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Five parameters extraction of single diode PV model by metaheuristic optimization method by identified built-up data

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ABSTRACT

Precision calculation of unknown photovoltaic (PV) modules or single diode models for PV cell specifications under various environmental conditions is needed to build a sunlight-based PV framework. Installing a PV system requires knowledge of all parameters, modeling, and optimization techniques because PV system analysis and configuration help generate renewable energy. This concept requires accurate modeling and calculation of identified and unknown parameters. The single-diode model is simple and accurate for different mathematical equations. Streamlining calculations requires distinguishing this nonlinear model. The current investigation calculated five unknown parameters and compared them with particle swarm optimization (PSO) and wind-driven optimization (WDO) optimization results. The said approach utilizes MATLAB software, analytical as well as optimization methods, and manufacturing data. The suggested method is simple, fast, and accurate for calculating diode ideality factor (A), output currents (I_o), series resistance (R_s), shunt resistance (R_{sh}), and photocurrent (I_{ph}).

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1. INTRODUCTION

In recent days, the demand for different sustainable energy/fuel sources is found to be increasing continuously as they can be an alternative source to fossil fuel as well as a minimum toxic effect on the environment. Among all, solar-based energy sources arise as a potential choice as it is a renewable source of energy. Currently, photovoltaic (PV) plants are normally used by enormous people for energy production and utilization. Concerning its pragmatic execution, the sun-powered PV framework ought to be advanced before its establishment. This can be guaranteed by exact demonstrating, recognizable proof, and recreation of sun-powered PV modules. Solar-based PV represents its current as well as power voltages i.e. (I-V) and (P-V) relations over different temperature conditions and irradiances [1]-[6]. These characteristics and the relation of the I-V and P-V curves of the PV cell or the module were analyzed with various diode (single, double, triple, and multiple) models [7]-[9]. Regarding different article conclusions along with an estimation of unknown parameters for the different diode models, the author has used different methods such as analytical, numerical, and hybrid (a combination of numerical and analytical or called metaheuristic method) [9], [10]. Among all, the metaheuristic optimization method is the best evolutionary method as it deals with the analytical and numerical approach as well as the nonlinear characteristics of the diode model.

In the last decade, different analytical as well as optimization methods were used by different researchers for the estimation of identified and unknown parameters. These methods included biology-based algorithms (genetic, performance-guided JAYA, whale optimization, and, flower pollination) and optimization (artificial bee swarm, improved ant lion, biogeography based, bird mating, grey wolf, and cuckoo search) [11]-[14]. While, physics-based algorithms (evaporation rate-based water cycle, fireworks, lozi map-based chaotic optimization, mutative scale parallel chaos optimization, and simulated annealing) and optimization (particle swarm and wind-driven) were also reported by different scientists [7]-[10]. In the present work, the author presented an analytical approach and particle swarm optimization (PSO) algorithms by using a single diode model for the simulation of PV cells and modules by using diverse manufacturing data. The results are compared along these methods that applied to different modules and took results in the MATLAB tool platform. The present study mainly focused on result-based calculation of various unknown five parameters such as the ideality factor of the diode (A), output currents (I_o), series resistance (R_s), shunt resistance (R_{sh}), photocurrent (I_{ph}) for single diode model of PV cell or PV module. The proposed strategy utilizes an iterative calculation unique to the recently introduced models that attention to the enhancement of the five parameters which are mentioned above. The technique utilizes iterative methods to appraise the five parameters of the electrical model, beginning from the manufacturing datasheet with considering the characteristics of parameters. The author fills in some discrepancies from prior projects throughout this study by considering several techniques for a single-diode model and trying to compare expected variables to analytical and combinatorial optimization. It is possible to use one analytical approach and two optimization methods, such as PSO and wind-driven optimization (WDO), and compare the results using a graphic representation. However, the PV cell model is utilized in this work, and the MATLAB programming version -2020 is being used. On the task monitor's graphical user interface, the predicted variable from all PV modules has been envisioned.

2. PHOTOVOLTAIC DIODE MODELLING AND PROBLEM FRAMING

A mathematical concept for modeling diodes together with analytical and optimization methods was stated here. For this, a complete discussion about the single diode PV cell model mathematical equation was done as it is required [15], [16]. In this section mathematical modelling concept for single diode model has been explained. This modelling concepts with the support of analytical as well as optimization methods. A complete discussion along with PV cell mathematical model with all analytical equations such as photocurrent, diode ideality factor, saturation current, series and parallel resistance has been discussed in section 3 as a single diode model analytics.

2.1. Single diode model (PV cell model)

Various types of circuit models existed for presenting the PV cell's mathematical model. PV cell-ideal circuit model with the use of single diode model: here, the circuitry diode is parallel connected with light generated current source (Figure 1).

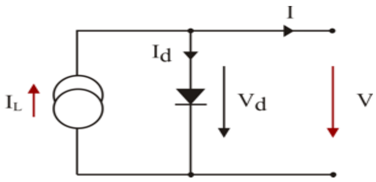

Figure 1. PV cell-ideal diode model

In the above model (Figure 1), I_L=current source. I=output current and it can be presented by using Kirchhoff's current law:

$$I = I_L - I_d \quad (1)$$

and I_d

$$I_d = I_S[exp(\frac{V}{nV_T}) - 1] \quad (2)$$

By reconstructing (1) with the help of (2):

$$I = I_L - I_S[exp(\frac{V}{nV_T}) - 1] \quad (3)$$

2.2. PV cell–non-ideal circuit model with the use of single diode model

The present model is called five parameter model. Here, the model is discussed with the help of parameters such as series resistance (R_s), and, shunt resistance (R_{sh}) as these parameters play important roles in this circuit. The circuitry diode is parallel connected with light generated current source (Figure 2) [1]-[3].

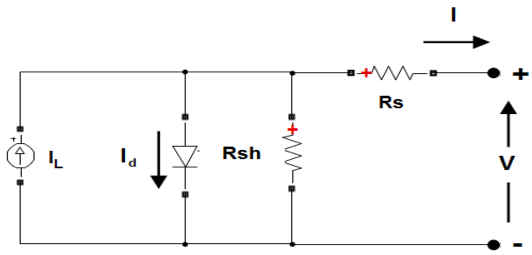

Figure 2. Non-ideal single diode circuit model for PV cell

In this model, '*A*' indicates the diode ideality factor, I_d indicates the current of the diode, I_L indicates the current source generated by light, R_{sh} indicates the shunt resistance and R_s indicates the series resistance [1]. The mathematical equation of the non-ideal single diode circuit model is as [17], [18].

$$I = I_L - I_d - I_{sh} \tag{4}$$

Diode current (I_d) calculation can be calculated from (5) and (6):

$$I_d = I_O(exp(\frac{V+IR_S}{n_S V_T}) - 1 \tag{5}$$

$$I = I_L - I_O(exp(\frac{V+IR_S}{n_S V_T}) - 1) - \frac{V+IR_S}{R_{sh}} \tag{6}$$

With consideration of the above equations, it can confirm the consisting of five unknown parameters i.e. *A*, I_0, I_L, R_{sh}, and R_s, in a single diode model [19].

3. SINGLE-DIODE MODEL ANALYTICS

Analytical and metaheuristic-based optimization method was used for the mathematical modeling and designing of the PV module. Combining different work and comparison of obtained data is called a hybrid type method. For calculating all parameters, it is required to find relative equations one which calculates mathematical equations. A software tool known as MATLAB is used for the analysis of the same [10]. For parameter calculations and understanding of the behavior of the PV module, a single diode model is used as it is simple to use as well as maintains the highest accuracy [20]. As discussed in this section the mathematical model is shown in Figure 3. By considering all basic constant and manufacturing data it can rewrite the equations of Figure 2.

