INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND CREATIVE ENGINEERING (ISSN:2045-8711)
VOL.6 NO.9 SEPTEMBER 2016, IMPACT FACTOR:0.61

Modeling Of Photovoltaic Cell and Study Partial Shading Effect Using Matlab/Simulink

Anurag Rai
Department of Electronics & Communication, University of Allahabad
Allahabad, India
Email: anuragrai07@gmail.com
Bhoomika Awasthi
Department of Electronics & Communication, University of Allahabad
Allahabad, India
C. K. Dwivedi
Department of Electronics & Communication, University of Allahabad
Allahabad, India

Abstract - The aim of this study is to develop a model for solar photovoltaic cell based on mathematical expression. The conventional single diode model for solar cell with series and shunt resistance is used for illustration. The effect of change in environmental condition like irradiance and temperature on output of photovoltaic module is shown. The effect of partial shading on photovoltaic module output is also considered. The photovoltaic module of 60 series connected cell is developed and the characteristic of proposed model is compared with the reference photovoltaic module. The solar system can also be modeled and simulate by using this model. Simulation was performed at each step using MATLAB/ Simulink software.

Keywords- Photovoltaic cell, PV characteristic, partial shading, Matlab/ simulink.

1. INTRODUCTION

Today there is a growing concern regarding demand of energy. Unarguably, Energy is required for all our basic needs whether it be for transportation, communication or even as simple as cooking food, lighting in homes. Fortunately, nature provided us with vast sources of energy like coal, oil, gas which could be later transformed into more desirable form of energy [1,2].

Past few decades has seen tremendous growth in both the population and industry, which in result have put enormous pressure on energy resources. The conventional energy resources mentioned above take thousands of years to replenish itself and the rate of consumption far exceeds the rate of replenishment. The need for energy is ever growing and thus it is important to look for alternatives as it has been speculated by scientists that the resources are going to run out in near future. Also the combustion of such fuels causes environmental hazards which are an even more serious concern [3-5].

In present time many renewable sources are available such as wind energy, solar energy, biomass energy etc. but solar energy is most popular among them. The solar energy is widely used because it is abundantly available almost everywhere and availability of technology i.e. solar photovoltaic (PV) cells which directly converts sunlight in to electrical energy. The energy produced by solar cell is proportional to intensity of sunlight. Solar cell is basically a PN junction fabricated on layer of semiconductor. When solar cell is exposed to light the electrical energy is produced by photoelectric effect. The voltage produced by a PV cell may vary from 0.6V to 0.8V depending on semiconductor material and technology used [6].

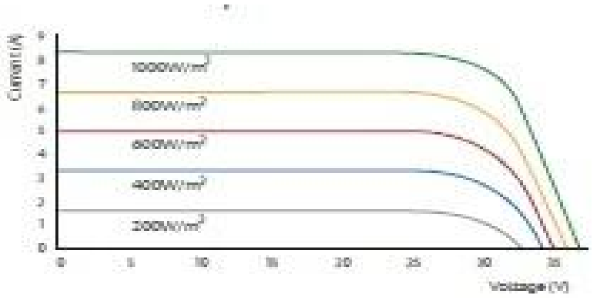
2. Mathematical Modeling of PV Cell

In this research work includes the modeling of PV cell as well as PV module. The modeling is based on mathematical expression which was found from equivalent circuit of solar cell. The effect of parameter variation on output of PV module is also considered [7].

The developed model of PV module based on single diode model as shown in Fig.2. The simulation result was compared with characteristic of 250Watt standard solar PV module manufactured by TATA Power Solar. The available information from datasheet was used in simulation model. The specification and characteristic curve for various values of irradiance and temperature is shown in table I and Fig.1 respectively. The modeling and simulation was performed using Matlab/ Simulink software.

TABLE I: Specification of TP250 PV module at STC [8]

Electrical parameter	TP250 PV module
Nominal power output	250 W
Voltage at Pmax VMPP (V)	30.2 V
Current at PMax IMPP (I)	8.30 A
Open circuit voltage VOC (V)	37.30 V
Short circuit current ISC (I)	8.71 A



