Effects of Parameter Variations of PV Module based on MATLAB - Simulink Modeling

Himanshu Sharma  
Senior Research Fellow, Department of Electrical Engineering,  
Indian School of Mines (under MHRD, Govt. of India), Dhanbad, Jharkhand, India

Pankaj Kumar  
Junior Research Scholar, Department of Electrical Engineering,  
Indian School of Mines (under MHRD, Govt. of India), Dhanbad, Jharkhand, India

Jagannath Patra  
Junior Research Scholar, Department of Electrical Engineering,  
Indian School of Mines (under MHRD, Govt. of India), Dhanbad, Jharkhand, India

Nitai Pal  
Associate Professor, Department of Electrical Engineering,  
Indian School of Mines (under MHRD, Govt. of India), Dhanbad, Jharkhand, India

ABSTRACT

Recent applications in remote areas need low-cost source of power. Standalone PV system could assure this power. This paper includes the effect of variation of parameters of PV panel model in MATLAB/Simulink. This build model is based on mathematical equations of the equivalent circuits which consists of a current source, series resistance, and parallel resistance along with a diode. The model is built for the predetermination of nature of the Solar-PV module for different radiation, temperature and other physical parameters. Moreover, PV-array system has been studied in the given research work. For the validation of Simulink results, a real time set also has been studied.

Keyword: MATLAB /simulink, solar radiation; series and shunt resistance; saturation current; panel temperature; maximum power point

I. INTRODUCTION

Photovoltaic cell has been widely used because of ability to convert solar energy coming from sunlight into electrical energy [1]. In the constructional theory of photovoltaic cell, it consists of semiconductor materials of p and n type, connected with each other. The basic principle of PV cell is shown in figure 1. It shows, when photons of sunlight strikes on cells, electrons free from the outer layer of the atom. Then electrons starts flowing from negative to positive terminal. The opposite direction of flow of electrons shows the flow of current from positive terminal to negative terminal in the electric circuit.

The "photovoltaic effect" is the fundamental physical and chemical process by which, voltage or electric current is obtained in a solar cell when it is exposed on sun light [2]. As shown in the figure 1, it is a phenomenon through which a collection of light-generated carriers causes flow of electrons and holes towards N-type and P-type of the junction respectively.

Fig.1. Photocurrent generation principle.
This acts as a source of current. Because of the high cost of PV modules, optimal exploitation of the available abundant solar energy is imperative [3]. This needs a precise, consistent and comprehensive simulation of the designed system before installation. PV panel modeling is a very important factor that affects the output of the PV panel.

The simplest way of representing the solar cell is the single diode model. It is shown with a current source parallel with a diode [2]. A single PV cell generates 0.5-0.8V and therefore, connected in series in a number of 36 to 72 to make PV module. Short circuit current (I_s), open circuit voltage (V_o) and diode ideality factor are the required parameter for the circuit. Diode ideality factor can be obtained from the principle that describes how nearly it follows ideal diode equation. The basic model is improved for accuracy by introducing the series resistance (R_s). It does not prove to be efficient under temperature variations [4] [5]. To overcome this drawback, an additional shunt resistance (R_sh) is included. This paper carried out a model of PV panel of 72 cells connected in series in MATLAB/Simulink. The Proposed model is used to forecast the PV panel characteristics by varying different physical parameters such as solar radiation and ambient temperature. Moreover, same model is used to predict the behavior of the solar panel by varying circuit parameters such as series resistor, shunt resistor, diode saturation current, etc [6] [7] [8].

The single diode model and double diode model has been extensively used in the many literatures but single diode model is more effective due to its comprehensive approach towards the modeling [9].

II. Equivalent Single Diode Circuit of photovoltaic Cell

Figure 2 shows the equivalent circuit of photovoltaic cell. The main components of the circuit have a current source, a diode, a shunt resistance as well as a parallel resistance. The equivalent circuit is based on the equation given below

\[ I = I_{ph} - I_D - I_{sh} \]  
\[ I = I_{ph} - I_{sc} \left( \exp \frac{q(V + R_s I)}{NKT} - 1 \right) \frac{(V + R_s I)}{R_{sh}} \]

where, \( I_{ph} \) represents the photocurrent, denotes the reverse saturation current of the diode, \( q \) stands for the electron charge, \( V \) is the voltage across the diode, \( K \) stands for the Boltzmann's constant, \( T \) denotes the junction temperature, \( N \) represents the ideality factor of the diode, \( R_s \) and \( R_{sh} \) are the series and shunt resistors of the cell respectively [10].

Fig. 2. Equivalent circuit of the solar cell.

The power output of the photovoltaic cell is based on the external input such as solar irradiation, temperature and internal parameters like \( I_{ph} \), \( I_s \), \( R_s \) & \( R_{sh} \).

Fig. 3. PV cell MATLAB/Simulink model.

Fig 4 Model cell.

Fig. 4. I-V curves and P-V curves for a given PV cell.

