Enhancing Performance of Interleaved Boost Converter with Water Cycle Optimized PO Algorithm for MPPT in Solar-Powered Electric Vehicles

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Received: 29.05.2023 Accepted:30.07.2023

Abstract: For SPEVs (sun-powered E-vehicles), the IBCs (interleaved boost converters) are created that differ from typical configurations because it has minimal filters of outputs or inputs, quicker dynamic features, and lower device pressure. The size of inert components and changes in the voltages of the outputs and the voltages of the inputs are often and extremely effectively reduced when employing the present loop of control of the IBC. To supply the UPS and sustain the transportation of the vehicles in unpredictable situations, the PV-battery systems need to utilize the MPPT controllers. Although shadowing, radiation, temperatures, and angle of inclination can cause the photovoltaic system to be substantially shadowed, this is not always the case. Photovoltaic systems work effectively according to optimal conditions. It is challenging to identify the global peak when there are several energy levels. The MPPT approach employed by the solar system tracks and sustains the maximum power point (MPP) to prevent variations. To address the issues, the novel water cycle optimized perturbs and observe (WCO-PO) approaches are introduced in this paper. In a range of meteorological conditions utilizing the MATLAB/Simulink applications, the suggested approach demonstrated a lower computing time, quick converging rates, and minor deviations after attaining the MPP. Along with the comparisons of a tested strategy and alternative approaches, these test outcomes are provided.

Keywords: Interleaved Boost Converter (IBC), Solar Powered E-vehicles (SPEVs), PV-Battery System, MPPT, Water Cycle Optimized Perturb and Observe (WCO-PO).

1. Introduction

PV-based energy-generating technologies are expected to gain popularity as a preferred source of energy for the automotive industry due to their purity, superior effectiveness, and extreme dependability. Even while photovoltaic panels demonstrate outstanding quality of powers through steady effectiveness, their dynamic behavior during fluctuating and synchronous peak energy demands was somewhat sluggish [1]. As a result, the photovoltaic system might be linked to energy storage systems (ESSs) to boost its ability to operate to satisfy the instantaneous or transient peak energy requirements of electrical vehicles and to additionally produce power across the process of brake regeneration [2].

In these circumstances, the high-power dc-to-dc converters are essential for attaching the photovoltaic panels or ESSs to the SPEV's engine's Dc-buses [3] [4]. Therefore, future power plant innovation can be largely dependent on a DC power supply with several converters of the DC-to-DC. The structural evolutions of converters of Dc-to-Dc have been depicted in various works of literature [5]. The setup of higher energy converters of Dc-to-Dc topology and its controllers are essential for managing force, particularly for the DC buses. According to their distinctive elements, experts have analyzed the benefits and drawbacks of numerous converters of Dc-to-Dc [6]. High-power interleaved DC-to-DC converters topology was additionally proposed for application in electrical vehicles. The SPEV, depicted in Fig.1, employs a photovoltaic panel as its main energy source and an ESS as the supplementary source of power to enable the speed of the vehicle in transitory situations and to recover power when the brakes regenerate [8]. In this setup, the PV is linked to the Dc-bus using the IBC, and the ESSs are coupled to the dc-bus using unidirectional Dc-to-Dc converters.

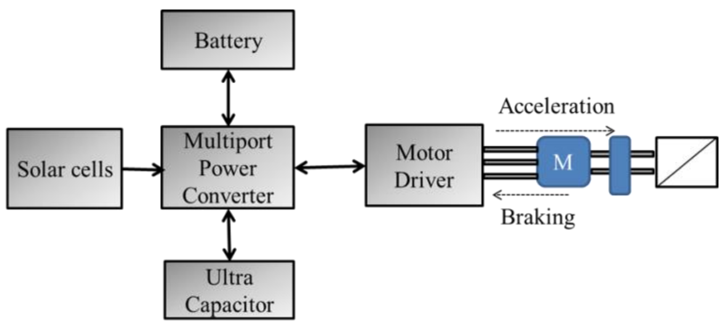

Fig.1. The proposed sun-powered E-vehicles with sources

The system that utilizes solar power has dc/dc converters, which is one of its most important components. This enables one to achieve a preset voltage in the DC limitation without having to increase the primary sources. The effectiveness of the dc/dc converters also has a direct effect on the characteristics of the PV/ESS. The current's ripples/harmonics are one of the numerous elements influencing the battery's lifespan and solar power efficiency. To deal with non-linear behavior MPPT techniques are utilized to attempt to force the structure to function at that MPP as well as to predict the MPP during every possible environment. The creation of several MPPT techniques has improved the efficiency of PV systems.

Paper's organizations – Section 2 explicates the literature review of our work. Section 3 provides explanations of the approach models PV and IBC. The suggested MPPT techniques of PO and WCA are described in Sections 4 and 5. The analysis of the simulation results follows in section 6. The results of the research are highlighted in section 7.

