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MAXIMUM POWER-POINT TRACKING OF A PHOTOVOLTAIC SYSTEM USING HYBRID COMBINATION OF GA-PSO ALGORITHM AND PID CONTROLLER

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Abstract - Maximum power point tracking (MPPT) techniques are considered a crucial part in photovoltaic system design to maximise the output power of a photovoltaic array. PID controllers are deployed in the photovoltaic system to track the maximum power point. The performance of the PID controller is influence by controlling parameters. In this paper, we have calculated the optimal parameter values of PID controller using the hybrid combination of GA-PSO algorithm. The proposed method Simulink is designed in MATLAB. After that, various parameters such as settling time, rise time, overshoot, peak time, undershoot, rotor speed, and power generated. The results show that the proposed method provides lower undershoot and settling time as compared to the existing method.
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Keywords - Genetic Algorithm, MPPT, Particle Swarm Optimization, Photovoltaic System, PID Controller.

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1.Introduction

The benefits of photovoltaic (PV) energy include minimal maintenance, clean energy, ease of installation, environmental safety, and the lack of fuel costs. Furthermore, the high capital expenditures and poor efficiency of the conversion process. PV systems, though, are still constrained by high initial costs and poor conversion efficiency [1–3]. Photovoltaic technology for the generation of electric power from solar energy is showing the most fast expansion of any renewable resource, compared to other forms of renewable energy. Over the last 15 years, solar power plant capacity factor has grown by an average of 40% each year, as per the latest study from the Joint Research Center (JRC). All investment plans in renewable energy sources in 2016 accounted for 55 percent of all new investments in solar energy (113.7 billion US$). Using PV energy means dealing with nonlinear power–voltage properties that are influenced by solar irradiation and temperature. This may be a substantial hurdle to overcome. Because of this, MPPT is needed to enhance energy conversions by providing the greatest power to the load from Photovoltaic modules. Several well-known methods have been applied to MPPT techniques. For example, constant voltage [8], incremental inductance [10], P&O [9], hill climbing [11], ripple correlation control [13], frictional short-circuit current [12], and sliding control [14]. Under normal irradiance, these approaches respond well; under partial shade, they fall short of tracking the GMPP. A cloud, the shadow of neighbouring trees and buildings, or any other partial shadowing condition (PSC) is common while PV solar cells are really in operation. Solar panels' P–V characteristics are affected by the presence of several local peaks (LPs) under PSC, making it difficult to determine the solar panels' global maximum power point (GMPP). In solar station controllers, all standard techniques of searching for the MPPT are not dependable in monitoring the GMPP of the P–V characteristic, leading to greater losses and reduced PV power plant dependability [15].

The main contribution of this research is to determine the optimal parameter values of PID controller. To achieve this goal, two optimizations are taken under consideration such as GA and PSO. GA algorithm is deployed in PSO algorithm to update the position of the particles [4-6]. The simulation evaluation is done using various parameters. The results show that the presented technique shows lower undershoot and settling time as compared with other method.

The remaining paper is as follows. Section 2 shows the related work is done in MPPT of a photovoltaic system. Section 3 explains the preliminaries are required in the proposed method. Detailed description of the presented method is shown in Section 4. Section 5 shows the simulation evaluation of the presented technique [7,9]. In the last, in section 6, conclusion and future scope is drawn.

2.Related Work

In this section, we have studied the existing methods are proposed for maximum power-point tracing of a photovoltaic system.

Pathak et al. [16], In this research, a WFDC motor drive is used to demonstrate an N-DPID controller’s use in MPP tracking. The presented MPPT controllers are optimized using GA and PSO algorithms. PID and N-DPID controllers are also used to compare these methods. Large waves, settling times, and oscillations all around MPP are generated by P&O and IC MPPT approaches. When optimizing PID and N-DPID controller settings using GA and PSO algorithms, it was discovered that PSO-optimized controllers had the lowest fitness value of the two. When it comes to minimizing the objective function, PSO outperforms GA. Another conclusion is that the PSO optimised controllers have less undershoot, ripple, and settling time than the GA optimised controllers. Moreover, With its PSO adjusted N-DPID MPPT mechanism, the WFDC motor can easily monitor its MPP and reach its rated rotor speed while operating in rapidly changing environmental circumstances.

