A MATLAB Based Modelling of Solar Photovoltaic (P-V) Cell to predict its basic key Behaviours

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Abstract: The Shortage of Electrical Energy is a worldwide major concern issue. the day–by–day increasing in electrical energy utilization leading to major crisis. The Promising Solution to the current world's energy crisis is generating Electrical Energy from the sunlight. A solar cell, which converts Solar energy into Electrical Energy, must be more reliable and economical to compete with the available traditional resources. In this work, the basics of photovoltaic (PV) cells, operation and the working principle of the PV cell, the major physical properties of PV cell materials, the prospects and the significance of gallium arsenide (GaAs) in solar technology and some mathematical analysis of P-Nn junction solar cells. In addition to this, the paper projects the standard model of solar cells, I-V and P-V Characteristics Investigations, solar radiance etc.,

Keywords- Solar cell; solar radiation; PV array; temperature; MATLAB; mathematical Model; maximum power point.

INTRODUCTION

The generation of Electrical Energy through Renewable energy is a great solution as well as the green solution to solve these Energy Crisis phenomena. Solar Energy is pollution-free, highly reliable, and durable, renewable energy source. Among various solar technology, the photovoltaic array (PV) has been making positive attention due to its capability of energy conversion without intermediate thermal process

Solar PV generates Direct Current (DC) using the Principle of Semiconductor PN Junction Diode. The Solar Cells are made of Semiconductor materials that have very weekly bonded electrons occupying the valence band. When an external energy is applied to a valence electron (greater than threshold energy), the bonds of valence electron are broken and electron is free to move to another energy band named conduction band. The band gap separates the free electrons from conduction band to valence band. Photons which are particle of lights supplied the energy to free the electrons

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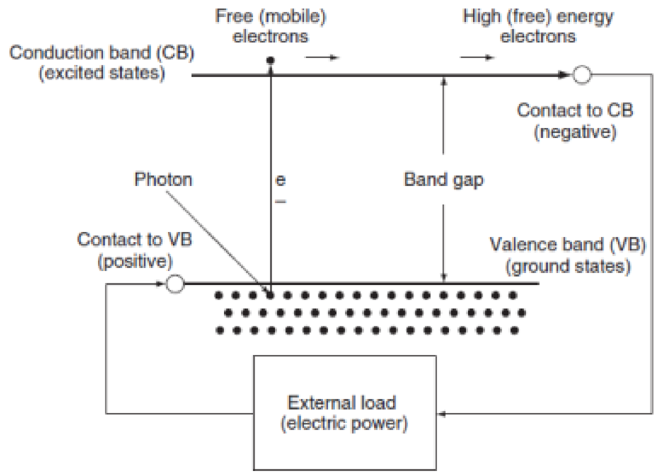


Fig. 1. Solar P-V Cell – Valance Band

Solar P-V Cell:

The Working Principle of Solar P-V Cells

A Photovoltaic (PV) cell plays the key part of a solar energy generation system in which sunlight is converted to electrical energy. The solar cell is a PN Diode, where N-type refers to the negatively charged electrons donated by donor impurity atoms and P-type refers to the positively charged holes created by acceptor impurity atoms Figure 2 shows the basics of a PV structure.

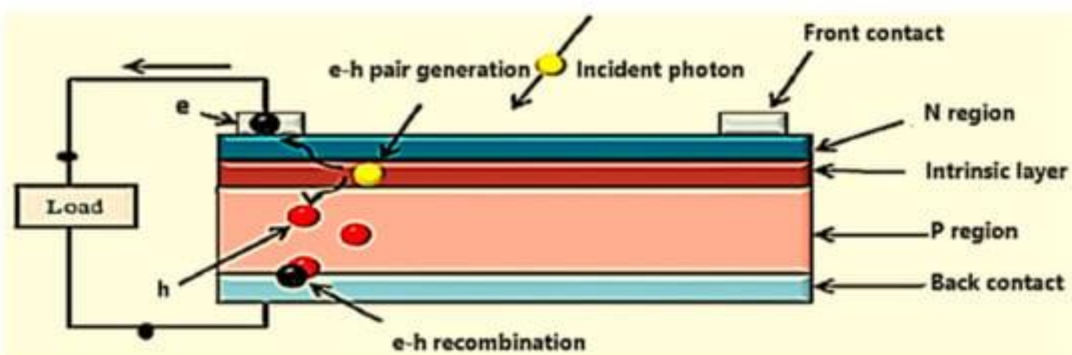


Fig. 2. Solar Cell

Solar P-V cell models:

A common analytical model is the single-diode equivalent circuit model. The Single-diode model is based on the modified Shockley diode equation adding a diode quality factor to account for the effect of recombination in the space-charge region. Particularly inaccurate

in describing cell behavior at low illuminations.

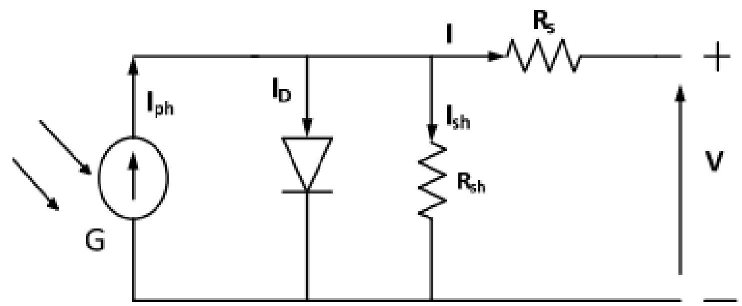


Fig. 3 Solar Cell Equivalent One-Diode Model

By applying KCL, to fig 1.1, we get, $I_{ph} = I_D + I_{sh} + I$ and $I_{sh} = V_{sh} / R_{sh}$

A space charge recombination Effect is taken into consideration in Double-diode models. This Double – diode Model is the proper way of understanding the solar-cell behavior than single-diode models.

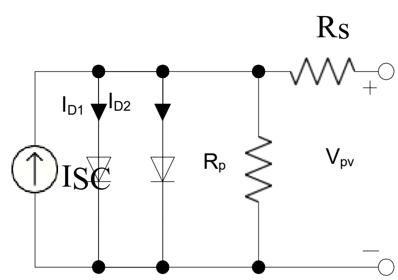


Fig. 4 Solar Cell Equivalent Two-Diode Model

However, these circuit models are based on certain hypothesis that may not always be valid:

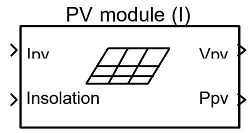
- material parameters are supposed to be insensitive to changes in either bias or illumination.
- minority-carrier concentrations at the edges of the space-charge regions are supposed to bedependent on the junction bias and independent of illumination

Considering these two suppositions to be true, the current flowing through the cell can be hypothesized to be a superposition of two currents, one due to junction bias and the other due to illumination.

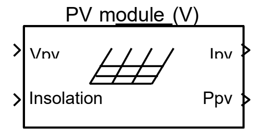
But this hypothesis may not be accurate. However, the models generally fit experimental I-V characteristics quite accurately and provide a useful tool to characterize the solar-cell performance if their parameters can be determined simply and rapidly, associating them to manufacturing process parameters.

Colorado model

Colorado model uses One-Diode Model.



PV



PV

(a) Current-input PV module (b)Voltage-input PV module

Fig. 5 Colorado PV module model

The model consists of the following I/O:

Current-input module model		Voltage-input module model	
Inputs	Output	Inputs	Output
PV current I_{pv} [A]	PV voltage V_{pv} [V]	PV voltage V_{pv} [V]	PV current I_{pv} [A]
Insolation [W/m^2]	PV output power P_{pv} [W]	Insolation [W/m^2]	PV output power P_{pv} [W]

Table -1. Comparison of Current Input Module and Voltage Input Module

From the Above table, When the P-V Modules are connected in series, the Current - Input Module model is more suitable.

When the P- V Modules are connected in parallel, The Voltage – input module model is preferable.

