Journal of Data Acquisition and Processing
ISSN: 1004-9037
https://sjcjycl.cn/
DOI: 10.5281/zenodo.776651

PARTICLE SWARM OPTIMIZATION-BASED MPPT TECHNIQUE UNDER PARTIAL SHADING FOR PHOTOVOLTAIC SYSTEMS

Elbar Mohamed, Korich Belkacem, Bakria Derradji, Teta Ali, Beladel Abdelkader
Faculty of Science and Technology, Applied Automation and Industrial Diagnostic Laboratory, University of Djelfa, Djelfa, Algeria.

Dourari Ahmed Lamine
ICEPS Laboratory, Department of Electrical Engineering, Djillali Liabes University Sidi Bel Abbes, Algeria

ABSTRACT

Partial shading is a common problem in photovoltaic (PV) systems, and is notoriously difficult to solve. To address this issue, multiple approaches have been made. This paper proposes the use of the metaheuristic optimization method, PARTICLE SWARM OPTIMIZATION (PSO), to track the multiple-peak P–V curve in PV systems under partial shading conditions (PSCs). The results of the PSO algorithm were found to be very fast, reliable, and precise in normal conditions, PSCs, and changes in irradiance. Furthermore, the PSO algorithm was shown to have a significant improvement in performance when compared to the perturb and observe (P&O) algorithm.

Keywords: Photovoltaic system, maximum power point tracking, partial shading condition, PSO optimization.

INTRODUCTION

In Algeria, Photovoltaic solar energy is a renewable energy source with great potential for development. Its advantages include being inexhaustible and clean, as well as providing a high level of safety when used. However, the two main issues that limit its use are the high cost of installation and the low efficiency of energy conversion, with only twenty percent of solar energy being converted into electrical energy. The rest is lost in the environment, as it cannot be converted into useful electrical energy [1].

To enhance productivity, experts have honed in on three main components: designing solar irradiance tracking systems, incorporating effective power converters, and formulating MPPT algorithms. Although the former two are only relevant to new PV systems [1], the third can be utilized in new and existing systems alike. Despite this, it remains difficult to maintain ideal efficiency when the weather is unpredictable [2].

To maximize the electrical power output of a PV system, a maximum point power tracking algorithm must be adjusted to the operating point. This is achieved by connecting the system to a load through a DC-DC converter, which is responsible for the MPPT [2]. The output of the MPPT algorithm can then be used to regulate the operating point of the PV system, by setting the reference voltage, current, or duty cycle of the PWM controller.

Under consistent irradiance, the power-voltage curve has an individual maximum power point (MPP) that fluctuates in response to temperature and irradiance changes. To find the new optimal operating points, various MPPT algorithms such as the perturbation and observation algorithm (P&O) [3], incremental conductance algorithm, and extremum-seeking control algorithm [4-5] are used.

In photovoltaic systems, the power-voltage curve can possess various maximum power points (MPPs) when exposed to partial shading. This includes one global maximum power point (GMPP) as well as a cluster of local maximum power points (LMPP) [06]. When clouds or other objects like trees, buildings, or adjacent items cast a shadow on some elements of the system, the irradiance received by these components is reduced.

Under the PSC, scientists found that the traditional MPPT algorithms had a low performance, particularly when assuming only one MPP on the P-V curve. In reality, due to their inadequate global search capability, these methods (such as the P&O method) are often stuck in LMPPs and cannot ensure convergence to the GMPP [07].

In recent years, various algorithms based on artificial intelligence and stochastic optimization have been proposed to address the shortcomings of classical MPPT algorithms [8, 9].

This paper utilizes the PSO algorithm to develop a fast, reliable, and accurate MPPT algorithm for PV systems [10-12]. The PSO algorithm is a novel and powerful approach that has been demonstrated to be successful in solving optimization problems with multiple local optimum points.

In this research paper, the performance of the proposed method is evaluated under various environmental conditions by simulating a PV system. The paper is structured as follows: Section II covers the modelling of PV model, Section III reviews P&O method and introduces the PSO algorithm, and Section IV presents the simulation results and analysis.