IJTSRD | May-Jun 2017
Available Online @www.iijtsrd.com
The MATLAB/Simulink model shown in the figure 3 is developed from the equation 1. Figure 4 shows the graph I-V and P-V for some particular values of temperature and irradiation.

### III. Impact of Change in Solar Radiation

Influence of spectral distribution of solar irradiance widely effects the output performance of a solar panel [11]. The equivalent circuit shown in figure 2 have a current source showing $I_{ph}$ which depends on temperature and irradiation as shown in equation 3.

$$I_{ph} = \frac{B}{1000} [I_{sc} + K_i(T_j - 298)]$$  \hspace{1cm} (3)

where, $B$ is solar irradiation in ($W/m^2$) and $K_i = 0.0017 A/^\circ C$ stands for the cell short circuit current.

![Fig. 5. Iph MATLAB/Simulink model.](image)

It can be clearly observed from the model in figure 5, figure 6 and figure 7 that PV panel current and output power is directly varies with the solar irradiation. Moreover, It also shows that, as solar irradiation on the solar panel increases, the open circuit voltage ($V_{oc}$), short circuit current ($I_{scc}$), Maximum current and maximum power also increases.

### IV. Impact of change in temperature of the panel

The relation between temperature of the panel and reverse saturation current ($I_{sc}$) is shown in the equation 3 as:

$$I_s(T) = I_{s}(\frac{T}{T_{nom}})^{\frac{E_s}{NVT}}$$  \hspace{1cm} (4)

![Fig. 8. MATLAB/Simulink on diode reverse saturation current.](image)
The model shown in figure 8 is developed from equation 3. As shown in figure 9 and figure 10 of I-V & P-V graphs, the open circuit voltage as well as the short circuit currents increases and decreases with increasing of the temperature of the panel.

**V. Impact of Changing of Series Resistance (Rs)**

The resistance connected in series is generally low. As shown in the figure 11 and 12, the short circuit current and open circuit voltage remain same with the small change in series resistance. Maximum power point shift from lower to higher value with small increase in series resistance.

**VI. Impact of Change in shunt resistance(Rsh)**

As shown in figure 13 and figure 14, with the increase in shunt resistance the power output increases. With the low value of shunt resistance large drop in the output power in the open circuit voltage can be seen.
VI. Effects of Varying reverse saturation current (Isc)

In the short circuited solar panel, voltage across the panel becomes zero. The current through the solar panel in this condition is referred as short circuit current and usually denoted by as Isc as shown in figure 15.

![Image](fig.15.png)

**Fig. 15. I-V curves for different Isc**

Light generated carriers produced by the light incident on it causes the production of short circuit current. The short circuit current and the light generated current are same for an ideal solar panel at most reasonable resistive loss systems. Hence, Ishc is the largest current that can be drawn from the solar panel.

The curves of figures.15 and 16 were plotted for four different values of Is: 0.2A, 0.4A, 0.6 and 0.8A. The influence of an increase in Is is evidently seen as decreasing the open-circuit voltage Voc.

![Image](fig.16.png)

**Fig. 16. P-V curves for different Isc**

VIII. PV Array

The identical 6 PV panels connected in series with different MPPT topologies [12][13][14]. Figure 21 and figure 22 shows that different output current Vs voltage and power Vs Voltage graph.

![Image](fig.17.png)

**Fig. 17. I-V curves for the PV panel**

![Image](fig.18.png)

**Fig. 18. P-V curves for the PV array model**

The PV modules connected in series can have faults consist of open circuits, short circuits, mismatch between PV modules, and partial shading. Mismatch faults are generally caused by encapsulant degradation, antireflection coating deterioration, manufacturing defects[15].

VIII. Experimental Results and Validation

In the real time experiment, a PV Module (model number: JP36F150) as shown in the figure 19 has been tested under the solar radiation with multimeter and thermometer to measure the temperature listed in the Table 1.

![Image](fig.19.png)

**Fig. 19. PV Module (model number: JP36F150)**

The JP36F150 model is developed in the MATLAB/Simulink with the same specifications.
Under the similar input conditions in the MATLAB Simulink model and real time experiment on the model number JP36F150, results are shown in the figure 20 and figure 21.

![Fig. 19. Setup of the JP36F150 solar laminate panel.](image)

![Fig. 20. JP36F150 solar laminate panel experimental results.](image)

![Fig. 21. MATLAB simulation results.](image)

| Table 1. Parameters of solar panel |
|-----------------------------------|
| **Rated Power(Pmax) watt**        | 150 |
| **Volt at Max. power(Vmp in volt)** | 18.03 |
| **Open circuit voltage(Voc in volt)** | 22.12 |
| **Current at Max. Power(Imp in Amp)** | 8.32 |
| **Short circuit current(Isc in Amp)** | 8.68 |

**X. Conclusion**

In this paper, a PV module and array MATLAB/Simulink model was proposed. Basic equivalent circuit equations of solar panel was used to develop the model. The model was simulated under different environment conditions and physical parameters like solar irradiances and ambient temperature. The JP36F150 panel of solar was used to verify experimentally with the developed simulated MATLAB/Simulink model.

