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Design and development of extract maximum power from single-double diode PV model for different environmental condition using BAT optimization algorithm

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Abstract. To minimize real-time errors in a Photovoltaic (PV) system performances must be forecasted through precise simulation design before continuing into a practical application. However, due to the scarcity of data in datasheets and the inherent transcendental connections are between PV current and PV voltage, to determining the Single Diode Model (SDM) parameters becomes a more challenging problems. This paper offers a simulated study of a SDM and Double Diode Model (DDM) solar PV system under various irradiation represents, and the performance was developed by incorporating an optimization-based Maximum Power Point (MPP) tracking techniques. According to the present simulation presented in this article, a mathematical model for a SDM/DDM as well as optimization methodologies has been estimated MATLAB platform. The present MPP circuit model designed and compared with BAT optimization algorithms. The nonlinear relationship between Voltage (V) - Current (I) and Voltage (V) – Power (W) acknowledged as characteristic curves for different temperature (○c) and irradiance (W/m^2) values are verified in numerical simulation results. MPP tracking power and efficiency are examined for maximum power (P_{max}) to test the optimization based system. The simulation results show that the BAT optimization model was achieved the highest tracking efficiency better than other heuristic algorithms.

Keywords: Photovoltaic, maximum power point, BAT Optimization, firefly algorithm, solar irradiations

1. Introduction

The necessity for sustainable energy has grown up considerably over the years due to the fast depletion of fossil fuel, greenhouse effect in particularly solar, and also the wind has become more popular demanding requirements [1, 2]. However, it is necessary to improve the quality of the energy from these sources to safeguard the load connected equipment and maintain the customer continuity of supply without any disturbances. To fulfill the goal, it is necessary to connect intelligent optimization techniques assists by the power electronic-based MPP controller which enables the P-Q improvement in between the input source, and loads. The Solar-Photovoltaic (S-PV) panels are a versatile energy technology that can help electrical customers within all kinds of electricity needs. PV generation will supply a large proportion of the electricity demand suggested by the World Energy

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Council 2020 and can meet solar energy demand by 16% as much as 2030 needs in India [3]. Due to the reduction of fossil fuel, and the greenhouse effect need for RE has grown a lot over the years.

The growth of the solar-power module in India ranged from 2.6 GW to 28.18 GW in 2020-21 and the future it would be around 38 GW and 45 GW due to the increased demand for the electricity is needed (Solar power total installation capacity in India demands prepared by Ministry of New and Renewable Energy, Annual Report 2021) [4]. However, it is necessary to improve the P-Q in RE sources for putting forth electrical load. The renewable power conversion from one stage to another stage without any disturbance, and continuity of the power supply is very important to the customer as prescribed by [5].

The solar electricity is developed by power semiconductor devices. It's capable of converting the incident PV energy Direct Current (DC) within a theoretical efficiency range while varied from 3% up to 31% as estimated by [6]. In such efficiency depends on manufacturing technology, temperature, panel tilt angle, shadows, and incident light spectrum, etc., The minimized harmonic content of the output voltage was produced by using PV array SDM/DDM topology, which is operating under low solar irradiance condition applied in linear and non-linear load conditions, which is operating in ON/OFF grid mode under the sufficient PV-irradiance condition proposed by [7]. The input source of S-PV that aims to enhance P-Q with harmonious reduction process in various loads with the help of optimization or intelligent techniques, and it is convenient to integrate for both functionalities of power generation as well as P-Q development by using optimization algorithms suggested by [8]. Solar-PV modelling is directly occurred the efficiency and accuracy values [9]. Which is desired parameters depends on solar and environmental conditions, and also PV array connections such as series or parallel combinational of the cells [10, 11]. As per accurate PV output voltage and current are depends on the crucial factors like temperature (○c) and irradiances (W/m^2). In this simulation or experimental study base on the performance comparative results investigations are measured by using manufacturing solar materials. The solar research model has been verified and investigation by different authors, that is multi-diode, two-diode, and singe diode category [12, 13].

A proposed SDM often known as the five parameters model, it is composed of a parallel connection or series combination of an ideal diode, and a current source with bypassed shunt resistance [14, 15]. To increase the performance of PV systems, a SDM solar cell was characteristics may be easily studied and verified. The ultimate aim of this research contribution is as follows:

- Design of PV SDM, DDM operative different solar irradiation and environmental conditions.
- To obtain the SDM, DDM solar system incorporate with optimization control techniques like as MPP, metaheuristic, and heuristic algorithms.
- To Evaluate and compare the proposed SDM, DDM model for different solar optimization algorithms incorporate to find a best optimum results.

The proposed research article is well prepared as follows; Section.2 presents an overview of previous research studies. Section.3 presents extensive mathematical formulations for the proposed solar-PV model and MPP model. Section.4 presents the experimental results and observations. Section.5 concludes with the conclusion and future scope.

