A Modified Hybrid Alo–Pso-Based Maximum Power Point Tracking for Photovoltaic System

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February 5, 2024

A MODIFIED HYBRID ALO–PSO-BASED MAXIMUM POWER POINT TRACKING FOR PHOTOVOLTAIC SYSTEM

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Abstract

A photovoltaic system is a renewable energy system that converts sunlight into electricity. PV systems can be used for various applications, such as powering homes, remote off-grid locations, and providing electricity to utility power grids. PV systems can face several issues that can affect performance and efficiency. Some common problems include shading from trees, buildings, or other objects, which can reduce the amount of sunlight that reaches the PV modules. Temperature: the efficiency of PV modules decreases as the temperature increases; that is why the PV system has non-linear characteristics. Controlling photovoltaic systems is challenging due to their non-linear factors. As a result, the PV system must have a flexible controller that can adapt to changing weather conditions. This paper focuses on enhancing the performance of renewable energy sources by implementing intelligent control techniques. The study aims to apply these techniques to optimize the power output of the PV system under variable weather conditions. The paper proposes a new Maximum Power Point Tracking (MPPT technique called ALO (Ant Lion Optimizer). The proposed technique uses a hybrid ALO and PSO to increase the solar system's efficiency. The results show the proposed hybrid ALO-PSO MPPT algorithm offers an efficient and reliable method for maximizing power output in PV systems under changing environmental conditions.

Keywords: Perturbation and Observation, Maximum Power Point Tracking, and incremental conductance, Ant lion optimization , Particle Swarm Optimization .

ENGINEERING JOURNAL Volume # Issue #
Received Date Month Year
Accepted Date Month Year
Published Date Month Year
Online at https://engj.org/
DOI:10.4186/ej.20xx.xx.x.xx

DOI:10.4186/ej.year.vol.issue.pp

1. Introduction

2. Renewable energy sources are promising for generating electricity because they are non-polluting, low maintenance, and easy to install. However, the characteristics of solar photovoltaic (PV) cells are nonlinear and depend on weather and environmental conditions. To maximize the power output of a PV system, it is essential to use a maximum power point tracking (MPPT) controller, which can quickly and accurately adjust the system to changes in solar radiation and other environmental factors.
3. This thesis proposes a hybrid MPPT algorithm that combines ant lion optimization (ALO) and particle swarm optimization (PSO) for a PV system under realistic solar radiation conditions. The algorithm calculates a suitable duty cycle for a DC-DC converter based on the total number of solar panels and the demand load. The proposed algorithm achieves high performance, with an efficiency of over 99.97%, a low ripple of 0.25%, zero oscillation, and a fast response time of 0.013s to reach the MPP.
4. This algorithm offers improved responses, efficiency, reliability, complexity, and cost performance compared to previous works. To validate the system's robustness, the PV system was subjected to the European standard test EN50530 using Matlab (R 2021a) Simulink. The plan was tested under four conditions: standard test condition (STC), irradiation variation, temperature variation, and simultaneous variations of temperature and irradiation.
5. The results show the proposed hybrid ALO-PSO MPPT algorithm offers an efficient and reliable method for maximizing power output in PV systems under changing environmental conditions.

2. Design A PV System Based on Optimizer Algorithms

The demand load must be calculated to design the photovoltaic (PV) system properly, as depicted in Figure 1, and determine the correct size for each component. The load requirements must be factored in when selecting the size of the PV panels. The paper uses a residential house as a sample load and examines the daily usage for each type of load. The demand load is broken down into categories in Table 1.

Consumer appliances (day)				
Appliances	**Hours (h)**	**Power (W)**	**NO. Appliances**	**Energy (Wh/day)**
Microwave oven	0.8	800	1	640
Refrigerat	9	183	1	1,647
Television	3	70	2	420
Clothes Washing Machine	2	600	1	1,200
Floor Standing Air Conditioner	8	3,200	1	25,600
Ceiling Fan	10	75	4	3,000
Fluorescent Tube	5	30	2	300
Fluorescent Lamp	5	11	2	110
Bulb	5	60	2	600
Total				33,337

Table 1 Consume appliances per day.

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2.1 PV sizing

This section provides details for typesetting your manuscript according to the formatting guidelines set for Engineering Journal. Use 11-point Garamond regular font for typesetting the main text in the document.
The main text starts at the top of the page and continues in a two-column format. Place an indentation for each paragraph beginning from the first in all sections or subsections. There is no space between paragraphs within the text. Add an 11-point margin after the text in each department or subsection.

The total load (Wh) $= \mathbf{33,337 \times 1.25}$ **(3.1)**

Where 1.25 acts as a design safety limit[R. A. Mohammed, S. A. Hamoodi, and A. N. Hamoodi, pp. 782-789, 2021.].

The total load (Wh)= 41671.25 Wh.

3.3 PV sizing

The mathematical calculations are obtained according to the theoretical total daily energy.