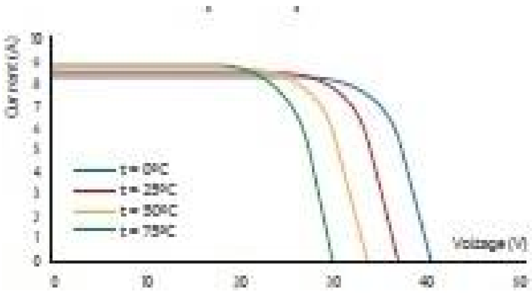


Fig. 1. Characteristic curve of TP250 at different irradiance and temperature

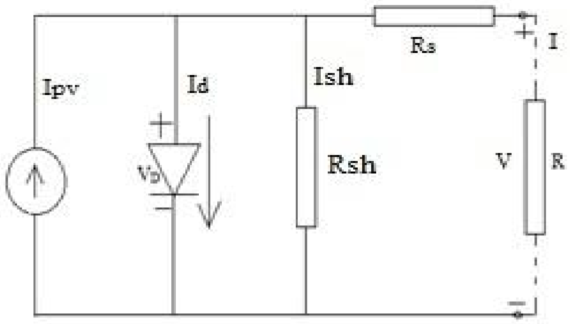


Fig. 2. Equivalent circuit of solar cell with R_s and R_{sh}

The solar PV cell can be consider as current source. The outputs current (I) can be determine from Fig. 2, as given in (1). The output current is proportional to irradiance, temperature and resistances. The output current mainly depends on photocurrent (Iph), Photocurrent increases with sun irradiance. The expression for output current (I) of solar cell from equivalent circuit in can be written as

$$I = I_{ph} - I_{D} - I_{sh} \qquad (1)$$

Here, I = Output current or load current of PV cell, I_{ph} is Photocurrent generated by solar cell, I_D is Diode forward current, I_{sh} is the shunt current flowing through resistance R_{sh}.

A. Determination of Diode forward current

Diode current I_D can be determine by Shockley diode current equation

$$I_D = I_O \left[exp \left({}^{V_o}/_{nV_t} \right) - 1 \right] \qquad (2)$$

Here, I_O is diode reverse saturation current, V_o is applied forward voltage on diode, n is Ideality factor, V_t is thermal voltage.

$$V_t = {}^{KT}/_q = 26\ mV \text{ at } 25°C$$

$K = 1.381 \times 10^{-23}\ J/K$, is Boltzmann constant, T is temperature of PV cell, $q = 1.602 \times 10^{-19}\ C$, is charge on an electron.

$$V_o = V + IR_s \text{, from fig. 1(b)}$$

$$I_D = I_O \left[exp \left(\frac{V + IR_s}{nV_t} \right) - 1 \right] \qquad (3)$$

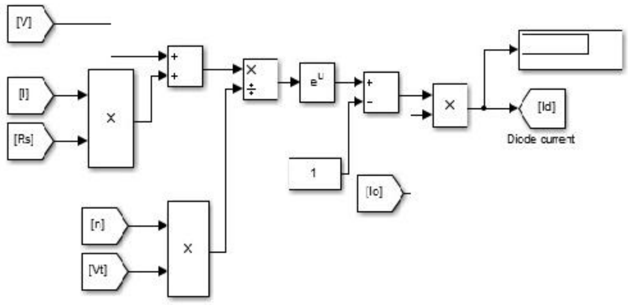


Fig. 3. Simulation model subsystem for diode current

B. Determination of reverse saturation current

I_0 is diode reverse saturation current, it is temperature dependent current. The saturation current is cubic function of temperature, it can be expressed as in (4) .

$$I_0 = I_{o,ref} \left(\frac{T_{op}}{T_{ref}} \right)^3 \exp \left[\left(\frac{qE_g}{AK} \right) \left(\frac{1}{T_{ref}} - \frac{1}{T_{op}} \right) \right] \qquad (4)$$

$I_{o,ref}$ is diode reverse saturation current at standard test condition (STC), T_{op} is operating temperature (cell temp.) in $°K$, T_{ref} is standard temperature (25 °C) in $°K$, E_g is band gap energy its depends upon the used material. Fig. 6 represents simulation model of reverse saturation current [9].

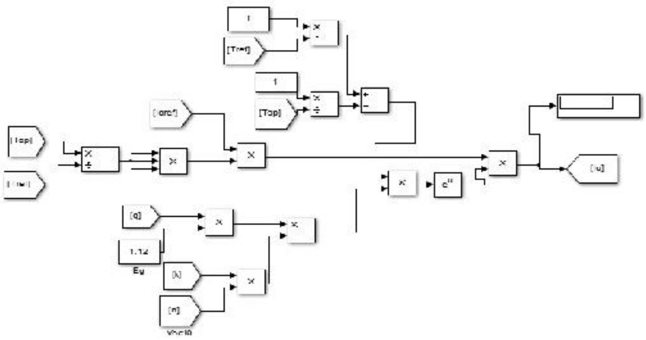


Fig. 4. Simulation model for reverse saturation current

C. Determination of photocurrent

Photocurrent depends on irradiance and temperature. The relationship written as in (5). The simulation subsystem is shown in Fig. 5.

$$I_{ph} = \frac{B}{B_{ref}} [I_{sc,ref} + k_i (T_{op} - T_{ref})] \qquad (5)$$

B is actual Irradiance, B_{ref} is irradiance at STC (1000 W/ m2), $I_{sc,ref}$ is short circuit current provided in datasheet, k_i is temperature coefficient of the short circuit current [10].

