İSTANBUL UNIVERSITY
CERRAHPAŞA

ORIGINAL ARTICLE
Electrica 2022; 22(3): 403-409

Photovoltaic Power Generation Systems and Applications Using Particle Swarm optimization Algorithms

Jian Wang[1], Kai Wei[1], Mohd Dilshad Ansari[2], Mohammed Saleh Al. Ansari[3], Amit Verma[4]

[1]Marketing Service Center, State Grid Gansu Electric Power Company, Lanzhou, China
[2]Department of Computer Science and Engineering, CMR College of Engineering & Technology, Hyderabad, India
[3]Department of Chemical Engineering, College of Engineering, University of Bahrain, Kingdom of Bahrain
[4]Department of CSE, University Centre for Research & Development, Chandigarh University, Mohali, India

Cite this article as: J. Wang, K. Wei, M. Dilshad Ansari, M. Saleh Al. Ansari and A. Verma, "Photovoltaic power generation systems and applications using particle swarm optimization algorithms," *Electrica*, 22(3), 403-409, 2022.

ABSTRACT

In order to alleviate the great harm caused by traditional fossil energy to the natural environment, photovoltaic power generation has become a good choice for human available resources. In this article, the photovoltaic array is used as the object of research, and the maximum power point tracking (MPPT) control algorithm of the photovoltaic array is used as the main research line. The photovoltaic array simulation model was simulated using the MATLAB/SIMULINK software to simulate the output characteristics. The following results were obtained. When the illumination intensity is fixed, the particle swarm optimization (POS) algorithm reaches the end condition after 0.015 s, stops the iteration, the photovoltaic array reaches the maximum power point, and the maximum power value found is 10.704 W, which is less than 1 W from the theoretical power value 10 W, with an error of 0.64%; this shows that the MPPT management approach based on the optimization algorithm has a positive effect. In the event of an immediate change in light, the particle optimization algorithm is re-optimized, with an optimization time of only 0.004 s, that is, it reaches the maximum power point and runs stably. This requires approximately 97% less time than the shock observation method and about 75% less time than the method required to increase the variable transmission, and the power curve is an almost smooth straight line. This shows that the PSO algorithm is able to quickly and accurately control the maximum power point in the event of a sudden change in lighting. The method optimized in this article is superior to the method of observing shocks in the case of stable lighting and sudden changes in light intensity also array and relatively high performance as well as high practical value.
Index Terms—Maximum power point tracking, particle swarm optimization, photovoltaic array, photovoltaic power generation.

I. INTRODUCTION

Increased use of greenhouse gases has led to a number of problems, including resource overheating and environmental pollution. Solar energy is attracting worldwide attention for its unlimited use of renewable energy. Photovoltaic power generation is a new generation promise of new energy in the world and is being developed rapidly [1,2]. In this article, the photovoltaic power generation system is taken as the object of research, and the maximum power point tracking (MPPT) control algorithm of the photovoltaic array is taken as the main research line. First, the development status of the photovoltaic industry, trends, and research status of MPPT algorithm for photovoltaic power generation system were introduced, and second, the structure and classification of photovoltaic system were introduced, and the working principle, classification, and mathematical photovoltaic cell model were analyzed. The photovoltaic array simulation model is established by the Matlab/Simulink software to simulate the output characteristics. Then, the MPPT control algorithms of several photovoltaic power generation systems are deeply analyzed and studied. Aiming at the shortcomings of conventional MPPT algorithm such as simple implementation, strong reliability, and high stability but poor control accuracy and poor response to environmental changes such as climate change, the MPPT control of the photovoltaic power generation system suggests the use of the particle swarm optimization (PSO) algorithm. The particle herd optimization algorithm has a powerful global search capability and high optimization accuracy. The design method and steps of PSO algorithm are introduced. The disturbance observation method, variable step conductance increment method, and PSO algorithm are simulated by simulation software [3,4]. Fig. 1 is a technical diagram of the method of controlling the maximum power of a photovoltaic power generation system based on a particle algorithm.