I. SYSTEM DESCRIPTION

Modeling of PV model

The photovoltaic (PV) cell is the main component of a system that directly generates electrical power from sunlight. This device can be represented by a single diode model due to its simple structure. This analogy can be explained as follows:

$$I = I_{pvn} - I_D - \frac{V + R_s I}{R_p}$$

where: I_{pvn} the PV current source (photocurrent), R_s the series equivalent resistance, R_p the equivalent parallel resistance, I_D the diode current, I the difference between I_{pvn} and I_D.

I_D is given below:

$$I_D = I_o \left[\exp\left(\frac{V_D}{V_t a}\right) - 1\right]$$

where: I_o the saturation current, V_t the thermal voltage, a ideality factor of diode.

$$V_t = \frac{N_s KT}{q}$$

where: K the Boltzmann's constant, q the charge of the electron, T effective cell temperature, N_s number of cells in series.

The equation of output current for a PV module is provided below [08],[13],[14]:

$$I_{PV} = N_{pp}\left\{I_{pvn} - I_o\left[\exp\left(\frac{V + R_s I}{N_{ss} V_t}\right) - 1\right]\right\} - \frac{V + R_s I}{R_p}$$

where: N_{pp} is the number of cells connected in parallel, q the charge of the electron, T effective cell temperature, N_s number of cells in series.

For this evaluation, the panel of type Kyocera KD250GX-LFB2 (as seen in Table 1) was utilized in all simulations [15]. Additionally, a DC-DC boost converter connected to a PV system was included, with parameters listed in Table 2.

Table 1. Electrical Characteristics data of PV module (Kyocera KD250GX-LFB2) in the standard conditions.

KD250GX-LFB2		
P_{mp}	250	W
V_{mp}	29.8	V
I_{mp}	8.39	A
V_{oc}	36.9	V
I_{sc}	9.09	A
P_{tol}	+5/-3	%

Table 2. Parameters Of Dc-Dc Boost Converter

Element	Value
Inductance	300 (μH)
Output Capacitor	100 (μF)
Load	100 (Ω)
Switching frequency	10 (kHz)

The P-V characteristic of the PV panel Kyocera KD250GX-LFB2, as seen in Figure.2, was obtained through simulation.

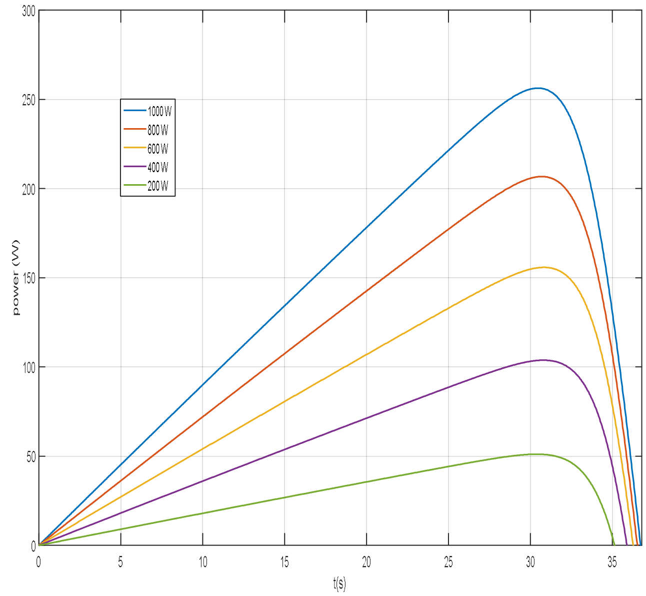

Fig. 1. P-V characteristics of PV module (Kyocera KD250GX-LFB2) at constant temperature and varying insolation

The installation of bypass diodes in parallel with PV modules can help to reduce the potential for issues arising during periods of rapid and dynamic insolation change, such as on cloudy days. This is demonstrated in Fig. 3, which shows multiple peaks on the P–V curve (local and global maximum points). Bypass diodes allow the PV system to increase its power while avoiding such problems [16].

In Fig. 2, the structure of the PV system being studied is depicted and simulated using Matlab/Simulink.

