Review Article
ISSN (Online): 2454-1907

International Journal of Engineering Technologies and Management Research
January 2023 10(1), 64–78

BRIEF REVIEW ON SOLAR PHOTOVOLTAIC PARAMETER ESTIMATION OF SINGLE AND DOUBLE DIODE MODEL USING EVOLUTIONARY ALGORITHMS

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Received 07 December 2022
Accepted 08 January 2023
Published 26 January 2023

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DOI
10.29121/ijetmr.v10.i1.2023.1291

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ABSTRACT

In modern years several researchers contribute to renewable energy specifically solar as atmosphere responsive. Solar panels are an essential and chief constituent for solar energy selecting as they are active in transformation of solar radioactivity into electrical voltage correspondent. The principal concern in optimum generation of power from these solar panels is to be contingent on numerous characteristics mostly correlated to the sizing and modelling of photovoltaic (PV) panels for the essential presentations. An array of solar cells is castoff for generation of slight to average gauge power generation in numerous cases. Sizing of panels, the storing progression and application of electrical tracks in the procedure are some vital research qualities which together regulate and describe supreme power generation from solar panel. Parameter and circuit level modelling has been occupied as major problem of examination and several state of the art practices to govern the ideal sizing with respect to many circuit models such as single diode model (SDM) and double diode models (DDM) have been inspected in an widespread way in this review article. It offers the perceptions, features, and climaxes the strength and weaknesses of PV cell models. This article debates some algorithms and methods used in both SDM and DDM and a deep learning into the investigation of parameter assessments in each diode have been studied. Based on the showed evaluation, some commendations for upcoming research are provided.

Keywords: Renewable Energy, Photovoltaic Cell, Parameter Estimation, Single Diode and Double Diode Model, Evolutionary Algorithms

1. INTRODUCTION

With rapid depletion of fossil fuels (petroleum products, natural gas etc.,) consecutively called as non-renewable sources of energy necessity for renewable sources for tapping energy without touching our atmosphere is in tall claim and has involved extensive research in the previous some eras. Well recognized renewable sources of energy contain wind, solar and tidal energies out of which solar is

considerably favoured outstanding to its tall insolation levels and plenty in greatest share of the world power requirement. This is main reason and motivation for solar installations to be more dominant in the world. Among many renewable energy resources solar is an important energy source which directly received from sun for entire centuries. Solar energy is categorized into two type's namely active and passive solar systems. In active systems consists of water heater and concentrated solar systems. Orientation of buildings towards sun, selection of materials and properties of light dispersion comes in passive systems De Groote & Verboven (2019). In recent years power requirement for practical devices starts to utilize solar energy Mohan & Senthilkumar (2022), Nathangashree et al. (2016), Suganya et al. (2014), Senthilkumar et al. (2022), Senthilkumar et al. (2022). Many countries provide subsidies to encourage the renewable energy usage along with different technologies, like solar and wind energy systems. Building construction cost is reduced by installation of solar systems on top of the buildings in order to remain inexpensive Araújo et al. (2019). Earth temperature is increasing day by day and there is a necessity for endorsements to reduce the CO_2 productions with the help of renewable energy. A system with fixed sustainability for classification of parameters in the solar is evidently reviewed Choudhary & Srivastava (2019). Figure 1 shows simple block diagram of PV system.

Solar PV cell modelling has grown over several decades, with the attention on an analytical approach based on simply accessible constructer data for the complex element. The substitute attitude of trusting on arena measurement to support the progress of a precise model for a collection of attention has been mainly uncharted. The outcomes of a better-quality yet simple model can accurately simulate and calculate the output power of an installed PV array system in a given area with different environment conditions López-Guede et al. (2013). Lots of research works available in the literature on multi-level inverters to reduce the harmonics during the dc to ac conversion G et al. (2023), Chitrakala et al. (2019), Krithiga & Mohan (2022), Chitrakala et al. (2018), Sivamani & Mohan (2022), Bharatiraja et al. (2016). Diverse tactics are hired for parameter approximations are Analytical techniques Ayodele et al. (2016), Numerical extraction Ibrahim & Anani (2017) and Evolutionary algorithm techniques Chen et al. (2019), Senthilkumar et al. (2022). Among different diode models SDM is the frequently used model for modelling solar cell modules and arrays in many cases. In SDM five parameters have to be extracted when modelling a system.

