Modeling And Simulation of Solar Photovoltaic System Using MATLAB

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Abstract- *In current scenario, solar energy is one of the economical and useful energy. In this paper a photovoltaic (PV) system using a MATLAB simulink is designed. The performance of PV Cell, PV module and PV Array are analyzed by observing VI and PV characteristic of each . The output performance of system model is found satisfactory. Result shows that very useful and economical.*

Keywords- Solar PV system, Solar Cell ,PV Array, Solar Energy, MATLAB

I. INTRODUCTION

The renewable energy sources are assuming a significant function in power frameworks. The most plentiful fuel source in the area of renewable energy is the sun. The use and demand of solar energy is increasing day by day.

Solar photovoltaic cells are generally made of silicon, an element that naturally liberation electrons when uncovered to light. Amount of electrons librated from silicon cells depend upon intensity of light hit on it. The silicon cell is protected with a grid of metal that straight the electrons to run in a path to generate an electric current. This current is conductor into a wire that is connected to a battery or DC device. Typically, one solar cell generates about 1.5 watts of power. Separate solar cells are connected jointly to form solar cells effective of generating 3 to 110 Watts power. Solar panels can be connected jointly in series and parallel to build a solar array , which can generate any amount of Wattage as capacity will permit. Solar modules are normally sketched to supply electricity at 12 Volts. Solar photovoltaic modules are cost by their vertex Watt output at solar midday on a clear day.A PV array is formed by series/parallel combination of PV solar modules [1]. Solar energy is generated using solar photovoltaic (PV) arrays.

The output power generated from the solar panels is intermittent in nature and varies with the irradiance level, temperature, different orientations, panel aging, and so on [1-3]. A PV system is the most cost effective and environment friendly in many applications especially in isolated areas [4].
The contributions of work in this paperare defined as:

1. Modeling and analysis of solar cell
2. Modeling and analysis of PV Panel
3. Modeling and analysis of PV System

In this paper, PV cell modeling is based on the Shockley diode equation in MATLAB [5-7] is discussed

II. MODELING OF PV CELL

A PV cell produces current when sun light is irradiated upon on it and produces electron-hole pair as PV cell materials absorb photons having energy exceeding the band-gap of the material [8-10]. The simplest model of a PV cell and its equivalent circuit is presented in Fig.1. That consists of an ideal current source in parallel with an ideal diode with zero series resistance, infinite shunt resistance and unity ideality factor for junction. The current source represents the current generated by photons (often denoted as I_{ph} or I_L), and its output is constant under constant temperature and constant incident radiation of light. There are two key parameters frequently used to characterize a PV cell. Shorting together the terminals of the cell, as shown in Fig. 2a, the photon generated current i_{ph}, will flow out of the cell as short-circuit current (I_{SC}). Thus, $I_{Ph} = I_{SC}$ as shown in Fig. 2.b, when there is no connection to the PV cell (open-circuit), the photon generated current is shunted internally by the intrinsic PN junction diode. This gives the open circuit voltage (Voc). The PV module or cell manufacturers usually provide the values of these parameters in their datasheets.

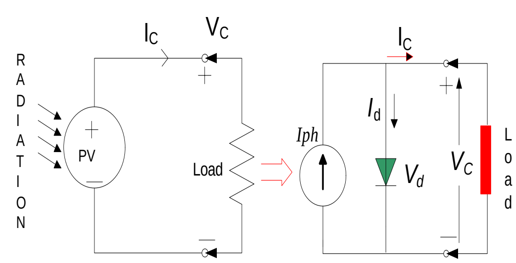

Fig 1: PV Cell with a Load and Its Simple Equivalent Circuit

The output current (I_C) from the PV cell is found by applying the Kirchhoff's current law (KCL) on the equivalent circuit shown in Fig. 1[11-12].

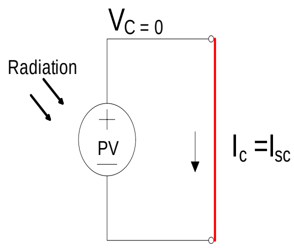

Fig. 2 (a) Short Circuit Condition of PV cell

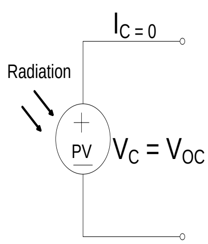

Fig. 2 (b) Open Circuit Condition of a PV Cell

$$I_C = I_{SC} - I_d \qquad (1)$$

where: I_{SC} is the short-circuit current that is equal to the photon generated current, and I_d is the current shunted through the intrinsic diode. The diode current i_d is given by the Shockley's diode equation.

$$I_d = I_0\left(e^{\frac{qVd}{kTc}} - 1\right) \qquad (2)$$

where, V_d is the voltage across the diode (D). For the ideal case, this voltage is equal to the cell voltage, v_{ac}.K is boltzmann constant (1.38 × 10-23 J/ºk), Q is electron charge (1.602 × 10^{-19} c), I_O is reverse saturation current of diode (0.000025 A), T_C is reference cell operating temperature (25 °C).