Ahmad et al. [17],Maximizing PV system efficiency requires monitoring the maximum power point (MPPT) of each module. The P&O method is among the most extensively used strategies. Optimal controller settings for P&O MPPT are provided via tuning strategies based on the cuckoo search (CS) and genetic algorithm (GA). As a result of the large range of system characteristics and nonlinearity, it is difficult to optimize controllers using standard tuning approaches to achieve high performance in P&O MPPT applications for PV systems There are problems with the conventional P&O MPPT, such as oscillations around MPP and slow convergence speed, that may occur while operating in rapidly changing atmospheric circumstances. Algorithms' capacity to follow the MPP in the face of rapidly changing meteorological circumstances is shown by their ability to cope with shifting insolation levels. To test the effectiveness of the suggested optimum tuning techniques, a 1 kW PV system was constructed and tested using a dSPACE DS1103 controller board and an E4360 Keysight modular solar array simulator. Modeling and analytical system findings closely match the observed results. Experimentation and modelling findings show that both the transient and steady-state performances, together with the MPT efficiency, have improved significantly since the beginning of development. 99.95% and 94.02 % are steady-state and transient efficiency, respectively, which are nearly 17.59 percent and 10.61 percent, respectively, better than the conventional P&O one and 14.66 percent and 1.52 percent, respectively. It is possible to improve any controller's performance by using these recommended optimum tuning methods, as well.

Hariz et al. [18],Incremental demand for electrical energy and the resulting increase in environmental problems are the main reasons forcing managers in the energy sector to expand the use of renewable energy sources in the production of electricity. In the future, the use of renewable energy systems will be increased and will play a very important role in the economic indices of power systems. The hybrid energy systems use two or more renewable energy sources, to increase the reliability and profitability of the installation. This article proposes a new application of the proportional-integral-derivative (PID) controller based on genetic algorithms and the P&O method to effectively reach the MPPT of solar panel. To evaluate the performance and profitability of the proposed methodology, a comparison study of this method with the classical P&O approach was carried out.

Yasukawa et al. [19],In a switching power converter using solar input, this work investigates a multi-objective issue in the control system for monitoring the maximum power point. For maximum output from input, switching power converters have their duty ratios optimized by the control system. PSO is used to choose two important parameters for the control system. Input power efficiency and control system convergence speed are the two primary goals of the objective issue. There are two different objection functions that characterise the issue. To better understand the trade-off between the two, an evolutionary algorithm may be used. The findings may be used to develop smart city renewable energy supply systems that are efficient and environmentally friendly.

Eltamaly et al. [20],P–V curves with partial shading have several peaks. All except one of these summits are located within a 100-mile radius of the global peak (GP). Metaheuristic strategies like PSO have proved to be superior to traditional techniques in acquiring the GP and preventing entrapment in an LP (local peaks). Because of this, the PSO must reinitialize when the GP moves or changes its value in the P–V curve due to partial shading circumstances (PSC). Premature convergence may occur if PSO particles are re-initialized too early in the convergence process. After PSC modifications, this work presents a unique scanning approach that doesn't need reinitialization. Any peak with more power than the current GP will be searched for by a particle sent to the expected locations of peaks, and when it locates this new GP, the PSO particles may be sent immediately to the new GP. Reinitialization times were decreased 650 percent by using this procedure instead of random reinitialization in the usual PSO method. In addition, the typical PSO technique's early convergence is fully avoided by this new method.

3. Preliminaries

In the proposed method, two optimization algorithms (GA and PSO) are hybrid. Therefore, a detailed description of these algorithms are given below. [21]

3.1 Genetic Algorithm (GA)

The evolutionary algorithm class known as Genetic Algorithms (GA) is a significant area. John Holland utilised the genetic algorithm for the first time in 1975. (Holland, 1975). An approximate solution to a problem is frequently provided by GA. As a genetic algorithm (GA), it employs a wide range of biological procedures, such as selection, recombination, mutation, and reproduction. As a result, real-coded GA is often quicker than binary GA since it does not require binary compression and decompression. The algorithm has a number of stages, including:

1) Randomly or heuristically choose a starting population.

