

Mathematical Investigation to evoke the solar cell based parametric quantities from Implicit to Explicit form

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Abstract- The solar photovoltaic cell equivalence is of non-linear nature and it is more intricate to analyze. Henceforth, it is essential to explicate a mathematical based model in order to understand the non-linear dynamics of solar cell. To adjudicate the maximum power point, it is required to study and examine the composite characteristics by implementing iterative methods to perform mathematical computations. A mathematical canvas is needed to determine the values of series and shunt resistances present in solar cell. We can also compute different parasitic components of solar photovoltaic cell; fill factor analysis and also ideal factor calculations. Voltage equation is formulated in both 2-dimensional and 3-dimensional equation form. Mathematical based analysis has been performed and converted implicit form of equation to explicit based equation.

Index Terms- explicit, implicit, mathematical canvas, non-linear dynamics, parasitic components.

Introduction

An implicit equation is one form of an equation which associates the variables required whereas an explicit equation so called $y=f(x)$, we can clearly establish a relation between x and y respectively. It can be noted that, the solar photovoltaic (PV) cell equation is one kind of an implicit equation. Hence, it should be converted to an explicit equation so that, one can extract the parametric relations which are concerned with the solar cell respectively. In this paper, an implicit equation is being commuted to an explicit equation such that various parameters like voltage and current can be educed.

Thither exists numerous publishings which are demonstrated and exercised the complex nature and nonlinear based relation of solar cell under irradiation conditions, various frameworks and technological methods were formulated for the sake of prototyping the non-linearity of current as well as voltage profiles [1,2]. The implicit based mathematical relation of voltage-current (V-I) related feature of solar cell, by including the various parasitical related phenomenons like series-shunt resistance values and current is depicted on Fig. 1. For simplicity reasons, the mathematical based parasitical relation of V-I characteristics of solar PV cell single-diode model is modeled by [3-5].

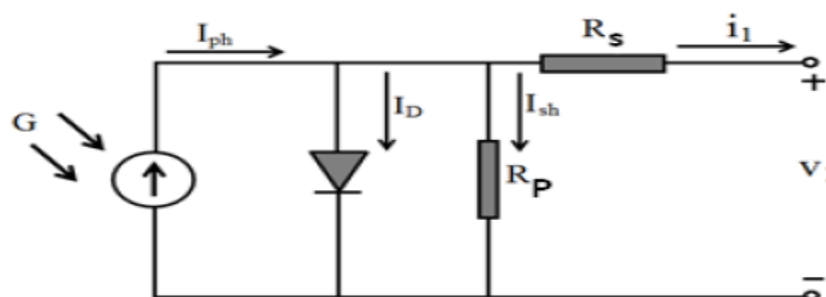


Fig. 1: Single diode based PV cell

The fundamental relation of a single-diode PV cell model is represented as below:

$$i_1 = I_{ph} - I_0 \left[\exp \left(\frac{v_1 + R_s i_1}{v_t a} \right) - 1 \right] - \left(\frac{v_1 + R_s i_1}{R_p} \right)$$

Where i_1 and v_1 represents the output current and output voltage of a PV cell respectively.

The exponential (second) portion of the above relation basically represents the current flowing through the diode.

For the same irradiance levels, the p-n junction diode temperature considerations, the series resistance has been included in the model to imply that, there is a usage of a re-current based equation in order to find out the output current in mapping with the output voltage at the terminals respectively. A simpleton reiterative proficiency initially attempted, thus it is converged for currents. It is found that, the method of Newton–Raphson meets quickly for current.

Considering the losses in the PV cell, we need to include one more diode in parallel to the existing PV cell model which is depicted below.