Corresponding author:
Mohd Dilshad Ansari

E-mail:
m.dilshadcse@gmail.com

Received: May 28, 2022

Accepted: July 13, 2022

Publication Date: September 26, 2022

DOI: 10.5152/electrica.2022.22086

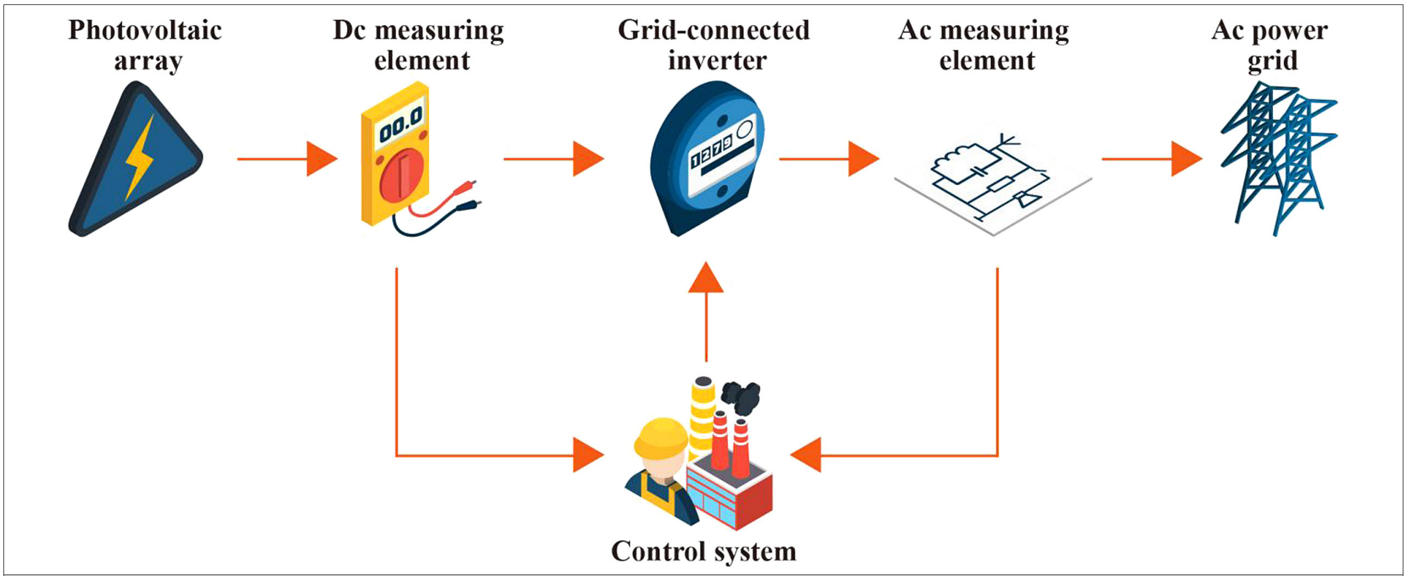

Fig. 1. Maximum power tracking method and technology of photovoltaic power generation system based on particle swarm optimization algorithm.

II. LITERATURE REVIEW

Develop the economy and keep pace with population growth, the contradiction between traditional petrochemical energy and economy and environment is becoming more and more prominent, and the resources of primary energy such as coal and oil are becoming increasingly scarce. The limitation of primary energy and uneven regional distribution led to the imbalance of energy supply in most countries around the world, which has increasingly become the bottleneck of sustainable economic development [5]. According to the comparison of proved reserves of some primary energy between the world and China, China is a country with relatively poor primary energy. At present, China's energy situation is "rich in coal, less gas and poor in oil." At the current rate of exploitation of petrochemical energy, the coal reserves can be exploited for 70 years, the proved reserves of natural gas can be exploited for 33 years, while the proved reserves of oil for only 10 years [6]. In addition, the most worrying thing is that petrochemical energy will seriously pollute the human living environment in the process of consumption and use, and will also cause great damage to the environment in the process of mining and transportation [7]. As an endlessly usable, clean, pollution-free, widely distributed kind of energy, it has a wide range of development prospects and enormous development potential [8].

As a huge energy resource, solar energy has great utilization potential. The energy emitted by the sun can reach the land surface with only one-tenth of the radiant energy within the scope of the earth. If it can be fully utilized, this energy is about tens of thousands of times of the current global energy consumption in a year [9]. The former is limited in application due to its relatively complex technology and only used for relatively large capacity, so there are few practical applications at present. Photovoltaic power generation has many advantages, such as being inexhaustible, inexhaustible, and pollution-free. It has become a hot spot for human beings to seek new energy. Photovoltaic power generation has the following series of advantages:

(1) The maintenance is convenient, and the conversion links are the least and the most direct: photons are directly converted into electrons. There is no conversion of thermal energy or mechanical energy, and there is no mechanical movement. The form of power generation is very simple. And in theory, high electric conversion efficiency can be obtained.
(2) Infinity and wide geographical distribution: solar energy is inexhaustible and inexhaustible and can be used indefinitely. Where the sun shines, there is solar energy.
(3) Clean and pollution-free: the solar light generates photoelectric effect by irradiating the photovoltaic array and is directly converted into electric energy without combustion and emission, so as to achieve real green power generation [10].

From the point of view of electricity consumption, photovoltaic systems can be divided into two types: stand-alone and grid-connected, which is not limited to restricted areas and does not require additional electrical equipment, is a future improvement [11]. At present, compared with the advanced technology of international large enterprises, there are still some gaps in China's photovoltaic power generation technology. Therefore, our primary task is to develop relevant technologies with self-intellectual property rights and realize their industrialization [12].

Since the 1990s, some industrial developed countries have built photovoltaic power stations ranging from 100 kilowatt to megawatt. In the 20th century, the world's photovoltaic industry has developed rapidly, mainly in two aspects: the continuous improvement of photovoltaic cell conversion efficiency and the increasing attention of countries around the world to photovoltaic power generation, especially the photovoltaic roof plan formulated by various countries, showing the infinite bright future of photovoltaic power generation [13].

