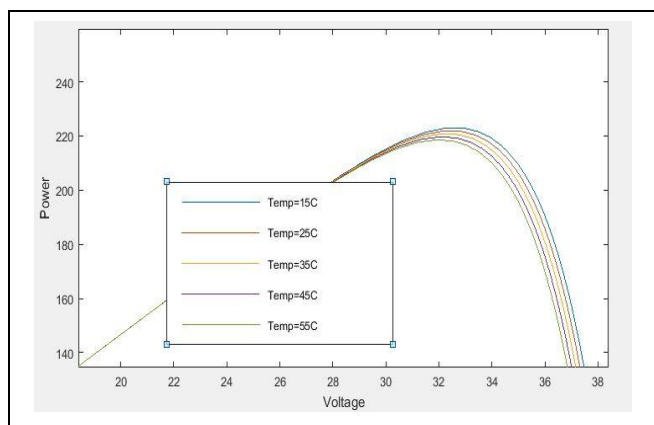


Fig. 8. V-P characteristics for different temperatures.

Irradiance effect on PV Array Performance $T=25 \text{ }^\circ\text{C}$

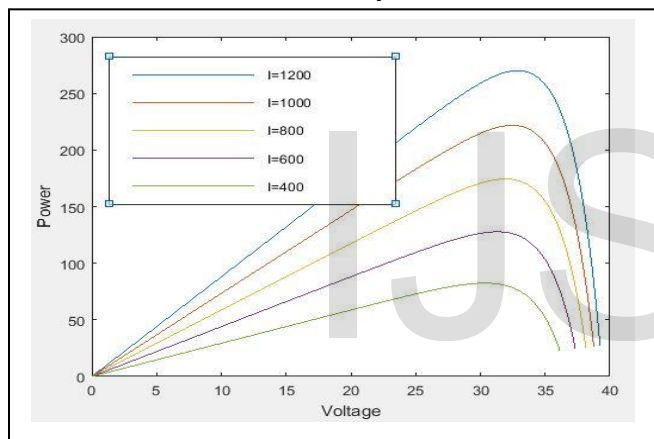


Fig. 9 V-P characteristics for different levels of solar radiation at the same temperature.

From Fig. 9 is observed that for an irradiance of 800 w/m^2 which corresponds to yellow curve, is obtained a maximum power of 170 W and for an irradiance of 1000 w/m^2 which corresponds to the dark blue curve, the photovoltaic panel can provide a maximum power of 222 W. That gives an idea of measure in that the power produced by a photovoltaic array is affected by changing of irradiance

5. CONCLUSIONS

This work describe a new implementation of solar cell by using MATLAB®/Simulink® of photovoltaic arrays and modeling using experimental data. To build photovoltaic panel was used the Solar Cell block and the power produced by a photovoltaic array is affected by changing of irradiance. The implemented model was validated through simulation.

The simulation results show that the proposed method is efficient in terms of modeling of the functioning of the photovoltaic system.

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REFERENCES

- [1] Bevrani, H., Ghosh, A., Ledwich, G.: 'Renewable energy sources and frequency regulation: survey and new perspectives', IET Rnew.Power Gener., 2010, 4, (5), pp. 438–457
- [2] ABB, Technical Application Papers No.10 Photovoltaic plants
- [3] *** www.mathworks.com, Osorio, C., Recorded Webinar-Model-Based Design for Solar Power Systems.
- [4] *** www.mathworks.com, Help - Solar Cell Blocks.
- [5] Messenger, R.A., Ventre, J., Photovoltaic Systems Engineering, CRC Press LLC, 2000.
- [6] Gow, J.A., Manning, C.D., Development of a Photovoltaic Array Model for Use in Power Electronics Simulation Studies, IEE Proceedings of Electric Power Applications, Vol. 146, No.2, March 1999, pp. 193-200.
- [7] Villalva, M.G., Gazoli, J.R., Filho, E.R., Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays, IEEE Transactions on Power Electronics, Vol. 24 No. 5 May, 2009, pp. 1198 -1208 About the authors Eng. Ioan-
- [8] Pavan Kumar, A.V.; Parimi, A.M.; Uma Rao, K., "Performance Analysis of a Two-Diode model of PV cell for PV based generation in MATLAB," in Advanced Communication Control and Computing Technologies (ICACCCT), 2014 International Conference on, vol., no., pp.68-72, 8-10 May 2014. doi:10.1109/ICACCCT.2014.7019191