Total Power $= \frac{\text{Total Load}}{\textit{Sun Arc Rate}} = \frac{41671.25\ \text{Wh}}{6.5\ h} =$ $\mathbf{6410.9615\ W}$. **(3.2)**

Power of PV model= $\mathbf{540\ W}$**.**

Then,

No. of PV modules$= \frac{\text{Total Power}}{\text{Power of PV model}} = \frac{6410.9615\ W}{540\ W}$ **(3.3)**

$$= \mathbf{11.8721 \approx 12\ pcs}.$$

2.2 Proposed System Configuration

The proposed setup includes three components: PV panels, DC/DC boost converters, and the proposed maximum power point tracking (MPPT) strategies, as shown in Figure 3.1. The photovoltaic system has a 12-panel array set up in three parallel strings, each of four panels connected in series based on power demand calculations. The system's total output power is around 6480W (12 panels x 540W per panel), with each forum having a capacity of 540W and 110 cells. The specifications of the PV panels can be found in Table 3.2. The design, mathematical modelling, and analysis of each component are discussed in separate sections, including the introduction of optimizer algorithms like particle swarm optimization (PSO) and ant lion optimization (ALO) and how they are used in the MPPT controller to address varying.

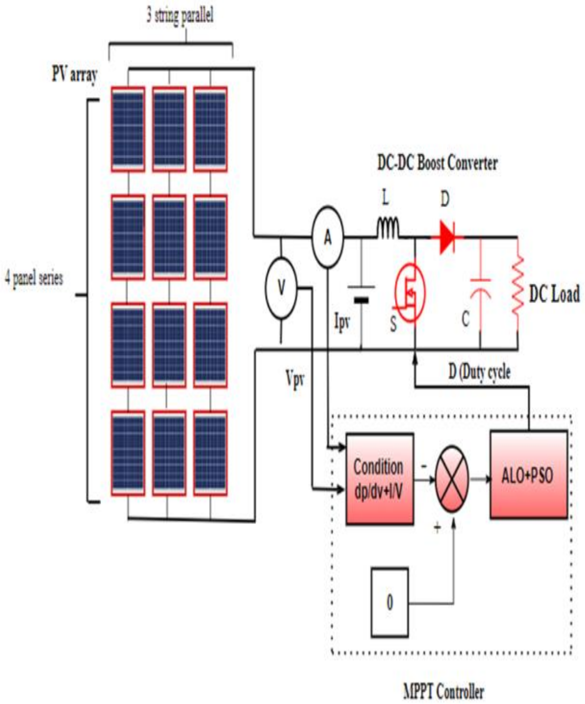


Figure 1: The block diagram of the PV system

2.3 DC/DC Boost Converter

MPPT (Maximum Power Point Tracking) aims to determine the maximum output of a photovoltaic (PV) module through a DC/DC boost converter. This calculation allows the load impedance to be matched with the PV module, resulting in the most efficient energy transfer, which is given as follows:

$$Z_{Load} = \frac{V_o}{I_o}$$

optimal impedance for photovoltaic (PV) operation to be determined

$$Z_{opt} = \frac{V_{MPP}}{I_{MPP}}$$

V_{MPP} , I_{MPP} ; The maximum values of voltage and current for the photovoltaic (PV) system

The boost converter has a voltage output that is represented by

$$V_o = \frac{1}{1-d} V_{in}$$

(3.6)

To design a suitable boost converter, it is assumed to have 95% efficiency, so losses cannot be considered. Therefore, the output power (P_0) equals to the input power (P_{in}). The input current can then be:

$$I_O = \eta I_{in}\ (1 - d\ )$$

(3.7)

DOI:10.4186/ej.year.vol.issue.pp

Where $I_{in} = I_L$ and $\eta = \frac{P_o}{P_{in}}$ is the efficiency of the boost converter. The duty cycle may be written using the following equation:

$$d = 1 - \frac{\eta \times V_{in}}{V_o}$$

(3.8)

The parameters of the boost converter in Continuous Conduction Mode (CCM)

may be calculated according to Eq 3.9.

$$L = \frac{V_{in}\ d}{f_s\ \Delta I_L}$$

(3.9)

Where f_s is the switching frequency, and $\Delta I_L = 0.3 I_L$.

The output capacitor may be determined according to the following equation:

$$C_O = \frac{I_o\ d}{f_s\ \Delta V_o}$$

(3.10)

Where $\Delta V_o = r \times V_O$ and $r = 0.5\%$. Therefore, C_O must be larger than the calculated value to maintain the output voltage ripple within the desired limits for the boost converter. The input capacitor, crucial for separating the PV power and decreasing voltage harmonics, can be determined using the following Eq:

$$C_{in} = \frac{d \times V_{in}}{8 \times {f_s}^2 \times L \times \Delta V_C}$$

(3.11)

Where $\Delta V_c = r \times V_{in}$ and $r = 1\%$.

In conclusion, the parameters of the boost converter circuit are calculated using previously defined equations for one photovoltaic panel. The total number of meetings is 12, arranged in three parallel strings of four series-connected modules, forming the desired PV array. The combined power output is 6480W, with a PV voltage of 150V. The design of each boost converter is detailed in Table 2.