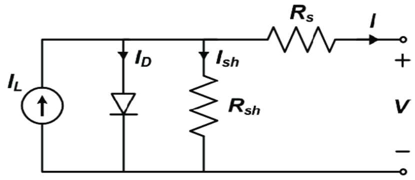

Figure 3. Single diode schematic mathematical model

3.1. PV cell-single diode circuit model

Figure 3 has given detailed information about the single diode model's equivalent circuit where a parallel connection of schottky diode was seen with source current ($I_{ph}=I_L$), series resistance (R_s), and, shunt resistance (R_{sh}). From all the above circuit detail, the equation can be modified as:

$$I = I_{ph} + I_o - I_o\, exp\frac{q(V+IR_S)}{AN_SkT} - \frac{V}{R_{sh}} - \frac{IR_S}{R_{sh}} \tag{7}$$

Analysis can also be done based on the condition of open and short circuits as well as the highest power point. Suppose, the short circuit condition is $I=I_{sc}$ and $V=0$, then the equation can be:

$$I_{sc} = I_{ph} + I_o - I_o\, exp(\frac{I_{sc}R_S}{AN_SV_t}) - \frac{I_{sc}R_S}{R_{sh}} \tag{8}$$

$$V_t = \frac{kT}{q} = 0.256796 \tag{9}$$

By considering the modules thermal voltage and circuit voltage zero i.e. $I=0$ and $V=V_{oc}$, then (8) is modified and the modified equation can be:

$$I_{ph} = I_o(\frac{V_{oc}}{AN_SV_t}) - I_o + \frac{V_{oc}}{R_{sh}} \tag{10}$$

The above equation can be covert logarithmically for speedy analysis and maintaining maximum accuracy; the equation can be prepared as (11):

$$ln(I_{ph} + I_o - \frac{V_{oc}}{R_{sh}}) - ln(I_o) = \frac{V_{oc}}{AN_SV_t} \tag{11}$$

Assuming the maximum power point condition is $I=I_{mpp}$ and $V=V_{mpp}$, then the modified (8) is as (12):

$$I_{mpp} = I_{ph} + I_o - I_o\, exp(\frac{V_{mpp}+I_{mpp}R_S}{AN_SV_t}) - \frac{V_{mpp}+I_{mpp}R_S}{R_{sh}} \tag{12}$$

The above equation is rewritten as:

$$ln(I_{ph} + I_o - I_{mpp} - \frac{V_{mpp}+I_{mpp}R_S}{R_{sh}} - ln(I_o) = \frac{V_{mpp}+I_{mpp}R_S}{AN_SV_t} \tag{13}$$

Subtract (11) and (13) then the result as:

$$ln(\frac{I_{ph}+I_o-\frac{V_{oc}}{R_{sh}}}{I_{ph}+I_o-I_{mpp}-(\frac{V_{mpp}+I_{mpp}R_S}{R_{sh}})}) = \frac{V_{oc}-V_{mpp}-I_{mpp}R_S}{AN_SV_t} \tag{14}$$

The above can be used for the mathematical modeling of five parameters and rewritten as:

$$A = \frac{V_{oc}-V_{mpp}-I_{mpp}R_S}{N_SV_t[ln(I_{ph}+I_o-\frac{V_{oc}}{R_{sh}\overline{I_{ph}}+I_o-I_{mpp}-(\frac{V_{mpp}+I_{mpp}R_S}{R_{sh}})}]} \tag{15}$$

As know, there are five unknown parameters of single-diode PV cells. The rest of the four parameters are needed to calculate. It can be calculated with the help of a manufacturing data sheet [21], [22]. The five parameters can be determined from the aforementioned information using various mathematical formulas that are then applied to various solar modules. By taking into account manufactured data sheets, (17)-(21) in Figure 4 flowchart provide detailed explanations of analytical methods for calculating parameters.

3.2. Photocurrent (I_{ph}) analysis

The photocurrent is nothing but a light-generated source of PV cells and it is one of the most important sources of the same. For calculating I_{ph}, need to rearrange the photocurrent equation and the equation has become.

$$I_{ph} = I_{sc} - I_o + I_o\, exp(\frac{I_{sc}R_S}{AN_SV_t}) + \frac{I_{sc}R_S}{R_{sh}} \tag{16}$$

By considering, the photocurrent with temperature, irradiance, and temperature coefficient of short circuit current K_1, then the equation can be written as:

$$I_{ph} = \frac{S}{S_{STC}}[I_{phSTC} + K_1(T - T_{STC}) \quad (17)$$

Where 'T' indicates the actual temp. (K), 'T_{STC}' indicates the temperature of standard test condition (298.15K), 'S' indicates the PV cell surface irradiance, 'S_{STC}' indicates the irradiance at STC (~1,000 W/m^2) and 'I_{phstc}' indicates the standard current generated by light at STC.

3.3. Analysis of diode ideality factor (A)

In this, data obtained from the manufacturing data sheet and standard test condition is maintained for analyzing the diode ideality factor. These manufacturing data sheets provide the standard parameters that can be used for the calculations of the diode ideality factor. The provided data includes I_{sc}, I_{mpp}, V_{oc}, and V_{mpp}. By considering the R_s=0 and R_{sh}=∞ as short circuit current conditions then the analysis of the ideality factor is as follows based on the (15).

$$A = \frac{V_{oc}-V_{mpp}}{N_sV}[ln(\frac{I_{sc}+I_0}{I_{sc}+I_0-I_{mpp}})]^{-1} \quad (18)$$

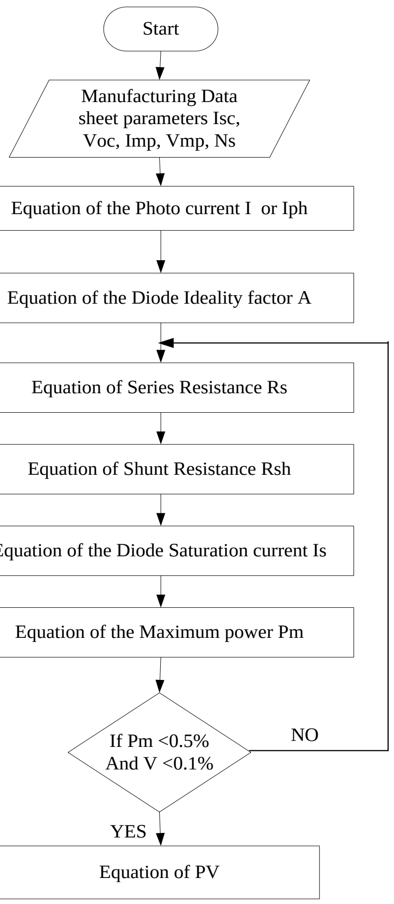

Figure 4. Flow chart analytical methods for calculation of parameters

3.4. Saturation current analysis

This can be done by consideration and combination of (7), (8), and (10). At the condition of open circuit voltage and short circuit, it can be obtained as:

$$[I_0]_{I_{sc}V_{oc}} = \frac{I_{sc}R_{sh}+I_{sc}R_S-V_{oc}}{R_{sh}[exp(\frac{V_{oc}}{AN_sV_t})-exp(\frac{I_{sc}R_S}{AN_sV})} \quad (19)$$

The above equation expressed that the current acted on constant STC. So, the 'I_0' depends on temperature. By considering the R_s (R_s=0) and R_{sh} (R_{sh}=∞), It can calculate the optimum value [17]-[20].

