Study of P-V and I-V Characteristics of Solar Cell in MATLAB/ Simulink

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Abstract

There are demanding applications of Solar Cells in recent times. More emphasis is given to upgrade the technology so as to get the maximum efficiency out of a module. In this paper, a MATLAB/Simulink model of a Solar Cell is designed by implementing the basic current equations. Various parameters are discussed and their effect on Solar Cell is plotted in the form of I-V and P-V curves. The Module can be made up of 36 Solar cells.

Key Words : MATLAB/Simulink, Solar Module, Solar Cell, I-V and P-V Curves, MPPT.

1.1 Introduction

The introduction of superior methods of renewable energy resources utilization in the 21\textsuperscript{st} century and the subsequent rapid advancement has led to more diverse applications of such resources particularly solar energy. Overall the usage of solar energy is increasing rapidly and have become a more essential contributor to the overall consumed energy particularly in domestic segment. The demand has been raised by 20\% to 25\% in the last 20 years [1]. The market
for PV systems is growing exponentially in recent times. In fact, solar PV provides around 4800 GW in between 2004 and 2009, grid connected PV capacity goes to 21 GW and was increasing at an average rate of 60% annually matching technological advancement in this sector [2]. The rapid usage of various fossil fuels has led to their deposit to be reduced and has drastically influenced the environment that results in depletion of the biosphere and effecting the global warming. Solar energy, which is available abundantly, it has made possible to harvest it and utilize it properly. Solar energy can either be a grid connected generating unit or a standalone generating unit depending upon the availability of a grid in the vicinity. Thus it can be used to supply power to the rural areas also where the grid power accessibility is low. Another benefit of using solar energy is the easy portability operation anywhere and whenever required. In order to handle current energy consumption scenario, effective techniques have to be developed to tap solar radiation energy efficiently and economically using Solar Modules [4].

The Solar Module basically consists of various solar cells (normally 32 or 72 cells). The working principle of solar cells is essentially similar that is photovoltaic effect. Generally, the photovoltaic effect is given as the generation of potential difference at the p-n junction when visible or other radiation comes to contact with it. The I-V and P-V curves of a solar module are of main importance since various techniques and algorithms are applied based on the analysis of these curves including Maximum Power Point Tracking (MPPT) [5]. The typical I-V and P-V curves are shown in figure 1.1.

![Fig.1.1 I-V and P-V Curves of Solar Cell/Module](image-url)
1.2 Methodology

The standard model of PV Cell is designed in this paper using MATLAB/Simulink software using equivalent circuit of a Solar PV cell. The equivalent circuit contains a current source, a Diode, a series resistor and a shunt resistor as shown in figure 1.2. The different I-V and P-V curves are studied by varying the parameters of the solar cell which are discussed in this paper later on.

![Fig.1.2. Equivalent Circuit diagram of Solar Cell](image)

It is essential to understand the electronic behavior of a solar cell and beneficial to design a model which is electrically equivalent, discrete electrical components based whose standard behavior is well known. An ideal solar cell could be modeled by a current source in parallel with a diode; in practical manner no solar cell is ideal, that’s why shunt resistance and a series resistance component are added to the model.

The characteristic equation of a solar cell is given by:

\[
I = I_{ph} - I_0 \left[ \exp\left(\frac{q}{n k T} (V + I R_s)\right) - 1 \right] - \frac{V + I R_s}{R_{sh}}
\]  

(1.1)

In this equation, \( I \) is the photoelectric, \( q \) is the charge of electron, \( I_0 \) is the reverse saturation current of the Diode, \( V \) is the voltage across the diode, \( T \) is the temperature at junction, \( n \) is the ideality factor of the diode, \( K \) is the Boltzmann’s constant, and \( R_s \) and \( R_{sh} \) are the series and shunt resistors of the PV cell, respectively.
1.3 Simulation Models

The Equation 1.1 is modeled in Simulink to plot the I-V and P-V curves. The Simulink model for the equation 1.1 is shown in figure 1.3. There are two subsystems in the model—one is of photocurrent and second is of reverse saturation current.

Fig.1.3. Simulink Model of Solar Cell

1.4 Results

The results are obtained by varying two main solar cell parameters as described below:

Effect of varying solar radiation
Solar radiation affects both photocurrent and open circuit voltage of solar cell as shown in figure 1.4. The effect on Power by changing the solar radiation is shown in figure 1.5.

**Fig.1.5. Effect of solar radiation on P-V Curve**

**Effect of varying Temperature**

The effect of varying cell temperature on I-V curve is shown in figure 1.6.
Fig. 1.6. Effect of temperature on I-V Curve

The effect of varying cell temperature on P-V curve is shown in figure 1.7.

Fig. 1.7. Effect of temperature on P-V Curve
1.5 Conclusion

After plotting the I-V and P-V curves of solar cell by varying two main parameters, it was found that the solar radiation directly affects the solar cell power and the open circuit voltage. The radiation values were changed in the range of 400 W/m$^2$ to 1000 W/m$^2$ and output current and voltage behaviors were observed. However, there is a noticeable effect on the photocurrent. Secondly, increase in temperature decreases the open circuit voltage of cell. The temperature is varied from 25°C to 42°C. The Maximum Power Point of solar cell array can also be traced using these curves.

It is concluded that these results are helpful to study the behavior of solar cell and the model can be upgraded to solar module (36 or 72 Solar Cells) and then several MPPT techniques can be applied to get the maximum efficiency out of solar module.

References


