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Analysis Of Mathematical Model Of PV Cell Module in Matlab/Simulink Environment

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ABSTRACT: The physical modeling of the system is not that much efficient so the analysis is done through the mathematical modeling approach. In this paper mathematical analysis is done for the single diode model. Single diode model is employed to investigate the I-V and P-V characteristics of 46 W module . The effect of irradiation and temperature is also considered. The analysis is done in MATLAB/SIMULINK environment. This mathematical analysis approach is a very flexible to change the parameters of the system.

Keywords: Solar Energy, Photo Voltaic Effect, MATLAB/SIMULINK, Characteristics of PV cell.

I. INTRODUCTION

Conventional energy sources are unable to meet the increasing demand for energy worldwide. So, alternative energy sources like sunlight, wind and biomass come into picture. In that context, photovoltaic energy is a source of interesting energy; it is renewable, inexhaustible and non-polluting, and it is used as energy sources in various applications[10] . But because of its high cost and low efficiency, energy contribution is less than other energy sources. It is therefore essential to have effective and flexible models, to enable you to perform easy manipulation of certain data (irradiance and temperature) investigate how to get its performance as maximum as possible.

The use of these simple models provides sufficient accuracy to analyse the behaviour of the solar cell and have proven to be effective in most cases. Solar cells convert solar energy into electrical energy. This phenomenon occurs in materials which have the property of capture photon and emit electrons. The main material used in the photovoltaic industry is silicon. For the better understanding of the PV module the mathematical model is continuously updated. The output characteristics are of PV module depends on

The solar Isolation.
The cell Temperature and
The Output Voltage of PV Module.

It is necessary to model the PV module for the design and simulation of Maximum power point tracking for PV system applications because it has non-linear characteristics. Mathematical modelling of the solar array (module) here is done mainly for obtaining the performance characteristics. The performance characteristics of PV module mainly depend on the operating conditions, they also depend on solar array design quality.

The output quantities (Voltage, current and power) very as a function of irradiation, temperature and load current. The effects of these three variations are considered in the modeling, so that any change in the temperature and solar irradiation levels should not adversely affect the PV module output. The Photo voltaic analysis model proposed in this paper is circuitry based model to be used with simulink. Here module is modelled and P-V & I-V characteristics are plotted for different irradiation(1000W/m2,600W/m2, 200W/m2) and for different temperatures(25^0 C, 50^0C and 75^0 C).

II. PV CELL MODELLING

For computer simulation of a physical system modeling should be done .It includes all the physical elements & all the parameters influencing the system.

In this modeling the physical system is converted to computer codes and characteristics are plotted. To describe the behaviour of the physical PV cell, the PV model is chosen by the researchers. Most commonly used model is a single diode model

The single diode model is as shown in Fig.1.

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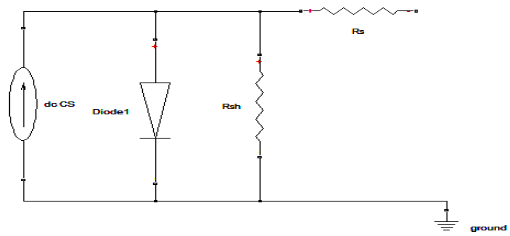

Figure1. Solar Cell Model.

Electron-hole pairs are created, when light falls at the junction and it provides an electrical current flow across the junction of constant rate. Then net current is calculated by considering difference between the normal current and light generated current. The internal series Resistance R_s is in series with the junction. It is mostly due to the high sheet Resistance of the diffused layer which is in series with the junction.
The light generated current is acted as a constant current source supplying the current to either the junction or a useful load depending on the junction characteristics and the value of the external load resistance. [7]

Module photo-current:

$$I_{ph} = [I_{SCr} + K_i(T - 298)] * \lambda / 1000 \qquad (1)$$

Module reverse saturation current – I_{rs}:

$$I_{rs} = \frac{I_{SCr}}{\left[\exp\left(\frac{QV_{oc}}{N_s kAT}\right) - 1\right]} \qquad (2)$$

The module saturation current I_0 varies with cell temp.

$$I_0 = I_{rs}\left[\frac{T}{T_r}\right]^3 \exp\left[\frac{q * E_{go}}{Bk}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}\right] \qquad (3)$$

The current output of PV module

$$I_{PV} = N_p * I_{ph} \quad N_p * I_0\left[\exp\left\{\frac{q*(V_{PV}+R_s)}{N_s AkT}\right\} \quad 1\right] \qquad (4)$$

The conversion of operating temperature into centigrade- Kelvin is done by using following equation:

$$T_{Rk} = 273 + 259(\text{Ref Temp}) \qquad (5)$$

$$T_{ak} = 273 + T_{op}(\text{operating temp}) \qquad (6)$$

The block diagram shown in Fig.2 is modelled by interconnecting all the blocks[1].The Blocks are derived from the above expressions.