Model parameters are the standard PV module data-sheet parameters:

- short-circuit current I_{SC}
- open-circuit voltage V_{OC}
- rated current I_R at maximum power point (MPP)
- rated voltage V_R at MPP

under standard test conditions (1kW/m^2, 1.5 AM, 25°C). A bypass diode (a single diode acrossthe entire module) can be included. Temperature effects are not modeled.

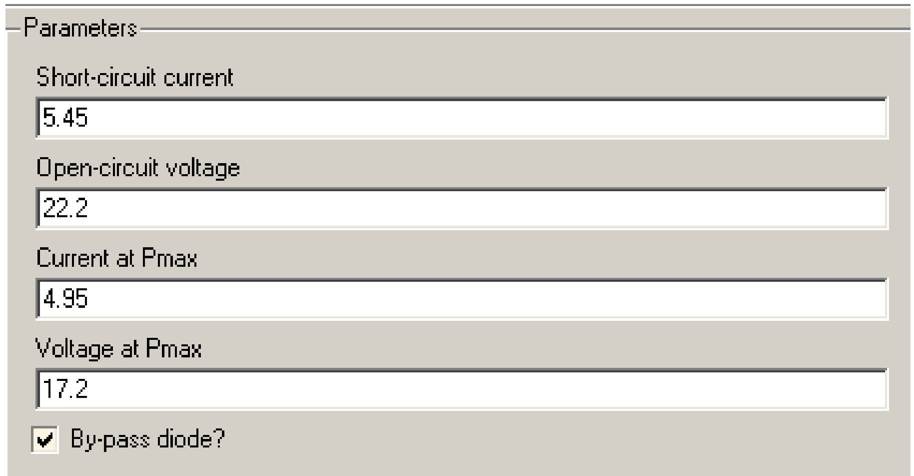


Fig. 6 Parameters of Colorado PV module model

Since Voltage-input PV module is modeled based on Current-input PV module model, as shownin Fig. 5, here will only discuss Current-input PV module model.

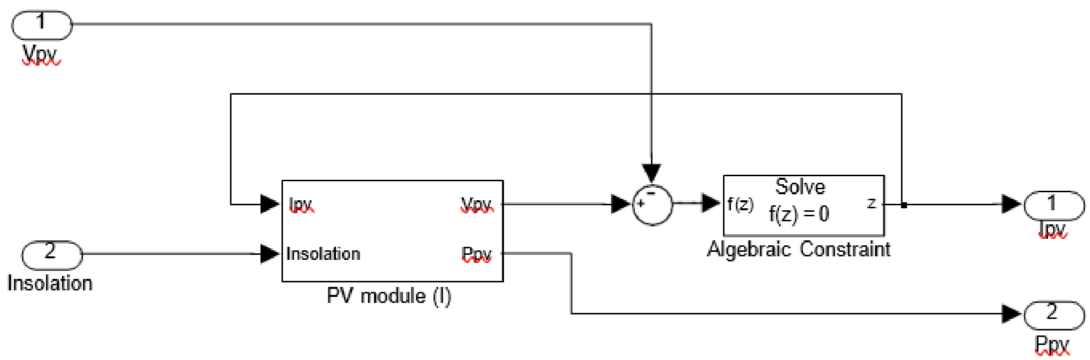


Fig.7 Colorado Voltage-input PV module model

Analysis of PV Solar Cell:

Analysis is by using the MATLAB Software to investigate the Maximum Power Point in different types of Environmental and Electrical Parameters. To perform this analysis we have used the data list of table 1. These data are based on 180 W ZED fabric mono-crystalline PV solar panel.

Parameters	Type/Value
Cell Technology	Si crystalline
Number of cells in series	72
Open circuit voltage (Total)	45 Volt
Short circuit current (Total)	5.25 Ampere
Voltage at maximum power	36.31 volt
Current at maximum power	4.98 ampere
Maximum system voltage	1000 volt
Maximum power	180 watt
Temperature coefficient	.0023 $V/^0$Celsius
Saturation current	1.6595 nA
Temperature range	-40^0C to 80^0C
Cell efficiency	15.2%
Module efficiency	15%
Standard test temperature	25^0C
Standard test radiation	1000 W/m^2

Table -2 – Parameters of PV Cell

A) Changes of I-V and P-V characteristics are plotted for the variation of temperature.

