Hybrid MPPT Using Particle Swarm Optimization And P&O For PV Boost Converters

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Abstract
Partially shaded condition pose significant challenges for the effective operation of Maximum power point Tracking algorithm in the photovoltaic system. These challenges include the potential for the algorithms to become stuck at local maximum power points (LMPP), extended tracking durations, and power variations while attempting to achieve the global maximum power point (GMPP) for the boost converter. This article contributes to the field by introducing an enhanced PSO based Hybrid MPPT techniques PSO specifically designed for PS scenarios. Initially, a comprehensive analysis of the traditional PSO Hybrid MPPT technique is conducted to Boost converter to identify its limitations regarding stability and steady-state performance under PS conditions and subsequently, the necessary criteria for achieving a stable and SteadyState response are established. Finally, A novel method, PO PSO, has been proposed for the implementation of a single-phase grid connected Inverter and photovoltaic (PV) system operating under partial shading conditions. This approach aims to estimate and regulate the grid voltage and current parameters associated with various loads. It ensures that the values of these parameters, including real and reactive power, remain within permissible limits. Ultimately, the system maintains a unity power factor despite variations in load and the presence of partial shading in the PV systems. This comprehensive study has been conducted using MATLAB software.

Keywords: PSO, MPPT, MATLAB/Simulink.

I. Introduction

Renewable energy has gained widespread adoption across the globe as a vital source for generating electricity. Ongoing research endeavors are dedicated to advancing renewable energy technologies utilized in power plants, such as solar photovoltaic (PV), wind, offshore tidal wave and hydro. The key to the successful deployment of renewable energy lies in developing resilient technologies that offer efficient power generation at a cost-effective price. This is particularly important because the output of renewable energy sources depends significantly on unpredictable environmental conditions. Consequently, there exists substantial potential to expand the role of renewable energy in meeting global energy needs, surpassing fossil fuels, which have traditionally served as the dominant energy source. Solar energy, in particular, stands out as the most abundant renewable resource on Earth [1], presenting significant opportunities for harnessing this valuable energy source. Solar energy is subject to weather conditions and can be adversely affected by factors like shading [2], leading to a significant reduction in the PV power output [3]. When part of a PV array is shaded, it results in multiple localized power points [4-5] due to the presence of bypass diodes. These diodes are designed to prevent overheating in shaded areas caused by reverse current, and this can lead to several peaks in the PV's power-voltage characteristic curve. Some traditional algorithms used in the maximum power point tracking (MPPT) methods, such as perturb and observe (P&O) and incremental conductance (IC), can only identify these local maxima. Consequently, failure to accurately track the true global maximum power point (GMPP) results in power losses and a subsequent reduction in the efficiency of the PV system [6-7]. Numerous solutions addressing the challenge of partial shading in PV systems have been extensively examined in existing literature. In their work, Ali Bidram [8] did a comprehensive overview of various techniques, encompassing MPPT control, array configurations, system architectures, and converter circuit topologies. However, the utilization of MPPT systems is still the most cost-effective approach for enhancing the overall efficiency of PV affected by shading [9]. Furthermore, modifications to conventional MPPT algorithms, such as modified IC, have been suggested in previous research [10-11] and subsequently validated through experimental setups. In low irradiance level scenarios, research conducted by Yongheng Yang and Frede Blaabjerg [12] has shown that modified P&O algorithm, incorporating a deadbeat control approach, results in improved tracking response and reduced steady-state oscillations. Nevertheless, when dealing with rapidly changing environmental conditions, whether it's variations in insolation levels or shading patterns, soft computing methods such as fuzzy logic, artificial neural networks, and evolutionary algorithms (EA) are better suited and exhibit promising results than conventional MPPT techniques [9, 13].

