Performance of Mono-Crystalline Photo-voltaic Cell on the Variations of Irradiance

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Abstract*- In this paper, simulation of photovoltaic module using Matlab Simulink approach is presented. The method is used to determine the characteristics of PV module in various conditions especially in different level of irradiations by having different values of irradiations , the results showed the output power, voltage and current of PV module can be determined. In addition, all results from Matlab Simulink are verified with the data sheet of 60 Cells Mono Somera Ultima Silver 1500 V Series by Vikram Solar. This proposed model helps in better understanding of PV module characteristics in different level of irradiations by having different values of irradiations.*

Keywords- Solar photovoltaic (SPV), standard test condition (STC), mathematical model, modeling; PV module; PV characteristic; simulink/matlab.

I. INTRODUCTION

Alternative energies become popular because of reservation of fossil fuel dwindling and the global warming effect. The most significance of alternative energies is solar energy. There are two types of technology that employed solar energy, namely solar thermal and solar cell. In this paper, the solar cell technology is used. A PV cell (solar cell) converts the sunlight into the electrical energy by the photovoltaic effect. Energy from PV modules offers several advantages, such as, requirement of little maintenance and no environmental pollution. A PV module typically consists of a number of PV cells in series. The conventional technique to model a PV cell is to study the p-n junction physics. A PV cell has a non-linear voltage-current (V-I) characteristic which can be modeled using current sources, diode(s) and resistors. Single-diode and double-diode models are widely used to simulate PV characteristics. The single-diode model emulates the PV characteristics fairly and accurately. The manufacturer provides information about the electrical characteristics of PV by specifying certain points in its V-I characteristics which are called remarkable points.

In this paper, a simplified PV equivalent circuit with a diode (The single-diode model) equivalent as model is proposed. The main contribution of this work is the implementation of a generalized PV model with Matlab/simulation.

II. MATHEMATICAL MODEL OF PHOTO VOLTAIC MODULE

A solar cell is basically a p-n I junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect. Being exposed to the sunlight, photons with energy greater than the band-gap energy of the semiconductor creates some electron-hole pairs proportional to the incident irradiation. The equivalent circuit of a Mono-Crystalline PV Cell is shown in figure 1. This model is known as a single diode model of solar cell. The current source I_{ph} represents the cell photo-current. R_{Sh} and R_S are the intrinsic shunt and series resistances of the cell respectively. Usually the value of R_{Sh} is very large and that of R_S is very small, hence they may be neglected to simplify the analysis.

The mono-crystalline PV panel can be modeled mathematically as given (1)-(4) below:

$$I_{ph} = [I_{SC} + K_i(T_C - T_R)) * \frac{S}{1000} \quad (1)$$

$$I_{rs} = I_{SC}/[\exp\left(\frac{qV_{oc}}{N_s kAT}\right) - 1] \quad (2)$$

$$I_S = I_{rs}[\frac{T_C}{T_R}]^3 \exp\left(\frac{qE_g}{kA(\frac{1}{T_R} - \frac{1}{T_C})}\right) \quad (3)$$

$$I_{pv} = N_p * I_{ph} - N_p * I_S[\exp\left(\frac{qV_{Pv} + I_{Pv}R_S}{N_s kAT}\right) - 1] \quad (4)$$

Where,

$I_{ph} = photo\ \ current$

$I_{rs} = reverse\ saturation\ current$

$I_S = Saturation\ current$

$I_{pv} = output\ current$

$N_p\ = No.of\ parallel\ branches$
$in\ the\ Mono\ Crystalline\ PV\ Cell$

A = Diode Ideality Factor

k = Boltzmann's Constant $= 1.3805 \times 10^{-23}\ J/K$

Ki = Short Circuit Temperature Coefficient $mA/^{\circ}C$

N_S = Number of Cells Connected in series

q = Magnitude of Charge on the Electron $= 1.6 \times 10^{-19}\ C$

R_S = Series Resistance (Ω)

R_{Sh} = Shunt Resistance (Ω)

S = Solar irradiation Intensity $(W/m2)$

T_C = Working Cell Temperature (K)

T_R = The Reference Temperature $= 298\ K$

V_{oc} = Open Circuit Voltage (V)

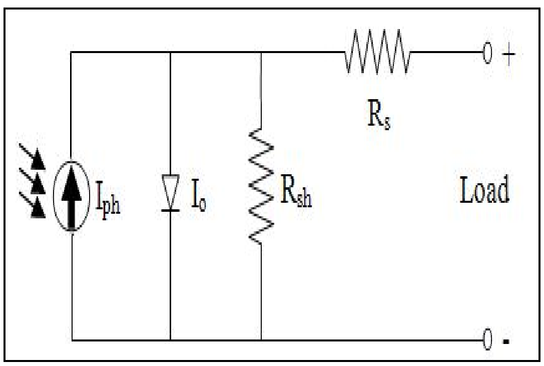

Figure 1. Equivalent circuit of PV cell.

