



PV Module Parameters Estimation Using Newton Raphson

Ranjith Dharmarajan^{1*}, Rajeswari Ramachandran²

¹PG Scholar, Department of Electrical Engineering, Government College of Technology, Coimbatore, TN, India

²Associated Professor, Department of Electrical Engineering Government College of Tech, Coimbatore, TN, India

*Corresponding author E-Mail ID: ranjithgct17@gmail.com, Mobile: +91 9790978785

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ABSTRACT

The estimation of solar photovoltaic (PV) system with help of electrical model parameters, such as photon generated current, the diode saturation current, series resistance, shunt resistance, and diode ideality factor, are desirable to predict the real performance characteristics of solar PV under varying environmental conditions. Finally, performance indices, such as PV characteristics curve are estimated for the various solar PV panels, using Newton Raphson (NR) to reveal the effectiveness of the proposed method. Also, validation with experimental data has been considered. Finally, through the comparative analysis of the results, it is revealed that the proposed method offers solar PV characteristics closer to the real characteristics.

Keywords: Newton Raphson (NR), Photovoltaic (PV).

1. INTRODUCTION

Solar panels harness the sun energy in the form of light and convert the energy into electricity. Although the average consumer might associate solar panels with residential rooftop assemblies, solar panels are available for a wide range of applications, including powering individual gadgets, electronic devices and vehicle batteries.

The reserves of fossil fuels are rapidly decreasing at present due to the increased use of thermal power plants and air pollution associated with the combustion of fossil fuels is increasing. Hence, in the present scenario, there is an urgent need to speed up the research and development of renewable energy technology, especially solar energy, to meet the world energy demand.

The goal of this dissertation is to develop and apply an integrated assessment framework, for one of the sustainable electricity options, solar photovoltaic (PV) technology. In this dissertation different types of photovoltaic modules are considered that are widely manufactured in the market at present, and the future implications of using PV technology in the electricity sector is evaluated.

The word 'Sustainable' in this context implies energy, environmental and economic sustainability. Higher output energy generated by the PV panels during their lifetime when compared to the input energy for manufacturing and end of life management constitutes energy sustainability. Generating cleaner (lower criteria pollutants and greenhouse gas emissions

released) electricity when compared to the grid electricity sources constitutes environmental sustainability.

PV electricity mitigates emissions from thermal power plants to the grid. Inclusion of such monetary benefits from mitigation into the evaluation of the economic performance, PV technology encourage economic sustainability.

2. ANALYSIS OF SINGLE DIODE PV MODULE

A single diode model of the solar PV module is have the unknown parameters from figure 1, namely I_{lg} , I_{sat} , A , R_{se} , and R_{sh} . By taking the datasheet information provided by the manufacturer of the PV module at standard test conditions (STCs), the PV module's parameters are estimated.

2.1. Single Diode Solar PV Module

A single diode model of the PV module is shown in Figure 1. Using Kirchoff's current law, the $I - V$ relationship of the PV module can be written as follows [10, 11]. By using the PV module parameters obtained at STCs, the values of the five parameters and the MPP of the PV module can be estimated at any temperature and irradiance condition.

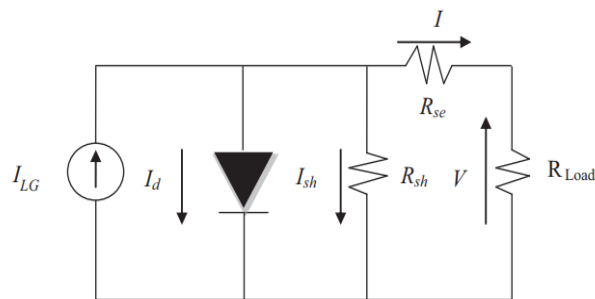


Fig 1. Equivalent circuit of PV module

$$I = I_{lg} - I_{sat} \left[e \left(V + \frac{IR_{se}}{N_s V_t} \right) - 1 \right] - \frac{V + IR_{se}}{R_{sh}} \quad (1)$$

Where,

I_{lg} - Light generated current in amps

N_s -Number of solar cells connected in series

I_{sat} - Diode reverse saturation current in amps

R_{se} -Series resistance of solar module in ohms

R_{sh} -Shunt resistance of solar module in ohms

The thermal voltage of diode, V_t , is expressed as,

$$V_t = AkT_c/q \quad (2)$$

Where,

A- Diode ideality factor

k -Boltzmann constant ($1.3806 * 10^{-23}$ J/K)