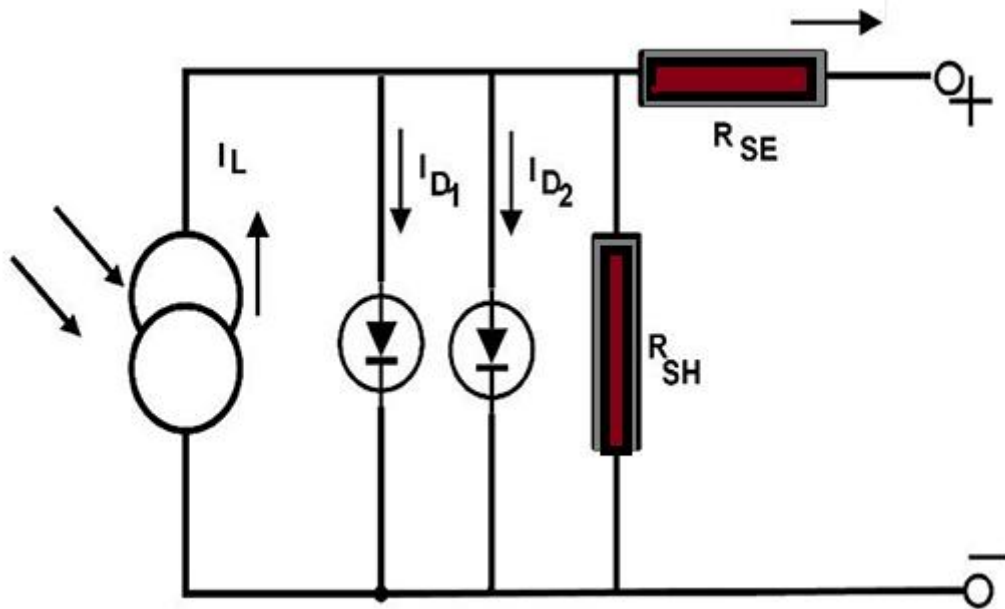


Fig. 2: Two-diode based PV cell

The mathematical equation pertaining to the two-diode model is given below in a lucid manner:

$$I = I_{ph} - I_{D1} - I_{D2} - \left(\frac{v_1 + R_{se} i_1}{R_{sh}} \right)$$

Where ' R_{SE} ' is termed as series resistance and ' R_{SH} ' is referred as shunt based circuit resistance.

II. MATHEMATICAL ANALYSIS OF PV CELL

The solar PV cell equation cannot be resolved in an explicit way. It necessitates the descent of various solar cell based parameters such as the photovoltaic based current ' I_{ph} ', the diode related saturation reverse-current ' I_0 ', the resistance in series configuration ' R_s ' and the shunt-resistance parameter ' R_{sh} '. These parameters are exclusively not furnished in manufacturer's data-sheet. Typical Manufacturers basically render the pursuing

information likely: the open-circuit based voltage (V_{OC}), short-circuit based current (I_{SC}), voltage at maximum power point (V_{MPP}), and current at maximum power point condition (I_{MPP}) and also the values pertaining to temperature coefficients of voltage and current. These values are evaluated at the standard temperature conditions i.e., $T = 25^\circ\text{C}$ and solar insolation i.e., $G = 1000 \text{ W/m}^2$. Few makers also provide the V-I related performance curvatures based on the external environmental factors. These circumstances are adequately enough in order to draw the parametric quantities.

