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A Review in Application of Particle Swarm Optimization in Photovoltaic System

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Abstract

Solar energy is abundantly available and environmentally beneficial, which has led to a rise in the acceptance of solar energy for the generation of power. The availability of solar power varies despite the fact that it appears to be a desirable source of energy due to a variety of reasons, including changes in temperature, shadow, and irradiance. Therefore, in recent years, research has focused on how to get the most power possible from solar photovoltaic (PV) systems utilizing the Maximum Power Point Tracking (MPPT) method. Without using excessive amounts of arithmetic, bioinspired algorithms shown good qualities for handling non-linear, non-differentiable, and stochastic optimization problems. This work evaluates a variety of applications using the Particle Swarm Optimization (PSO) method, a global metaheuristic optimization technique. The results of literature review highlighted the most important features of this algorithm and the most important fields of its application in the photovoltaic system especially the MPPT optimization of control system. Metaheuristics have established themselves as effective methods for handling challenging optimization issues throughout the past three decades.

Keywords: Photovoltaic System (PV), DC/DC converters, Maximum Power Point Tracking (MPPT), Particle Swarm Optimization (PSO).

1. Introduction

Around the past several decades, research on renewable energy sources—each with their own benefits and drawbacks—has been a popular issue for scientists all over the world. The cost-benefit ratio of renewable energy is comparable to that of coal and gas, in particular. With the growing problem of global warming and other environmental issues, the photovoltaic power production industry is the world's high-tech industry with the quickest growth rate among the aforementioned alternative energy sources **[1][2] .**

In our daily lives, the goal of optimization is to improve in a particular area. In the field of computational intelligence, optimization can be broadly defined as the process of identifying a parameter in a function that can improve a given solution among all feasible solutions, with the best value being referred to as the optimum solution **[3][4]**.

Metaheuristic, especially bio-inspired optimization techniques have obtained great attention in recent years and are popular global optimization techniques due to their durability, simplicity, and effectiveness in solving challenging optimization issues, also try to replicate social behavior or natural occurrences **[4][5]**.

Particle swarm optimization (PSO) is a global and a stochastic optimization algorithm, population-based evolutionary algorithm (EA) search method. It was proposed by Eberhart and Kennedy in 1995. It has great advantages in multiple peak curve optimization problem for optimizing hard numerical functions on metaphor of social behavior of flocks of birds and schools of fish. Where it has been used across a wide range of implement MPPT control and other applications **[3] [6].** In Ref**. [3]** the PSO algorithm is applied to the MPPT control algorithm in two different PV structure. The objective of Ref. **[7]** is to develop new variable size of the PSO algorithm for the PV systems to improve the speed and accuracy of MPPT control algorithm. The authors of **[8]** presented a modified Particle Swarm Optimization technique with an effective duty cycle initialization for Maximum Power Point Tracking.

The Literature survey show that PSO and all modified-based PSO algorithms are powerful and important in photovoltaic system and anther applications for solving the optimization problems.

Gaing, Z. L., [9] Proposed a novel design method for determining a proportional- integral -derivative (PID) controller for an AVR system that uses the particle swarm optimization (PSO) technique to find the optimal PID controller parameters. The PSO technique is used in the suggested way to determine the best PID controller settings for an AVR system rapidly. And has better qualities including simple implementation, consistent convergence characteristics, and strong computing efficiency. High-quality solutions are produced quickly by tuning the PID controller's optimal parameters. An additional new time-domain performance criterion function was established to aid in assessing the performance of the proposed PSO-PID controller. The proposed technique was in fact more effective and reliable in enhancing an AVR system's step responsiveness than the genetic algorithm (GA).

Li, X. Z., et al., [10] Created PID controller online self-tuning framework using the particle swarm optimization technique. MATLAB is used to model the system using the particle swarm optimization technique. Experiment focuses on several application-related issues. The results include that various fitness functions might result in varying time responses and that application systems should initialize each particle's range as narrowly as feasible. The results also state that they should select a modest generation rather than a bigger one for the online system with linearly inertia weight consumption less times evolutionary generation. These findings can primarily benefit application systems that deal with computation costs.