T_c - PV module temperature (STC) in K

q - Electronic charge ($1.602 * 10^{-19}$ C)

The important parameters to be noted from the manufacturer's datasheet are short circuit current (I_{sc}), open circuit voltage (V_{oc}), and maximum power point are (V_{mpp} & I_{mpp}). The values at STCs, for which the irradiance (G_{stc}) is 1000 W/m^2 and the cell temperature (T_{stc}) is 25°C . The data sheet also provides temperature coefficients for short circuit current (k_i), open circuit voltage (k_v), and maximum power (k_p).

2.1.1. Extraction of PV Module Parameters

The five unknown parameters are to be estimate of the PV module from the nonlinear equation (1), five independent equations are required. The first three equations, (4), (7), and (9), are derived from Eq. (1) by applying short circuit, open circuit, and MPP conditions. The remaining two equations, (12) and (14), are derived by differentiating the values of power and current with respect to voltage.

2.2. Short Circuit Condition (SCC)

Under the short circuit condition,

$$I_{sc} = I_{lg} I_{sat} \left[e \left(\frac{I_{sc} R_{sh}}{N_s V_t} \right) - 1 \right] - \left(\frac{I_{se} R_{se}}{R_{sh}} \right) \quad (3)$$

After some approximation, the light generated current (I_{lg}) can be written as

$$I_{lg} = \frac{I_{sc}(R_{se} + R_{sh})}{R_{sh}} \quad (4)$$

2.3. Open Circuit Condition (OCC)

Under the open circuit condition,

$$0 = I_{lg} - I_{sat} e \left(\frac{V_{oc}}{N_s V_t} \right) - \frac{V_{oc}}{R_{sh}} \quad (5)$$

This equation is rearranged and the reverse saturation current is expressed as

$$I_{sat} = \left(I_{lg} - \frac{V_{oc}}{R_{sh}} \right) e \left(-\frac{V_{oc}}{N_s V_t} \right) \quad (6)$$

Substituting I_{lg} from short circuit, the saturation current can be derived as,

$$I_{sat} = \left(\frac{I_{sc}(R_{se} + R_{sh}) - V_{oc}}{R_{sh}} \right) e \left(-\frac{V_{oc}}{N_s V_t} \right) \quad (7)$$

2.4. Maximum Power Point (MPP) Condition

The maximum power point calculation are as follows:

$$I_{mpp} = I_{lg} - I_{sat} \left[e \left(\frac{V_{mpp} + I_{mpp} R_{se}}{N_s V_t} \right) - 1 \right] - \frac{V_{mpp} + I_{mpp} R_{se}}{R_{sh}} \quad (8)$$

Inserting I_{lg} and I_{sat} into this equation, we get the equation as

$$I_{mpp} = \left(\frac{I_{sc}(R_{se} + R_{sh}) - (V_{mpp} + I_{mpp} R_{se})}{R_{sh}} \right) - \left(\frac{I_{sc}(R_{se} + R_{sh}) - V_{oc}}{R_{sh}} \right) e \left(\frac{V_{mpp} + I_{mpp} R_{se} - V_{oc}}{N_s V_t} \right) \quad (9)$$

2.5. Calculation of Initial Values

To select the initial value for R_{se} and R_{sh} , the following equations are considered. Because of high sensitivity, the numerical methods may fail to converge due to improper selection of the initial value of the PV module parameters.

$$R_{se} \text{ initial} = \left(\frac{V_{oc}}{I_{sc}} \right) - \left(\frac{V_{mpp}}{I_{mpp}} \right) \quad (10)$$

$$R_{sh} \text{ initial} = V_{mpp} / (I_{sc} - I_{mpp}) \quad (11)$$

The V_t , R_{se} and R_{sh} are given by the equations,

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

$$R_{se} = \frac{V_{oc} - V_{mpp} + N_s V_t S}{I_{mpp}} \quad (13)$$

Where,

$$S = \ln \left(\frac{(N_s V_t (I_{mpp} (R_{se} + R_{sh}) - V_{mpp}))}{I_{sc} V_{mpp} (R_{se} R_{sh}) + I_{mpp} R_{se} (V_{oc} - I_{sc} R_{se} - I_{sc} R_{sh}) - V_{mpp} V_{oc}} \right)$$

