

Modelling and Design of Solar PV Cell Using MATLAB/Simulink

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ABSTRACT

Due to extensive work on the solar panel, the development of the solar cell simulation model is very popular today. Solar cells are a means of generating electrical energy by converting solar radiation to direct electricity by means of a semiconductor having a solar effect. This paper presents the method used to model and simulate photovoltaic arrays in MATLAB using a solar cell block. The method is used to perform and determine the characteristics of a particular solar cell panel and to study the effect of different values of solar radiation at varying temperatures on the performance of photovoltaic cells. This model can be used to build a model of the solar circuit for any photovoltaic array. All modules that make up the photovoltaic system model are individually modeled and evaluated in Simulink.

Keywords : Solar Cell Model, Photovoltaics, Simulation, Software.

I. INTRODUCTION

Photovoltaic (PV) and renewable energy sources (RES) have undergone significant advances in recent years, largely due to increasing concern about climate change and rising oil prices, leading several countries to introduce new legislation to support these sources. Photovoltaic cells are very low operating costs (free fuel), minimal maintenance requirements, robust, silent and easy to install. However, in some stand-alone applications, photovoltaic cells are certainly convenient compared to other energy sources, particularly in those locations that are not available and that are unprofitable for the installation of traditional power lines.

II. SOLAR CELL MODEL

Any photovoltaic model is based on diode behaviour, which gives the photovoltaic cell its exponential

characteristic. Three modelling systems can be used for modelling the solar cell. Modelling with instruments that can implement any differential equation or algebraic relationship of a highly complex mathematical model can be done as soon as possible. The relationship between a complex mathematical model. Another possibility is provided by Simscape™, which allows direct modelling using the physical components of the electrical field (resistors, capacitors, diodes) to perform exactly the same mathematical equation. A more complex modelling system than those described above is performed using the Sim-Electronics Advanced Component Library, which contains a block called the Solar Cell. MATLAB Solar Cell 9.6.0. (R2019a) is a source of solar current, including solar induced current and temperature dependence.

A. SOLAR – INDUCED CURRENT

The solar cell block constructed from a single solar cell as a serial resistance R_s connected to a parallel combination of a current source, two exponential diodes and a parallel resistor R_p

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

When I_{ph} is a solar-induced current, $I_{ph} = I_{ph0} \cdot I_r / I_{r0}$, where I_r is irradiance in W / m^2 falling on the cell surface; I_{ph0} is measured by solar generated current for I_{r0} irradiance; I_s is the saturation current of the first diode; I_{s2} is the saturation current of the second diode; $V_t = kT / q$ is thermal voltage, depending on the temperature of the device T , K is the Boltzmann constant and q is the elementary electron charge; N is the quality factor (the diode emission coefficient) of the first diode; N_2 is the quality factor (the diode emission coefficient) of the second diode; V is the voltage at the solar cell terminal.

This block allows one of the two models to be chosen: an 8-parameter model in which the previous equation defines the output current, and a 5-parameter model if the following simplification assumptions for this equation are added: the parallel resistor impedance is infinite and the second diode saturation current is nil. The 5-parameter model enables the corresponding circuit model parameters and short circuit current and open circuit voltage to be optimized for this block.

B. TEMPERATURE DEPENDENCE

Many parameters of the solar cells (solar-induced current I_{ph} , first diode saturation current I_s , second diode saturation current I_{s2} , series resistance R_s and parallel resistance R_p) are temperature dependent. The temperature of the photovoltaic cell is determined by the defined circuit voltage parameter T_{FIXED} . There is a relationship between the current solar inductive I_{ph} and the T temperature of the solar cell:

$$I_{ph}(t) = I_{ph} \cdot (1 + T_{IPH1} \cdot (T - T_{meas})) \quad (2)$$

Where: T_{IPH1} is the first temperature coefficient of I_{ph} ; T_{meas} is the extraction temperature parameter.

III. SIMULATION MODEL OF PV CELL

Figure 1 shows the corresponding PV-cell circuit. It has a real source, diode, series resistance, and shunt resistance.

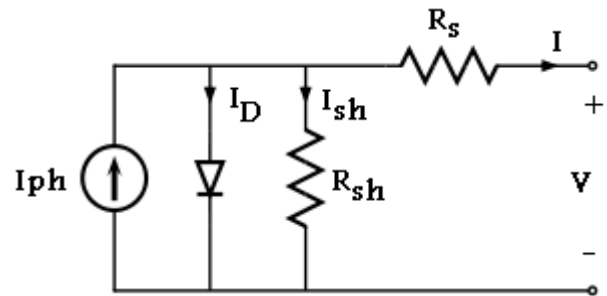


Fig. 1. PV cell equivalent circuit.

