

# Iterative Based Parameter Estimation for Non-Linear Model of a PV Module

T. Ramesh Babu, N. Prema Kumar

**Abstract:** *The modeling of Photovoltaic will assist in the assessment of the final output from the PV generation system. The estimation of five unknown parameters would contribute to building a single diode model. The equivalent circuit will facilitate in estimating five unknown parameters by considering the input parameters of the datasheets. The current and voltage from the cell are determined through using these parameters at different temperature and irradiance. The work states the Gauss-Seidel approach in a stepwise approach to obtain the 5 quantities including series and shunt resistances used in the solo diode prototype. The graph of the I-V features of the PV module is based on these quantities. SQ80 module at various temperature and irradiance are considered. The software program is used for the execution of the model. The reproduction outcomes are tested using graphs from the datasheet of the SQ80 solar cell.*

**Keywords :** PV Module; single-diode model; parameter detection; SQ80 Datasheet.

## I. INTRODUCTION

Non-conventional energy systems use resources straight from the environment to generate power, hence increasing the use of these resources causing challenges to the world [1]. The interactive application, that identifies from an arbitrary couple which can be chosen by ticking on any point. The performance of a numerical and graphical contrast of five parameter and four parameter of a single diode model, is to facilitate rebuilding of the I-V graph of the solar cell [2]. The author has proposed a method to find the five unknown parameters.

It assess the parameters based on the P-V graphs provided by the manufacturer's data sheets, but some limitations are obligatory on each parameter of the model to realm their natural meaning [3].

Non-linear mathematical equations that are used for modeling of solar cell in obtaining unidentified parameters of a single diode model are finding solutions with developing tools. The typical 60W multi-crystalline solar cell specifications are used for model exactness evaluation [4]. Serial-Parallel-Ratio (SPR) is a simplified method that reduces the number of parameters from five to four. The author considered the shunt resistance with infinite value, thus neglecting it into the model. This technique allows calculating the outstanding four parameters of the prototype, without resolving the not linear five equation system iteratively [5].

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A comparative analysis of the PV module modeling method has classified a single diode model into 5 models. Each model is groupings of diode diffusion current and photo generated current designed under unstable irradiance and temperature [6]. The fireworks explosion optimization algorithm (FEO) described a different technique to assess the parameters of the PV cell model. The author uses a different technique to assess the PV parameters precisely [7]. A new electrical model is generated which guarantees the least absolute slip between the P-V graphs. The author uses P-V graphs instead of I-V graphs to estimate the five parameters [9]. Implicit optimization algorithms used in the estimation of parameters, these algorithms use power controller strategies with first and second presumption prototypes. A plain operator linking voltage, current, and power of PV is used to acquire the parameters. This technique gives straight analytical answers, consequential from a shortened Taylor series for the prototype model. The set of equations prescribed are useful for optimal voltage estimation [10].

Gravitational search algorithm (GSA) describes the solution to parameter estimation with a linear decrease of gravitational constant. This method specifies the intent function standing on resultant variables and by iterative bases the gravitational and path loads are simplified. The GSA sets the number of loads to 100 and the number to maximum iterations to 1009, thereby reducing the period time for execution. Each time kbest is evaluated and the program is run till gravitational and velocity functions become zero [11]. The explicit identification method chooses explicit formulas to evaluate the parameters of PV cell at any standard test conditions. The method is dependent on a form of quality of the PV generator. The series or shunt resistance is neglected in this model so that the model is mounted down from five to four parameters. The two elected explicit techniques use 4 and 5 quantities, respectively [12].

The PV module is modeled using single diode model, the method is a parameterization approach to estimate the parameters of PV Module, which has high accuracy and less complexity with Grey Wolf Optimization (GWO). The simulation results are given for Shell ST40 at diode factor equal to 20.58 and SST230-60P at diode factor equal to 1.888 [14].

## II. SINGLE-DIODE MODEL

At STC conditions the solar cell modeling imply two steps, one is to assess the prototype and the other is to use the evaluated values to prepare the I-V distinctiveness under changing temperature and irradiance using the datasheet quantities as key source.

Fig. 1 shows the correspondent model for the single diode consisting of a current supply, a parallel connected diode, in addition to the series and shunt resistance.

