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European Journal of Advances in Engineering and Technology, 2017, 4(9): 649-656

Research Article ISSN: 2394 - 658X

New Trends in Solar Energy Modeling and Developing a Relation for Performance of Solar Radiation

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ABSTRACT

Solar photovoltaic system performance depends on environmental conditions. Solar photovoltaic panel is a power source having nonlinear internal resistance. As the intensity of light falling on the panel varies, its voltage as well as its internal resistance both varies. This paper presents a circuit-based simulation model for a PV cell in order to allow estimate the electrical behaviour of the cell with respect changes on environmental parameter of temperature and irradiance. The general model was implemented on MATLAB scrip file, and accepts irradiance as variable parameters and outputs the I-V characteristic. A particular typical solar panel was used for model evaluation, and results was compare with points taken directly from the manufacturer's published curves and show excellent correspondence to the model.

Key words: Modeling and behaviour, photocurrent, photovoltaic module

INTRODUCTION

The solar photovoltaic system technologies have increasing roles in electric power technologies, providing more secure power sources and pollution-free electric supplies. A great deal of research has been conducted in this field over the last few decades. The solar photovoltaic panel is a power source having nonlinear internal resistance. The panel output power varies with temperature and insolation. It is desired to operate The solar photovoltaic panel at its maximum power point for economic reasons. To extract maximum power from the panel, its internal resistance should be equal to the load resistance [1].

The solar modules have along lifetime (20 years or more) and their best production efficiency is approaching 20%. Solar energy can be utilized in two ways, solar heating/cooling and solar electricity. Some appliances can be connected directly because they work on dc at the system voltage. Solar arrays were developed for power satellites in the space program. In high power applications, parallel connected converters are often used to provide electrical power. As the power supplied by solar arrays depends upon the insolation, temperature and array voltage, it's required to draw maximum power from solar array.

A PV system directly converts sunlight into electricity. The basic device of a PV system is the PV cell. Cells may be grouped to form panels or arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors. More sophisticated applications require electronic converters to process the electricity from the PV device. These converters may be used to regulate the voltage and current at the load, to control the power flow in grid-connected systems, and mainly to track the maximum power point (MPP) of the device [2].

In order to study electronic converters for PV systems, one first needs to know-how model the PV device that is attached to the converter. PV devices present a nonlinear I–V characteristic with several parameters that need to be adjusted from experimental data of practical devices. The mathematical model of the PV device may be useful in the study of the dynamic analysis of converters, in the study of MPP tracking (MPPT) algorithms. A set of connected cells form a panel. Panels are generally composed of series cells in order to obtain large output voltages. Panels with large output currents are achieved by increasing the surface area of the cells or by connecting cells in parallel. A PV array may be either a panel or a set of panels connected in series or parallel to form large PV systems. The PV module with all necessary variables and constraints of the governing equations are considered and the tracking efficiencies are confirmed by simulations and experimental results [3-6].

PHOTOVOLTAIC MODULES

Solar cells consist of a p-n junction [7] fabricated in a thin wafer or layer of semiconductor. In the dark, the I-V output characteristic of a solar cell has an exponential characteristic similar to that of a diode. When exposed to light, photons with energy greater than the band gap energy of the semiconductor are absorbed and create an electron-hole pair. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. When the cell is short circuited, this current flows in the external circuit; when open circuited, this current is shunted internally by the intrinsic p-n junction diode. The characteristics of this diode therefore sets the open circuit voltage characteristics of the cell [8-13].

Modeling of Solar PV Module

In electrical terminology Modeling of Photovoltaic cell means representing with its equivalent circuit. PV cell can be represented in three equivalent circuits. A solar cell can be operated at any point along its characteristic current-voltage cure, as shown in figure 1. Two important points on this curve are the open circuit voltage (V_{oc}) and short-circuit current (I_{sc}). The open-circuit voltage is the maximum voltage at zero current, whereas the short-circuit current is the maximum current at zero voltage. A plot of power (P) against voltage (V) for this device shows that there is a unique point on the I-V curve at which the solar cell will generate maximum power. This is known as the maximum power point (V_{mpp}, I_{mpp}) [14-15]. Because a silicon solar cells typically produce only about 0.5V. A number of cells are connected in series in a PV module. A panel is a collection of modules physically and electrically grouped together on a support structure. An array is a collection of panels.

An even more exact modelling could be achieved by the two-diode-model. Here two different diodes with different diode ideally factors m connected in parallel. At the equations of the diode it was always taken for granted that there is no breakthrough at operation in the inhibited direction of the diode, but at high negative voltages a breakthrough at solar cell could be observers. This was modelled at figure 2 by a variable current source I (VD) [16-19].