2. Literature Review

In the realm of practical photovoltaic (PV) systems, critical challenges involve power reduction stemming from shifting operating conditions, the computational burden associated with advanced maximum power point tracking (MPPT) mechanisms, and the imperative to optimize PV array output during swift weather changes. The conventional perturb and observe (P&O) technique, a staple in PV systems, often falters in swiftly changing solar insolation, causing erroneous maximum power point (MPP) tracking decisions. To address these issues, this study introduces an improved P&O MPPT technique, incorporating changes in current (dI) alongside voltage and power variations of the PV module. The novel approach is evaluated against fixed and variable step-size methods, mathematically deriving a drift-free condition and its effectiveness in accurately tracking MPP under diverse operational scenarios [8]. This study addresses the challenges of efficient solar energy conversion through an interleaved boost (IB) converter integrated into a solar photovoltaic (SPV) system. The IB converter offers benefits such as increased voltage gain, reduced output ripple, and minimized switching losses. The research focuses on maximizing power extraction using maximum power point tracking (MPPT) techniques. The proposed system's operational characteristics and efficiency are analyzed, employing perturb and observe (P&O) algorithm for MPPT [9]. This study introduces a novel solar-powered interleaved high-gain boost converter (IHGBC) as an enhanced DC-DC converter with reduced output voltage ripples. The primary objective is to devise a hybrid-based maximum power point tracking (MPPT) strategy that integrates flower pollination (FP) algorithm and perturb & observe (P&O) MPPT approach for solar photovoltaic (SPV) systems utilizing the IHGBC. The hybrid MPPT technique highlights benefits such as improved voltage gain, reduced oscillations, and enhanced convergence speed. The hybrid-based MPPT with IHGBC underscores the potential for effective MPPT in SPV systems [10]. This research focuses on the crucial role of DC/DC converters within solar photovoltaic (PV) system-integrated Brushless DC (BLDC) motors for water pumping applications. Optimal DC/DC converters are essential for extracting maximal power from PV arrays at the intermediate stage. Proposed are diverse converter topologies suitable for BLDC motors, accompanied by advanced maximum power point tracking (MPPT) systems integrating fuzzy logic, perturb and observe, grey wolf, and whale optimization algorithms, along with PI controllers. Evaluation encompasses SEPIC, LUO, and interleaved LUO converters, emphasizing output, motor parameters, and grid performance. Interleaved LUO converter excels, delivering a voltage gain ratio of 1:22, conversion efficiency of 98.3%, and grid current THD of 2.9%, while adhering to power quality standards and offering stand-alone and grid-connected operation modes [10]. The past decade has seen extensive utilization of artificial intelligence (AI) techniques for effective maximum power point tracking (MPPT) in solar power systems. AI integration addresses the limitations of conventional MPPT methods under partial shading conditions, ensuring accurate global maximum power point (GMPP) tracking while enhancing efficiency. Although AI-based MPPT methods exhibit faster convergence, reduced oscillations, and high efficiency compared to traditional techniques, their computational intensity and cost are notable challenges. Hybrid approaches, combining conventional and AI-based techniques, strike a balance between performance and complexity [12].Integrating photovoltaic arrays onto fuel cell hybrid electric vehicles (FCHEVs) demands agile maximum power point tracking (MPPT) under diverse conditions. To address this, an innovative MPPT algorithm is proposed, enabling rapid MPP tracking amidst irregular driving, temperature shifts, and irradiation changes. Applied to SAMAND FCHEV with a PV array, the method showcases increased daily driving mileage and swift power change identification, reinforcing efficient energy management and vehicle performance [13]. This work contributes to advancing sustainable transportation technologies through dynamic MPPT strategies [14]. A semi-active hybrid energy storage system, comprising various packs such as Li-ion battery and capacitor packs with a dc/dc converter, was devised for a range-extended plug-in vehicle. Featuring a series-parallel drivetrain, the system, aligned with peak power demands, aids vehicle propulsion. Through dynamic programming, the various perceptions of the model-guided real-time control system were estimated [15]. A Scaled Electric Vehicle Drive System was examined by its acceleration performance and energy consumption across varying drive system ratings. However, the acceleration time (0-100 km/h) decreases with higher system ratings, while drive cycle energy consumption generally decreases with lower ratings [16]. A novel approach to enhance MPPT involves a variable and P&O method with current predictive control in three-phase three-level neutral-point clamped (NPC) photovoltaic (PV) systems. The technique [17] incorporates decoupled power control and space vector modulation for independent active and reactive power control, while a proportional-integral mechanism balances neutral-point voltage. Experimental validation on a 12 kVA three-phase NPC inverter demonstrates the method's feasibility and advantages compared to conventional fixed perturbation MPPT algorithms [18]. Addressing escalated demand for renewable energy in remote regions, this study introduces an innovative hybrid optimization technique for sizing independent solar and wind systems. Combining chaotic search, harmony search, and simulated annealing, enhances reliability and efficiency [19]. Utilizing weather forecasting and neural networks, accurate solar, temperature, and wind predictions inform sizing. Emphasizing cost-effectiveness and reliability, the approach is tested in Khorasan, Iran city and showcases its efficacy in optimizing hybrid renewable energy systems [20].

The advantages of the PO approach, including its low complexity and rapid settling time, form the basis of a hybrid technique determined by WCO and PO. The power produced near where the photovoltaic cells influence the IBC's duty cycles is determined by PO once the settings have been implemented. Before computing the adjusted energy level utilizing the revised currents and voltage ranges, it adjusts the resultant voltages and currents. Lastly, it contrasts the current estimation of the capacity with the previous one. If the power's new values are higher than the power's current levels, it alters the duty cycles periodically. PO finds the global peaks by this increasing and shrinking, even if once reaching the top of the slopes, new powers start to decline and reverse the disrupting effect. The parameters are now migrated to the WCO approach because of the PO's constraints. At first, when PO varies about the globe maximal, it is difficult to sustain a constant condition. Furthermore, PO cannot function well in CPS circumstances, which are described as quickly changing conditions in the atmosphere. As a consequence, our suggested framework includes WCO at this stage, where it takes over and keeps operating. Its primary responsibilities are ensuring output stability, or the lack of oscillations, and obtaining the most electrical power from the solar system's resources feasible during PS/CPS conditions. After obtaining the highest PO value in the shortest settling time, the WCO approach is employed to do its calculations [22].

3. Proposed Methodology

3.1 Photovoltaic Modeling

Based on a P-N diode, it's feasible to ascertain the numerical representation of a photovoltaic cell. The PV current I_{ph}, which is proportional to sunlight, is included together with an equation for inside phenomena. The photovoltaic-cells currents of outputs 'I' is thus shown in the equation (1):

$$\text{Output Current (I)} = \mathrm{I_{ph}} - \mathrm{I_0}\left(\mathrm{e}^{\mathrm{q}\left(\frac{\mathrm{V+R_sI}}{\mathrm{nkT}}\right)} - 1\right) \tag{1}$$

Where, the $\mathrm{D} = \text{behaviors of the cells in darkness},$

The MATLAB/Simulink model of simulation for the SCA component BP solar power SX 50 was selected. It belongs to the SXTM units designed by BP Solar Power.

