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Photovoltaic Device Modeling and Effect of its Parameters

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Abstract

Today, due to the excessive use of fossil fuels environmental contamination has reached a crisis. Use of renewable and clean energy for a better life and the replacement of to be ending fossil fuels are essential. Photovoltaic has grown in the past two decades and will have many benefits in the future; hence it is necessary to know the influence of each parameter. This paper examined all of the PV parameters and used a simulated model to predict the PV electrical behavior against changing various parameters. At first the ideal and practical models are described then for simulation and by using MATLAB software, different amounts of resistance, sun irradiation, temperature and parameters of the diode, are considered as input and the I-V and P-V are considered as output.

Keywords: Photovoltaic, equivalent circuit, the characteristic curve, MATLAB.

Introduction

Renewable energy is undoubtedly an important part of life in the future constitute. These energy sources have increased rapidly all due to environmental conditions, pollution, rising temperatures around the Earth and to be ending fossil fuels[1-7]. Renewable energy has many advantages, including being free, producing no pollution, sending out no emissions or noise. Photovoltaic is one of the means that has widely grown in the past two decades, and its panels has been made, installed and used with different capacities. Good reliability and low maintenance costs are some of its advantages[8]. Photovoltaic receives solar irradiation and without any pollution directly converts it into electrical energy. Electrical energy produced by the PV terminal can directly load the small DC loads without the need of converters; however, many equipments need the convertor to use PV produced energy. The produced voltage is about 0.5 to 0.8 volts which is dependent on cell semiconductor technology[9]. PV output voltage and current has a nonlinear relationship. Physical structure of PV is shown in figure 1:

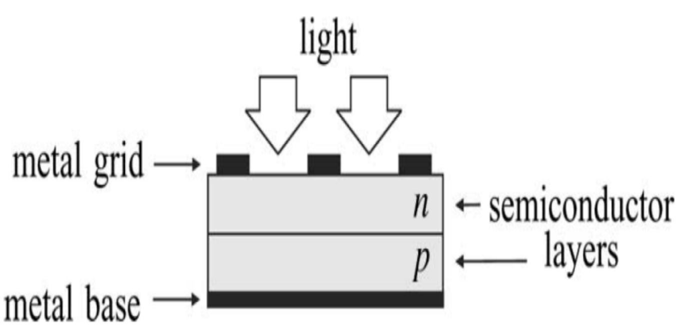


Figure-1
Physical structure of PV cell

Model of PV cell

There are several models to describe the behavior of the PV model, the ideal model including: the general model, the appropriate model (without the parallel resistance), and the models with two and three diodes. All of the practical models consisted of diode, resistance and DC current source. Changes in any of these parameters impact on the non-linear I-V and P-V characteristic curve. This section describes the general mathematical PV model but before that, familiarization with the relevant equivalent circuit of an ideal model is useful.

The ideal PV model: The simplest equivalent circuit for the PV cell is the ideal equivalent circuit where a current source in parallel with a diode is placed. The model is presented in figure 2[10]:

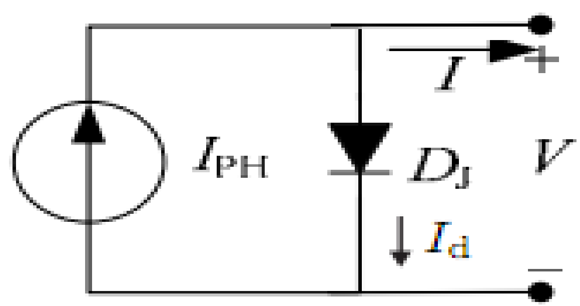


Figure- 2
Ideal PV cell

Since this circuit is ideal there is no resistance in it. Mathematical equation describing it is as follow:

$$I = I_{ph} - I_s\left[\exp\left(\frac{qV}{NkT}\right) - 1\right] \quad (1)$$

The I-V curve is shown in figure 3:

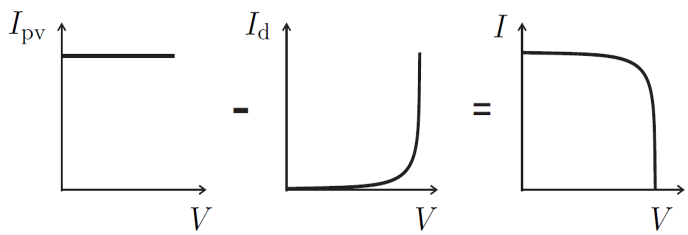


Figure-3
I-V curve

General model: In practice there is always resistance so the ideal model is not a practical model. General and practical model for PV which has been studied many times in the past two decades is shown in Figure 4[11]:

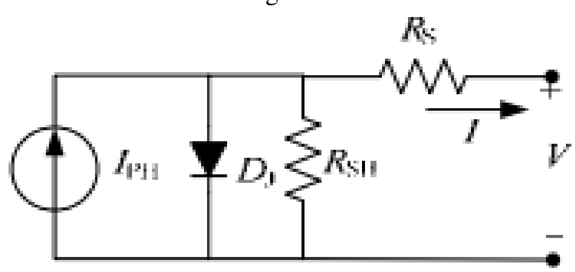


Figure- 4
General model

The mathematical equation is as follow:

$$I = I_{ph} - I_s\left[\exp\left(\frac{q.(V+IR_s)}{NkT}\right) - 1\right] - \frac{(V+IR_s)}{R_{sh}} \quad (2)$$

A number of authors have used an Additional diode in the models for their goals[12-16]. With this additional diode a section is added to equation (2), thus this equation must be rewritten. PV behavior is described by five parameters. Series and parallel resistance represent losses in PV, The parallel resistance is typically large and doesn't have significant effect on the behavior of I-V and P-V characteristics, that's why some authors to have simple model ignore this resistance [17-26]. I_s and N are parameters associated with the diode model. I_{PH} is dependent on the solar irradiation and the equation is as follow:

$$I_{PH} = (I_{sc} + K_I \Delta T)\frac{G}{1000} \quad (3)$$

Where: $\Delta T = (T - T_n)$ (4)

T_n is the reference temperature, and T is the temperature of the PV cells. Diode reverse saturation current is described by equation 5:

$$I_s(T) = I_s\left(\frac{T}{T_n}\right)^3 \exp\left[\frac{E_g}{V_t}\left(\frac{T}{T_n} - 1\right)\right] \quad (5)$$

V_t is called the thermal voltage. Mathematical formula which shows a thermal voltage is given below:

$$V_t = kT/q \quad (6)$$

Simulation Results

To perform the required simulations the MATLAB software has been used. The results of the simulation for practical model described in the previous section, is presented in this part. The schema of the simulated model by MATLAB software in figure 5 and main parameters and environmental conditions that have been considered in the simulation are presented in the following table:

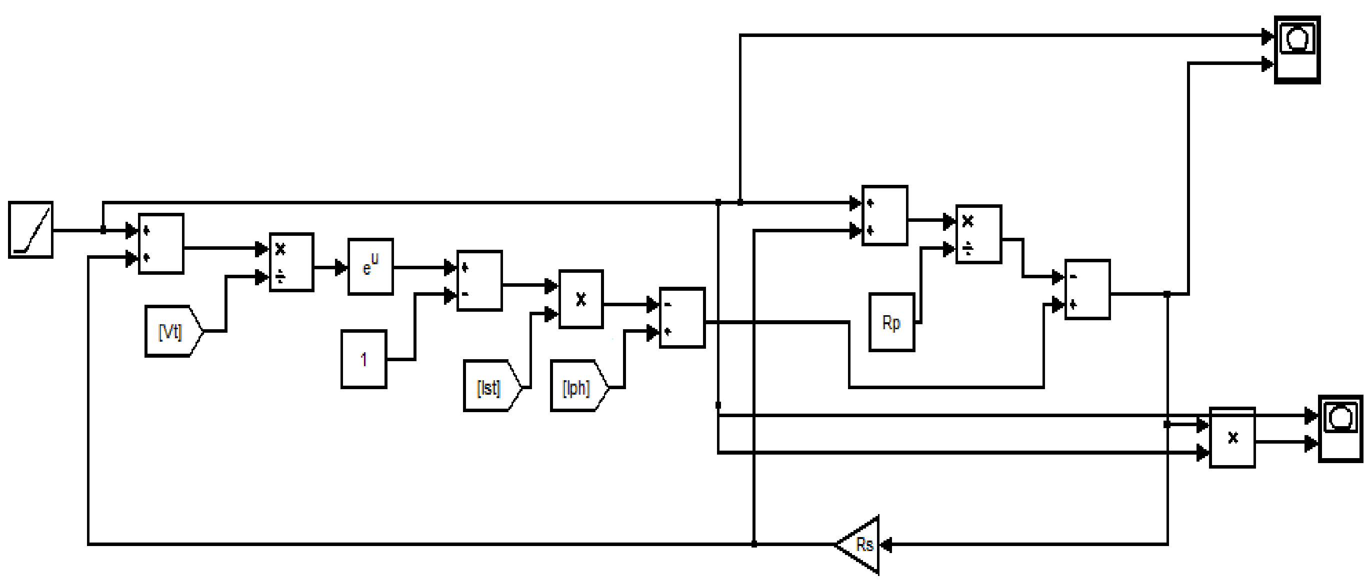


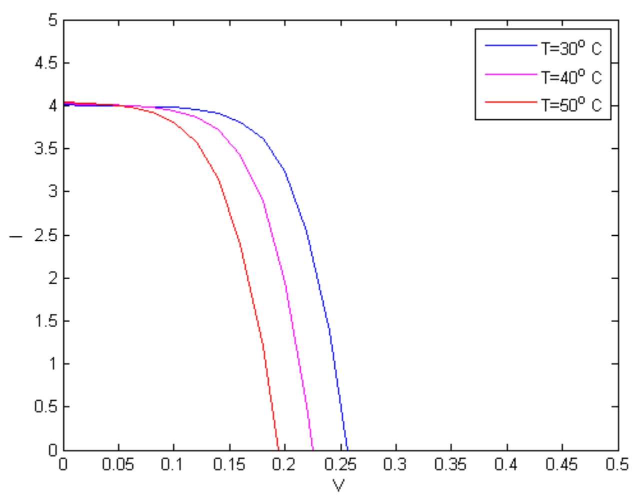
Figure -5
Simulation model

Table **Main parameters and environmental condition**

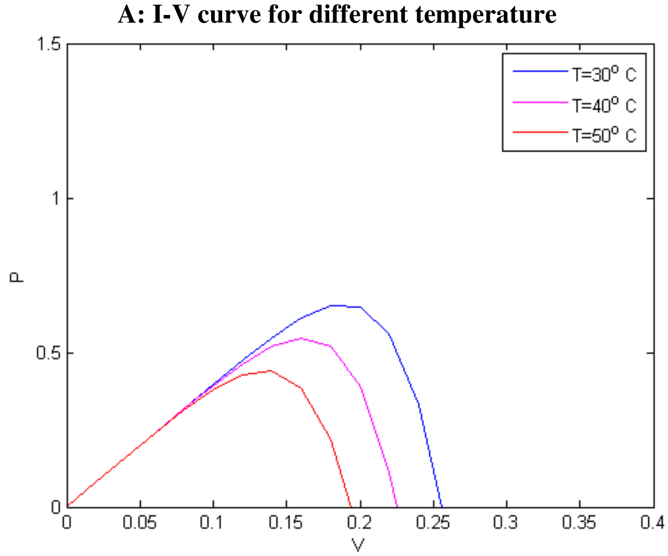
R_p	0.004 Ω
R_s	10 Ω
N	1
I_s	100µA
T	40°C
Sun irradiation	1000 w/m^2

Effect of Temperature

Figure 6 shows the Effect of temperature on I-V and P-V curve.