3.5. Analysis of R_s and R_{sh}

The best possible value calculates the optimum value of the solar module at the maximum power point value parameter with in absence of R_s and R_{sh}, it can, even so, take into account various conditions such as maximum power point, short circuit current, and voltage conditions. The obtained is as (20):

a. Maximum power point condition-here, (12) can be rearranged as:

$$R_{sh} = \frac{V_{mpp}+I_{mpp}\,R_s}{I_{ph}-I_{mpp}-I_o(exp((\frac{V_{mpp}+I_{mpp}\,R_s}{AN_sV_t}))-1)} \tag{20}$$

b. Short circuit current and open circuit voltage-along with this condition, the (10) and (11) compared and correlate with R_s and R_{sh}. The newly formed equation is as (21):

$$R_{sh} = \frac{V_{oc}-I_{sc}R_s}{I_{sc}+I_0\,exp(\frac{I_{sc}R_s}{AN_sV_t})-I_o\,exp(\frac{exp\,V_{oc}}{AN_sV_t})} \tag{21}$$

From all the above data, it can conclude that five parameters can be calculated from various mathematical equations which can apply to various solar modules and that is explained in the flowchart in Figure 4.

4. PV CELL: SINGLE DIODE MODEL-OPTIMIZATION TECHNIQUE

4.1. Particle swarm optimization technique

Kennedy and Ebehart 1995 developed this method and this are one of the best optimization methods [20]. This method can be applied to different known and unknown parameters such as power systems, control systems, and the optimization of renewable energy. This method has the potential to obtain a higher level of intelligence. A simple and social behavioral model such as PSO is generally used for solving problems related to optimization. This method also used for effective and competitive algorithms, as this technique has population-based optimization (Figure 5). For the present study, have been used the MATLAB software tool for calculating the unknown parameters. A swarm of particles initiates in PSO algorithm one which is the parameters of the model on that work and the position of those particles is represented by '*Si*' [21].

$$S_i = S_{i1}, S_{i2} \ldots\ldots\ldots\ldots\ldots\ldots S_{id}$$

'*d*' indicates the dimensional vector in problem space, *i*= 1, 2,…M, M indicates the population size.

On a predefined fitness function, the performance of the PSO algorithm is analyzed. Every particle which is present in dimensional space acts as a member solution of the PSO. i^{th} particle velocity, in PSO, revealed as:

$$V_i = V_{i1}, V_{i2}, \ldots\ldots\ldots\ldots\ldots\ldots V_{id}$$

This one is used as changing the position of particle one which was compared with input parameters. For the successful execution of the technique, the global best value worked for the PSO algorithm. Here, every particle in the optimized system amends with the individual's earlier position namely P_i and P_g. This is also monitored by the iteration updated by the following equations.

$$V_i(t+1) = V_i(t) + C_1 rand_1(P_i - S_i(t)) + C_2 rand_2 \tag{22}$$

$$S_i(t+1) = S_i(t) + V_i(t+1) \tag{23}$$

Here, 'P_i' in sequence denotes the i^{th} particle's best position, 'P_g' denotes the member's best position from the whole swarm population, '*T*' indicates the iteration counter, 'C_1' and 'C_2' represents the acceleration coefficients, '$rand_1$' and '$rand_2$' indicates 0 and 1 i.e. two random uniform numbers. For optimization or calculation of unknown parameters of a single diode model, if it compares the above method then the mathematical model of the same is encoded into the binary strings. These are called chromosomes. Length of string used further for calculations purpose. These results were matched and compared with various manufactured data sheets. MATLAB (MATLAB 2020a version by GUI interface) software is used for the same [22].

PSO algorithm works under a different condition that matched the value calculated as well as practical data but the present study, consider only manufacturing data to calculate unknown parameters and it has been compared with the analytical method. PSO fitness function is very important in the PSO method [23]-[25]. PSO calculation requires the meaning of wellness metric to assess every molecule. The objective is to coordinate with model parameters to various tested focuses. Subsequently, the wellness metric is the blunder between model expectation and genuine estimation. For the open circuit voltage and the short circuit current condition along with output calculation to I_o which has been shown in (19). Just recall the terms which are used for considering the PSO fitness such as open circuit voltage at *I*=0, then mathematical equations such as (24):

$$V_{OC} = \frac{nkT}{q} ln(\frac{I_{ph}}{I_o} + 1) \tag{24}$$

At short circuit current *V*=0 then, $I_{sc}=I_{ph}$ according to this assumption can write an equation for the predicted saturation current.

$$I_P = \frac{I_{ssc}}{e^{\frac{qV_{SOC}}{nkT_S}} - 1} \tag{25}$$

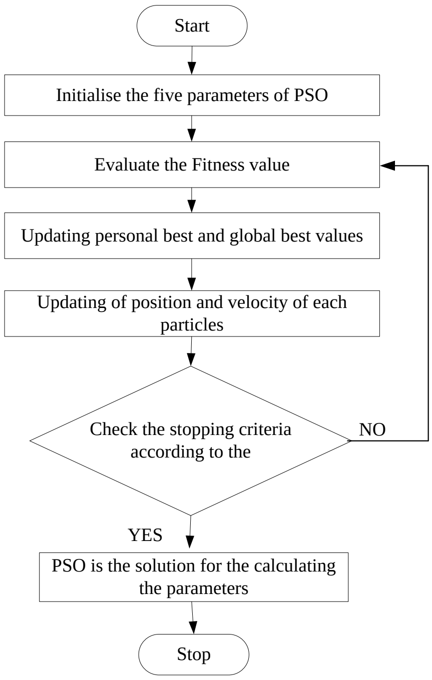

Figure 5. Particle swarm optimization method

Then by adding sample load current equation for the same:

$$I_P = I_{ssc} - I_{PRSC}(e^{\frac{q(V_{SLV}+I_{SLC}R_S)}{nkT_S}} - 1) - \frac{V_{SLV}+I_{SLC}R_S}{R_{sh}} \tag{26}$$

Where I_P is predicted load current; I_{SS} is sample short circuit current; V_{SLV} is sample load voltage; I_{SLC} is sample load current; V_{soc} is sample open circuit voltage; and T_S is sample environmental team. The effectiveness of the suggested PSO technique optimization was assessed. Using the particle swarm optimization method described in Figure 5 describes the method for deciding which PV features are optimal for the installation site. To choose the best installation location environmental, geographic, topographical, and climate considerations are taken into account using decision-support systems that incorporate multicriteria analysis for PSO. The size of the population and acceleration factors has an impact on how the PSO is executed. The convergence of the optimal fitness value is shown in Figure 5 considering (22)-(26). For each sample of the solution, the optimization process was run 500 times with various population sizes to examine for variations in the outcomes. The PSO algorithm frequently produces an optimal solution after a few rounds using a random approach. The examination of the convergence of PSO for the developed technique for PV modules is evaluated for each irritation with varying values for the constant temperature to achieve the average of optimal results. To get the best results, the PSO was iterated 500 times with various populations. The fitness value in curves converges regardless of operation temperature and irradiance.

4.2. Wind-driven optimization technique

This algorithm is a recent type of global optimization methodology that is inspired by nature and based on atmospheric motion [26], [27]. This technique is also a population-based iterative heuristic global optimization algorithm. This technique is used to solve multi-dimensional and multi-modal problems as it has the potential to administer constrictions of the search domain. At its core, a population of infinitesimally small air parcels navigates over an N-dimensional search space following Newton's second law of motion, which is also used to describe the motion of air parcels within the earth's atmosphere. If comparisons were made for an algorithm that is based on a similar particle, WDO added more terms in gravitation and Coriolis forces (velocity update equations), which provide strengths and an additional degree of freedom for fine-tuning optimization. Besides the theory and concept of WDO, it is the mathematical study of WDO parameters (Figure 6) [28].

