

# Different Methods of Modeling and Analysis of PV Module using Matlab/Simuling

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**Abstract**— The use of renewable energy sources is increasing and will play an important role in the future of power systems. Solar energy, radiant light and heat from the sun, has been used by humans since ancient times using a range of ever-evolving technologies. Solar radiant energy accounts for most of the usable renewable energy on earth. Photovoltaic (PV) is a method of generating electrical power by Converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. In this paper the PV module is modeled and analyzed using different methods and model of PV cell and its voltage-current characteristics and power-voltage characteristics are simulated.

**Key words:** PV Module, Matlab/Simuling

## I. INTRODUCTION

Energy from the sun is by far the largest energy source available on the earth: the amount of solar energy reaching the surface of the earth annually ( $3.9 \times 10^{24}$ J) is about ten thousand times more than the global primary energy demand and more than all available energy sources on the earth. Furthermore, it is inexhaustible and clean source of energy, which is essential in the globally prevailing circumstances: Environmental issues with concerns on global warming, green house effects, depletion of natural reserves like fossil fuels, natural gas, coal, etc. is motivating research to invest in technologies that can harvest energy from renewable energy sources like wind, solar, tidal waves, etc. Of these, the solar energy with irradiance levels of up to 1kW/m<sup>2</sup> is abundant and photovoltaic power is a prime candidate for electrical energy generation, population is increasing and environmental problems are growing ever more serious. One of the most potential and versatile methods for utilizing this vast energy source is its direct conversion into electrical energy with photovoltaic (PV) devices.

## II. PHOTOVOLTAIC CELL

Solar cells are made from semiconductor materials (pn junction, usually silicon), which are specially treated to form an electric field, positive on one side (backside) and negative on the other (towards the sun). When solar energy (photons) hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material, creating electron-hole pairs. If electrical conductors are then attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current  $I_{ph}$  (photocurrent).

## III. PRESENTATION OF DIFFERENT DIODE MODELS:

### A. $R_s$ -Model

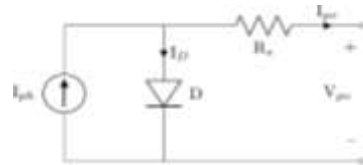


Fig. 1:  $R_s$ -Model (Single diode four parameter model)

Fig. 1 .Shows the equivalent circuit of the  $R_s$ -model. It has four unknown parameters and is known as the Single diode four-parameter model. Similar to the ideal diode model, this model is very simple and requires minimal computation power. The accuracy is better than the ideal diode model, but it still exhibits some serious deficiencies, particularly with temperature variations. This model is by far the most widely used in PV system simulation.

### B. $R_p$ -Model

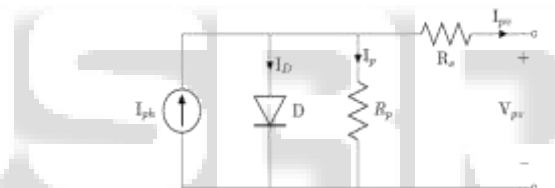


Fig. 2:  $R_p$ -Model (Single diode five parameter model)

The  $R_p$ -model, or single diode five parameter model, adds a shunt resistance ( $R_p$ ) to the four parameter model and therefore considers the leakage current to the ground. Fig. 3 shows the equivalent circuit and equation 1 shows the current-voltage (I-V) characteristics. This model is used for implementation in Simulink/MATLAB in this paper.

$$I_{pv} = I_{ph} - I_0 \left[ \exp \left( \frac{V_{pv} + I_{pv} R_s}{a N_c V_{th}} \right) - 1 \right] - \frac{V_{pv} + I_{pv} R_s}{R_p} \quad (1)$$

The  $R_p$ -model is insufficiently accurate when dealing with low irradiation levels. This model is based on the assumption that the recombination loss in the depletion region is absent. In a real solar cell this loss is significant and the single diode model cannot be used to accurately model this effect.