Using equations (1) and (2), the current and voltage of the PV cell can be written as:

$$I_C = I_{Ph} - I_0\left(e^{\frac{qV_C}{kT_C}} - 1\right) \qquad (3)$$

$$V_C = \frac{kT_C}{q}\ln\left(\frac{I_{Ph} + I_O - I_C}{I_O}\right) \qquad (4)$$

The reverse saturation current of diode (I_o) is constant under the constant temperature and found by setting the open-circuit condition as shown in Fig. 4.2(b). Putting I_C = 0 in equation (4), the open circuit voltage is obtained as:

$$V_{OC} = \frac{kT_C}{q}\ln\left(\frac{I_{Ph} + I_O}{I_O}\right) \qquad (5)$$

As $I_{Ph} >> I_o$ Equation (5) Can be written as:

$$V_{OC} = \frac{kT_C}{q}\ln\left(\frac{I_{Ph}}{I_O}\right) \qquad (6)$$

To a very good approximation, the photon generated current, which is equal to I_{SC}, is directly proportional to the irradiance, the intensity of illumination, to PV cell .thus, if the value, I_{SC}, is known from the datasheet, under the standard test condition, S_c=1000 W/m^2 at the air mass (am) = 1.5, then the photon generated current at any other irradiance, S_x in (W/m^2) is given by:

$$I_{SC-S_X} = \left(\frac{S_X}{S_C}\right) * I_{SC-S_C} \qquad (7)$$

A solar cell can be represented by a widely accepted equivalent circuit shown in Fig. 3 and 4 [8]. The model consists of a current source (I_{SC}), a diode (D1 and D2), and a series resistance (R_s). As the effect of parallel resistance R_P is negligible, it been omitted in this model.

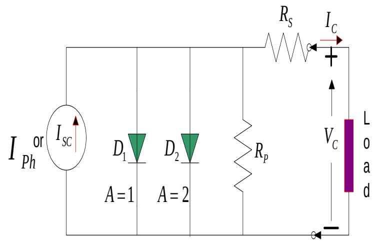

Fig. 3 More Accurate Equivalent Circuit of PV Cell.

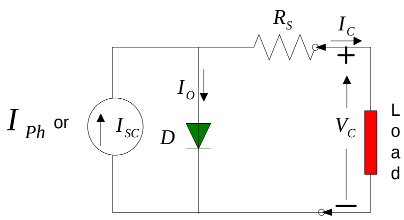

Fig. 4 Model, With Moderate Complexity.

To make a better model, it also includes temperature effects on the short-circuit current (I_{SC}) and the reverse saturation current of diode (I_o). It uses a single diode with the diode idealist factor (*a*) set to achieve the best *I-V* curve matching. Since it does not include the effect of parallel resistance (R_P), putting $R_P = \infty$ in equation the current-voltage relationship of the PV cell is given by

$$V_C = \frac{AkT_C}{q} \ln\left(\frac{I_{Ph} + I_O - I_C}{I_O}\right) - I_C R_S \quad (8)$$

Both *k* and T_C should have the same temperature unit, either Kelvin or Celsius. The curve fitting factor *a* is used to adjust the I-V characteristics of the cell to the actual characteristics obtained by testing. The two-diode model takes into account the effect of recombination between electron-hole pair. In it, the number of equations as well as unknown parameters increases, thereby making calculations little bit more complex but gives more accurate results as compared to the single-diode model. Considering mathematical computations and number of iterations, computational errors are less in the single-diode model and it is faster than two-diode model due to less complex equations [9]. To enhance the power rating of a PV system, a suitable number of PV modules are connected in series and parallel to form a PV array.

III. MODELING OF PV SYSTEM

The basis simulink model of PV Cell is designed in MATLAB and it is shown in Fig. 5.The simulink model of PV model is obtained by combining the multiple PV Cell .Fig. 6 shows the simulink model of PV Module. Simulation model of PV array is obtained from the PV module model. The output voltage of the cell is the multiplied by the number of the cells in series nose to obtain the array voltage "Array" the no. Of series connected cell in the array is given by nose = nms nan Where nms is no. Of series connected module in the array and nan is the no. of cells in each module. The array current is obtained by multiplying the cell current with the number of modules connected in parallel (nap) . The array power is simply obtained by multiplication of the array voltage and current using dot product block. The PV array model is shown in Fig.6