Parameters	Value	Unit
L	0.67	mH
C_{out}	100	μF
f_s	50	kHz
C_{in}	100	μF
d_{max}	0.5003	-

Table 2 The boost converter simulation parameters

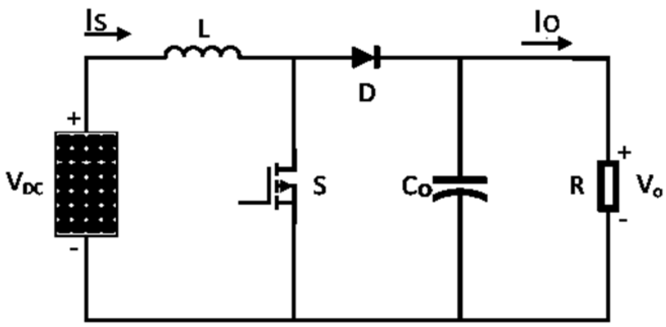


Figure 2 Electrical circuit of the boost converter

3 Proposed MPPT Based on hybrid ALO with PSO

A crucial problem in both conventional MPPT and some intelligent MPPT methods is their reliance on fixed changes in the duty cycle, leading to slower tracking and fluctuations. To resolve this challenge, the ALO proposes utilizing a variable step size for PSO and the PSO suggests a new duty cycle based on the step change determined by equation 3.21.

$$D(i+1) = D(i) \pm \Delta D \qquad (3.21)$$

Di+1 represents the new duty cycle, ΔD represents the position that provides accurate duty in each iteration, and Di serves as the duty cycle at each iteration.

This section presents a hybrid optimization algorithm that combines the strengths of Particle Swarm Optimization (PSO) and Ant lion optimization Algorithm (ALO). PSO excels at exploring the search space but needs help finding the optimum local solution and converging. ALO, on the other hand, overcomes these weaknesses. By combining the two algorithms, a balance between exploration and exploitation is achieved, yielding the benefits of both. PSO is utilized in the global search due to its fast convergence in quest, while ALO is employed in the local search due to its fine-tuning in exploitation. A flowchart of the proposed hybrid algorithm of ALO and PSO is illustrated in Figure 3. The details of this hybrid algorithm will be discussed in the following.

Step 1: Initialization:

1.1: Set the input parameters for the hybrid algorithm.

1.2: Randomly assign positions and velocities to particles within a specified range.

1.3: Evaluate the fitness and determine the global and personal best particles (g_{best} and b_{best}).

Step 2: This step encompasses the exploitation and exploration phases based on the particles' local best positions and the swarm's global best.

2.1: Exploitation phase: During this phase, the algorithm compares the fitness of a particle with the best global value observed so far using Eq 3.22.

$$\text{f(i,t)=} \begin{cases} true \quad f(P_i^t) \le f\left(g_{best}^{t-1}\right), \\ false \quad f(P_i^t) > f\left(g_{best}^{t-1}\right), \end{cases} \tag{3.22}$$

When P_i^t represents the i^{th} particle in its current state t , if $f(i,t)$ this state is determined to be true, the local search will continue and the particle will be manipulated through a simulated ALO.

The current position is then stored in X_{temp}. The new position is evaluated using the ant-lion algorithm, and the velocity is calculated using Eq 3.23.

$$Vi_d(t+1) = Xi_d(t+1) - Xi_{temp}, \tag{3.23}$$

If f(i,t) is false, the particle will be manipulated by PSO and PSO will continue its standard process using this particle according to equations 3.12 and 3.13. The minimum and maximum velocities, V_{min} and V_{max}, are applied to restrict the next movement of the particle. These velocities are randomly set at the start of the proposed hybrid algorithm within a certain range. A linear decreasing inertia weight is employed, which is calculated using equation 3.24.

$$w = w_i - \left(\frac{w_i - w_f}{n}\right) * t, \tag{3.24}$$

Where: n and t represent the maximum number of iterations and the current iteration, respectively. w_i and w_f stand for the initial and final values of the linearly decreasing inertia weight. This weight is updated dynamically to enhance the global search

DOI:10.4186/ej.year.vol.issue.pp

ability of the particle and to prevent premature convergence, where improvements are made based on previous personal bests.

Exploration phase: Calculate the fitness function and examine the range restrictions for all particles and ant-lions that occur. After the fitness function is determined, the best solutions (and) are updated.

Step 3: The hybrid algorithm will end when the maximum number of iterations (n) has been reached. The result of the proposed hybrid algorithm will be the identification of the global best particle (g_{best} and its fitness value).