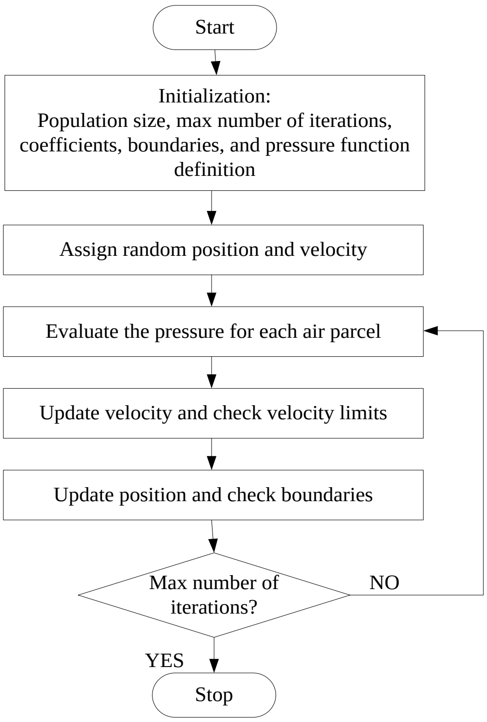

Figure 6. WDO optimization method

5. RESULT AND DISCUSSION

The work on the extraction of five parameters using analytical, PSO, and WDO optimization techniques has been discussed in this study. This same MATLAB programming software is used for the analysis of unknown variables. Table 1 represents the manufacturing data of various PV modules for the evaluation of unknown parameters of the diode. In detail, it represents the boundaries of different producers such as Adani solar, First solar, Senesco solar, Triana solar, and Vikram solar.

Table 1. Manufacturing data of various PV modules for calculation of unknown parameters of diode

PV Module\Parameters	Adani solar 305	First Solar 6420	Senseco Solar 305	Triana Solar 285	Vikram Solar 335
I_{sc} (A)	9.00	2.54	9.04	8.5	9.22
I_{mpp}(A)	8.65	2.33	8.19	8.02	8.66
V_{oc} (V)	44.94	218.5	44.72	44.7	46.5
V_{mpp}(V)	35.26	180.4	37.24	35.6	38.71
N_s	72	72	72	72	72

As seen in Tables 2-6 author uses manufacturing information from Table 1. Based on the standard assumption, only those unknown parameters with the basis of theoretical concept observed that at open-circuit voltage, series resistance does not affect the solar cell, because there is zero value for series resistance. Ideality factor for the diode in the range of 1 to 2 and shunt resistance having infinite value so that it has a major impact on the operating curves of the solar PV array. As low power output is recorded if the value of shunt resistance enters the circuit. Analysis, as well as enhancement methodologies, were used with these standard assumptions, and the results are shown in Tables (2-6).

The standard test conditions were used for examining the unknown variables of the single-diode model. These identified variables are used for analyzing the unknown variables and also compared with the proposed method (Tables 2-6). In Tables 2-6, analytical, PSO, and WDO methods were used for the evaluation of unknown variables.

Table 2. Comparison between analytical, PSO, and WDO methods for Adani solar 305

PV modules\parameters	Adani solar 305		
Estimated parameters	Analytical method	PSO method	WDO method
I_{ph}	9.004	9.009	9.009
I_0	2.548E-10	3.38E-10	3.389E-11
A	1	0.9234	0.9235
R_S (ohm)	0.5335	0.5117	0.5118
R_P (ohm)	1294	500	498.8

Table 3. Comparison between analytical, PSO, and WDO methods for First solar 6420

PV modules\parameters	First solar 6420		
Estimated parameters	Analytical method	PSO method	WDO method
I_{ph}	9.05	9.048	9.048
I_0	2.408E-9	6.355E-08	6.333E-08
A	1.1	1.29	1.29
R_S (ohm)	0.0708	0.09432	0.09428
R_P (ohm)	65.36	113.1	112.9

Table 4. Comparison between analytical, PSO, and WDO methods for Senseco solar 305

PV modules\parameters	Senseco solar 305		
Estimated parameters	Analytical method	PSO method	WDO method
I_{ph}	9.05	9.048	9.048
I_0	2.408E-9	6.355E-08	6.333E-08
A	1.1	1.29	1.29
R_S (ohm)	0.0708	0.09432	0.09428
R_P (ohm)	65.36	113.1	112.9

Table 5. Comparison between analytical, PSO, and WDO methods for Triana solar 285

PV modules\parameters	Triana solar 285		
Estimated parameters	Analytical method	PSO method	WDO method
I_{ph}	8.507	8.507	8.507
I_0	5.5E-10	7.954E-10	7.946E-10
A	1.03	1.046	1.046
R_S (ohm)	0.4151	0.4189	0.4189
R_P (ohm)	481.1	500	477.3

Table 6. Comparison between analytical, PSO, and WDO methods for Vikram solar 305

PV modules\ parameters	Vikram solar 335		
Estimated parameters	Analytical method	PSO method	WDO method
I_{ph}	8.507	9.225	9.225
I_0	5.5E-10	1.142E-09	1.141E-09
A	1.03	1.102	1.102
R_S (ohm)	0.4151	0.1942	0.1942
R_P (ohm)	481.1	369.1	368.8

5.1. Comparative account of analytical, PSO, and WDO methodologies

Tables 2-6 show a comparison of explanatory PSO and WDO method used by various solar producers (Adani solar 305, First solar 6420, Senseco solar 305 Triana solar 285, and Vikram solar 335). During the extraction process, such methods were used to assess five unknown variables. The analytical method is applied to all parameters and producers. The result is then made accessible in a variety of formats using analytical as well as optimization methods such as PSO and WDO.

Five parameters that have been evaluated using an analytical method and comparison have been shown in Figure 7. Tables 2-6 shows the recorded findings for five modules such as Adani solar 305, First solar 6,420, Senseco solar 305, Triana solar 285, and Vikram solar 335. The finding has been obtained from Tables 2-6 for the first parameter, i.e. I_{ph} (9.004, 9.05, 9.05, 8.507, and 9.226). The results showed that the Triana 285 module had the lowest I_{ph} value at 8.507 ampere and the Vikram solar 335 module had the highest at 9.226 ampere. The second parameter, diode saturation current I_0, is highest for First solar 6,420 and Senseco solar 305 modules and lowest for Vikram solar 335 from such findings (2.548E-10, 2.408E-9, 2.408E-9, 5.5E-10, and 8.853E-10) obtained from Tables 2-6. The third parameter is diode ideality parameter A (1, 1.1, 1.1, 1.1, 1.03, and 1.09), which is equal to 1, and produced the best results for Adani solar 335. The fourth parameter, series resistance Rs (0.5335, 0.0708, 0.4151, 0.1919), is close to zero for standard consideration. The Senseco solar 305 offered a minimum resistance of 0.0708. The fifth parameter, shunt resistance, was developed by Adani solar 305 and has an infinite range of possible values, such as R_{sh} (1294, 65.36, 65.36, 65.36, 481.1, and 306.2 ohm).