Figure 1

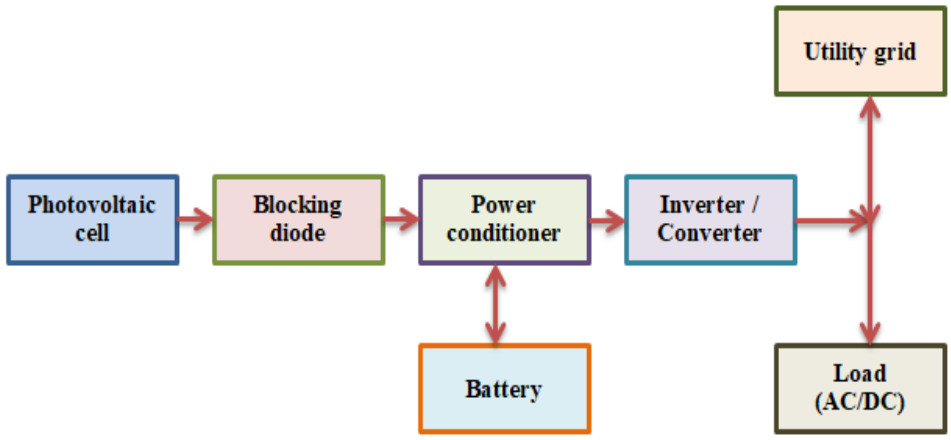

Figure 1 Primary Photovoltaic Model

The V-I characteristics of the equivalent circuit model of a single-cell is determined with the aid of its explicit non-linear inspirational equation, which is tough to clear the practice of analytical approaches. Due to this reason, in many situations, this method is not considered a correct one. This trouble brought about the enhancement of numerous algorithms for cracking this equation by numerical techniques. This is a prospective instrument for investigators and designers running exclusively in the area of PV assemblies to make conclusions related to determining on the satisfactory achievable set of rubrics for extracting the eye parameters of 5-parameter PV models with single diode Waly et al. (2019). But numerical techniques have some downsides involving of premature integration, low precision, and uncertainty. The claim of curving to the linear equation of a diode is unconditionally limited. However, the parameter extraction of SDM using 3-point method, the evolution algorithm routines most active the relaxation of the curve for outstanding alteration. As an end result, the complexity of the set of rules is substantially reduced and lots extra correct than other documented strategies Muangkote et al. (2019). The evolutionary algorithm techniques are superior for processing nonlinear equations. To estimate solar cell parameters different types of optimization techniques have been introduced. These study ambitions to decide the optimization of energy generation to raise the complete performance of the PV module Kabeel et al. (2019).

A fast-converging modest Maximum Power Point Tracking (MPPT) technique with dissimilarities in radiation of solar and load resistance (R_L) with cheap losses in generated strength of solar cell was proposed by Tey & Mekhilef (2014). The algorithm proposed is four times faster while in comparison with traditional (incremental conductance) algorithms with appreciate to dissimilarities in solar irradiation and load. Sahu & Nayak (2017) counselled an estimation technique for MPPT the use of Levenberg-Marquardt scheme below specific situations on atmosphere for a DDM of a machine and compare the obtained end result with experimental facts obtain from MATLAB simulation and found a higher overall show from the projected method. Jadli et al. (2018) have modelled solar cell parameters to analyze the feature performance at specific environmental conditions and found that the traits of proposed model are very correct when comparing with present one.

2. MODELING OF SOLAR SYSTEMS

Solar energy plays a significant character in total energy creation within the global and swiftly increasing every day. On the alternative side, cost of solar panels, batteries and inverters are lowering appreciably. Due to those motives, many countries in the global are changing their strength rules toward solar energy.

In recent years modelling of solar cells attracts many researchers. In solar cell modelling, different types of equivalent circuits are used based number diodes present in that particular circuit. Some models of solar cell are Senthilkumar et al. (2020),

1) Single-Diode Model (SDM)
2) Double-Diode Model (DDM)

2.1. SINGLE-DIODE MODEL

Design and implementation of SDM is very simple. The equivalent circuit of SDM is depicted in Figure 2. In the shown SDM model, five unknown parameters need to be estimated namely light induced current (I_{ph}), diode dark saturation current (I_{d1}), series resistance (R_s), shunt resistance (R_{sh}) and diode ideality factor (n).

