Matlab Based Empirical Model of PV System

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Abstract— ***The basic one diode & two diode model of photovoltaic has too many parameters. Evaluating values of some parameter are very difficult. This paper proposes general and specific modelling and simulation for empirical model of solar / PV cell. Studies and draw various characteristics of Photovoltaic cell as a function of temperature. The PV module is represented by the empirical model. The P-V & I-V characteristics are obtained and studied at different irradiances & temperatures. Developed model is validating by the comparison of the executed characteristics with one given by the manufacturer of PV cells. Proposed model can be extended to draw photovoltaic cell characteristics at any temperature & irradiance.***

Keywords—Solar cell, PV cell, Empirical, Simulation, BPSX150.

1. INTRODUCTION

The most of conventional fuel sources are used for power generation & they will be lost in future. Now the entire researcher going to work on the renewable energy conversion for meeting power demands. One of this renewable energy source photovoltaic cell is most common in uses which convert solar energy into electrical energy. The solar / PV cell is used as main power source where the transmission of electrical power is not possible or difficult like remote or rural area, space etc. Many PV models are developed & PV simulation program are written in last few decades. Those model treats solar cell as an irradiance dependent current source connected in circuit. This model has four parameters & given by:

$$I = I_L - I_0\left[\exp\left(\frac{q}{\gamma k T_c}(V + IR_s)\right) - 1\right] \quad \text{.....................(1)}$$

Where: γ - Dimensionless diode curve-fitting factor.

I_0- Reverse saturation current.

q- Electrical charge.

k- Boltzmann constant.

T_c-Temperature in ^{0}kelvin.

A new modification to this model made by connecting a shunt resistor R_{sh} parallel to the previously connected diode. This five parameter model developed by Lehman & Chamerlin & given by:

$$I = I_L - I_0\left[\exp\left(\frac{q}{\gamma k T_c}(V + IR_s)\right) - 1\right] - \frac{V + IR_s}{R_{sh}} \quad \text{..............(2)}$$

This model has major limitations due to its parameter dependencies like R_s, R_{sh}, I_0, I_L & γ. These above mentioned parameters are not provided by the solar cell manufacturer & that can't easily determined by developer.

PV / solar cell manufacturers provided specification sheets include I-V curve at standard reporting conditions (SRC) or other sets of operating conditions. Manufacturers of solar cell provide some parameters on their specification sheet such as short circuit current, open circuit voltage, current at maximum power & voltage at maximum power rather than variable data used to plot characteristics curve. So our research is based to develop a model which can generate characteristic curve with manufacturers provided data sheets.

2. EMPIRICAL MODEL OF SOLAR CELL

One diode & two diode model required too many input parameters. Some parameters are known & remaining are physical constants. The empirical model is developed to simulate PV / solar cell with manufacturers provided four parameters such as short circuit current I_{sc}, open circuit voltage V_{oc}, current at maximum power I_{mp} & voltage at maximum power V_{mp} without requirement of additional data input. The proposed model generating P-V & I-V curves by following equation:

$$I = I_{sc} - C_1\exp\left(-\frac{V_{oc}}{C_2}\right)\left[\exp\left(\frac{V}{C_2}\right) - 1\right] \quad \text{.....................(5)}$$

Model equation constant are denoted by C_1 & C_2. This model shows that required PV/solar cell module voltage is zero when current equal to I_{sc}. Now we can determine C_1 & C_2 for zero current i.e. **V= V_{oc}**. Equation (5) becomes

$$0 = I_{sc} - C_1\left[1 - \exp\left(-\frac{V_{oc}}{C_2}\right)\right] \quad \text{.........................(6)}$$

Rewrite the Equation (6)

$$C_1 = \frac{I_{sc}}{\left[1 - \exp\left(-\frac{V_{oc}}{C_2}\right)\right]} \quad \text{........................(7)}$$

Dimensional analysis of equation (7) shows that C_1 & C_2 has units of current & voltage respectively. At a point maximum power current I_{mp} & maximum power voltage V_{mp}, equation (5) reduces to:

$$I_{mp} = I_{sc} - C_1\exp\left(-\frac{V_{oc}}{C_2}\right)\left[\exp\left(\frac{V_{mp}}{C_2}\right) - 1\right] \quad \text{.........(8)}$$

