



Pre- Assessment Model of Solar Photovoltaic Module Using User-Friendly Matlab Program

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ABSTRACT

The model of the PV cell transforms the solar energy into electrical and provides the characteristic curves for given radiation and temperature as an input parameter. To get a quick estimate of the solar energy yield of a PV system, a computer program is required. In this study, the PV Mathematical equations along with electrical parameters obtained from the datasheet of Prime Solar photovoltaic Module type PS-P310-36 was modelled using MATLAB software program. In the modelled program, different irradiance (200 W/m^2 to 1000 W/m^2) at a constant temperature of 25°C and different temperature (25°C to 45°C) at constant irradiance of 1000 W/m^2 under Standard Testing Conditions (STC) were used to obtain I-V, P-V and P-I characteristic curves. The module has optimal values of 340 watts for solar radiation of 1000 W/m^2 . Also, the optimal power was obtained at a temperature of 25°C . The modelled results agreed with the characteristics values of the PV module of previous similar PV studies. This program can be used to predict the behaviour of the photovoltaic cells under distinct physical and environmental conditions.

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INTRODUCTION

Solar power is the key to clean future energy. Every day, the sun gives off far more energy needed in our day to day activities. These give room for the researchers to develop models that can predict the potential of this renewable energy. Among of which are Abdullahi *et al.* [1] developed a model using Gunn-Bellan radiation integration. This model was used to assess the potential of solar radiation for electricity generation in Potiskum, Yobe State, Nigeria. Amusat *et al.* [3] developed Mathematical models to predict monthly average daily global radiation of Maiduguri, Borno State, Nigeria. The results of the

model that best fit the data were chosen by comparing the regression of the coefficient of the models. Luqman *et al.* [8] developed a pre-assessment model using single variables and multivariable regression techniques of Angstrom type. The model was used to evaluate the total solar radiation reaching a horizontal surface in Maiduguri, Borno State, Nigeria.

Using renewable energy such as wind, solar and hydropower to generate electricity does not deplete the energy. There will always be consistent sunlight shining on Earth's surface, and after turning sunlight into electricity, there is still an infinite amount of sunlight to turn into



electricity in the future. That is what makes solar power, by nature, renewable energy. The major benefit of solar energy over other conventional power generators is that the sunlight can be directly converted into electrical energy with the use of the smallest photovoltaic (PV) solar cells.

There have been many research activities using solar energy to develop solar cells/panels/module with high converting power to electrical energy [9]. Photovoltaic output power depends on many factors, such as sun position, weather conditions, module temperature, thermal characteristics, module material composition, mounting structure, and shading [11]. Thus modelling of PV cells is vital for the solar energy system. The diode-based PV cell modelling has gained considerable attraction by many researchers due to the graphical interface of software like Matlab/Simulink software which assists in the simulation of these models.

Pandiarajan and Ranganath [10] use step by step procedure for Simulink modelling of the module. In this case, the final model takes irradiation, the operating temperature in Celsius and voltage as an input and give output current I_{pv} and output voltage V_{pv} to obtained I-V and P-V characteristics under varying irradiation and constant temperature. Dominique *et al.* [4] and Kamal *et al.* [7] worked on modelling and simulation of photovoltaic module considering single diode equivalent circuit model in Matlab. They obtained results from different input parameters to produce the I-V and P-V curves of a PV system at Standard Test Condition.

Table1: Technical characteristics of the photovoltaic modules [2]

Characteristic Value	Module
Open Circuit Tension (V_{oc}), [V]	42.9
Short Circuit Current (I_{sc}), [A]	9.31
Maximum Rated Tension (V_{max}), [V]	36.3
Maximum Rated Current (I_{max}), [A]	8.54
Maximum Power (P_{max}), [W]	310

Other researchers worked on how to use numerical methods in the estimation of Photovoltaic parameters. Reis, *et al.* [13] use Newton Rapson Methods, a program which was developed in the Octave computational tool to generate two curves I-V and P-V. Also, Ranji *et al.* [12] studied PV Module to estimate parameters (ideality factor, the series resistance of solar module, shunt resistance of the solar module, diode reverse saturated current and light generated current) using Newton Raphson at different environmental conditions.

In the present work, the Prime Solar photovoltaic Module (PS-P310-36) *model was developed using* Matlab Program Script. This model was used to obtain the I-V and P-V characteristics curves under the varying irradiation and temperature. This model unlike the previous PV Model will be easy to use by the PV designers because the programs require the user (designer) to enter the required input parameters to obtain the required output parameters.