$$R_{sh} = \frac{\left((N_s V_t (R_{se} + R_{sh}) + R_{se} (I_{sc} (R_{sc} + R_{sh}) - V_{oc})) \left(\frac{e^{(I_{sc} R_{se} - V_{oc})}}{N_s V_t} \right) \right)}{\left((N_s V_t + (I_{sc} (R_{se} + R_{sh}) - v_{oc})) e^{\left(\frac{I_{sc} R_{se} - V_{oc}}{N_s V_t} \right)} \right)} \quad (14)$$

The PV module parameters I_{lg} , I_{sat} , A , R_{se} and R_{sh} can be obtained by open and short circuit test. First, these three equations are solved by Newton Raphson method and the values of V_t , R_{se} , R_{sh} are obtained

The remaining parameters are obtained from short and open circuit test using the values of V_t , R_{se} , R_{sh} .

2.6. Effect of Varying Irradiance and Temperature

The light generated current and short circuit current are directly proportional to irradiance and depends on temperature.

$$I_{lg}(G) = I_{lg}(stc) \times \frac{G}{G_{stc}} \quad (15)$$

$$I_{sc}(G) = I_{sc}(stc) \times \frac{G}{G_{stc}} \quad (16)$$

Where,

G_{stc} – Irradiance at STC (w/m^2)

G – Irradiance under given operating condition

The open circuit voltage equation can be described as the function of irradiance as given by and this equation is solved by Newton Raphson.

$$V_{oc}(G) = N_s V_t \ln \left(\frac{I_{lg}(G) R_{sh} - V_{oc}(G)}{I_{sat} R_{sh}} \right) \quad (17)$$

The short circuit current and open circuit voltage can be evaluated for the given operating temperature as given by

$$I_{sc}(T) = I_{sc}(stc) + k_i (T_c - T_{stc}) \quad (18)$$

$$V_{oc}(T) = V_{oc}(stc) + K_v (T_c - T_{stc}) \quad (19)$$

Where,

T_{stc} – Cell temperature at STC, K.

The light generated current can be determined as a function of temperature and is given by,

$$I_{lg}(T) = I_{sc}(T) (R_{se} + R_{sh}) / (R_{sh}) \quad (20)$$

The short circuit current, open circuit voltage and light generated current can be estimated at any temperature and irradiance using the following three equations.

$$I_{lg(GT)} = \left(I_{lg(stc)} + k_i(T_c - T_{stc}) \right) \left(\frac{G}{G_{stc}} \right) \quad (21)$$

$$I_{sc(GT)} = \left(I_{sc(stc)} + k_i(T_c - T_{stc}) \right) \left(\frac{G}{G_{stc}} \right) \quad (22)$$

$$V_{oc(GT)} = V_{oc(G)} + K_v(T_c - T_{stc}) \quad (23)$$

The thermal voltage V_t is directly proportional to PV panel cell temperature and is given by,

$$V_{t(T)} = V_{t(stc)} \left(\frac{T}{T_{stc}} \right) \quad (24)$$

The diode reverse saturation current, which is a function of irradiance and temperature can be calculated from the equation,

$$I_{sat(GT)} = \frac{I_{sc(G)}(R_{se} + R_{sh}) - V_{oc(GT)}}{R_{sh}} e^{\left(-\frac{V_{oc(GT)}}{N_s V_{t(T)}} \right)} \quad (25)$$

2.7. Estimation of Maximum Power Point

The proper initial values of V_{mpp} and I_{mpp} should be chosen to estimate the accurate MPP by using the well-known values of V_{oc} and I_{sc} under given operating conditions. Under varying irradiance and temperature, $V_{t(GT)}$, $R_{se(GT)}$ and $R_{sh(GT)}$ are obtained by using the estimated parameters of the PV module such as I_{lg} , I_{sat} , A , R_{se} , and R_{sh} at STC's.