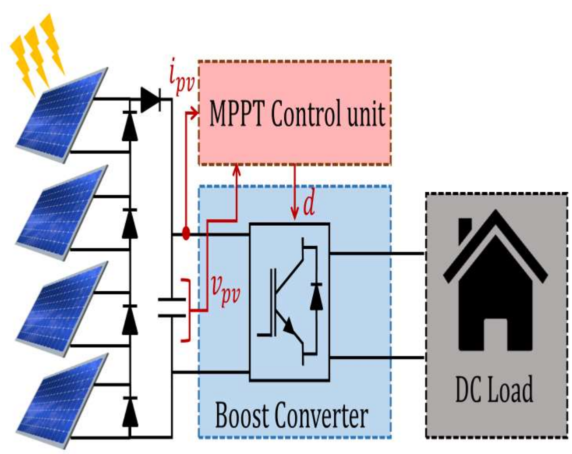

Fig. 2. Simulation of a PV system using MATLAB/Simulink

Fig. 3 illustrates that the GMPP of the PV system is highly dependent on the shading pattern. Consequently, tracking the GMPP is essential in order to maximize the power generation efficiency when the system is partially shaded. In this study, a 04 series PV module array of [Kyocera KD250GX-LFB2].

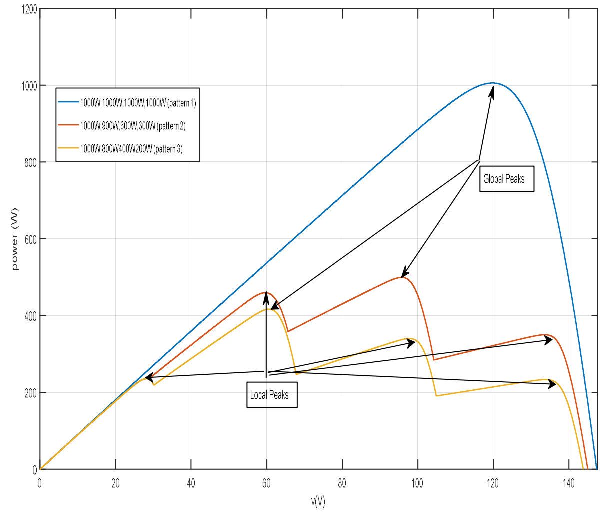

Fig. 3. P-V characteristics for shade patterns (Kyocera KD250GX-LFB2)

II. P&O AND GWO ALGORITHMS

1-PO Algorithm

The P&O MPPT algorithm [16] is widely regarded as the most effective method for tracking the Maximum Power Point (MPP) of a Photovoltaic (PV) system. It is highly valued for its straightforward simulation and easy implementation [03], [11].

$$\begin{cases} D_{new} = D_{old} + \Delta D (if P > P_{old}) \\ D_{new} = D_{old} - \Delta D (if P < P_{old}) \end{cases} \qquad (5)$$

