The use of soft computing for electronic and mechanical system surveillance and examination

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Abstract Soft computing has made great strides in recent years, giving cutting-edge methods for observing and managing intricate electronic and mechanical devices. For photovoltaic (PV) systems to maximize energy extraction, Maximum Power Point Tracking (MPPT) is essential. However, fluctuating environmental factors and system parameters might have an impact on the effectiveness of MPPT algorithms, resulting in less-than-ideal power generation. So, using soft computing approaches, this research suggests a unique fuzzy logic control and modified mayfly optimization (FLC-MMOn) methodology for MPPT monitoring in PV systems. PV systems are precision and nonlinearity are handled by FLC, which offers an adaptable and flexible regulation. Additionally, MMO is used to optimize the FLC's parameters, enhancing its performance and accelerating convergence. MMO was motivated by the foraging behavior of mayflies. The outcomes of the experiments show how successful the suggested strategy is. The suggested MPPT surveillance system produces a greater energy extraction rate as compared to traditional MPPT methods.

Keywords: soft computing, electronic and mechanical systems, photovoltaic (PV) system, MPPT, fuzzy logic control, modified mayfly optimization

1. Introduction

The utilization of photovoltaic (PV) systems for the generation of renewable energy has dramatically grown in recent times (Çeçen 2022). Through the use of these technologies, sunlight is captured and converted into clean, reliable electricity. Maximum Power Point Tracking (MPPT) strategies must be applied to maximize the efficiency of PV systems. For PV systems to operate as efficiently as possible, it is necessary to employ Maximum Power Point Tracking (MPPT) methods (Saidi 2019). PV systems could be used at their maximum power output in a variety of climated conditions thanks to MPPT algorithms, which guarantee optimal power conversion.

Historically, methods of MPPT used in PV systems included Disturb and Observer (P&O) with Cumulative Conductivity (INC) (Brahim 2023). They have a few several drawbacks, such as noisy sensibility, oscillating behavior, and subpar efficiency in quickly changing environmental conditions. Experts have focused on soft computing methods, which provide smart and flexible methods for MPPT monitoring, to address these problems.

A group of computer techniques known as “soft computing,” including artificial neural systems, fuzziness, and swarm intelligence, were motivated by organic and ecosystems (Supriya 2023). Scientists have developed sophisticated algorithms for MPPT that increase the effectiveness and resilience of solar energy systems by utilizing the inherent adaptability, fault tolerance, and learning capabilities of soft computing techniques (Hanzaei 2020; Shalf 2020). A complete investigation of MPPT tracking in PV systems using soft computation is the goal of this work.

This study proposes a novel fuzzy logic control and modified mayfly optimization (FLC-MMOn) methodology for MPPT monitoring in PV systems using soft computation methods.

The next part of this paper is structured like this: Part 2-Related work, part 3- Methods, Part 4- Simulation Results, and Part 5- Conclusion.

2. Related Works

Among the most important and recent SC-based MPPTs are differentiated evolutionary programming (EP) and degeneration (DE), modified mayfly optimization (MMOn), cuckoo search (CS), genetic algorithms (GA), and cuckoo search (CS) (Hashim 2019). The results indicated that, for a PV system operating under the multimodal partial shadowing situation, EP is the SC approach for MPPT which is both desirable and practical.
To evaluate the Perturbation and Observations (P&O) technique and soft computing-based fuzzy logic computations, 5 and 7 languages were utilized together with varying irradiation and temperatures (Srinivas 2021). More in-depth analysis and information about the findings of the different relationships used in the fuzzy logic method.

Numerous evaluations have been conducted on conventional MPPT techniques such as fractional of closed-circuit (FOCV), altered incremental conductivity (MIC), and variable step size perturb and observe (VSS-P&O) (Basha 2020). Additionally, the single-diode type solar cell and the double-diode type PV panel’s fill factor (FF) and maximum power extraction have been compared. It is amply shown that MPPT methods are suited for various converter schemes.

The P&O approach was shown to be sufficient for tracking GMPP. In comparison to methods described in publications, the suggested approach is precise, simple to use, and adaptable to any size of PV array. The suggested approach is highly suited and can be implemented for both main and string-type inverters, whereas methods currently used in the literature are only appropriate for inverters with strings. In general, it is anticipated that the suggested (Pillai 2019) method will work well to overcome the drawbacks of all current MPPT tracking methods.

In this paper, several computing Techniques are suggested (Ndiaye 2020) for evaluation. MMO and the Adaptive Neuro-Fuzzy Inference System (ANFIS) are used in Maximum Points Tracking (MPPT). The procedures were simulated using a MATLAB/Simulink model of a photovoltaic system. Results showed that ANFIS performs well, providing prompt responses and minimal mistakes.

An effective MPPT-FLC-based soft computing for grid-tied (PV) scheme was shown (Priyadarshi 2020) Space vector pulse width modulation (SVPWM) technology is used to implement a converter regulator for grid-tied PV systems that operate at unity power factor. Inverter and utility grid interaction is still the zeta helicopter. Simulations estimates were provided for stable, changing, and various stress circumstances.

The capabilities of the Variability Skipping Size-Incremental Resistance (VSS-IR) or Varying Step Size-Feedback Circuit (VSS-FC)-based MPPT approaches were evaluated and contrasted with other algorithms. The efficiency of nine precision systems was examined by factoring in steady-state settling time, MPP tracking speed, algorithm complexity, dependence on PV arrays, restricted shade shipping, and total efficacy (Hussain Basha and Rani 2020).