III. REFERENCE MODEL

60 Cells Mono Somera Ultima Silver 1500 V Series by Vikram Solar is taken as the reference model for simulation and above equations are simulated. The data sheet is given in Table I below:

Table 1. Datasheet at STC: 1000 W/m^2 irradiance, 25°C cell temperature

Parameters	Values
Peak Power	280 W
Open Circuit Voltage	39.5 V
Short Circuit Current	9.24 A
Temp. Coeff.. for Short Circuit Current	0.00053
NOCT	45°C ± 2°C

IV. SIMULINK MODEL FOR MONO-CRYSTALLINE PV CELL

A generalized PV model is built using Matlab/Simulink according to Equations (1) to (4). Solar module [60 Cells Mono Somera Ultima Silver 1500 V Series by Vikram Solar] was taken as a reference for simulation input parameters. The proposed model is implemented using Matlab/Simulink along with PV & I-V characteristics.

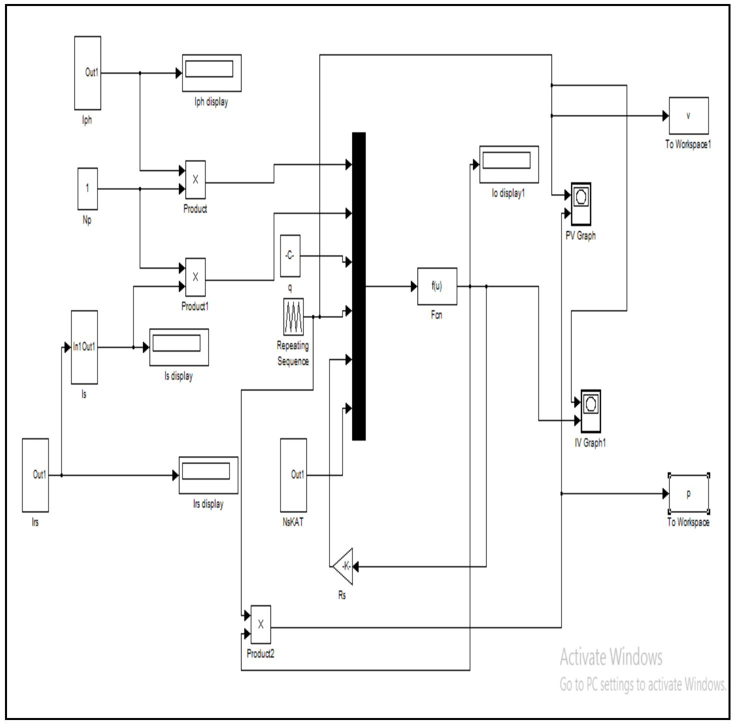

Figure 2. Simulink model

V. SIMULATION RESULTS

Here in this paper PV & I-V Graphs have been plotted by varying irradiance parameter. The PV & I-V graphs are plotted at irradiance G=1000 W/m^2 as shown in figure-3 & 4.

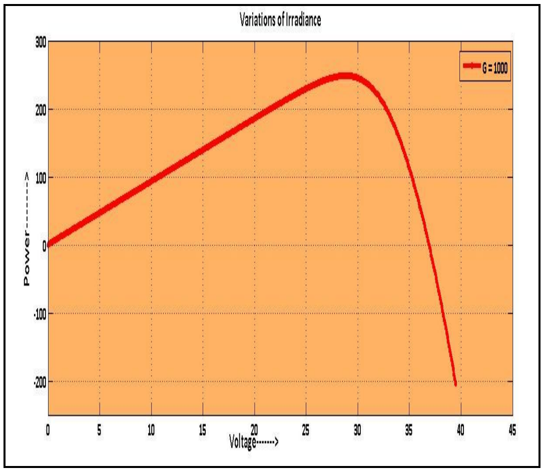

Figure 3. PV Graph for Irradiance G=1000 W/m^2

At G=1000 irradiance, the maximum power is 247.66 watt in figure-3 and the maximum current is 9.24 Ampere as shown in figure-4.