Rewrite the Equation (8)

$$C_1 = \frac{I_{sc} - I_{mp}}{\left[\exp\left(\frac{V_{mp}}{C_2}\right) - 1\right]\left[\exp\left(-\frac{V_{oc}}{C_2}\right)\right]} \quad \text{.....................(9)}$$

It is difficult to determine C_1 & C_2 by analytical solution of equation (5) & (7). With the help of some product parameter (I_{sc}, V_{sc}, I_{mp} & V_{mp}) we can easily solve these two equations by graphical method for constant C_1 & C_2 where

ISSN: 2278-0181

the solution is intersection point of both two curves. We can find C_1 & C_2 by another way with following assumptions:

(1) Assuming that $\mathbf{V_{oc} / C_2 >> 1}$, we find that equation (7) reduces to

$$C_1 \cong I_{sc} \qquad \text{....................(10)}$$

(2) Assuming that $\mathbf{V_{mp}/C_2 >> 1}$, we find that equation (8) reduces to

$$I_{mp} \cong I_{sc} - C_1 \exp\left(\frac{V_{mp} - V_{oc}}{C_2}\right) \qquad \text{.......................(11)}$$

Rearranging terms, we obtain

$$C_1 = \frac{I_{sc} - I_{mp}}{\exp\left(\frac{V_{mp} - V_{oc}}{C_2}\right)} \qquad \text{..........................(12)}$$

Now substituting equation (10) into (11) & Rearranging terms, we obtain:

$$\frac{I_{sc} - I_{mp}}{I_{sc}} = \exp\left(\frac{V_{mp} - V_{oc}}{C_2}\right) \qquad \text{..........................(13)}$$

After solving above equation we get

$$C_2 = \frac{V_{mp} - V_{oc}}{\ln\left(1 - \frac{I_{mp}}{I_{sc}}\right)} \qquad \text{..........................(14)}$$

The assumptions taken are valid when they fulfill equation (10) & (12) that is approx to solution of equation (7) & (9). Plotting curve of equations (10) & (12) with equation (7) & (9). The graph shows that the solution of this two sets of equations intersecting at the same point. Thus, the assumptions cannot affect the values of C_1 & C_2.

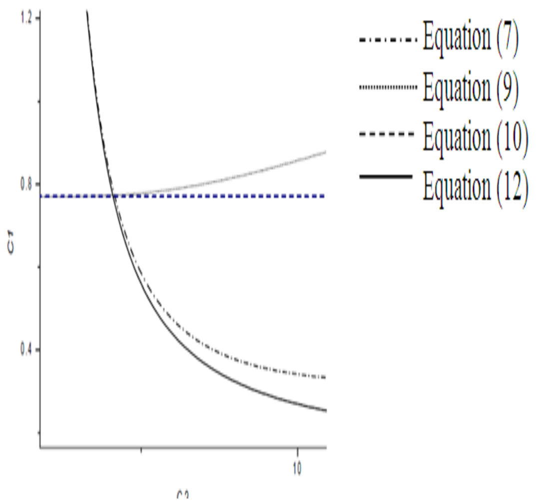

Fig. 1: Characteristics behavior of C_1 & C_2

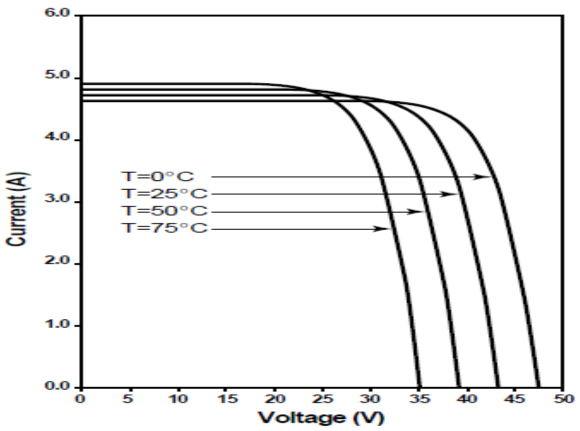

Fig.2: Standard I-V characteristic of BPSX150 solar cell

3. SIMULATION RESULTS

For simulation result the empirical model of solar cell is implemented in Matlab/Simulink. We use the BPSX150 PV module. The electrical parameter for BPSX150 PV module is given by:-

Maximum power (P_{max})	=150W
Voltage at P_{max} (V_{mp})	= 34.5V
Current at P_{max} (I_{mp})	= 4.35A
Warranted minimum P_{max}	=140W
Short-circuit current (I_{sc})	= 4.75A
Open-circuit voltage (V_{oc})	= 43.5V
Maximum system voltage	= 600V
NOCT = 47±2°C	