2) Determine each individual's fitness level within the group.

3) Make each member's selection probability proportionate to its fitness value.

4) To create the next generation, choose people from the present generation to generate offspring.

5) Re-run the processes until a satisfactory solution is discovered.

6) Populations are defined by GA as a wide variety of substances and every individual particle is referred to as one of those particles. The fitness function, another name for the cost function, is used to assess the quality of these chromosomes. The initial problem's objective function is commonly the cost function. The following are among the processes that are connected to GA:

a) When it comes to selecting the chromosome that will replicate, selection is the most common method.

b) "Reproduction" is the act of passing on an organism's genetic material to future generations.

c) Genetic information is exchanged across chromosomes through a process known as crossover. A single or multi-point crossover might have been used.

d) Mutation is a single individual's chromosomes are altered by this procedure. Mutation ensures that the algorithm does not become stuck at a certain point in the process.

e) The last stage in GA is to set the stopping criterion. When the intended result is reached or the max number of iterations is reached, the iteration comes to an end.

After each cycle, GA uses a specified fitness function to produce a new set of fittest members. The Genetic Algorithm's fundamental flow chart is shown in the following image (Figure 1).

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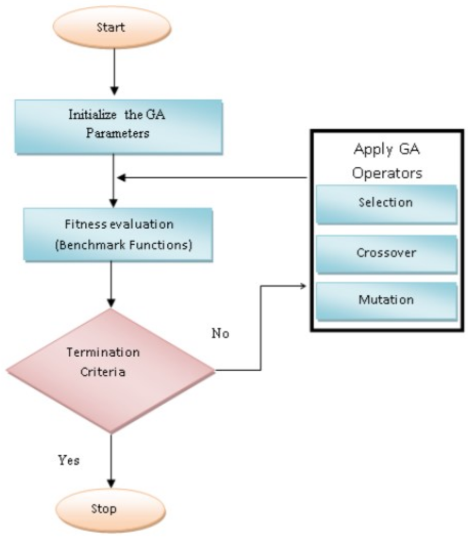

Figure 1 Flowchart of GA Algorithm

3.2 Particle Swarm Optimization (PSO)

A swarm of particles is defined by the PSO algorithm, which is a kind of evolution algorithm. According to the predetermined rules, the swarm's particles are then modified. A particle's new position is based on its former location and the particle's best-known location in its search space. Each iteration involves a new initialization of the particles with a new velocity and position so that they may progress toward their pbest and gbest targets. Weighting the acceleration coefficients with random variables increase the effectiveness of search strategy and converge to the global optimal solution. It is possible to create random data for acceleration at both pbest and gbest locations. The particles in the PSO algorithm are manipulated as per the below equations:

$$v_{id} = w * v_{id} + c_1 * rand(\quad) * (p_{id} - x_{id}) + c_2 * Rand(\quad) * (p_{gd} - x_{id}) \quad (1)$$

$$S_{id} = S_{id} + v_{id} \quad (2)$$

In above equations, c1, and c2 represents two positive constants and Rand() and rand() represents the random functions in range 0 and 1. W represents the inertia weight.

The PSO is an evolutionary algorithm that needs to generate random data in order to function properly. Both the amount and the quality of the data that are created have an impact on the efficiency of PSO algorithm. The search space is traversed in its entirety during the first iteration of the process. Figure 2 presents an overview of the PSO algorithm's fundamental use.