3.2 Modeling of the interleaved DC/DC converter

Due to the restricted conversion effectiveness of photovoltaic cells, improving the system's effectiveness is an essential consideration for photovoltaic systems. This can be somewhat assisted by using MPPT in conjunction with very effective converters. The DC-to-DC simulating conversion with interleaved changing phases uses similar changing converters phases connected to the input and outputs buses. Super-capacitors, also known as ultra-capacitors, are high-capacity capacitance with lower-voltages restrictions and a value of capacitance that is substantially greater than that of normal capacitance. Between chargers for batteries and capacitors for electrolysis, it bridges the distance.

Two fundamental conditions need to be met by such converters: (a) the current source cannot fluctuate, and (b) the efficiency can be acceptable even at low sun intensities. To control the mean DC voltage of the loads, the intermediary converters adjust the generated DC voltages. To receive maximum energy, converters also periodically balance the input and output features of the photovoltaic generators and the loads. For solar panels, there were various ideas for intermediary conversions utilizing MPPTs [21]. Basic converters, such as buck-and boost-converters, have excessive interruptions in the present state at lesser irradiation intensities, which leads to improper energy device consumption and increased loss of conduction due to the extra present fluctuations. For photovoltaic systems, we advise adopting the two-cell inter-leaved Dc-to-Dc converters to reduce the current-input ripples and address the problem of interruption of the current input. Even though this converter has more components than standard boost converters, the cost doesn't necessarily rise noticeably. The resultant wave has a smaller ripple magnitude value and a higher fluctuating frequency as a consequence. Additionally, the interleaved operation needs less upkeep, increases reliability, and is fault-tolerant. Photovoltaic panels use the suggested MPPT to obtain MPP from the SCAs via any radiations [23].

4. Working Principal of Proposed Maximum Power Point Tracking MPPT Method

4.1 Perturb and Observe Approach

PO is the strategy that is widely employed to obtain the global best. It uses a machine that creates hills for its operation. It initially calculates the energy output caused by the Dc-to-Dc converter's duty cycles being perturbed by the photovoltaic cell, which cause alters the generated voltages and currents. However, after gathering the updated currents and voltage data, it calculates the fresh energy. In the end, it contrasts fresh energy with the previous one [24]. The D-cycle change is reiterated until the fresh energy exceeds the previous values. As soon they get to the highest point of the hill, the constraining effect is reversed, however, the increased energy starts to deplete. With this expansion and decrease, PO discovers the global maximum. By this, equations (2) and (3) indicate the results of the analysis of PO for expansion and decrease.

$$\mathrm{V_{current}} = \mathrm{V_{past}} + \triangle\,\mathrm{V};\ \ \text{when } \mathrm{P_{current}} > \mathrm{P_{past}} \tag{2}$$

$$\mathrm{V_{current}} = \mathrm{V_{past}} - \triangle\,\mathrm{V};\ \ \text{when } \mathrm{P_{current}} < \mathrm{P_{past}} \tag{3}$$

4.2 Water Cycle Optimized Approach

The WCA design has been influenced by the environment and is based on scientific data on the water's cycles and how that rivers and streams flow naturally and reach the ocean. To further understand this, here's a brief description of how rivers are created and the way water travels from hills to the ocean. Every time water flows from one location to another while traveling downward, a stream or river is created. Slopes are produced by the water's motion. The absence of snow and the locations where the past glaciation has evaporated suggest that large quantities of rivers originate in the highlands. Frequently, "rivers" flow downward as they drop and finally reach the sea, and "rain and other types of streams" gather water.

To use population-level meta-heuristic approaches to address the optimization problem, the values of the optimizing factors need to be organized into a collection. It is specified as "R_d" in the protocol given for the one response. In the N_{pop} dimensional optimizations problem, raindrops extremely provide an instance of a collection of $1N_{var}$. This array is explained as follows:

$$\mathrm{R}_d = \left[\mathrm{A_1, A_2, \ldots, A_n}\right] \tag{4}$$

$$\text{Population\_R}_d = \begin{bmatrix} \mathrm{R}_{d1} \\ .. \\ \mathrm{R}_d\ \mathrm{N_{pop}} \end{bmatrix} \tag{5}$$

Wherein, $\mathrm{N_{pop}}$ denotes the amount and population of raindrops.

$$\mathrm{CF_k = Cost_k = Pop_C = N \times V_{cell} \times I_C} \tag{6}$$

Wherein, $\mathrm{CF_k}$ refers to the cost function.

The finest individual is selected to portray the ocean, just as the finest raindrop is chosen. Some of the great droplets are chosen to represent rivers, while the majority of the other droplets are categorized as streams that flow into rivers and oceans. The raindrops turn into streams, and the streams' confluence creates fresher rivers. It's probable that most of the streams empty into the sea. Ocean (optimal points) is the final destination of each of the streams and rivers. The rivers that empty into the sea may additionally be considered using this theory. As a result, the cutting-edge river and stream positions should be outlined as follows:

$$\mathrm{A^{current}stream = A_{stream} + rand \times 2 \times (A_{river} - A_{stream})} \tag{7}$$

$$\mathrm{A^{current}river = A_{river} + rand \times 2 \times (A_{sea} - A_{river})} \tag{8}$$

The positions of the rivers are changed if the stream provides a better option than the connecting rivers. In rivers and the seas, comparable interactions may occur [25].

The cloud carries the water that has been emptied into the atmosphere, where it condenses in the cool air and forms rain. As rivers flow closer to the ocean, new streams are created by the rainfalls into them. According to the proposed method, as rivers or streams flow toward the ocean, condensation causes the ocean's water to become evaporated. To avoid getting dried into the local best solutions, this assumption is made [26].

Here is an example of the way to utilize equation (9) to discover if a river flows into the sea. Once the following conditions are achieved:

$$\mathrm{|A_{sea} - A_{river}| < D_{maximum}} \tag{9}$$

Searching is dampened by large $\mathrm{D_{maximum}}$ values while searching near the water is supported by low $\mathrm{D_{maximum}}$ values. Therefore, $\mathrm{D_{maximum}}$ controls the intensity of search activity near the ocean (optimal solutions).