A: I-V curve for different temperature

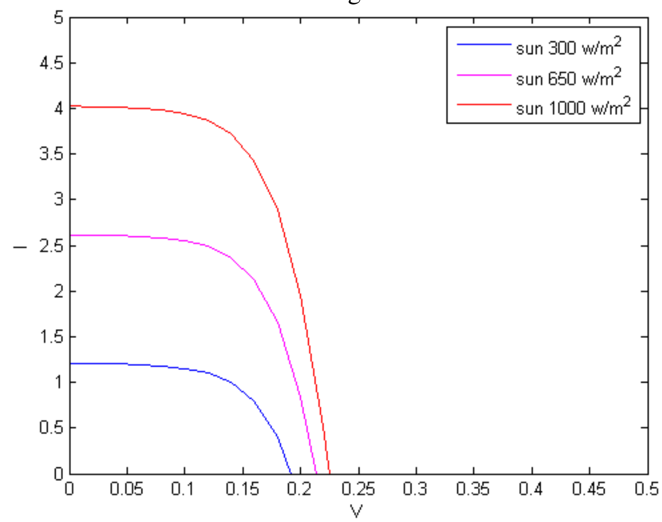


B: P-V curve for different temperature
Figure- 6
Effect of different temperature

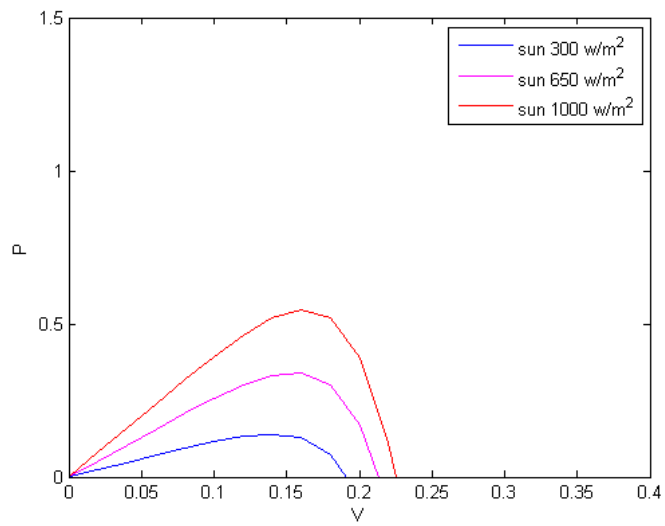
From figure 6 (a) it is clear that with the increase of temperature, voltage drops and also current has very little changes and with changes in the temperature stays about the same amount of 4 A. Figure 6 (b) also shows that if the temperature rises, the amount of power will be reduced.

Effect of Sun Irradiation

The effect of the sun irradiation changes on the PV characteristic curve is shown in figure 7:



A: I-V curve for different solar irradiation

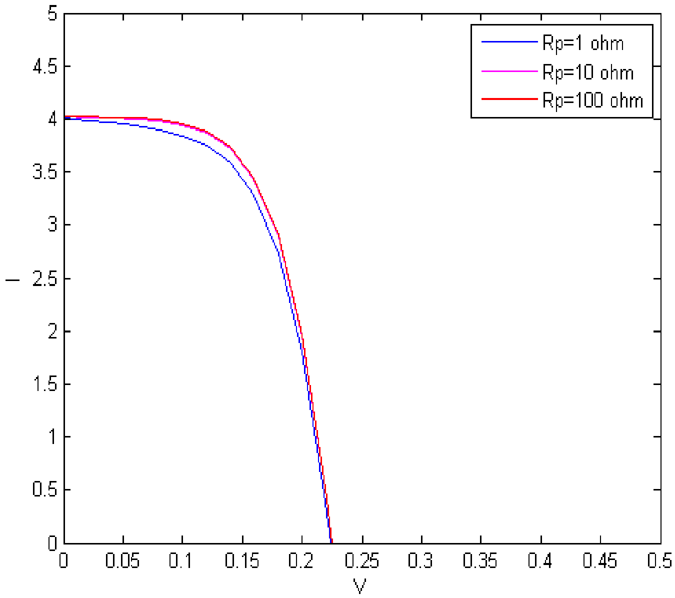


B: P-V curve for different solar irradiation
Figure- 7
Effect of different solar irradiation