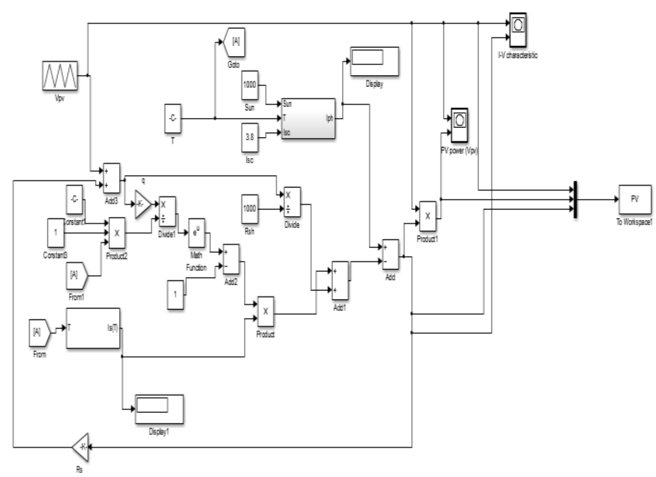

Fig. 5 Modeling of PV Cell Model.

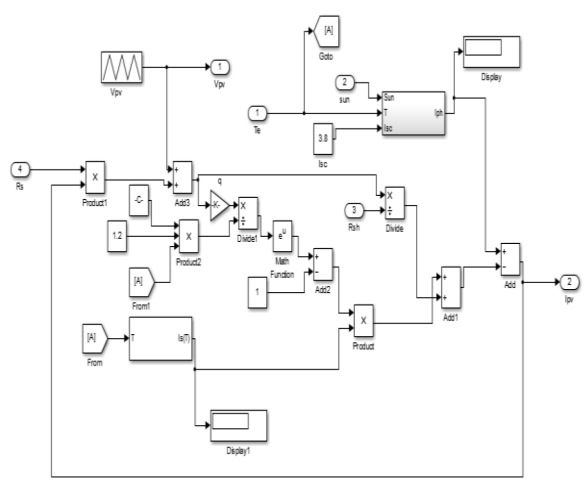

Fig. 6 Modeling of PV module

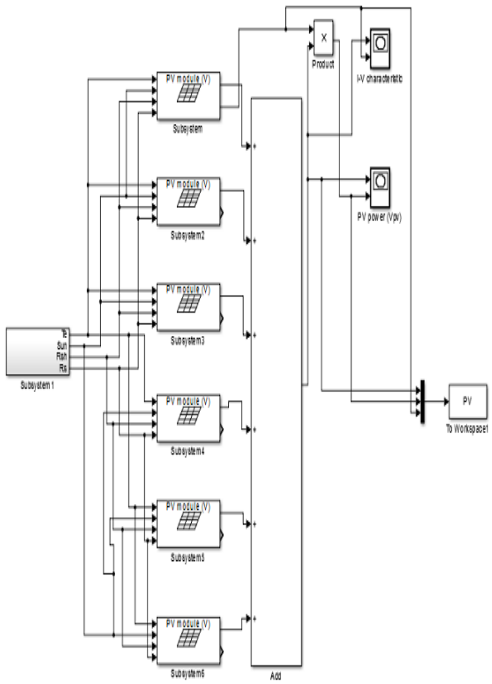

Fig. 7 Modeling of PV Array

IV. SIMULATION RESULTS

MATLAB simulink is used to get the output of proposed model.Fig. 8 shows the V I and P V characteristics of PV cell. In Fig. 8(a). Y Axis shows the current and X Axis shows the voltage and in Fig. 4.6b, Y Axis shows the power and X Axis shows the voltage.