The current of the solar cell and voltage through the output is shown by (1)

$$I = I_{ph} - I_0 \left[ \exp \left( \frac{V+IR_s}{N_s V_t} \right) - 1 \right] - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Here  $I$  is the cell current,  $V$  is the cell voltage,  $I_{ph}$  is the photo-generated current,  $I_0$  is the overload current,  $R_s$ ,  $R_{sh}$  is the series and shunt resistances,  $N_s$  is the numeral of cells serially coupled in the cell,  $V_t$  is the node voltage and is stated as  $V_t = \frac{kAT}{q}$ , here  $k$  is the Boltzmann's constant,  $q$  is the electron charge,  $T$  is the temperature of the module and  $A$  is the ideality diode constant. The 5 quantities exist in (1), which are not present in the datasheet, they are  $I_{ph}$ ,  $I_0$ ,  $R_s$ ,  $R_{sh}$  and  $A$ .  $N_s$  is given in the datasheet always.

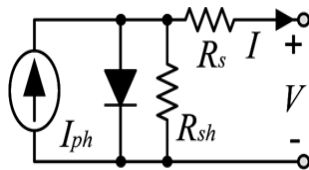


Fig. 1: Correspondent figure for single diode model

The estimation of 5 quantities of a single diode prototype will end the primary part of the PV model. The equations are derived from three unlike functional conditions of the solar cell. The conditions are follows:

1. Open circuit condition

The output terminals of the solar cell is open circuited, therefore the voltage across the solar cell will be high i.e.,  $V = V_{oc}$ . The output current is zero as the circuit is opened, Hence  $I = 0$ .

2. Closed circuit condition

The output terminals of the solar cell are closed circuited such that the voltage through PV panel is zero, i.e.,  $V = 0$ . The current becomes maximum and flow across the solar cell, it is known as closed circuit current. It is denoted as  $I_{sc}$ .

3. Maximum power point

Maximum power at a point occurs when the Current in the solar cell i.e.,  $I = I_{mp}$  and the voltage through i.e.,  $V = V_{mp}$ .

The source of equations is as follows

Open circuit condition:

The output terminals of the solar cell are opened, i.e.,  $I = 0$  and  $V = V_{oc}$ , after substituting equation (1), leads to equation (2)

$$0 = I_{ph} - I_0 \left[ \exp \left( \frac{V_{oc}}{N_s V_t} \right) - 1 \right] - \frac{V_{oc}}{R_{sh}} \quad (2)$$

Closed circuitspecification:

In closed circuit specification of procedure of a solar cell, i.e.,  $I = I_{sc}$  and  $V = 0$  in (1), leads to (3)

$$I_{sc} = I_{ph} - I_0 \left[ \exp \left( \frac{I_{sc} R_s}{N_s V_t} \right) - 1 \right] - \frac{I_{sc} R_s}{R_{sh}} \quad (3)$$

Considering the differentiation of the current by the voltage  $\frac{dI}{dV} = \frac{-1}{R_{sh}}$  over closed model specifications leads to (4) found by derivation (1) by the voltage.

$$\frac{dI}{dV} = \frac{-I_0}{N_s V_t} \left[ R_s \frac{dI}{dV} + 1 \right] \exp \left( \frac{V+IR_s}{N_s V_t} \right) - \frac{1}{R_{sh}} - \frac{R_s}{R_{sh}} \frac{dI}{dV} \quad (4)$$

Solving for  $\frac{dI}{dV}$  applying the relationship  $\frac{dI}{dV} = \frac{-1}{R_{sh}}$  in (4) results in (5)

$$\frac{1}{R_{sh}} = \frac{\frac{I_0}{N_s V_t} \exp \left( \frac{I_{sc} R_s}{N_s V_t} \right) + \frac{1}{R_{sh}}}{1 + \frac{R_s I_0}{N_s V_t} \exp \left( \frac{I_{sc} R_s}{N_s V_t} \right) + \frac{R_s}{R_{sh}}} \quad (5)$$

Maximum power point:

At maximum power the current and voltage are

$I = I_{mp}$  and  $V = V_{mp}$ , substituting these values results in equation (6)

$$I_{mp} = I_{ph} - I_0 \left[ \exp \left( \frac{V_{mp}+I_{mp}R_s}{N_s V_t} \right) - 1 \right] - \frac{V_{mp}+I_{mp}R_s}{R_{sh}} \quad (6)$$

The differentiation of power with by the voltage is given by,  $\frac{dP_{mp}}{dV_{mp}} = 0$  at maximum power point.