1) Germany first implemented the "1000 roof plan" with financial support from the government in 1990 and then expanded to "2000 house project plan." By 1997, more than 10000 grid connected residential photovoltaic roof systems have been

successfully built and 33 MW photovoltaic modules have been installed. In 1998, the German government put forward the "100 000 roof plan," which has been implemented since January 1999, and the total installed capacity of photovoltaic modules has reached 300 MW. According to statistics, about 320 MW photovoltaic power generation facilities were installed in Germany in August 2012, becoming the first country in the world to reach this level [14].

2) According to the statistics released by the Italian national electricity authority and the European Photovoltaic Industry Association, as of 2008, the cumulative installed capacity of photovoltaic power generation in Italy was only 710 MW. The photovoltaic industry, which is popular in Europe, has not produced much attraction in Italy. However, in 2009, Italy's photovoltaic industry developed rapidly, with a cumulative photovoltaic installed capacity of more than 1.14 GW; solar power generation also increased from 190 GWh in 2008 to 670 GWh. By July 2011, it reached 9 GW, which has completely broken through the previously established total photovoltaic installed capacity, and achieved the development goal of 8 GW by 2020, becoming the second largest solar photovoltaic market in Europe, second only to Germany. However, the Italian government was not satisfied with such achievements and put forward the breakthrough photovoltaic development goal of realizing the total installed capacity of 23G W by 2016 [15].
3) The Japanese government has carried out the "Asahi 7-year plan" since January 1994, with a total installed capacity of 185 MW. In 1997, the "70000 roof plan" was formulated and implemented, and the total installation of photovoltaic modules was 280 MW. The development goal set by the Japanese government is that the total installation of photovoltaic modules will reach 4.7 GW by 2010. In 2012, the installed capacity of photovoltaic in Japan was 1.398 GW; of which, civil photovoltaic systems accounted for 1.027 GW and non-civil photovoltaic systems accounted for only 371 MW. An analysis report on Japan's solar energy industry shows that Japan's cumulative total photovoltaic installed capacity reached 7.6 GW by the end of 2012, ranking among the top three in the world, second only to Germany and Italy [16].

III. RESEARCH METHODS

A. Maximum Power Point Tracking

Solar cells are the most important link in a photovoltaic power generation system. In order to improve the power generation capacity of the whole system, it is necessary to make the energy conversion of the solar cell to increase the energy output, provide point voltage, for example, photovoltaic. Maximum Power Point Tracking is called MPPT (Maximum Power Point Tracking) [17]. In a conventional linear system shown in Fig. 2, the maximum power of the load can be obtained only by properly adjusting the load. In other words, the maximum power of the load can be obtained when the load is also equal to the internal resistance of the power supply system [18].

In Fig. 2, U_i is the power supply voltage, R_i is the internal resistance of the power supply, and R_0 is the load resistance, so the power consumed by the load is given in (1):

$$P_{R_0} = iR_0^2 = \left(\frac{U_i}{R_i + R_0}\right)^2 R_0 \tag{1}$$

In the above formula, U_i and R_i are constants. By deriving R_0, (2) can be obtained:

$$\frac{dP_{R_0}}{dR_0} = U_i^2 \times \frac{R_i - R_0}{\left(R_i + R_0\right)^3} \tag{2}$$

When $\frac{dP_{R_0}}{dR_0} = 0$, $R_i = R_0$, P is the largest.

If the internal resistance of the power supply system remains unchanged, the maximum output power can be obtained by this method of measuring the internal and external resistances. In photovoltaic power generation, the internal energy of solar energy is affected by light consumption and temperature, which are constantly changing and have a negative effect. However, in a short time, it can be regarded as a linear circuit. Therefore, the principle of MPPT control in the photovoltaic array is essentially impedance matching [19].

B. Particle Swarm Optimization

Particle optimization is a powerful tool for function optimization. Its advantages include:

1) Particle swarm optimization algorithm is simple, without crossover and mutation operations. It only depends on the speed of particles to complete the search, and the convergence speed is fast [20]. Especially after introducing inertia weight, setting