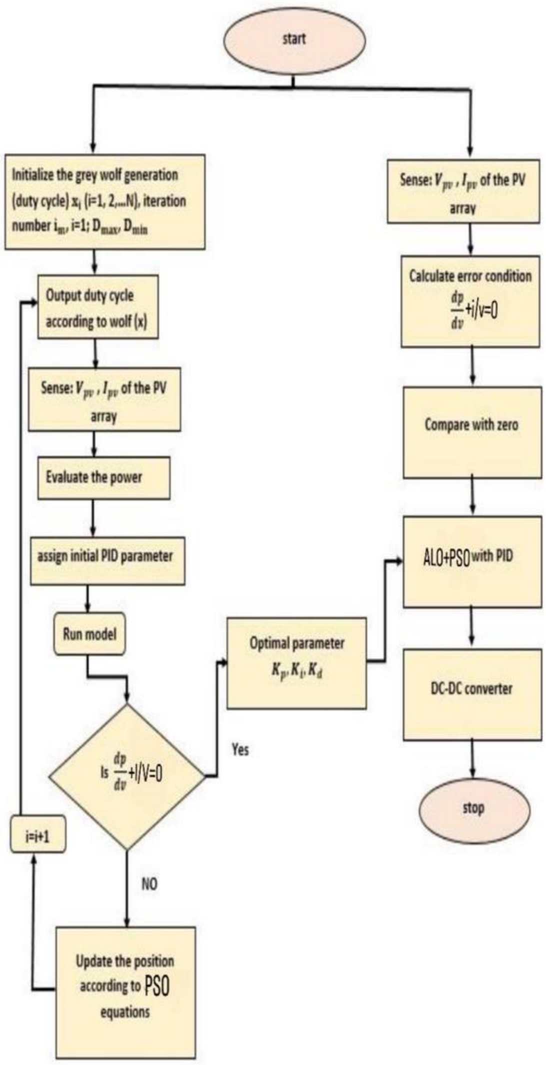


Figure 3 The flowchart of ALO-PSO method.

4 ANALYSIS OF SIMULATION RESULTS

This section examines the efficiency of the proposed hybrid MPPT for obtaining the maximum amount of energy from a PV system in non-uniform environments. The proposed system has been tested under various situations, including regular operation, variable irradiations, temperatures, combined irradiation and temperature, and sinusoidal conditions. Additionally, different MPPT algorithms, such as the P&O and IC algorithms, have been evaluated to demonstrate the capability of MPPT in extracting maximum power even in challenging conditions.

Simulink and the m-file in MATLAB can create a hybrid system (R2021a). MATLAB's Simulink will synthesize the ideas presented earlier in the system validation design and simulation, such as designing a solar panel plant, a DC-DC converter, and MPPT with a resistive load.

4.1. Case one: (normal operation test).

Under simulated Standard Test Conditions (STC) of 1000W/m2 and 25°C, the results of the proposed intelligent MPPTs, such as the PSO-based MPPT and hybrid ALO with PSO-based MPPT, were compared to traditional MPPTs. It was shown that the proposed algorithms had a more rapid and efficient response when it came to the PV system's current, voltage and power output. Figures 4.1, 4.2 and 4.3 revealed that the ALO-PSO had the best dynamic reaction, arriving at the maximum power point in a shorter time than the traditional methods. However, the P&O and IC algorithms were found to be the least viable due to their large oscillations around the MPP, which reduced the generated output power. To address this issue, the hybrid intelligent MPPT was proposed to increase the duty cycle step size, thus improving efficiency.