II. Research Motivation

As the global population continues to increase, so does the energy demand; hence, this demand has placed significant pressure on existing energy resources and infrastructure [1]. A significant portion of the global population experiences daily power outages due to insufficient electricity production, making it essential to discover and develop efficient technologies for harnessing electrical energy [2]. Although conventional fossil fuels are most abundantly used for the generation of electric power, they are depleting at a fast pace and causing adverse environmental effects due to carbon emissions [3]. At the current pace of consumption, fossil fuels will be depleted in the near future if rising energy demand is not taken into account [4]. Renewable energy sources (RESs), particularly photovoltaic (PV), have emerged as a leading source of energy today, due to cost-effectiveness and environmental advantages [5]. However, a study related to long-term monitoring of PV power plants reveals that first-tier PV panels, particularly in moderate climates, often begin to degrade or fail after approximately 10–12 years [6]. Due to this, maximum power extraction from PV systems is necessary to make them more reliable, economically viable, and capable of compensating for the gradual degradation of panels over their operational lifespan.

Maximum power point tracking (MPPT) plays a substantial role in reducing inefficiencies associated with solar power systems. By continuously adjusting the operating point, MPPT ensures that the PV system generates maximum possible power, minimizing energy losses and enhancing overall system performance [7]. To ensure the system operates at its maximum power point (MPP) under varying conditions, MPPT algorithms have been instrumental in optimizing energy harvesting from PV panels [8]. These algorithms have played a significant role in harvesting energy and significantly improved the efficiency and reliability of solar energy systems [9,10]. However, despite their importance, conventional MPPT controllers still have limitations in terms of tracking speed and accuracy, requiring a viable solution that reduces the cost of solar power and enhances its efficiency [11]. Researchers have developed a range of both simple and complex techniques to enhance energy harvesting, energy conversion, power tracking efficiency, etc. However, there remains significant potential for improvement [12].

Conventional MPPT control methods are easy to implement due to the relative simplicity of these algorithms; one such algorithm is perturb and observe (P&O) [13]. The P&O technique is more well-known because of its flexibility and adaptability [14]. However, one of the principal disadvantages of this conventional MPPT technique is the sharp fluctuations around the MPP. These fluctuations can lead to power losses over time, and frequently overlook the impact of solar converters, making it difficult to accurately track the true MPP [15].

Metaheuristic algorithms are advanced optimization techniques designed to address complex problems that are beyond the reach of traditional methods [6]. They are particularly useful when the search space is large, complex, or contains diverse regions, which is often the case in PV systems. One major category of metaheuristic control algorithms is bio-inspired control algorithms [7]. These algorithms draw inspiration from natural processes and systems to enhance their ability to extract electric power efficiently. By mimicking biological mechanisms and behaviors found in nature, bio-inspired control algorithms are designed to optimize performance and improve energy harvesting in PV systems [8]. They can address the rapid irradiance fluctuations by replicating natural systems and processes. These controllers employ their own set of modern techniques to maximize energy collection and enhance the operational efficiency of the system [9].

III. **Stand -Alone Solar Power System With P&O For PV Boost Converters**

The solar PV system consists of a PV module, the dc/dc boost converter, the maximum power point tracking algorithm and the load. Radiation (R) is incident on the PV module. It generates a voltage (V) and current (I) which will be fed into the load [3]. The voltage power characteristic of a photovoltaic (PV) array is nonlinear and time varying because of the changes caused by the atmospheric conditions. When the solar radiation and temperature varies the output power of the PV module also changes. In order to obtain the maximum efficiency of the PV module, it must operate at the maximum point of the PV characteristic. The most extreme power point relies upon the temperature and irradiance which are non-direct in nature. The greatest power point following control framework is utilized and work viability on the non-straight varieties in the parameters, such as temperature and radiations [4]. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. A dc/dc converter (boost converter) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the load and the module. The dc/dc converter with maximum power point tracking algorithm and the load is shown in Fig. 1. By changing the duty cycle, the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