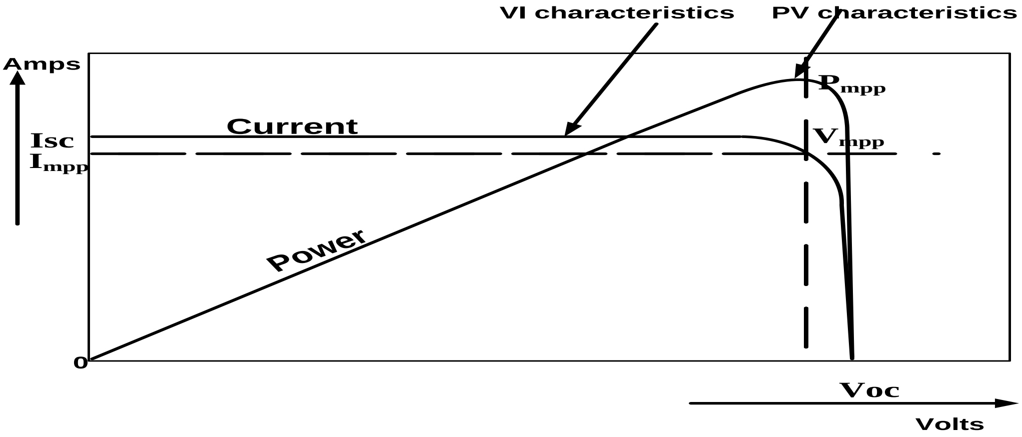


Fig. 1Characteristics of Photovoltaic System

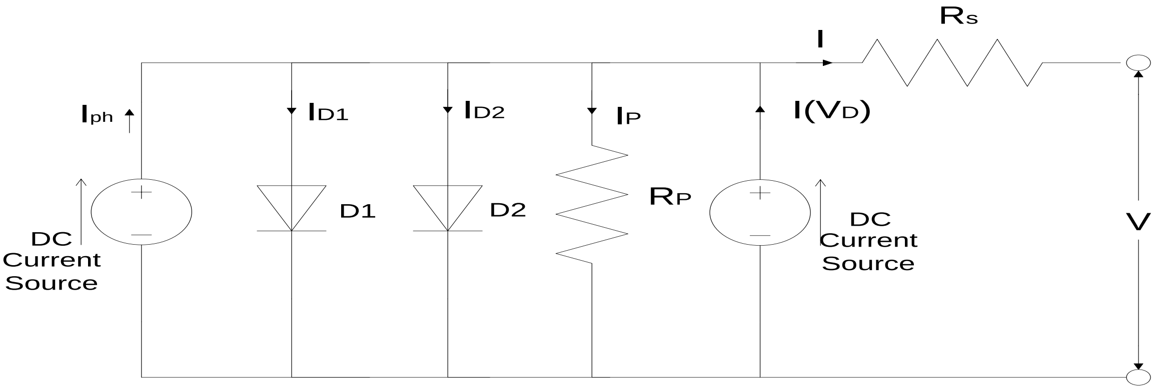


Fig. 2 Two-diode model

SIMULATION RESULTS

The simulation of solar PV module characteristics is done on the MATLAB/ Simulink.

Parameters of Solar PV module

Output voltage, current and power curve of Solar PV model is shown in the figure 9.

Open circuit voltage (V_{oc}) = 22.22V
Short circuit current (I_{sc}) = 5.45 A
Current at P_{max} = 4.95A
Voltage at P_{max}=17.2 V
Diode 'ideality factor'*m*=2
Thermal Voltage = v_T= (k.T/e)
Charge of an electron *e*=1.6021733*10^{-19} as
Constant of Boltzmann *k*= 1.380658*10^{-23} Jk^{-1}
Insolation= 800W/M^2