2. Literature study

The electrical load devices are needed constant power with minimum harmonics. A solar SDM connected in series fed converter is the main problem of P-Q issues [16]. It is multiple integrals of fundamental (50 Hz) frequency in sinusoidal output waveform, i.e., voltage waveform or current waveform. In general non-sinusoidal waveform generates more number of harmonics, due to Electro Magnet Interference (EMI) problem, over-heating equipment (core winding-electric drives), and non-linear connected system [17].

To minimize the harmonics level and maximize the output voltages are enhanced on the three sorts of the operation.

1. Solar-PV panel design and manufacture
2. PV panel output with constant irradiations by using MPP or any control optimization method implementation.
3. PV panel connections

The solar power output is applied or interconnect in all types electrical load. The single and multi-diode technique is the most powerful method [18], which is minimized harmonics and maximize the output power. The harmonic range depends on the switching frequency and the framework of the converter topology [19]. The primary input of solar is generated the active power into an electrical load and the output waveforms are minimized the harmonics used in various filters, i.e., shunt/series active filter [20], low/high pass filter [21], and active/passive power filter [22], and electrolytic capacitor [23], etc. The solar-PV array module type is normally designed as sun-power 305 Watts. The design of solar-PV contains series-connected modules as per the string is 9, modules as per the number of cells are 96, and the parallel number as per string is 250. There are 4 Solar-PV arrays connected in single module SDM/ DDM parameters such as photo-generated current I_{ph}, diode saturation current I_{sat}, parallel resistance R_p, and series resistance R_s adjusted to fit the following 4-module parameters measured under Standard-Test Conditions (STC): Irradiance-1000 W/m^2, Diode Quality factor (Q_d), and cell temperature-25°C [24].

The PV array consists of numbers as per parallel (Npar) module strings are connected in parallel, and each PV array consists of Numbers as per series (Nser) module strings are connected in series. The S-PV$_1$ to S-PV$_4$ made by supply are open-circuit voltage (V_{oc})-64.2 V, short circuit current (I_{sc})-5.96A, the voltage at maximum power point (V_{mp})-54.7, current at maximum power point (I_{mp})-5.58. In the photovoltaic arrays (SPV$_1$-SPV$_4$) PV terminal current is not uniform to the constant MPP when the panel output voltage is lowered due to cloudy conditions during checking of PV-module in the day time [25]. The MPP rule assists with the optimization algorithm is supported to generate the Duty Cycle (D). The basic formula for maximum efficiency (η) calculation of PV cell is given by the equation (1.1), and the ratio of maximum output power to the incident S-PV power using by radiation flux time for the area (A) [26].

$$\eta = \frac{P_{max}}{E.A_{cell}} \tag{1}$$

A proposed [27] new 5 parameter SDM of PV panels are simplified, It is able to calculate the SDM panel parameters from data sheet. Which is used to estimate the two iterative steps, first step is calculated Rp, and second step is to find ideal diode factor. However, [28] the SDM characteristics equations are more complicated. Therefore it is compute only 4 equations to formulate panel module. Introduce power law model [29] that is operated with under different operating conditions without any iterative process. The characteristics of V-I curve was predicated effectively, it will demonstrate in different PV panels. In most research was prescribed single, two diode model with common basic electronic modules [30]. Unfortunately, these models are statics that can generate V-I curves for fixed irradiation conditions. The combination of 2 parameter models are verified by numerical optimization based pattern search algorithm. A behaviors of Non-convex parameter optimization problem has been minimized by using SDM model [31], which is adopted to minimize the computational complexity, and don't depends on preliminary data selection.

An influenced by the PV irradiance to estimate (open-circuit voltage, and short-circuit current) parameters are required through converter model. In case of disconnecting supply from PV converter to avoid this kind of issues, which is co-ordinate with MPP controller approach [32]. An assessment of novel equation based on the thermal coefficient of power that connects maximum power to irradiance and cell temperature was provided. A study of the relation between the electric parameters and the operating circumstances was carried out in order to calculate the irradiance and temperature of a solar module. This relates to the modelling of the solar cell in terms of parameter identification and translation. IEC-60 891 offers voltage and current translation equations of solar generators was also taken into account. A novel PV 5 parameter extraction method was described as per SDM unit, first module has been proposed non-linear explicit model, and second module has been implemented least-square non-linear model [33]. This model that has been tested by using MATLAB software programming language with least computational cost. A PV panel requires temperature and irradiance, this procedure was allowed SDM model with some necessary parameters like diode factor, and series resistance [34], it will computed with V-I characteristics curves. The silicon PV modules with wide range of temperature varied upto 1.2 kW/m^2.

This study provides a well-organized and succinct assessment of MPPT approaches used in PV systems in the literature, as well as existing papers on different hardware design strategies [35]. Depending on the tracking method used to track MPP under PSCs, they are classified into four categories: classical, intelligent, optimum, and hybrid. Because the P-V curve has only one peak during uniform insolation, classical approaches are highly favored. In the P-V curve, on the other hand has several peaks with one global MPP and local MPP. The classical methods are fail to work at MPP with requiring the development of more complex MPP approaches. Every MPP approach has benefits and drawbacks, but a streamlined MPPT considers a number of factors including like as number of sensors needed, hardware implementation, cost feasibility, tracking speed, and tracking efficiency [35].