1) P-V characteristics:

For P-V analysis we have taken the value of radiation as fixed as G=1000 w/m^2 and the Temperature value is varied from T= 0^0 C to 40^0 C. From Figure 8 it is observed, that, for 0^0 C we have got the maximum output power, but at 40^0 C maximum power point is minimum than others. So we conclude that PV cell output power is highly dependent on Temperature variation.

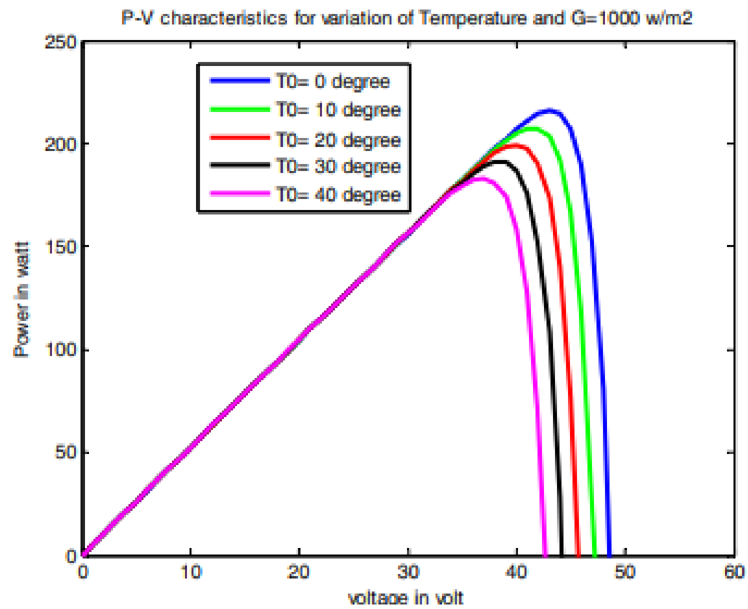


Fig.8. P-V Characteristics for temperature variation and G=1000 w/m^2

Suppose, we change the solar radiation condition to G=500 w/m^2 , then value of maximum power is almost half than the previous condition. The effect of solar radiation G=500 w/m^2 is shown in Figure 9.

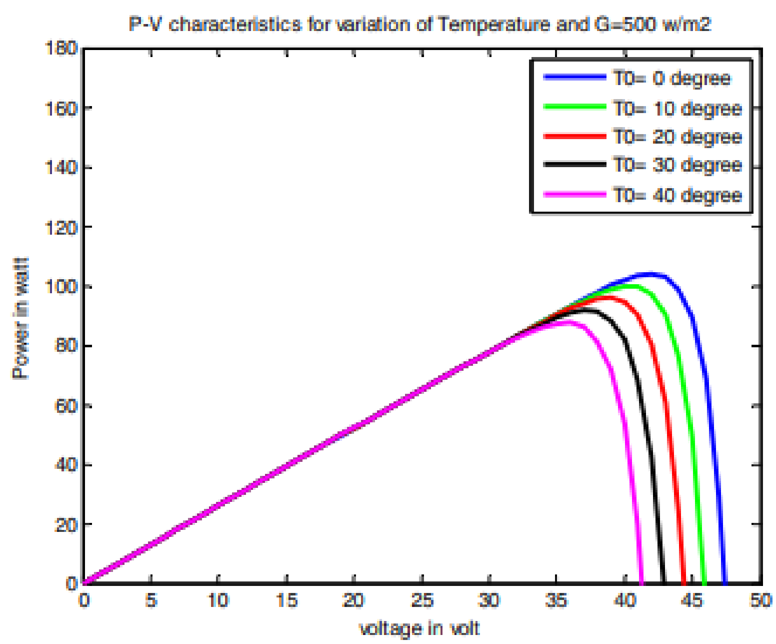


Fig.9 P-V Characteristics for temperature variation and G=5 00 w/m^2

2) I-V Characteristics:

I-V characteristics plays major role in verifying the device characteristics. The change in I-V characteristics with the variation of temperature is shown figure 10.