MATLAB Model of PV Module

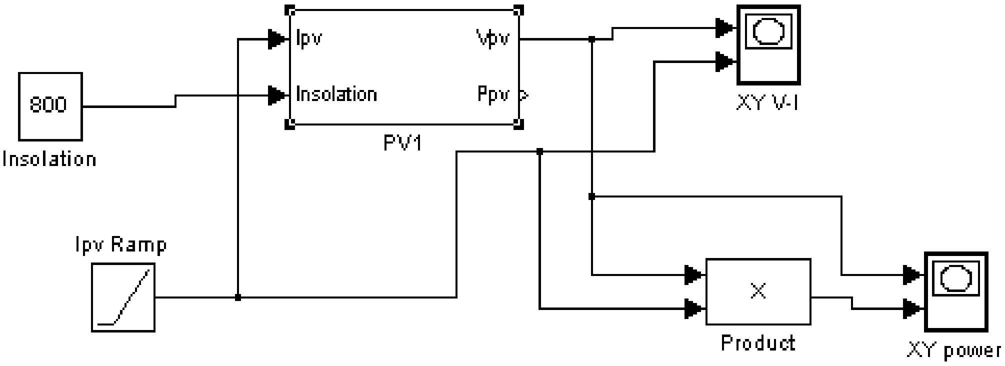


Fig. 3 (a) PV Module

Inside the PV Module Subsystem

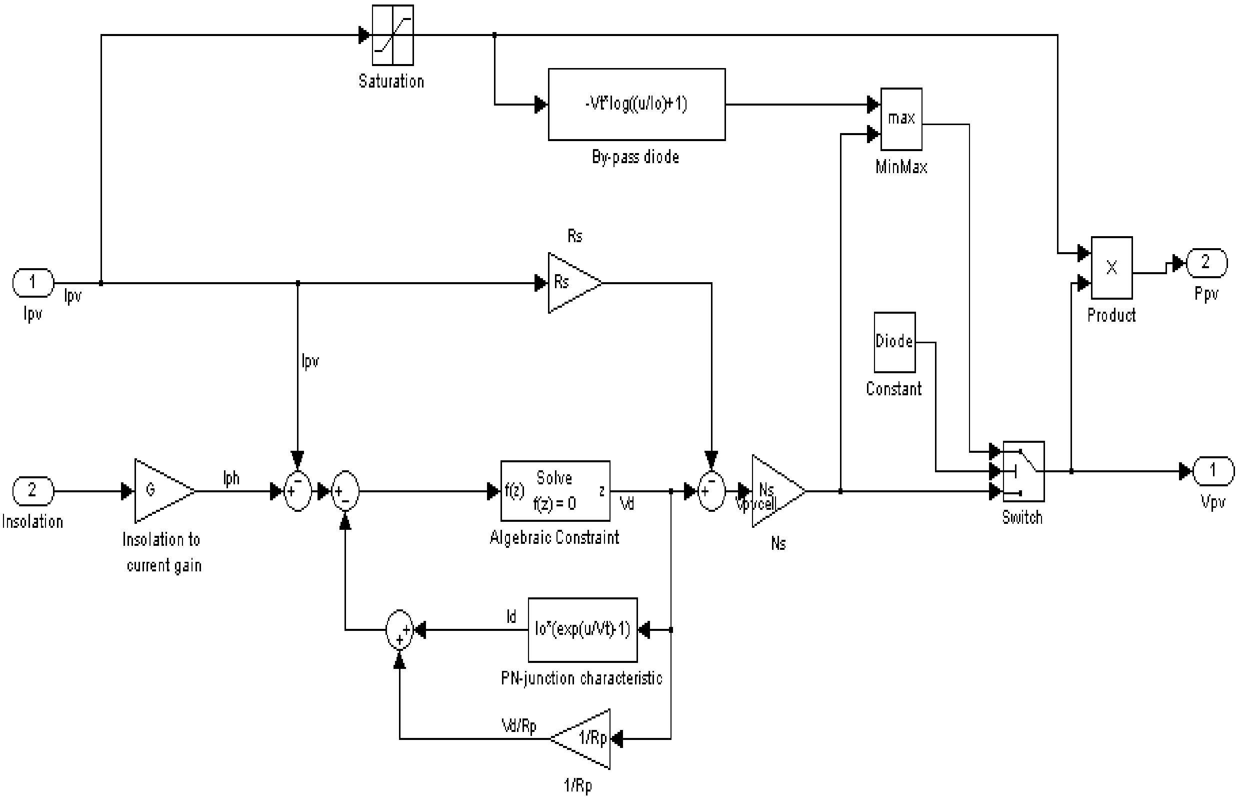
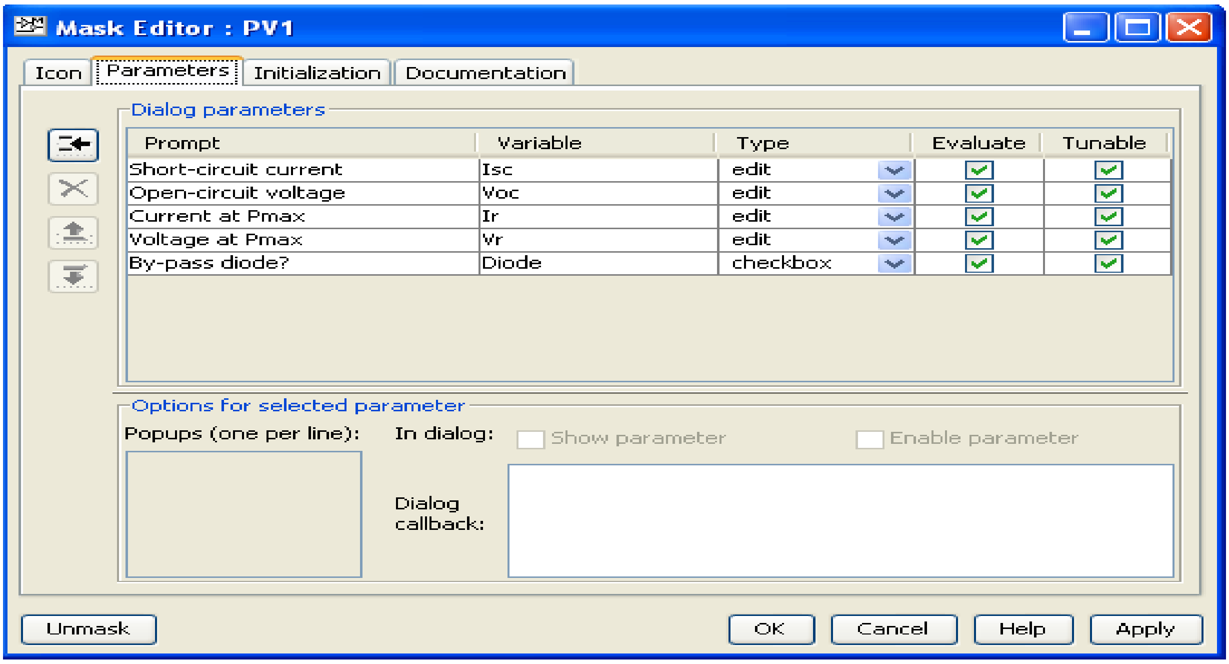