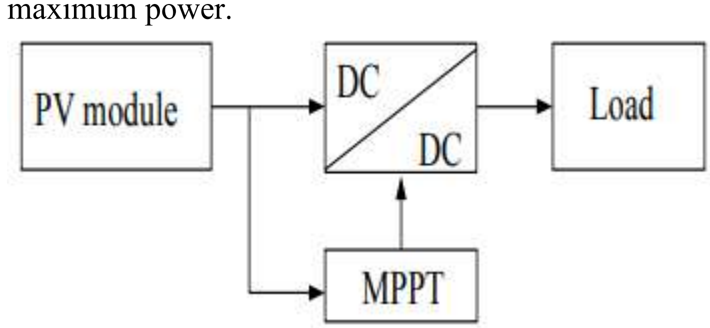

Fig. 1 Block Diagram of PV System with MPPT

MPPT Classifications

PV systems and components generate varying amounts of power due to parameters such as temperature, irradiance, and solar incidence angle [3]. Various MPPT controllers are utilized in the operation of PV modules, with their effectiveness determined by how quickly they can respond to changes in environmental conditions. MPPT techniques are classified into three main categories based on their tracking characteristics, such as conventional MPPT controllers (direct and indirect), novel MPPT controllers (nature-inspired and intelligent), and hybrid MPPT controllers [4]. These classifications provide a foundation for effectively describing and analyzing the proposed research. Figure 2 provides an overview of the classifications of various MPPT control techniques.

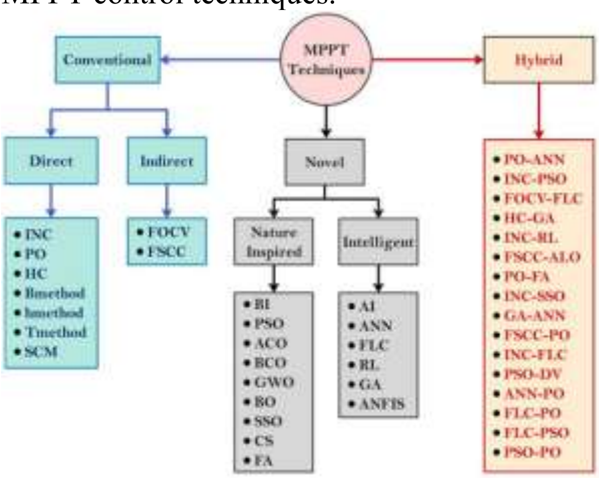

Fig 2. MPPT controller classifications.

IV. Proposed Methodology

A charge controller algorithm called MPPT is used to extract the maximum power from a PV module in specific circumstances. The maximum power fluctuates with variations in irradiation from the sun, outside temperatures, and solar cell temperature. The PV cell absorbs light uniformly when there is coherent irradiance, irrespective of total radiation or total shadowing. When the sun's energy hits the PV panel in an uneven manner, partial shadowing happens [2]. The block diagram of the MPPT-based solar PV system reported in this work is depicted in Figure 3.

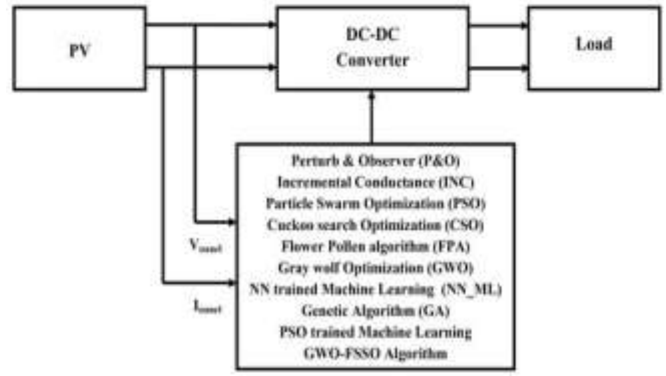

Fig.3. Block diagram of MPPT-based solar PV system.