Figure 2

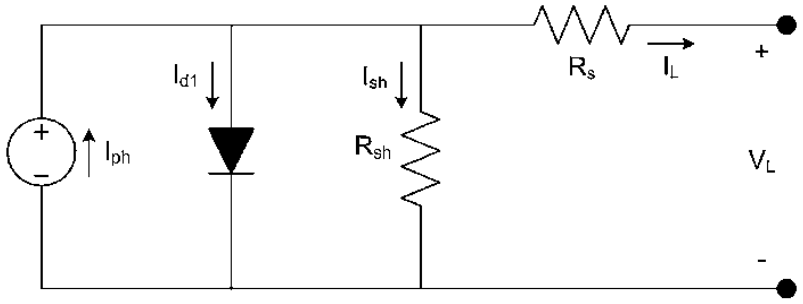

Figure 2 SDM -Equivalent Circuit

In many situations, SDM is used to extract I-V curve of a solar cell. Output current from SDM is written as

$$I_L = I_{ph-} I_0(\exp\left(\frac{V_L+I_L R_s}{aV_T}\right) - 1) - (\frac{V_L+I_L R_s}{R_{sh}}) \quad (1)$$

Equation for diode current of SDM is written as follows

$$I_{d1} = I_0(\exp\left(\frac{V_L+I_L R_s}{aV_T}\right) - 1) \quad (2)$$

The value of ideality factor 'n' is assumed as a constant in the case of SDM. In reality the surfaces and the bulk regions dominates the ideality factor and its value is closer to one.

2.2. DOUBLE-DIODE MODEL

The equivalent circuit of DDM is depicted in Figure 3. Output current from DDM is written as follows

$$I_L = I_{ph} - I_{D1} - I_{D2} - I_{sh} \quad (3)$$

Figure 3

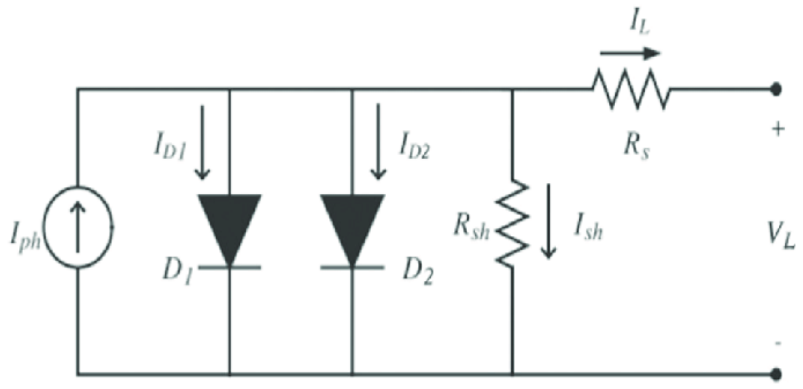

Figure 3 DDM - Equivalent Circuit

Current through diodes in DDM is written as follows

$$I_{D1} = I_{01}(\exp\left(\frac{V_L+I_LR_s}{a_1V_T}\right) - 1) \tag{4}$$

$$I_{D2} = I_{02}(\exp\left(\frac{V_L+I_LR_s}{a_2V_T}\right) - 1) \tag{5}$$

Shunt resistance in DDM is calculated by the following equation

$$I_{sh} = (\frac{V_L+I_LR_s}{R_{sh}}) \tag{6}$$

Losses due to recombination current inside the depletion region are considered in DDM which leads to improvement in accuracy which is not considered in SDM. In DDM seven unknown parameters need to be estimated namely Light induced current (I_{ph}), Diode dark saturation current (I_{01}), Diode dark saturation current (I_{02}), Diode quality factor (a_1), Diode quality factor (a_2), Series resistance (R_s) and Shunt resistance (R_{sh}).

Table 1 shows the comparison between SDM and DDM.