MATERIALS AND METHOD

Materials

The material used is the manufacturer cell datasheet of monocrystalline photovoltaic modules type of PS-P310-36 under STC. Also environmental conditions such as temperature, 25°C to 45°C, radiation, 200W/m² to 1000 W/m² of irradiance level, 25°C of cell temperature and 1.5 of the air mass. (AM). The Technical characteristics of the photovoltaic modules used for this model are shown in Table 1

Some important solar parameters

Irradiance (s): This is the amount of solar energy reading the cell given in watts per meter square (W/m^2). It is an input parameter which is varied from 1000 W/m^2 to 200 W/m^2 .

The Nominal Operating Cell Temperature: This is defined as the temperature reached by open-circuited cells in a module under STC.

Open Circuit Voltage (VOC): This is the maximum voltage available from a solar cell and this occurs at zero current. The Open Circuit Voltage corresponds to the amount of forwarding bias on the solar cell due to the bias of the solar junction with the light-generated current. This value depends on solar radiation and operating Temperature.

Short Circuit Current (I_{sc}): This is the current through the solar cell when the voltage across the solar cell is zero, (i.e when the cell is short-circuited). The values also depend on solar radiation and operating Temperature.

The Maximum Voltage (V_{max}): This is the voltage generated by the solar panel when the power output is highest. It is the actual amperage which the panel should read when it is connected to solar equipment under STC.

The Maximum Current (I_{max}): This is the current generated by the solar panel when the power output is maximum. It is the actual amperage that the panel should read when connected to solar equipment under STC.

The Maximum Power (P_{max}): This is the highest power output of the solar panel under STC. It is derived from the product of current and voltage at the maximum point.

Methods

The adopted method is based on a MATLAB (version 10.3.2) program and simulation of the photovoltaic cell of module type of PS-P310-36. This program depends on the fundamental circuit equations of a solar PV cell considering the effects of physical and environmental parameters such as the solar radiation and cell temperature. The performance of photovoltaic systems (solar cell/panels), that is, the output current/voltage curve (I-V curve) and Power/Voltage (P-V curve) are studied using an equivalent circuit model. This equivalent circuit consists of a current source with two resistors, one connected in parallel and the other in series. Based on these electronic components, equations (1-5) were used for the photovoltaic systems [6]. Figure 1 shows an equivalent circuit of a Photovoltaic with one diode.

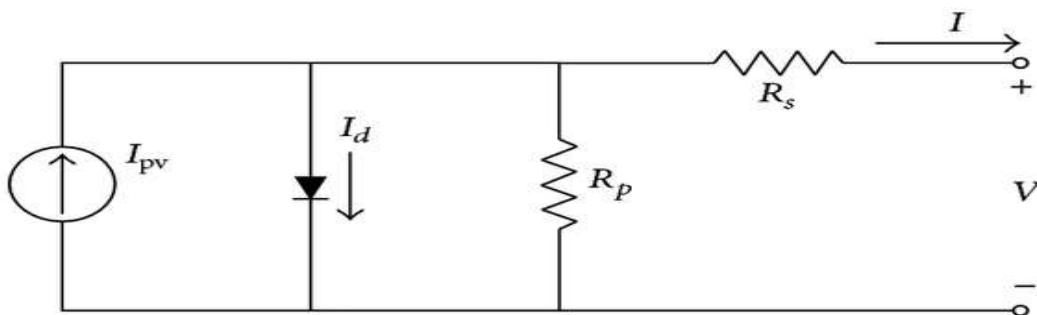


Fig 1: Equivalent Circuit of a Photovoltaic with one diode [5].

The Mathematical models of PV in Figure (1) used in the program are shown in equations (1–5) [6].

$$I_{ph} = \left[I_{sc} + K_i(T_r - T_o) * \left(\frac{S}{1000} \right) \right] \quad (1)$$

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

$$I_o = I_{rs} \left(\frac{T_o}{T_r} \right)^3 \exp \left[\frac{q * E_{go}}{AK} \left(\frac{1}{T_r} - \frac{1}{T_o} \right) \right] \quad (3)$$

$$I_{PV} = N_p * I_{ph} - N_p * I_o \left[\exp \left(\frac{qV_{PV}}{N_s AKT} \right) - 1 \right] \quad (4)$$

$$P = I_{PV} * V_{PV} \quad (5)$$

Where

I_f : Photocurrent (Ampere)

