International Journal of Research in Engineering, Science and Management
Volume-1, Issue-10, October-2018
www.ijresm.com | ISSN (Online): 2581-5792

Parameters Optimization of Photo Voltaic Module: A Survey

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***Abstract*—A solar PV array system is comprised of the following components - solar cells, panel modules, and an array system. Thus, overall optimal design of a solar PV system involves the optimal design of the components at three levels - solar cell, panel module, and array. In the present work, a comparison between different optimization methods is applied to design optimization of single channel Photovoltaic (SCPVT) system. The purpose of these methodologies is to obtain optimum values of the design parameters of SCPVT system, such that the overall economic profit is maximized throughout the PV system lifetime operational period which is not directly calculated in our work rather energy efficiency is calculated. In this work we compared the latest work done by several researchers and concluded them in a tabular format in the appendix.**

***Index Terms*— Photo Voltaic Module, Parameters Optimization**

I. Introduction

The hybrid photovoltaic thermal (PVT) module is a collection of collector with the provision of a channel or channels to convert solar energy into thermal and electrical energies simultaneously. The PVT collector can be used whenever both electrical and thermal energy are required, for domestic uses. It is well known fact that the efficiency of the photovoltaic cells decreases as operating temperature increases. Therefore, the use of these cells as a hybrid photovoltaic thermal collector is better and a more efficient for cooling the cells as well as getting thermal energy. Another method for cooling the PV cells is to use a heat exchange system, which cools the cells by means of a heat absorbing medium, such as water, flowing in pipes. Another advantage of the PVT collector is its higher overall efficiency per unit area and lower packaging costs due to its compact design. The electricity conversion-efficiency of a solar cell for commercial application is about 6–15%. More than 85% of the incoming solar energy is either reflected or absorbed as heat energy. A PVT collector is a system in which the electrical and thermal energy produced simultaneously by the photovoltaic. In this way, heat and power are produced simultaneously; it is also called co-generation system. In applications of PVT system, the main work of the PVT module is to produce electricity, and therefore, it is necessary to operate the PV modules at low temperature in order to keep the PV cell electrical efficiency at a sufficient level. The heat from the back surface of PV modules is withdrawn with the help of natural or forced air circulation. It is simple and low cost methods to remove heat from PV modules. It is simple and low cost methods to remove heat from PV modules, but they are less effective. When ambient air temperature is over 25°C. To overcome this problem, the heat can be extracted by circulating water through a heat exchanger that is mounted on the back surface of the PV module.

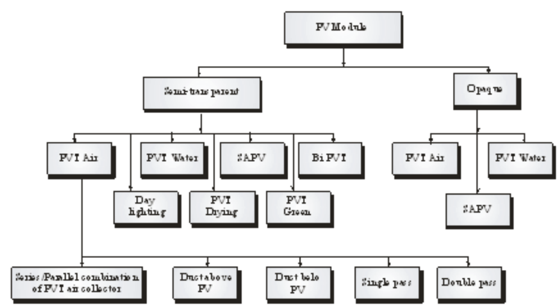

Fig. 1. Classification of photovoltaic systems on the basis of their use

The basic idea of a photovoltaic cell is to convert light energy into electrical energy. The energy of light is transmitted with the help of photons, small packets or quantum's of solar light. Electrical energy is stored in electromagnetic fields, which in turn can make a current of electrons flow.

Several researchers worked in this area and proposed their latest work in this field. We have reviewed some of their latest papers in this work. Further section in this paper will review the previous work on PVT module optimization in section 2 and a review table is made tabulating advantages/drawbacks of existing solutions in the appendix. Conclusion is drawn in section 3.