### C. Two Diode Model

The two diode model represents the PV cell more accurately than the single diode models. Two new variables are introduced ( $I_{02}$  and  $a_2$ ) and this increases the complexity drastically. The single and two diode model show similar results at STC, but differ closer to  $V_{oc}$  and with low irradiance. Fig. 3.show the equivalent circuit and equation 2 shows the current-voltage (I-V) characteristics.

$$I_{pv} = I_{ph} - I_{01} \left[ \exp \left( \frac{V_{pv} + I_{pv} R_s}{a_1 V_{th1}} \right) - 1 \right] - I_{02} \left[ \exp \left( \frac{V_{pv} + I_{pv} R_s}{a_2 V_{th2}} \right) - 1 \right] - \frac{V_{pv} + I_{pv} R_s}{R_p} \quad (2)$$

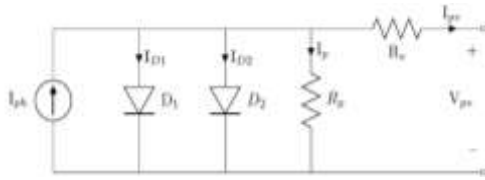


Fig. 3: Two diode model

#### IV. DIFFERENT METHODS OF MODELLING

There are several methods and models that can be used for the analysis of a PV module and PV arrays. generally a one diode model is preferred over the two diode model as it is simple for the purpose of analysis and the approximation result are also not much different from the two diode model. Here is some models used in matlab which have been described below:

##### A. Matlab Programming

This model is made only in Matlab, based on mathematical equations that define the photovoltaic cell. From the work Ahikiro [4] a function in Matlab [2] has been developed which calculates the current module from data of voltage, solar radiation and temperature. Setting the constant temperature or radiation, curves *IV* and *PV* will be obtained. From another script also calculates the maximum power point.

##### B. Matlab Tools

This section has taken into account two ways to represent the *IV* and *PV* curves. In the first form of representation, the graphic interface for curve fitting Cftool (Curve Fitting Toolbox) has been used. The starting point of this model is the manufacturer's datasheet, in which the *IV* and *PV* curves of the panel are represented. In this curve at least three coordinates (*V*, *I*) are known, (0, *ISC*), (*V<sub>mpp</sub>*, *I<sub>mpp</sub>*) and (*VOC*, 0). Manually more coordinates can be approximated to facilitate the representation. With these coordinates, the tool will provide an equation of a similar curve to the original one. In the second form, the model consists of two Matlab programs. The first serves for the presentation and data capture and calculations are made in the second one. These calculations are based on three functions of MATLAB: *fsolve*, *fzero* and *lsqnonlin*. In this case the data used were obtained experimentally from the panels analyzed. Data can be exchanged from one form of representation to another.

##### C. Basic Model in Simulink

It is a model like the one shown in section D, also based on mathematical Equation (1) but made with elements of Simulink. It is a basic model in which the values of *R<sub>s</sub>* (0.001 Ω) and *R<sub>sh</sub>* (1000 Ω) are assumed to be known.

##### D. Simulink Model with Tags

This is the usual way to model a PV cell It starts from the same equations as in section A, but it is developed in Simulink. Based on this kind of programming could also simulate the basic model of the previous section in this way. The model developed with tags, presented in this paper (Fig. 3 and 4), model in Section C is the basic model based on Equation (1). Therefore the results have to be the same.

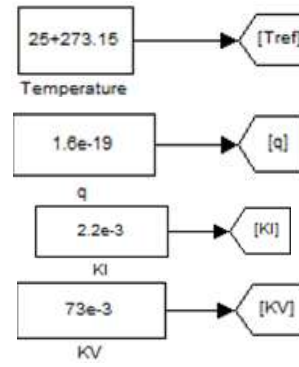


Fig. 4: Types of tags.

