INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING & APPLIED SCIENCES
ISSN: 2322-0821(O) VOLUME 10 ISSUE 2
ISSN: 2394-9910(P) Apr 2022 - June 2022
www.irjeas.org

MAXIMUM POWER TRACKING OF A SOLAR SYSTEM USING IMPROVED PARTICLE SWARM OPTIMIZATION ALGORITHM

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Abstract- For photovoltaic systems to be more efficient, maximum power point (MPP) tracking of the solar arrays is necessary. The output power of solar arrays is influenced by two factors: temperature and solar irradiation. It is also possible that a traditional MPP tracker would operate incorrectly because to the mismatch effect produced by partial shadow. There are many maximum values for the solar array power–current characteristics when it is partly shaded. For PV systems in partly shadowed conditions, this research provides an MPPT approach with enhanced particle swarm optimization algorithm.

Keywords- Chaotic Map, Particle Swarm Optimization, Renewable Energy Source, Solar System.

Manuscript Received: 22 Mar 2022, Accepted: 04 May 2022
DOI – 10.55083/irjeas.2022.v10i2004

1. INTRODUCTION

It is predicted that by the year 2050, solar energy will account for a significant portion of the world's energy needs due to its unlimited, clean supply and lack of environmental impact [1]. By 2010, it is predicted that the amount of power generated by solar-based devices would have increased by 225 times. By early 2050, solar power is predicted to contribute for between 2980 TW h/Year and 7740 TW h/Year of energy production [2]. PV systems typically include solar panels, a DC-DC converter, an MPPT controller, and interfaces to the grid and the loads they are powering. These components of the solar system must work together in order to maximize the overall performance of the system.

Recently, the solar cell's conversion efficiency was as low as 17% [3]. By 2012 the effectiveness of research photovoltaics had increased by 20%, resulting in a maximum efficiency of more than 40%. The P-V and I-V physiologies of a solar cell are usually nonlinear under certain temperature and irradiance conditions. Solar cells' output voltage and current both are affected by changes in temperature and irradiance fluctuations [5], respectively. In particular, there is a point on the P-V curve known as the Maximum Power Point (MPP), when the whole PV system is operating at its peak efficiency and producing the most power. The exact location of the MPP is unknown, hence appropriate MPPT methods are required to maintain the PV array's operating point at its MPP. Additional benefits include an improvement in system lifespan, which is due to the use of MPPT.

Genetic algorithm and particle swarm optimization algorithm are successfully deployed in the literature for tuning the controller parameters. However, the selection of the initial population in the genetic algorithm plays an important role in searching for the optimal solution. Thus, if the selected population is not good, generating a new population from it is not good. When applied to high-dimensional space, the particle swarm optimization (PSO) algorithm's shortcomings include that it is likely to fall into a local optimum and it has a poor convergence rate when used in an iterative process. This paper has overcome these issues and designed an improved particle swarm optimization algorithm that does not fall in the local optima problem and provides a better convergence rate to find the optimal solution.

The main contribution of this paper is to determine the controller gain value for the N-DPID controller. An improved particle swarm optimization algorithm is designed to achieve this goal. The improved PSO algorithm generates the initial population of gain value using the chaotic logistic map algorithm. After that, the PSO algorithm is applied to generate a new gain value. The whole process is repeated for a fixed number of iterations. The Simulink model for the proposed method is designed in MATLAB. Further, the performance analysis is done using various performance metrics such as undershoot, settling time. The result shows that the proposed is superior to the existing methods.

The rest of the paper is organized as follows. In section 2, a literature review is done to understand existing work and challenges. Section 3 explains the MPPT system. Section 4 defines the improved PSO algorithm is designed for tuning of controller parameters. Section 5 shows the simulation results of the proposed method. Conclusion and future scope are drawn in Section 6.

2. LITERATURE SURVEY

This section shows the literature survey to understand the existing methods proposed to tune the controller parameters.

Baba et al. [6],The output of photovoltaic (PV) systems has increased rapidly, although this growth is largely dependent on the conditions in which they are operated. It's difficult to get the best results most of the time. Because of this, MPPT controllers are getting plenty of attention as a key area for improving PV systems. One algorithm may be more efficient than another, while another may be more complicated than another. The development of MPPT controllers has been fast, and they may be divided into two main categories: conventional and advanced. Conventional approaches are easy, but their efficiency is limited because they cannot discriminate between local and global peaks when partial shading occurs. The usage of advanced tracking systems is growing in popularity because of their superiority in terms of performance. Hybrid approaches have emerged as a solution to the constraints of traditional and advanced methods. A study of the currently used MPPT techniques might resolve the difficulty of selecting the best one. In this work, the categorization and assessment of all MPPT approaches are summarized and evaluated. Furthermore, this study serves as an easy-to-use guide for future MPPT research projects.