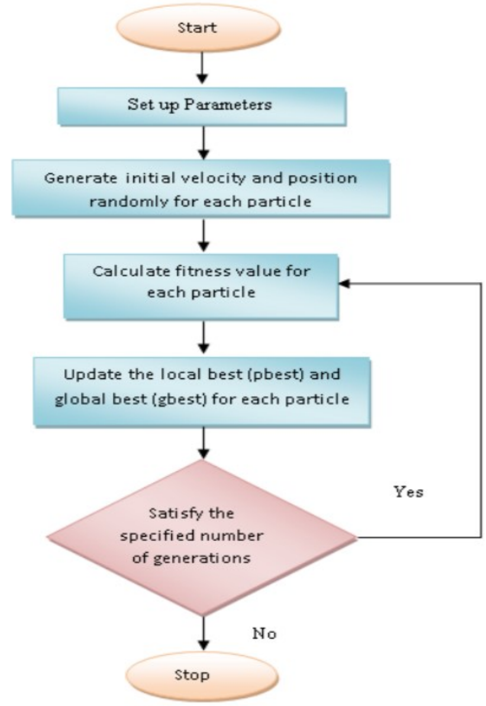

Figure 2 Flowchart of the PSO Algorithm

The following is a list of the several stages that make up the PSO algorithm:

i) Give the particles in the search space some arbitrary starting locations and velocities to get the process started.
ii) Begin the process of determining the appropriate value of the fitness value for each of the swarm particle.
iii) Determine an equation that equates the fitness value assessment with the values of the particle's pbest at the present time. If the current value is higher than pbest, the present value should be used as the new pbest value, and the pbest location should be set to the same place as the current position in n-dimensional space;
iv) After that, compare the current value of fitness to the prior all-around best. If the current value is higher than gbest, then gbest should be reset to reflect the array index and values of the currently active particle;
v) Assign those values, in the end, to the appropriate positions and velocities of the swarm particles.

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4. Proposed Method

In the proposed method, GA-PSO algorithms are hybrid to determine the optimal parameter values of the PID controller. In the proposed method, GA algorithm is deployed in the PSO algorithm to update the position of the particles. Next, how GA-PSO algorithm is deployed for maximum power tracking is explained below.

Step 1: Specify input data. Solar irradiance S, cell temperature T, shaded cell temperature Tshade, shaded cell number Nshade, and shaded cell insolation Sshade are included. Also mentioned are the OFFC silicon solar array and PSO parameters.

Step 2: Create the starting population by selecting individuals at random from their respective disciplines. The amount of current that is produced by the solar cell serves as the deciding variable in the algorithm that has been suggested.

Step 3: Perform an analysis on the fitness function of every particle: As per the equation (3), the power output of the solar panel serves as the fitness function for the algorithm that has been suggested. The power output of the shaded cells is combined to the power output of other cells in order to determine the output power under the circumstances of partial shading.

$$k(e) = \cosh(k_0 e) = \frac{\exp(k_0 e) + \exp(-k_0 e)}{2}, \quad \text{where} \quad e = \begin{cases} e & ; |e| \le e_{max} \\ e_{max}\, sgn(e) & ; |e| > e_{max} \end{cases} \tag{3}$$

Step 4: After we have determined the optimal location for each particle (Pi) as well as the ideal position for the whole system (Pg), one should use the equation (1) to update the velocity values. To update the positions, a random number generated if its probability is lesser than 0.5 then Eq. (2) is applied else GA crossover operation is applied to update the position.

Step 5: Repeat steps 3 and 4 as many times as necessary until a terminating criterion is met. The criteria for terminating that is taken into consideration in this work is the number of iterations. Moreover, the algorithm is finished running after the predetermined maximum number of iterations has been reached.

5. Simulation Evaluation

This section shows the simulation evaluation of the presented technique to validate its. The Simulink for the proposed method is designed in MATLAB. The Simulink model of the proposed work is shown in Figure 3.