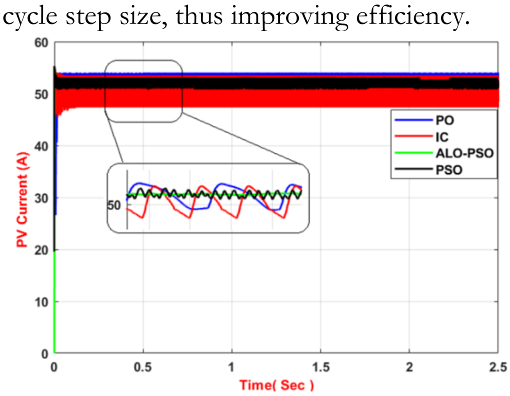


Figure 4.1 the dynamic response of the PV current at STC

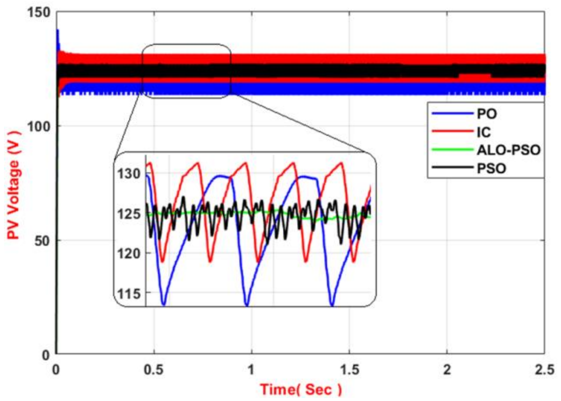


Figure 4.2 the dynamic response of the PV voltage at STC

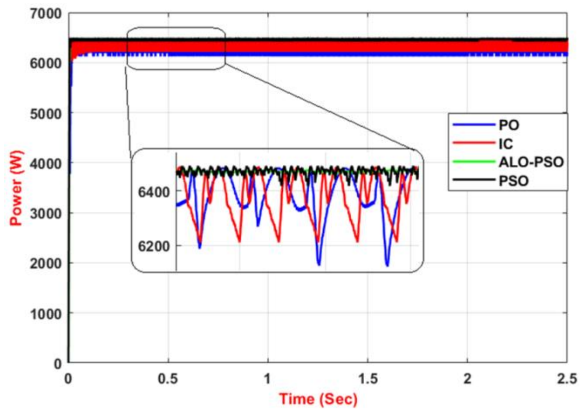


Figure 4.3 the dynamic response of the PV power at STC

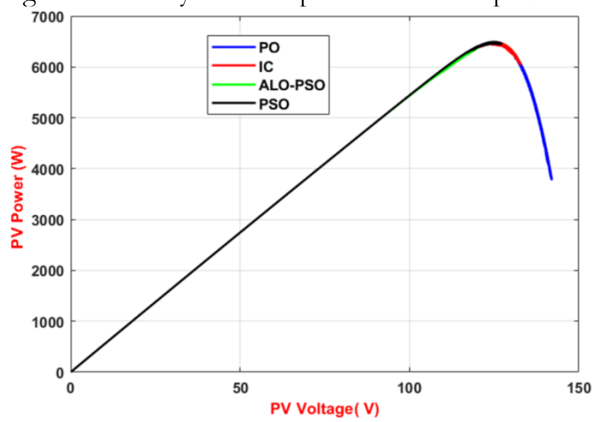


Figure 4.4 the P-V characteristic curve.

4.2. Case Two :(Irradiation Variation)

This section discusses the environmental conditions that change almost daily, with the temperature remaining constant but the irradiance changing constantly. The profile for this scenario is depicted in Figure 4.5. It's worth noting that the variation occurs between a low irradiation level of 500 W/m2 and the highest possible irradiation level of 1000 W/m2. Additionally, the temperature is maintained at Standard Test Condition (STC) levels of 25C during irradiation variations.

The figures mentioned (4.6, 4.7, and 4.8) likely show the responses of the various MPPT controllers to changes in irradiation, with PV current, voltage, and maximum power plotted as functions of time or irradiation intensity. Based on these plots, it appears that the Hybrid ALO and PSO algorithm controllers can more accurately and quickly adjust the system to changing irradiation conditions, resulting in higher power output and more stable operation.

This suggests that the Hybrid ALO and PSO algorithm MPPT controllers may be a good choice for applications where rapid and accurate MPPT is critical, such as solar power generation systems.

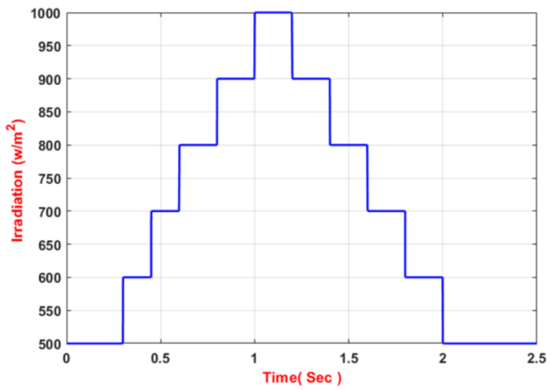


Figure 4.5 non-uniform irradiance

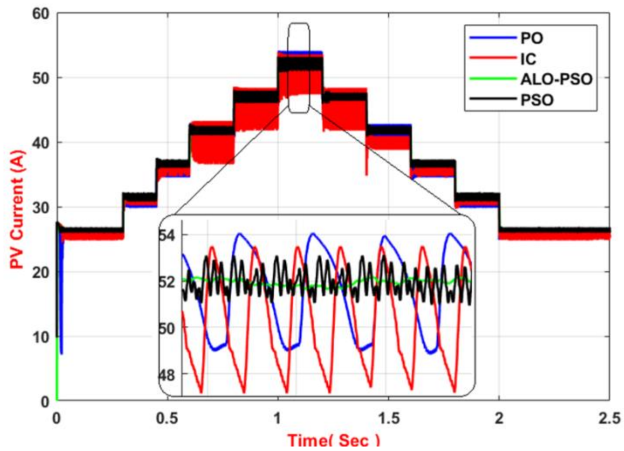


Figure 4.6 the dynamic response of the PV current under variation irradiation &constant temperature

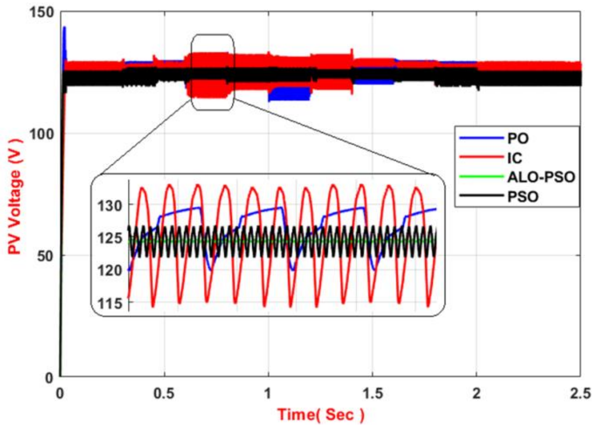


Figure 4.7 the dynamic response of the PV voltage under variation irradiation &constant temperature