The fundamental idea behind MPPT is to optimize the maximum amount of electricity that a PV module can produce by using the optimum effective voltage. In order to select the optimal power, which allows the PV module to deliver the maximum current into the battery, MPPT first evaluates the output of the PV module and identifies it to the battery voltage. On smoggy days or in extreme heat MPPT is utilized to extract the most power from PV modules, which frequently function better at higher temperatures. To achieve the maximum energy harvest, PV systems must therefore operate near their MPP because of the PV cell's low efficiency. In contrast to the open-circuit voltage's direct correlation with the cell temperature, the short-circuit current is only loosely correlated with solar irradiance. Hence, it is essential to have a MPPT method, which continuously monitors and analyzes the MPP to optimize the PV system's renewable power. Using MPPT depends on the region, solar field direction, season, and the time of day because photovoltaic modules receive different amounts of solar irradiation. Irradiance and temperature have similar effects on the energy utilized by each solar cell. Modelling based analysis algorithms are used to calculate V/I (voltage/current) at MPPs by employing observed voltage and current values of the PV module as raw data. Such algorithms can also be employed under uniform irradiation circumstances.

PSO

The PSO (Particle Swarm Optimization)-trained neural network is an efficient methodology for optimizing the performance of a MPPT (Maximum Power Point Tracking)-based Solar PV (Photovoltaic) system. PSO is a stochastic optimization algorithm that is inspired by the social behavior of birds in a flock, where particles (or birds) search for the best solution to a given problem by exchanging information with their neighbors in the flock. The PSO algorithm was used to train a neural network to identify the best operating point of the solar PV system, in order to maximize its power output. This is done by using the PSO algorithm to optimize the weights of the neural network, which are adjusted until the best operating point of the system is identified. The PSO methodology is an alternative approach to identify the best operating point of the solar PV system. This method uses an iterative approach to search for the optimal operating point of the system, using a search pattern that resembles a squirrel flying in a spiral pattern. The PSO algorithm is used to optimize the parameters of the solar PV system, such as the panel tilt angle and the panel azimuth angle, in order to maximize its power output. This method is especially useful for systems with multiple PV panels, as it allows the user to optimize the performance of the entire system, rather than just a single panel.

The PSO-trained neural network with PSO methodology in MPPT-based solar photovoltaic (PV) systems is a technique used to optimize the maximum power point tracking (MPPT) of a solar PV system. It combines the advantages of PSO to improve the tracking performance of the MPPT algorithm. The PSO algorithm is used to optimize the parameters of a neural network model, which is then used to predict the maximum power of a solar PV system. This prediction is then used by the PSO algorithm to adjust the PV system's operating point to follow the maximum power point. This hybrid methodology results in a higher efficiency in tracking the maximum power point than conventional MPPT algorithms. The advantage of using the PSO methodology in MPPT-based solar PV systems is that it can quickly and accurately track the maximum power point of the PV system with less computational effort than the conventional methods. This makes it an attractive option for optimizing the performance of PV systems.

Previously some traditional MPPT techniques, such as the perturbation and observation technique, the behavioral increase technique and the optimal gradient procedure. All these techniques work well in uniform lighting and constant temperature conditions. Mainly Particle Swarm Optimization (PSO) are currently used the main MPPT algorithm for complex lighting conditions. The Particle Swarm optimization is most commonly used thanks to its simple and fast solving.