In general, the PV module parameters change considerably due to various environmental conditions.

$$R_{se(GT)} = R_{se(stc)} \left(\frac{I_{lg(GT)}}{I_{lg(stc)}} \right) \quad (27)$$

The value of shunt resistance is considered a constant in [10] but the value of shunt resistance of the PV module is indirectly proportional to the short circuit current under varying operating conditions in this paper, anew equation is introduced for the shunt resistance variation with respect to temperature and irradiance and is expressed as

$$R_{sh(GT)} = R_{sh(stc)} \left(\frac{I_{sc(stc)}}{I_{sc(GT)}} \right) \quad (28)$$

In order to find MPP, The maximum voltage is found as a function of temperature and irradiance and is given by,

$$V_{mpp} = V_{oc(GT)} - I_{mpp} R_{se(GT)} + N_s V_{t(GT)} U \quad (29)$$

Where,

$$U = \ln \left(\frac{\left((I_{sc(GT)} - I_{mpp}) (R_{se(GT)} + R_{sh(GT)}) - V_{mpp} \right)}{I_{se(GT)} (R_{se(GT)} + R_{sh(GT)} - V_{oc(GT)})} \right)$$

The maximum current serves as a function of temperature and irradiance and is given by,

$$I_{mpp} = \frac{\frac{V_{mpp} Q}{N_s V_t(GT) R_{sh(GT)}} + \left(\frac{V_{mpp}}{R_{sh(GT)}} \right)}{1 + \left(\frac{Q R_{se(GT)}}{N_s V_t(GT) R_{sh(GT)}} \right) + \left(\frac{R_{se(GT)}}{R_{sh(GT)}} \right)} \tag{30}$$

Where,

$$Q = (I_{sc(GT)} (R_{sc(GT)} + R_{sh(GT)}) - V_{oc(GT)}) e^{\left(\frac{V_{mpp} + I_{mpp} R_{se(GT)} - V_{oc(GT)}}{N_s V_t(GT)} \right)}$$

These three equations can be solved using the Newton Raphson method and Generalised Hopfield Neural Network method. In these two method the error value is taken as the 1×10^{-10} . These are all the mathematical modelling of the 80W PV module that can be used for extracting the five parameters and finding the maximum power point of the prescribed PV module.

3. ESTIMATION OF PV MODULE PARAMETERS

The parameters of PV module are namely I_{lg} , I_{sat} , A , R_{se} , and R_{sh} . By taking the datasheet information Table 1, provided by the manufacturer of the PV module at standard test conditions (STCs), the PV module's parameters are estimated. By using the PV module parameters obtained at STCs, the values of the five parameters and the MPP of the PV module can be estimated at any temperature and irradiance condition.

3.1. PV Module Parameters Estimation Under STCs Using Newton-Raphson Method

In this section about the solution of a set of nonlinear equations through Newton-Raphson method. Let us consider that a set of n nonlinear equations of a total number of n variables x_1, x_2, \dots, x_n . Let these equations be given by

$$\begin{aligned} f_1(x_1, \dots, x_n) &= \eta_1 \\ f_2(x_1, \dots, x_n) &= \eta_2 \\ &\vdots \\ f_n(x_1, \dots, x_n) &= \eta_n \end{aligned} \tag{3.1}$$

Where f_1, \dots, f_n are functions of the variables x_1, x_2, \dots, x_n . Then another set of functions g_1, \dots, g_n as given below

$$\begin{aligned} g_1(x_1, \dots, x_n) &= f_1(x_1, \dots, x_n) - \eta_1 = 0 \\ g_2(x_1, \dots, x_n) &= f_2(x_1, \dots, x_n) - \eta_2 = 0 \\ &\vdots \\ g_n(x_1, \dots, x_n) &= f_n(x_1, \dots, x_n) - \eta_n = 0 \end{aligned} \tag{3.2}$$

Let us assume that the initial estimates of the n variables are $x_1^{(0)}, x_2^{(0)}, \dots, x_n^{(0)}$. Let us add corrections $\Delta x_1^{(0)}, \Delta x_2^{(0)}, \dots, \Delta x_n^{(0)}$ to these variables such that the correct solution of these variables defined by

$$\begin{aligned} x_1^* &= x_1^{(0)} + \Delta x_1^{(0)} \\ x_2^* &= x_2^{(0)} + \Delta x_2^{(0)} \\ &\vdots \\ x_n^* &= x_n^{(0)} + \Delta x_n^{(0)} \end{aligned} \tag{3.3}$$