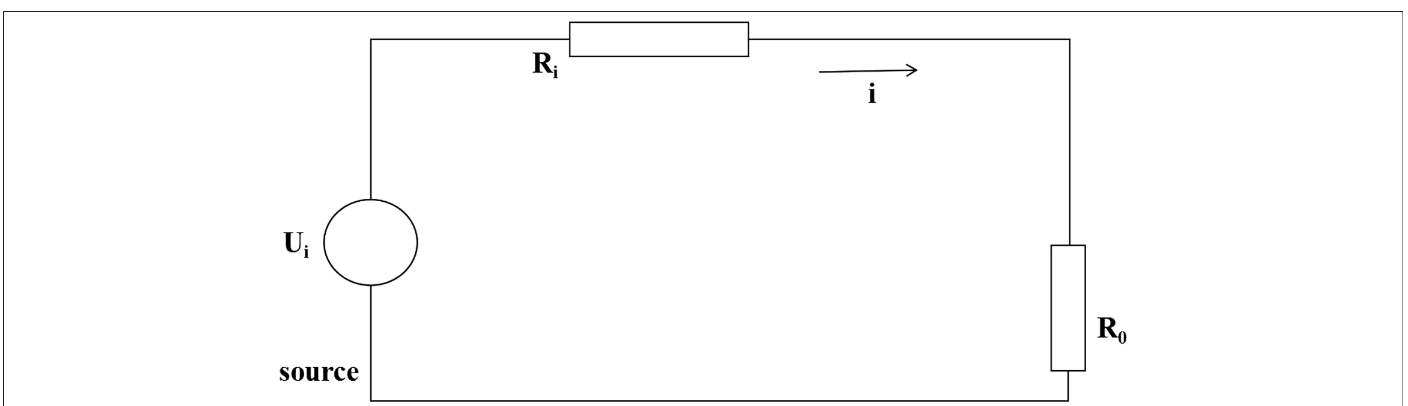

Fig. 2. Schematic diagram of linear circuit.

parameters according to experience can speed up the convergence speed of the algorithm.
2) Particle swarm optimization algorithm adopts real number coding, which can be solved directly in the problem domain, with less parameters to be set, convenient and simple adjustment, and easy engineering implementation.
3) Compared with classical optimization algorithms, the PSO algorithm has strong advantages in solving nonlinear continuous optimization problems.
4) Another important feature of PSO algorithm is that each particle has memory, and the neighborhood operator can not destroy the searched better solution [21,22,23].

Firstly, initialize a group of random particles, each particle has two attributes of velocity and position, and then iterate to search for the optimal value. In the iterative process, the particle compares with two optimal values to update its speed and position. The first optimal value is the optimal value searched by the particle itself at present, which is called the individual optimal value, abbreviated as P_{best}. Suppose there is a one-dimensional search space, a population of particles, which is recorded as formula (3):

$$X_i = \left(x_{i1}, x_{i2}, \cdots, x_{id}\right) \tag{3}$$

The "flying" velocity of the third particle is also shown as a one-dimensional vector, denoted by equation (4):

$$V_i = \left(v_{i1}, v_{i2}, \cdots, v_{id}\right) \tag{4}$$

The individual optimal value found from the ith particle to the current time is recorded as equation (5):

$$P_{\text{best}} = \left(p_{i1}, p_{i2}, \cdots, p_{id}\right) \tag{5}$$

The global optimal value found by the whole population to the current time is recorded as equation (6):

$$G_{\text{best}} = \left(p_{g1}, p_{g2}, \cdots, p_{gd}\right) \tag{6}$$

After searching these two extreme values, particles update their velocities and positions according to (7) and (8). Assuming that the search space is one dimension, the renewal equation of the i-th particle velocity v_i^{k+1} and position x_i^{k+1} in the k+1-th iteration is as follows:

$$v_i^{k+1} = wv_i^k + c_1 r_1 \left(P_i^k - x_i^k\right) + c_2 r_2 \left(G_i^k - x_i^k\right) \tag{7}$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \tag{8}$$

P_i and G_i have the following definitions, namely formula (9) (10):

$$P_i = \begin{cases} P_i, f\left(X_i\right) \geq f\left(P_i\right) \\ X_i, f\left(X_i\right) < f\left(P_i\right) \end{cases} \tag{9}$$

$$G_i = max\left\{f\left(P_0\right), f\left(P_1\right), \cdots, f\left(P_N\right)\right\} \tag{10}$$

When $v_i > V_{max}$, take $v_i = V_{max}$; When $v_i < V_{max}$, take $v_i = V_{max}$.

w: inertia weight; k: number of iterations.

IV. RESULT ANALYSIS

A. Simulation Results

1) Fixed Light Intensity

Set the constant light intensity as 1000 W/m^2 and the constant temperature as 25°C. Figures 3-5 show the output power of the photovoltaic array of disturbance observation method, variable step conductance increment method, and PSO algorithm, respectively [24]. From Fig. 3, we can see that the observed shock is near the maximum energy after 0.25 s, and it is true that the energy output of the array fluctuates on both sides of the height maximum power point when the power output is stable. Figure 4 shows the output curve using a differential phase transmission method. The output power value is 109.446 W, which is less than 1 W from the theoretical maximum power 110 W. It shows that the variable step conductance increment method has good accuracy, takes 0.018 s, and has good rapidity.