Wang, Y. B., et al, [11] Have been improved the functionality of digital PID auto-tuning controllers built on the PSO algorithm. The suggested approach splits the search into two phases. Particle parameter K_d is first constrained in a small space and then expanded to a bigger one. The results show that the technique significantly enhances PID controller performance. In their project on auto-tuning of PID controllers, they first predict the general PID controller parameters by relay feedback experiment before using an upgraded particle swarm optimization technique to get the optimum solution. They use the two-step assigned search space of K_d , which first allocates the search area in a narrow range and then in an extended one, to avoid particles from trapping into the local optimum.

Fu, Q., & Tong, N. [12] Proposed an algorithm for particle swarm optimization based on complex method, a namely CPSO. The Complex method is used to quickly locate the local optimal point after the group of particles has crossed the local optimum area, which may significantly enhance the performance of local search. The PSO is used to execute global search at the beginning of the evolution. In order to escape the local optimum and improve population variety while resolving the issue of premature convergence, the CPSO additionally employs the mutation inertia weight. The usefulness and efficiency of this novel algorithm are shown in the testing results when it comes to the solar system's maximum power point tracking (MPPT).

Cheng, Z., et al., [13] Have been applied in two various PV structures, the PSO algorithm to the MPPT control algorithm. The building of the PV array's multi-peak model under partially shadowed conditions is the basis of the multi-peak MPPT algorithm. Modular structure is given as a means of introducing the distributed MPPT algorithm. Using MATLAB, the efficacy of the method and the benefits and drawbacks of two distinct algorithms are investigated. Although there is not much of a difference in the two algorithms' responses, they will both become slightly slower as the number of dimensions' rises. These two algorithms are better at tracking in environments where there are mutations. The outcomes of the studies demonstrate the MPPT system's efficacy and precision.

Liu, Y., et al., [7] Developed the variable size of particle swarm optimization (PSO) technique to measure the real maximum power point (MPP) in a photovoltaic (PV) system when there is just partial shading, further to enhance MPPT's performance and precision. With each iteration, the method gradually reduces the particle movement step after increasing it initially. MATLAB is used to simulate the MPPT control algorithm. According to the simulation findings The MPPT control algorithm calculates the global maximum power value to be 61.5887 W. Additionally, it has a very quick convergence rate with a 0.082 second optimization time. The outcomes validate the MPPT optimization algorithm's claimed accuracy.

Rahimian, M., & Raahemifar, K. [14] Used Particle Swarm Optimization Algorithm in order to obtain a high order automatic voltage regulator (AVR) by designed the optimum PID controller parameters. The suggested method, which features a newly defined time-domain cost function, is relatively simple to implement, exhibits consistent convergence, and allows for quick tuning of the optimum PID controller parameters with a low iteration rate. In order for the controlled system to provide the appropriate step response output, three optimal controller parameters ,K_p , $K_i$and K_d, are determined using the PSO algorithm. To judge the effectiveness of the PSO-PID controller, the results are contrasted to those of the genetic algorithm (GA). The comparison shows that the PSO-PID method is more dependable and successful in improving an AVR system's step responsiveness.

Ishaque, K., & Salam, Z. [6] Proposed a deterministic particle swarm optimization (DPSO) method to track the maximum power point of a photovoltaic system when there is just partial shading. The key concept is to eliminate randomness from the accelerations element of the standard PSO velocity equation. Additionally, the maximum velocity change is constrained to a certain value, which is chosen after carefully examining the P-V characteristics under partial shade. One benefit of the approach is that it produces a consistent solution even with little particles. (2) There is just one parameter that has to be tuned, the inertia weight, and (3) The MPPT structure is significantly more straightforward than the traditional PSO. The algorithm is applied to a buck-boost converter and contrasted with the traditional hill climbing (HC) MPPT approach in order to assess the concept. According to simulation findings, the suggested technique surpasses the HC method in terms of global peak (GP) tracking speed and accuracy in a range of partial shading situations. Additionally, a tropical overcast day's measured data from the swift movement of the passing clouds and the partial shadowing are used to evaluate it.

