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Evaluation of Diode Model Parameters for a Solar Panel Simulation

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ABSTRACT

Background: Simulation studies involving solar panels are generally preferred to laborious and time consuming experimental studies for the evaluation of solar panel performance. Generally, commercial solar PV panel datasheets give three parameters namely, open circuit voltage(Voc), maximum power point(MPP), and short circuit current(Isc). write background about topic of paper. Objective: To implement the commonly used diode model, it is necessary to determine two unknown parameters, series resistance Rs and shunt resistance Rp. Results: In this paper, a simple procedure is presented to evaluate these unknown parameters using the parameters given by the manufacturer. Conclusion: The procedure is validated by obtaining the performance curves using the evaluated model parameters and comparing them with those given by the manufacturer. The procedure proposed enables simulation studies of any given solar panel with the minimum data provided by the manufacturer's datasheet.

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INTRODUCTION

Global energy usage is increasing every year due to increase in world population. The need for the use of renewable energy is rapidly growing, as fossil fuels are limited. Solar energy is considered better among renewable energy sources, since it is free and readily available in abundance. Solar energy is converted into electrical energy using Photovoltaic (PV) system. The basic unit of PV system is called as cell and several group of cells combined to form a panel. The recent advancements in semiconductor industry and power electronics techniques, have enhanced the application of PV systems in electric power applications, such as, street lighting, fountain decorations in entertainment places, heaters, gate opening system, irrigation system, battery charging system besides satellite and robotic applications.

The PV systems are made up of a number of series/parallel connected solar panels to obtain the desired voltage/current levels. To predetermine the performance of such systems under varying weather and irradiance conditions, experimental studies can be conducted. Such studies are not only expensive and time consuming and limited by weather conditions. Therefore simulation studies are preferred for which precise solar panel models are required.

Generally all commercial solar PV panel datasheets give three parameters namely open Voc, MPP, and Isc. To implement the commonly used diode model, it is necessary to evaluate two unknown parameters: Rs and Rp.

Alichemitti *et al.*, (2012) presents a library of components model for PV systems under Matlab/Simulink. The toolbox allows analysis of the behaviour by the PV generator depending on the climatic conditions and load. Modelling and simulation of PV panel using Matlab/Simulink is discussed in Krismadinata *et al.*, (2013). The simulated results are compared with various manufacturer datasheets and verified. In addition to the basic model, some authors have proposed sophisticated model with more number of diodes for precision results (Pongrtananukul.T and Kasparis.T, 2004 and Chowdury.S *et al*., 2007).

The Resistance Rp exists during leakage current of the PN junction and the value is usually high and some researchers neglect the Rp value to simplify the model (Benavides.N.D and Chapman.P.L, (2008)). The value of Rs is small and some researchers neglect the Rs (Celik.A.N and Acikgoz.N, 2007). Modelling and simulation of PV arrays is proposed by (Marcelo Gradella Villava *et al*., 2009). The proposed model is validated with the manufacturer's data of commercial PV arrays. The procedure given in involves a number of considerations leading to more complexity.

In this paper, a simple procedure is presented to evaluate Rs and Rp using the manufacturer's data

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sheet. The procedure is validated by obtaining the performance curves using the determined parameters and comparing them with those given by the manufacturer.

Design And Implementation:

Solar Panel Model:

A simple PV equivalent circuit consists of single diode, photo current source, resistors (Rs and Rp) as shown in Fig.1. Depending upon the intensity of the incident light, the current source generates current. The Schottky diode represents the junction of the cell. Rp represents the leakage current on the surface of the cell due to non-ideality of the PN junction. Rs represent various contact resistances and semiconductor resistances.

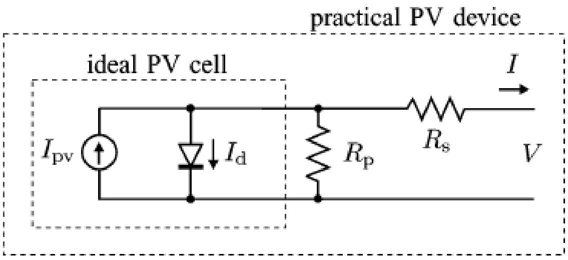

Fig. 1: Solar Panel Model.

The equations related to the equivalent circuit are given below:

$$I = I_{pv} - I_d \quad (1)$$

Ipv is the panel current and Id is the diode current.

$$I = I_{pv} - I_{0,cell}\left[\exp\left(\frac{qV}{akT}\right) - 1\right] \quad (2)$$

$I_{0,cell}$ is Diode Leakage current.

q is electron charge(1.607*10-19 C)

k is Boltzmann constant(1.380*10-23J/k)

T is PN junction temperature (K)

'a' is Diode Ideality constant

Including additional parameters to the equation (2)

$$I = I_{pv} - I_0\left[\exp\left(\frac{V+RsI}{Vt.a}\right) - 1\right] - \frac{V+RsI}{Rp} \quad (3)$$

$Vt = \frac{NskT}{q}$ is the thermal voltage of the array with Ns cells connected in series.