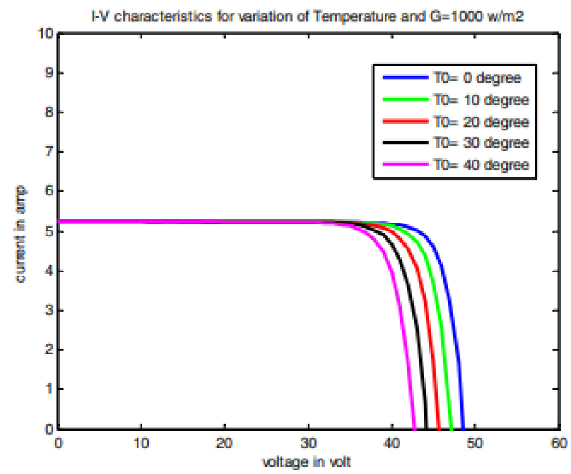


Fig. 10. I-V Characteristics for temperature variation and G=1000 w/m^2

If we half the value of solar radiation G from 1000 w/m2 to 500 w/m2 , corresponding value of maximum current is decreased from 5.5 to 2.75 ampere. Figure 11 shows the Variation of I-V characteristics with temperature.

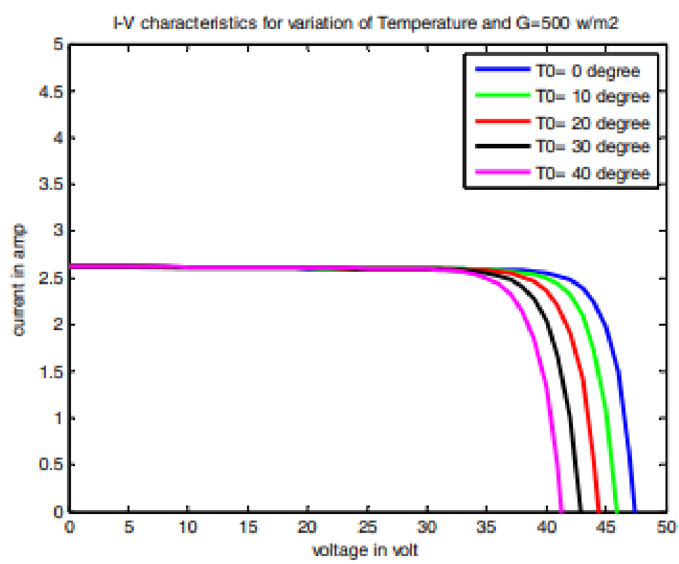


Fig. 11. I-V Characteristics for temperature variation and G=500 w/m^2

B) Effect of Variation of Radiation:

If we operate the solar cell with fixed radiation and increases the cell temperature, then the value of open cicuted Voltage (V_{oc}) decreases slightly but short circuit current (Isc) increases. These conditions are shown below.

1) **P-V characteristics:**
 We have taken the operating temperature T=30 degree and 45 degree. Then we made a comparison between the two effects