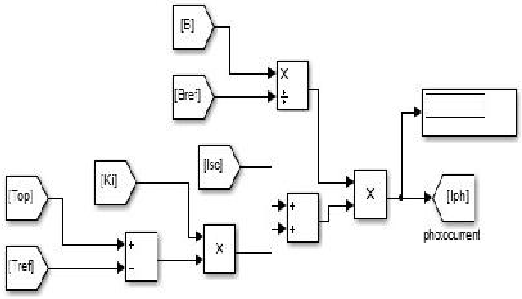


Fig. 5. Simulation model for photocurrent

D. Determination of Shunt current

Ish is shunt current for PV module is expressed as in (6). The simulation model for shunt current was shown in Fig. 6. The complete simulation model of solar PV module is shown in Fig.7.

$$I_{sh} = \frac{V_0 + IR_s}{R_{sh}} \tag{8}$$

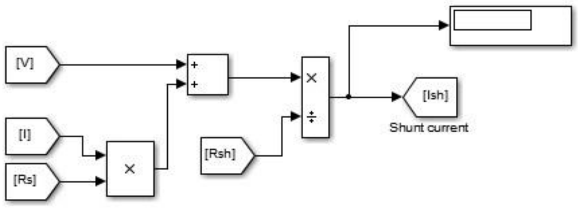


Fig. 6. Simulation model for shunt current

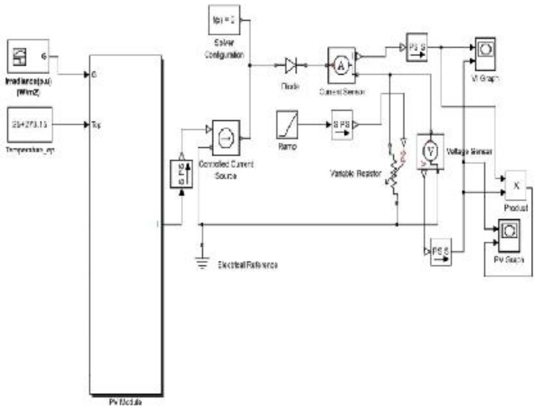


Fig. 7. Simulation model for solar PV Module

A. Effect of Parameter Variation

This study includes the analysis of environmental such as irradiance and temperature variation effect on output of solar PV module.

B. Effect of Solar Irradiance Variation

The photocurrent varies with irradiance, the simulation was performed or different values of irradiance (1000, 800, 600, 400 W/m2) at STC (Standard test condition). Fig. 8 and 9 shows I-V and P-V curve after simulation at different irradiance. The percentage change in short circuit current (Isc) is much more than the percentage change in Open circuit voltage (Voc).