##### E. Model of Physical Component

This model is made from physical elements using Simscape. With those elements, electrical equivalent circuit diagram of the cell is performed. This model is presented in Section 5.4.

##### F. Model of Advanced Component Library

This is the simplest model. It works with an element of Sim Electronics, that is a toolbox dependent of Simscape. The element to model, Solar Cell, appears in the Source Library. Only, it is needed to enter the parameters that define the cell, provided by the manufacturer's data sheet.

##### G. Model According with LookTable Function

This model is created from experimental data of the panel that is going to be simulated. It is based on the element Look Table (2D) Lookup Tables library in Simulink which generates a vector of data, from the experimental data of irradiance, voltage and current. Then use the surface fitting tool. In this case also the simulated photovoltaic panel is Mitsubishi PV TD185MF5.

#### V. MODEL BASED ON SIMULINK WITH TAGS

In this model two types of tags (Fig. 4) were worked with: From: Outputs the data type (or types) of the signal connected to the corresponding Goto block. Library: Signal Routing.

Goto: Pass block input To/From blocks. Input can be of any type. Library: Signal Routing. From/Goto combinations can be quite powerful in Simulink. These blocks are useful tools to structure a complex design which would otherwise have many crossing signal lines, a stylistic choice that can make a model harder to decipher. But, From/Goto blocks can only be used with a local scope. They are basically nonfunctional, simply hiding a signal line from view. The model developed (Fig. 5) is based on the equivalent circuit of solar cell (Fig. 1) and its characteristic equation, Equation (1). Where current (*I*) obtained in the solar panel is defined by the following expression:

$$I = I_{ph} - I_s \left( e^{\frac{(V+I R_s)q}{\alpha k T N_s}} - 1 \right) - \frac{(V+I R_s)}{R_{sh}}, \quad (1)$$

$$I = I_{ph} - I_d - I_{sh}, \quad (2)$$

*I<sub>ph</sub>*, *I<sub>d</sub>* and *I<sub>sh</sub>* Being:

$$I_{ph} = I_r \frac{I_{sc}}{I_{ro}} \quad (3)$$

$$I_d = I_s \left( e^{\frac{(V+I R_s)}{n V_t N_s}} - 1 \right) \quad (4)$$

$$I_s = I_{sc} \left( e^{\frac{V_{oc}}{n V_t}} - 1 \right) \quad (5)$$

$$V_t = \frac{k \cdot t}{q}, \quad (6)$$

The model developed is shown in Fig. 5. In this model the irradiance ( $I_r$ ) is a vector of value [200 400 600 800 1000]. It will be represented an  $I_V$  characteristic curve for each irradiance value in the same graph, as shown in Fig. 6. The same goes for the  $P_V$  curve in Fig. 7. If 50 cells are put in series a full panel simulation is obtained.

### VI. MODEL BASED ON PHYSICAL COMPONENT

For this model the starting point is the knowledge of the system. In this case, instead of knowing the mathematical equations the equivalent circuit of the photovoltaic cell is known.