The proposed study presents a comprehensive approach of the modeling of photovoltaic power generation system in the MATLAB/Simulink model with respect to PV power utilization. Moreover, it demonstrates the characteristics of basic components of a PV array under the different weather and physical parameters which would be very much effective to forecast the performance of any solar panel.

**Acknowledgements**

Authors are thankful to the Indian School of Mines, Dhanbad and UNIVERSITY GRANTS COMMISSION, Bahadurshah Zafar Marg, New Delhi, India for granting financial support under Major Research Project entitled “Development of Hybrid Off-grid Power Supply System for Remote Areas [UGC Project: F. No. 42 152/2013(SR), w.e.f. 01/04/2013]” and also grateful to the Under Secretary and Joint Secretary of UGC, India for their active cooperation.
References

[1] A. Tofighi, “Performance Evaluation of PV Module by Dynamic Thermal Model,” *Journal of Power Technologies*, vol. 93, no. 2, pp. 111–121, 2013.

[2] F. Reis, M. Pravettoni, J. Wemans, G. Sorasio, and M. C. Brito, “Modelling the effects of inhomogeneous irradiation and temperature profiles on CPV cells behaviour,” *IEEE Journal of Photovoltaics*, vol. 5, no. 1, pp. 112–122, 2015.

[3] H. Liu, A. M. Nobre, D. Yang, J. Y. Ye, F. R. Martins, R. Ruther, T. Reindl, A. G. Aberle, and I. M. Peters, “The impact of haze on performance ratio and short-circuit current of PV systems in Singapore,” *IEEE Journal of Photovoltaics*, vol. 4, no. 6, pp. 1585–1592, 2014.

[4] R. D. Tapakis and A. G. Charalambides, “Performance evaluation of a photovoltaic park in Cyprus using irradiance sensors,” *Journal of Power Technologies*, vol. 94, no. 4, pp. 296–305, 2014.

[5] A. Gourbi, I. Bousmaha, M. Brahami, and A. Tilmatine, “Numerical Study of a Hybrid Photovoltaic Power Supply System,” *Journal of Power Technologies*, vol. 96, no. 2, pp. 137–144, 2016.

[6] E. A. Silva, F. Bradaschia, M. C. Cavalcanti, and A. J. Nascimento, “Parameter Estimation Method to Improve the Accuracy of Photovoltaic Electrical Model,” *IEEE Journal of Photovoltaics*, vol. 6, no. 1, pp. 278–285, 2016.

[7] A. Chikh and A. Chandra, “An Optimal Maximum Power Point Tracking Algorithm for PV Systems with Climatic Parameters Estimation,” *IEEE Transactions on Sustainable Energy*, vol. 6, no. 2, pp. 644–652, 2015.

[8] M. Hejri and H. Mokhtari, “On the Comprehensive Parametrization of the Photovoltaic (PV) Cells and Modules,” *IEEE Journal of Photovoltaics*, vol. 7, no. 1, pp. 250–258, 2017.

[9] P. H. Huang, W. Xiao, J. C. H. Peng, and J. L. Kirtley, “Comprehensive Parameterization of Solar Cell: Improved Accuracy with Simulation Efficiency,” *IEEE Transactions on Industrial Electronics*, vol. 63, no. 3, pp. 1549–1560, 2016.

[10] K. Ding, X. Bian, H. Liu, and T. Peng, “A MATLAB-Simulink-based PV module model and its application under conditions of nonuniform irradiance,” *IEEE Transactions on Energy Conversion*, vol. 27, no. 4, pp. 864–872, 2012.

[11] E. S. Cells, E. F. Fern, F. A. Cruz, T. K. Mallick, and S. Sundaram, “Effect of Spectral Irradiance Variations on the Performance of Highly Efficient,” *IEEE Journal of Photovoltaics*, vol. 5, no. 4, pp. 1150–1157, 2015.

[12] A. El Shahat, “PV Module Optimum Operation Modeling,” *Journal of Power Technologies*, vol. 94, no. 1, pp. 50–66, 2014.

[13] P. Sharma, S. P. Duttagupta, and V. Agarwal, “A Novel Approach for Maximum Power Tracking From Curved Thin-Film Solar Photovoltaic Arrays Under Changing Environmental Conditions,” *IEEE Transactions on Industrial Applications*, vol. 50, no. 6, pp. 4142–4151, 2014.

[14] F. Zebiri, A. Kessal, L. Rahmani, and A. Chebabhi, “Analysis and Design of Photovoltaic Pumping System based on Nonlinear Speed Controller,” *Journal of Power Technologies*, vol. 96, no. 1, pp. 40–48, 2016.

[15] T. Temperature, Y. Hu, W. Cao, S. Member, J. Ma, S. J. Finney, and D. Li, “Identifying PV Module Mismatch Faults by a Distribution Analysis,” *IEEE Transactions on device and materials reliability*, vol. 14, no. 4, pp. 951–960, 2014.