Table 1

Table 1 Comparison of SDM, DDM and TDM

Parameter	SDM	DDM
No. of parameters to be extracted	5	7
Components prerequisite	Less	More
Design process	Easy	Complex
Efficiency	Good	Better than SDM Derick et al. (2016)
Precision	Low	Better
Performance	Good	Better than SDM

This study estimates the contrast among SDM and DDM to enhance the efficiency of solar PV systems. Among SDM and DDM, design and implementation of SDM is easy with lower accuracy, but the DDM has extra accurate, which will improve the overall performance of PV systems. Different algorithms are available to find the parameters of different solar PV models such as SDM, DDM and TDM. Such algorithms are clearly summarized in the following section.

3. EVOLUTIONARY ALGORITHM

Figure 4 shows different methods available for parameter estimation of various solar PV models. This section describes detailed literatures in parameter estimations using different evolutionary algorithms.

Figure 4

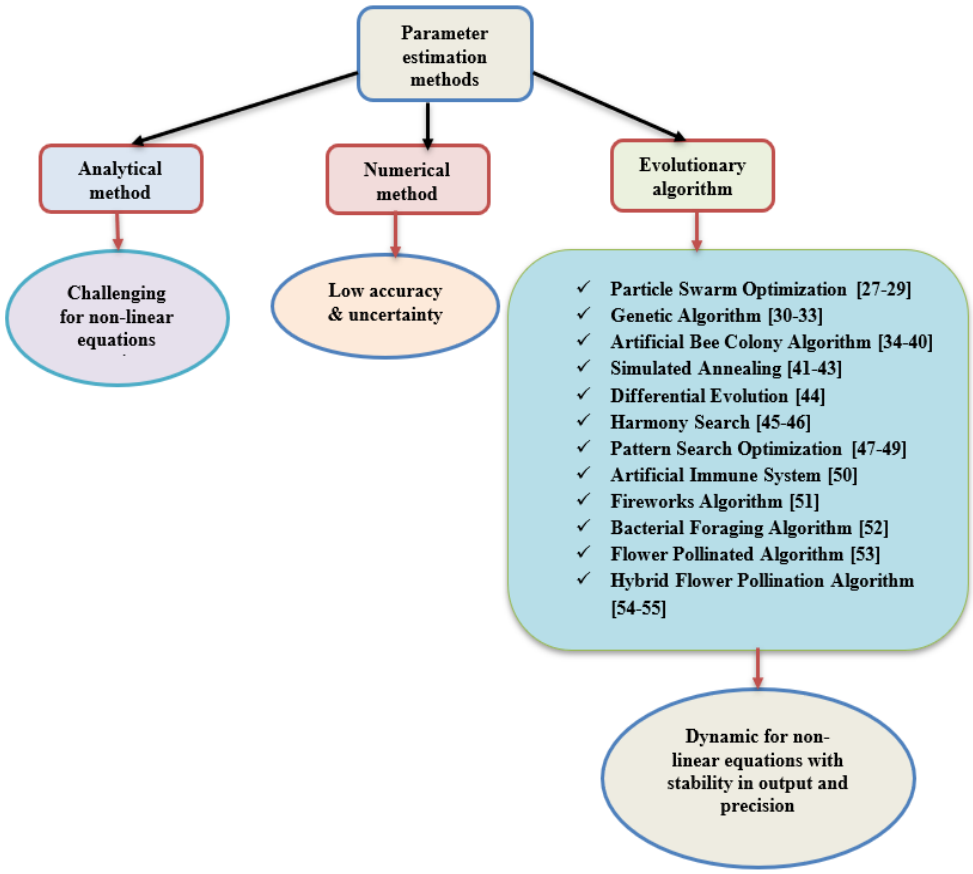

Figure 4 Classification of Solar Parameter Estimation Methods

3.1. PARTICLE SWARM OPTIMIZATION

Meiying et al. (2009), carried out PSO algorithm for estimation of solar PV cell parameters and compare the obtained results some other algorithms like GA for SDM and DDM and decided that that the PSO algorithm provides good accuracy in the estimated parameters with excellent performance in computational time. Hamid et al. (2013) presented a PSO algorithm to estimates the parameters from SDM with 5 unknown values for a silicon solar cell 57 mm diameter and recognized the reliability of predicted parameters accuracy with other strategies. Khanna et al. (2014) developed PSO algorithm to extract the solar PV parameters from DDM and

find the V-I characteristics of solar PV cell. Flow chart for PSO algorithm is depicted in Figure 5.