In view of this, the current to the load can be specified as:

$$I = I_{ph} - I_s \left(\exp \left(\frac{q(V + R_s I)}{NKT} \right) - 1 \right) - \frac{(V + R_s I)}{R_{sh}} \quad (3)$$

In this equation, I_{ph} is the photocurrent, I_s is the reverse saturation current of the diode, q is the electron charge, V is the voltage across the diode, K is the Boltzmann constant, T is the junction temperature, N is the ideality factor of the diode, and R_s and R_{sh} are the cell series and shunt resistors, respectively.

As a result, the entire physical activity of the pV cell is related to the I_{ph} , I_s , R_s and R_{sh} of the one side and to the temperature and solar radiation of the other two environmental parameters.

A. CHARACTERISTICS OF PV MODULE

The PV cell array associated with the variable resistance is shown in the model (Figure 2). It has an input ramp that linearly varies the resistance of the closed circuit until the 30th step is reached. The array

subsystem contains 8 rows of connected photovoltaic solar cells, consisting of 8 solar cells of the SimElectronics ® library (Fig. 3). Multiple strings of solar cells can be connected to this structure in a single configuration in series or in a parallel.

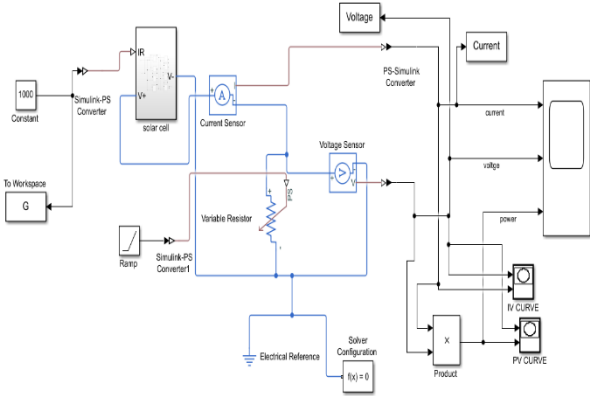


Fig. 2. The Simulink model for photovoltaic arrays.

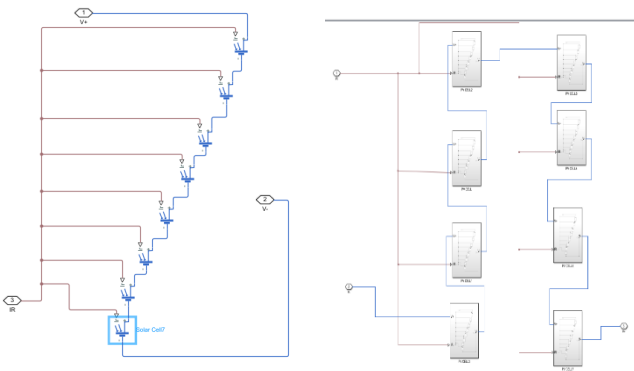


Fig. 3. Connection of solar cells in PV panel subsystem.

A simple equivalent circuit has much more complex parameters, including the effect of the instrument temperature, which is extremely important for the behaviour of this type of device. This high level of implementation is beneficial. A radiance simulation of 1000W / m² and a temperature of 25 ° C is used to validate the photovoltaic panel model.

In the Fig.4. The current, voltage and power generated at the output of the PV array are shown. These are the current, voltage and power curves versus time curves. When the resistance varies, the current and the voltage will vary depending on the voltage-time relationship that gives the power curve.