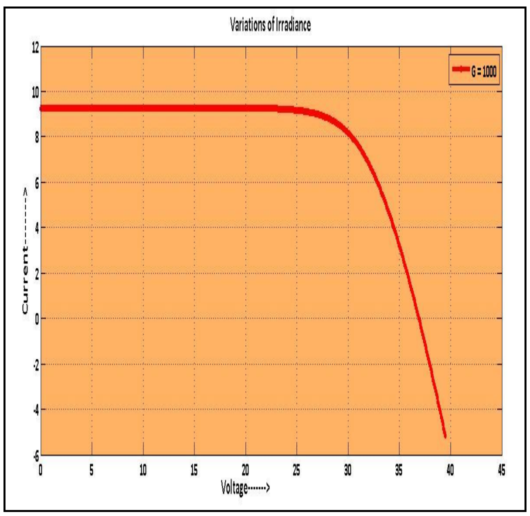

Figure 4. I-V Graph for Irradiance G=1000 W/m^2

Now figures 5 & 6 show the PV& IV Graph on decreasing the value of irradiance to G=800 W/m^2 as shown in figure 5 & 6. At G=800 irradiance, the maximum power is 198.66 watt in figure 5 and the maximum current is 7.40 Ampere as shown in figure 6.

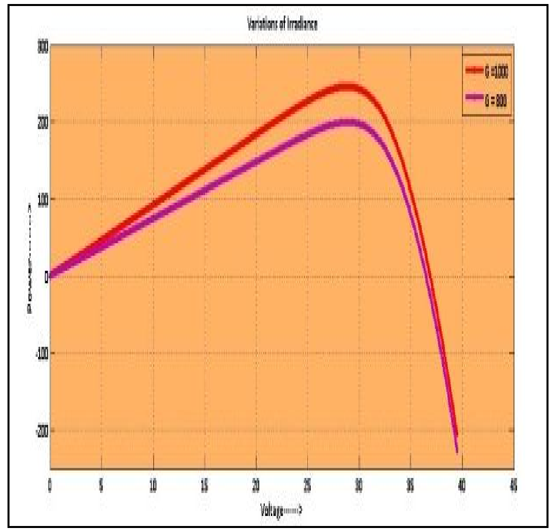

Figure 5. PV Graph for Irradiance G=800 W/m^2

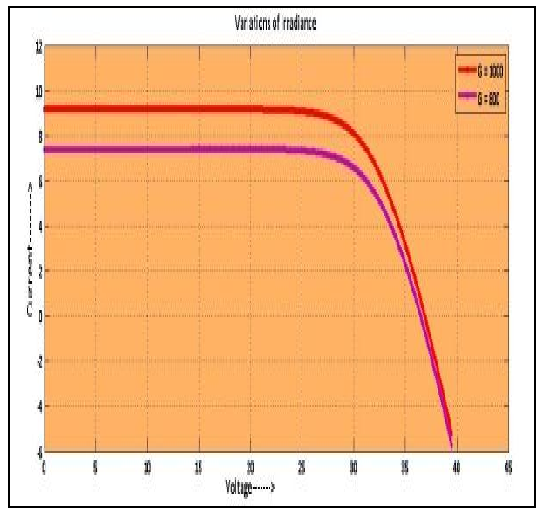

Figure 6. I-V Graph for Irradiance G=800 W/m^2

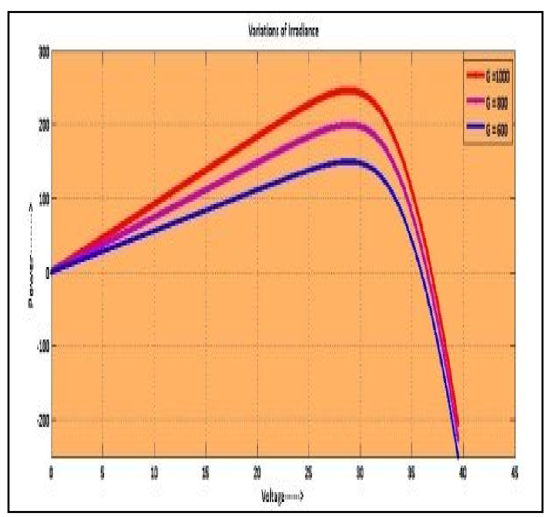

Figure 7. PV Graph for Irradiance G=600 W/m^2

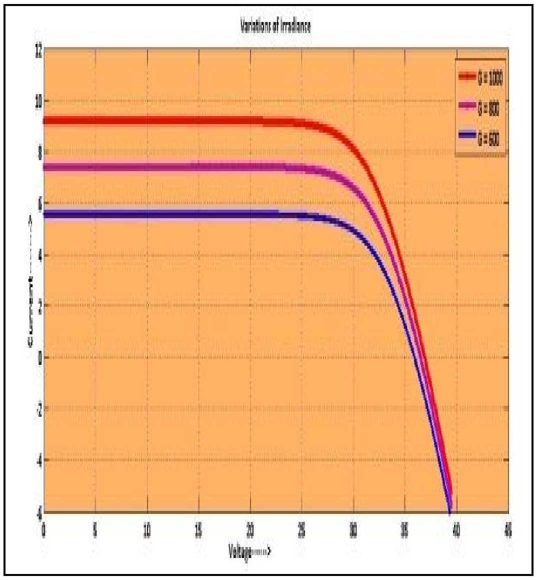

Figure 8. I-V Graph for Irradiance G=600 W/m^2

Figures 7 & 8 show the PV & I-V Graph on decreasing the value of irradiance to G=600 W/m^2 as shown in figure 7 & 8. At G=600 irradiance, the maximum power is 149.66 watt in figure 7 and the maximum current is 5.55 Ampere as shown in figure 8.

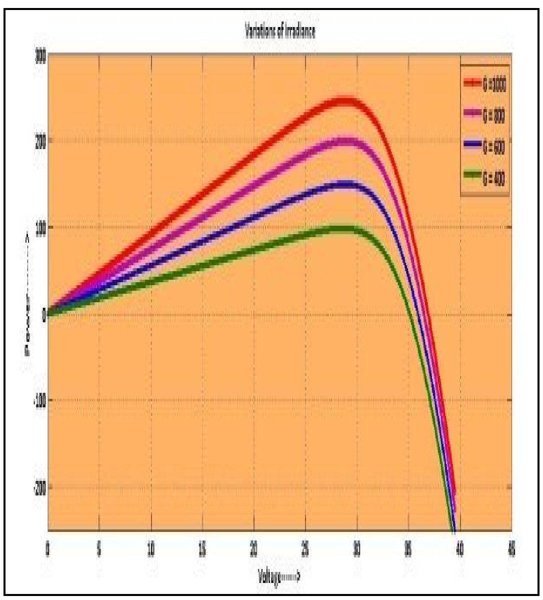

Figure 9. PV Graph for Irradiance G=400 W/m^2