The functions in (3.1)

then can be written in terms of the variables given in (3.3) as

$$g_k(x_1^*, \dots, x_n^*) = g_k(x_1^{(0)}, \dots, x_n^{(0)}) + \Delta x_1^{(0)} \left. \frac{\partial g_k}{\partial x_1} \right|^{(0)} + \Delta x_2^{(0)} \left. \frac{\partial g_k}{\partial x_2} \right|^{(0)} + \dots + \Delta x_n^{(0)} \left. \frac{\partial g_k}{\partial x_n} \right|^{(0)} \quad \text{where } k = 1, \dots, n$$

$$\left. \frac{\partial g_k}{\partial x_i} \right|^{(0)} \tag{3.4}$$

Expand the above equation in Taylor's series around the nominal values of $x_1^{(0)}, x_2^{(0)}, \dots, x_n^{(0)}$. Neglecting the second and higher order terms of the series, the expansion of $g_k, k = 1, \dots, n$ is given as

$$\tag{3.5}$$

Where is the partial derivative of g_k evaluated at $x_1^{(0)}, \dots, x_n^{(0)}$.

Equation (3.5) can be written in vector-matrix form as

$$\begin{bmatrix} \left. \frac{\partial g_1}{\partial x_1} \right|^{(0)} & \left. \frac{\partial g_1}{\partial x_2} \right|^{(0)} & \dots & \left. \frac{\partial g_1}{\partial x_n} \right|^{(0)} \\ \left. \frac{\partial g_2}{\partial x_1} \right|^{(0)} & \left. \frac{\partial g_2}{\partial x_2} \right|^{(0)} & \dots & \left. \frac{\partial g_2}{\partial x_n} \right|^{(0)} \\ \vdots & \vdots & \ddots & \vdots \\ \left. \frac{\partial g_n}{\partial x_1} \right|^{(0)} & \left. \frac{\partial g_n}{\partial x_2} \right|^{(0)} & \dots & \left. \frac{\partial g_n}{\partial x_n} \right|^{(0)} \end{bmatrix} \begin{bmatrix} \Delta x_1^{(0)} \\ \Delta x_2^{(0)} \\ \vdots \\ \Delta x_n^{(0)} \end{bmatrix} = \begin{bmatrix} 0 - g_1(x_1^{(0)}, \dots, x_n^{(0)}) \\ 0 - g_2(x_1^{(0)}, \dots, x_n^{(0)}) \\ \vdots \\ 0 - g_n(x_1^{(0)}, \dots, x_n^{(0)}) \end{bmatrix} \tag{3.6}$$

The square matrix of partial derivatives is called the Jacobian matrix \mathbf{J} with $\mathbf{J}^{(l)}$ indicating that the matrix is evaluated for the initial values of $\mathbf{x}_2^{(0)}, \dots, \mathbf{x}_n^{(0)}$. Then write the solution of (3.6) as

$$\begin{bmatrix} x_1^{(1)} \\ x_2^{(1)} \\ \vdots \\ x_n^{(1)} \end{bmatrix} = \begin{bmatrix} x_1^{(0)} \\ x_2^{(0)} \\ \vdots \\ x_n^{(0)} \end{bmatrix} + \begin{bmatrix} \Delta x_1^{(0)} \\ \Delta x_2^{(0)} \\ \vdots \\ \Delta x_n^{(0)} \end{bmatrix} = \begin{bmatrix} x_1^{(0)} \\ x_2^{(0)} \\ \vdots \\ x_n^{(0)} \end{bmatrix} + [\mathbf{J}^{(0)}]^{-1} \begin{bmatrix} \Delta g_1^{(0)} \\ \Delta g_2^{(0)} \\ \vdots \\ \Delta g_n^{(0)} \end{bmatrix} \quad (3.7)$$

$$\Delta g_k^{(0)} = g_k(x_1^*, \dots, x_n^*) - g_k(x_1^{(0)}, \dots, x_n^{(0)})$$

Since the Taylor's series is truncated by neglecting the 2nd and higher order terms, It cannot expect to find the correct solution at the end of first iteration. So that go for further iterations.

$$(3.8)$$

These are then used to find $\mathbf{J}^{(l)}$ and $\Delta g_k^{(l)}, k = 1, \dots, n$. Then find $\Delta x_2^{(l)}, \dots, \Delta x_n^{(l)}$ from an equation like (3.7) and subsequently calculate $\mathbf{x}_2^{(l)}, \dots, \mathbf{x}_n^{(l)}$. The process continues till $\Delta g_k, k = 1, \dots, n$ becomes less than a small quantity.