Where  $P_{mp}$  is the maximum power of the solar cell at STC.

The differentiation of power can be simplified as shown in (7)

$$\frac{dP_{mp}}{dV_{mp}} = \frac{d(I_{mp} V_{mp})}{dV_{mp}} = I_{mp} + V_{mp} \frac{dI_{mp}}{dV_{mp}} \quad (7)$$

By substituting the differentiation of power by the voltage in the above expression, and further substituting the yield in equation (4), yields in (8).

$$I_{mp} = \frac{V_{mp} \left( \frac{I_0}{N_s V_t} \exp \left( \frac{V_{mp}+I_{mp}R_s}{N_s V_t} \right) + \frac{1}{R_{sh}} \right)}{1 + \frac{R_s I_0}{N_s V_t} \exp \left( \frac{V_{mp}+I_{mp}R_s}{N_s V_t} \right) + \frac{R_s}{R_{sh}}} \quad (8)$$

The five equations are, (2), (3), (5), (6) and (8) which are obtained from the 3preconditions of procedure of a solar cell. Unknown parameters are derived from the above equations by rearranging in demand to answer for the required parameters.

III. GAUSS-SEIDEL METHOD

The 5equalities which areresultant can be resolved to obtain the 5indefinite parameters of a solar cell. The Gauss-Seidel Iteration



technique is expended to solve the above equations.

The technique requires first value of  $X^0$  built on identified evidence near theresolution. Through iterative process the following rate is evaluated by expending equation (9)

$$X^{k+1} = f(X^k) \quad (9)$$

The iteration technique will need that those equations are rearranged in the form of equation (9). After certain assumptions the equations are rewritten into the below expressions in terms of  $V_t$ ,  $R_s$  and  $R_{sh}$ .

$$V_t = \frac{V_{mp} + I_{mp}R_s - V_{oc}}{N_s \ln \left( \frac{I_{sc}R_{sh} + I_{sc}R_s - V_{oc} - V_{mp} - I_{mp}R_s - I_{mp}R_s}{I_{sc}R_{sh} + I_{sc}R_s - V_{oc}} \right)} \quad (10)$$

Readjusting and writing (8) in terms of  $R_s$ , results in (11)

$$R_s = \frac{V_{oc} - V_{mp}}{I_{mp} - I_{mp}} + \frac{N_s V_t R_{sh} I_{mp} - N_s V_t V_{mp} + N_s V_t I_{mp} R_s}{N_s V_t \ln \left( \frac{V_{mp} I_{sc} R_{sh} + V_{mp} I_{sc} R_s - V_{mp} V_{oc} + I_{mp} R_s V_{oc} - I_{mp} R_s I_{sc} R_s - I_{mp} R_s I_{sh} I_{sc}}{I_{mp}} \right)} \quad (11)$$

Re arranging and writing (5) in terms of  $R_{sh}$  results in (12)

$$R_{sh} = \frac{N_s V_t R_{sh} + (R_s I_{sc} R_{sh} + R_s I_{sc} R_s - R_s V_{oc}) \exp \left( \frac{I_{sc} R_s - V_{oc}}{N_s V_t} \right) + N_s V_t R_s}{(I_{sc} R_{sh} + I_{sc} R_s - V_{oc}) \exp \left( \frac{I_{sc} R_s - V_{oc}}{N_s V_t} \right) + N_s V_t} \quad (12)$$

The first rates are allocated constructed on the assessment of a specific quantity, the initial value for  $R_s = 0$  ohms and  $R_{sh} = 1000$  ohms. Expending the above rates, the rate of  $V_t$  is premeditated by (10).

The other conventional rates are premeditated for the quantities constructed on the same initial values. The error which is distinct among the present and earlier rates is in the acceptance, then the present rate is considered as the result and the iteration is stopped.

A Matlab program is composed to realize thestages. The Matlab operation grabs the quantities from the datasheet of a solar cell and yields  $I_{ph}$ ,  $I_0$ ,  $R_s$ ,  $R_{sh}$  and  $V_t$ . Table I shows datasheet parameters for SQ80 solar cell [8] and Table II displays STC quantities obtained by expending the technique.