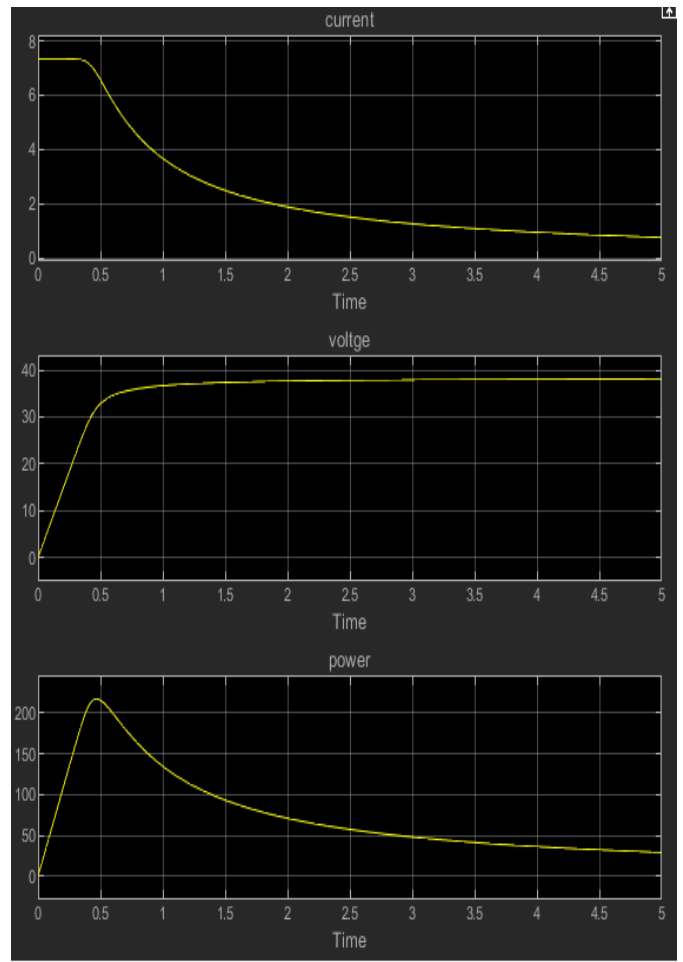


Fig. 4. Current, voltage and power curves for PV array.

The characteristics of the photovoltaic array V-I and V-P are given in Fig. Yeah, 4 and Fig. 5 Five. The V-I curve represents the standard behaviour of the photovoltaic and photovoltaic arrays, respectively. The maximum power point is in the middle of this characteristic. This is a very critical point for this type of system for the maximum power extraction from the photovoltaic array. As a result, the main objective is to try to operate around this maximum point in order to make the photovoltaic cells work as efficiently as possible.

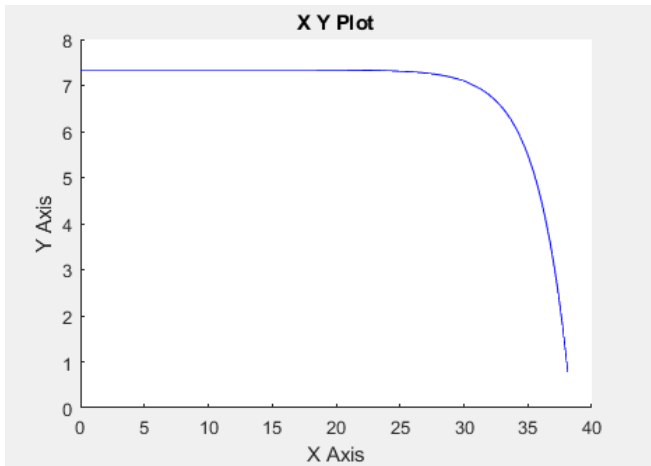


Fig. 5. The V-I characteristics of photovoltaic array

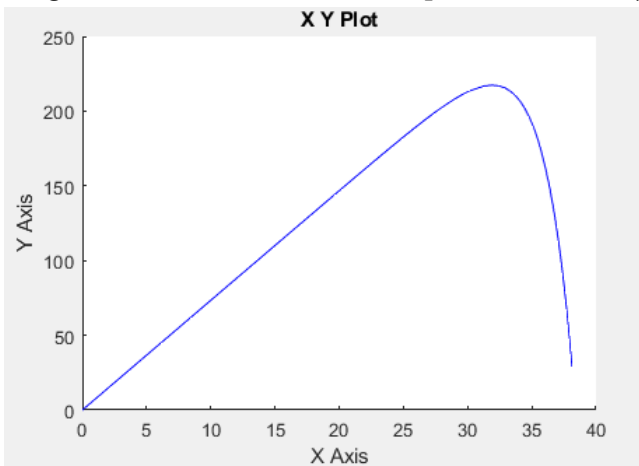


Fig. 6. The V-I characteristics of photovoltaic array

IV. EXPERIMENTAL RESULTS

The V-I curve characteristic of the photovoltaic cell radiation incident is modified in Fig.7. If the

The PV Array VI Curves-data Irradiance effect on PV Array Performance $T=25\text{ }^{\circ}\text{C}$ is shown in below

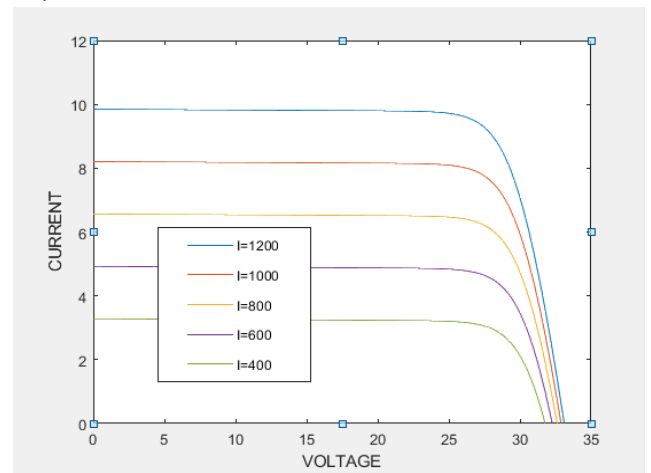


Fig.7.V-I characteristics for different values of solar radiation at temperature of 25°C .