For last six years, to survey the different MPP methods are found such as uniform, non-uniform, and hybrid optimization mode PV irradiance MPP controllers. In this case, most of MPP techniques should reviewed classification in offline, online, and hybrid optimization type of MPP [36]. During the recent decade, there was a substantial increase in solar installation in both independent and grid-connected power production systems. Because of weather intermittency, and the PV system has a non-linear output characteristic, which has a significant influence on overall system output. As a result, multiple MPP strategies have been utilized to improve the output of a PV system.

A polynomial PV array model has been investigated with SDM model, the modelling and MPP parameters are reported by measuring 3 points around MPP techniques. Therefore fixed PV array voltage by using MPP without any isolation part in real-time operating conditions [37]. Overall results are considered the losses of V-I, and estimation speed of the system process. Hybrid PSO-ANFIS technique was presented based on MPP PV-zero power tracking system, to implement with aid of no extra sensor with MATLAB interface grid optimized system. Proposed MPP methods are interfaced with optimization algorithm such as Ant-colony, P&O, PSO, and artificial bee-colony [38]. In order to accomplish the MPP methods with Zeta converters, it is controlled by ANFIS-PSO technics with zero output harmonic agreement, and retained between PV modules to load regulator power circuit. From that above literature study concluded that, a SDM and DDM modules are commonly used for all renewable solar photovoltaic environment. A comparison of DDM, SDM are gives better performance and accuracy to other methods. Therefore, compare to other existing research for DDM, and SDM are interconnected MPP-PV system circuit, the performance and anlaysis models under operating different optimization experimentally verified for better validation.

3. Mathematical model for proposed SDM-DDM model

The MPP based PV panel installations are considered in two methods: 1. Grid-connected S-PV model, 2. Standalone S-PV model. The standalone system is an automatic small scale PV system that produces electrical power to charges capacitor banks or battery banks during day time. The need for several sources on the input side of the converters is fed into load drive, that makes the multiple control and complexity issues should be created in converter topology. Therefore, the PV installations may be preferable in residential, commercial or industrial,

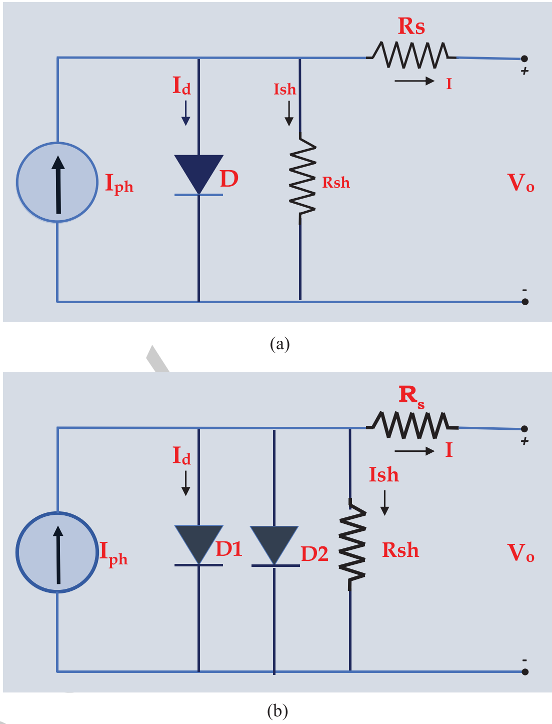


Fig. 1. (a). SDM solar cell equivalent circuit. (b). DDM solar cell equivalent circuit.

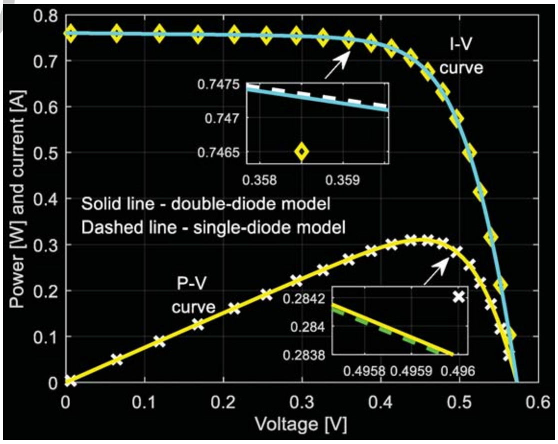


Fig. 2. V-I & P-V characteristic curve.