As seen in equation (10), the value of D_{max} dynamically decreases.

$$\mathrm{D^{current}maximum = D_{maximum} - \frac{D_{maximum}}{maximum\ iteration}} \tag{10}$$

When the "evaporation process" is complete, the "raining procedure" is started. It starts to rain, new drops begin to form streams in various locations. To identify where the newly formed streams are located, equation (11) is utilized.

$$\mathrm{A^{new}stream = A_{sea} + \sqrt{0.1} \times randn(1,\ N_{var})} \tag{11}$$

The proposed WCO-PO approach is illustrated in Fig.2.

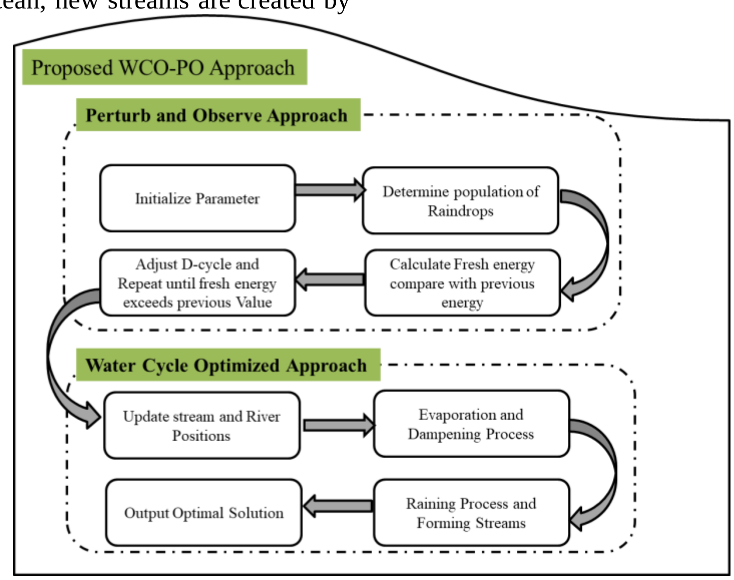

Fig.2. Block diagram for the proposed Water Cycle Optimized Perturb and Observe algorithm

5. Results and Discussion

The complete systems were simulated utilizing the Matlab/Simulink tool, and the efficacy of a proposed strategy was evaluated. Figure 2 demonstrates the loads as switching impedance while assuming the desired temperatures of 25°C. Although the quick alterations of light might not precisely mirror the actual scenario (illumination variations are much less dramatic), they make it feasible to observe how the MPPT approach has evolved even in the most challenging circumstances [27] [28]. In this phase, employing four different instances that indicate different performing conditions, we'll simulate the proposed MPPT approach, which concentrates on WCO and PO, and compare it to current methods, including 'PSO (particle swarm optimizations), ACS (adaptive cuckoo-search optimizations), the DF (dragon-fly) technique, the HHO (Harris hawk optimizations), and P&O (perturb and observer)". A detailed summary of the instances is provided in the tables as follows.

In case 1, each PV panel is exposed to an identical quantity of sunlight, which is known as the identical irradiation conditions. Cases 2 and 3 belong to the PS category, whilst Case-4 is the CPS case.

5.1 Case-1

The uniform irradiation scenario in Case 1 refers to a situation when each PV panel is displayed with identical quantities of light. Table 1 of this work offers designation information for numerous cases along with a list of the irradiation ranges. The power evaluation is shown in Figure 3.

Table1. Comparative list of four cases based on the irradiance levels

		Irradiance Levels	$P_{maximum}$(watts)
Case 1	Photovoltaic-1	1000	1258
	Photovoltaic -2	1000	
	Photovoltaic -3	1000	
	Photovoltaic -4	1000	
Case 2	Photovoltaic-1	900	799
	Photovoltaic -2	1000	
	Photovoltaic -3	800	
	Photovoltaic -4	400	
Case 3	Photovoltaic-1	1000	596
	Photovoltaic -2	600	
	Photovoltaic -3	900	
	Photovoltaic -4	300	
Case 4	Photovoltaic-1	400	1080
	Photovoltaic -2	200	
	Photovoltaic -3	600	
	Photovoltaic -4	300	

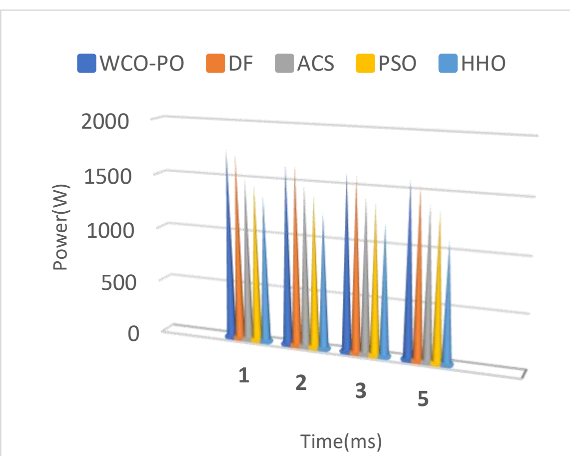

Fig.3. Performance evaluation of power (case-1)

It is clear that the recommended technique requires less time to obtain the MPP and that it fluctuates considerably less once achieved. The proposed technique produced the most power, 1258W, during the conditions of continuous irradiance, followed by the HHO, 1256W, the DF, 1246W, the PSO, and the ACS, which produced the least power, 1237W, out of 1261W overall. The recommended approach, which outperformed the HHO, DF, PSO, and ACS in the continuous irradiation scenario, by a margin of 99.8%, 99.5%, 98.5%, 99.6%, and 99.2%, respectively, was utilized. The duty cycles,

voltages, and current fluctuations in Figures 4–6 demonstrate that the recommended methodology operates significantly better than the other possibilities [28].