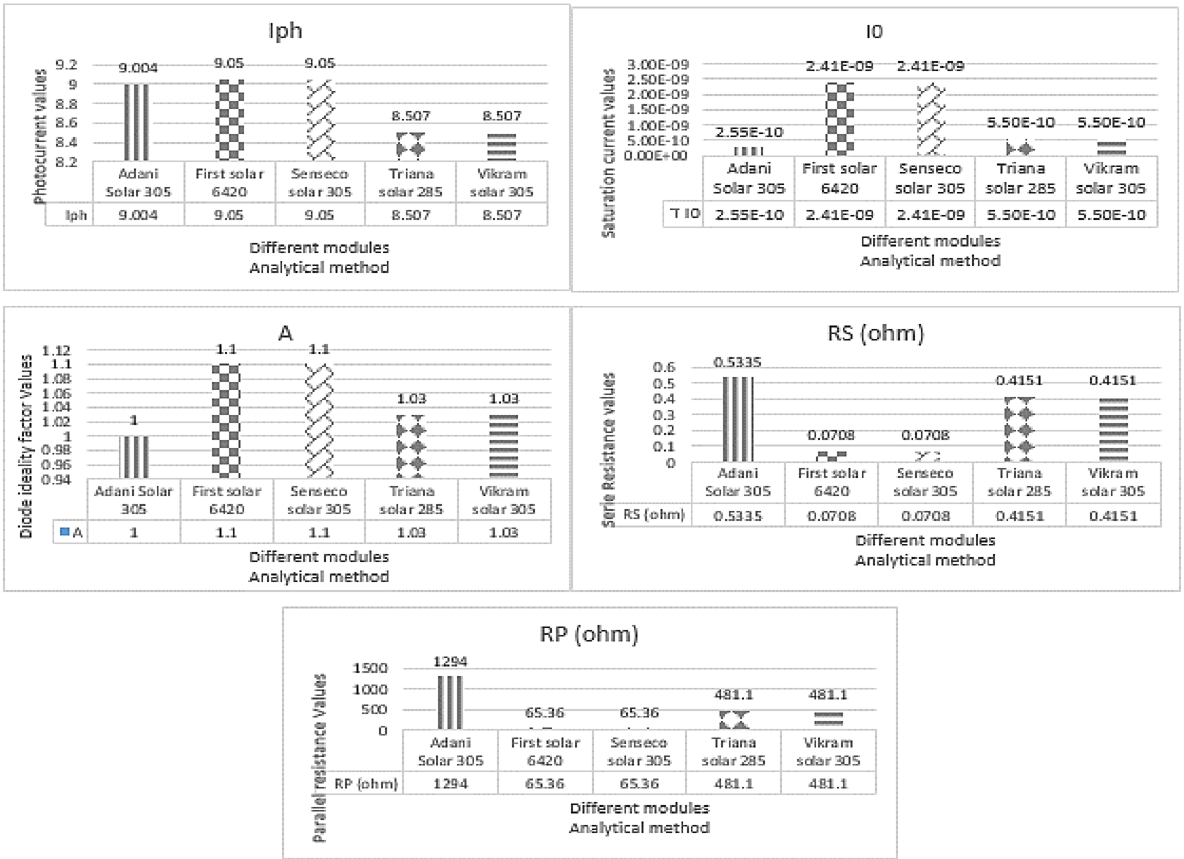

Figure 7. Comparative analyses with analytical method among five different modules considering five unknown parameters

Five parameters that have been evaluated using a PSO method and comparison have been shown in Figure 8. Tables 2-6 shows the recorded findings for five modules such as Adani solar 305, First solar 6,420, Senseco solar 305, Triana solar 285, and Vikram solar 335. The finding has been obtained from Tables 2-6 for the First parameter, i.e. I_{ph} (9.009, 9.048, 9.048, 8.507, and 9.225). According to the results, Vikram solar module had the highest photocurrent value at 9.226 ampere and Triana 285 had the lowest at 8.507 ampere. 2nd parameter is diode saturation current I_0 (3.38E-10, 6.355E-08, 6.355E-08, 7.594E-10, 1.142E-09) was the highest for both the First solar 6,420 module, Senseco solar 305, and lowest for Vikram solar 335. For Adani solar 335, diode ideality parameter A (0.9234, 1.29, 1.29, 1.046, and 1.102) produced the best results that are near about 1 which is 0.9234. For standard consideration, the fourth parameter is series resistance R_s (0.5117, 0.09432, 0.09432, 0.4189, and 0.1942) is close to zero. The smallest resistance provided by the First solar 6420 and Senseco solar 305 it is 0.09432. Shunt resistance is the fifth parameter created by Adani solar 305 and Traina solar 285, with infinite predicted values R_{sh} (500, 113.1, 112.9, and 500,369.1) such as 1,294 ohms.

Five parameters that have been evaluated using a WDO method and comparison have been shown in Figure 9. Tables (2-6) shows the recorded findings for five modules such as Adani solar 305, First solar 6,420, Senseco solar 305, Triana solar 285, and Vikram solar 335. The finding has been obtained from Tables 2-6 for the First parameter, i.e. I_{ph} (9.009, 9.048, 9.048, 8.507, and 9.225). According to the results, Vikram solar 335 modules had the highest photocurrent value at 9.225 Ampere and Triana 285 had the lowest at 8.507 Ampere. 2nd parameter is diode saturation current I_0 (3.389E-11, 6.333E-08, 6.333E-08, 7.946E-10, and 1.141E-09) was the highest for both the First solar 6420 module, Senseco solar 305 and lowest for Adani solar 305. For Adani solar 335, diode ideality parameter A (0.9235, 1.29, 1.29, 1.046, and 1.102) produced the best results that are near about 1 which is 0.9235. For standard consideration, the fourth parameter is series resistance R_s (0.5118, 0.09428, 0.09428, 0.4189, and 0.194) is close to zero. The smallest resistance provided by the First solar 6420 and Senseco solar 305 is 0.09428. Shunt resistance is the 5th parameter created by Adani solar 305 module, with an infinite predicted value R_{sh} (498.8, 112.9, 112.9, 477.3, and 368.8) such as 498.8 ohms.

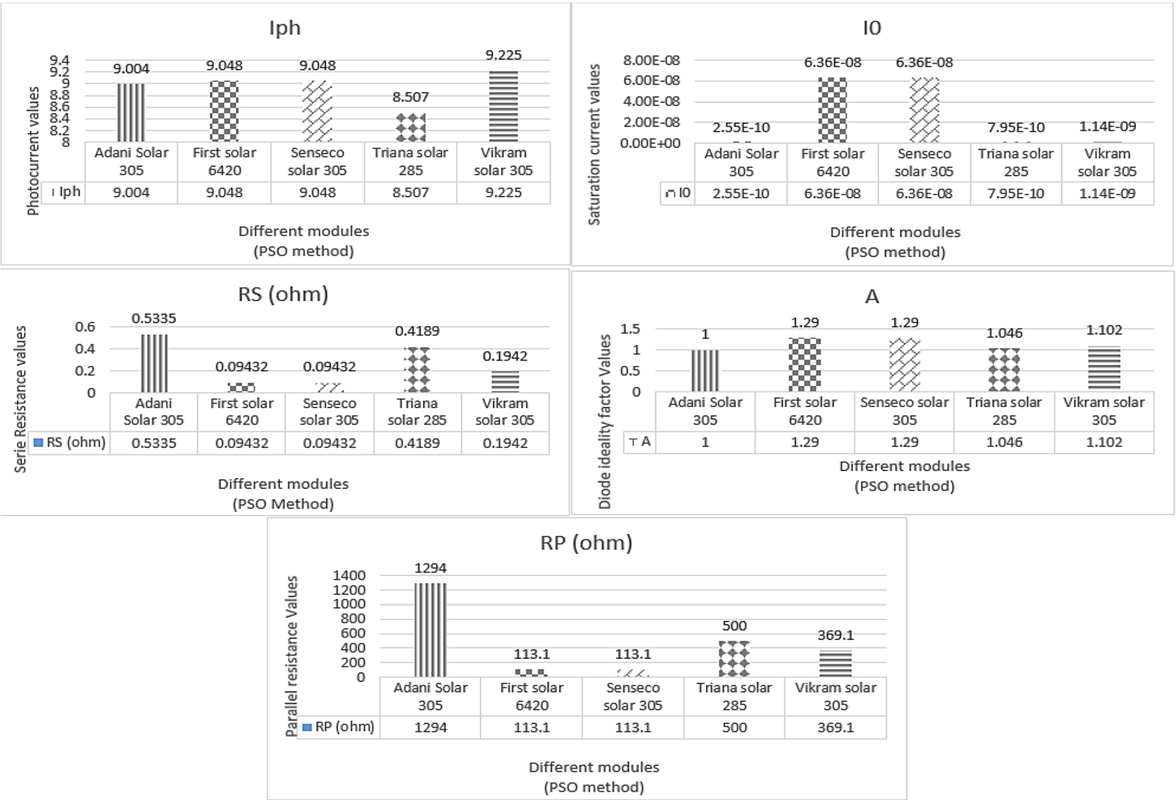

Figure 8. Comparative analysis with the PSO method among five different modules considering five unknown parameters

5.2. Comparative analysis of three methods for each module

In this section, three methods (analytical, PSO, and WDO) have been shown and used the data sheets of each module separately for comparative analysis. This comparative based on individual modules along with undefined five parameters. It is used for module identification and calculated parameters value match with standard considerations such as photocurrent should be maximum for all calculations, ideality factor of diode near about 1, series resistance ideal value is zero, and shunt resistance having infinite ideal value. Among all this diode saturation current must be minimum.