Liu, Y. H., et al., [15] For centralized-type PGS working under PSC, a particle swarm optimization (PSO)-based MPPT method was proposed. To satisfy the practical consideration of PGS functioning under PSC, the conventional version of PSO is updated. The suggested approach boasts benefits including simplicity, great tracking effectiveness and system independence. To demonstrate the efficacy of the suggested technology and to confirm its accuracy, simulation and experimental data for a 500-W PGS will also be supplied. In-depth descriptions and explanations are provided for the issue formulation, design process, and parameter setting approach that take hardware restriction into consideration. The suggested technique can attain the GMPP in less than 27 iterations, and the averaged tracking efficiency is better than 99.9%, according to simulation results of 1000 test cases.

Yadav, A. K., et al., [16] Introduced an innovative approach of control system for boosted type dc-dc power converters in which the gain variables of the PID controller are adjusted by two paralleled DC/DC converters with closed-loop PWM, and the outcomes are compared and simulated to provide constant output voltage. Utilizing the Particle Swarm Optimization Algorithm, the best feedback PID controller values are found (PSOA). The goals of the optimization issue are to reduce the steady state inaccuracy, rippling, rising time and settling time of the boost converter's output voltage corresponding to step changes in input voltage and load. When designing a PID controller with transient performance specifications (T-PID) for an underdamped system, results from PSOA-based and T-PID designs are compared. The performance index for various error criteria for the proposed controller adjusted with the PID controller with transient performance specification (T-PID) technique is demonstrated to be lower.

Sahin, E., et al., [17] Controlled a PV system's DC/DC boost power converter via designing of a fractional-order PID (FOPID) controller. To get the optimal system performance, the parameters of the proposed controller are modified using the Particle Swarm Optimization (PSO) technique. By altering the sunlight and a load resistor levels, the FOPID and conventional PID system responses are examined under varied power situations. The simulation outcomes are compared using the integral of time weighted squared error (ITSE) criteria, percentage overshoot (M_p) and rising time (T_r). The controllers' performance statistics demonstrate that the FOPID controller has a better system responsiveness than the traditional PID controller. When employing the fractional-order PID controller, it is possible to achieve fewer percentage overshoot values and ITSE criteria. While both controllers have a relatively low steady-state error and the same rising time.

Babu, T. S., et al., [8] Given a modified Particle Swarm Optimization method with a successful duty cycle initialization for Maximum Power Point Tracking. The capacity to measure the global peak power correctly when environmental conditions vary with nearly no steady state oscillations, quicker dynamic reaction, and simple implementation are some of this method's significant advantages. Since the convergence of PSO and MPSO methods depends on proper selection of parameters to reach the best possible solution. Utilizing hardware set up for scenarios involving both uniform and partial shade, the suggested strategy was evaluated together for Hill Climbing and Incremental Conductance.

Yunliang, W., & Nan, B., [3] Used the improved PSO algorithm to implement MPPT control of the shaded photovoltaic in two different PV structure and build simulation model. The multi-peak MPPT algorithm has been developed. based on constructing a multi-peak pattern of the solar panels in a partially-shadowed environment. Through the inclusion of modular constructing, the distributed MPPT method is introduced. Using MATLAB, two separate algorithms' advantages and drawbacks are compared, as well as the algorithm's efficacy. The technique is capable of tracking the global maximum power point and successfully avoiding the local maximum. The tracking of the global maximum power point moves quickly and steadily. It has a certain value in that it helps the system operate more effectively.

Mirbagheri, S. Z., et al., [18] Proposed a combination of two commonly - maximum tracker for power point (MPPT) methods regarding an independent PV system. A variable step size (VSS) incremental conductance (IncCond) MPPT re-initializes a Particle Swarm Optimization (PSO)-based approach to find the exact position of the MPP. Eliminating output ripple and reducing tracking time in rapidly varying insolation conditions are the main motivating forces behind this (RCIC). By using MATLAB/SIMULINK, the suggested method's functionality is assessed. The benefit of the suggested approach over the (IncCond) approach is that the Solar outcomes are much more precise and have significantly lower ripple-plotting. When compared to the PSO-based technique, the suggested method significantly reduces tracking time. The output voltage and current oscillate much less than before around the working region.

Jordehi, A. R., [19] Developed a thorough and up-to-date review of MPPT techniques. The present MPPT tactics are divided into two groups, and the strategies within each category are examined. Some recommendations for further study are made in light of the review that was done. The author firmly feels that this study will benefit engineers and researchers working on PV systems, and he offers some suggestions for further research in this area. The results of this research show that the best candidates for MPPT are metaheuristic optimization algorithms because of benefits like system independence, efficient performance under partial shading situations, and the lack of oscillations around maximum power point.