After the simulation process we get following characteristics:

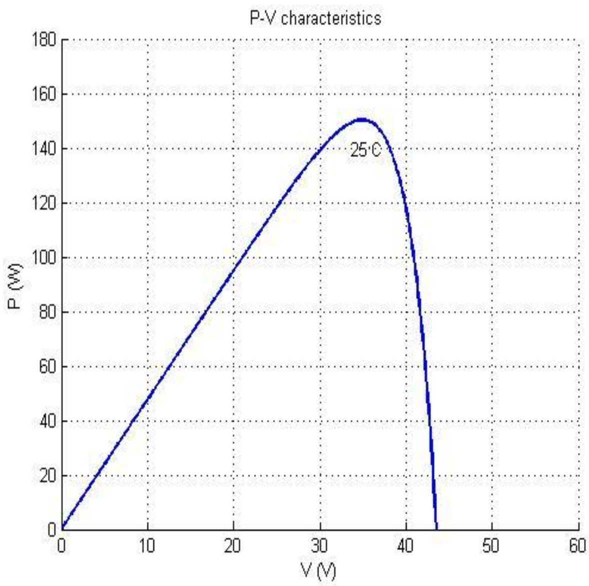

Fig. 3: P-V characteristics for temperature 25^0C

International Journal of Engineering Research & Technology (IJERT)
NCETECE`14 Conference Proceedings
ISSN: 2278-0181