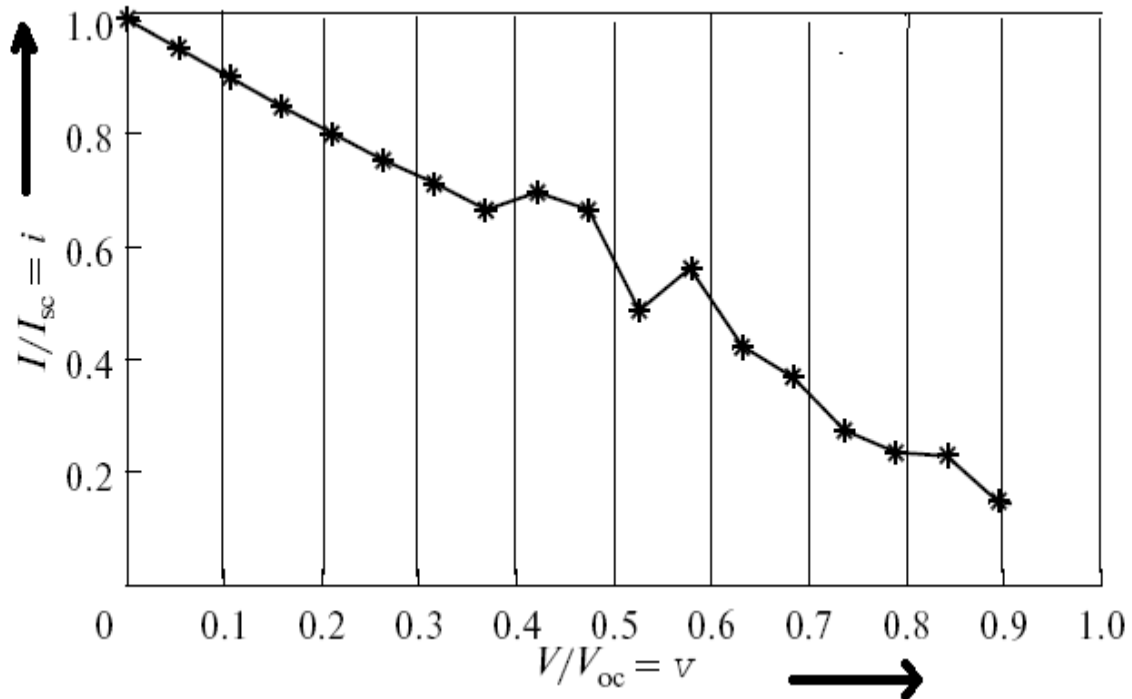


Fig. 3 Variation of Solar cell parameters

We obtain, the relation of short circuit current as,

$$I_{SC} = \frac{I_{ph}}{1 + \frac{R_s}{R_p}}$$

Also, the equation of photovoltaic current as,

$$I_{Ph} = I_{SC} \left(1 + \frac{R_s}{R_{sh}} \right)$$

The normalized equation of solar PV cell of a single diode model is represented as follows: namely:

$$i_1 = 1 - \frac{V_{oc}}{I_{ph} R_p} v - \left(1 - \frac{V_{oc}}{I_{ph} R_p} \right) \exp \left(\left(\frac{I_{sc} R_s}{a V_t} \right) i_1 - \frac{V_{oc}}{a V_t} (1 - v) \right)$$

Where, i_1 gives the information about the solar PV cell output current. The plot of current and voltage which is obtained from the above PV cell equation is represented below:

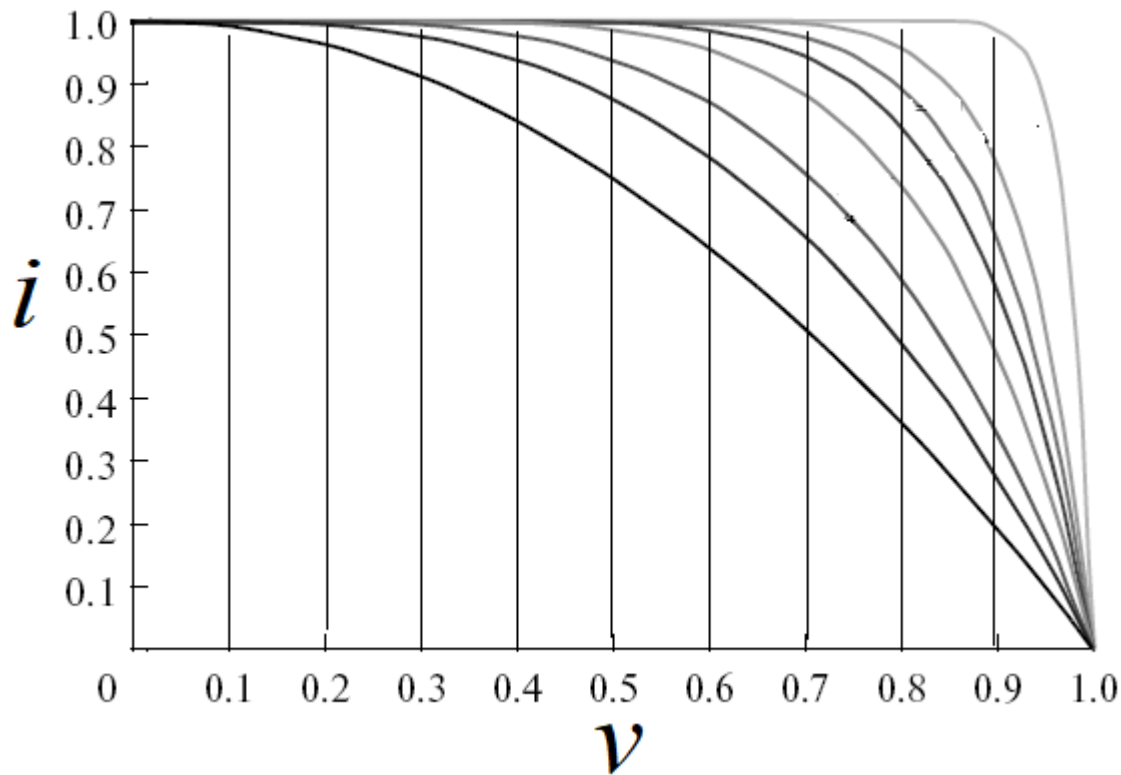


Fig. 4 Plot of I – V non-linear curve

III. Conclusion

In this paper, focus has been given on analyzing the mathematical equation of solar PV based cell. The equation and its related plots have been shown in this paper to demonstrate the non-linear nature of the PV cell. The explicit equation of PV cell is depicted in this paper and thus the extraction of current and voltage is done without any complexity. This paper also showed the non-linear variation of solar cell parameters so that, one can understand the nonlinear behavior of solar cell.

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