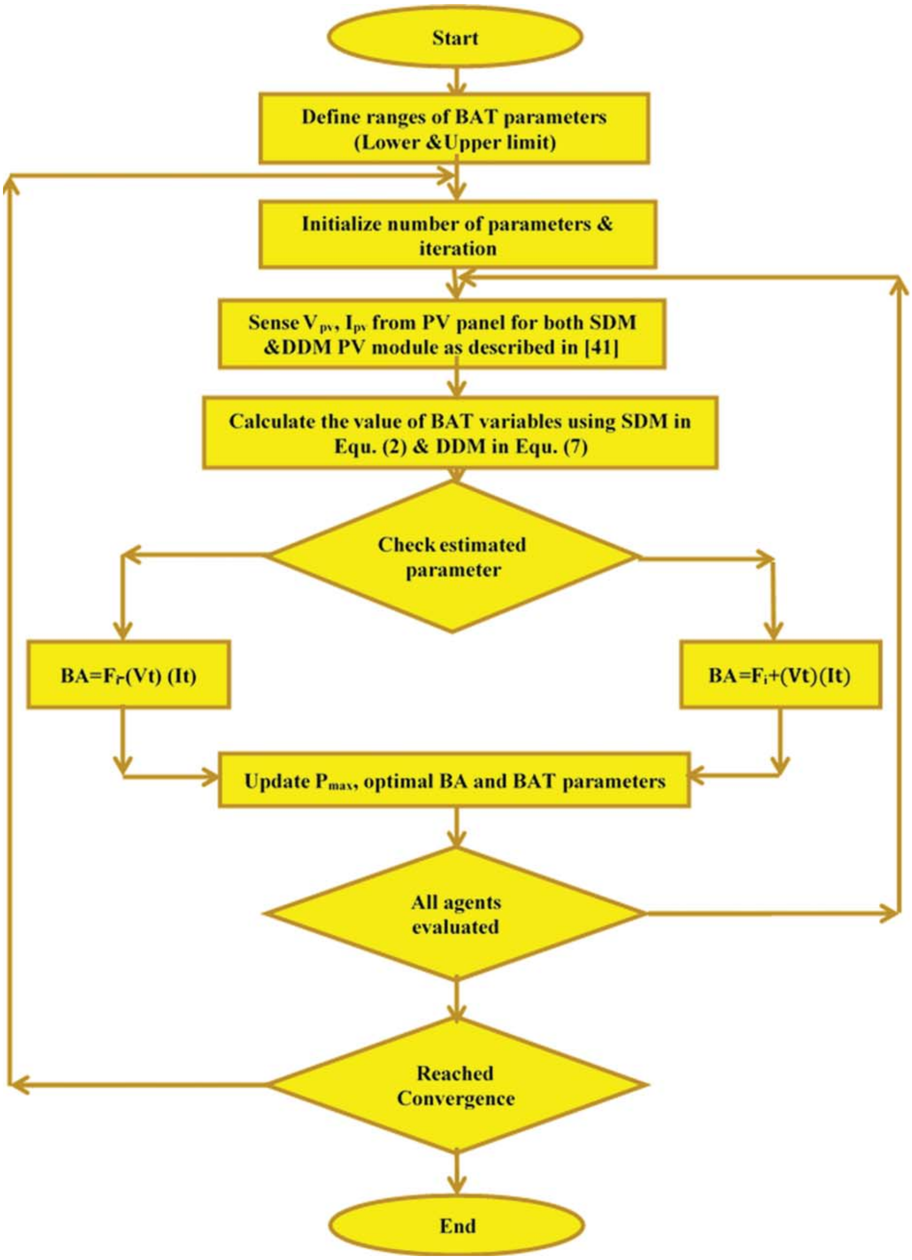


Fig. 3. Process flow of BAT based MPP algorithm.

utility-scale, ground-mounted, rooftop-mounted, and wall-mounted or floating, etc. Proposed SDM, and DDM equivalent circuit model as shown in Fig. 1 (a&b). The MPP algorithm is used to extract the maximum power available from the PV module under certain conditions using Perturb and Observe (P&O) technique. The maximum solar irradiation of SDM, DDM variables with cell temperatures in voltage, current, (V-I) and solar power (P-V) as show in Fig. 2. It shows that the solid line for DDM and dashed line for SDM module output PV characteristics model curve [39].

In PV module voltage, which can produce the maximum power is referred to as the MPP or peak voltage. I-V curve relationship of DDM, and SDM as shown in Equation 2. The different solar radiations are delivered by PV modules variation in parameters as followed:

1. P_m - Maximum Power
2. V_{pm} - Maximum power voltage
3. V_{oc} - Open circuit voltage
4. I_{pm} - Maximum power current
5. I_{sc}-Short circuit current

$$I = I_{PV} - I_0 \left(e^{\frac{V+IR_s}{n.V_{th}}} - 1 \right) - \frac{V + IR_s}{R_p} \quad (2)$$

Where I_{PV} is solar generated current, Rs parasitic series resistance, Rp thermal parasitic resistance, Io saturation current, n is ideality factor, and $V_{th} = K_B T/q$ is thermal voltage (K_B is boltzmann constant equal to $1.39 \star 10^{-23}$ J/K [40].