Figure 5

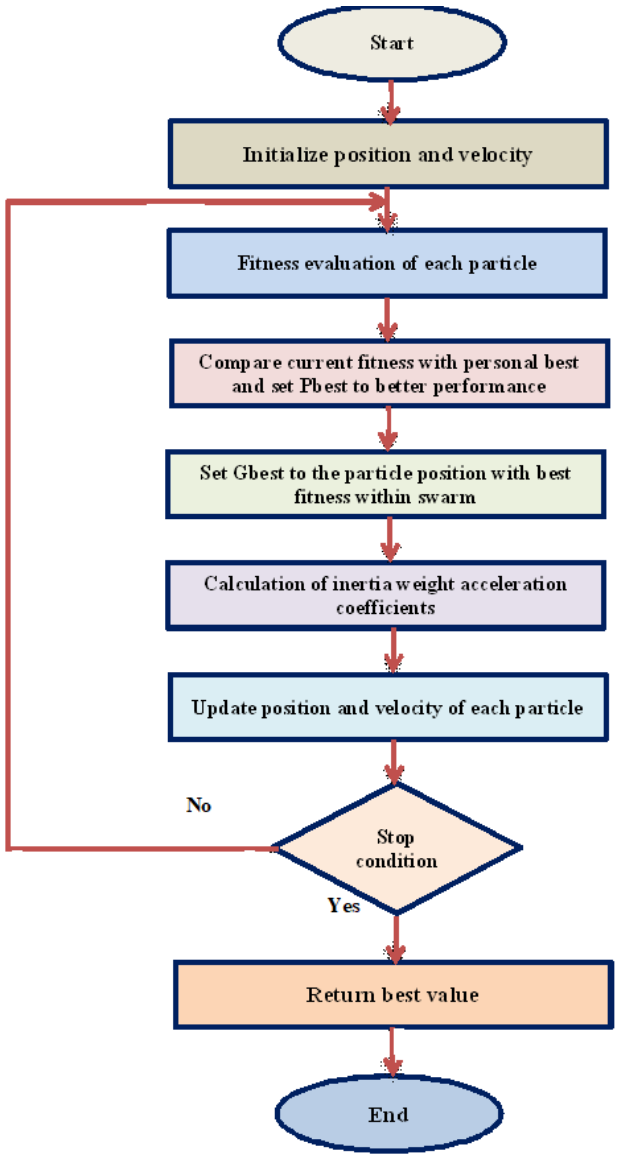

Figure 5 Process Flow of PSO Algorithm

3.2. GENETIC ALGORITHM

Bastidas-Rodriguez et al. (2017) have recognized a SDM with five working factors of creators jogging external situations the practice of GA for distinct eco-friendly situations like solar irradiances and hotness; observed that estimated parameters are very accurate whilst in comparison with other available estimating strategies. Jervase et al. (2001) have proposed GA to enhance the already to be had solar cell parameter abstraction techniques and gain a result with errors at the parameters extracted became ± five% at the module standards. Harrag & Messalti (2015) have cautioned a GA mainly based solar parameter extraction approach for five and seven parameter version to improve the possibility of locating global minimal with super accuracy in brief time. Here there's no limit in solution area all through the procedure Warkad & Asole (2019).

3.3. ARTIFICIAL BEE COLONY ALGORITHM

ABC algorithm developed to extract the parameters of solar PV cell by Chen et al. (2018), provides a parameters value with more accuracy; it become discovered that ABC affords well seek potential for multi model objective features and reveals top overall performance on parameter extraction while as compared with other optimization algorithms like BFA, PSO, GA and HS. An effective ABC algorithm to find solar PV cell parameters for SDM and DDM models was proposed by Mohammad Jamadi et al. (2015), discovered a fast and accuracy on parameters estimations in comparison with PS, ABSO, GA and PS algorithms. Chen et al. (2018) developed Hybrid Teaching Learning based totally Artificial Bee Colony (TLABC) to estimate the solar cell PV parameters SDM, DDM and TDM; Obtained outcomes whilst compared with different optimization techniques and located the proposed set of rules provides true accuracy and performance for estimation of various cell parameters. More works in this algorithm available in literatures Salmi et al. (2016), Pilakkat & Kanthalakshmi (2019), Hassan et al. (2017), Oliva et al. (2014).