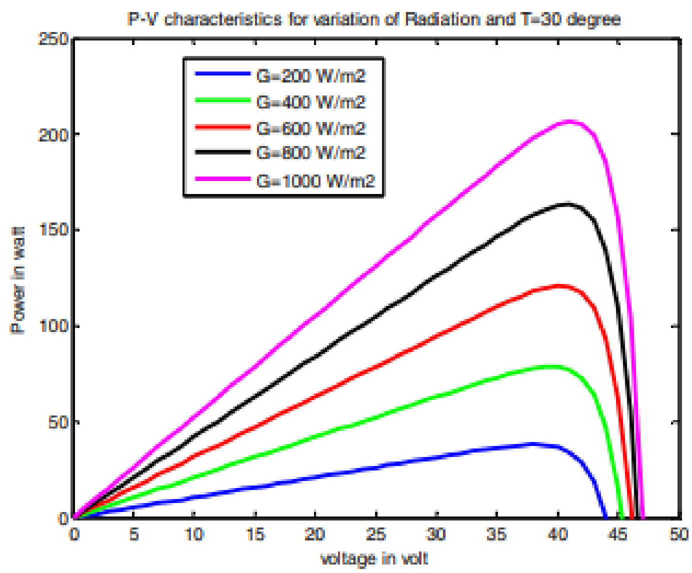


Fig. 12. P-V Characteristics for radiation variation and T=30^0 C

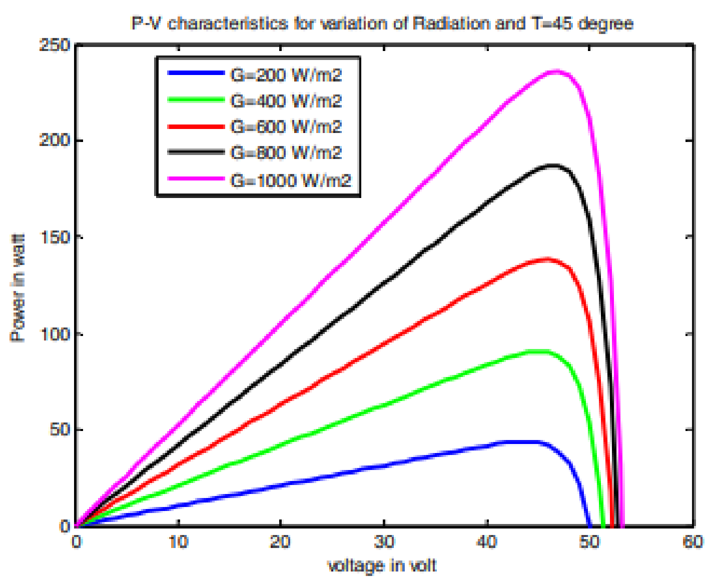


Fig. 13. P-V Characteristics for radiation variation and T=45^0 C

we can be predict, if we increase the temperature the maximum power point also increases at same solar radiation.

2) **I-V Characteristics**:

P-V cell current is highly dependent on solar radiation. That effect can be understood from the figure14 of I-V characteristics with the variation of radiation.

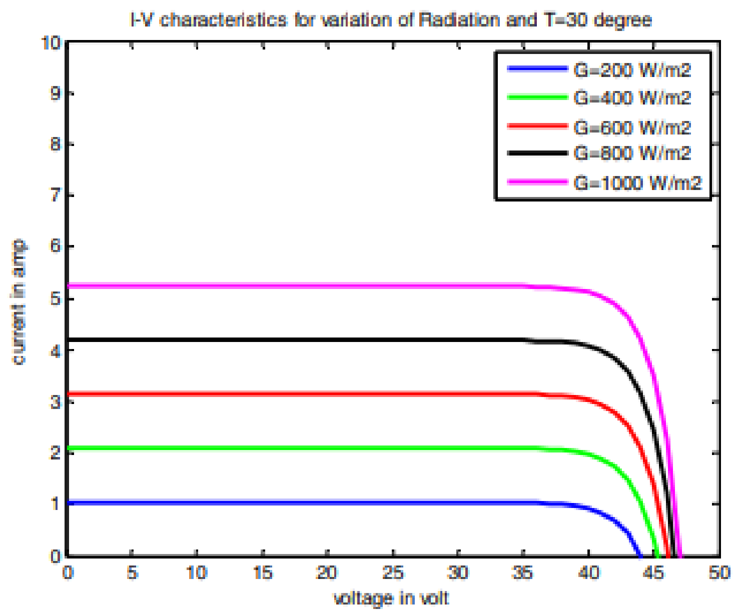


Fig. 14. I-V Characteristics for radiation variation and T=300 C

C) Effect of Variation of Shunt Resistance of equivalent solar cell model:

Shunt resistance has a significant property of the solar cell. Without selecting the proper value of shunt resistance, proper I-V and P-V characteristics will not be obtained.