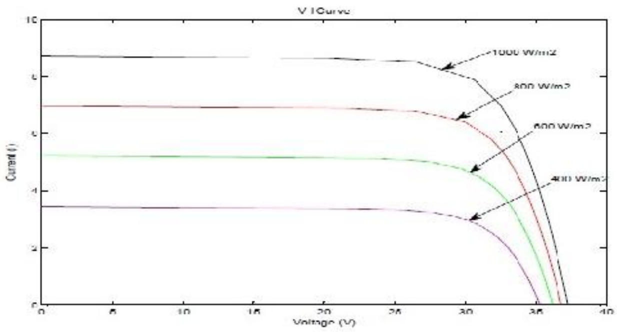


Fig. 8. I-V Characteristic of PV module at different irradiance

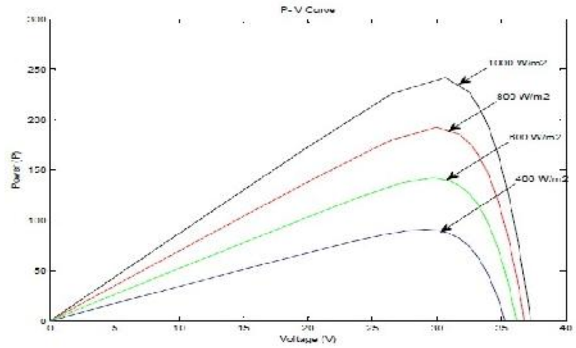


Fig. 9. P-V Characteristic of PV module at different irradiance

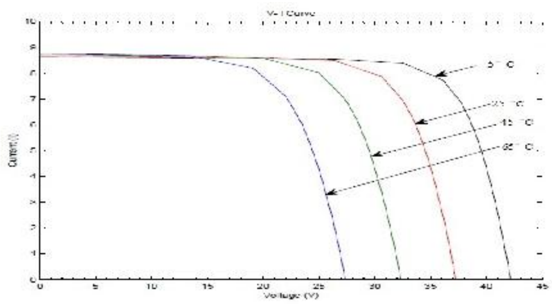


Fig. 10. I-V Characteristic of PV module at different temperature

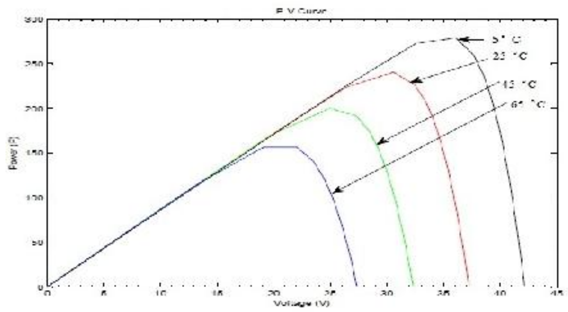


Fig. 11. P -V Characteristic of PV module at different temperature

C. Effect of Temperature Variation

The simulation was performed for different values of temperature (5, 25, 45, 65˚C) at STC. Fig. 10 and 11 shows I-V and P-V graph of simulation result for different cell temperature. The current Isc increases in very small amount but decrement in open circuit voltage VOC is considerable with increase in temperature.

3. Effect of Shading and Partial Shading

The performance of PV module is adversely affected if illumination is not uniform. The PV cells are generally connected in series to form a PV module and in case of partial shading of PV module, the current is limited due to shaded cells and all cells connected in series are forced to carry minimum current even though only few cells or even one cell is shaded. The shaded cells gets reverse biased and act as a load which may cause hot spots to arise and PV cell might get damaged permanently.

In this section the effect of shading and partial shading is shown by simulation. The simulation is performed under the following three conditions: no shading, uniform shading and partial shading. I-V and P-V graph of simulation result is shown in Fig.12 & 13 for the above mentioned condition. In no shading condition all 36 cell receive irradiance of 1000 W/m2 and shown by blue line in curve. In uniform shading, irradiance received by all cell is 700 W/m2 and it is shown by red color line. In case of partial shading only three cell are shaded and receives irradiance of 200 W/m2 and other cells are at irradiance of 900 W/m2, it is indicated by black line. It can be clearly seen that from simulation results, in partial shading condition, current is limited at minimum current produced by shaded cell. Bypass diodes are used to overcome the problem of hot spot that arises due to partial shading. Bypass diode provide path for current flow for shaded cells.

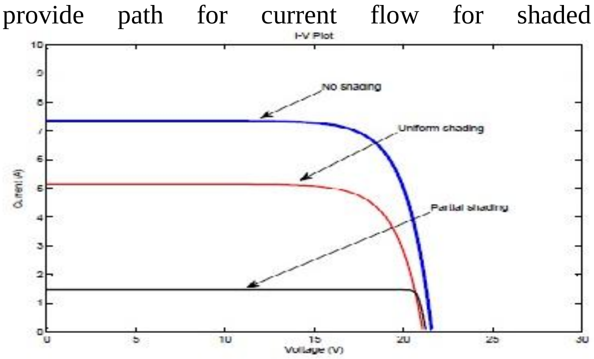


Fig. 12. I V plot for shading and partial shading

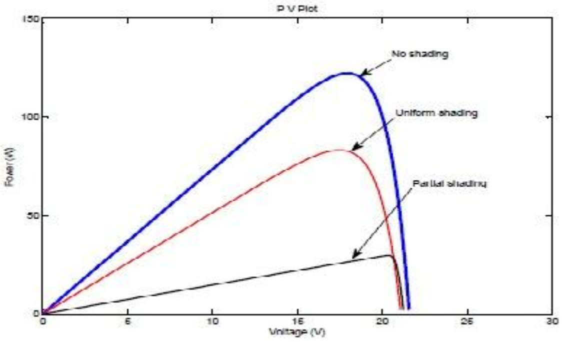


Fig. 12. P V plot for shading and partial shading

6. CONCLUSION

The paper explains the modeling of solar PV cell based on mathematical expression. The single diode model is used for modeling. The step by step simulation is performed using blocks present in library. All simulation work is done in Matlab/ Simulink environment. The 250 Watt solar PV module is simulated at STC for varying environmental condition and simulation result is verified by reference PV module. The simulation results validate the proposed model. The effect of partial shading without bypass diode is discussed. The simulation results show that current is reduced in very large amount due to partial shading. Methods to prevent losses from partial shading are mentioned.

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