4. BAT optimization objective function for proposed system

A nature-inspired technique based on the echolocation aspects of a bat's food optimization finding mechanism was proposed. In the optimization model to use echolocation identification insects, the strength and direction of the return signal are the most important factors in locating the prey. The ultrasonic pulses are produced at a specific amplitude and rate, and the receiver receives its own signal as feedback in between the pulse trains to determine the location of the prey. The distance is measured based on the strength of the feedback. If the intensity is high, the prey will be close to the bat, and the bat will go towards the prey by increasing the strength of the pulse to catch the prey. Bats' flying characteristics are random with velocity (v_i), and their position and loudness are supplied as (x_i) and (l_i), respectively. The emission rate of bats is assumed to be in the range of [0, 1] depending on the target vicinity. The position and velocity of the bat at each process has been formulated as,

$$x_i^{t+1} = x_i^t + v_i^{t+1} \quad (3)$$

$$v_{ij}^{t+1} = v_i^t + \left(x_i^t - x^* \right) f_i \quad (4)$$

Where 'Fi' random frequency allocation that is shown below,

$$f_i = f_{min} + (f_{max} - f_{min})\,\phi \quad (5)$$

Where the uniform distribution random vector is given as φ that varied the ranges from [0, 1], and best global optimum solution is 'x' that is minimize from the main objective derivative function (BA) found in each iteration. The pulse emission rate is taken into account during the position updating procedure. The exploitation stage is chosen if the random vector is bigger than the emission. The current position is replaced with the result of the local search procedure, and the result is reported as,

$$x_n = x^* + l^t \quad (6)$$

Where random numbers are described from another metaheuristic optimization method [40], which is calculated uniform distribution ranges varied [–2, 2]. The proposed bat optimization is calculated based on bat conduct that is very powerful optimization method, which converter the parameters are 'x' into BA. In this proposed approach first case is SDM; BA = [Rp, Rs, I_0, Ipv, & n] parameters described in equation (2), and another second case DDM; BA = [Rp, Rs, I_0, Ipv, & n_1, & n_2] parameters described in equation (7). Therefore, in general factors variables limited lower (L) & upper (U) values are defined [40].

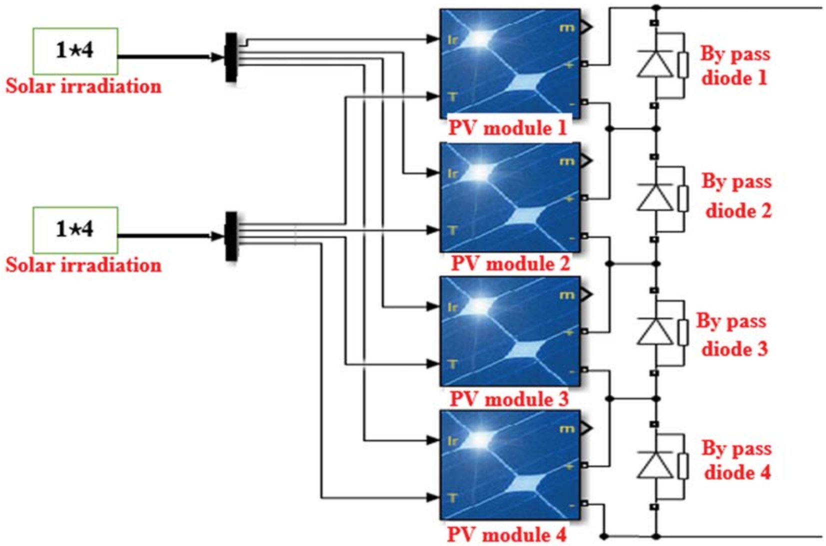
$$I = \sum_{t=1}^{N} \left(I_{pv} - I_{01} \right) \left(e^{\frac{v_t + I_t R_s}{n_1 \cdot V_{th}}} 1 \right) - I_{02} \left(e^{\frac{v_t + I_t R_s}{n_2 \cdot V_{th}}} - 1 \right) - \frac{V + IR_s}{R_p} - I_t \quad (7)$$

Where N is number of measured values and characteristics curve (V-I & P-V), and Voltage, current value of pair (Vt & It) represented as 't'. Procedure for bat optimization using SDM, and DDM methods are shown in Fig. 3. It shows 5 step optimization procedures as follow;