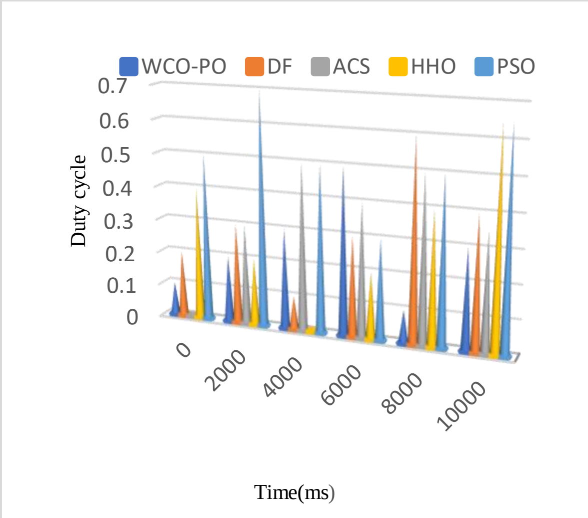

Fig.4. Performance evaluation of duty cycle (case-1)

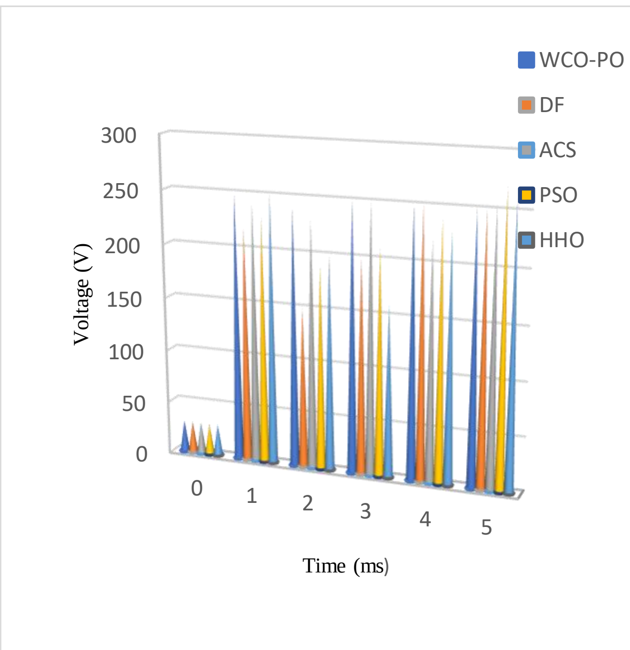

Fig.5. Performance evaluation of voltage (case-1)

Fig.4 to 6 demonstrate the variations in current, voltages, and duty cycles, illustrating that our recommended method remains comparatively reliable after reaching the maximum power point in contrast to other methods, thus explaining why we can identify the unpredictability in the plot of the duty cycles.

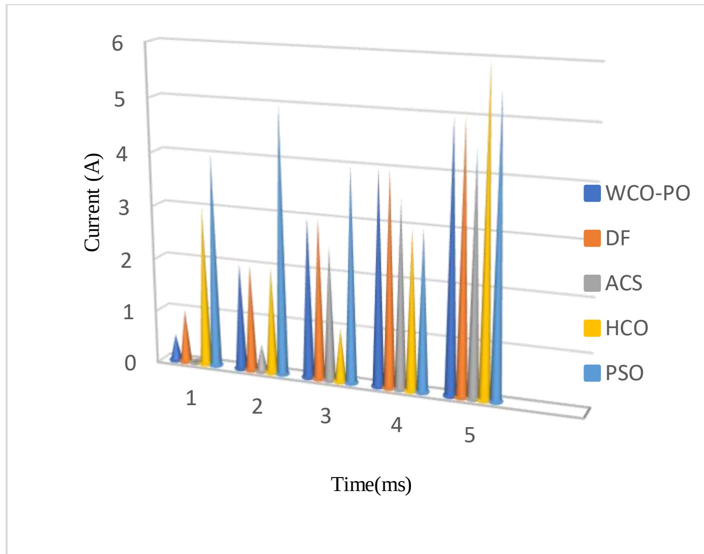

Fig.6. Performance evaluation of current (case-1)

5.2. Case-2

In this case, 799 W is where the MPP is stated. The lighting setup is shown in Table 2. The comparisons of the duty cycles are depicted in Fig.7. The duty cycles diagram clearly shows the alterations: the recommended approach has almost uniform duty cycles after it had reached its greatest electrical capability due to stable voltages and currents outputs, while the other lines indicate multiple fluctuations, proving that the voltages and currents outcomes of the rival techniques are not constant. Fig.8–10 compare the energy, voltages, and current of the recommended methodology with the values of the other approaches.

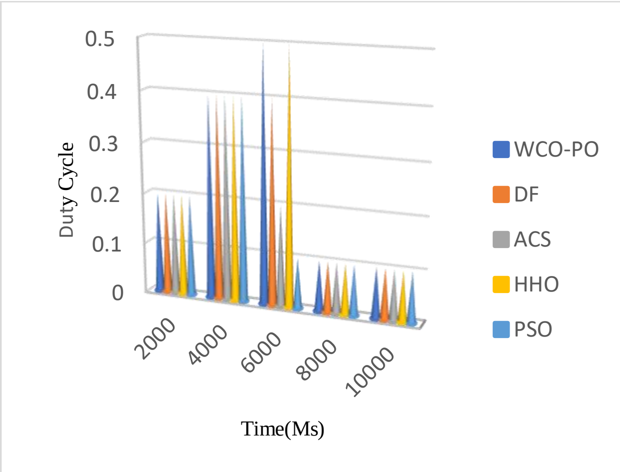

Fig.7. Comparing the Performance of Our Proposed Method and the Existing Method Using Duty Cycle Insight (Case-2)