The diagram of perturb and observe algorithm is presented in Fig. 4

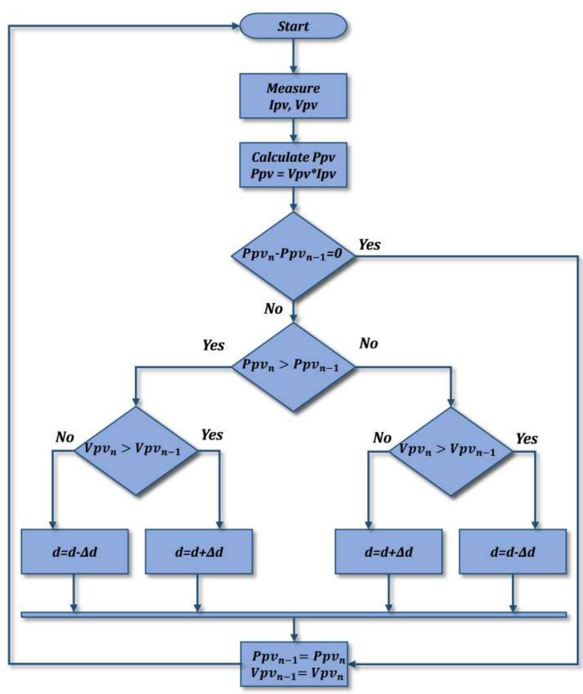

Fig.4. Flowchart of the P&O algorithm principle

2-PSO Algorithm

Particle Swarm Optimization (PSO) is an efficient and effective nonlinear optimization technique inspired by the behavior of birds, fish, and bees. It is widely used in many areas of engineering and science for optimization and design purposes. PSO works by utilizing two fundamental principles: remembering past data and enabling communication between swarm agents. By utilizing these two principles, PSO provides a simple solution to complex optimization problems [17].

The two major rules associated with swarm agents, or particles, are that all particles should follow the particle with the best performance and move towards the one with the best condition. Once the termination criterion has been satisfied, the velocity and position of the highest performing particle is used as a reference for the others to move towards the global particle fitness. This motion can be mathematically represented through the velocity and position updating of conventional PSO [17].

$$V_i(k+1) = wV_i(k) + x_i + C_1 r_1 \left(P_{best} - x_i(k)\right) + C_2 r_2 \left(G_{best} - x_i(k)\right) \quad (06)$$

$$x_i(k+1) = x_i(k) + v_i(k+1) \quad (07)$$

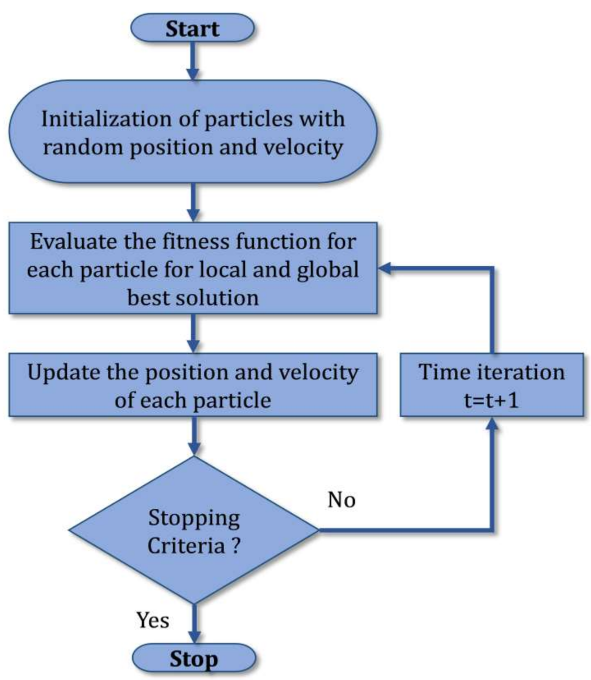

Fig.5 Flowchart of the PSO algorithm principle

SIMULATION AND ANALYSIS PO ALGORITHM

We utilized the MATLAB/Simulink Kyocera KD250GX-LFB2 PV model module for our simulations and compared the performance of our proposed PSO MPPT algorithm against that of the P&O algorithm using the structure of the PV system in Figure 2.

1-Performance under Standard Conditions

The effectiveness of the proposed method is assessed through PV system simulations conducted under standard conditions. Figure 3 (pattern 1) shows that the irradiance of the 4 PV modules is set to 1000W/m2 (250*4 = 1000W), and the temperature of the modules is 25°C.

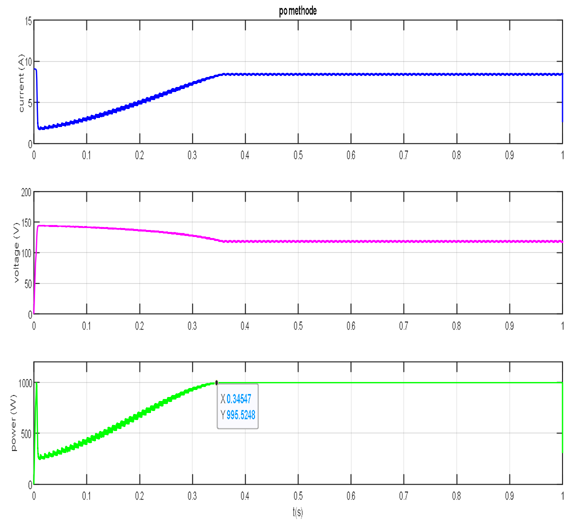

Fig 06 Performance of P&O algorithm under standard conditions.