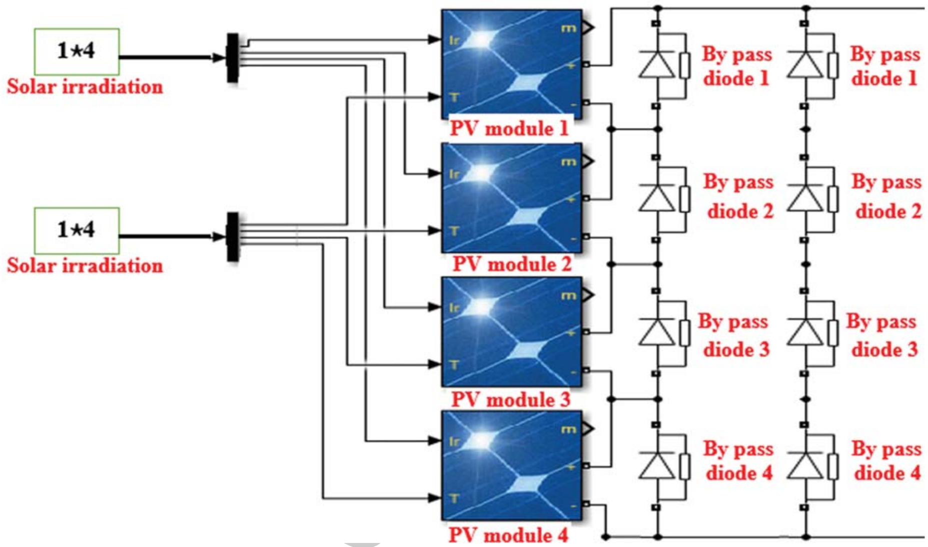
1. Define ranges of BAT parameters
2. Initialize number of parameters & iteration
3. Sense SDM & DDM PV module output value

Table 1
Solar-PV cell specification

PV module parameters	Quantity
Input power (Ipv)	360W
Short circuit current (I_{sc})	9.98A
Open circuit voltage (V_{oc})	70.31V
Temperature coefficient of I_{sc}	0.06% per °C
Temperature coefficient of V_{oc}	–0.33% per °C
Reference temperature minimum	20°C
Reference temperature minimum	28°C
Idea factor diode (n_1)	0.94
Idea factor diode (n_2)	2.00
Saturation diode current density (SDM)	$9.09*10^{-4}$
Saturation diode current density (DDM)	$8.97*10^{-4}$



(a)



(b)

Fig. 4. (a). Proposed SDM PV module. (b). Proposed DDM PV module.

4. Calculate BAT variables by using MPP (P&O) method
5. Calculate SDM & DDM values using equation (2) & (7). Find optimum values.
6. Once reached convergence value, and stopping criteria.

5. Result and discussion

A proposed analysis of SDM and DDM models are calculated in five parameters, the 4 PV module has been tested MATLAB platform. Tested experiment V-I dataset 58 mm N-type IBC silicon cell are measured maximum value of different irradiations 1500 W/m^2 and temperature of (28°C). PV cell specifications are shown in Table 1. Initially the parameters are obtained numerical anlaysis bat optimization algorithm, which is compared to other meta-heuristic optimization methods. In this section proposed SDM, DDM PV modules outcome are compared with optimization techniques. The 5-parameters are described the PV- SDM, PV-DDM approach, and this proposed models are analysis different irradiation ranges

Table 2A
(a). Compare and calculated SDM parameters

Reference	Algorithm	I_{pv} (A)	I_0 (μA)	Rs (Ω)	Rp (Ω)	n	RMS (Root mean square) Error
[42]	Hybrid optimization	0.760	0.3106	0.0365	51.421	1.4772	$9.8*10^{-4}$
[43]	Modified PSO	0.7607	0.31068	0.03654	52.178	1.47526	$7.3*10^{-3}$
[44]	Learning PSO	0.7607	0.31062	0.03654	53.451	1.477	$1.2*10^{-3}$
[45]	GWO	0.7609	0.24303	0.0373	52.487	1.4512	$7.2*10^{-3}$
[46]	CAT swarm	0.7767	0.3301	0.0356	53.987	1.4913	$9.9*10^{-3}$
[47]	Artificial bee colony	0.7607	0.3315	0.03512	52.789	1.4687	$2.8*10^{-3}$
[51]	MPP Bird mating optimizer	0.7704	0.3211	0.03541	54.789	1.5412	$9.9*10^{-4}$
Proposed BAT optimization algorithm		0.6904	0.2911	0.03541	57.485	0.9412	$9.0*10^{-4}$

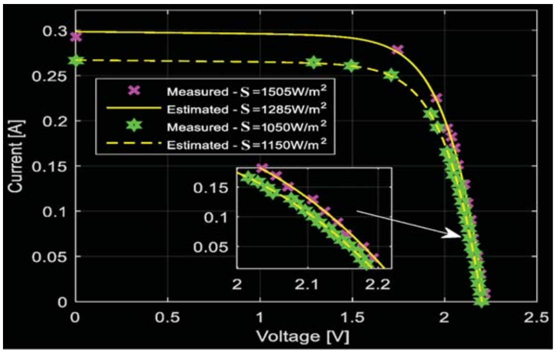
Table 2B
(b). Compare and calculated DDM parameters