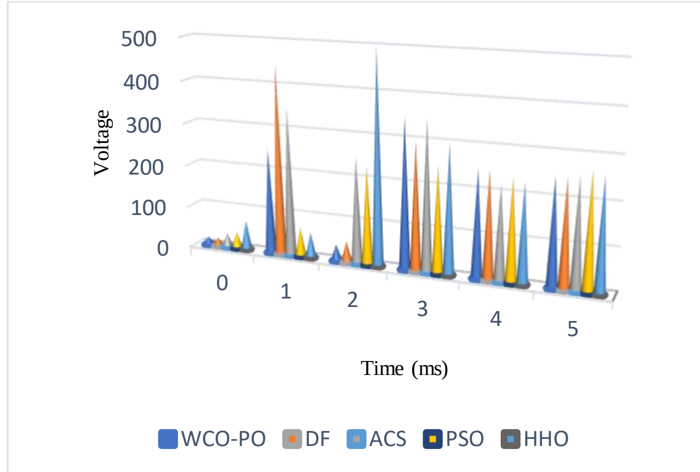

Fig.9.Comparing the Performance of Our Proposed Method and the Existing Method Using Voltage Insight (Case-2)

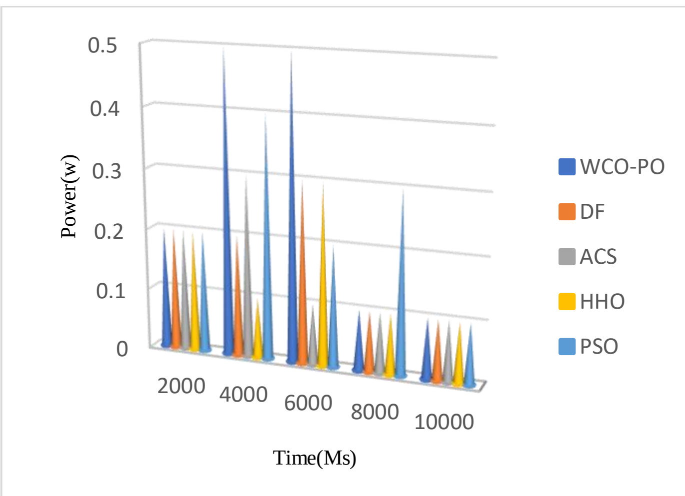

Fig.8. Comparing the Performance of Our Proposed Method and the Existing Method Using Power Insight (Case-2)

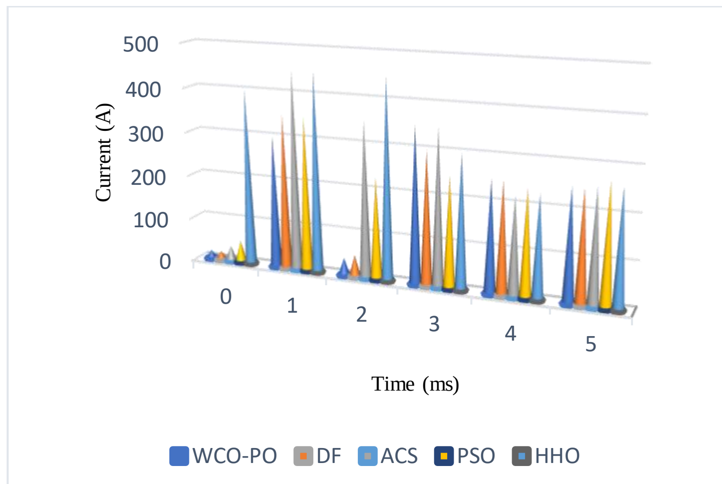

Fig.10. Comparing the Performance of Our Proposed Method and the Existing Method Using Current Insight (Case-2)

The power achieved by the recommended strategy is the greatest, at 794.9W, based on case-2 data, followed by an HHO of about 793.5W, an ACS of about 793.1W, a DF of about 792.4W, and the PSO of 792.1W, in that order, out of 799W overall. The efficacy of the proposed method, in this case, is 99.85%, compared to 99.68% of HHO, 99.3% of ACS, 99.55% of DF, and 99.91% of PSOs. The MPPT's durability is demonstrated by effective global maximum settling time and global maximum quick-tracking. Experimental simulations indicated that the suggested approach needs 0.31sec, 1.42sec for the DF, 3.5sec for the PSO, 2.35sec for the ACS, and 2.72sec for the HHO.

5.3. Case-3

Although the global MPPs are set at 596W, we investigated a distinct PS scenario in this case. The comparisons of the duty cycles are shown in Fig.11. The duty cycles chart modifications, as it did in the initial two examples; the recommended approach has a constant duty cycle after it reaches MPP because of constant currents and voltages, while the other lines exhibit multiple fluctuations, demonstrating that the currents and voltages outcomes of the remaining approaches become unreliable. The energy, voltages, and current of the recommended methodology are correlated with the values of the other techniques in Fig.12 and 13.

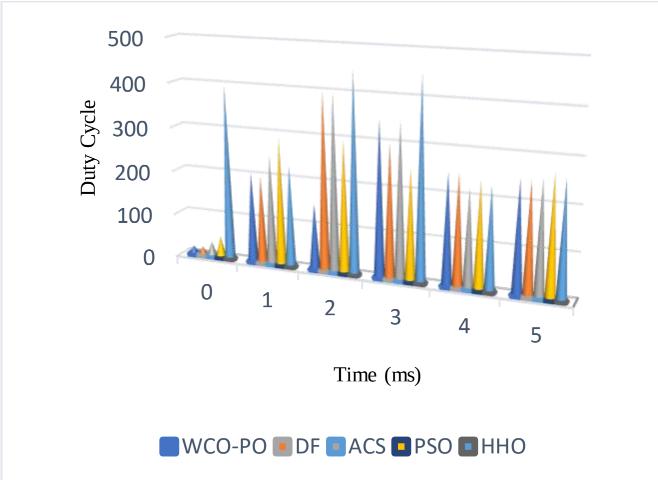

Fig.11. Evaluating Algorithms Performance Based on Duty Cycle Measurement (Case-3)