I_{sc} : Short-circuit current (Ampere)

K_i : Cell_s short-circuit current temperature coefficient (Ampere /Kelvin)

T_o : Cell operating temperature (Kelvin)

T_r : Cell_s is reference temperature in degree (Kelvin)

S : Solar irradiance (Watt/meter square)

I_{rs} : reverse saturation current of the diode

q : Electron charge (1.602×10^{-19} Coulomb)

V_{oc} : Open circuit voltage (Volt)

N_p : Cells interconnected in parallel

N_s : Cells interconnected in series

A : Ideality factor

k : Boltzmann's constant (1.38×10^{-23} Joule/Kelvin)

T : the temperature of p-n junction

I_{pv} : Output current of a PV module (A)

I_o : PV module saturated current (A)

V_{pv} : Output voltage of a PV module (A)

E_{go} : bandgap for silicon

RESULTS AND DISCUSSION

The results of the PV model developed was based on mathematical equations (1-5) [6] and the characteristic values obtained from the Datasheet as provided by the manufacturer under the varying intensity of irradiance from 200 W/m² to 1000 W/m² and different temperature from 25°C to 45°C are shown in Figures 2-6. The results for I-V, P-V and P-I characteristics of the module show a good agreement in term of short circuit current, open-circuit voltage and maximum

power respectively concerning previous similar PV studies [4, 14]

Figure 2 shows the output I-V results for different values of irradiance ranging from 200 W/m² to 1000 W/m².

The I-V curve showed that the output current is directly proportional to solar radiation.

The maximum and minimum values of short circuit current which occurred at 1000 W/m² and 200 W/m² respectively gave 80.1% decrease in output current. Also, for each solar radiation, the output current remains constant until it

reaches the maximum voltage of 36.6 V where a sharp fall in output current is experienced.

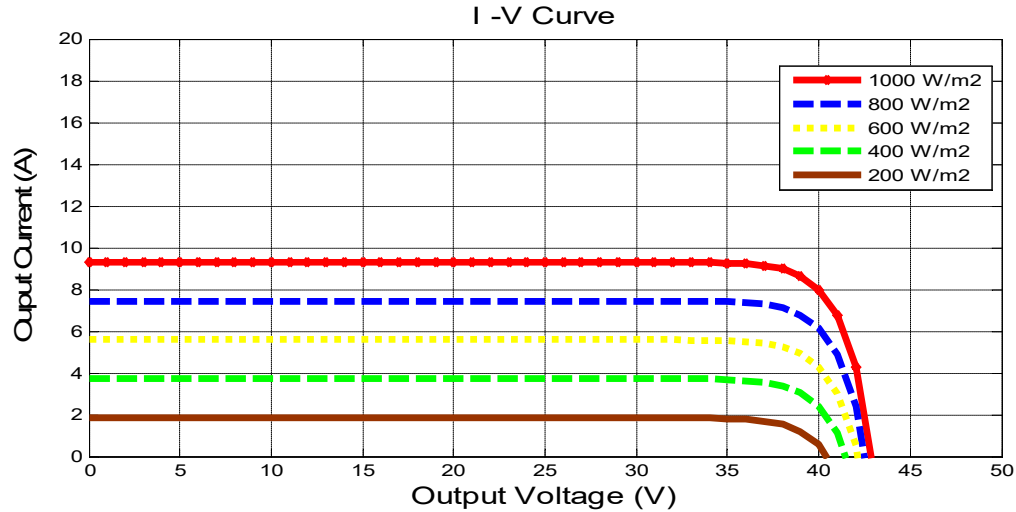


Figure 2: I-V characteristics by varying irradiance

Figure 3 is the P-V curves for a single PV module with varying irradiance. It shows that the output power varied directly with solar radiation. Also, for each solar radiation, there is an increase in output voltage concerning an increase in output

power until it reaches maximum voltage which is 36.6 V where a sharp drop in output power is experienced. There is 81.2% decrease in maximum power when the solar radiation values changes from 1000 W/m² to 200 W/m².