For simulation studies, model parameters are to be determined using the manufacturer's datasheet. The typical manufacturer datasheet (Canadian solar Panel model CS6P-255) is given below in Tables.1, 2 and 3. The parameters are provided under Standard Test Conditions (STC) and Nominal Operating Cell Temperature (NOCT).

Table 1: Canadian solar Panel model CS6P-255P Data sheet.

S.No	Characteristics	STC	NOCT
1	Irradiance (W/m2)	1000	800
2	Spectrum	AM 1.5	AM 1.5
3	cell temperature (°C)	25	20
4	Wind speed		1 m/s

Table 2: Under STC.

S.No	ELECTRICAL DATA / STC*	255P
1	Pmax	255 W
2	Vmp	30.2 V
3	Imp	8.43 A
4	Voc	37.4 V
5	Isc	9.00 A
6	Efficiency	15.85 %

Table 3: Under NOCT.

S.No	ELECTRICAL DATA / NOCT*	255P
1	Pmax	185 W
2	Vmp	27.5 V
3	Imp	6.71 A
4	Voc	34.4 V
5	Isc	7.29 A

Unfortunately, some of the parameters [PV current(Ipv), the resistances Rs and Rp, the diode ideality constant(a), the diode reverse saturation current, and the bandgap energy of the semiconductor] required for adjusting PV panel models to provide performance matching with real

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panel performance, are not found in the manufacturer's datasheets.

The practical PV device presents hybrid behaviour; depending on the operating point, it may act as a current source or voltage source. Characteristic I–V curve of a practical PV device with three important points (0, Isc), (Vmp, Imp), and (Voc, 0) are shown in Fig.2. When the device operates as a voltage source, the influence of Rs is stronger. The influence of Rp is stronger when the device operates as a current source. The regions where the device operates as voltage/current source are highlighted in Fig.2.

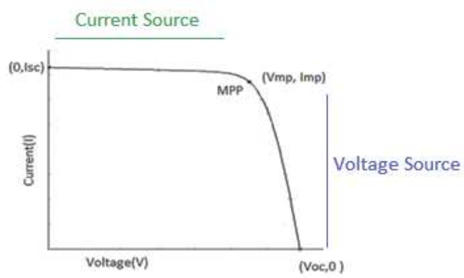

Fig. 2: V-I Curve for Solar PV Panel.

The series and parallel resistance can be calculated by using the equations given below. Under nominal irradiance at 25^{o}C with 1000 W/m^2 and the nominal operating temperature is 298.15K. There are two approaches for the evaluation of the model parameters (method1 and method 2) .Method 1 includes both resistances (Rs and Rp).The related equations are given below (Equations 4-8). Method 2 includes only Rs assuming Rp to be very large. The related equation for Rs calculation is given in Equation 9.

Method1: Evaluation of Ipv

Ipvn = (Rs+Rp)/Rp * Iscn; (4)

Ipv = (Ipvn + Ki*dT) *G/Gn; (5)

Isc = (Iscn + Ki*dT) *G/Gn; (6)

Evaluation of Rs and Rp

Rs_max = (Vocn - Vmp)/ Imp; (7)

Rp_min = Vmp/(Iscn-Imp) - Rs_max; (8)

// Initial values of Rp and Rs: Rs = 0; Rp = Rp_min;

Method-2 Evaluation of Rs

Rs = (a * ns * Vtn * log (1-Imp/Ipvn)+Vocn - Vmp)/Imp; (9)

Rp = 9999999999; // Rp = infinity (10)

RESULT AND DISCUSSION

For a typical solar panel chosen the model parameters have been evaluated by using the two methods (method 1 and method 2) and listed in Table 4.

Table 4: Model parameters values of method1 and Method 2.

S.No	Parameters	Method 1	Method 2
1	Rs	1.028316 Ω	0.466754 Ω
2	Rp	142.629799 Ω	-
3	a	0.965660	0.965670
4	T	25.000000	25.000000
5	G	1000.000000	1000.000000
6	Pmax(data sheet)	185W*	185W*
7	Pmax(simulation)	184.525000W **	184.525000W**
8	P_error	-0.000350	-0.000350
9	Ipv	7.309818A	7.290000
10	Isc	7.290000A	7.290000
11	Ion	6.50462e-010	6.71232e-010

Validation of Evaluated Parameters:

The evaluated parameters have been validated by obtaining the performance curves (I-V and P-V) using these parameters and comparing the performance curves (I-V and P-V) given in the manufacturer datasheet.