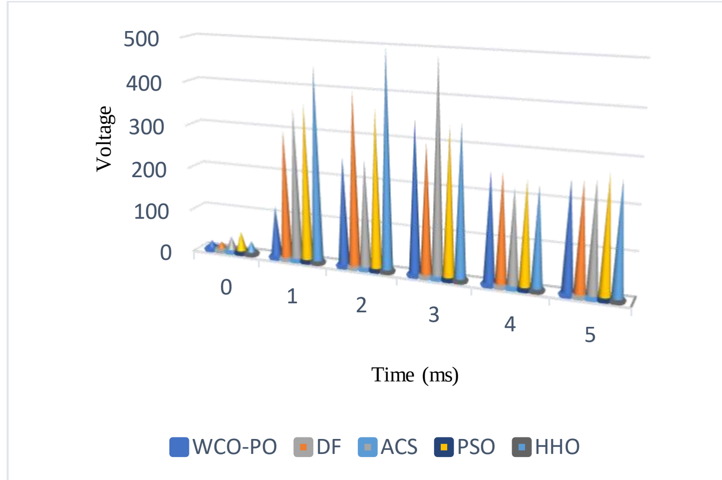

Fig.13. Evaluating Algorithms Performance Based on Voltage Measurement (Case-3)

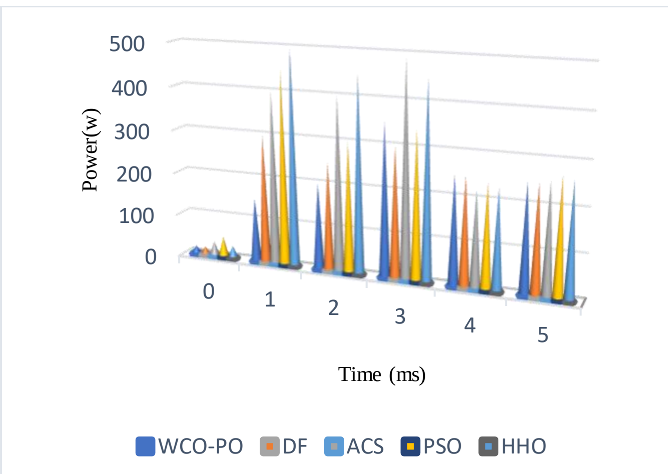

Fig.12. Evaluating Algorithms Performance Based on Power Measurement (Case-3)

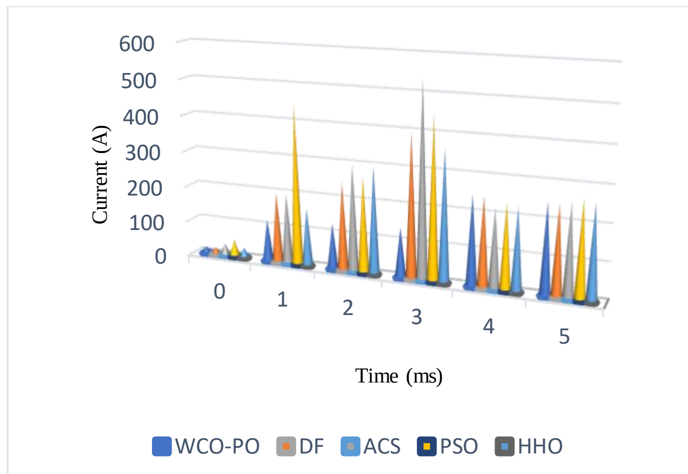

Fig.14. Evaluating Algorithms Performance Based on Current Measurement (Case-3)

According to Fig.14, out of 596W, the amount of energy acquired using the recommended technique is the greatest at 593.2 W, followed by those generated by the ACS (570.6W), PSO (570.5W), the HHO (568.1W), and DF (552.7W). The recommended technique performs better (99.86%) than PSO (96.04%), DF (93.14%), HHO (95.65%), and ACS (96.06%). The effective settling time throughout the global maximum and the quick tracking of the global maximum show how reliable the MPP monitoring performs. Actual testing has demonstrated that the proposed approach takes 0.4sec for the DF, 0.4sec for the ACS, 1.4sec for the HHO, and 2.4sec for the PSO to settle before they may set at 0.6sec, 0.6sec, 1.6sec, 2.4sec, and 2.5sec, respectively.

5.4. Case-4

The final and foremost crucial instance is the CPS states. In this instance, we employed 12 photovoltaic cells, designated PV-1 across PV-12, with levels of light indicated in Table-2. In this case, the MPPs are found at 1080W. We have substituted the HHO for the conventional basic PO approach to compare the "basic PO and a hybrid PO" further strikingly. The comparison assessment of the duty cycles is shown in Fig.15.

The effectiveness of the recommended approach is also significantly higher in this case since the stable voltage and current result in a practically steady cycle of duty after the maximum power point [29]. The fact that both the current and voltage results of the earlier techniques are unsteady is shown by the fact that the other current lines exhibit frequent fluctuations. Once paired with the indicated method, DF takes longer to stabilize but eventually reaches an unchanged cycle of duty after the proposed method. Comparison of the voltage, energy, and currents of the recommended method compared to each of the competing approaches are shown in Fig.15–18. According to Fig.16, out of a total of 1080W, the amount of energy obtained by the recommended strategy is the greatest at 1077.3W, followed by the DF at about 1075.1W, PSO at about 1068.2W, ACS at about 1068W, and conventional PO about 262.3W. The suggested technique's efficacy is 99.61%, higher than the 99.52% of DF, 99.22% of PSO, 99.24% of ACS, and 24.73% of typical PO. Table 2 displays an assessment of the recommended and existing voltage strategies [30] [31]. Table 3 compares the recommended and actual methods for the duty cycles.