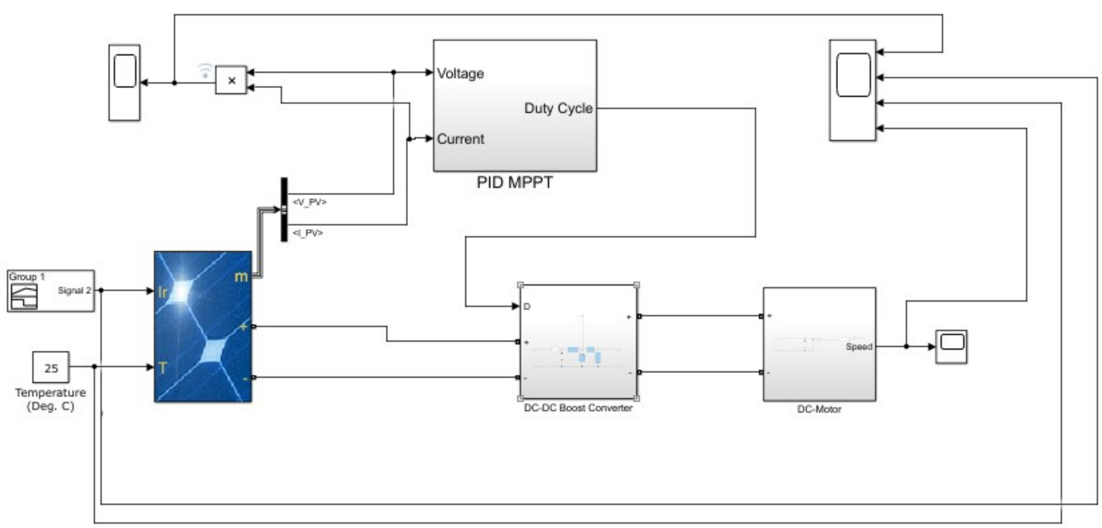

Figure 3 Simulink Model of Proposed Work

The setup configuration of the presented method is shown in Table 1.

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Table 1 Setup Configuration of the Proposed Method

Parameters	Value
Particle size	10
Iteration	50
C1	1.5
C2	2
W	0.5

Next, we have measured various performance metrics for the proposed method, as explained below.

- Settling Time: The amount of time necessary for the response curve to attain and remain within a range around the final price of size that is indicated by an absolute % of the final value is referred to as the settling time (usually 2 percent or 5 percent).
- Rise Time: The rise time is the amount of time it takes for the reaction to climb from 10% to 90%, 5% to 95%, or 0% to 100% of its ultimate value. The 0 percent to 100% rise time is often utilized for 2nd order systems that are underdamped. One frequent rise time for overdamped systems is 10% to 90%.
- Overshoot: Response curves are shown with their peaks offset by a factor of 1.0 to determine their maximum overrun value. To ensure that the response is as close to unity as possible, the maximum percent overrun is often used. An overrun in percentage reveals how stable a system is.
- Peak Time: It is the time it takes for the reaction to reach its initial peak of overshoot, which is called the peak time.

Table 2 shows the performance parameter values for the proposed method and represented in bar graph in Figure 4.

Table 2 Performance Parameters for the Proposed Method

Performance parameter	GA-PSO
Settling Time	0.0564
Rise Time	0.0318
Overshoot	0
Peak Time	0.5000
Under Shoot	0.0212

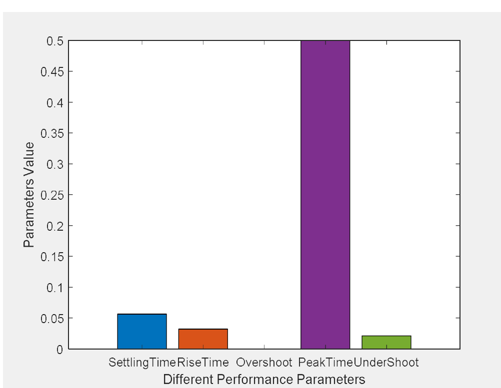

Figure 4 Different Performance Parameters for the Proposed Method

Figure 5 shows the convergence curves of the presented approach using GA-PSO. The results show that the presented approachachieves an optimal solution in the 13th iteration.

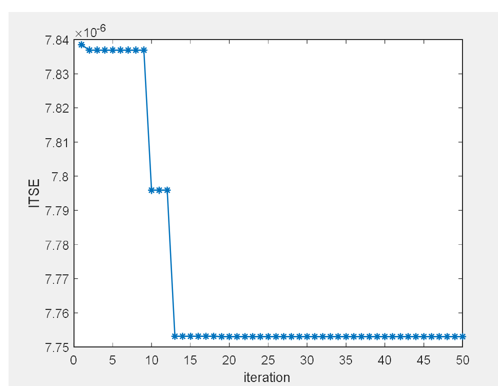

Figure 5 Convergence Curves of Proposed Method Designed using GA-PSO

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Various environmental circumstances are used to test the controllers' abilities to maintain desired performance. A controller should be able to respond quickly to changes in temperature and irradiation. Figures 6 and 7 demonstrate the irradiation and temperature profiles utilized to produce the panel power outputs using the suggested technique.