Reference	Algorithm	Ipv (A)	I_{01} (μA)	I_{02} (μA)	Rs (Ω)	Rp (Ω)	n_1	n_2	RMS (Root mean square) Error
[48]	Teaching learning	0.7751	0.210	0.5545	0.0356	54.59	1.54	1.98	$9.82*10^{-4}$
[49]	Evolution algorithm	0.7684	0.245	0.7495	0.0365	56.48	1.45	2	$9.93*10^{-4}$
[50]	Simplified swarm	0.7778	0.2314	0.6874	0.0377	55.41	1.34	1.94	$1.05*10^{-3}$
[46]	CAT swarm	0.7641	0.2214	0.7245	0.0354	55.51	1.25	1.99	$9.84*10^{-4}$
[47]	Artificial bee colony	0.7607	0.2410	0.6304	0.0378	53.74	1.91	2.00	$9.97*10^{-4}$
Proposed BAT optimization algorithm		0.7007	0.2110	0.7304	0.0278	51.74	0.94	2.00	$8.97*10^{-4}$

Table 3
Comparison for computational time with different optimization algorithm

Reference	Algorithm	Case	Average computational time (sec)	Absolute error	Relative error	Standard deviation	Accuracy
[48]	Teaching learning		642.87	0.9754	1.054	0.08545	97.5
[49]	Evolution algorithm		554.3	0.9354	1.573	0.08142	96.54
[43]	Modified PSO		640.2	1.094	0.987	0.08745	95.41
[46]	CAT swarm		778.21	1.542	1.347	0.08324	97.84
[47]	Artificial bee colony		847.54	1.354	0.875	0.08451	98.47
[51]	MPP Bird mating optimizer	**5 Parameters**	975.12	1.265	0.997	0.0875	97.5
[45]	GWO		547.19	0.954	1.042	0.0897	96.7
[42]	Hybrid optimization		754.54	1.984	1.004	0.0824	97.2
[44]	Learning PSO		765.45	1.845	0.875	0.0863	95.7
Proposed BAT optimization algorithm			510.54	0.911	0.910	0.0767	98.13

[1500 to 100] W/m^2. V-I characteristics of SDM model are depicted in Fig. 4(a), and another model is obtained V-I characteristics of DDM model as shown in Fig. 4(b). Calculating SDM and DDM parameter solar cells are prescribed with different optimization control algorithms shown in Table 2 (a&b). In Table 2 values of the parameters are compared with recent published articles, which is shows the state of the art in the objective of this manuscript. The comparative study for computational time using different optimization algorithms are shown in Table 3, and the aim of this table is compared execution time for PV cells five parameters using proposed SDM, DDM methods.



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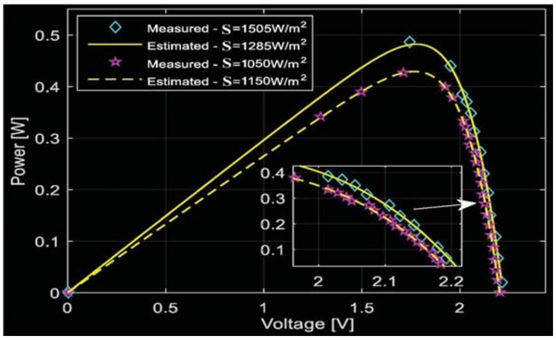
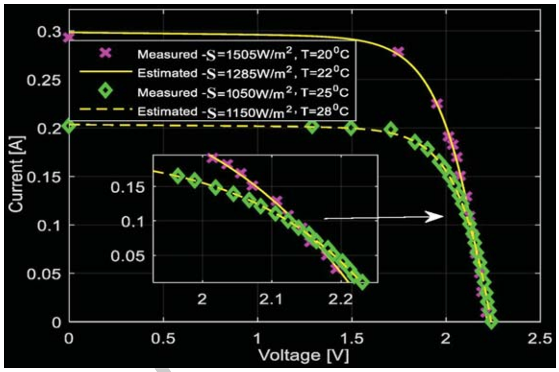


(b)

Fig. 5. (a). V-I curve for different solar insolation and temperature (T = 25°C). (b). P-V curve for different solar insolation and temperature (T = 25°C).



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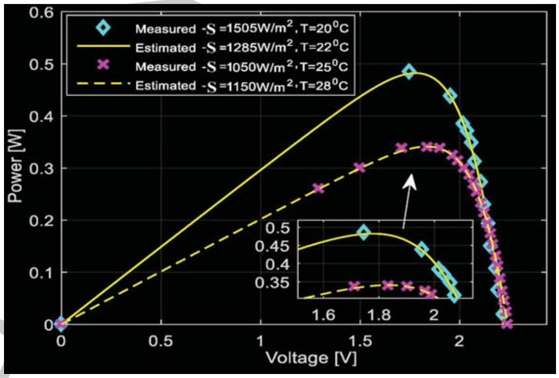

(b)

Fig. 6. (a). V-I curve for different solar temperature and insolation (T = 20°C-28°C). (b). P-I curve for different solar temperature and insolation (T = 20°C–28°C).

Based on data provided BAT optimization to find accurately was predict the solar module circuit characteristics curve shows in Fig. 5(a&b). To compare more than the other metaheuristics as well as analytical and numerical approaches in terms of estimation accuracy was successfully determined in Table 3. The solar characteristics curve (V-I & P-V) was determined insolation and temperature shown in Fig. 6(a&b).