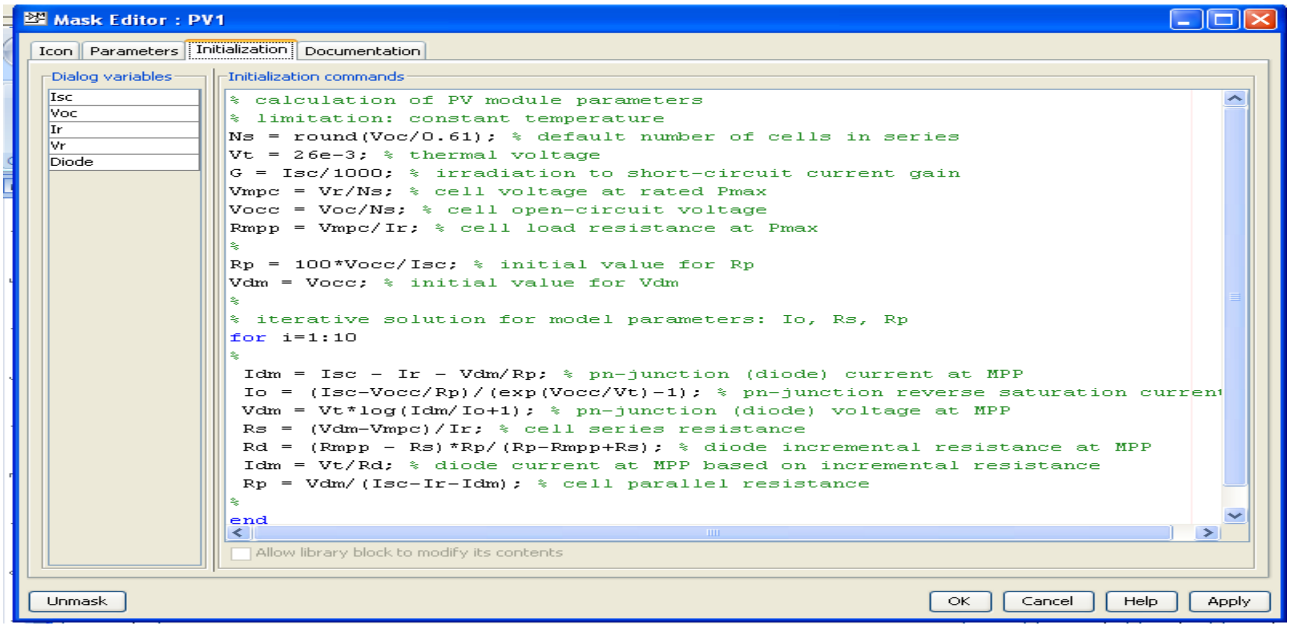
Fig. 3 (b) PV Module

Masked subsystem model parameters are defined as [Fig. 4]. The MATLAB code computes model parameters I_o, R_s, R_p based on the model parameters (short-circuit current I_{sc}, circuit voltage V_{oc}, rated voltage V_r, and rated current I_r) [Fig. 5].



Prompt	Variable	Type	Evaluate	Tunable
Short-circuit current	Isc	edit	☑	☑
Open-circuit voltage	Voc	edit	☑	☑
Current at Pmax	Ir	edit	☑	☑
Voltage at Pmax	Vr	edit	☑	☑
By-pass diode?	Diode	checkbox	☑	☑

Fig. 4 Subsystem Model Parameters



```
% calculation of PV module parameters
% limitation: constant temperature
Ns = round(Voc/0.61); % default number of cells in series
Vt = 26e-3; % thermal voltage
G = Isc/1000; % irradiation to short-circuit current gain
Vmpc = Vr/Ns; % cell voltage at rated Pmax
Vocc = Voc/Ns; % cell open-circuit voltage
Rmpp = Vmpc/Ir; % cell load resistance at Pmax
%
Rp = 100*Vocc/Isc; % initial value for Rp
Vdm = Vocc; % initial value for Vdm
%
% iterative solution for model parameters: Io, Rs, Rp
for i=1:10
%
 Idm = Isc - Ir - Vdm/Rp; % pn-junction (diode) current at MPP
 Io = (Isc-Vocc/Rp)/(exp(Vocc/Vt)-1); % pn-junction reverse saturation curren
 Vdm = Vt*log(Idm/Io+1); % pn-junction (diode) voltage at MPP
 Rs = (Vdm-Vmpc)/Ir; % cell series resistance
 Rd = (Rmpp - Rs)*Rp/(Rp-Rmpp+Rs); % diode incremental resistance at MPP
 Idm = Vt/Rd; % diode current at MPP based on incremental resistance
 Rp = Vdm/(Isc-Ir-Idm); % cell parallel resistance
%
end
```