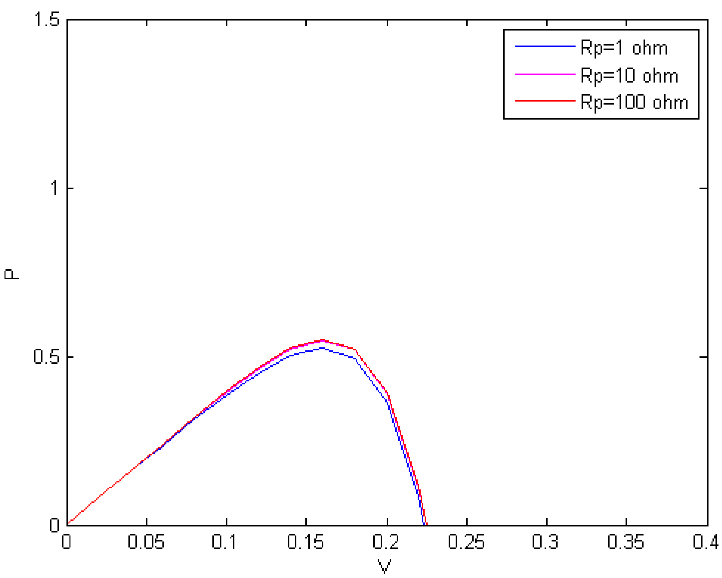
The above I-V curve shows the effect of changes on the sun irradiation on current is very high and it is more than the voltage, with the increase of sun irradiation, the amount of voltage and current value increases in which the latter is much greater. PV curve indicates the fact that the power will also increase with increasing sun irradiation.

Effect of Parallel resistance

The value of this resistance is generally high, and as mentioned, some authors do not consider it. The results of the effect of three different values for this parameter on the behavior of the PV cell are shown in figure 8:



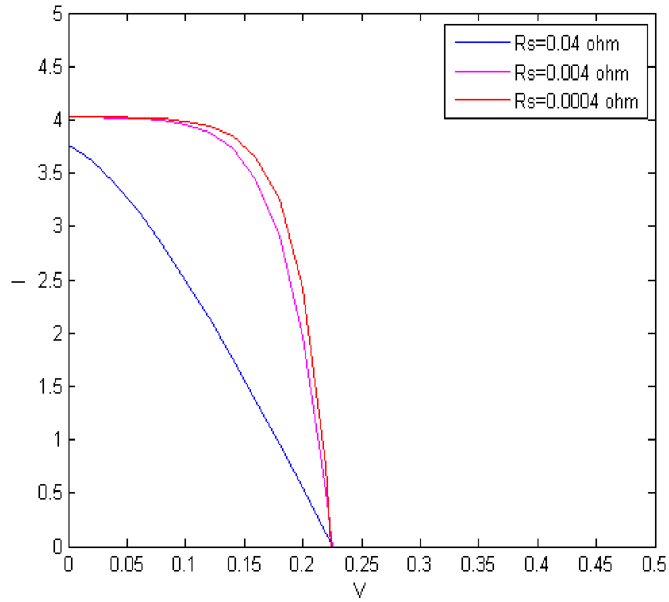
A: I-V curve for different shunt resistor