DOI:10.4186/ej.year.vol.issue.pp

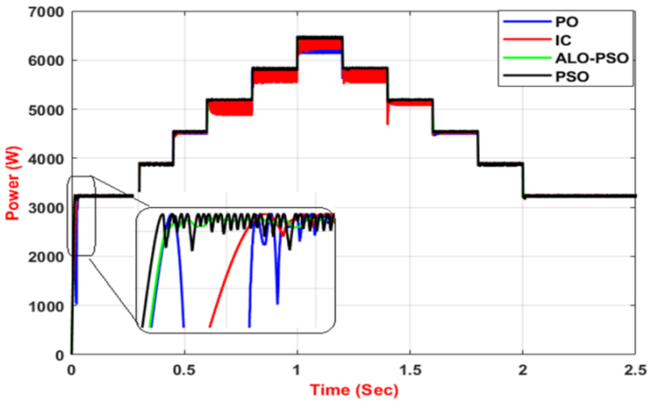


Figure 4.8 the dynamic response of the PV power under variation irradiation &constant temperature

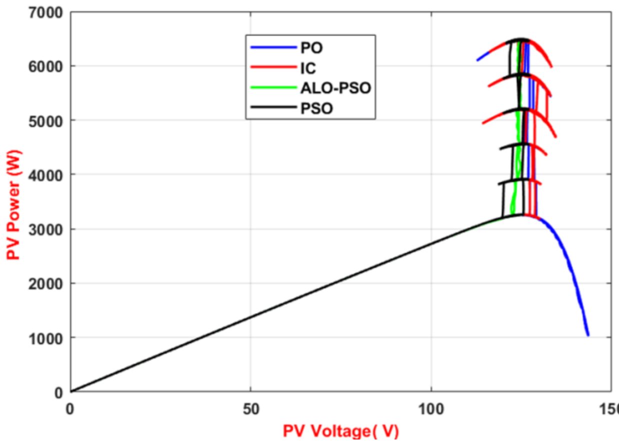


Figure 4.9 The P-V curve under variation irradiation &constant temperature

4.3 Temperature Variation

The temperature fluctuations did not significantly impact the performance levels of the MPPT controllers. This suggests that the proposed ALO-PSO approach is robust and effective in maintaining optimal power output even under varying temperature conditions. Figures 4.10, 4.11, and 4.12 further demonstrate that the proposed ALO-PSO controller has a lower undershoot than traditional-based MPPT controllers. This indicates that the proposed approach can more accurately track the maximum power point and prevent the system from deviating too far from the set point. Additionally, Figure 4.13 demonstrates that the proposed ALO-PSO approach still offers minimal ripple and the least amount of energy loss under daytime heat conditions. This suggests that the proposed approach can maintain stable and efficient power output even under challenging temperature conditions.

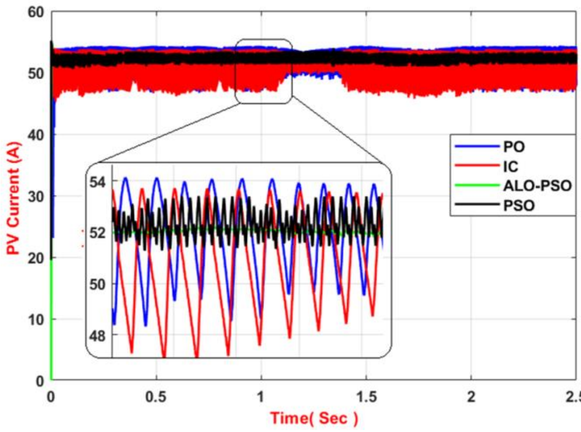
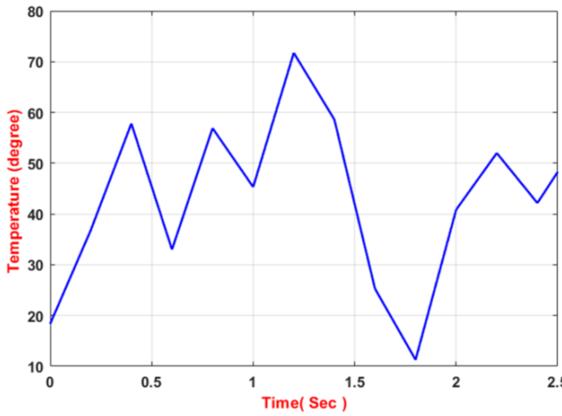
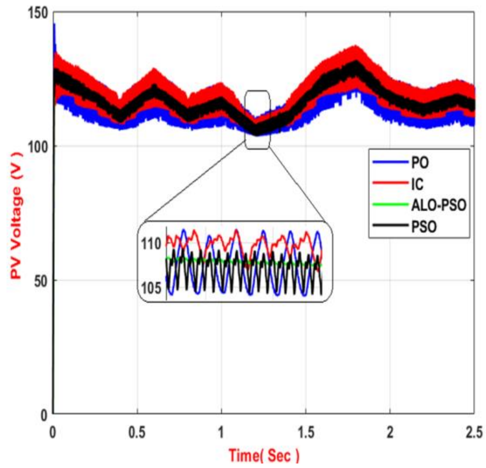