Abdelrassoul et al. [7],The improved efficiency of solar cells and the development of solar panel manufacturing technologies have resulted in a dramatic rise in the deployment of photovoltaic (PV) power producers in recent decades. Photovoltaic systems are modelled and operated in this study, with a focus on constructing a PID controller to regulate the system. A genetic algorithm (GA) is used to fine-tune the controller's variables, resulting in the greatest possible effectiveness for the intended PV system. It is possible to achieve a maximum overshoot and rising time of 0.1 percent and 0.175 seconds when using GA.

Pathak et al. [8],Here, a smart non-linear discrete proportionally integral and derivative control system is used to monitor the maximum power point tracking (MPPT) of a photovoltaic system (PV). Traditional PID controller qualities are retained in this N-DPID MPPT technique, which uses the Forward Euler formula to discretize integral and derivative terms, and changes its integral gain during the simulation period in response to error. It is difficult for N-DPID controllers to determine the value of controller gains. It is possible to discover the benefits in a dynamic situation by using smart technique that uses Particle Swarm Optimization (PSO) and Genetic Algorithms (GA). In order to keep tabs on the MPP, several optimization methods are examined for the proposed N-DPID MPPT. PV module performance study and comparison are offered for a commonly available PV module, the SunPower SPR-305E-WHT D. In addition, the efficiency of a WFDC motor powered by a photovoltaic array is evaluated for smooth functioning. It is then compared with the results of MPPT and WFDC motor operation for P&O, IC and the various approaches of PSO-N-PID, PSO-PID, and PSO-N-PIDMPPT techniques.

Arora et al. [9],There has been an increase in the demand for electricity, which has prompted an increase in the investment in renewable energy sources. As a result of this, the power quality of the grid is affected by renewable energy sources such as wind and PV, which are very variable in nature. As a result, it is necessary for the power system to maintain a balance between supply and demand. It is necessary to employ PID controllers in order to enhance stability. However, they are controllers with a set gain. Artificial Intelligence (AI) is the only way to solve this problem. The hybrid renewable energy technology with grid-connected wind, photovoltaics (PV), and fuel cells is

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described in this study. Using the Particle Swarm Optimization approach, the system's variables are fine-tuned using the PID controller. Improved system stability is achieved by this improvement. For improved performance under varying loading situations, MATLAB is used for modelling and simulations.

3. MPPT SYSTEM

In this section, the main components are explained to understand the MPPT system. The block diagram of the MPPT system is shown in Figure 1.

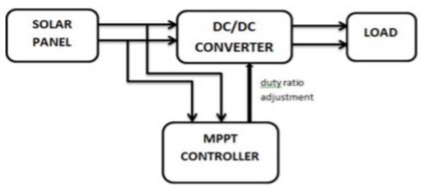

Figure 1 Block Diagram of Maximum Power Point Tracking (MPPT) System

Next, the detailed description of main components is given below [10].

3.1 Solar Panel: The solar panel is used to convert sun light into electricity energy.

3.2 DC/DC Converter: As a connection between the solar panel and the load, DC/DC converters are often employed in photovoltaic producing systems. To get the most power from the solar panel, one'll need to match the load's voltage and current to the panel's. In order to find the greatest power point, the converter has to be able to connect directly to a solar panel and complete the necessary operations. Avoiding these losses is possible due to the usage of DC/DC converters and MPPT (maximum power point tracking systems).

3.3 MPPT Controller:MPPT controller is control the maximum power point in the MPPT system to avoid the losses and generate maximum energy.

4. TUNING OF CONTROLLER PARAMETERS USING IMPROVED PSO ALGORITHM

In this paper, an improved particle swarm optimization (PSO) algorithm is designed for tuning controller parameters. The chaotic map and PSO algorithm are hybrid to overcome PSO challenges such as low convergence rate and local optima problem in the improved PSO algorithm. A detailed description of the chaotic logistic map algorithm and PSO is given below.