II. Literature Review

S. Singh et.al. [1] investigated an improvement in the efficiency of photovoltaic thermal (PVT) system with the help of Genetic Algorithm (GA) with multi-objective functions for New Delhi, India climatic condition. There are several parameters influencing efficiency of PVT system which inter alia include length and depth of the channel, velocity of air fluid flowing into the channel, thickness of the tedlar and glass, temperature of inlet fluid. All these parameters have been considered to optimize the efficiency of the PVT system. An attempt has also been made to model and optimize the parameters of glazed hybrid single channel PVT module considering the two objective functions separately which are: (i) the overall exergy efficiency (ii) the overall thermal efficiency. Using GA, both of the above objective functions are separately optimized and analyzed for each of the two cases.

S. Mirjali et.al. [2] proposed a novel nature-inspired meta-heuristic optimization algorithm, called Whale Optimization Algorithm (WOA), which mimics the social behavior of humpback whales. The algorithm is inspired by the bubble-net hunting strategy. WOA is tested with 29 mathematical optimization problems and 6 structural design problems. Optimization results prove that the WOA algorithm is very competitive compared to the state-of-art meta-heuristic algorithms as well as conventional methods.

S. Singh et. al. [3] used Genetic Algorithm–Fuzzy System (GA–FS) approach identify the optimized parameters of the glazed photovoltaic thermal (PVT) system and to improve its overall exergy efficiency. The fuzzy knowledge base is used to improve the efficiency of Genetic Algorithm (GA). It is observed that three GA parameters, namely: (i) crossover probability (Pcross), (ii) mutation probability (Pmut) and (iii) population size are changing dynamically during the program, according to fuzzy knowledge base to maximize the efficiency of the GA. Here, overall exergy efficiency is considered as an objective function during the optimization process for GA–FS approach. The effort has been made to identify the different optimized parameters like; length and depth of the channel, velocity of flowing fluid, overall heat transfer coefficient from solar cell to ambient and flowing fluid and overall back loss heat transfer coefficient from flowing fluid to the ambient to maximize the overall exergy efficiency using GA–FS approach. Performance of glazed PVT using GA–FS approach has been compared with performance using GA approach and without GA. It has also been observed that the GA–FS approach is a better approach as compared to GA approach because it converges faster as compare to GA.

S. Aggarwal et.al [4] evaluated the performance of hybrid modified micro-channel solar cell thermal (MCSCT) tile. Based on energy balance of each component of modified MCSCT tile, analytical expressions for the different parameters of modified MCSCT tiles connected in series have been derived. An attempt has also been made to validate the thermal model with experimental results of prototype of modified micro-channel solar cell thermal tile in indoor condition for New Delhi. An indoor test setup and modified micro-channel solar cell thermal (MCSCT) tile has been developed for experimental purpose. Performance evaluation of modified micro-channel solar cell thermal tile over different intensities has been studied. It has been observed that the thermal and electrical efficiency of the modified micro-channel solar cell thermal tile are 35.7 % and 12.4 %, respectively. On the basis of numerical computation, overall energy and exergy analysis have also been carried out.

F. Sarhaddi [5] presented the overall thermal energy and exergy analysis of three types of hybrid Photovoltaic Thermal (PVT) array which is a series parallel combination of 36 numbers of PV modules (10.08m x 2.16m). A comparison has been made between the three confiurations, which are explained as, case-A: 2 integrated columns each having 18 opaque PV modules in series are connected in parallel, case-B: Two integrated columns of 18 modules each having 36 PVT tiles in the module is connected in series (area of each tile is 0.124m x 0.124m) and case-C: 2 integrated columns each having 18 semi-transparent PV modules in series are connected in parallel.

S. Singh [6] maximized the exergy efficiency of micro-channel photovoltaic thermal module. There are some parameters that affect the efficiency of PVT solar system like length of the solar cell, length of the channel, depth of the channel and velocity of flowing fluid etc. An attempt has been made to model and optimize the parameter of hybrid single channel photovoltaic thermal (PVT) module. In this paper all equations for solar cell and thermal collector have been derived. By using genetic algorithms (GAs), thermal efficiency and electrical efficiency of the system may be optimized. All the parameters that are used in genetic algorithms are the parameters that could be changed, and the non changeable parameters, like solar radiation, ambient temperature cannot be used in the algorithm. By compare to other methods, we found that the GaAs are very efficient technique to estimate the design parameters of hybrid single channel PVT module.