In Figure 10, it is observed that Adani solar 305 provides the best performance output for unknown parameters, such as diode ideality factors that range from 1 to 2, series resistance that is less than shunt or parallel resistance, and photocurrent values in the range of 9 to 10 ampere (Figures 10-14). In Figure 11 it is observed that First solar 6,420 provides better performance output for unknown parameters, such as diode ideality factors that range from 1 to 2, series resistance that is less than shunt or parallel resistance, and photocurrent values in the range of 8 to 9 ampere (Figures 10-14).

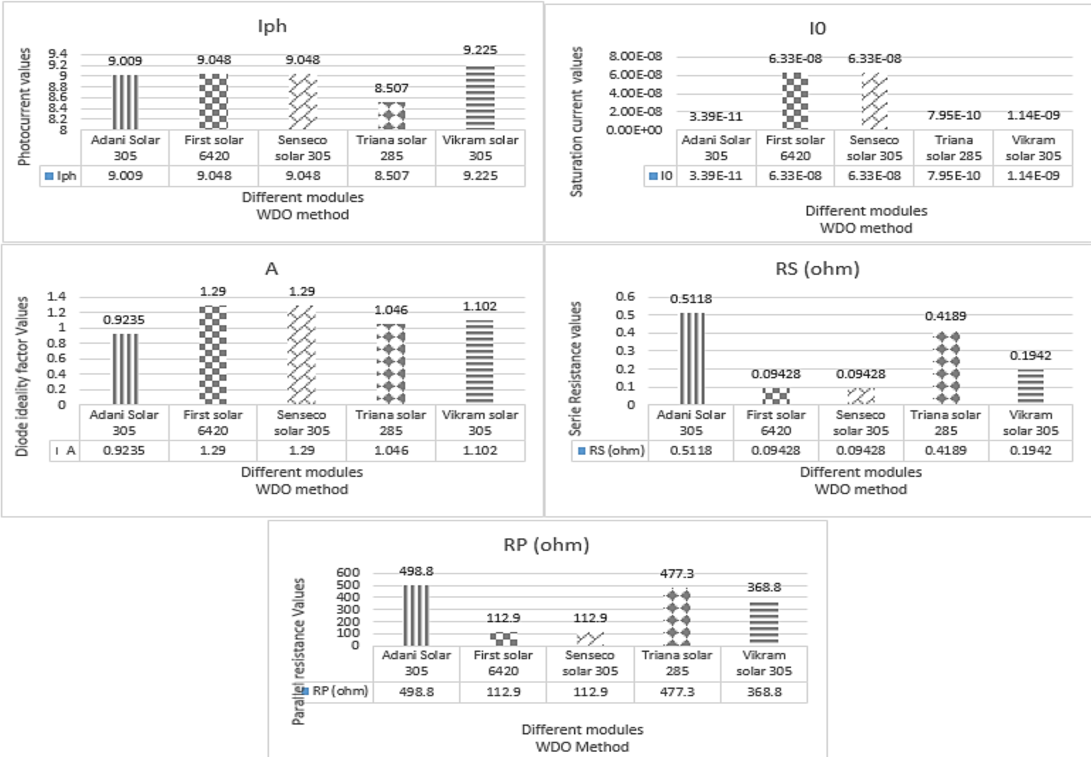

Figure 9. Comparative analysis with the WDO method among five different modules considering five unknown parameters