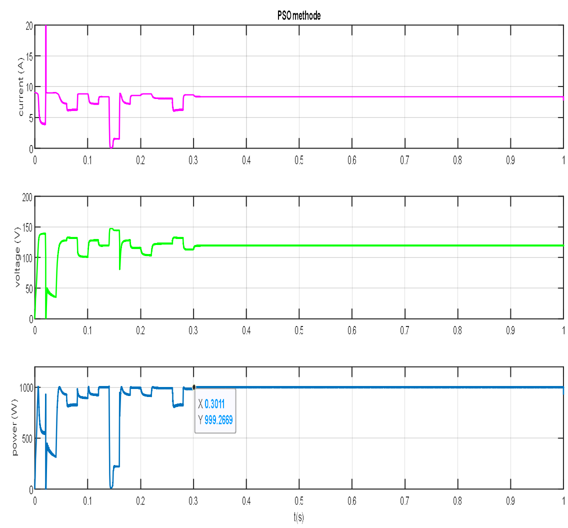

Fig 07 Performance of PSO algorithm under standard conditions.

The performance of the tow algorithms, P&O and PSO, in terms of their PV output's current, voltage, and power can be seen in Figures 06 and 07. It took P&O and SHO approximately 0.345s and 0.3s respectively to reach the maximum power point (MPP).

The results of the PSO algorithm show a better time response and more accurate steady-state output power (999.26 W) than the P&O approach.

This leads us to the conclusion that the PSO algorithm is more effective than the P&O one

2-Performance Under partial shading conditions

For this experiment, four irradiance values of 1000, 900, 600, and 300W/m2 were set at 25°C as seen in Figure 3 (pattern 2). We noticed a GMPP of 499.84W and three LMPPs. Figures 08-09 indicate the output current, voltage, and power of the two algorithms as they relate to the PV modules.

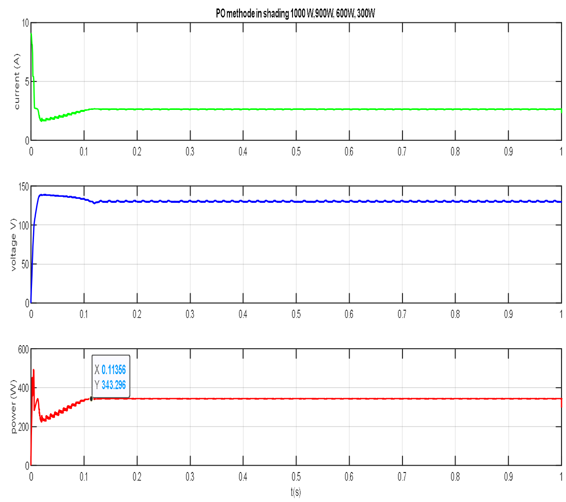

Fig.08 P&O algorithm under Partial shading conditions.

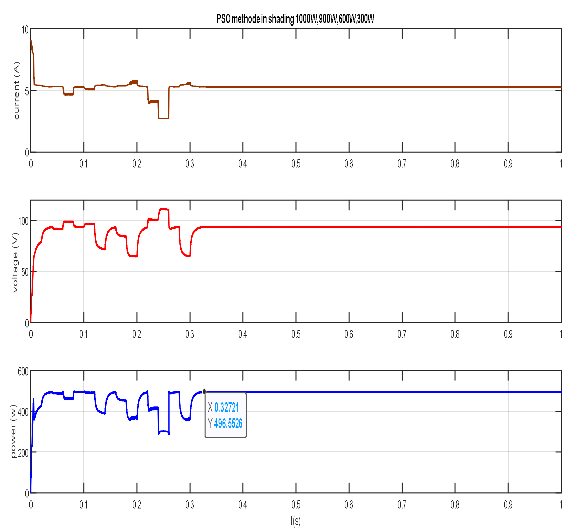

Fig.09 PSO algorithme under Partial shading conditions.

