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Simulation of Single-Diode Equivalent Model of Polycrystalline Silicon Solar Cells

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Abstract: A solar module is composed of photons of different energies, and some are absorbed at the p-n junction. A single-diode equivalent model is used to describe the electronic properties of solar cells. The theory as well as the construction and working of photovoltaic cells using single-diode method are also presented. So, choosing a electrical equivalent model can is based on area in which we would like to realize for study of solar cell characteristics. Parameters solar cell (Short-Circuit Current, Open-Circuit Voltage) are changed due to changing the light intensity and temperature. In the current paper we present the effect of temperature, series resistance and shunt resistance on the (P-V) characteristics simulated in Matlab/Simulink.

Keywords: Short-Circuit Current, Open-Circuit Voltage, Output Power, Solar Cells

1. Introduction

Studies of polycrystalline silicon are numerous especially through the technical development of characterization methods in order to raise the performance of solar cells made from this material [1-7]. The electrical energy produced by a solar cell at any time instant depends on its intrinsic properties and the incoming solar radiation [8, 9]. The solar cell is basically a semiconductor diode exposed to light. Solar cell parameters including: short-circuit current (I_{CC}), open-circuit voltage (V_{OC}), efficiency, series resistance (R_S) and shunt resistance (R_{Sh}) could be changed due to light intensity and temperature variations [10-13]. Thus modeling of PV cell is vital for solar energy system. The diode based PV cell modeling has gained considerable attraction due to the graphical interface of software's like Matlab/Simulink family which assist in simulation of these models. In the current paper we present the effect of temperature, series resistance and shunt resistance on the (P-V) characteristics simulated in Matlab/Simulink.

2. Theory

The single-diode model [14, 15], which is derived from physical principles and represented by the following circuit:

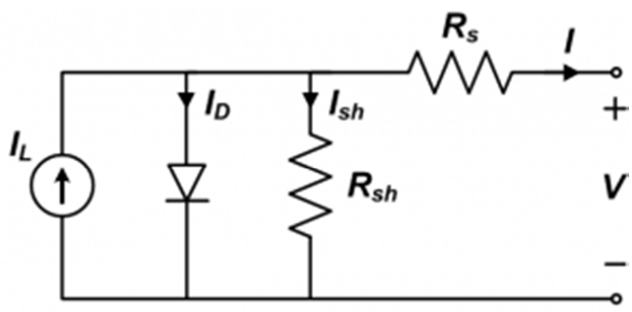

Figure 1. *Equivalent model of single-diode.*

The governing equation for this equivalent circuit is formulated using Kirchoff's current law for current [16, 17]:

$$I = I_L - I_D - I_{sh}$$

Where I_L represents the light-generated current in the cell,

I_D represents the voltage-dependent current lost to recombination, and I_{sh} represents the current lost due to shunt resistances. I_D is modeled using the Shockley equation for an ideal diode:

$$I_D = I_0 \left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1\right]$$

Where n is the diode ideality factor, I_0 is the saturation current. The thermal voltage given by:

$$V_T = \frac{kT_0}{q}$$

Where k is Boltzmann's constant.
Here, the shunt current as:

$$I_{sh} = \frac{(V + IR_s)}{R_{sh}}$$

And combining this and the above equations results in the complete governing equation for the single-diode model:

$$I = I_L - I_0 \left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1\right] - \frac{(V + IR_s)}{R_{sh}}$$

Five parameters in this equation are primary to all single-diode models:
I_L: light current (A); I_0: diode reverse saturation current (A); R_S: series resistance (Ω); R_{sh}: shunt resistance (Ω); n: diode ideality factor.
The output power is given by:

$$P = V\left(I_L - I_0 \left[\exp\left(\frac{V + IR_s}{nV_T}\right) - 1\right] - \frac{(V + IR_s)}{R_{sh}}\right)$$

3. Results and Discussion

Figure 2 shows (P-V) characteristics for varying temperature T. It is observed that as temperature increases cell current also increases slightly and cell voltage shows significant decrease in its value. From the curve, it can be noted that the temperature has a negligible effect on the short circuit current. In constant irradiation the open circuit voltage V_{OC} decreases with temperature. High temperature lowers the V_{OC} and short circuit I_{CC} current increases with temperature. This increase is much less than the voltage drops. The influence of temperature on the I_{CC} can be neglected in the majority of cases.

Figure 3 and Figure 4 are showing (P-V) characteristics of solar cell through which we can locate its peak i.e. maximum power point with respective voltages for varying irradiance and temperature respectively.