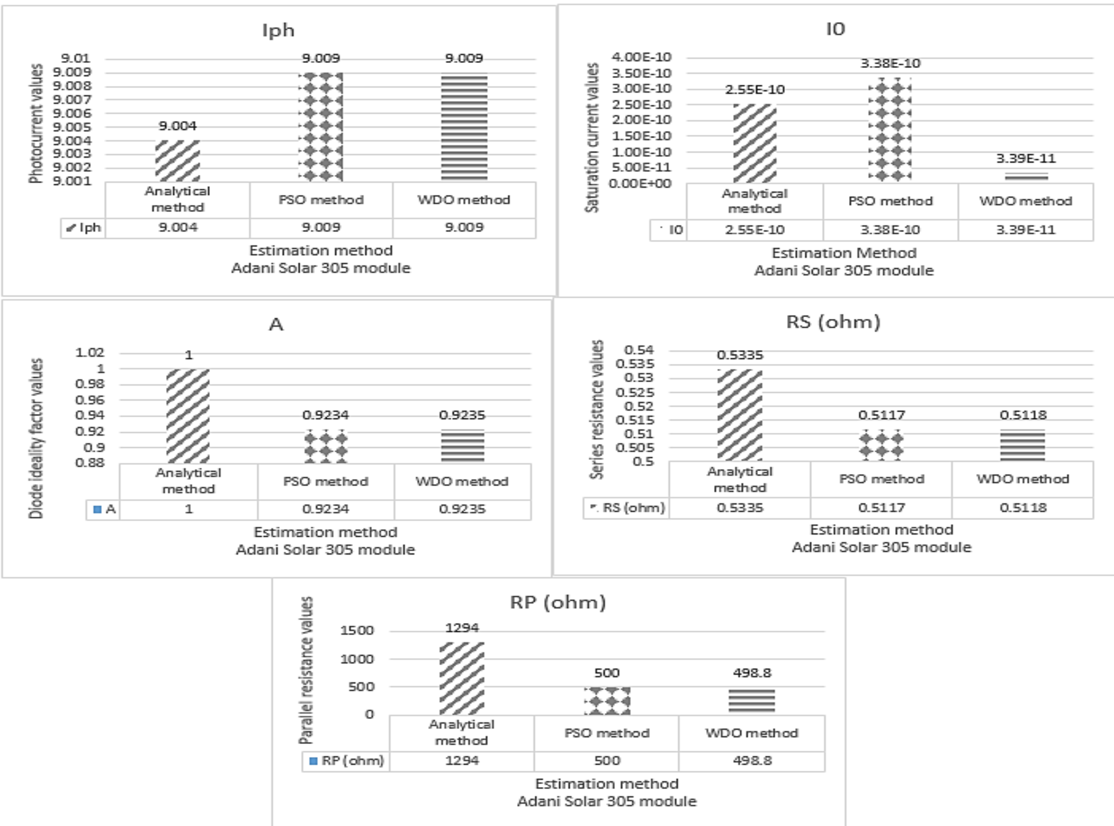

Figure 10. Comparative analysis with three methods considering Adani solar 305

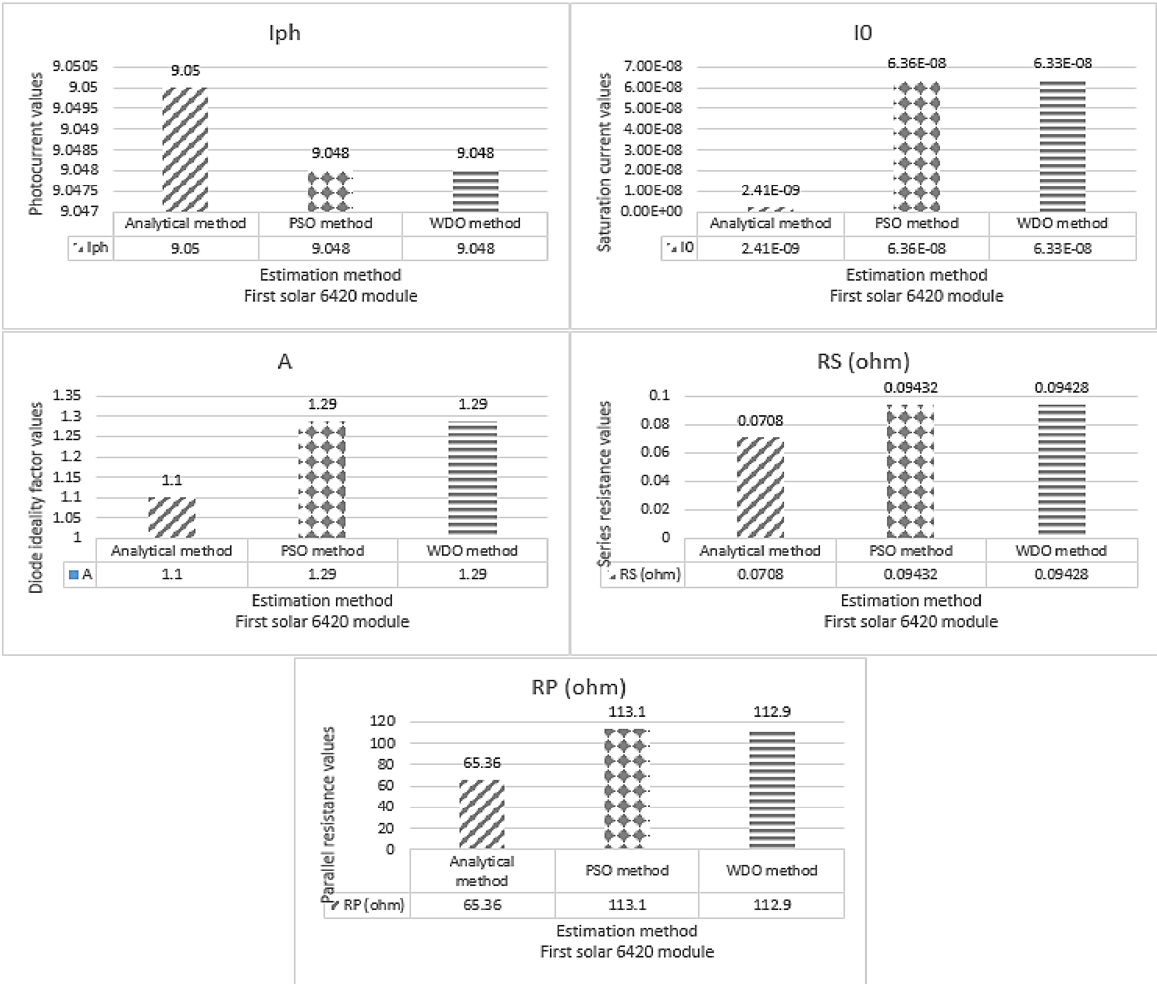

Figure 11. Comparative analysis with three methods considering First solar 6420

In Figure 12 it is found that Senseco solar 305 provides better performance output for unknown parameters, such as diode ideality factors that range from 1 to 2, series resistance that is less than shunt or parallel resistance, and photocurrent values in the range of 9 to 10 ampere (Figures 10-14). Figure 13 with comparative analysis using graph Triana solar 285 provides better performance output for unknown parameters, such as diode ideality factors that range from 1 to 2, series resistance that is less than shunt or parallel resistance, and photocurrent values in the range of 9 to 10 ampere (Figures 10-14). Figure 14 with comparative analysis using graph Vikram solar 335 provides better performance output for unknown parameters, such as diode ideality factors that range from 1 to 2, series resistance that is less than shunt or parallel resistance, and photocurrent values in the range of 9 to 10 ampere (Figures 10-14). Here, as shown analysis of unknown data with different methods and producers. With this, it can conclude that whatever mathematical method used here has tremendous importance as it provides the best performance value when manufacturing data for the first five modules were taken into consideration. From the obtained results, it is found that the analytical and met heuristic methods are the best ones for calculating unknown parameters and provide the greatest options for selecting a method from available manufacturing and reference data (Figures 10-14). The overview of all results is in the mentioned Tables 2-6. Models of PV modules that are exceptionally accurate and based on experimental data are necessary for parameter extraction, assessment, monitoring, and use of PV systems. Effective optimization strategies are required for this assignment. For quickly and accurately estimating the properties of solar cells and PV modules, an optimization approach is given in this study. Because of its structure, the suggested algorithm is simple to implement and is both analytical and optimization-based, like PSO and WDO. The experimental results obtained using a variety of PV and solar cell models, including the single diode model, sufficiently indicate the effectiveness of this technology. In terms of solution accuracy, convergence speed, and stability, the recommended method outperforms the majority of described techniques.