Fig. 5 Model Mask: Initialization

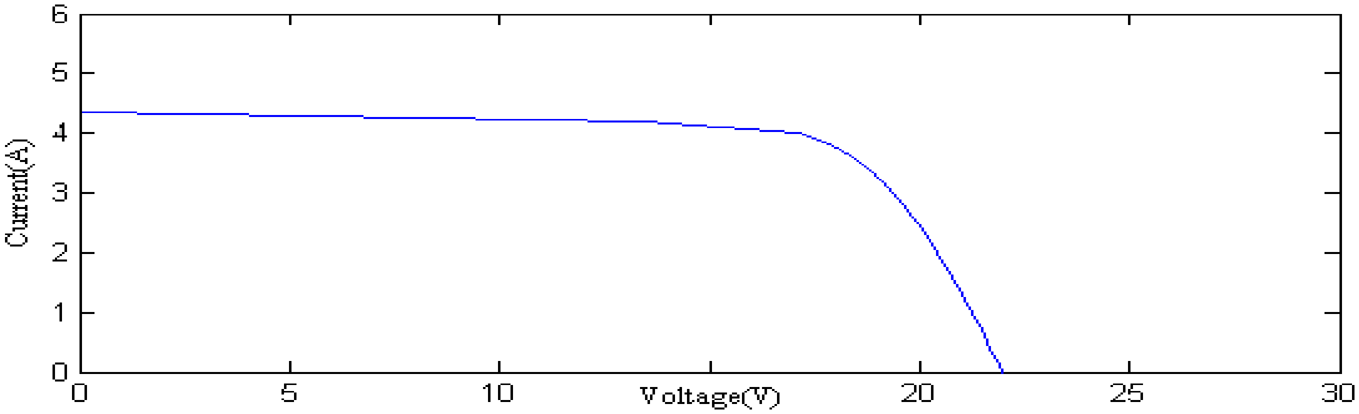


Fig. 6 I-V Characteristics of PV Module

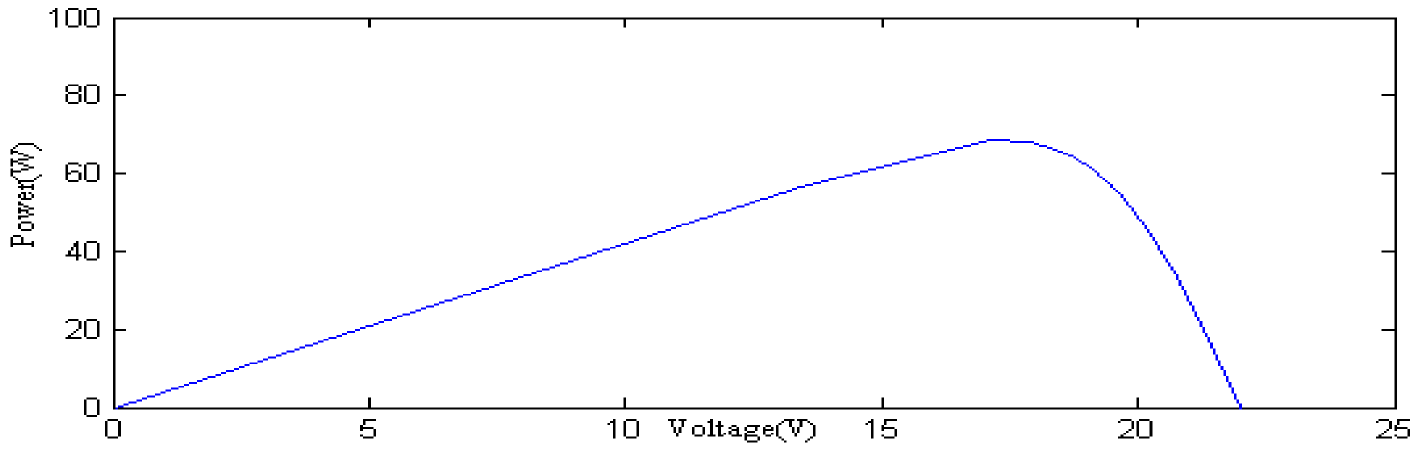


Fig. 7 P-V Characteristics of PV Module

Characteristics of Solar PV Module at Different Insolation

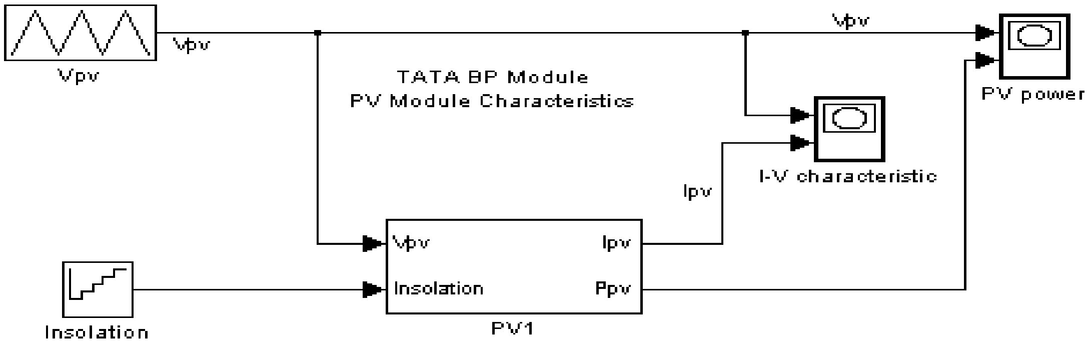


Fig. 8 PV Module at different Insolation

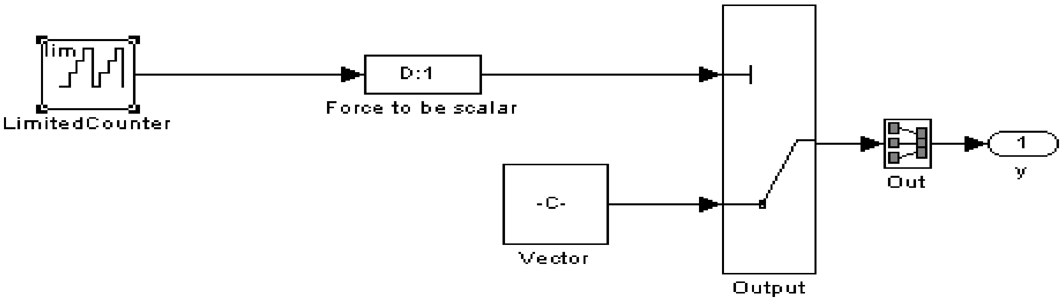


Fig. 9 Insolation Mask Sub System

Insolation = 200, 400, 600, 800, 1000 W / M^2

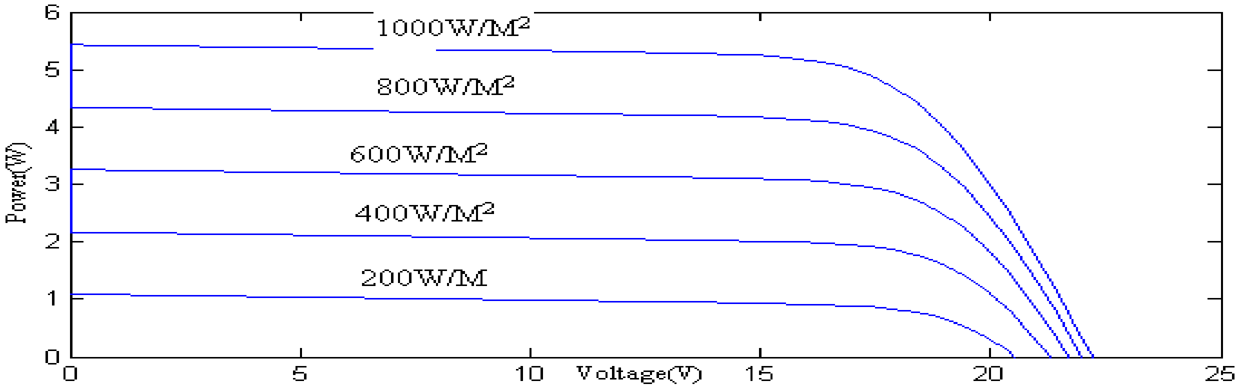


