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Exact Parameter Identification of Photovoltaic Panel by Using Datasheet Details

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Abstract

This paper deals with two main aspects of Photovoltaic systems. One is the analysis of Photovoltaic panel using the datasheet values provided on the PV panel and the other is to find the exact values of parameters of PV panel. Characterization of PV panels refers to the ability to predict the panel's output for given ambient conditions. To predict the exact characteristics and for exact mathematical modeling of PV panel, it is essential to find the parameters of the solar panel rather than assuming the parameters in modeling. One of the objectives of this study is to find the parameters like series resistance and shunt resistance values in single diode model by analyzing the relationship between different parameters. The analyzing process will cover the parameter estimation from the given datasheet parameters of solar panel, and mathematical algorithm involved in finding the solar panel parameters.

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Keywords: PV Panel; Parameter identification;Exact modeling;

1. Introduction

The power output of a solar panel varies significantly with varying load conditions given constant illumination on the panel's surface. Recent trends in Photovoltaic applications and control in maximum energy harvesting in

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Photovoltaic systems are discussed in literature [4] [6]. Under standard conditions, a 40W solar panel can deliver the 40W power to an ideal load. Before designing a Maximum power point Tracker circuit, it is very important to analyze the given Photovoltaic Panel. It is a general practice in research environment to assume the parameters of Solar panel while modeling it. The assumed data is always gives assumed results in Maximum power point tracking. In literature[1] [3] various methods are discussed for extracting the panel parameters and among these most of the methods are based on measurements of the I-V curve or other characteristic of the panel[3].The main objective of this paper is an attempt to find the Exact parameters of Solar Photovoltaic panels using the data available on datasheet. In this paper 40 watt panels named BP340 parameters are calculated. Same can be applicable to any Panel provided by nameplate details.

Nomenclature		Iph -	the photo-generated current in STC
Isc -	short-circuit current in STC	Io -	dark saturation current in STC
Voc -	open-circuit voltage in STC	Rs -	panel series resistance
Vmpp -	voltage at the MPP in STC	Rsh -	panel parallel (shunt) resistance
Impp -	current at the MPP in STC	A -	diode quality (ideality) factor
Pmpp -	power at the MPP in STC	k -	Boltzmann's constant
		q -	The charge of the electron

2. Datasheet based PV Panel Parameter Identification

A solar cell is the main building block of solar panel. Development of a model to simulate the performance characteristics of PV panel is discussed in literature [2][5][7]. A number of solar cells are connected in series and parallel combination to increase the voltage rating and current rating of solar panel. Modeling of solar cell is necessary to analyze the performance at different conditions. In general it is common practice to take approximate values of panel parameters for modeling a solar panel. The assumed series resistance and shunt resistance values give an approximate model of solar panel. It is very essential to develop an exact model of solar panel by calculating exact values of panel parameters. The exact model of solar panel helps in analyzing the exact effect of irradiance and temperature on solar panel. A single diode model of solar cell having a diode in parallel to the current source and having series and shunt resistance is used in modeling of exact PV panel.

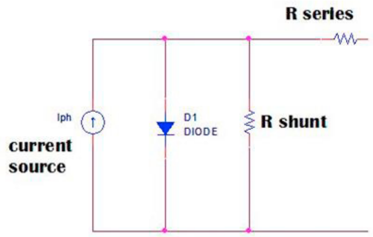

Fig 1 Single diode model of a solar cell

A solar cell can be modelled by a single diode cell model as shown in Figure3.1. The current-voltage (I-V) equation for a single solar cell using above model can be written as

$$i = \mathrm{Iph} - \mathrm{Io}\left(e^{\frac{V+iRs}{Vt}} - 1\right) - \frac{V+iRs}{Rsh} \qquad (1)$$

In the above equation, V_t is the junction thermal voltage:

$$Vt = \frac{AkT_{stc}}{q} \qquad (2)$$

The I-V equation for a PV panel (with Ns cells in series) is given by (3)

$$i = \mathrm{Iph} - \mathrm{Io}\left(e^{\frac{V+iRs}{n_s Vt}} - 1\right) - \frac{V+iRs}{Rsh} \qquad (3)$$

Where n_s is the number of cells in the panel connected in series

(3) Forms the basis for modeling a PV panel. Here V, I refer to terminal voltage and current. Modeling refers to the evaluation of panel parameters of (3), as mentioned in Table 3.1.