Method 1:

The performance curves (I-V and P-V) for the Irradiance of 1000W/m^2 and at the temperature of 25°C using method 1 are shown in Fig.3(a) and Fig.3(b).The current goes to a maximum of 7.3A and voltage rises to 34V for the values of Rs and Rp given in Table 4. I-V curves for various irradiances and constant temperatures are shown in Fig.4 (a). The irradiance value started from 200W/m2 goes upto 1000W/m2 with the increment of 200 W/m2 while temperature was maintained at 25°C. As the irradiance increased, the current increased. Voltage, remained relatively constant for the above mentioned irradiance range as shown in Fig.4 (a). The P-V curves are plotted for various irradiance values at constant temperature is shown in Fig.4 (b). The power increases for the increase in irradiance values.

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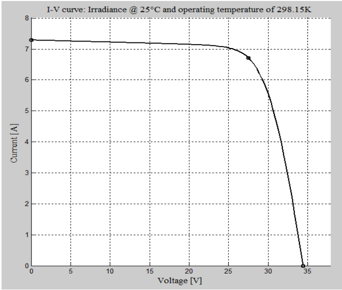


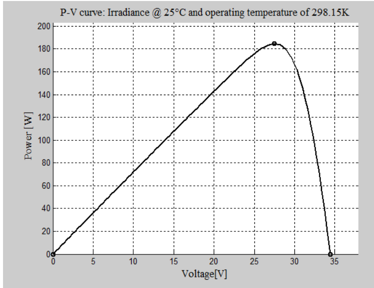
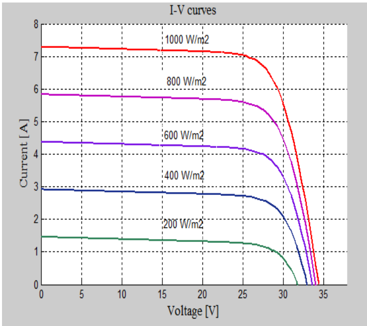


Fig. 3(a):

Fig. 3(b):



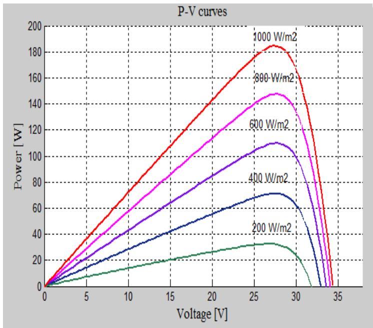
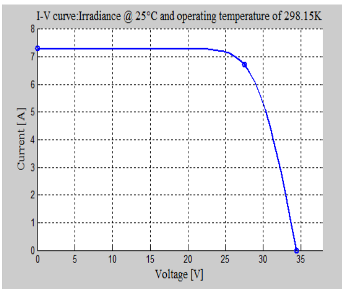


Fig. 4(a):

Fig. 4(b):

Method 2:

The performance curves (I-V and P-V) for the Irradiance of 1000W/m^2 and at the temperature of 25°C using method 2 for the values of Rs given in Table 4 are shown in Fig.5(a) and Fig.5(b). Similar I-V and P-V curves for various irradiances and at constant temperature of 25°C are obtained as shown in Fig.6 (a) and 6(b).



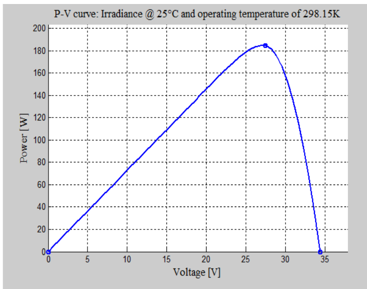
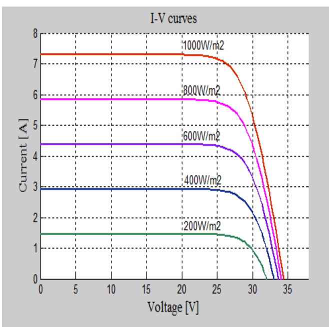


Fig. 5(a):

Fig. 5(b):



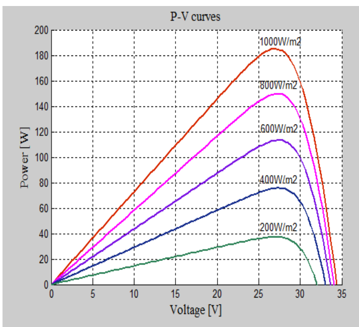


Fig. 6(a):

Fig. 6(b):

From Table 4, it is seen that, the estimated maximum power (184.525 W) using the proposed procedure, closely agrees with the maximum power (185W) given in the manufacturer's data sheet. The performance curves (I-V and P-V) obtained from simulation, using the proposed procedure show the same trend of variations as the I-V and P-V curves given in the manufacturer's data sheet.

Conclusion:

In this paper, a procedure is given to evaluate the single diode model parameters using the data provided by the manufacturer. The procedure is validated by obtaining the performance curves using the model parameters determined based on the proposed procedure and comparing them with those given by the manufacturer. The maximum power determined using the proposed procedure is found to closely agree with that given in the data sheet. The performance curves follow the same trend of variations as the curves given in the manufacturer's data sheet. Therefore, the proposed procedure enables simulation studies of any given solar panel using only the data provided by the manufacturer's datasheet.

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