The PSO algorithm was able to accurately pinpoint the GMPP, which resulted in a value of 496.55W, in contrast to the P&O algorithm, which only resulted in the LMPP (334.29W). This indicates that not following the GMPP could lead to considerable energy losses. Furthermore, the PSO algorithm was more efficient than the P&O algorithm, needing only 0.327s to find the GMPP.

3-Performance under Fast Changing Solar Irradiance

At a temperature of 25°C and irradiance of 1000W/m2, all four modules of the array were tested and analyzed to gauge the efficacy and accuracy of the PSO algorithm when the solar irradiance rapidly fluctuates. 0.5s into the experiment, a step variation was implemented on the irradiance, with the second, third, and fourth modules' irradiances dropping to 800, 400, and 200W/m2 respectively, while the irradiance of the first module stayed fixed (Figure 3, pattern 3).

This resulted in a new curve with a GMPP of 417W and three LMPPs. The trajectories of the solar array for the PSO algorithm can be seen in Figure 10.

As evidenced by Figure 10, the PSO algorithm was able to accurately identify the GMPP (417W) after a step change of the solar irradiance and achieved convergence at a satisfactory rate. After the sudden change in solar insolation, the time of convergence increased by approximately 0.31s.

It can be seen from the simulations results that the GMPP tracking can be achieved more accurately with the PSO algorithm proposed.

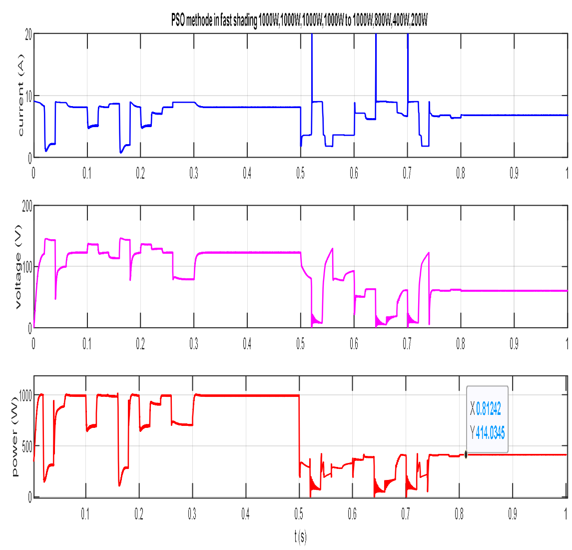

Fig. 10 PSO tracking trajectories under rapid solar irradiance change

III. CONCLUSION

In this research paper, the PSO algorithm, an MPP tracker designed for PV systems to work under PSCs, was tested and compared with the P&O algorithm. The results showed that PSO was highly effective in tracking the GMPP with great accuracy, particularly under PSCs, and demonstrated quick, resilient, and precise performance. Comparatively, the presented optimization method was better than the P&O method in terms of tracking ability.