3.4. SIMULATED ANNEALING

SA algorithm for battery model parameterization proposed by Ben (2020), have a long battery life time and very good efficiency when compared with some other optimization algorithms. The same algorithm with three steps for SDM parameter extraction of SDM suggested by Ramzi Ben Messaoud AlRashidi et al. (2013), in first step parameters are extracted using conventional method, in second step parameters are extracted using uncertainty determination and in final step is instantaneous values of parameters determination, the projected algorithm delivers active performance of the solar panel when compared with already existing algorithms. M.R. AlRashidi et al. (2013), Brondani et al. (2017), suggested SA algorithm for solar parameter estimation and found that the suggested algorithm delivers accurate parameter assessments.

3.5. DIFFERENTIAL EVALUATION

Abido & Khalid (2018) estimated seven parameters of DDM six solar panels constructed from mono crystalline silicon, poly crystalline silicon and thin film technologies using DE algorithm. The values of seven parameters extracted from DE algorithm were compared with I-V curves of experimental data and found that projected algorithm offers more accuracy on estimated parameters of panels.

3.6. HARMONY SEARCH BASED ALGORITHM

Askarzadeh & Rezazadeh (2012) considered solar cells with 57 mm diameter made up of silicon for parameter estimations of both SDM and DDM and proposed HS algorithm with easy and better performance, simulation was done in MATLAB Simulink, detected a reduced RMSE value when compared with other algorithms like PS and SA and also observed a very narrow difference between simulated values and values extracted experimentally from I-V curves. Satapathy et al. (2017), discussed about HS based hybrid firefly algorithm for micro grid applications with rapid convergence time and compact randomization when compared with FA and observed that stability is considerably improved.

3.7. PATTERN SEARCH OPTIMIZATION

PS algorithm is proposed by Derick et al. (2016), to invention solar cell parameter of SDM by simulation as well as experimental method and examine the helpfulness of PS algorithm for parameter approximation in MATLAB / Simulink software with respect to different ecological conditions like different solar irradiance and temperature; results of PS algorithm display a better accuracy with short convergence time. PS algorithm for SDM and DDM presented by AlHajri et al. (2012) precisely abstract the parameter standards of stated models. The parameters of SDM and DDM was estimated by Beigi & Maroosi (2018) using PS algorithm, the estimated values are compared with other optimization algorithms available and concluded that the results obtained from PS algorithm is better one for solar cell modeling.

3.8. ARTIFICIAL IMMUNE SYSTEM

AIS algorithm proposed by Jacob et al. (2015) evaluation of the parameters of solar cell for DDM, compare the performance of AIS algorithm with other algorithms like GA and PSO for different types of two modules and find that performance of AIS especially convergence speed is better than GA and PSO algorithms.

3.9. FIREWORKS ALGORITHM

To estimate the parameters sol solar PV systems, FA faced algorithm developed by Sudhakar Babu et al. (2016), the developed algorithm decreases premature in meeting probability and computational difficulty and obtained from parameters value from developed algorithm are very accurate closer to the data sheet values of the given solar panel.

3.10. BACTERIAL FORAGING ALGORITHM

BFA algorithm proposed by Rajasekar et al. (2013) for three different type's solar cell models observed better results like good accuracy, high precision, low merging time, good consistency and lower error values when matched with additional optimization algorithm like GA and AIS.

3.11. FLOWER POLLINATION ALGORITHM

Alam et al. (2015), suggested FPA for solar PV parameter estimations in order to attain lesser values on RMSE, fast outcome of optimal solution and reduced convergence time under extensive array of temperature and solar irradiations. Only few control parameters needed in the suggested algorithm.