S. Soni at.al [7] investigated a new hybrid system in which integrated photovoltaic thermal solar system (IPVTS) is coupled with earth water heat exchanger (EWHE). The performance of such coupled system is evaluated analytically by developing a theoretical model and validated experimentally on an experimental set-up installed in Pilani, India. Further to identify the grey areas for the improvement and to utilize the maximum energy, second law thermodynamic analysis of coupled system has been carried out in terms of exergy losses and exergy destructions. An electrical efficiency comparison was made between the PV panel connected to the broad water channel cooling and normal PV panel. The results show that with EWHE cooling, there is increase in experimental electrical efficiency of IPVTS by 1.02– 1.41% as compared to without cooling. The second law analysis for two different scenarios was carried out. The second law analysis shows that the exergetic efficiency for a first scenario varies from 8.50% to 8.75%; while for the second scenario, it ranges from 8.16% to 8.54%. The analysis provides the feasibility of IPVTS coupled with EWHE system which could be used for the semi-arid regions of North-West India.

Khaki M at.al [8] used genetic algorithm-based multi-objective optimization of a building integrated photovoltaic/thermal (BIPV/T) system is carried out to find the best system configurations which leads to maximum energetic and exergetic performances for Kermanshah, Iran climatic condition. In the proposed BIPV/T system, the cooling potential of ventilation and exhaust airs are used in buildings for cooling the PV panels and also heating the ventilation air by heat rejection of PV panels. Four scenarios with various criteria in the form of system efficiencies and useful outputs are considered to reflect all possible useful outputs in the optimization procedure. This study models a glazed BIPV/T system with various collector areas (Apv = 10, 15, 25 and 30 m^2) and different length to width ratio (L/W = 0.5, 1, 1.5 and 2) to determine the optimum air mass flow rate, bottom heat loss coefficient, depth of the channel as well as the optimum depth of the air gap between PV panel and glass cover that maximize two defined objective functions in different scenarios. Results showed that using fourth scenario (with the annual total useful thermal and electrical outputs as objective functions) and first scenario (with the annual average first and second-law efficiencies as objective functions) for optimizing the proposed BIPV/T system leads to the highest amount of useful thermal and overall outputs, respectively.

L. Guo et.al [9] proposed an optimization technique based on cat swarm optimization (CSO) algorithm to estimate the unknown parameters of single and double diode models. To investigate the effectiveness of proposed approach, comparative studies with other techniques are presented. The evaluation for the quality of identified parameters is also given. Results demonstrate the high performance of developed approach, high accuracy of estimated parameters, and calculated I–V curve is in good agreement with experimental I–V data. In addition, the sensitivity of performance to control parameter of CSO is also investigated. Results show the proposed CSO algorithm can be an effective tool to solve the optimization problem of parameter identification of solar cell models.

S.Xu et.al [10] developed based on the flower pollination algorithm by incorporating it with the Nelder-Mead simplex method and the generalized opposition-based learning mechanism. The proposed algorithm has a simple structure thus is easy to implement. The experimental results tested on three different solar cell models including the single diode model, the double diode model, and a PV module clearly demonstrate the effectiveness of this algorithm. The comparisons with some other published methods demonstrate that the proposed algorithm is superior to most reported algorithms in terms of the accuracy of final solutions, convergence speed, and stability. Furthermore, the tests on three PV modules of different types (Multi-crystalline, Thin-film, and Mono-crystalline) suggest that the proposed algorithm can give superior results at different irradiance and temperature. The proposed algorithm can serve as a new alternative for parameter estimation of solar cells/PV modules.