Accuracy test was calculated and observed by using Equation (8&9), where 'n' is the variation of voltage, I/V is measured-calculated voltage/current data set for different solar irradiations [43, 45, 47, 51].

$$\text{Total Absolute Error (AE)} = \sum_{i=1}^{n} \mathrm{I}_{AEi} \qquad (8)$$

$$\text{Relative erroe (RE) calcualtion} = \frac{\mathrm{I}_{\text{measured}} - \mathrm{I}_{\text{calcuated}}}{\mathrm{I}_{\text{measured}}} \qquad (9)$$

$$\text{Standard deviation (SD)}\,\sigma = \sqrt{\frac{\sum(\mathbf{X}-\mu)^2}{\mathbf{N}}} \qquad (10)$$

Where N is the quantity of the voltage, X is value of different irradiation, and μ is population of bat variables.

The value of the parameters are elevated in the range of ± 3.9%, it is initial observation that depends on the parameters estimation. In other hand observation of the PV module both SDM, DDM comparison are already evaluated, and subsequently relative error for proposed BAT algorithm with number of different temperature experiment data as shown in Fig. 7. It is evidence for five parameter solar-PV module executed with BAT optimization relative error in different unit. Figure 7 shows BAT based MPP optimizations that compare to other approach such as PSO, Artificial bee colony, the relative error is better for BAT optimization compare to other methods. As per the accuracy and relative error measurements consider the DDM is better than the SDM five parameter

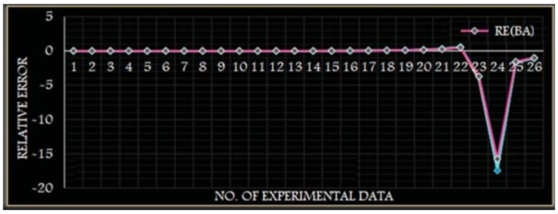

Fig. 7. Relative error for proposed BAT algorithm.

Table 4A
(a) BAT based MPP performance analysis stage 1

Panel test	S1	S2	S3	S4	Pmax	MPP	η'(efficiency)
PV1	1490	1390	1500	1500	974.1	936.7	97.52
PV2	1380	1350	1503	1500	910.2	879.5	97.**03**
PV3	1380	1450	1500	1503	857.7	826.1	98.16
PV4	1448	1390	1500	1503	850.6	789.9	98.56

Table 4B
(b) BAT based MPP performance analysis stage 2

Panel test	S1	S2	S3	S4	Pmax	MPP	η'(efficiency)
PV1	1490	1500	1150	1500	974.1	936.7	97.02
PV2	1450	1503	1203	1500	910.2	879.5	97.31
PV3	1380	1500	1500	1503	857.7	826.1	98.16
PV4	1258	1500	1380	1503	850.6	789.9	98.56

PV output. Furthermore to anlaysis and improve the performance of PV interconnected MPP controller is described the proposed work. Four PV array is connected in series. It is performed the under working in partial shading analysis, hence the experimental verification is consider the three major case as follows.

❖ **Stage 1:** As per Fig. 5 & 6 consider the uniform irradiances with 1500 W/m^2 are applied in panel S3, S4, and remaining panel S2, S1 is applied with non-uniform PV irradiance.

❖ **Stage 2:** As per Fig. 5 & 6 consider the uniform irradiances with 1500 W/m^2 are applied in panel S4, S2, and remaining panel S1, S3 is applied with non-uniform PV irradiance.

❖ **Stage 3:** As per Fig. 5 & 6 consider the uniform irradiances with 1500 W/m^2 are applied in panel S1, S2, and remaining panel S4, S3 is applied with non-uniform PV irradiance.

In each number of stage the MPP controller was measured in terms of maximum current, voltage, and efficiency as shown in Table 4 (a,b&c). Performance of BAT based MPP optimized controller was analyzed for all 3 stages and listed in Table 4. It can be measured and observed that BAT based MPP techniques obtain an average efficiency level 98%.

Table 4C
(c) BAT based MPP performance analysis stage 3

Panel test	S1	S2	S3	S4	Pmax	MPP	η'(efficiency)
PV1	1500	1500	1150	1350	974.1	936.7	97.12
PV2	1503	1500	1203	1403	910.2	879.5	97.03
PV3	1500	1503	1300	1403	857.7	826.1	98.06
PV4	1500	1503	1380	1250	850.6	789.9	98.56

6. Conclusion

Experimental modeling of PV cell SDM, DDM methods are optimized using five parameters approach successfully verified. The parameters are DDM, SDM module analysis under different characteristics curves (V-I&P-V) observed with under constant and variable temperature. Irradiance and temperature also varied to measure BAT based MPP optimization techniques. In this proposed techniques attains maximum efficiency 98% that is much higher than other optimization algorithms. In this proposed works are implemented in future may be applied black-chain technology or IOT based fault identification/detection, because day by day increasing global warming environmental changes the proposed PV cell maximum power extraction are optimized with emerging technologies by using Balance of System (BoS).

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