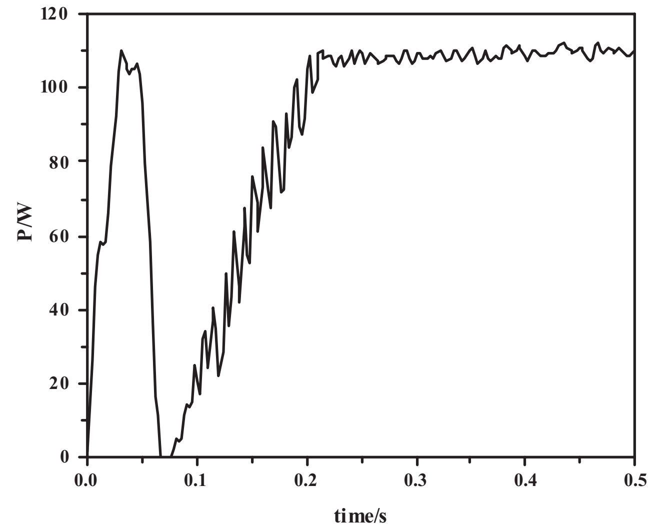

Fig. 3. Output power of disturbance observation method.

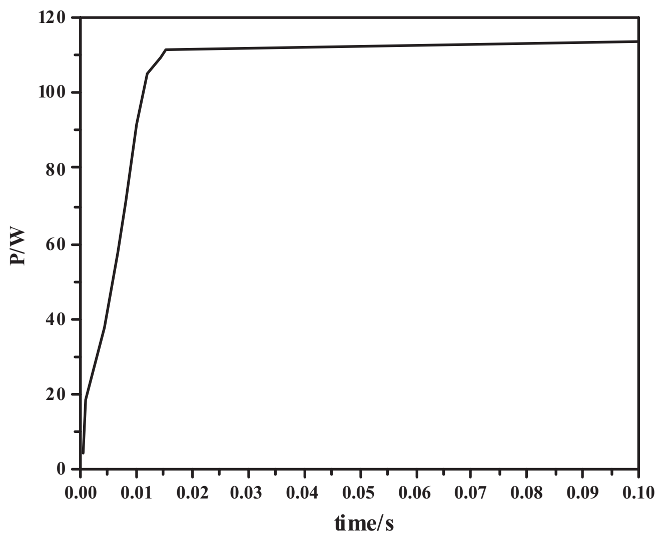

Fig. 4. Output power of variable step conductance increment method.

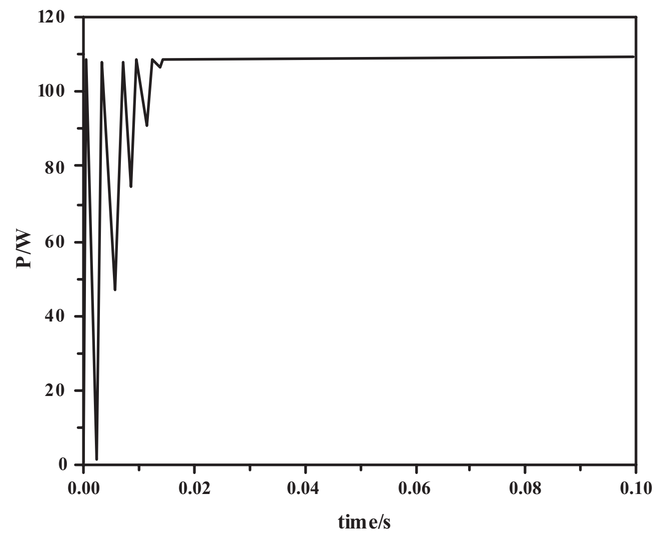

Fig. 5. Output power of particle swarm optimization algorithm.

Fig. 5 shows the output power curve of photovoltaic array controlled by MPPT based on PSO algorithm. The change of corresponding output power is shown in the figure. The optimization starts to iterate. At 0.015 s, the algorithm reaches the end condition, stops the iteration, and the photovoltaic array reaches the maximum power point. The maximum power value found is 10.704 W, which is less than 1 W from the theoretical power value 10 W, with an error of 0.64%. It shows that the MPPT control method based on PSO algorithm has good accuracy. The optimization time of the algorithm is 0.01 5s, which is the same as the variable step conductance increment method and much faster than the disturbance observation method, indicating that the convergence speed of the algorithm is very fast [25,26,27].

2) Sudden Change of Light Intensity

Set the temperature as 25°C, and Figs. 6 to 8 show the output power curve of photovoltaic array using different algorithms when the light intensity changes from 100 W/m2 to 600 W/m^2. From