II. REFERENCE MODEL

A 46 W PV module is taken as the reference module for simulation and the name-plate details are given in Table I below.

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TABLE I
ELECTRICAL CHARACTERISTICS DATA OF SOLAR 46W PV MODULE

Power Rated	37.08 W
V_{mp}	16.56 V
I_{mp}	2.25 A
V_{oc}	21.24 V
I_{SCr}	2.55 A
N_s	46
N_p	1

*Specifications : irradiance of 1kW/m2, spectrum of 1.5 air mass and cell temperature of 25^{0}C.(under test conditions)

A. Simulink Block Diagram

The block diagram of a 46W solar cell module is as shown in Fig.2.

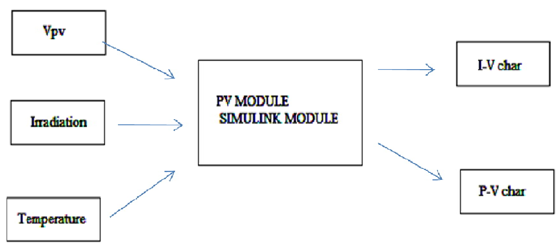

Figure 2.The Block diagram of a 46 W solar cell module.

Vpv → Triangular wave with max value of 21.24V.

Irradiation → at 0.2, 0.6, 1.0 in KW/m^2.

Temperature → at 25, 50, 75 in ^{0}C.

The repeating sequence is dragged into the Model and the amplitude of the triangular wave is given as:

Time as [0 2 4]
Output as [0 21.24 0]

For providing the irradiation and temperature signal Builder Block is selected and the required signal is selected with desired specifications as shown in Fig.3 & Fig.4.
The input constant irradiation is as shown in Fig.3 and similarly the input irradiations 600W/m^2 and 400W/m^2 are also considered.

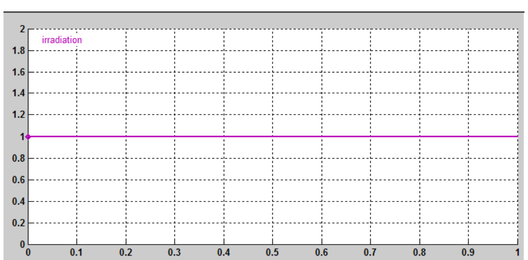

Figure 3. Input-constant irradiation(1000W/m^2).

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Input constant temperature is considered as shown in Fig.4 and similarly temperatures at 50^0C and 75^0 C are also considered.

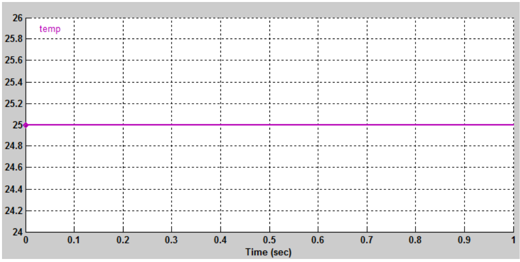

Figure 4. Input-Constant Temperature(25^0C).

The Fig.5 represents the various values of irradiation as a step signal and in the same we can consider the step signal for different temperatures by using the signal Builder.

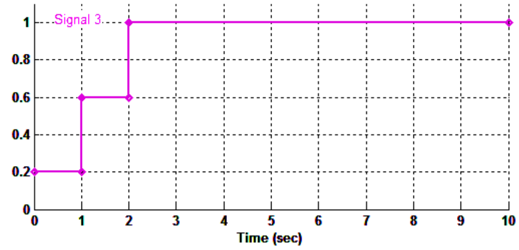

Figure 5. Step Irradiation for(0.2,0.6,1.0W/m^2).

B. PV Simulink Module:

The simulink model of a PV cell module is as shown in Fig.3.It is modelled by the (1),(2),(3)&(4) and I-V and P-V graphs are plotted as shown in Fig.7.& Fig.8. [8]

X-Y plotter is used to plot I-V and P-V characteristics

XY graph is plotted by Matlab code and is given below.
plot (Vpv,Ipv)
plot (Vpv, Ppv)

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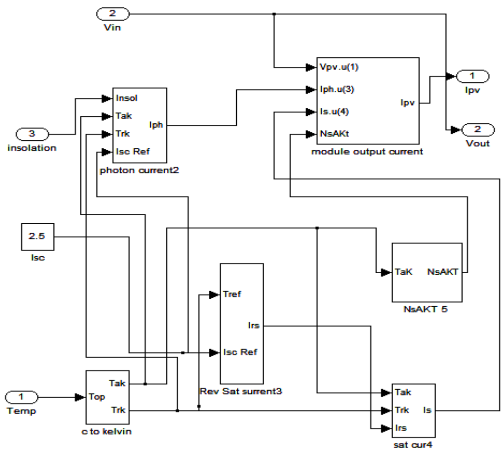

Figure6. The PV Cell Module Simulink Modeling.