4.1 Chaotic Logistic Map Algorithm

To avoid local optimum, swarm algorithms employ the chaos theory [11]. Deterministic nonlinear dynamical systems, such as chaos systems, undergo deterministic transitions with each iteration of their dynamics. Logistic maps are non-linear systems with quadratic nonlinearity in one dimension. The logistic map is given by the function $f : [0,1] \rightarrow \Re$ defined by

$$f(x) = \mu x(1 - x) \quad (1)$$

which is expressed in state equation form as

$$x_{n+1} = f(x_n) = \mu x_n(1 - x_n) n = 0,1,2 \ldots ..(2)$$

In Eq. (2), $x_n$is the state of the system at time n and its value varies between (0, 1). On the other side, μ is the control parameter and its values varies between 0 to 4.

4.2 Particle Swarm Optimization

It is an evolutionary approach that relies on a population of individuals. In 1995, Kennedy and Eberhart first suggested the PSO. It was influenced by the way birds and fish gather in large groups. Under partly shaded conditions, PSO can discover the global peak and hence determines the solar array MPP [12]. Using group mobility and intelligence, PSO is among the strongest optimization methods. As in birds, a group of particles are employed to form a group and move about in search space to discover the optimum answer. This approach was influenced by this behaviour. An adaptive velocity is applied to each particle in PSO based on its own flying experience as well as the flying experience of other particles. When running PSO, every particle seeks to surpass its succeeding neighbors by adopting attributes from those who have gone before it. In addition, because each particle has a memory, it can recall the best position in the search space it has ever visited. Each particle in the PSO technique is a potential solution to the optimization issue. Particles are given two vectors, one for their location and one for their velocity. The particles are updated according to the following equations:

$$v_{id} = w \times v_{id} + c_1 \times r_1 \times (p_{id} - x_{id}) + c_2 \times r_2 \times (p_{gd} - x_{id}) \quad \ldots\ldots.(3)$$

$$x_{id} = x_{id} + v_{id} \quad \ldots..(4)$$

Here i = 1, 2, …, N, N represents the size of swarm, and D represents the total number of dimensionfor every particle. When a particle's former velocity has an effect on its present

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velocity, it is said to have inertia weight (or w). The range of r1 and r2 is determined by two independent random variables with uniform distributions (0,1). The acceleration coefficients are c1 and c2. A linearly decreasing inertia weight, as shown in Eq. (5), is utilized to update the inertia weight as follows.

$$w^k = w_{max} - ((w_{max} - w_{min}) \times k)/k_{max}(5)$$

where k represents the iteration number and kmaxrepresents the maximum number of iterations

Next, how improved PSO algorithm is deployed for maximum power tracking is explained below.

Step 1: Define the input data: Solar irradiance S, cell temperature T, and the number of shaded cells Nshade as well as their temperature (Tshade) and insolation (Sshade) are determined in this stage. The properties of an OFFC silicon solar array as well as PSO parameters are also established in this step.

Step 2: Create a random sample of the population from each domain. The output current of the solar cell is used as a decision variable in the suggested method.

Step 3: For each particle, fitness function is evaluated in next step.The suggested algorithm's fitness function is the solar array's output power as calculated by Eq (7). In partial shading situations, the output power of the shaded cells is summed by the output power of the other cells to get the total output power.

Step 4: Update the velocities and locations of each particle (Pi) and the global optimal position (Pg) using Eqs (10) and (11).

Step 5: Steps 3 and 4 should be repeated until a condition for termination is met. The terminating criteria is the number of iterations in this study. Additionally, if the maximum number of iterations is met, the algorithm is terminated.

5. SIMULATION EVALUATION

A Simulink model of the proposed method is designed in MATLAB with DC motor as load, as shown in Figure 2.