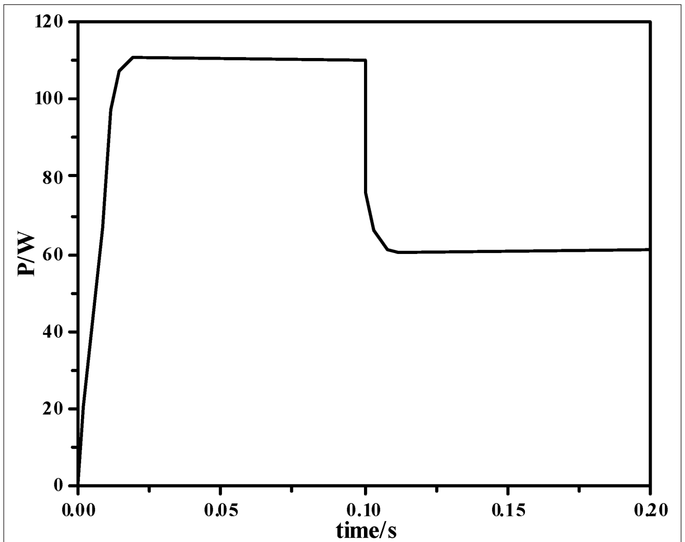

Fig. 7. Output power of variable step conductance increment method under sudden illumination change.

Fig. 6, we can see that when the light intensity changes from 0.5 s to 600W/m^2, the disturbance observation method reaches near the maximum power point (MPP) again after 0.13 s disturbance and oscillates. Although the disturbance observation method can track the MPP, oscillation near MPP will lose a certain power value and reduce the working efficiency and service life of solar panels. In Fig. 7, when the illumination changes suddenly at 0.1 s, it runs stably after 0.015 s, and the power curve is an almost smooth straight line; this suggests that the additional process of variable conversion is faster and is controlled at the maximum feed allowed.

Figure 8 shows the output power change curve corresponding to the particle optimization algorithm in the event of a sudden change in light. The light intensity suddenly changes to 600 W/m^2 in 0.1 s reached capacity. The point stability is much shorter than the time required for the fault observation method and the variable phase

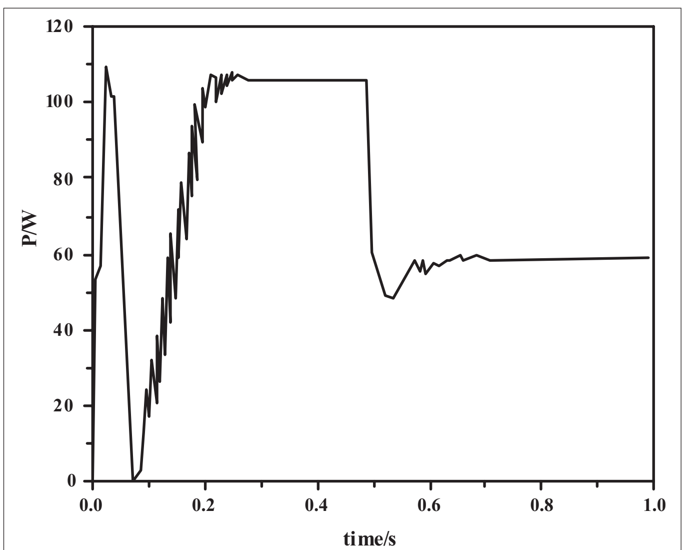

Fig. 6. Output power of disturbance observation method under sudden illumination change.

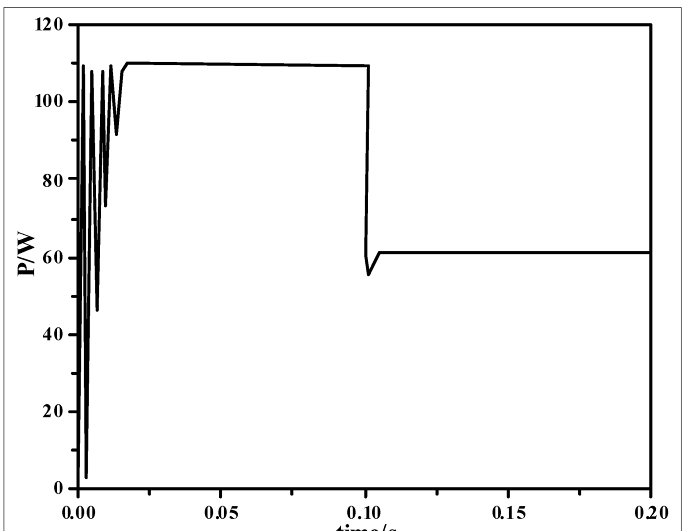

Fig. 8. output power change curve corresponding to the particle optimization algorithm in the event of a sudden change in light.

increase method, and the power curve is almost uniformly straight. This shows that the PSO algorithm is able to quickly and accurately control the maximum power point in the event of a sudden change in lighting.