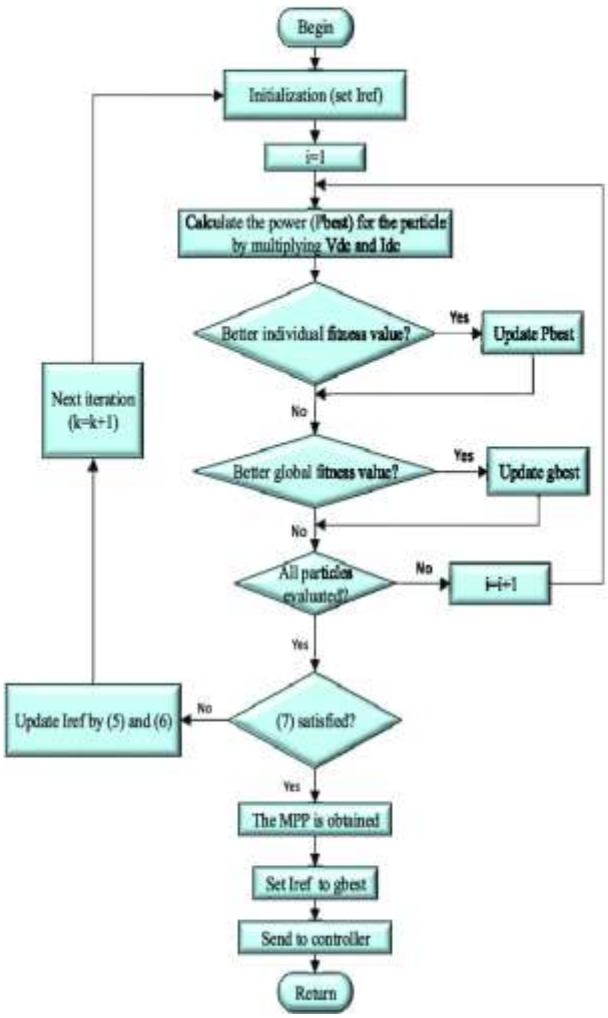

Fig.4. PSO and MPPT.

The proposed new technique combine the natural and the traditional MPPT selection mechanism to improve the particle swarm to find the optimal solution to replace the half particles fitness and location, the worst of which is the best for each iteration. Every N dimensional search area particle I has a function in the PSO algorithm, to be optimized with a determined fitness and vector adjustment value which can determine the direction and distance of their flight. Meanwhile, all particles know their best position (the best person) and their best position (the optimal solution for the world) for currently grouped particles.

V. Result and Simulation

The models of P&O and PSO techniques are implemented in MATLAB. The voltage, current and output power is the main points of comparison to take into account.

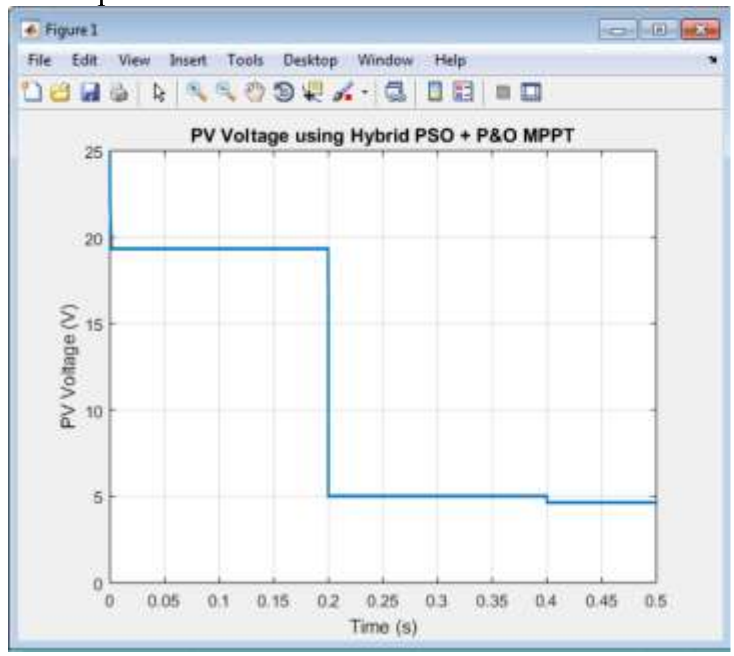

Fig.5. Voltage and Time Curve.

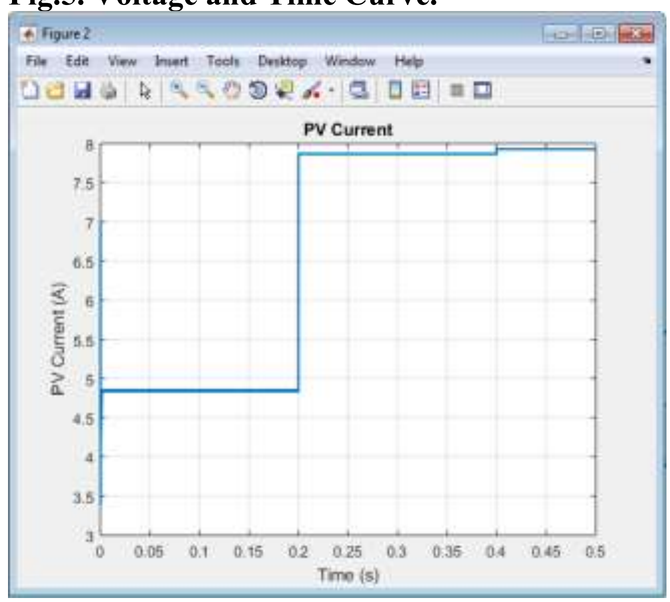

Fig.6.Current and Time.