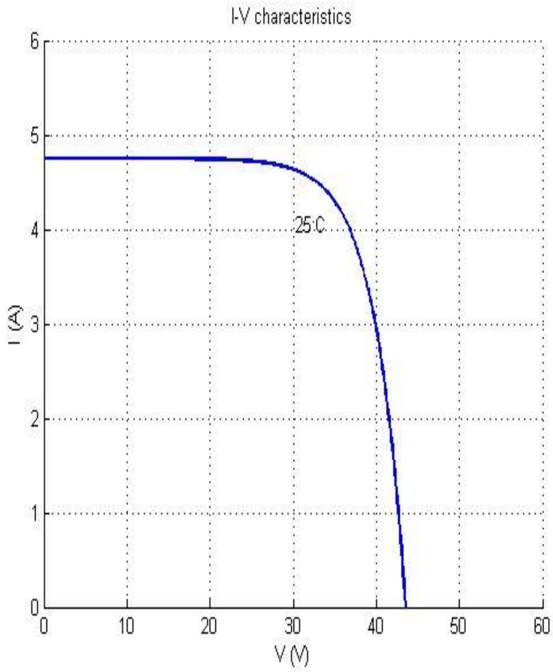

Fig. 4: I-V characteristics for temperature 25^{0}C

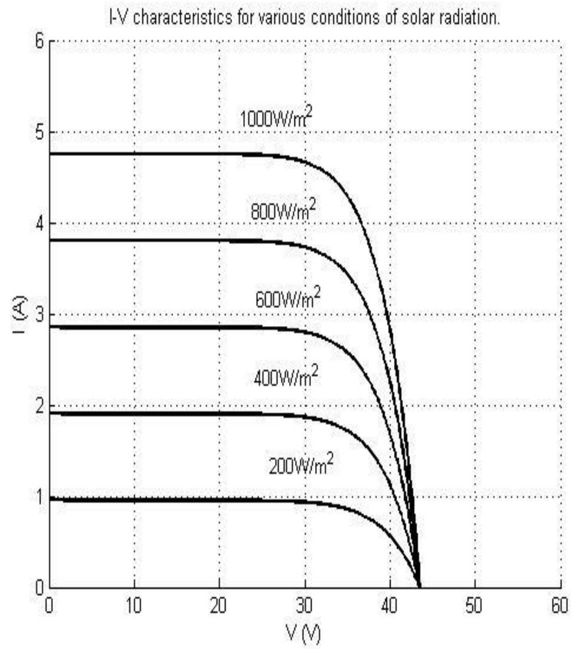

Fig. 6: I-V characteristics for various conditions of solar radiation

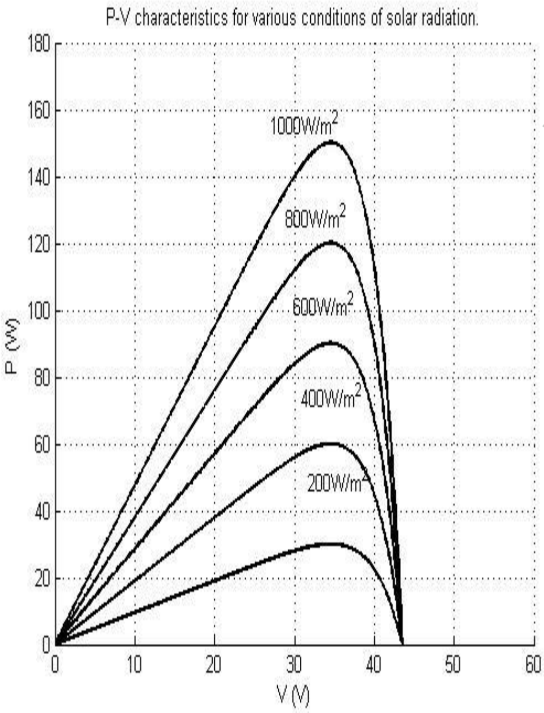

Fig. 5: P-V characteristics for various conditions of solar radiation

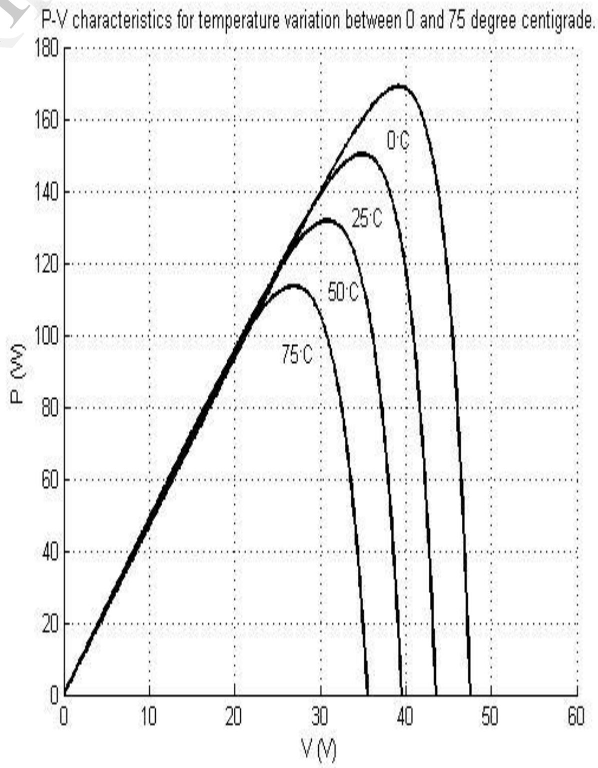

Fig. 7: P-V characteristics for temperature variation from 0^{0}C to 75^{0}C

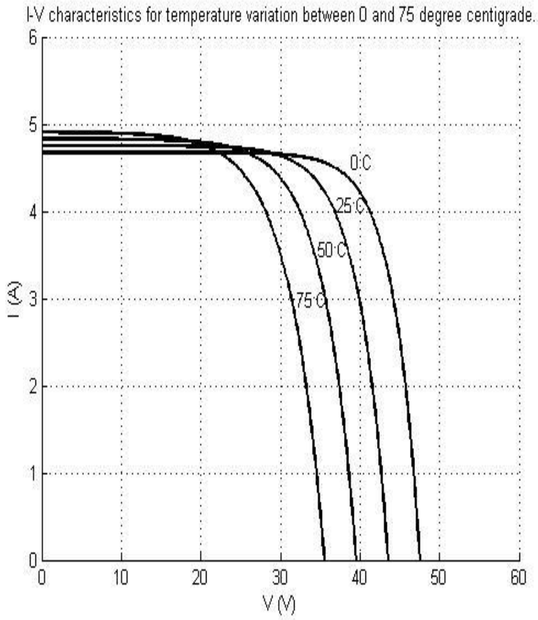

Fig. 8: P-V characteristics for temperature variation from 0^0C to 75^0C

4. CONCLUSION

The behavior of empirical model of solar cell BPSX150 is studied in this paper. The various characteristics are drawn depending upon factors such as temperature dependence & solar radiation changes with help of the manufacturers provided data. Especially this empirical model is to be compared with standard curve that’s available on manufacturer’s website & found both curve matched to each other. This model is suitable to find the characteristics behavior of any solar cell with manufacturers provided data without internal knowledge of PV / solar cell.

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