Mistry, K., et al., [20] Proposed the evolutionary particle swarm optimization (PSO)- based on feature optimization method for face emotion identification. To create a discriminative initial face representation, the system initially uses modified local binary patterns, which compare pixels in the vicinity both horizontally and vertically. Then, a PSO variation dubbed mGA-embedded PSO is suggested to carry out feature optimization. The experimental findings show that the suggested scheme significantly performs various state-of-the-art PSO variations, traditional PSO, basic GA, and other relevant face recognition models published in the literature. This is the result of a thorough analysis employing within- and cross-domain photos from the expanded Cohn Kanade and MMI benchmark datasets, respectively.

Sabarish, P., et al., [21] Presented the maximum power point tracking (MPPT) approach to raise the photovoltaic (PV) system's output voltage. A PV system's maximum power can be obtained by using a PI controller with particle swarm optimization. The method can be easily built using low-cost microcontrollers, and it has a quicker tracking velocity, displays zero oscillations at the MPP, and can identify the MPP for all environmental variables. These are only a few benefits of utilizing this control method. In order to reduce response time and get eliminated of steady state error, the PI controller is utilized. MATLAB/SIMULINK was used to model the PV system with an intelligent MPPT. The full PV system is simulated, and the simulation's findings are confirmed. The boost converter elevates the solar panel's output voltage to the maximum power point voltage once the maximum power point tracker locates the MPP, enhancing the panel's efficiency.

In this research, the applications of the PSO algorithm in different fields, especially in the field of solar energy and MPPT were presented, and the best literature review about it were highlighted.

2. PV system

With the growth of the economy in recent years, there has been an increase in the need for energy, as well as a rise in environmental and energy-related concerns among the populace. People's requirements cannot yet be met by conventional energy. Solar energy is recyclable, renewable, and has some uses in particular industries. The solar photovoltaic (PV) system's output power is intermittent in nature, has a non-linear output voltage, and changes in temperature and irradiance at its maximum power point (MPP) **[7] [22]**.

A photovoltaic system is a set of parts intended to provide useful electricity for a range of applications **[23]**. Typical PV system includes: 1) a solar silicon cell, and a solar photovoltaic module is created if numerous are joined in series. where each cell produces a relatively modest voltage (approx. 0.7V under open circuit condition). There can be up to 36 solar cells in a standard module, 2) maximum power point tracking, 3) control unit, 4) DC/DC converter (and/or inverter), 5) the load (or batteries) **[24] [25] [26]**.

3. DC/DC converter

As an interface between the solar panel and the load, DC/DC switching power converters are frequently employed in photovoltaic producing systems. Which considered the only way to get a tracking of maximum power point from PV Modules **[27]**. Consequently, a better feasible control mechanism is necessary to handle the fluctuation in output voltage of the DC/DC converter caused by the variation happening in the external dynamical input parameters such as light, temperatures, and inner photovoltaic (PV) module impedance.

These dynamic, nonlinear systems are the DC/DC converters. High frequency switching, power components like MOSFETs and diodes, and passive parts like inductors and capacitors are the major causes of the nonlinearity. In order to handle their inherent nonlinearity, and a broad change in input voltage and load, it is necessary to develop an effective control approach for these DC/DC converters. and provide constancy under all functional conditions whilst also focusing on attaining a quick transient response **[16] [28]**.

4. Maximum Power Point Tracking (MPPT)

Photovoltaic system output power has a nonlinear characteristic because its affected by circumstances change, and this lead to diminution in efficiency of a PV system, this might result to a 25% energy loss, thus, to ensure that the PV module is operating at its Maximum Power Point (MPP) and to enhance a PV system's efficiency, Maximum Power Point Tracking (MPPT) management must be carried out **[7] [29]**.