Table 2. Comparative Analysis of Duty Cycle Performance

Time (millisec)	Analysis of Duty Cycle Parameter				
	Proposed WCO-PO	Dragon - Fly(DF)	Adaptive Cuckoo-Search optimizations (ACS)	Perturb and Observer(PO)	Particle Swarm Optimizations (PSO)
0	0.5	0.1	0.1	0.3	0.6
1	0.3	0.5	0.5	0.6	0.8
2	0.01	0.3	0.3	0.1	0.9
3	0.4	0.01	0.2	0.4	0.5
4	0.2	0.4	0.4	0.5	0.3

Table 3. Comparative Analysis of Voltage Performance

Time (millisec)	Analysis of Voltage Parameter (%)				
	Proposed WCO-PO	Dragon-Fly(DF)	Adaptive Cuckoo-Search optimizations (ACS)	Perturb and Observer (PO)	Particle Swarm Optimizations (PSO)
0	120	210	190	105	210
1	150	215	210	110	230
2	170	223	250	125	270
3	190	231	270	131	310
4	210	235	290	143	325

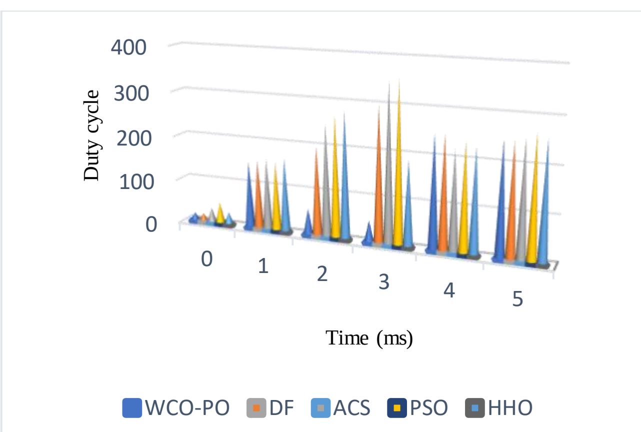

Fig.15. Evaluating Duty Cycle Performance (Case-4)

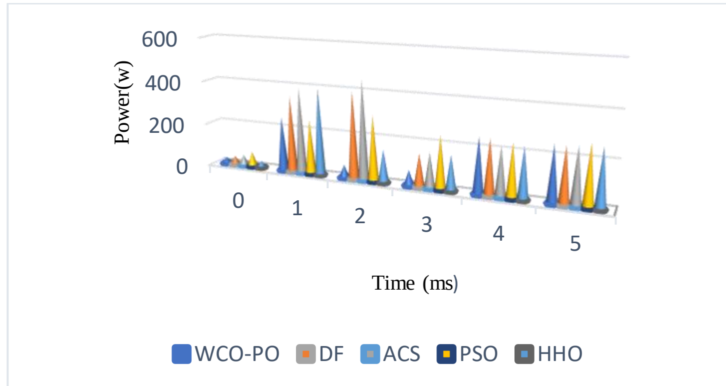

Fig.16. Evaluating power Performance (Case-4)

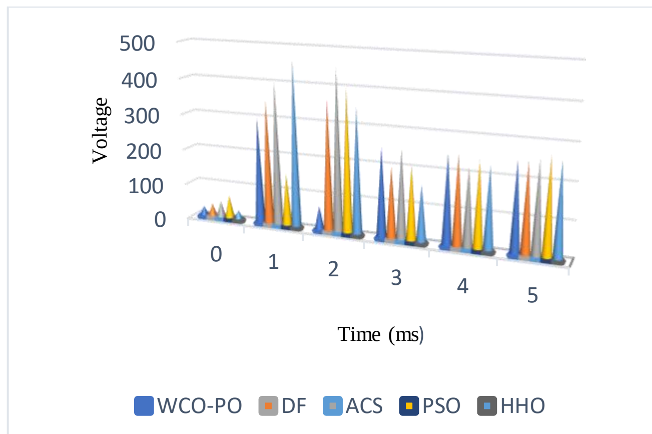

Fig.17. Evaluating Voltage Performance (Case-4)

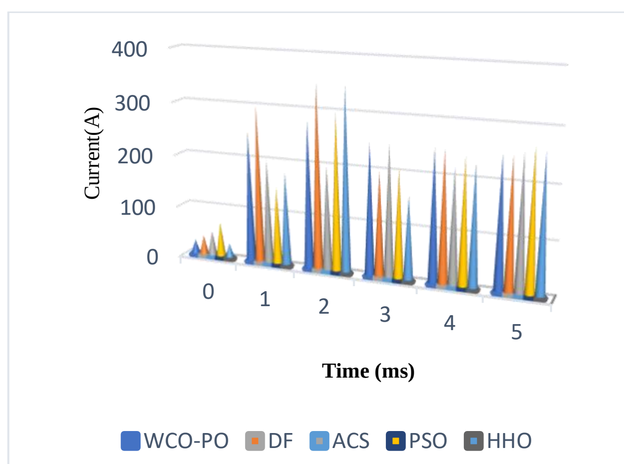

Fig.18. Evaluating Current Performance (Case-4)

As the basis for gauging efficiency, the suggested strategy is analytically assessed and contrasted with current approaches that are widely used to address the problems of MPPT. The suggested approach was carried out consistently well and yielded the MPP in each of the circumstances, involving the constant irradiation conditions, the PS scenario, and the CPS scenario. When moving to WCA from PS/CPS, the system's initial convergence occurs with the PO. As a consequence, the period of convergence can be significantly less in this case than it would be with other solutions [32] [33].

6. Conclusion

WCO and PO MPPT are suggested by this investigation. The proposed method was evaluated using PSO, PO, HHO, ACS, and DF. PS/CPS, irradiation degrees, and four different scenarios were employed in the testing. 12 photovoltaic cells were paired for the CPS situation to test the suggested fix. The study finds that the current methods are ineffective in the CPS situation since they can only provide 25% of the real electricity and result in a 75% outage of electricity, while the suggested technique is successful. Table 1 demonstrates how the recommended approach works better than others regarding the tracking of time, effectiveness of energy use, and oscillation reductions. The suggested approach identifies the global MPP in 92-316 microseconds, which is faster than previous computing methods. The suggested approach outperforms the competition with a median effectiveness of 99.61%. The additional tracing functions well and the MPPT reduces oscillations to less than 1W. This work will be enhanced by more investigation of IBC capacitors' lifespan expansion.

Declaration:

Ethics Approval and Consent to Participate:

No participation of humans takes place in this implementation process

Human and Animal Rights:

No violation of Human and Animal Rights is involved.

Funding:

No funding is involved in this work.

Data availability statement:

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study

Conflict of Interest:

Conflict of Interest is not applicable in this work.

Authorship contributions:

There is no authorship contribution

Acknowledgment:

There is no acknowledgment involved in this work.

Reference

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