3.12. HYBRID FLOWER POLLINATION ALGORITHM

Ram et al. (2017) offered HFPA for extractions of solar parameter for both SDM and DDM under different solar irradiance and temperature; offered algorithm deliver a good parameter estimations with low Least Mean Square Error (RMSE) value under very lower values of solar irradiation. A simple HFPA is built by Xu & Wang (2017) in order to finding the solar parameters efficiently and precisely for SDM and DDM and stated that the suggested algorithm offers superior good results like accuracy, convergence speed and stability of the model under different

temperature and solar irradiations. Table 2 summarizes different evolutionary algorithms with respect to merits, demerits, and applications.

Table 2

Table 2 Different Evolutionary Algorithms – Facts, Faults, and Applications

Algorithm	Facts	Faults	Applications
PSO	Fast computations	Initial parameter selection is difficult	Provide global optimization solution for nonlinear problems, vehicle oscillations,
GA	Improved solution	More computation time and less accuracy	Effective method for parallelization, machine learning, robot path generation, examination of DNA and data mining etc.,
ABC	High solution and fast convergence	Convergence disaster in recurrent evolution	Structural optimization, cluster analysis, bioinformatics, advisory system, and wireless sensor etc.,
SA	Well solution	Threatening in temperature-cooling programme match	Optimization problems, electric power systems and operational research
DE	Great accuracy	Finding of control parameters are difficult	Classification of DNA, single function optimization, multi-function optimization, data mining, clustering, network training, power systems
HS	High solution	Performance of the algorithm is affected by convergence trajectory	Power systems, control systems, image processing, signal processing and information technology etc.,
PS	Healthier solution	Premature in convergence	Computational molecular biology, network security and information retrieval, digital libraries, spam filters and web hunt engine etc.,
AIS	Search space is adaptable	Low convergence speed	Handwriting recognition, pattern recognition, data analysis, to diagnostic illness, optimization, clustering, machine learning, clustering, robotics, and computer security etc.,
FA	High accuracy Efficient, robust	More time consumption	Data management systems and information systems
BFA	Well solution, quick convergence	Computation is complex	Design of antenna array, distributed generation sizing and removal of voltage harmonic on PWM inverter
FPA	High solution	Convergence is late due to reduced fitness values	Optimization of non-linear problems and distributed systems
HFPA	Less RMSE value and convergence to global maximum	Precision is low	Optimization of non-linear problems and distributed systems,

4. OPPORTUNITY FOR RESEARCH IN SOLAR PARAMETER ESTIMATION AND MPPT

Conventional electric power systems create huge amount of carbon di oxide, which will increase the earth temperature day by day measured the capacity of the device to offer a giant percentage of a utility, creation of a huge hours of the system associates the amount of electricity to be determined and this is the reserving Indeed, penetration stages and further electricity systems inside the production of the current laws and guidelines of movement. Low precision, excessive RMSE value and lower computation time is vital outcomes of this assessment. On comparing the efficiency of different types of meta-heuristics at the problem of extracting solar PV parameters accuracy, convergence rate and steadiness and decisive the maximum suitable meta-heuristics to remedy this hassle, could be a thrilling and useful studies network inside the destiny. Apart from the problems debated overhead, some of troubles statements that could be derived from examine of literature are summarized under.

- Researcher can give additional focus maximum energy production from the available solar irradiations by proper mechanism and try to fully utilize the generated power by proper trapping generated energy.
- May develop effective algorithms to estimates the parameters of solar PV cells quick computational time with good accuracy.
- An appropriate optimization model has to be evolved with admiration to distinct overall performance parameters on the way to enhance the performance of the model.
- A powerful MPPT approach must be developed to track maximum strength beneath distinct situations like versions in temperature and irradiations.

5. CONCLUSION

Solar PV cell parameter estimation is the principal problem of nowadays researchers in environment friendly renewable energy. In this review, different evaluation algorithms for solar PV cell parameter estimation for both SDM and DDM performed studied by means of thinking about twelve varieties of algorithms. Also, the overall performance and limitations of a few existing methods are analysed. This review article will honestly be very supportive for new researchers and for the researchers already running in this vicinity to be able to replace their information. As in keeping with our preceding discussion, subsequently we can introduce a singular method to triumph over the previous limitations and develop a more suitable applicable technique.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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