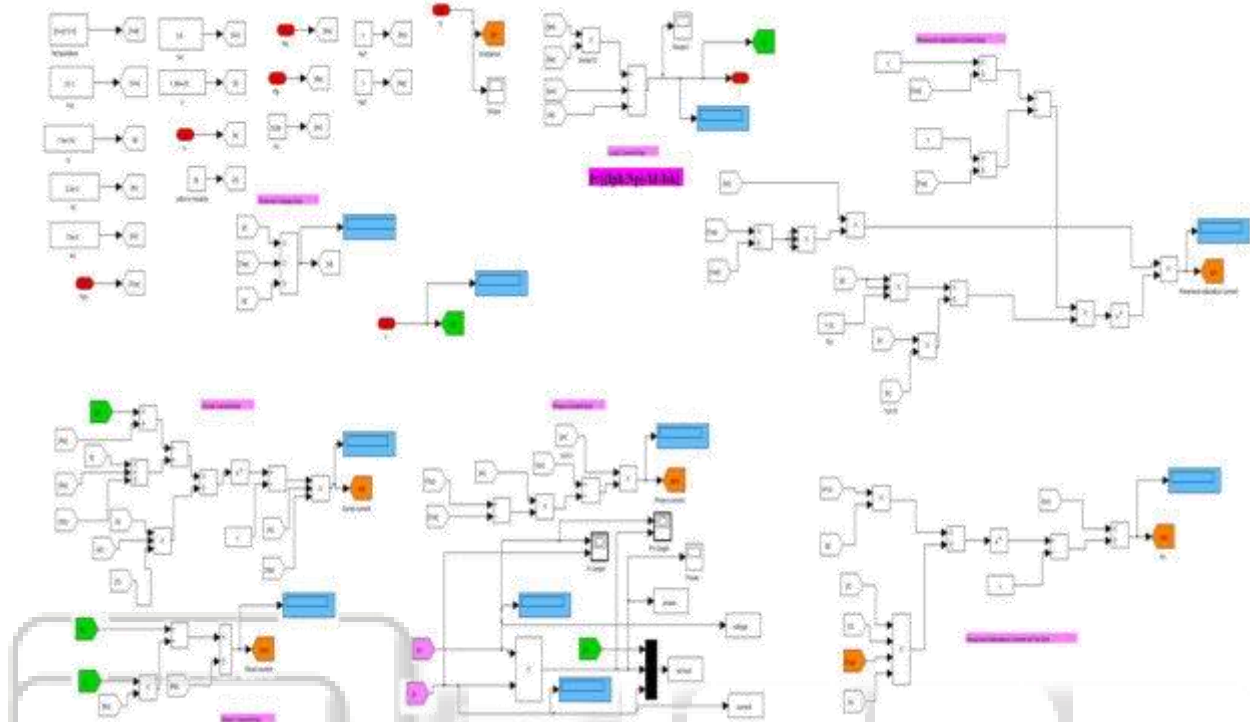


Fig. (5): Model of PV module

### VII. RESULT AND DISCUSSION

In the previous chapter the steps required for the modeling of PV module have been described. In this chapter the results obtained after analysis of PV module has been briefly discussed.

The model of the photovoltaic panel has been implemented in Simulink as shown in Fig. (4.7). The temperature and the irradiance are specified. The simulation allows having the curve I-V and P-V characteristics. The Simulink model and Psim uses a current source, voltage source and the value of the resistance in series and parallel of the PV.