Fig. 10 I-V Characteristics of PV Module at different Insolation

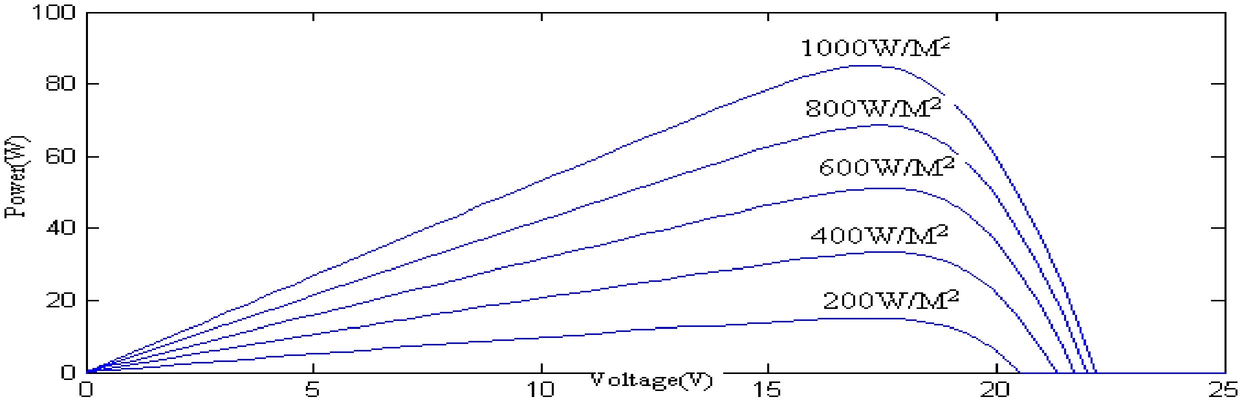


Fig. 11 P-V Characteristics of PV module at different Insolation

PV Module Connected in Series

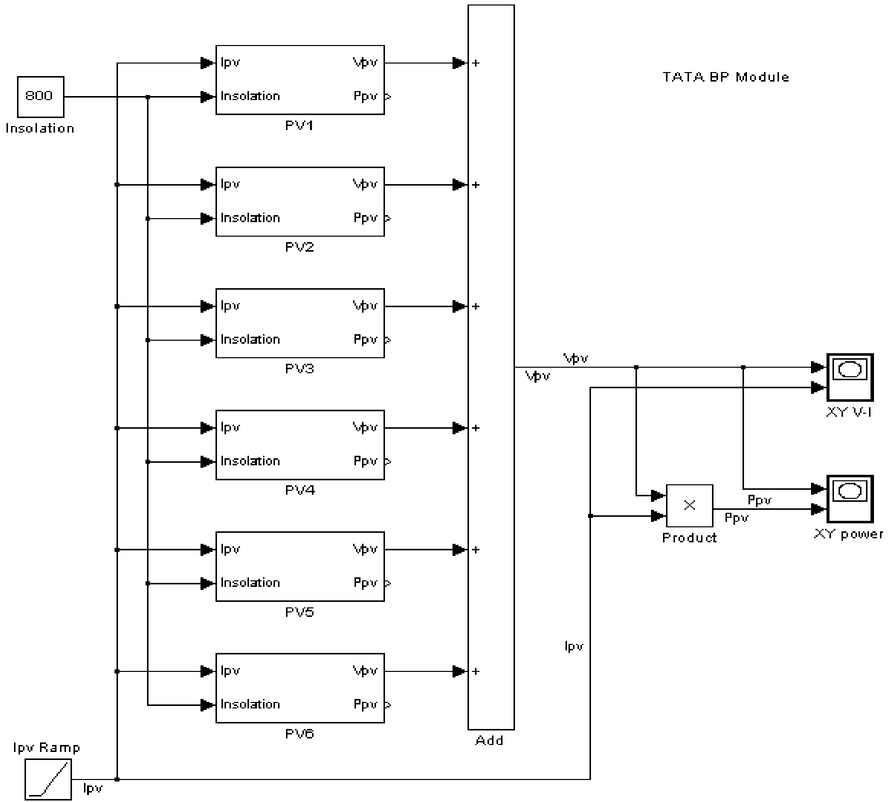


Fig. 12 Six module connected in series

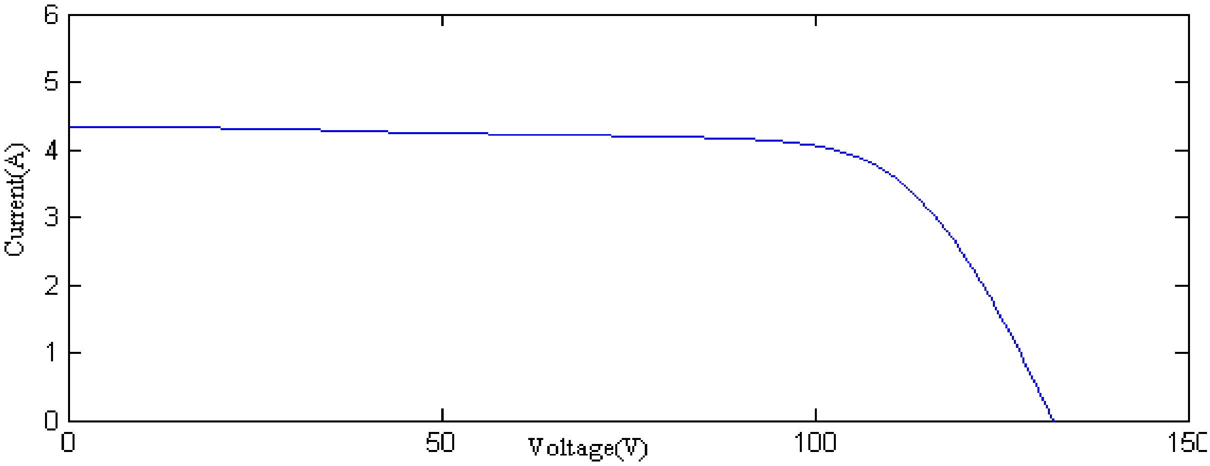


Fig. 13 I-V Characteristics of PV Array

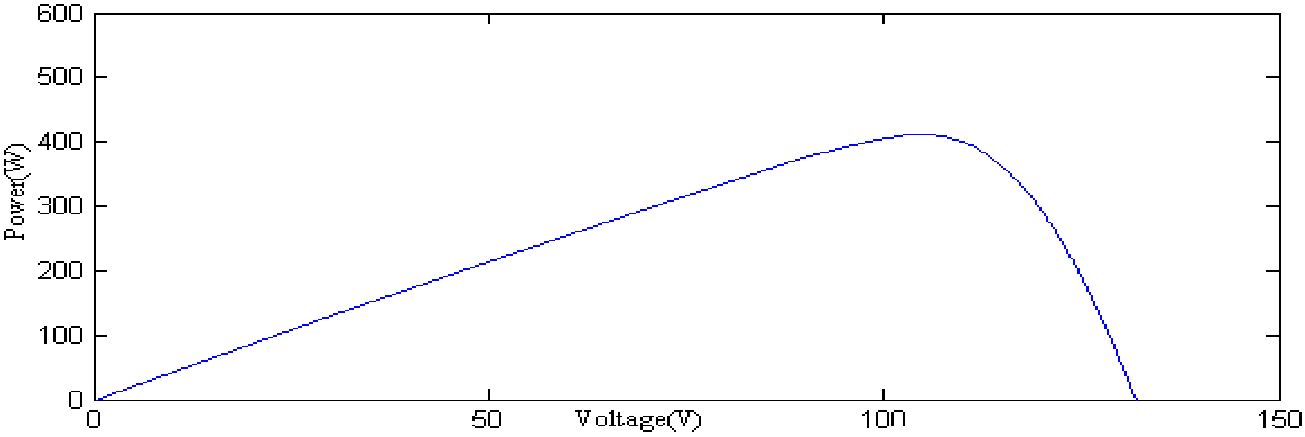


Fig. 14 P-V Characteristics of PV Array

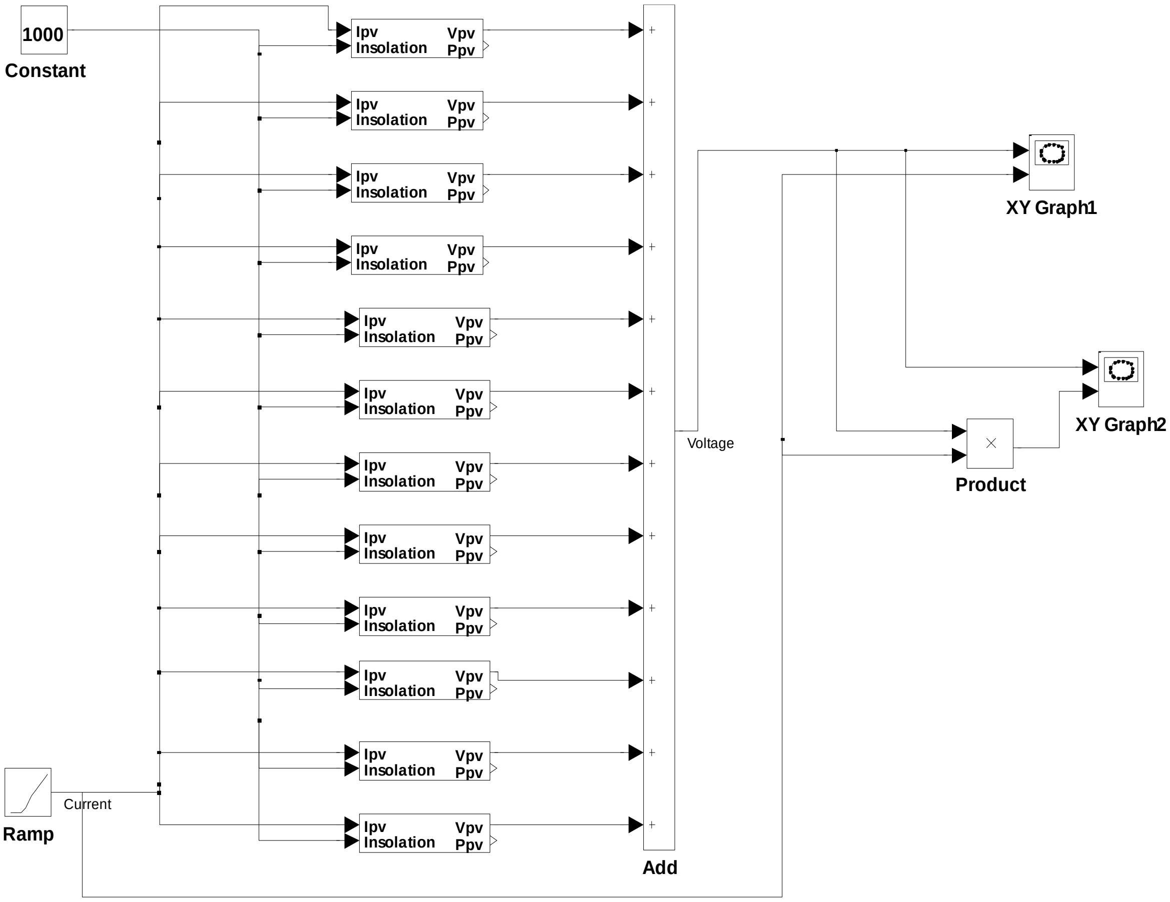


Fig. 15 Twelve Module Connected in Series