Table 1: data sheet quantities

Quantities	SQ80
$N_s$	36
$I_{sc}$ (A)	4.85
$V_{oc}$ (V)	21.8
$I_{mp}$ (A)	4.58
$V_{mp}$ (V)	17.5
$K_I$ (mA <sup>0</sup> C)	0.0014

$K_V$  (mV<sup>0</sup>C) -0.081

TABLE 2: Extracted parameters

Parameter	SQ80
$I_0$	$6.967 \times 10^{-11}$ A
$I_{ph}$	7.4003 A
$V_t$	0.0227 V
A	0.945
$R_s$	0.3763 $\Omega$
$R_{sh}$	1.005k $\Omega$

#### IV. RESULTS AND DISCUSSION

The I-V characteristics ininstable irradiance of STC parameters for SQ80 are shown in Fig.2. The red color indicates simulation and green color indicates the experimentally measured data for the SQ80 solar cell. The TABLE-II shows the extracted quantities by using the method explained in the previous paragraph. There are various techniques available to evaluate the quantities of the solar cell, some of which have assumptions made without any intrusion to the results. The single diode prototype which is depicted in the work consists of a diode across which is prototype of the solar cell's PN junction.

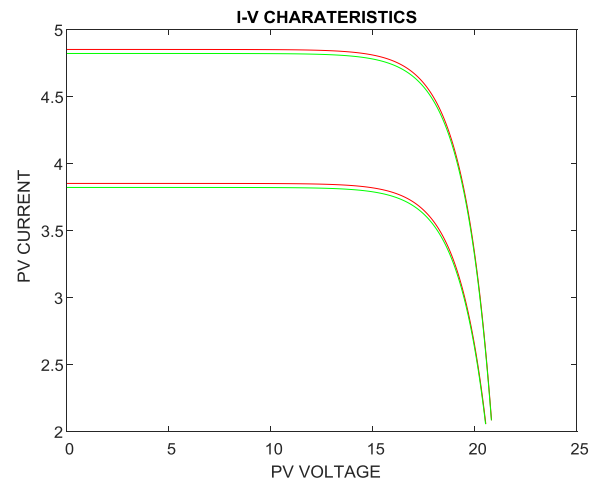


Fig. 2. I-V Characteristics plot for SQ80 under changing Irradiance for simulation and experimentally restrained values

Fig. 3 depicts I-V features produced through reproduction for the SQ80 solar cell under varying temperatures.



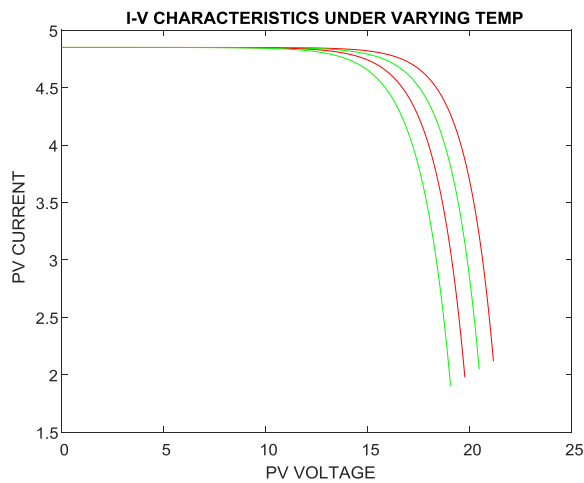


Fig. 3. I-V Features outline for SQ80 below changing Temperature for reproduction and experimentally restrained rates

### V. CONCLUSION

The work depicts the estimation of 5 parameters for the PV module using three different key operating points that are closed circuit, unguarded circuit and extreme power point functioning orders. These quantities are later expended to outline the I-V features of the solar cell with an extract from the manufacturer’s datasheet. In a distinct diode prototype, the series  $R_s$  and a shunt  $R_{sh}$  resistance are a dupe of inner cell resistances and contact resistances, in addition to the validity of outflow currents, respectively. The parameter values changes due to change in temperature and irradiance variation, the outcomes from the method here has depicted for various temperature and irradiance and have acquired satisfactory results.

The results are verified by contrast with results acquired from investigational measurements, and it can be inferred that the results acquired by the model are precise.

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