TABLE 1 PANEL PARAMETERS

Iph	Light Induced Current
I_0	Diode dark saturation current
Rs	Series Resistance
Rsh	Shunt Resistance
A	Diode quality (ideality) factor

Equation (3) can be written by considering the three key aspects of V-I characteristics, short circuit point, maximum power point and open circuit point. As the dark saturation current is very small compared to exponential term it is a common practice to neglect the term '−1' in equation (3).

$$\mathrm{Isc} = \mathrm{Iph} - \mathrm{Io}\ e^{\frac{\mathrm{IscRs}}{\mathrm{nsVt}}} - \frac{\mathrm{IscRs}}{\mathrm{Rsh}} \qquad (4)$$

$$\mathrm{Impp} = \mathrm{Iph} - \mathrm{Io}\ e^{\frac{\mathrm{Vmpp+ImppRs}}{\mathrm{nsVt}}} - \frac{\mathrm{Vmpp+ImppRs}}{\mathrm{Rsh}} \qquad (5)$$

$$\mathrm{Ioc} = 0 = \mathrm{Iph} - \mathrm{Io}\ e^{\frac{\mathrm{Voc}}{\mathrm{nsVt}}} - \frac{\mathrm{Voc}}{\mathrm{Rsh}} \qquad (6)$$

2.1. Parameter Identification of PV panel

A typical PV panel datasheet is shown in Table 3.2.

Table2. Datasheet values of BP340 PV panel

Parameter Type	Polycrystalline BP 340J Panel
Maximum Power (Pmax) @ STC	40W
Voltage at Pmax (Vmpp) @ STC	17.1 V
Current at Pmax (Impp) @ STC	2.33 A
Open circuit Voltage Voc @ STC	21.8 V
Short circuit Current Isc @ STC	2.56 A
Temp coefficient of Current K_{Isc}	0.04%
Temp coefficient of Voltage $K_{V\ oc}$	-0.34%

The number of parameters varies depending on the chosen model and on the assumptions adopted. The unknown parameters are Iph, I0, Rs, Rsh and Vt Where Vt = A* Ns*0.026 Volts are to be determined from Data Sheet parameters. The procedure to determine the unknown parameters from data sheet values for a particular PV panel is as follows.

At Maximum Power Point the derivative of power with respect to voltage is zero.

$$\frac{dP}{dV}\,(\mathrm{at\ V = Vmpp\ and\ I = Impp}) = 0 \qquad (7)$$

$$\frac{dI}{dV}\,(\mathrm{at\ I = Isc}) = \frac{-1}{\mathrm{Rsh}} \qquad (8)$$

Equation (6) can be rewritten as

$$\mathrm{Iph} = \mathrm{Io}\ e^{\frac{\mathrm{Voc}}{\mathrm{nsVt}}} + \frac{\mathrm{Voc}}{\mathrm{Rsh}} \qquad (9)$$

By inserting Eq.(9) into Eq.(4), it takes the form:

$$\mathrm{Isc} = \mathrm{Io}\left(e^{\frac{\mathrm{Voc}}{\mathrm{nsVt}}} - e^{\frac{\mathrm{IscRs}}{\mathrm{nsVt}}}\right) + \frac{\mathrm{Voc} - \mathrm{IscRs}}{\mathrm{Rsh}} \qquad (10)$$

Approximating the above equation we have

$$\mathrm{Isc} = \mathrm{Io}\ e^{\frac{\mathrm{Voc}}{\mathrm{nsVt}}} + \frac{\mathrm{Voc} - \mathrm{IscRs}}{\mathrm{Rsh}} \qquad (11)$$

Hence we have

$$\mathrm{Io} = (\mathrm{Isc} - \frac{\mathrm{Voc}-\mathrm{IscRs}}{\mathrm{Rsh}})e^{\frac{-\mathrm{Voc}}{\mathrm{nsVt}}} \qquad (12)$$

Eq.(9) and (10) can be inserted into Eq.(5), which will take the form:

$$\mathrm{Impp} = \mathrm{Isc} - \frac{\mathrm{Vmpp}+\mathrm{ImppRs}-\mathrm{IscRs}}{\mathrm{Rsh}} - (\mathrm{Isc} - \frac{\mathrm{Voc}-\mathrm{IscRs}}{\mathrm{Rsh}})e^{\frac{\mathrm{Vmpp}+\mathrm{ImppRs}-\mathrm{Voc}}{\mathrm{nsVt}}} \qquad (13)$$

The derivative of the power with voltage at MPP can be written as:

$$\frac{\mathrm{dP}}{\mathrm{dV}}(\text{at V} = \mathrm{Vmpp} \text{ and } \mathrm{I} = \mathrm{Impp}) = \frac{\mathrm{d(IV)}}{\mathrm{dV}} = \mathrm{I} + \frac{\mathrm{dI}}{\mathrm{dV}}\mathrm{V} \qquad (14)$$

To obtain the derivative of the power at MPP, the derivative of Eq.(13) with voltage should be found. However, (13) is a transcendent equation, and it needs numerical methods to express Impp. Eq.(13) can be written in the following form:

$$\mathrm{I} = \mathrm{f(I,V)} \qquad (15)$$

By differentiating (15):

$$\mathrm{dI} = \mathrm{dI}\frac{\partial \mathrm{f(I,V)}}{\partial \mathrm{I}} + \mathrm{dV}\frac{\partial \mathrm{f(I,V)}}{\partial \mathrm{V}} \qquad (16)$$