D. Kler et.al [11] explored a new and powerful metaheuristic optimization technique known as Evaporation Rate based Water Cycle Algorithm (ER-WCA) for effective parameters estimation of PV cell/module. Single and double diode based models of PV cell and single diode based model of PV module have been successfully identified from their respective single I-V non-linear characteristics and the modeling performance of ER-WCA, assessed in terms of root mean square error, mean absolute error and mean relative error, between computed and experimental data, is found to be superior to the several recent prominent published works particularly the modeling of a single diode based PV module. Furthermore, the PV module modeling capability of ER-WCA under varying temperature and irradiation conditions is also analysed and it is found to be effective, proving its practical applications. Based on the presented detailed investigation, it is concluded that ER-WCA is a promising optimization technique for PV cell/module identification.

S. Bana et.al [12] presented a particle swarm optimization (PSO) technique with binary constraints to identify the unknown parameters of a single diode model of solar PV module. Multi-crystalline and mono-crystalline technologies based PV modules are considered under the present study. Based on the results obtained, it has been found that PSO algorithm yields a high value of accuracy irrespective of temperature variations.

A. R. Jordehi et.al [13] used an improved PSO variant, with enhanced leader, named as enhanced leader PSO (ELPSO) for parameter estimation of photovoltaic cells. In ELPSO, by enhancing the leader through a five-staged successive mutation strategy, the premature convergence problem is mitigated in a way that more accurate circuit model parameters are achieved in the PV cell/module parameter estimation problem. RTC France silicon solar cell, STM6-40/36 module with monocrystalline cells and PVM 752 GaAs thin film cell have been used as the case studies of this research. Parameter estimation results for various PV cells and modules of different technologies confirm that in most of the cases, ELPSO outperforms conventional PSO and a couple of other state of the art optimisation algorithms.

D. F. Alam et.al [14] proposed a new Flower Pollination Algorithm (FPA) is proposed to extract the optimal parameters of a single diode and a double diode models. The proposed extraction technique is tested using three different sources of data. The first source is the data reported in the previous literature, while the second source is the experimental data measured at the laboratory. The third source is the experimental data obtained from the data sheets of different types of solar modules. The FPA results are compared with the results of the previous literature to validate the performance of the proposed technique. The results prove that FPA achieves the least error between the extracted and the measured data relative to the other techniques over the entire ranges of different environmental conditions, especially at low irradiation levels.

E.E. Ali et. al [15] extracted the five parameters of the single diode model of PV cells by using the Multi-verse optimization (MVO) metaheuristic approach. A conventional approximate mathematical method is first used to find initial values of the five unknown parameters. At this moment, MVO-based methodology is applied to generate the optimal values of the PV solar cell parameters. The best (optimal) five parameters obtained are used to simulate the behavior of PV cells under various conditions including sun irradiance and temperature variations. The efficacy of the proposed method is confirmed by comparing its realized numerical results to an approximate mathematical method and recent heuristic-based approaches. Identified parameters generated by the proposed MVO-based method are well-matched with actual experimental data and the given specifications by vendor's datasheets which signifies the proposed methodology.

M. Kumar et.al [16] presented a five parameter single-diode and seven parameter double-diode models of SPV system for ensuring the reliable and accurate performance assessment. Since these parameters are unknown, it is important to extract these parameters for accurate modeling of the SPV systems. The accurate parameter extraction using numerical method needs suitable initial values, for which an approximate analytical solution is provided which serves as an initial value. A hybrid approach of numerical and analytical solutions are utilized which require minimal information from the module datasheet. Moreover, the reciprocal of slope of I-V curve at short circuit and open circuit conditions is calculated, which further used in analytical and numerical algebraic equations of double-diode model to enhance the parameters extraction accuracy. This makes it a cheaper and efficient parameter extraction technique. The outcomes of both PV models are compared with the manufacturer, indoor and outdoor experimental results for validation.