3.2 Algorithm

Step 1: Assign the input values for $I_{SC}, V_{OC}, V_{MPP}, I_{MPP}$ & N_s .

Step 2: Initialize $iter = 1, V_t(ol)d=0$ & Calculate $R_{sh}(ol)d, R_{se}(ol)d$ For initialization.

Step 3: The condition $Iter = maxiter$ satisfies go fot next step if not stop.

Step 4: Evaluate values $V_t(new), R_{sh}(new), R_{se}(new)$ & A .

Step 5: Calculate error values $1 * e^{-10}$.

Step 6: The old values are updated $V_t(ol)d = V_t(new), R_{sh}(ol)d = R_{sh}(new),$

$$R_{se}(ol)d = R_{se}(new).$$

Step 7: It cannot expect to find the correct solution at the end of first iteration.

So that go for further iterations $Iter = Iter+1$.

Step 8: The end of iterations final values are updated as follows $V_t(fin)al)=V_t(new),$

$$R_{sh}(fin)al)=R_{sh}(new) \& R_{se}(fin)al)=R_{se}(new).$$

Step 9: Evaluate I_{lg} , I_{sat} & A and stop the program.

The N-R method for estimate five parameters of PV module with help of equations (12),(13) & (14) in STCs. The flowchart for evaluation of the five parameters of the PV module is shown in Figure 2.