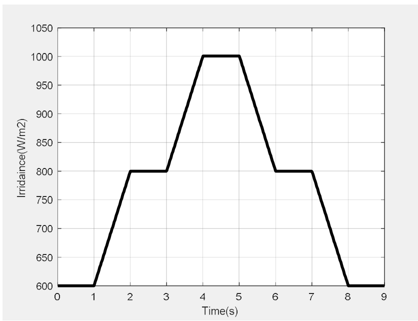

Figure 6 The Irradiation Profile used to obtain the Panel Power Responses of the Proposed Method

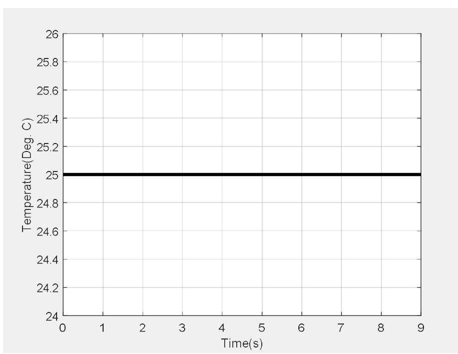

Figure 7 The temperature Profile used to obtain the Panel Power Responses of the Proposed Method

Figure 8 shows the irradiation profile for four controllers.

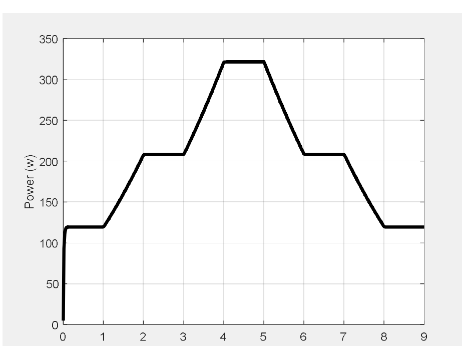

Figure 8 Power Generated by PV system in the Proposed Method

Fig. 9 shows the rotor speed response at 1000w/m^2 for the presented approach.

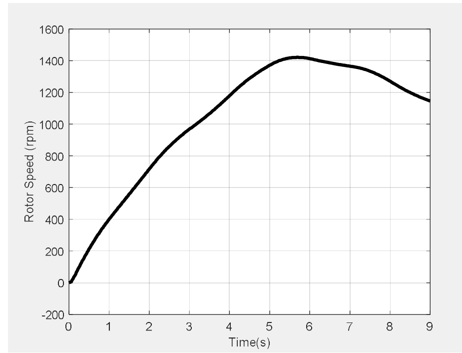

Figure 9 Rotor Speed Response at 1000W/m^2 for the presented approach

Table 3 shows the calculated controller parameters using hybrid combination of GA-PSO algorithm for the proposed method.

Table 3 Controller Parameters are Determined using Hybrid Combination of GA-PSO Algorithm in the Proposed Method

Algorithm	Kp	Ki	Kd
GA-PSO	10.8528	8.0250	0.0245

In the last, proposed method is compared with the existing method based on the undershoot and settling time in Table 4. Results represents that the presented approach as lowest undershoot and settling time as compared to the other.

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Table 4 Comparison of the presented approach with Existing Methods [16] based on Undershoot and Settling Time

Performance Index	GA-PID	PSO-PID	GA N-DPID	PSO N-DPID	GA-PSO-PID
Undershoot	0.039	0.031	0.033	0.027	0.021
Settling Time	19.7	19.69	19.79	19.59	0.056

6. Conclusion and Future Work

PID controllers are deployed in the photovoltaic system to track the maximum power point. Nevertheless, PID controller performance varies due to its parameter values. Therefore, in this paper, we have calculated the optimal parameter values of PID controller using the hybrid combination of GA-PSO algorithm. The simulation evaluation is done using various parameters. The outcomes represents that the presented approach provides lower undershoot as well as settling time as compared to the existing method.

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