K.Et-torabi et.al [17] presented a comparative study of two parameter estimation methods: the iterative method called Gauss Seidel, applied on the single diode model, and the analytical method used on the double diode model. These parameter estimation methods are based on the manufacturer's datasheets. They are also tested on three PV modules of different technologies: multicrystalline (kyocera KC200GT), monocrystalline (Shell SQ80), and thin film (Shell ST40). For the iterative method, five existing mathematical models classified from 1 to 5 are used to estimate the parameters of these PV modules under varying environmental conditions. Only two models of them are used for the analytical method. Each model is based on the combination of the photocurrent and the reverse saturation current's expressions in terms of temperature and irradiance. In addition, the results of the models' simulation are compared with the experimental data obtained from the PV modules' datasheets, in order to evaluate the accuracy of the models.

T.S Babu et. al. [18] proposed application of the Fireworks Algorithm (FWA) for the accurate identification of these unknown parameters in such a way to solve effectively this modeling problem. In particular, firstly, the FWA has been comprehensively tested with two different technologies of Mono-Crystalline (SM55 & SP70) and Multi-Crystalline (Kyocera200GT) PV modules. In addition, further statistical and error analysis for three different panels are exclusively carried out to validate the suitability of proposed methodology. The results of proposed algorithm are benchmarked with popular Genetic Algorithm and Particle Swarm Optimization (PSO) methods. Fitness convergence curves or FWA method for SM55, SP70 and Kyocera200GT produce very less objective function as 2.2498E−07, 2.85765E−08 and 4.0075E−08 respectively. This illustrates the wise and accurate validation of FWA method. Calculated curve-fit via FWA in agreement to datasheet curve strongly suggest the FWA can constitute the core of suitable optimization code for two diode PV parameter extraction.

V.J. Chin at. al [19] proposed an accurate computational technique for the two-diode model of PV module. Unlike previous methods, it does not rely on assumptions that cause the accuracy to be compromised. The key to this improvement is the implementation of a hybrid solution, i.e. by incorporating the analytical method with the differential evolution (DE) optimization technique. Three parameters, i.e. IPV, Io1, and Rp are computed analytically, while the remaining, a1, a2, Io2 and Rs are optimized using the DE. To validate its accuracy, the proposed method is tested on three PV modules of different technologies: mono-crystalline, poly-crystalline and thin film. Furthermore, its performance is evaluated against two popular computational methods for the two-diode model.

A. Askarzadeh et.al [20] provided a framework to accurately estimate the electrical equivalent circuit parameters of photovoltaic arrays by use of an efficient heuristic technique. Owing to the non-linearity of the current vs. voltage (I–V) characteristics of PV modules, using a superior optimization technique helps to effectively find the real electrical parameters. Inspired by the mating process of different bird species, bird mating optimizer (BMO) is a new invented search technique which has shown superior performance for solving complex optimization problems. In this paper, the original BMO algorithm is simplified and used to estimate the electrical parameters of the module model for an amorphous silicon PV system at different operating conditions.

III. CONCLUSION

After reviewing several latest papers on parameters optimization in PVT module, it is noticed that change in irradiation and temperature is cope up by two diode model effectively. Few researchers focused on this and tested on multi arrangement of PV arrays in PVT module. It is also noticed that with the change in geographical climate conditions, the PV cell arrangement has to be changed for maximum efficiency. Several heuristic optimization algorithms and analytical solutions are suggested to solve this parameter optimization problems but no clear distinction could be developed amongst all these but all suggested latest optimization performs better than PSO and its variants.