V. CONCLUSION

After reading several books and analyzing the depth of the principles of maximum energy management of photovoltaic systems and the principles of optimization algorithm, this paper uses a particle optimization algorithm for MPPT to control photovoltaic power generation. The system of nonlinear characteristics of the output characteristics of photovoltaic array, it improves accuracy control and integration to maintain maximum power. By studying the characteristics of photovoltaic equipment to compare the algorithms commonly used to control the maximum power in a photovoltaic system, including monitoring failure, increase efficiency transmission, improve transmission efficiency, and their effectiveness. Although the MPPT algorithm is simple to use, it has certain downsides, such as poor precision control and a poor capacity to adapt to environmental changes, such as climate change. Maximum power point tracking control introduces the use of particle optimization algorithm. The accuracy is very high, has developed the design and steps of the particle herd optimization algorithm, and developed the simulation model of the photovoltaic generator to measure the speed and accuracy of the MPPT controlled particle optimization algorithm. It can control the power point quickly and accurately when the light changes and immediately change the light intensity.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – J.W., K.W; Design – J.W; Supervision – M.D.A; Funding – M.S.A; Materials – A.M; Data Collection and/or Processing – K.W; Analysis and/or Interpretation – J.W., K.W.; Literature Review – M.D.A., M.S.A, A.M; Writing – J.W., K.W.; Critical Review – M.S.A.

Declaration of Interests: The authors declare that they have no competing interest.

Funding: The authors declared that this study has received no financial support.

REFERENCES

1. Z. Shafiei Chafi, and H. Afrakhte, “Short-term load forecasting using neural network and particle swarm optimization (PSO) algorithm,” *Math. Probl. Eng.*, vol. 2021, pp.1–10, 2021. [CrossRef]
2. S. Nabi, and M. Ahmed, “PSO-RDAL: Particle swarm optimization-based resource-and deadline-aware dynamic load balancer for deadline constrained cloud tasks,” *J. Supercomput.*, vol. 78, no. 4, pp. 4624–4654, 2022. [CrossRef]
3. A. Jain, B. P. Nandi, Charu Gupta, and D. K. Tayal, “Senti-NSetPSO: Large-sized document-level sentiment analysis using Neutrosophic Set and particle swarm optimization,” *Soft Comput.*, vol. 24, no. 1, pp. 3–15, 2020. [CrossRef]
4. W. Ali, and S. Malebary, “Particle swarm optimization-based feature weighting for improving intelligent phishing website detection,” *IEEE Access*, vol. 8, pp. 116766–116780, 2020. [CrossRef]
5. J. Liu, D. Yang, Mengjia Lian, and M. Li, “Research on classification of intrusion detection in Internet of things network layer based on machine learning,” IEEE International Conference on Intelligence and Safety for Robotics (ISR). IEEE Publications, 2021, pp. 106–110.
6. Z. Liu, Z. Qin, P. Zhu, and H. Li, “An adaptive switchover hybrid particle swarm optimization algorithm with local search strategy for constrained optimization problems,” *Eng. Appl. Artif. Intell.*, vol. 95, p. 103771, 2020. [CrossRef]
7. F. Wu *et al.*, “Inertia and damping analysis of grid-tied photovoltaic power generation system with DC voltage droop control,” *IEEE Access*, vol. 9, pp. 38411–38418, 2021. [CrossRef]
8. H. Zeng, and Daolian Chen, “A voltage-fed single-stage multi-input inverter for hybrid wind/photovoltaic power generation system,” *J. Power Electron.*, vol. 22, no. 4, pp. 593–602, 2022. [CrossRef]
9. D. Kim, Dohyun Kwon, Laihyuk Park, Joongheon Kim, and S. Cho, “Multiscale LSTM-based deep learning for very-short-term photovoltaic power generation forecasting in smart city energy management,” *IEEE Syst. J.*, vol. 15, no. 1, pp. 346–354, 2020. [CrossRef]
10. Y. Zhuang, F. Liu, X. Zhang, Y. Huang, X. Zha, and Zhouyang Liu, “Short-circuit fault-tolerant topology for multiport cascaded DC/DC converter in photovoltaic power generation system,” *IEEE Trans. Power Electron.*, vol. 36, no. 1, pp. 549–561, 2020. [CrossRef]
11. I. S. B. Hburi, H. F. A. Kazaali, O. Bayat, and N. H. A. S. Atab, “Maximum power point tracking control for wind turbines with battery storage system,” *Telkomnika*, vol.19, no. 2, pp. 564–574, 2021. [CrossRef]
12. D. V. Samokhvalov, A. I. Jaber, and F. Sh. Almahturi, “Maximum Power Point tracking of a wind-energy conversion system by vector control of a permanent magnet synchronous generator,” *Russ. Electr. Eng.*, vol. 92, no. 3, pp. 163–168, 2021. [CrossRef]
13. T. Sutikno, A. C. Subrata, and A. Elkhateb, “Evaluation of fuzzy membership function effects for maximum Power Point tracking technique of photovoltaic system,” *IEEE Access*, vol. 9, pp. 109157–109165, 2021. [CrossRef]
14. M. Ma, Xiangjie Liu, and K. Y. Lee, “Maximum power point tracking and voltage regulation of two-stage grid-tied PV system based on model predictive control,” *Energies*, vol. 13, no. 6, p. 1304, 2020. [CrossRef]
15. C. Gu, Y. Chen, and K. Jiang, “Research on maximum power point tracking control of acoustic energy harvest system,” *AIP Adv.*, vol. 11, no. 2, p. 025031, 2021. [CrossRef]
16. P. Bharadwaj, and V. John, “Optimized global maximum Power Point tracking of photovoltaic systems based on rectangular power comparison,” *IEEE Access*, vol. 9, pp. 53602–53616, 2021. [CrossRef]
17. S. A. Ibrahim, A. Nasr, and M. A. Enany, “Maximum Power Point tracking using ANFIS for a reconfigurable PV-based battery charger under non-uniform operating conditions,” *IEEE Access*, vol. 9, pp. 114457–114467, 2021. [CrossRef]
18. L. Fu, X. Fu, and P. Yang, “Maximum Power Point tracking in solar cells with power quality preservation based on impedance matching concept for satellite electrical energy supply,” *J. New Mater. Electrochem. Syst.*, vol. 24, no. 2, pp. 111–119, 2021. [CrossRef]
19. V. Jha, and U. S. Triar, “A novel maximum power point tracking technique based on extreme value theorem for photovoltaic systems,” *Int. J. Power Electron.*, vol. 13, no. 3, pp. 354–379, 2021. [CrossRef]
20. A. J. Balbino, BdS. Nora, and T. B. Lazzarin, “An improved mechanical sensorless maximum Power Point tracking method for permanent-magnet synchronous generator-based small wind turbines systems,” *IEEE Trans. Ind. Electron.*, vol. 69, no. 5, pp. 4765–4775, 2021. [CrossRef]
21. G. Zhou, Q. Bi, Q. Tian, M. Leng, and G. Xu, “Single sensor based global maximum Power Point tracking algorithm of PV system with partial shading condition,” *IEEE Trans. Ind. Electron.*, vol. 69, no. 3, pp. 2669–2683, 2021. [CrossRef]
22. X. Zhang, D. Gamage, Benfei Wang, and A. Ukil, “Hybrid maximum power point tracking method based on iterative learning control and perturb & observe method,” *IEEE Trans. Sustain. Energy*, vol. 12, no. 1, pp. 659–670, 2020. [CrossRef]
23. L. Costanzo, M. Liu, A. L. Lo Schiavo, M. Vitelli, and L. Zuo, “Backpack energy harvesting system with maximum power point tracking capability,” *IEEE Trans. Ind. Electron.*, vol. 69, no. 1, pp. 506–516, 2021. [CrossRef]
24. K. Bavarinos, A. Dounis, and P. Kofinas, “Maximum power point tracking based on reinforcement learning using evolutionary optimization algorithms,” *Energies*, vol. 14, no. 2, p. 335, 2021. [CrossRef]
25. I. Pervez, I. Shams, S. Mekhilef, A. Sarwar, M. Tariq, and B. Alamri, “Most valuable player algorithm based maximum power point tracking for a partially shaded PV generation system,” *IEEE Trans. Sustain. Energy*, vol. 12, no. 4, pp. 1876–1890, 2021. [CrossRef]
26. S. C. Nayak, S. Das, and M. D. Ansari, “Tlbo-fln: Teaching-learning based optimization of functional link neural networks for stock closing price prediction,” *Int. J. Sens. Wirel. Commun. Control*, vol. 10, no. 4, pp. 522–532, 2020. [CrossRef]
27. S. C. Nayak, and M. D. Ansari, “Coa-honn: Cooperative optimization algorithm based higher order neural networks for stock forecasting,” *Recent Adv. Comput. Sci. Commun.*, vol. 14, no. 7, pp. 2376–2392, 2021. [CrossRef]