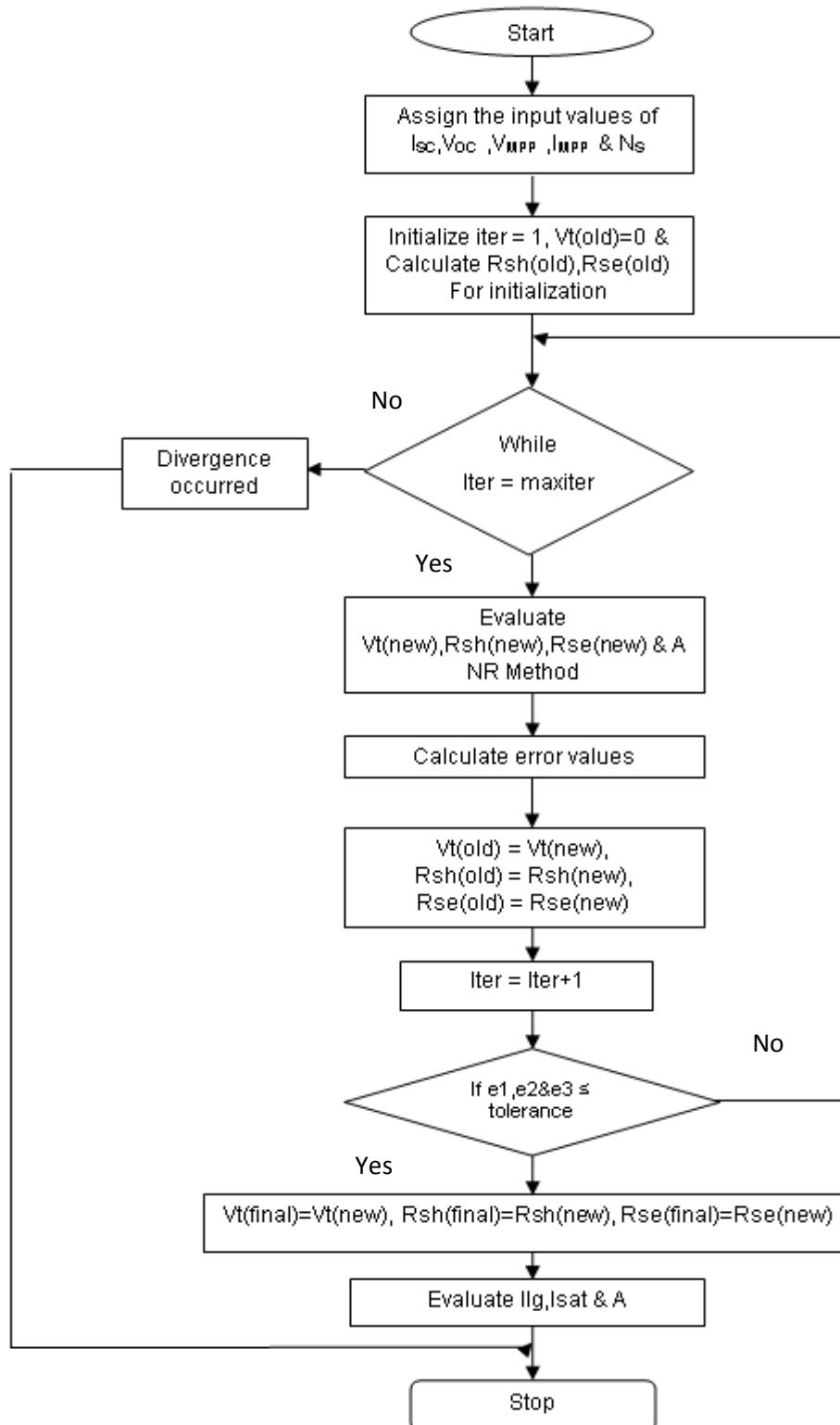


Figure 2 Flowchart for the N-R method

These values are given at STCs, for which the irradiance (G_{stc}) is 1000 W/m^2 and the cell temperature (T_{stc}) is 25°C

Table 1. Datasheet of PV modules

PV Module	Datasheet values				
	I_{sc} (A)	I_{mpp} (A)	V_{oc} (V)	V_{mpp} (V)	N_s
KD245GX	8.91	8.23	36.9	29.80	60
U5-80	5.21	4.58	21.34	17.46	36
Shell SP70	4.7	4.25	21.4	16.5	36
HST60FXXXM	8.82	8.39	37.9	31.03	60
HST36FXXXP	4.65	4.30	21.5	17.5	36
HST60FXXXP	8.80	8.27	37.6	30.23	60

Table 2. Estimated parameters for various PV modules at STCs

PV Module	Estimated parameters				
	A	R_{se} (Ω)	R_{sh} (Ω)	I_{lg} (A)	I_{sat} (A)
KD245GX	1.4290	0.1562	623.2350	8.9122	4.6709e-07
U5-80	1.6043	0.0086	66.6312	5.2107	2.7593e-06
Shell SP70	1.5536	0.3242	321.2234	4.2543	1.4181e-06
HST60FXXXM	0.9485	0.2920	38772.16	8.8201	4.8301e-11
HST36FXXXP	1.3862	0.1385	671.3679	4.6510	2.3925e-07
HST60FXXXP	1.1452	0.2893	4956.62	8.8005	4.9002e-09

The parameters are estimated in standard test conditions (STCs) and tabulated different PV modules of 250W solar panel KD245GX, HST60FXXXM, HST60FXXXP and 80W solar panels of U5-80, Shell SP70, HST36FXXXP.

The N-R method for estimated five parameters of PV modules with help of equations (12),(13) & (13) in STCs are shown in Table 2.

Table 3. Estimated parameters for various PV modules at varying irradiance and temperature

PV Module Parameters	G (W/m^2)	T_c ($^\circ\text{C}$)	A	R_{se} (Ω)	R_{sh} (Ω)	I_{LG} (A)	I_{sat} (A)	V_{mpp} (V)	I_{mpp} (A)	P_{mpp} (W)
KD245GX	1000	30	1.48346	0.1562	623.2831	8.9122	6.16E-07	29.8017	8.2304	245.3275
	1000	50	1.39161	0.1562	623.2756	8.9123	1.71E-06	29.799	8.2304	245.2597
	1000	70	1.31046	0.1562	623.2682	8.9124	4.22E-06	29.7962	8.2304	245.2404

	1100	25	1.50013	0.1718	566.6227	9.8034	4.24E-07	29.7861	9.0506	269.5705
	800	25	1.52890	0.125	779.1062	7.1298	5.85E-07	29.6937	6.5839	195.4961
	600	25	1.4485	0.0937	1039	5.3465	5.833e-07	29.3463	4.9321	145.2552