REFERENCES

1. Yatimi,H., E, Aroudam. Assessment and control of a photovoltaic energy storage system based on the robust sliding mode MPPT controlle. Solar Energy, vol. 139, pp. 557-568, December 2016. https://doi.org/10.1016/j.solener.2016.10.038
2. Aghaie, R.., Farshad, M. Maximum Power Point Tracker for Photovoltaic Systems Based on Moth-FlameOptimization Considering Partial Shading Conditions.joapeVol. 7, No. 2, Oct. 2019, Pages: 176-186 https://doi.org/10.22098/joape.2019.5360.1401
3. Esra, T., Chapman, P. L., Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 22, NO.2, JUNE 2007 pages439-44.**https://doi.org/**10.1109/TEC.2006.874230
4. ainK, J., Guptan M., Bohre, A. K. "Implementation and Comparative Analysis of P&O and INC MPPT Method for PV System", 978-1-5386-4996-1/18/$31.00 ©2018 IEEE. **https://doi.org/** 10.1109/IICPE.2018.8709519
5. Peng, L., Yaoyu, L., John, E. "Sequential ESC-Based Global MPPT Control for Photovoltaic Array With Variable Shading" ,IEEE TRANSACTIONS ON SUSTAINABLE ENERGY, VOL. 2, NO. 3, JULY 2011 IEEE pages 348-358 **https://doi.org/**10.1109/TSTE.2011.2141692
6. Nugraha, D. A., Lian, K. L. ,Suwarno. "A Novel MPPT Method Based on Cuckoo Search Algorithm and Golden Section Search Algorithm for Partially Shaded PV System", CANADIAN JOURNAL OF ELECTRICAL AND COMPUTER ENGINEERING, VOL. 42, NO. 3, SUMMER 2019 pages 173-182 **https://doi.org/**10.1109/CJECE.2019.2914723
7. Gavhane, P. S., Krishnamurthy, S., Dixit, R., Ram, J. P., Rajasekar, N. "EL-PSO based MPPT for Solar PV under Partial Shaded Condition", Energy Procedia 117 (2017) 1047–1053 https://doi.org/10.1016/j.egypro.2017.05.227
8. Rezka, H., Fathy, A., Abdelaziz, A. Y. "A comparison of different global MPPT techniques based on meta-heuristic algorithms for photovoltaic system subjected to partial shading conditions", Renewable and Sustainable Energy Reviews 74 (2017) 377–386 https://doi.org/10.1016/j.rser.2017.02.051
9. Jiang, L. L., Srivatsan, R., Maskell, D. L. " Computational intelligence techniques for maximum power point tracking in PV systems: A review", Renewable and Sustainable Energy Reviews 85 (2018) 14–45 https://doi.org/10.1016/j.rser.2018.01.006
10. Djalab, 1Aicha., Rezaoui, M, M., Mazouz, L., Teta, A., Sabri, N. "Robust Method for Diagnosis and Detection of Faults in Photovoltaic Systems Using Artificial Neural Networks", PeriodicaPolytechnica Electrical Engineering and Computer Science, https://doi.org/10.3311/PPee.14828
11. Villalva, M. G., Gazoli, J. R., Filho, E. R. "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 24, NO. 5, MAY 2009 **https://doi.org/** 10.1109/TPEL.2005.850975
12. Kyocera KD250GX-LFB2 High Efficiency Multicrystal Photovoltaic Module Datasheet Kyocera, [Online], Available: http: //www.kyocera.com

13. MasafumiMiyatake, M. Veerachary, Fuhito .T.N.Fujii, HidyoshiKo, Maximum Power Point Tracking of Multiple Photovoltaic Arrays: A PSO Approach, IEEE Transactions on Aerospace And Electronic Systems Vol. 47, NO. 1, 2011, 0018-9251.
14. S. Latreche, A. E. Badoud, and M. Khemliche, "Implementation of MPPT Algorithm and Supervision of Shading on Photovoltaic Module," Engineering, Technology & Applied Science Research, vol. 8, no. 6, pp. 3541–3544, Dec. 2018, https://doi.org/10.48084/etasr.2354
15. Mohamed ELBAR, Imad MERZOUK, Mohamed Mounir REZAOUI, Noureddine BESSOUS, “Three-Dimensional Pulse Width Modulation Techniques for Three-Phase Four Leg Voltage Source Converters”, Algerian Journal of Signals and Systems, Vol. 5, Issue 3, September 2020. pp: 153-158.
16. E. Mohamed, B. Abdelkader, K. Abdellah and H. Ahmed, "NPC three-level four-legged Shunt Active Power Filter under Non-Sinusoidal Power Supply Conditions," 2019 4th International Conference on Power Electronics and their Applications (ICPEA), 2019, pp. 1-6, doi: 10.1109/ICPEA1.2019.8911161.
17. ELBAR M., MERZOUK I., BEALDEL A., REZAOUI M .M., IRATNI A., HAFAIFA A., “Power Quality Enhancement in Four-Wire Systems Under Different Distributed Energy Resource Penetration”, in Electrotehnica, Electronica, Automatica (EEA), 2021, vol. 69, no. 4, pp. 50-58, ISSN 1582-5175.