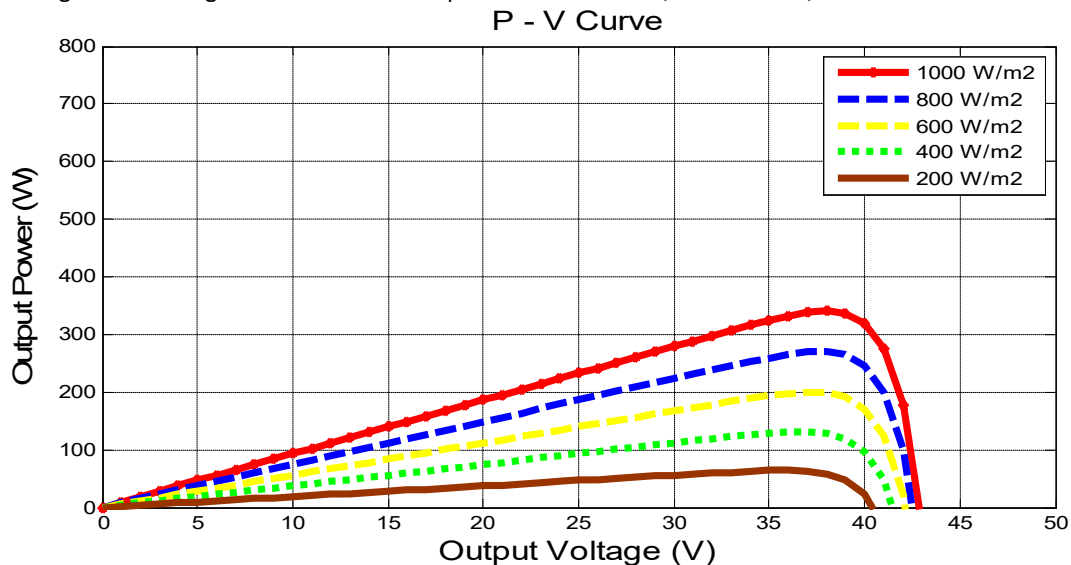


Figure 3: P-V characteristics by varying irradiance

Figure 4 shows the P-I characteristics under a constant temperature of 25°C and different irradiance of 200, 400, 600, 800 and 1000 W/m². The Figure also shows that the output current has dropped from 9.31A at

1000 W/m² to 1.86A at 200 W/m². The decrease in power is 80 % when the irradiance changes from 1000 W/m² to 200 W/m².

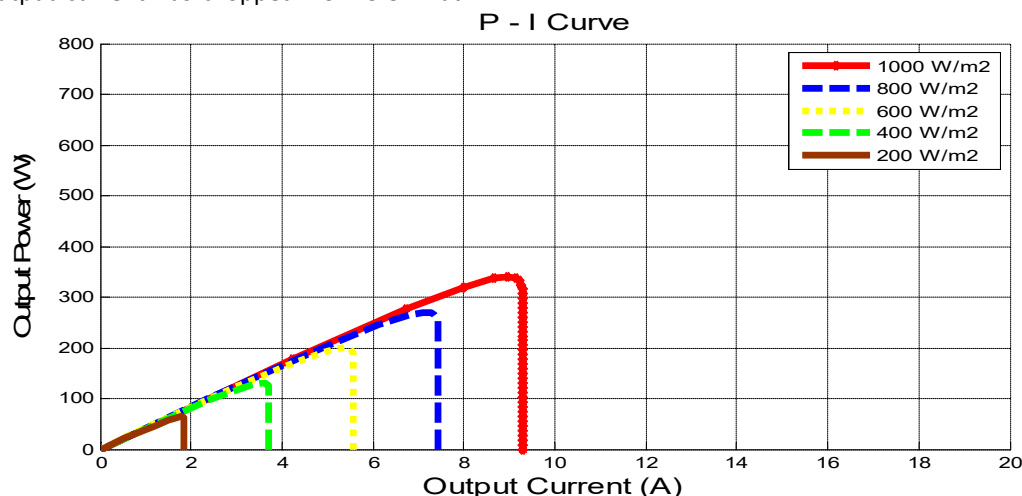


Figure 4: P-I characteristics by varying irradiance

Figure 5 shows the P-V characteristics under constant irradiance of 1000 W/m² and different operating temperature of 25, 30, 35, 40 and 45°C. The Figure also shows that the open-circuit voltage of the PV panel decreases with

increase in cell temperature which results in a net reduction in power output. The decrease in power is 80.1% when the temperature changes from 25°C to 45°C.