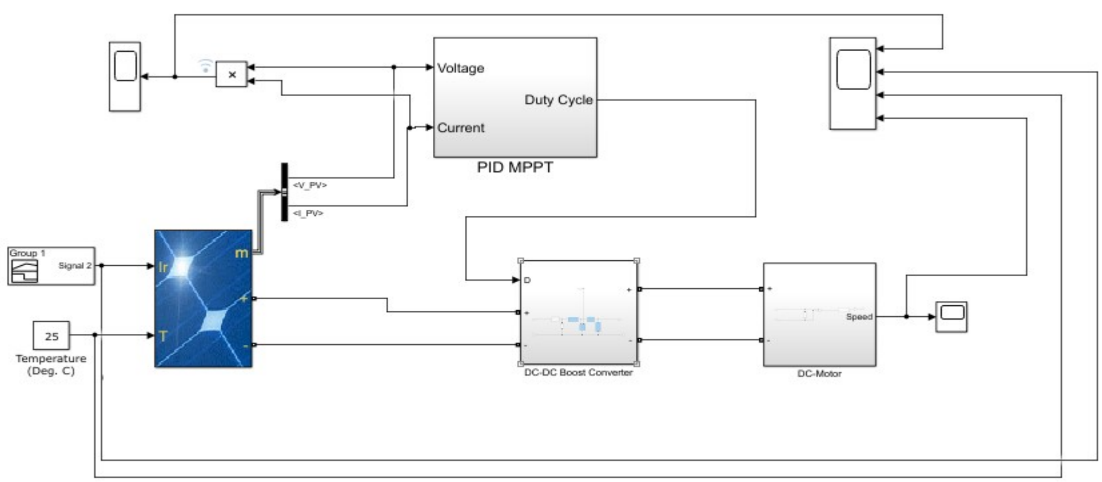

Figure 2 Simulink Model of proposed Method

5.1 Performance Metrics

In this section, the performance metrics are explained that are calculated for the proposed method [13].

- Settling Time:Time necessary for response curve to achieve and remain within range of final size indicated in absolute percentages of the final value is known as "settling time" (usually 2 percent or 5 percent). As the system's biggest time constant, the settling time is proportional to it. The percentage error criteria to apply may be selected based on the system design's goals.
- Rise Time:The rise time is the amount of time it takes for a reaction to climb from 10% to 90%, 5% to 95%, or 0% to 100% of its ultimate value, respectively. The 0 percent to 100% rise time is often utilised for second order systems that are underdamped. The 10% to 90% rise period is widely employed for overdamped systems.

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- Overshoot:Response curves are shown with their peaks offset by a factor of 1.0 to determine their maximum overrun value. It is usual to utilise the highest percent overrun if the actual steady-state response value departs from unity. System stability may be measured by looking at the highest overshoot (in percent).
- Peak Time:The peak time is the amount of time it takes for a reaction to reach the initial overshoot peak.

5.2 Simulation Setup

This section defines the simulation setup and performance parameters for the improved PSO algorithm in Tables 1 and 2. Figure 3 shows the performance parameter for the proposed method.

Table 1 Initial Parameters for the Proposed Method

Improved PSO Parameter	Improved PSO
Particle size	10
Iteration	50
C1	1.5
C2	2
W	0.5

Table 2 Performance Parameter for Proposed Method (Improved PSO)

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

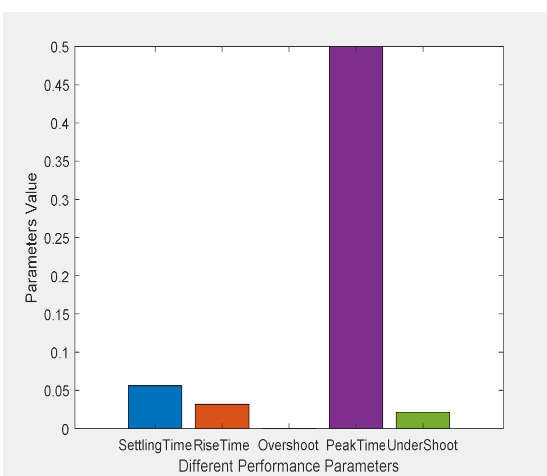

Figure 3 Performance Parameter

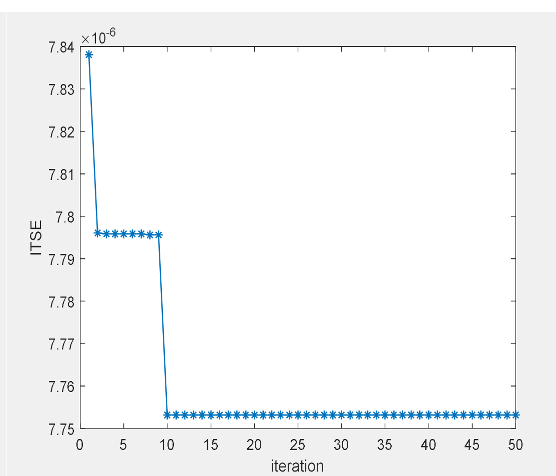

Figure4 Convergence Curves of Proposed Method

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5.3 Simulation Results

The simulation results of the proposed method is shown in this section. Table 3 shows that the controller parameters (Kp, Ki, and Kd) are determined for the proposed method.