It's a difficult challenge to solve to track the maximum power point in PV systems, which is a crucial task. where the DC-DC converter's duty cycle is changed to harvest the most power possible from the PV system. The following characteristics are necessary for an effective MPPT approach **[19]**:

- It should be highly accurate and able to ascertain the actual global maximum power point (MPP). A PV system with a precise MPPT mechanism is more efficient.
- High tracking speed is required. PV system efficiency suffers due to slow tracking speed, which lowers the amount of electricity harvested.
- should be able to function well in both uniform insolation and partial shade environments. Finding the real global peak power in situations of partial shadow is difficult since the P-V curve has several local optima.
- It must be system-independent, meaning it must function well with various PV systems.
- Not too much complexity is ideal. The virtue of simplicity.
- It shouldn't fluctuate towards the moment of maximum power.
- It should be able to reliably track the maximum power point even when the environment changes dramatically.

5. Implementation Particle Swarm Optimization (PSO) in Photovoltaic System

PSO is the most popular metaheuristic optimization algorithm. It has N_P particles in D-dimensional search space with position coordinate is represents X_i $(i = 1,2,3,\dots N_P)$, and velocity coordinate is denoted by $V_i(i = 1,2,3,\dots N_P)$ where every particle travels in this space gradually. The best position which found by each particle i and i has passed in the movement is referred to as a personal best P_i and P_{best} its equivalent objective value, also, a best position that whole particles have gone in the movement is called global best P_g and its related objective value is indicated by G_{best}. All particle movements are updated after each iteration to calculation the next velocities and positions via equations (1&2)

which are called update or flight equations **[7][8] [13] [19]**:

$$V_i(j+1) = W * V_i(j) + rand\,() * C_1(P_i - X_i) + rand\,() * C_2 * (P_g - X_i) \quad (1)$$

$$X_i(j+1) = X_i(j) + V_i(j+1) \quad (2)$$

Where j is the number of iteration in evolution process,, $X_i(j)$ and $V_i(j)$ represent the position and velocity of the variable i at iteration j, respectively, W is an inertia weight factor, rand () are random variables with values between [0,1], the cognitive acceleration coefficient C_1 ,encourages the attraction of the particle to its own personal best, the social acceleration coefficient C_2, encourages the attraction of the particle to the global best.
Following is a depiction of the optimization process using PSO **[9] [11]**:
1. Create a population of particles in the issue space with random locations and velocities on D-dimensions.
2. Analyze the required optimization fitness function in D variables for each particle.
3. Evaluate the particle's fitness and compare it to its P_{best} . Set P_{best} to the current value and P_i to the current position X_i in D-dimensional space if the current value is superior to P_{best} .
4. Find the neighborhood particle with the best performance so far, and give the particle, P_{best} its index.
5. Modify the particle's location and speed in accordance with Equation (1) and (2).
6. Repeat step 2 until a certain criterion is satisfied, often a sufficient level of fitness or a predetermined number of rounds.

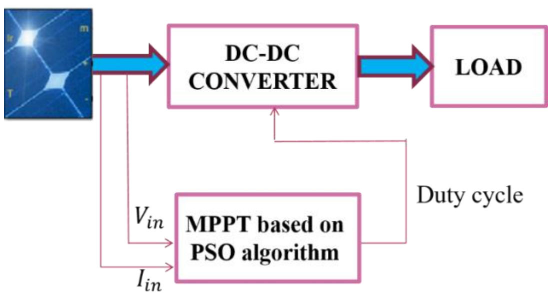

Fig.1 Schematic Diagram of Photovoltaic System

The PSO method is applied to realize the MPPT controller by adjusting the duty cycle power switching of converter. The role of the MPPT is to ensure the operation of the PV system at its MPP. Finally, extracting the maximum available power from the PV module as shown in Fig.1.

Conclusions

In solar systems, identifying the peak power point is a crucial task and a difficult challenge. The duty cycle of the DC-DC converter is changed in maximum power point tracking (MPPT) systems in order to extract the most power possible. The optimization is approach to finding the better solution among all the possible solutions. In this paper, the most popular metaheuristic optimization algorithm is known as Particle Swarm Optimization technique is reviewed in different applications. Where the effectiveness and efficiency of this technique has been proven in problems optimization treatment. The results of survey highlighted the most important features of this algorithm and the most important fields of its application in the photovoltaic system in general and the optimization of the control system in particular. Also had been demonstrated the implementation of this technique in PV through depiction of the optimization process using PSO in many points.

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