Jian Wang was born on October 6, 1983 and working as Deputy Senior Manager at Marketing Service Center, State Grid Gansu Electric Power Company, China. His research interest are Power Generation, Predication and Optimization Alogorithms.

Kai Wei was born on February 2, 1990 and Employed as Engineering in Marketing Service Center of State Grid Gansu Electric Power Company, China. His is doing research in Photovoltaic power generation, Prediction and Optimization Algorithms.

Dr. Mohd Dilshad Ansari is currently working as an Associate Professor in the Department of Computer Science and Engineering at CMR College of Engineering ans Technology, Hyderabad, India. His research interest includes Digital and Fuzzy Image Processing, Machine Learning, IoT and Cloud Computing.

Mohammed Saleh Al. Ansari earned his bachelor's degree in chemical engineering from King Saud University in Riyadh in 1983. In 1987, he received his MSc from the Desalination Engineering Desalination Technology-Glasgow. In 1998, he received his PHD in Corrosion and Protection Science and Engineering. He is currently employed as an Associate Professor at the University of Bahrain's College of Engineering, Department of Chemical Engineering.

Amit Verma is currently working as an Assistant Professor at Research and Development Department, Chandigarh University, Mohali. His interests are in Artificial Intelligence and Machine Learning Techniques (supervised and unsupervised), Deep learning techniques, Research and NLP/ML. He is currently working in DST Funded Project of Applications of AI in agriculture as Project Investigator.