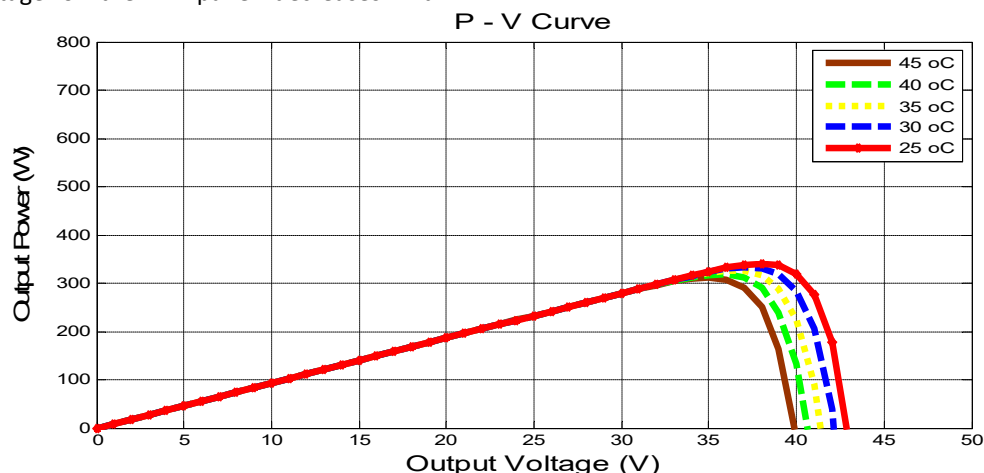


Figure 5: P-V characteristics at different temperature

Figure 6 shows the results for the I-V curve of the photovoltaic module under different operating temperature 25, 30, 35, 40 and 45°C at constant irradiation level of 1000 W/m². The Figure also shows that the open-circuit voltage of the PV panel

decreases with an increase in operating temperature which results in a net reduction in power output. The decrease in power is 6.75% when the temperature changes from 25°C to 45°C

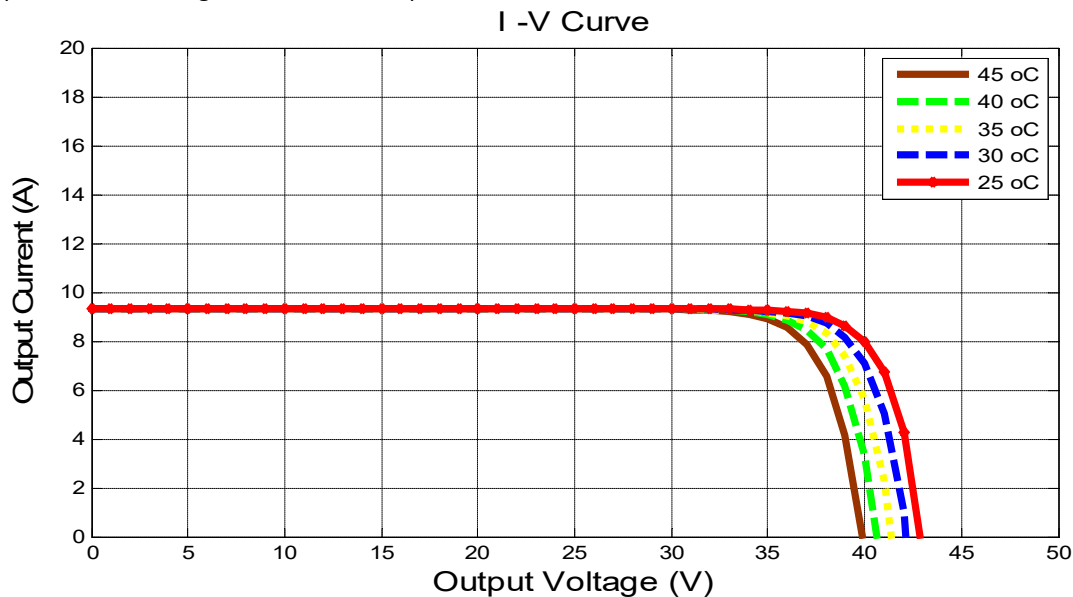


Figure 6: I-V characteristics at different temperature

CONCLUSION

The PV model developed was based on electrical features of PV provided by the manufacturer and Mathematical equations of the PV. The open-circuit I-V and P-V curves were obtained from the simulation of PV model developed in the MATLAB environment. The results obtained from the developed models showed reasonable agreement with the previous similar PV models. The model is said to stand as a pre-assessment tool for the engineers in the area of PV designing.

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