As shown in Fig.8, the voltage decreases and the generated current remains virtually constant as the temperature of the module increases. The efficiency of photovoltaic panels decreases in the production of electricity. The Temperature effect on PV Array Performance $I=1000\text{ w/m}^2$ is shown below.

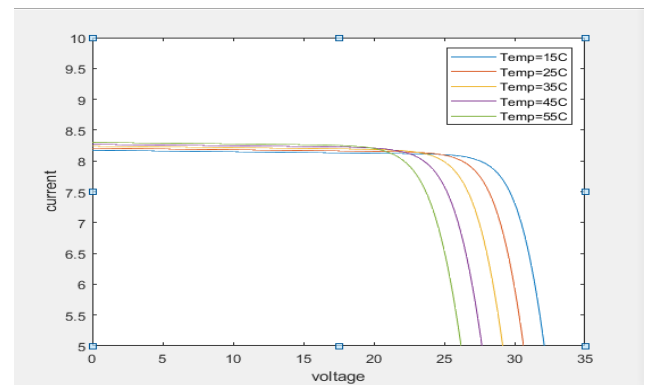


Fig. 8. V-I characteristics for different temperatures.

The V-P characteristics of the photovoltaic panel for an irradiation level of 1000 W / m^2 and for different temperatures are shown in Figure 9 and the V-P characteristics for different solar radiation levels at a temperature of $25\text{ }^{\circ}\text{C}$ are shown in the photovoltaic panel model shown in Fig. 2. The Temperature effect on PV Array Performance $I=1000\text{ w/m}^2$ and Irradiance effect on PV Array Performance $T=25^{\circ}\text{C}$ are shown below.

parameter	value
Quality factor	$N=1.5$
Short-circuit current [A]	$I_{sc} = 7.34$
Open-circuit current [V]	$V_{oc} = 0.6$
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 [$^{\circ}\text{C}$]	$T_{meas} = 25$

irradiance decreases, the photovoltaic current generated decreases proportionally, and the no-load voltage variation is very small.

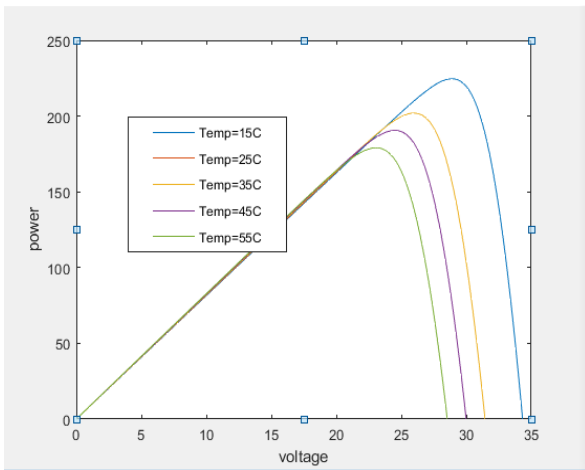


Fig. 9. V-P characteristics for different temperatures.

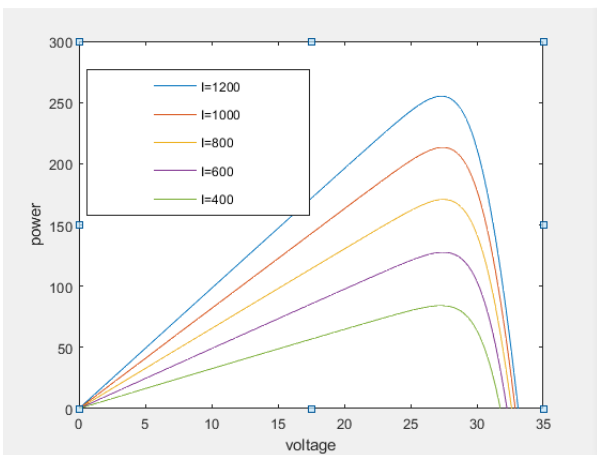


Fig. 10. V-P characteristics for different levels of solar radiation at the same temperature.

From Fig. 10 It is observed that a maximum power of 170 W is obtained for an irradiance of 800 w / m² corresponding to the yellow curve, and for an irradiation of 1000 w / m² corresponding to the dark blue curve, the photovoltaic panel can provide a maximum power of 222 W. This gives an idea of the measure in that the change in irradiance affects the power produced by the photovoltaic array.

V. CONCLUSION

This work describes a new implementation of experimental data on photovoltaic arrays and mode modelling using a MATLAB ® /Simulink solar cell. The photovoltaic panel was constructed from the solar cell block, and the power generated by the photovoltaic array is influenced by the change in

irradiance. The implanted model was validated by simulation.

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