TABLE I

Techniques	Author & Reference	Year	Advantages	Limitations
Genetic algorithm optimization for exergy improvement in PVT module	Sonveer Singh, Sanjay Agarwal, G.N. Tiwari, Deepika Chauhan [1]	2015	1. thermal efficiency is improved upto 13.14% 2.Overall exergy efficiency is improved upto 4.6%	Gentic algorithm local optimisation technique and may converge pre maturely
Whale optimization algorithm	Seyedali Mirjalili and Andrew Lewis [2]	2016	Performed better than PSO variants for truss structure design	NA
Genetic algorithm and fuzzy logic	Sonveer Singh, Sanjay Agrawal [3]	2015	1. GA-FS is better than GA 2. convergence rate is higher than GA	Fuzzy rules are static and not adaptable to sudden change in inputs
modified micro-channel solar cell thermal	Sanjay Agrawal, GN Tiwari [4]	2011	1. thermal and electrical efficiency are 35.7 % and 12.4 % respectively for single MCSCT tile	Tested on indoor conditions only
Three different PV modules with different climate conditions are tested	F. Sarhaddi, S. Farahat, H. Ajam, and A. Behzadmehr [5]	2010	2 integrated columns each having 18 semi-transparent PV modules in series are connected in parallel and have lowest cell temperature and highest thermal efficiency	PVT cell array number has to change as per the climate condition of city
Genetic Algorithm	Sonveer Singh, Sanjay Agarwal [6]	2014	Thermal and electrical efficiency is improved	Genetic algorithm local optimisation technique and may converge pre maturely
investigated integrated photovoltaic thermal solar system (IPVTS) is coupled with earth water heat exchanger (EWHE)	Sanjeev Jakhar, Manoj S. Soni, Nikhil Gakkhar [7]	2017	EWHE cooling improved electrical efficiency 1.02– 1.41% as compared to without cooling	Increase in manufacturing cost
Genetic algorithm for multi-objective function	Khaki M, Shahsavar A, Khanmohammadi S. [8]	2017	Performance improvement than single objective function	Gentic algorithm local optimisation technique and may converge pre maturely
cat swarm optimization algorithm	Lei Guo, Zhuo Meng, Yize Sun, Libiao Wang [9]	2016	Checked on single and double diode model	NA
hybrid flower pollination algorithm	Shuhui Xu, Yong Wang [10]	2017	Tested on three PV modules of different types at different irradiance levels and different temperature values	NA
Evaporation Rate based Water Cycle Algorithm	Dhruv Kler, Pallavi Sharma, Ashish Banerjee, K.P.S. Rana, Vineet Kumar [11]	2017	assessed in terms of root mean square error, mean absolute error and mean relative error, between computed and experimental data	NA
Particle Swarm Optimization with Binary constraints	Sangram Bana, R.P. Saini [12]	2017	Accuracy is achieved irrespective of temperature variation	One diode model is used which is not effective in partial shading effect
Enhanced leader particle swarm optimisation	A. Rezaee Jordehi [13]	2018	Premature convergence problem of PSO is mitigated 2. results are better than CPSO, GA, ABC, BSA, PS	NA
Flower Pollination Algorithm	F. Alam, D.A. Yousri, M.B. Eteiba [14]	2015	NA	NA
multi-verse optimizer is used	E.E. Ali, M.A. El-Hameed, A.A. El-Fergany, M.M. El-Arini [15]	2016	Five parameters of PVT module are optimised	Not tested on multi diode model
parameter extraction using numerical method using approximate analytical solution	Manish Kumar, Arun Kumar [16]	2017	Tested on five parameter single diode and seven parameter double diode model	Single diode model can't perform well as two diode model
Double diode model using gauss siedal method	K. Et-torabi, I. Nassar-eddine, A. Obbadi, Y. Errami, R. Rmaily, S. Sahnoun, A. El fajri, M. Agunaou [17]	2017	Tested on multicrystalline PV module	Multi models are tested but old analytical solution is used
Fireworks algorithm	T. Sudhakar Babu, J. Prasanth Ram, K. Sangeetha, Antonino Laudani, N. Rajasekar [18]	2016	Used double diode model with seven unknown parameters to be optimised	Computational complexity is reduced by not optimizing three parameters
Hybrid solution using analytical method with differential evolution	Vun Jack Chin, Zainal Salam, Kashif Ishaque [19]	2016	Tested on two diode model and gives superior performance for varying irradiation and temperature	Method is not hybrid however two methods are used-one for 4 parameters and other for rest 2 parameters
Bird mating optimisation approach	Alireza Askarzadeh, Leandro dos Santos Coelho [20]	2015	Original BMO algorithm is simplified to avoid the parameter setting in BMO.	Fails to cope up with lower temperature changes

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