In the last, figures 9 & 10 show the PV & I-V Graph on decreasing the value of irradiance to G=400 W/m^2 as shown in figure 9 & 10. At G=400 irradiance, the maximum power is 98.66 watt in figure 9 and the maximum current is 3.70 Ampere as shown in figure 10. The different values of maximum power and maximum current are also shown in tabular form in Table II, at irradiance G= 1000,800,600 and 400 W/m^2 , 25°C cell temperature ,at STC.

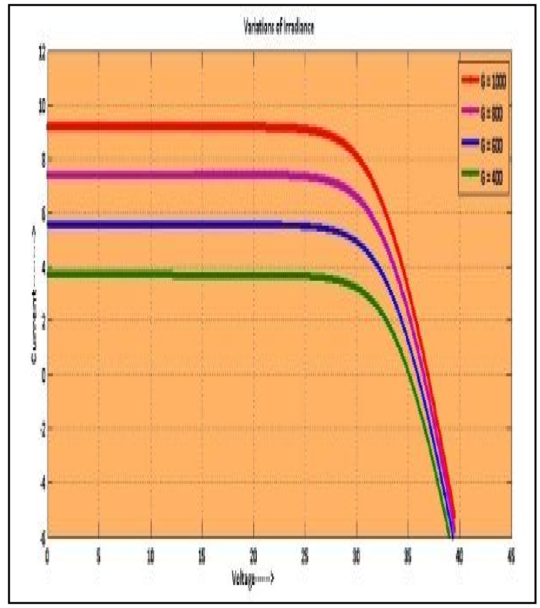

Figure 10. I-V Graph for Irradiance G=400 W/m^2

Table 2. Maximum Power & Current Values for Different Irradiance Value.

Irradiance (W/m2)	Maximum Power (in Watts)	Maximum Current (in Ampere)
1000	247.66	9.24
800	198.66	7.40
600	149.66	5.55
400	98.66	3.70

VI. CONCLUSION

Above figures and table show the simulation results of PV & I-V characteristics at the varying solar irradiance (1000 W/m^2 to 400W/m^2) with constant module temperature (25°C).The PV and I-V curves of a solar cell are highly dependent on the solar irradiation values. It is very clear that current generated and maximum output power decreases with decreasing solar irradiance. The accurateness of the simulation results is verified with manufacturer results PV and I-V characteristics

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