The derivative of the current with voltage results in:

$$\frac{\mathrm{dI}}{\mathrm{dV}} = \frac{\frac{\partial}{\partial \mathrm{V}}\mathrm{f(I,V)}}{1 - \frac{\partial}{\partial \mathrm{I}}\mathrm{f(I,V)}} \qquad (17)$$

Hence we get the value of dP/dV as follows:

$$\frac{dP}{dV} = Impp + \frac{Vmpp\,\frac{\partial}{\partial V} f(I,V)}{1 - \frac{\partial}{\partial I} f(I,V)} \qquad (18)$$

From the above:

$$\frac{dP}{dV}(\text{at } I = Impp) = Impp + Vmpp\,\frac{-\frac{(IscRsh - Voc + IscRs)e^{\frac{Vmpp+ImppRs-Voc}{nsVt}}}{nsVtRsh} - \frac{1}{Rsh}}{1 + \frac{Rs(IscRsh - Voc + IscRs)e^{\frac{Vmpp+ImppRs-Voc}{nsVt}}}{nsVtRsh} + \frac{Rs}{Rsh}} \qquad (19)$$

There are two equations now, Eq.(13) and (19), with three unknowns. Eq.(8) can be the used as the third equation. Equations(8), (18)and(19) lead to:

$$\frac{-1}{Rsh}(\text{at } I = Isc) = \frac{-\frac{(IscRsh - Voc + IscRs)e^{\frac{IscRs-Voc}{nsVt}}}{nsVtRsh} - \frac{1}{Rsh}}{1 + \frac{Rs(IscRsh - Voc + IscRs)e^{\frac{IscRs-Voc}{nsVt}}}{nsVtRsh} + \frac{Rs}{Rsh}} \qquad (20)$$

It is possible now to determine all unknown parameters, the Rs and Rsh using Eq.(13),(19) and (20)
Procedure to determine the unknown parameters from datasheet values is as described in the flowchart.

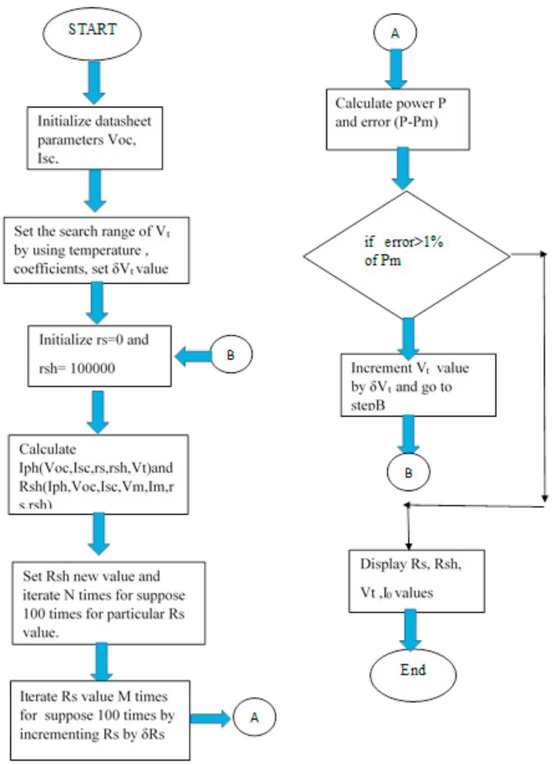

Fig 2 : flowchart for the procedure adopted to find parameters

To determine the unknown parameters BP340J PV panel using MATLAB Datasheet parameters are stored in MATLAB command window and then program is implemented in MATLAB to determine the unknown parameters from datasheet.

For a 40 watt PV panel BP340 the following parameters were obtained

Table: 3 Obtained Parameters for BP 340 PV panel

Parameter Type	Polycrystalline BP 340J Panel
Vt value	1.4698 volts
Iph value	2.542 A
I_0 value	9.06171e-007 Amps
Series Resistance Rs	0.34 ohms
Shunt Resistance Rsh	573.58 ohms

3. Conclusion

The paper was aimed at exact parameter identification of photovoltaic panels using datasheet values of panel. These parameters helps in finding the exact characterization which intended to develop a model for PV panels so that their output can be predicted for any time and place conditions. This requires irradiation and temperature conditions facing the panel along with a parameter model for PV panel. A solar Panel datasheet provides limited data about panels. This project determines the unknown parameters like series, shunt resistor values etc. required for modeling of solar panels. This present literature is concentrated on finding the parameters of PV Panel based on Datasheet values. For a particular 40Watt solar panel BP340 all the unknown parameters are determined and an exact model is developed. A 40 Watt panel at standard conditions is giving 40 watts at its MPP Point. The effect of irradiation and effect of Temperature on solar panel output are observed by keeping the other parameter constant and yet to be published.. Effects of series resistance and shunt resistance on solar panel output are observed. A perfect model for any solar panel with respective datasheet is developed and it is a perfect solution for modeling of solar panel.

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