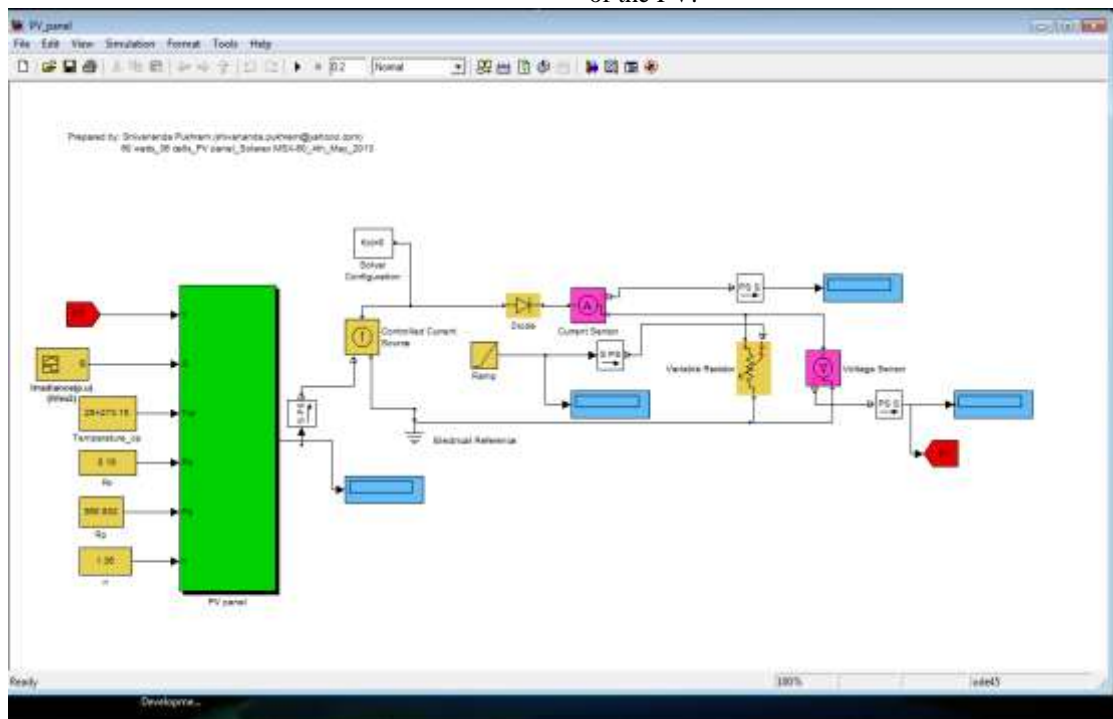


Fig. (6): PV module model in Simulink.

Inside the block PV panel we can see a schematic circuit and some blocks which represented the equation of

PV module as Fig. shown in.

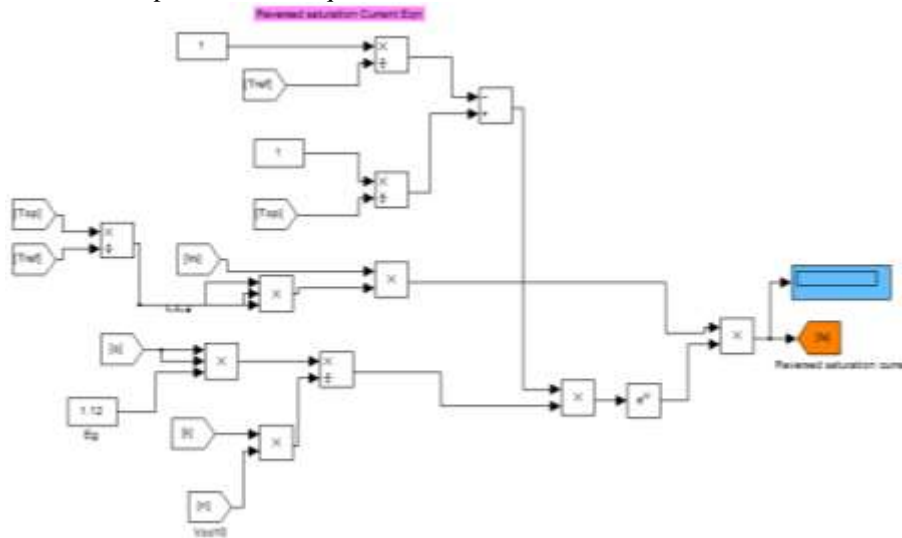


Fig. (a)