Table 3 Controller Parameters determined using the Proposed Method

Algorithm	Kp	Ki	Kd
Proposed Method (CHAOS-PSO)	19.1421	6.0903	0.3752

Further, Figure 5 shows the convergence rate graph of the proposed method to determine the optimal controller parameter. The graph is plotted between ITSE vs. iterations. The result shows that the proposed method searches for the optimal result in the 10th iteration. Next, the temperature Profile, generated power, and rotor speed for the PV system are shown in Figures 6-8.

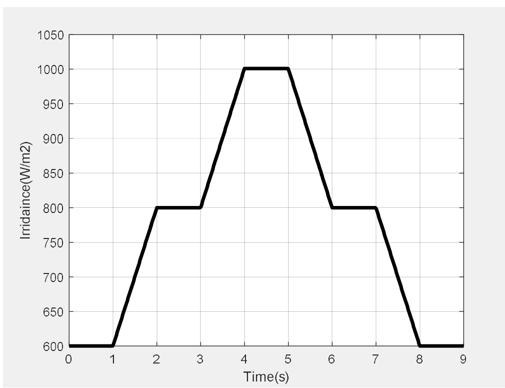

Figure 5 The Irradiation Profile used to obtain the

Panel Power Responses of the MPPT Method.

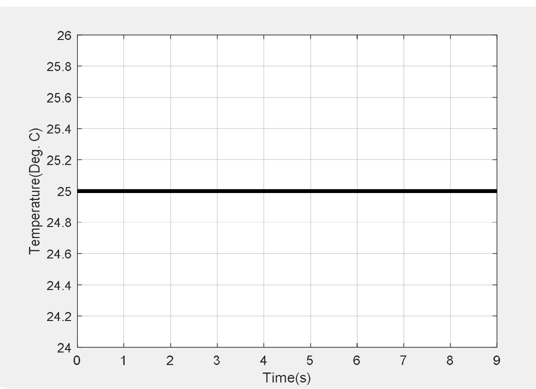

Figure 6 The Temperature Profile used to obtain the Panel Power Responses of MPPT Method

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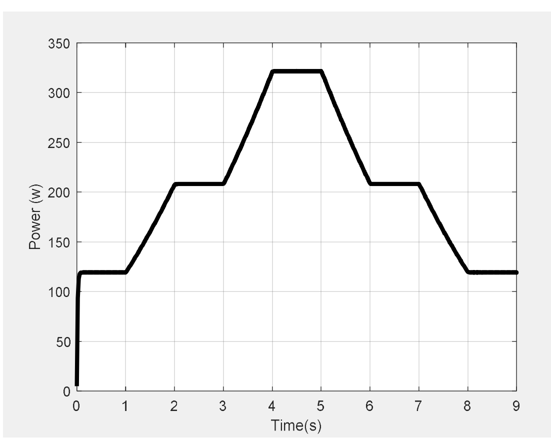

Figure 7Power Generated by PV System

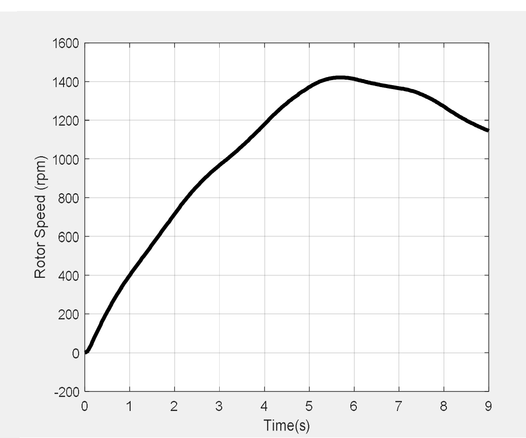

Figure 8 Rotor Speed Response at 1000 W/m2 for Different MPPT Methods

Table 4 shows the comparative analysis of the proposed method with the existing method based on two parameters known as undershoot and settling time. The results show that the proposed method achieves lesser undershoot and settling time over the existing methods [8].

Table 4 Comparative Analysis of the Proposed Method with the Existing Methods

Performance Index	GA-PID	PSO-PID	GA N-DPID	PSO N-DPID	Proposed Method (Improved 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

In this paper, optimal controller tuning parameters are determined using an improved PSO algorithm for maximum power point tracking for the solar system. In the improved PSO algorithm, the chaotic map and PSO algorithm are hybrid to overcome the local optima problem and enhance the convergence rate. A Simulink model is designed for the proposed method in MATLAB, and various performance metrics are calculated for it. Based on the findings, it seems that the new technique is better to the ones now in use.In the future, we will explore fuzzy and ANFIS algorithm for track the MPPT in the solar system.

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DOI – 10.55083/irjeas.2022.v10i2004

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