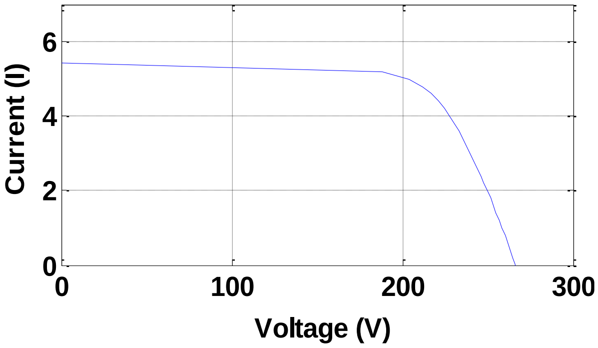


Fig. 16 I-V Characteristics of PV Array

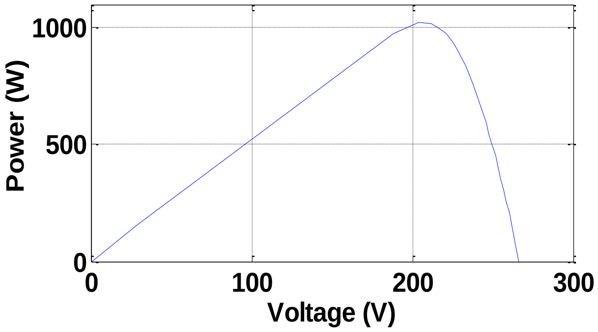


Fig. 17 P-V Characteristics of PV Array

When the module is connected in series, current is same and voltage is multiply by the number solar photovoltaic module is connected in series. The I-V & P-V characteristics are shown in figure 13 and 14 respectively. When the twelve module is connected in series, the power increases to 1000W. The I-V & P-V characteristics are shown in figure 16 and 17 respectively.