Figure 4.10 the dynamic response of the PV current under variation irradiation &constant temperature



(a) Temperature profile



b)PV voltage

Figure 4.11 the dynamic response of the PV voltage under variation irradiation &constant temperature

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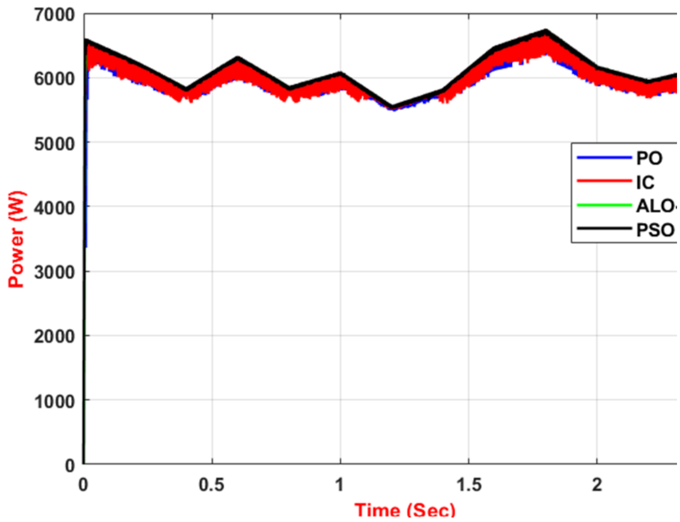

Figure 4.12 the dynamic response of the PV power under variation irradiation &constant temperature

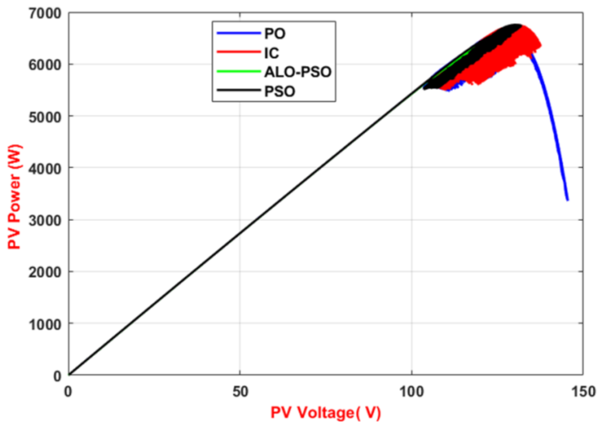

Figure 4.13 the P-V curve under variation irradiation &constant temperature

4.4 Simultaneous Variations of Temperature and Irradiation

Which can effectively track and maintain the optimal power output even under unpredictable and abrupt changes in irradiance and temperature. Figures 4.14 and 4.15 demonstrate the complex and varied nature of the test profile, which includes gradual and abrupt environmental changes. Despite this challenging profile, the proposed ALO-PSO approach can achieve the least amount of undershooting and quick tracking of random changes in temperature and irradiance, as demonstrated in Figures 4.16, 4.17, and 4.18. These results suggest that the proposed ALO-PSO approach is a robust and effective method for achieving maximum power point tracking in photovoltaic systems under various environmental conditions, even when these conditions are unpredictable and varied. Overall, the findings presented in these figures provide strong evidence for the efficacy of the proposed ALO-PSO approach and highlight its potential for improving the performance and reliability of photovoltaic systems.

The findings in Figure 4.19 demonstrate that the proposed ALO-PSO-based MPPT controller causes a significantly smaller ripple for steady-state conditions than the other MPPT controllers. This is particularly evident in the magnified region, where the proposed ALO-PSO-based MPPT controller surge is almost negligible. This suggests that the proposed approach can maintain a more stable and consistent power output under steady-state conditions, which is essential in ensuring the reliability and longevity of photovoltaic systems.