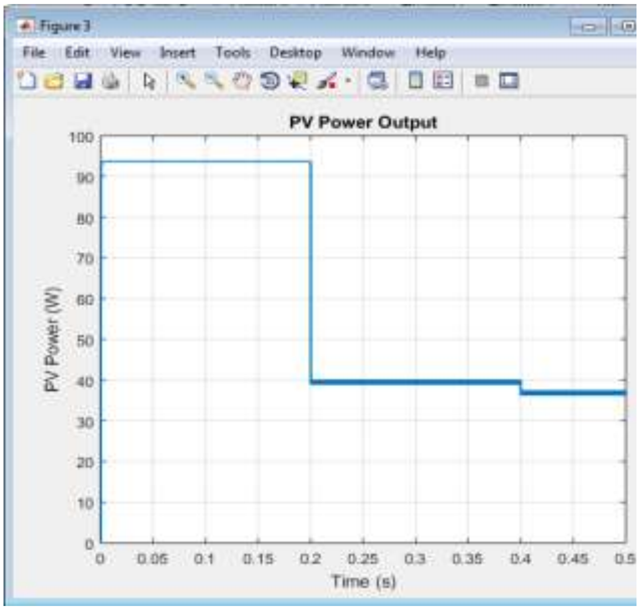

Fig.7.PV power and Time.

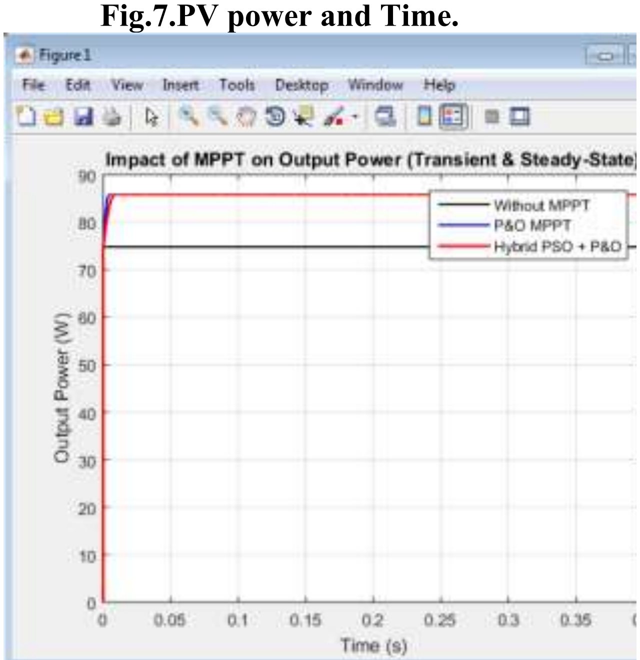

Fig.8.Without MPPT, PSO and hybrid PSO.

Fig.9. Comparison.

VI. Conclusion

This study compares in terms of tracking efficiency, convergence speed and performance between two different MPPT photovoltaic system techniques using photovoltaic algorithm PSO and P&O. The problem can be reduced by using the PSO based MPPT algorithm, to get the optimized values when we place the values are tune-up and every fraction value incremental checking the loops. The PSO is a constraint based algorithm with the limits and percentage increment decides within the loops. The PSO technique has managed to monitor MPP under all circumstances and benefits compared to other techniques including very high monitoring efficiency, simple structure, simple implementation, and rapid convergence with the required solution, according to simulation results.

Future Scope

- The possibility to combine two or more renewable energy sources, based on the natural local potential of the users.
- Environmental protection especially in terms of carbon dioxide emissions reduction.
- Low-cost wind energy and solar energy can be competitive with nuclear, coal, and gas energy, especially considering possible future cost trends for fossil and nuclear

energy. Diversity and security of supply Quick deployment: modular and easy to install.