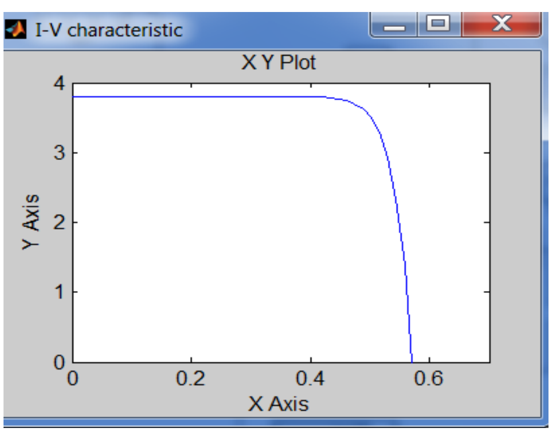

Fig.8(a) I-V Characteristics of PV cell

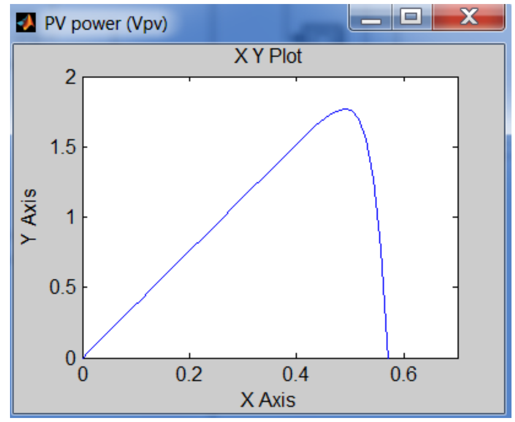

Fig.8(b) P-V Characteristics of PV cell

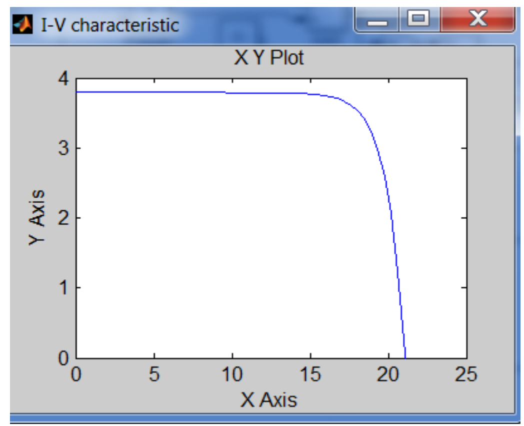

Fig. 9(a) I-V Characteristics of PV module

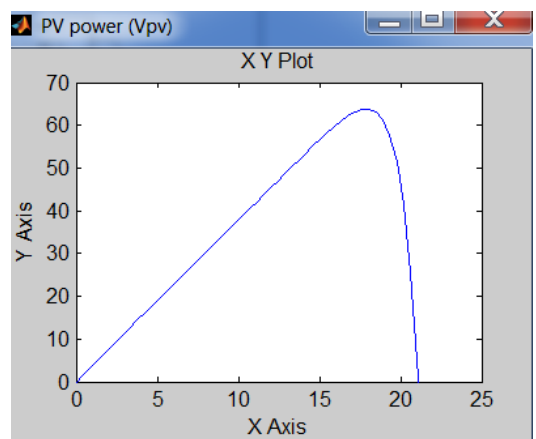

Fig. 9(b) I-V Characteristics of PV module

Fig. 9 shows the V -I and P -V characteristics of PV Module. In Fig. 9(a), Y Axis shows the current and X Axis shows the voltage and in Fig. 9(b), Y Axis shows the power and X Axis shows the voltage.

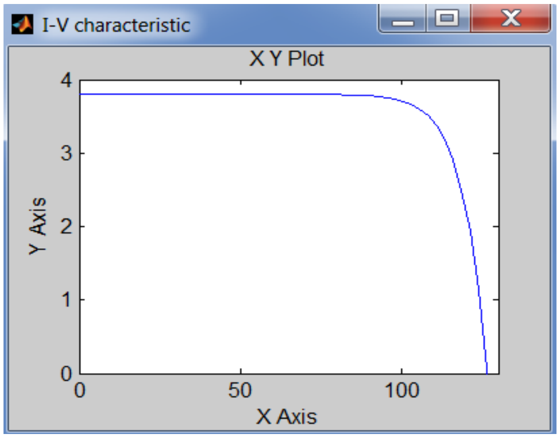

Fig. 10(a) I-V Characteristics of PV Array

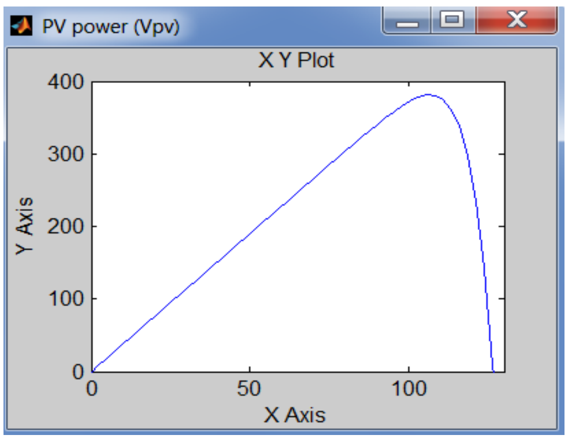

Fig. 10(b) P-V Characteristics of PV Array

Fig. 10 shows the V -I and P -V characteristics of PV Array. In Fig10(a), Y Axis shows the current and X Axis shows the voltage and in Fig. 10(b), Y Axis shows the power and X Axis shows the voltage.

V. CONCLUSION

Designing of PV module and PV Array is done using Matlab Simulink . This method is also verified by theoretical calculations based on the equations involved for PV module. This paper presents a clear understanding on the behaviour and parameters involved in PV module and PV Array especially on I-V and P-V characteristics. Simulation results for the PV Cell, PV module and PV Array based on P-V and I-V characteristics are shown and it is observed that power increases significantly in PV array.

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