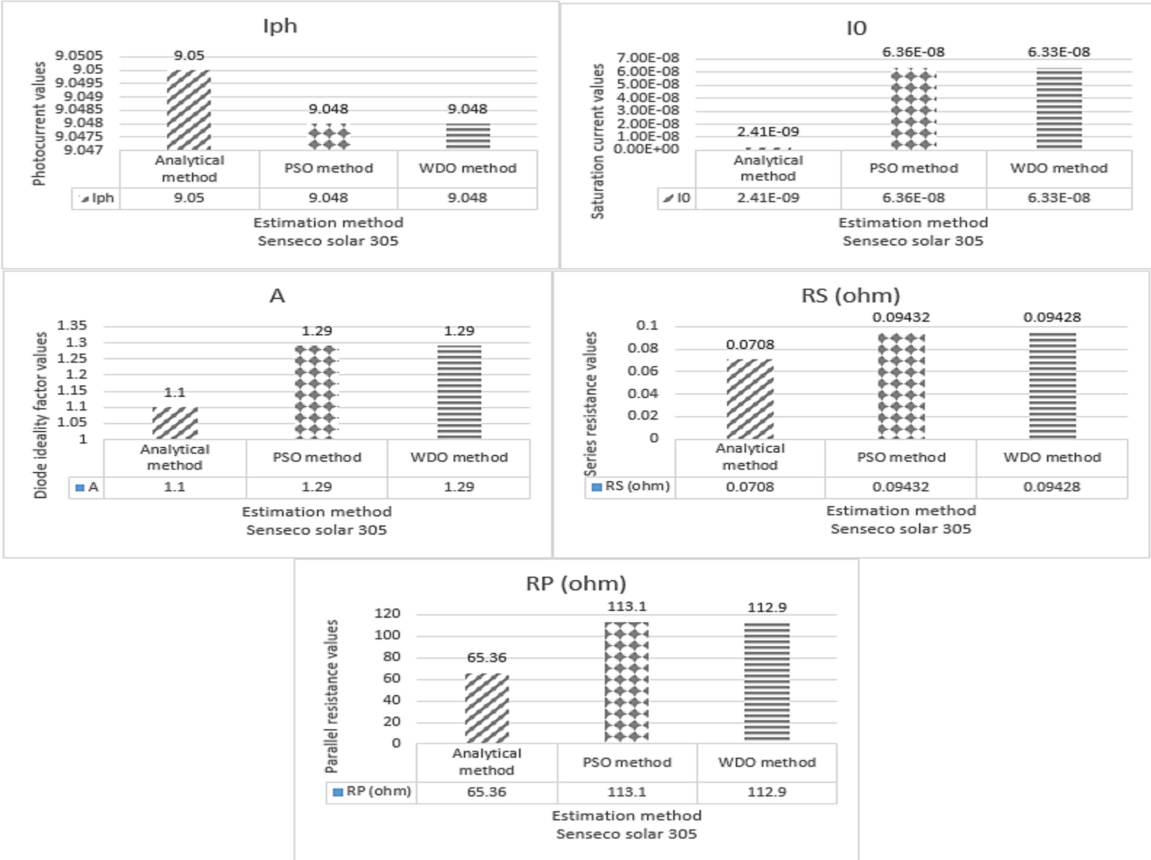

Figure 12. Comparative analysis with three methods considering Senseco solar 305

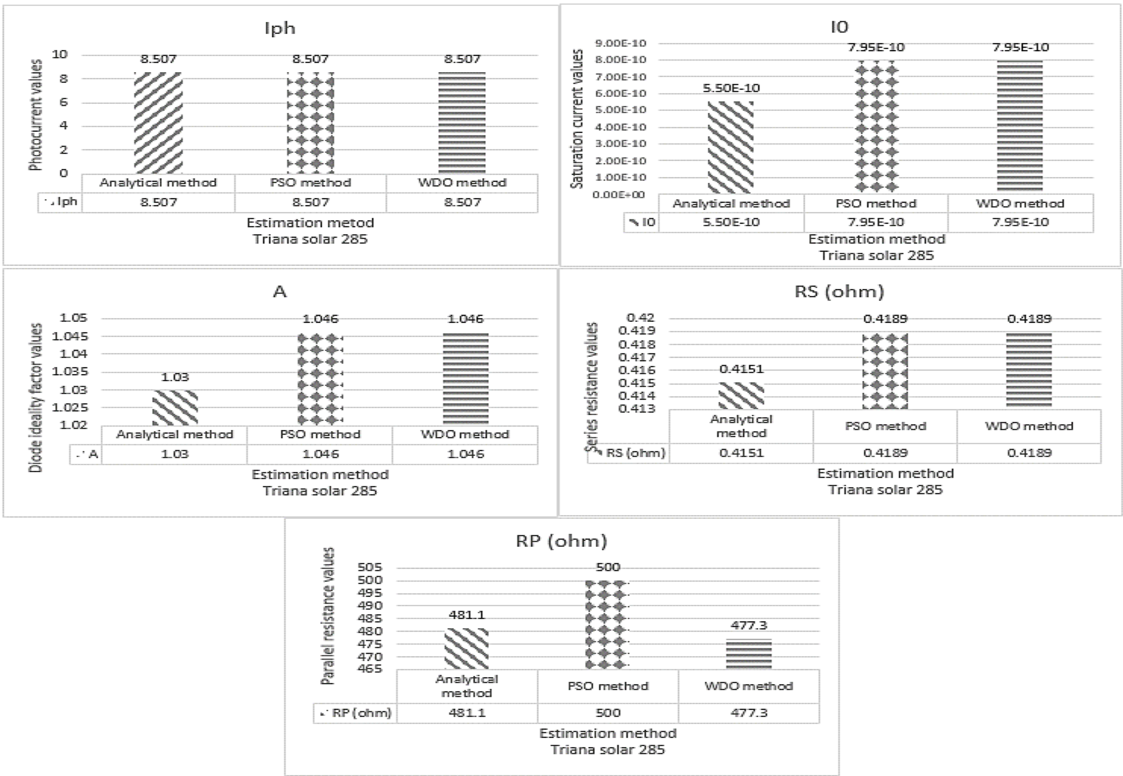

Figure 13. Comparative analysis with three methods considering Triana solar 285

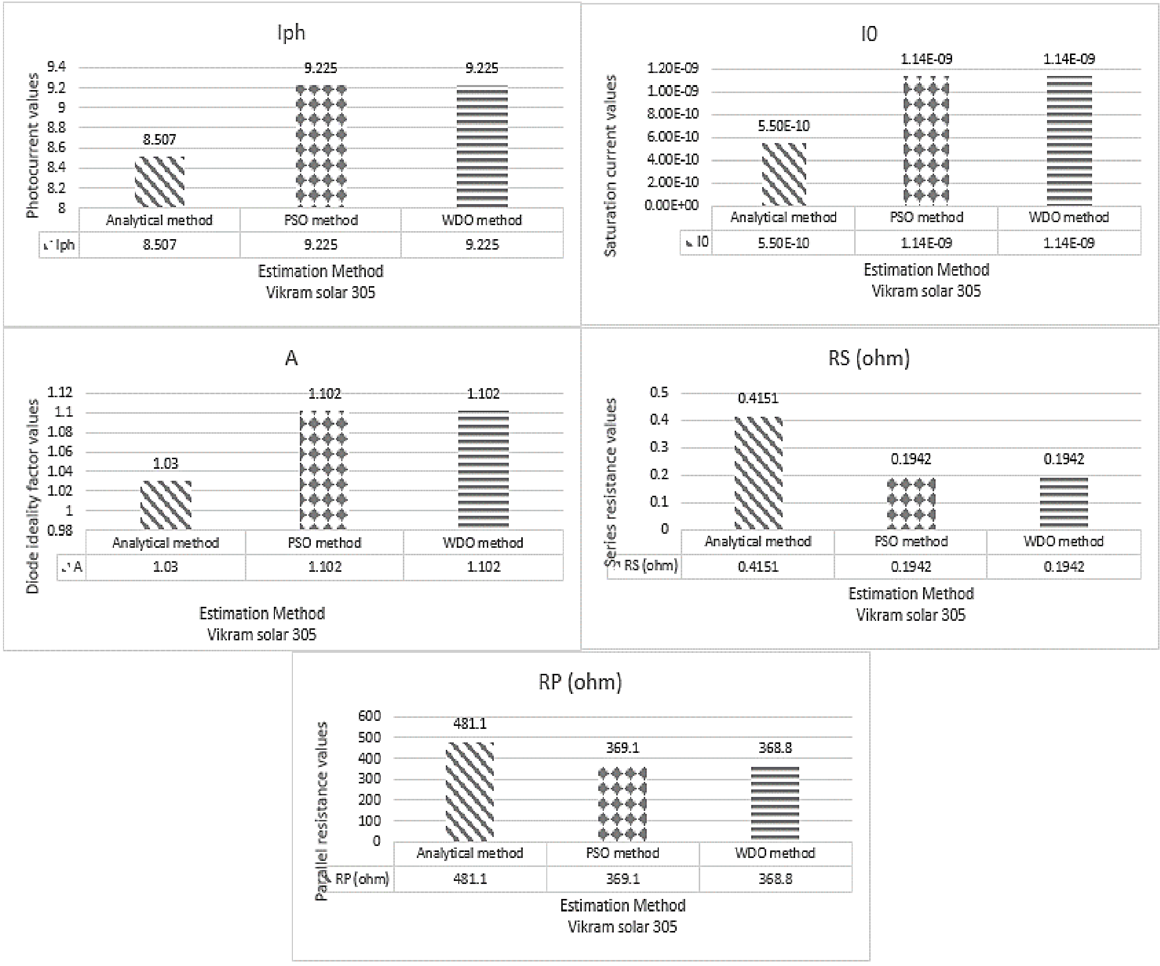

Figure 14. Comparative analyses with three methods considering Vikram solar 335

6. CONCLUSION

An improved method proposed here of the single diode model. The results obtained here are dependent on known assembling datasheet which gives different results along with other procedures. These procedures were recognized by mathematical conditions and required precise data sheet limits which provided us with ideal similar quick characteristics. These outcomes can be used for the particular module assurance with exact surveyed values. Data can be applied to natural conditions like irradiance and temperature. These all trials are appropriate for the establishment of various modules. It can also be useful to decide known and incomprehensible boundaries for the distinctive diode model.

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