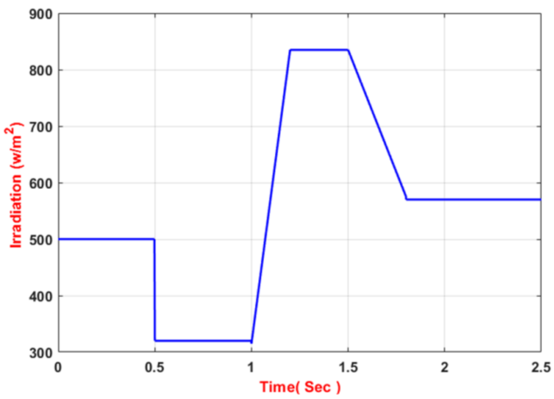

Figure 4.14 Profile of irradiance

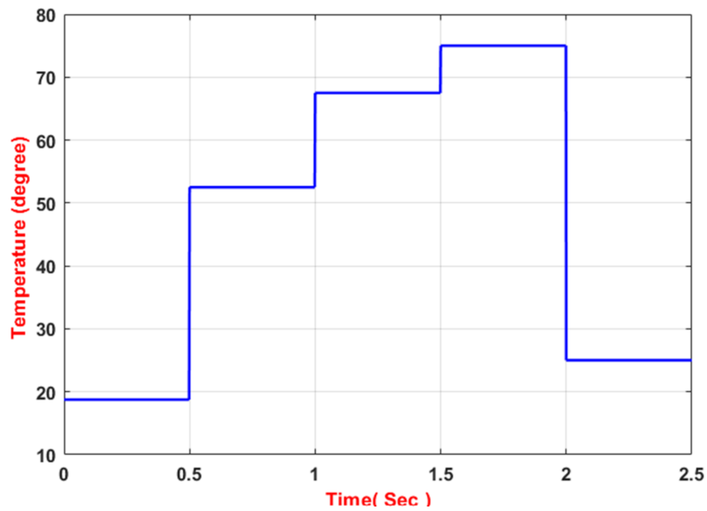

Figure 4.15 Profile of variable temperature

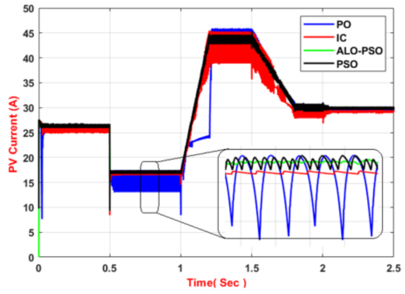

Figure 4.16 dynamic response of the PV current under variation temperature &irradiance

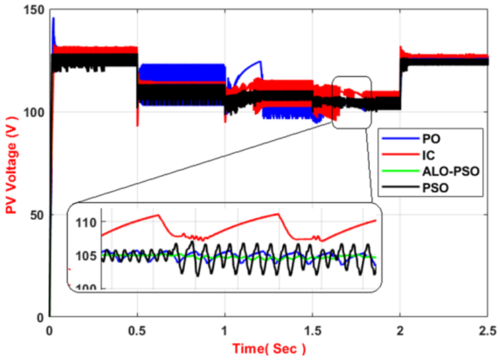

Figure 4.17 dynamic response of the PV voltage under variation temperature &irradiance

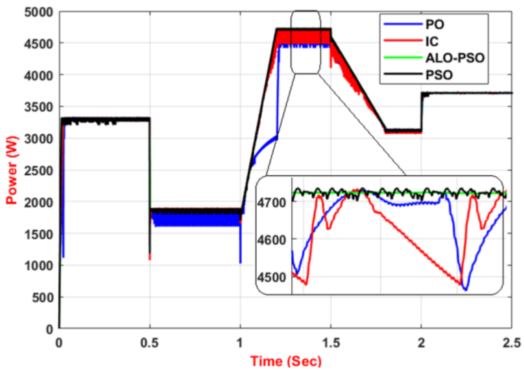

Figure 4.18 dynamic response of the PV power under variation temperature &irradiance

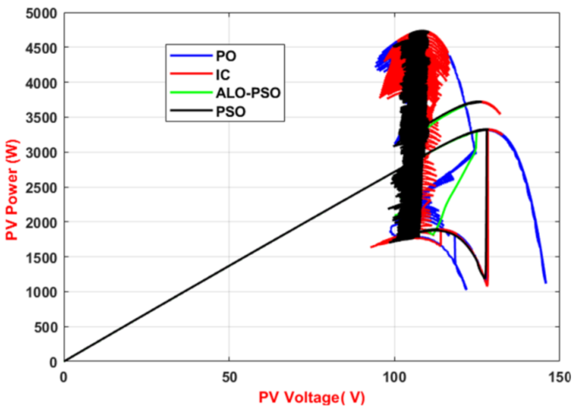

Figure 4.19 P-V curve under variation temperature &irradiance

5.CONCLUSION

The use of the maximum power point tracking (MPPT) technique is essential for maximizing the output power of a photovoltaic (PV) system. This The technique helps the system operate at the PV array's maximum power point (MPP), which is the point at which the variety produces the highest power.

In this research, a hybrid Ant lion Optimization Algorithm (ALO) with particle swarm Optimization (PSO) has been proposed to improve the performance and efficiency of the PV system. ALO and PSO are two optimization techniques that are commonly used for enhancing the performance of PV systems. The boost DC-DC converter is utilized in this research to improve the consistency and dependability of the PV power conversion, particularly during rapid shifts in weather conditions. A boost converter is a DC-DC converter that increases the input signal's voltage to a higher level. The boost DC-DC converter has several advantages over the conventional boost converter. For example, it provides a higher output voltage, which is helpful for applications that require a higher voltage level. It also has a lower input current ripple, which results in better efficiency and stability.

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