Shell SP70	1000	25	1.63987	0.3242	321.2234	4.7047	1.57E-06	16.4999	4.2499	70.1221
	800	25	1.66453	0.2594	401.5293	3.7638	1.97E-06	16.5844	3.4061	56.4933
	600	25	1.69741	0.1945	535.3723	2.8228	2.64E-06	16.4795	2.5542	42.1024
	400	25	1.75084	0.1297	803.0585	1.8819	4.01E-06	16.0991	1.698	27.3323
	200	25	1.84537	0.0648	1.61E+03	0.9409	8.27E-06	15.1711	0.8416	12.7678
U5-80	351	35.7	1.67421	0.003	189.3658	1.8335	1.41E-05	15.7182	1.5949	25.0731
	426	42	1.62451	0.0037	155.8012	2.2284	1.48E-05	16.0523	1.9431	31.1902
	568	44	1.57765	0.0049	116.7973	2.9726	1.18E-05	16.5378	2.6	42.9893
HST60FXXXP	841	49	1.4775	0.2802	6.87E+04	8.2418	4.77E-05	22.1535	7.3418	162.6971
	868	49	1.4775	0.2892	6.66E+04	8.5064	4.84E-05	22.0907	7.5706	167.2258
	872	49	1.4775	0.2905	6.63E+04	8.5456	4.85E-05	22.081	7.6044	167.8917
	881	49	1.4775	0.2935	6.56E+04	8.6338	4.87E-05	22.0589	7.6804	169.3776
	882	49	1.4775	0.2938	6.55E+04	8.6436	4.87E-05	22.0564	7.6889	169.5447
	887	49	1.4739	0.2955	6.51E+04	8.6926	4.74E-05	22.0439	7.731	170.4773
	908	47.7	1.4559	0.3005	6.41E+04	8.8394	3.49E-05	22.3972	7.8853	176.5793
HST60FXXXM	832	43.8	1.3809	0.1763	3.67E+03	7.9543	8.63E-06	24.3232	7.2374	176.0508
	835	43.8	1.3809	0.1769	3.66E+03	7.983	8.63E-06	24.3224	7.2633	176.6694
	840	43.8	1.3809	0.178	3.63E+03	8.0308	8.64E-06	24.3209	7.3066	177.6929
	845	43.8	1.3809	0.1791	3.61E+03	8.0786	8.65E-06	24.3192	7.3498	178.7144
	849	43.8	1.3809	0.1799	3.59E+03	8.1168	8.66E-06	24.3177	7.3844	179.5342

The light generated current and short circuit current are directly proportional to irradiance and also depend on temperature. The unknown parameters of PV module namely I_{lg} , I_{sat} , A , R_{se} , and R_{sh} , can be estimated at any temperature and irradiance condition.

PV modules of 250W solar panel KD245GX, HST60FXXXM, HST60FXXXP and 80W solar panels of U5-80, Shell SP70 are taken estimated parameters at any temperature and irradiance conditions are shown in Table 3.

4. CONCLUSION

In this work, the following PV modules are taken for estimate the five unknown parameters of KD245GX, U5-80, Shell SP70, HST60FXXXM, HST36FXXXP and HST60FXXXP. The N-R method is used to estimate the five unknown parameters of the PV modules at STCs. Here, good convergence is achieved in the N-R method during MATLAB coding, due to the selection of appropriate initial values from the series and shunt resistance equations. The SUR method is used to extract the MPP at different environmental conditions by considering the varying nature of shunt resistance, series resistance, and ideality factor. In particular, through the proposed equations of shunt resistance and ideality factor of the PV model,

accurate MPP value is obtained. For a wide range of operating conditions, the MPP and the five unknown parameters of various PV modules are estimated.

5. FUTURE SCOPE

The proposed methodology estimate the five unknown parameters of the PV module at STCs and variable temperature and irradiance conditions. Five unknown parameters of the PV module can be obtained with the GHNN based optimization technique

Solar power from the PV module the converter will help to get maximum power by taking PV module references of voltage and current. Instead of taking reference from the PV module, for different environment conditions five parameters are determined and can be used for generating pulse signal for driving converter for deliver maximum power from PV module.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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