Most solar cells, which are quite large compared to conventional diode, we will usually exhibit near-ideal behavior ($n \approx 1$).

The variable resistances are connected as a load. By varying the resistance from the open circuit voltage to the short circuit voltage, the corresponding current and power are recorded to plot the (P-V) characteristics curve.

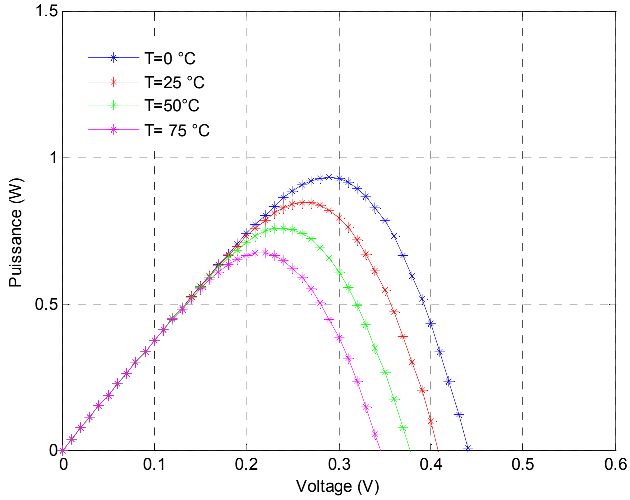

Figure 2. *Effect of temperatures on (P-V) characteristics of polycrystalline silicon solar cell.*

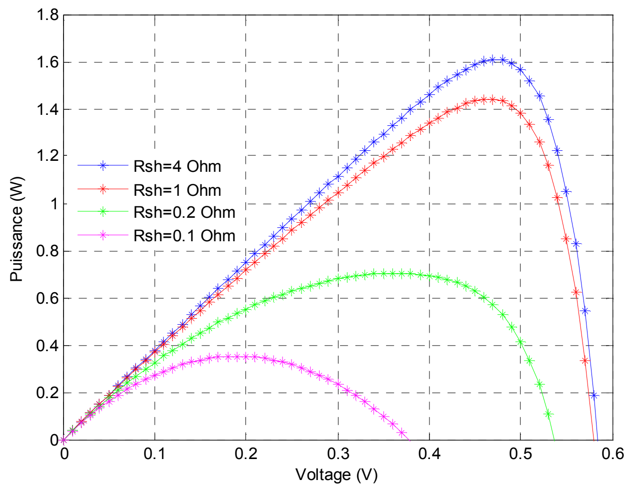

Figure 3. *Effect of variation in shunt resistance on (P-V) characteristics of polycrystalline silicon solar cell.*

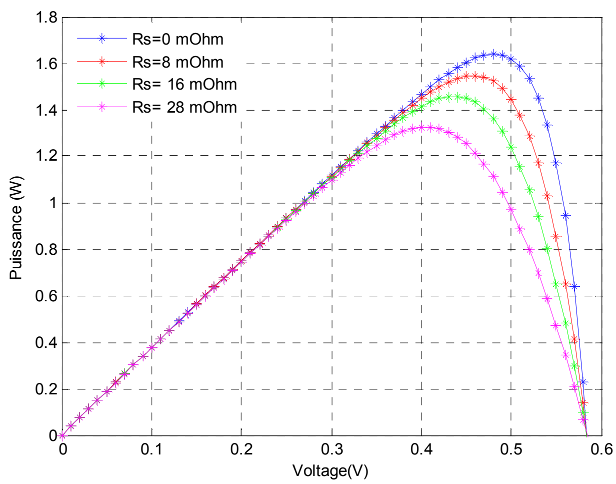

Figure 4. *Effect of variation in series resistance on (P-V) characteristics of polycrystalline silicon solar cell.*

We can observe the effect of shunt resistance variation as in Figure 3. We notice that the small value of R_{sh}. Thus the shunt resistance must be large, to increase output power. The voltage at maximum output power doesn't affect with change values of shunt resistance while that values not very small.

We can observe the effect of series resistance variation as in Figure 4. We notice that the large value of R_s. Thus the Series resistance must be low.

For power system planning purpose, single diode model is better as it will save time. But the characteristics of Solar cell at critical points two diode is more preferable [18].

4. Conclusion

In this paper we have studied the effect of temperature, series resistance and shunt resistance on the output power (P-V) characteristics simulated in Matlab / Simulink. However, trace the characteristics (P-V) needs of these three variables. Any change in the entries immediately implies changes in outputs. As the temperature increases, the output voltage decreases. We found that series resistance is proportional to the number of silicon solar cells in the panel.

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