1) **P-V Characteristics of solar cell:**

After observing the figure 15, we can conclude that, shunt resistance must be high for proper power output. If the value of shunt resistance is too small as Rsh=5 ohm or 10 ohm then the value of maximum power is not perfect. But if we increase the value of shunt resistance higher than 100 ohm, then we can get proper maximum power point.

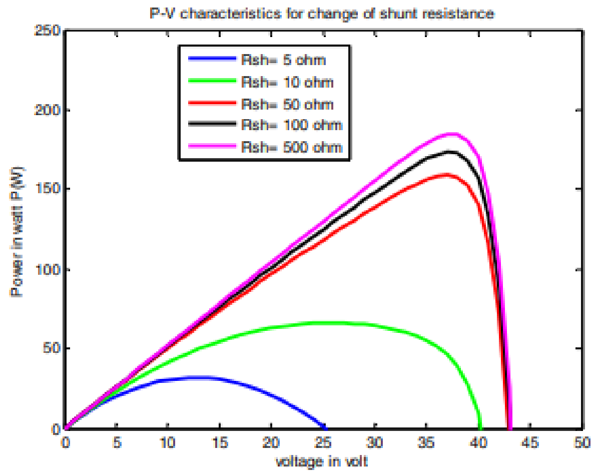


Fig. 15. P-V Characteristics for variation of shunt resistance of equivalent circuit of solar cell and G=1000 w/m^2 , T=30 degree

2) I-**V Characteristics of solar cell:**

Figure 16 gives us an idea how shunt resistance is important to design a proper solar cell model.

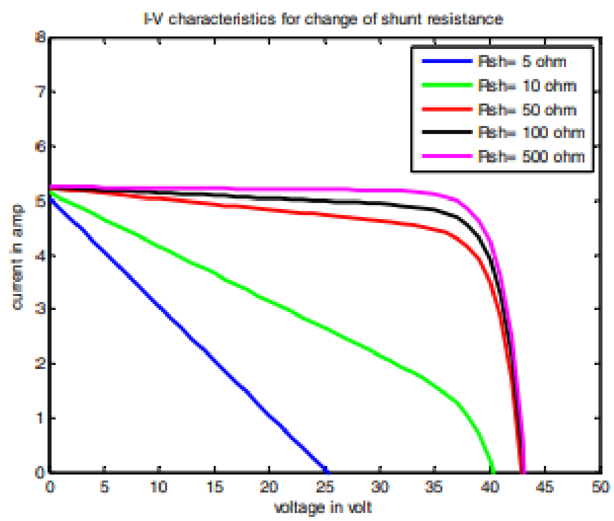


Fig. 16. I-V Characteristics for variation of shunt resistance of equivalent circuit of solar cell and G=1000 w/m^2 , T=30 degree

D) Effect of Variation of Ideality Factor of Diode:

In this section, we have analyzed the I-V and P-V characteristics of solar cell with the variation of ideality factor.

1) P-V characteristics:

After illustrating the following figure, we can see that, unity ideality factor is expected for modelling the PV cell with higher output

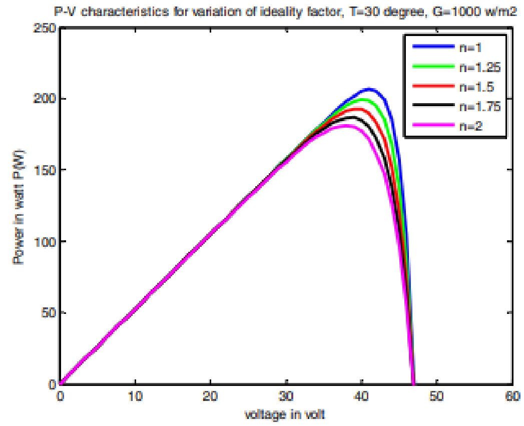


Fig. 17. P-V Characteristics for variation of ideality factor and G=1000 w/m^2 , T=30 degree