CONCLUSIONS

An accurate PV module is presented and demonstrated in MATLAB for a typical solar panel. The model draws I-V and P-V characteristics at given different solar insolation level. By connecting twelve modules in cascade combination we get efficient increment in the value of power. The results from the MATLAB™ model show excellent correspondence to manufacturer's published curves. Finally, the model development was used to show the effect of insolation. This paper is the first step to develop a complete solar photovoltaic power electronic conversion system in simulation. The proposed method offers different advantages which are: good tracking efficiency, response is high and well control for the extracted power.

REFERENCES

[1] Juan David Bastidas-Rodriguez, Edinson Franco, Giovanni Petrone, Carlos Andrés Ramos-Paja and Giovanni Spagnuolo, Maximum Power Point Tracking Architectures for Photovoltaic Systems in Mismatching Conditions: A Review, *IET Power Electronics*, **2014**, 7(6), 1396–1413.
[2] JP Ram, TS Babu, N Rajasekar, A Comprehensive Review on Solar PV Maximum Power Point Tracking Techniques, *Renewable and Sustainable Energy Reviews*, **2017**, 67, 826-847.
[3] Shongwe Samkeliso and Moin Hanif, Comparative Analysis of Different Single-Diode PV Modeling Methods, *IEEE Journal of Photovoltaics*, **2015**, 5 (3), 938-946.
[4] Ahmed Koran, Thomas LaBella and Jih-Sheng Lai, High Efficiency Photovoltaic Source Simulator with Fast Response Time for Solar Power Conditioning Systems Evaluation, *IEEE Transactions on Power Electronics*, **2014,** 29 (3), 1285-1296.
[5] HL Tsei, CS Tu and YJ Su, Development of Generalized Photovoltaic Model Using Matlab/Simulink, *Proceedings of the World Congress on Engineering and Computer Science*, San Francisco, USA, **2008**, 846–851.
[6] Masafumi Miyatake, Mummadi Veerachary, Fuhita Toriumi, Nobuhiko Fujii and Hideyoshi Ko, Maximum Power Point Tracking of Multiple Photovoltaic Arrays: A PSO Approach, *IEEE Transactions on Aerospace and Electronic Systems*, **2011**, 47 (1), 367-380.
[7] Bal Mukund Sharma and Kuldeep Sahay, A Comprehensive Survey of Maximum Power Tracker Techniques for Photovoltaic System, *I-Manager's Journalon Electrical Engineering*, **2014,** 8(1), 39-55.
[8] Bal Mukund Sharma and Kuldeep Sahay, Implementation of Perturb and Observe (P& O) Method to Track the Maximum Power Point Using Buck Converter, *I-Manager's Journal on Electrical Engineering*, **2016**, 9 (4), 37-46.
[9] Bal Mukund Sharma and Kuldeep Sahay, Effect of Perturb & Observe Algorithm and Incremental Conductance Algorithm on the Performance of Cuk Converters for Photovoltaic Application, *European Journal of Advances in Engineering and Technology*, **2017**, 4 (7), 516-523.
[10] Marcelo Gradella Villalva, Jonas Rafael Gazoli and Ernesto Ruppert Filho. Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays, *IEEE Transactions on Power Electronics*,**2009**, 24(5), 1198-1208.
[11] V Salas, M Alonso-Abella, F Chenlo and E Oliasas, Analysis of the Maximum Power Point Tracking in the Photovoltaic Grid Inverters of 5 KW, *Renewable Energy*, **2009**, 34(11), 2366-2372.
[12] H Patel and V Agarwal, MATLAB-Based Modeling to Study the Effects of Partial Shading on PV Array Characteristics, *IEEE Transactions on Energy Conversion*, **2008**, 23(1), 302-10.
[13] R Wai and W Wang, Grid-Connected Photovoltaic Generation System, *IEEE Transaction on Circuits and Systems*, **2008**, 55 (3), 953–964.
[14] G Bhuvaneswari and R Annamalai, Development of a Solar Cell Model in MATLAB for PV Based Generation System, *Proceedings of Annual IEEE India Conference (INDICON)*,**2011**, 1-5.
[15] MC Alonso-Garcia and JM Ruiz, Analysis and Modeling the Reverse Characteristic of Photovoltaic Cells, *Solar Energy Materials & Solar Cells*,**2006**, 90, 1105–1120.
[16] M Masoum, H Dehbonei and E Fuchs, Theoretical and Experimental Analyses of Photovoltaic Systems with Voltage and Current-Based Maximum Power-Point Tracking, *IEEE Transaction on Energy Conversion*, **2002**, 17(4), 514–522.
[17] W Xiao, W Dunford, P Palmer and A Capel, Regulation of Photovoltaic Voltage, *IEEE Transaction on Industrial Electronics*, **2007**, 54(3), 1365–1374.
[18] A El Shahat, PV Cell Module Modeling and ANN Simulation for Smart Grid Applications, *Journal of Theoretical and Applied Information Technology*, **2010**, 16(1), 9–20.
[19] JA Gow and CD Manning, Development of a Photovoltaic Array Model for Use in Power-Electronic Simulation Studies, *IEE Proceeding on Electrical Power Applications*,**1999**, 146(2), 193-200.