The syntax for plotting scope signal given by

plot (tout,Ipv)

IV. RESULTS

The P-V characteristics are as shown in Fig.7 at constant irradiation 1000W/m^2 Fig.3 and at constant temperature 25^{0}C Fig.4

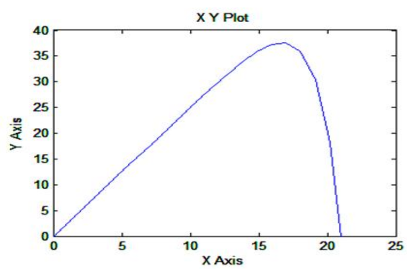

Figure.7 P-V Characteristics (Irradiation=1000W/m^2, Temp=25^{0}C).

For the voltage generated if we plot the power characteristics by considering power on y-axis and voltage on x-axis then the resultant curve is as shown.

The I-V characteristics are as shown in Fig.8 at constant irradiation 1000W/m^2 Fig.3 and at constant temperature 25^{0}C Fig.4.

Current and Voltage characteristics for the given value of irradiation , the voltage generation is taken on X-axis and current is taken on y-axis.

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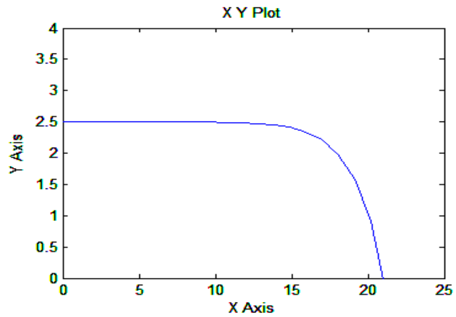

Figure 8. V-I characteristics(irradiation=1000W/m^2,Temp=25^0C).

The output power is as shown in the Fig.9 with respect to time. When we calculate the output power for different irradiations at different temperatures it is as shown below.

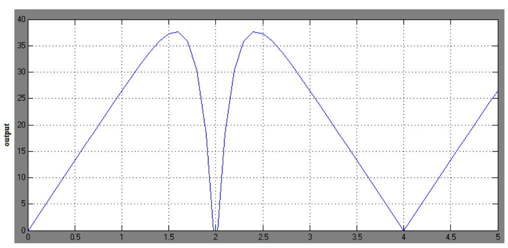

Figure 9. Output Power Vs Time.

V. CONCLUSION

The mathematical analysis of the single diode model is done. The I-V and P-V characteristics are verified for the 46W solar module for the constant Irradiation (1000W/m^2) and constant temperature (25^0C).

It is very difficult to change the parameters of the given module in the case of physical modeling. But by analysing the circuit with the help of mathematical model it is very convenient to verify required parameters just by changing values. Similarly the I_V and P-V characteristics are observed for different irradiations (600W/m^2, 200W/m^2) and different temperatures (50^0c and 75^0C).

NOMENCLATURE

Output Voltage PV Module = $\mathbf{V_{pv}}$ (V)
Output Current PV Module = $\mathbf{I_{pv}}$ (A)
Reference Temperature $\mathbf{T_r}$ = 298 K
Module Operating Temperature = **T** (K)
Light Generated Current of PV Module = $\mathbf{I_{ph}}$ (A)
PV Module Saturation Current = $\mathbf{I_o}$(A)
A = B is an Ideality Factor = 1.6
k is Boltzman Constant = 1.3805×10^{-23}J/K
q is Electron charge = 1.6×10^{-19} C
Series Resistance of a PV module = $\mathbf{R_s}$
PV Module Short-Circuit Current at 25^0C and 1000W/m^2 = $\mathbf{I_{SCr}}$ = 2.55A
Short-Circuit Current Temperature Co-efficient at I_{SCr} = $\mathbf{K_i}$ = 0.0017A / ^{o}C
PV Module Illumination (W/m^2) =λ =1000W/m^2
Band gap for silicon = $\mathbf{E_{go}}$ = 1.1 ev

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No. of cells connected in series **=** $\mathbf{N_s}$ =1
No. of cells connected in parallel. = $\mathbf{N_p}$ = 46

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