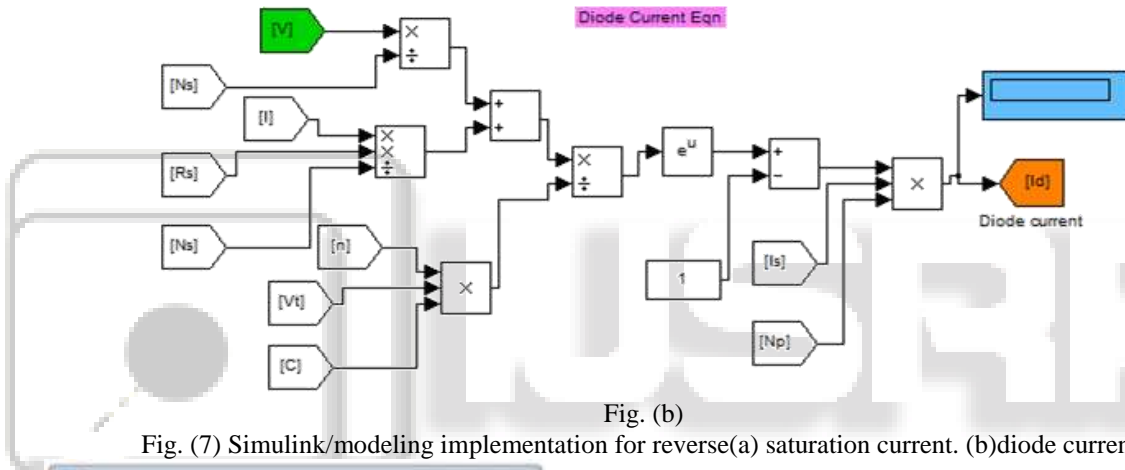


Fig. (b)

Fig. (7) Simulink/modeling implementation for reverse(a) saturation current. (b)diode current.

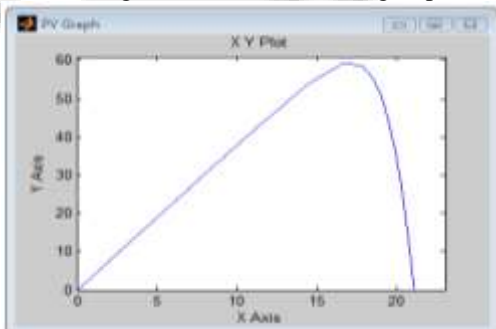


Fig. (8)(a): PV plot of simulating model of PV module.

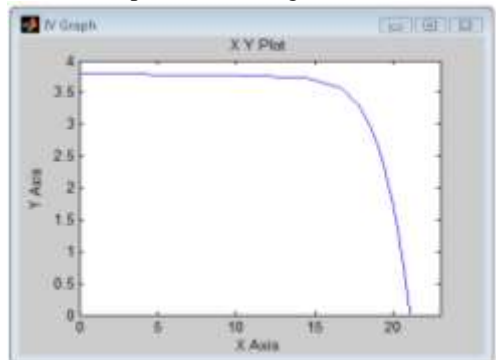


Fig. (8)(b): i-v plot for simulating model.

*A. Impact of solar radiation on I-V characteristic curve of photovoltaic module*

Standard sunlight conditions on a clear day are assumed to be 1000 watts of solar energy per square meter (1000 W/m<sup>2</sup>). This is sometimes called "one sun," or a "peak sun." Less than one sun will reduce the current output of the module by a proportional amount. For example, if only one-half sun (500 W/m<sup>2</sup>) is available, the amount of output current is roughly cut in half.

For maximum output, the front surface of the photovoltaic modules should be pointed as straight toward the sun as possible.

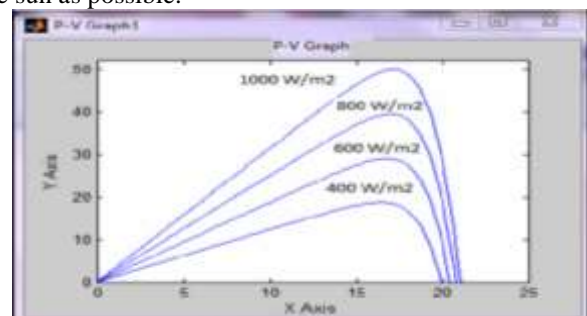


Fig. (9): P-V characteristics at T=25 C, by Simulink With different irradiances[Y- axis: power(watt), X -axis: voltage(volt)].

## VIII. CONCLUSION

This paper present different models and methods of analysing a PV module. Different models and methods have been studied from different papers and a detailed analysis have been done. A detailed modeling and simulation of the PV cell and module is implemented under MATLAB/Simulink environment.

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