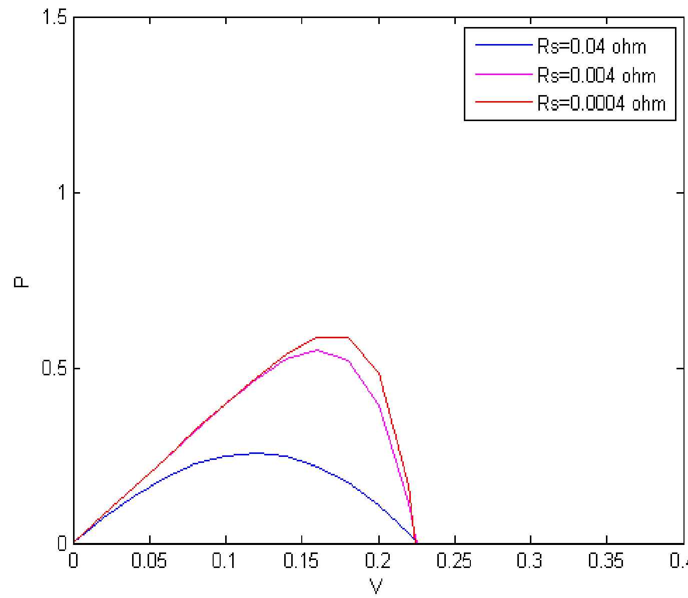
B: P-V curve for different shunt resistor

Figure -8

Effect of shunt resistor



A: I-V curve for different series resistor



B: P-V curve for different series resistor

Figure- 9

Effect of series resistor

Parallel resistance value has little effect on of I-V and P-V curves. As figure 8 shows the change of resistance has a very low effect on power, so, removing it to have a simple model does not have much impact on the characteristic curve of PV cells, and makes it possible to ignore it when performing simulations.

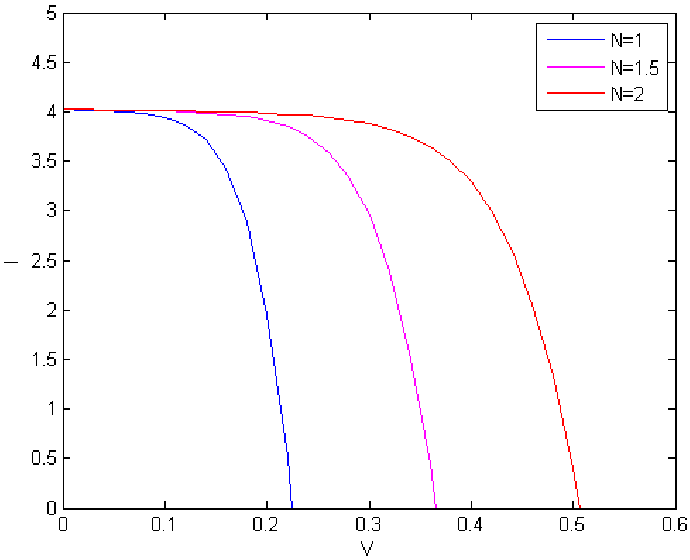
Effect of Series Resistance

Simulations have been performed for three values of series resistance. The results of I-V and P-V curves for variations of these parameters are given in figure 9:

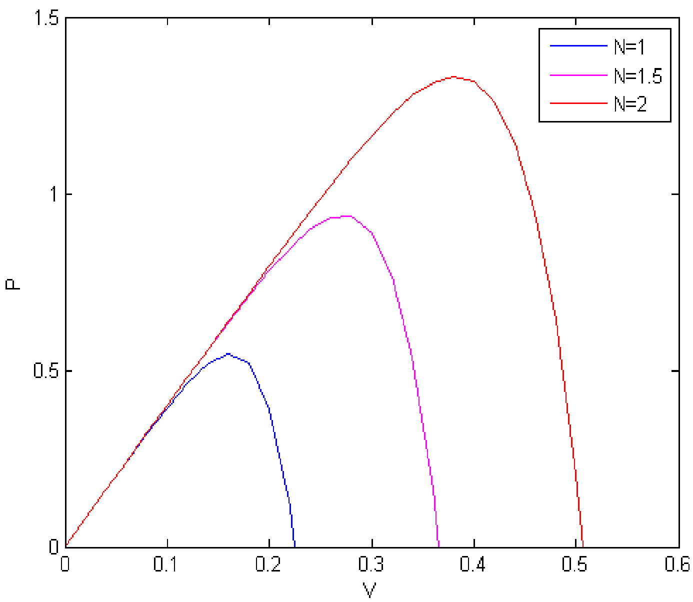
Changes in the series resistance have a great effect on the PV behavior. The resistance has great impact on the I-V curve slope, shown in figure 9 (a) and as figure 9 (b) shows, when the series resistance value is increased, the amount of power will reduce dramatically.