Reference

1. Dagal, I., Akın, B., & Akboy, E. (2022). MPPT mechanism based on novel hybrid particle swarm optimization and salp swarm optimization algorithm for battery charging through simulink. *Scientific reports*, *12*(1), 2664.

2. Douzi, M. A. K. (2021). *Particle Swarm Optimization (PSO) Based Control of Hybrid Boost Converter for a PV Charging Station* (Master's thesis, Southern University and Agricultural and Mechanical College).

3. Restrepo, C., Yanẽz-Monsalvez, N., González-Castaño, C., Kouro, S., & Rodriguez, J. (2021). A fast converging hybrid mppt algorithm based on abc and p&o techniques for a partially shaded pv system. *Mathematics*, *9*(18), 2228.

4. Alkhuzaie, A. M. R. (2022). Hybrid maximum power point tracking technique based on GWO-P&O for photovoltaic system under various conditions.

5. Borni, A., Bechouat, M., Bessous, N., Bouchakour, A., Laid, Z., & Zaghba, L. (2021). Comparative study of P&O and fuzzy MPPT controllers and their optimization using PSO and GA to improve wind energy system. *International Journal for Engineering Modelling*, *34*(2 Regular Issue), 55-76.

6. Hafeez, M. A., Naeem, A., Akram, M., Javed, M. Y., Asghar, A. B., & Wang, Y. (2022). A novel hybrid MPPT technique based on Harris hawk optimization (HHO) and perturb and observer (P&O) under partial and complex partial shading conditions. *Energies*, *15*(15), 5550.

7. Priyadarshi, N., Padmanaban, S., Bhaskar, M. S., Blaabjerg, F., & Holm‐Nielsen, J. B. (2020). An improved hybrid PV‐wind power system with MPPT for water pumping applications. *International Transactions on Electrical Energy Systems*, *30*(2), e12210.

8. Eltaher, E., Youssef, A. R., & Mohamed, E. E. (2021). Hybrid and adaptive P&O maximum power point tracking techniques for PV generation systems. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(6), 1694-1707.

9. Malobé, P. A., Djondiné, P., Eloundou, P. N., & Ndongo, H. A. (2022). Improvement of the energy production of a photovoltaic-wind hybrid system using NF-PSO MPPT. *Journal of Renewable Energies*, *25*(1), 5-25.

10. Nisha, M., & Nisha, M. (2022). Optimum Tuning of Photovoltaic System Via Hybrid Maximum Power Point Tracking Technique. *Intelligent Automation & Soft Computing*, *34*(2).

11. Hussaian Basha, C. H., Mariprasath, T., Murali, M., Arpita, C. N., & Rafi Kiran, S. (2022). Design of adaptive VSS-P&O-based PSO controller for PV-based electric vehicle application with step-up boost converter. In *Pattern Recognition and Data Analysis with Applications* (pp. 803-817). Singapore: Springer Nature Singapore.

12. Gupta, A., & Singh, O. (2021). Grid connected PV system with MPPT scheme using particle swarm optimization technique. *Int. J. Intell. Netw*, *2*(02).

13. Vargas Gil, G. M., Lima Rodrigues, L., Inomoto, R. S., Sguarezi, A. J., & Machado Monaro, R. (2019). Weighted-PSO applied to tune sliding mode plus PI controller applied to a boost converter in a PV system. *Energies*, *12*(5), 864.

14. Ram, J. P., Pillai, D. S., Ghias, A. M., & Rajasekar, N. (2020). Performance enhancement of solar PV systems applying P&O assisted Flower Pollination Algorithm (FPA). *Solar Energy*, *199*, 214-229.

15. Kabalci, E., & Boyar, A. (2020, November). Design and comparison of MPPT controllers with fuzzy logic and particle swarm optimization for PV power conversion. In *2020 2nd International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency (SUMMA)* (pp. 993-998). IEEE.