2) **I-V Characteristics:**

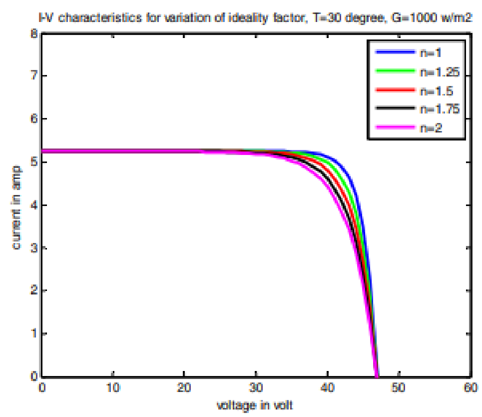


Fig. 18. I-V Characteristics for variation of ideality factor and G=1000 w/m^2 , T=30 degree

E) Effect of Variation of Series Resistance of equivalent solar cell model:

The Internal losses of the P-V Array can be signified by the Series resistance. By changing the series resistance value, we can predict the behavior of the P-V solar model. The simulation was performed with the value of series resistance 1mΩ, 5 mΩ, 10 mΩ, 20 mΩ and 50 mΩ.

1) **P-V characteristics of solar cell:**

By observing the P-V characteristics shown in figure 19, it can be found that lower value of Rs is suitable for design the PV model. Because we got maximum power output when Rs=1mΩ. 0 5 10 15 20 25 30 35 40 45 50 0 50 100 150 200 250 voltage in volt Power in watt.

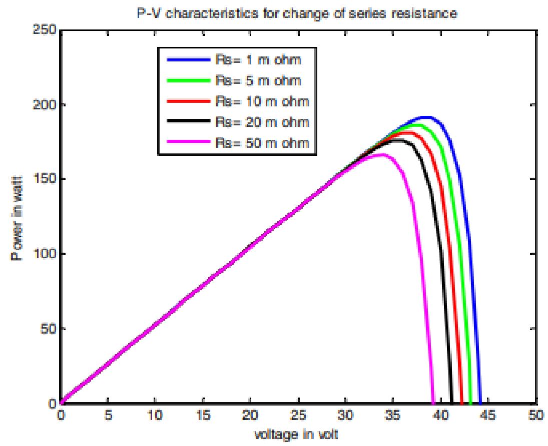


Fig. 19. P-V Characteristics for variation of series resistance

2) I-V characteristics of solar cell:

we need to apply negligible value of Rs for the PV cell design.

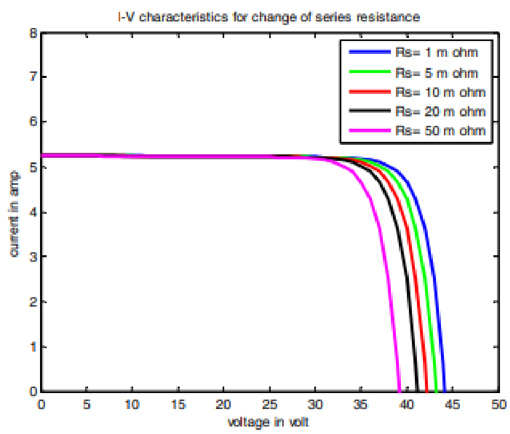


Fig. 20. I-V Characteristics for variation of series resistance

CONCLUSIONS

A generalized model of eco-friendly green power technologies was presented in this paper. An MTALAB Model of the Solar P- V cell was analyzed. In our analysis, the Temperature and Solar radiations were considered as environmental parameters while, series & shunt resistances, and reverse saturation current were considered as the electrical parameters. We found that Solar radiation and Temperatures were the two major factors to be considered while designing the P-V Array. The Maximum Power out is highly dependent on Solar radiation and Temperatures.

Similarly, it was found that the Electrical parameter such as Shunt resistance should be high and Series Resistance should be low for the proper output. Thus tis model predicts the behaviour of the solar P- V cells under Environmental and Electrical parameter changes.

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