Effect of ideality factor of the diode

One of the parameters that are associated with the diode is the ideality factor. The changes of I-V and P-V curves for three different values of the diode ideality factor (N) are respectively 1, 1.5 and 2 shown in figure 10:



A: I-V curve for different diode ideality constant



B: P-V curve for different diode ideality constant

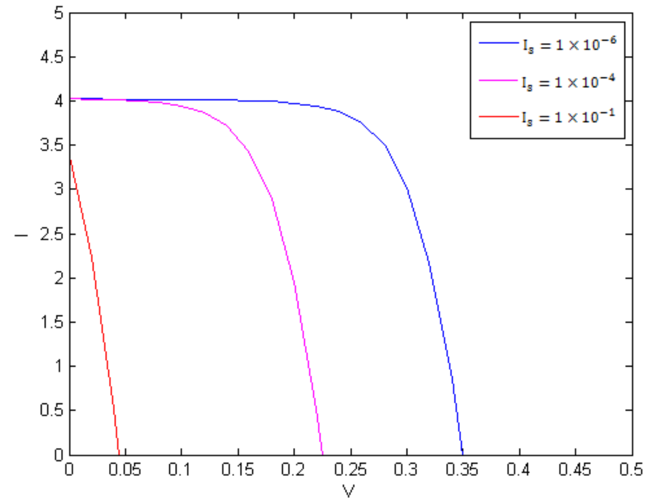
Figure -10

Effect of diode ideality constant

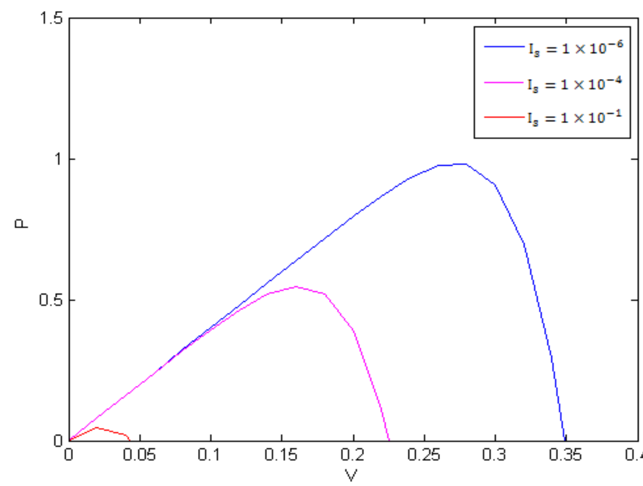
Part (A) of figure 10 shows increasing the diode ideality factor results in the increasing the value of voltage meanwhile value of current is near the 4 A. Figure 10 (b) also shows that by increasing the diode ideality factor, power has significant increase.

Effect of reverse saturation current of diode

Another parameter associated with the diode, is reverse saturation current. Effects of changing diode reverse saturation current with three different values on the PV curves are presented in figure 11:



A: I-V curve for different reverse saturation current of diode



B: P-V curve for different reverse saturation current of diode

Figure -11

Effect of reverse saturation current of diode

Figure 11 shows that the less the value reverse saturation current, the more the voltage, and also PV curve shows that the power will increase.

Conclusion

This paper examined all of the PV parameters to have an appropriate model to simulations and predict the behavior of the PV electrical changes in the various parameters. Different amounts of resistance, sun irradiation, temperature and parameters of the diode, are considered as input and the I-V and P-V are considered as output. Increasing temperature yields decreasing voltage and power and by increasing sun irradiation the voltage and current values and also power will increase. Parallel resistance has no significant effect on PV characteristics and it can be ignored and increasing the series resistance results in the decreasing the power. By increasing the diode ideality factor power is increased while by increasing the amount of reverse saturation current, power will reduce. Now, by knowing the information in this paper the behavior of a PV can be described in different conditions.

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