The blend monitoring approach described (Pillai 2019) effectively strikes a balance between traditional P&O and cutting-edge soft computation methods by precisely recognizing shadow instances. That makes use of P&O’s distinctive operational conductivity at the P-V curve’s leftmost wattage crest.

Using both algorithms for various solar insolations, the modelling of a PV power system has been completed. For efficient MPPT operations, a Cuk converter has been used in this study for connecting the PV array and load. A MATLAB/SIMULINK technique has been used to estimate (Priyadarshi 2020) the grid-tied PV system with a unity power factor. AFLC-based MPPT formulation’s efficacy and resilience are explained by simulated findings.

Comprehensive simulation tests for various input situations are conducted to analyse the performance of the proposed hybrid MPPT approach (Sheik Mohammed 2021). A thorough evaluation of the effectiveness of MPPT approaches such as the experiments involving P&O, variable step size (VSS) P&O, and the hybrid MPPT technique developed by combining P&O with LA.

3. Methods

3.1. PV Model

The fundamental components of a PV module are its PV cells (Figure 1). They’re able to convert the power of sunshine rays into electricity relying on the photovoltaic phenomena (Mateus 2022). The pentagon semiconductors junctions is a type of photovoltaic device that when exposed to light produces a DC flow. Many scholars have written extensively about the quadratic and hyperbolic interaction of the solar module’s produced power and volts; this relationship depends on solar irradiance, humidity, and loads. This exact sort of solar cell is recognized for its kind-diode variant, which appears in the next image. The basic formulae used to characterize all the current importation of the screens include the I-V property of the PV solar cell models.

3.2. MPPT using FLC

The photoelectric wattage tracking method’s flexible controller regulates the solar panel’s output voltage via a DC-DC converter to keep up the target value. This increases output power to its highest level. The MPP fuzzy logic processor monitors the current and voltage readings at the solar panel’s output and uses the data for calculating the power utilizing the equation to determine their inputs. The controller’s sharp output indicates when its amplitude modulates the DC-DC conversion. The resultant sunlight at every reading (time k) is examined by the FLC to determine the change in power about voltage (dp/dv). If this amount is < 0, the processor adapts the pulse width modulation, also called the PWM, duty cycle to increase lighting until it is highest, or if its value (dp/dv) is lower than little, the device adapts the duty cycle of PWM to reduce voltages until the electrical current is at its maximum level.
Warning and Change Error were both sources for the FLC, which also has one output that feeds into the pulse width modulation used to regulate the DC-DC conversion. Warning and Change Error, 2 FLC parameters, are set at sampling period’s k.

Where: P (k) is the solar generator’s instantaneous efficiency. The value of Change Error reflects how this location is changing, and the value of Error (k) indicates whether the burden operating level at current k is positioned to the PV feature’s highest output point’s left or right side. Using the essay method and FLC for the presentation display, uncertain reasoning is conducted. Fuzzification, Base rule, and Defuzzification are the three fundamental components of FLC. Another the author-style two-input (antecedent) criterion contains the following structure:

\[ D = X_3 \text{ if Error is } X_1 \text{ and Change Error is } X_2. \]

Wherein Failure, Shift Errors, and D are both input or outcomes, and X1, X2, and X3 are linguistic concepts related to each of them. The website describing the roles shown in Table 1 defines the standards for the intended interaction among the input and output variables.

<table>
<thead>
<tr>
<th>Ch_Error</th>
<th>Error</th>
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<tbody>
<tr>
<td>Very small</td>
<td>Very small</td>
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<tr>
<td>Very small</td>
<td>PG</td>
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<td>Small</td>
<td>PG</td>
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<td>Medium</td>
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<td>Large</td>
<td>PP</td>
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<td>Very large</td>
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3.3. Modified Mayfly Optimization

The MA hybridized computational structure is based on the spinning mayfly males’ sexual conduct, which attracts females. This technique builds on the MMO framework by combining the advantages of genes (GA) and FA.

3.3.1. Mayfly movement

Two individuals of MA seek regionally while adjusting their velocity and position under predetermined rules. Males modify their stances to compare with one another. Male members’ positions and speeds might be calculated using Equations (1) and (2), respectively.

\[ w_{j}^{l+1} = w_{j}^{l} + u_{j}^{l+1} \quad (1) \]

\[ w_{j}^{l+1} = u_{j}^{l} + b_1 f^{-\beta a_{2}} (obest_{j} - w_{j}^{l}) + b_2 f^{-\beta a_{2}} (hbest - w_{j}^{l}) \quad (2) \]

\( w_{j}^{l} \) represents Mayfly’s location during the r repetition; \( u_{j}^{l} \) relates to the mayfly’s l repetition r velocity; \( obest_{j} \) identifies the highest place that mayfly I have attained; \( b_1 \) and \( b_2 \) have favourable attraction factors; \( s_{q} \) refers to the Cartesian separation among everyone’s ideal location with its mayfly’s current location.

The most talented female is allocated to the greatest men, and so on, to elucidate the sexual process. This allows the speed as well as the location of the female mayfly to be represented as follows:

\[ u_{j}^{l+1} = u_{j}^{l} + b_2 f^{-\beta a_{2}} (w_{j}^{l} - z_{j}^{l}), e (z_{j}) > e (w_{j}) \quad (3) \]

\[ u_{j}^{l+1} = u_{j}^{l} = ek * q , e (z_{j}) \leq e (w_{j}) \quad (4) \]
\[ z_j^{l+1} = z_j^l + u_j^{l+1} \quad (5) \]

\[ u_j^l \text{ It means the female mayfly's velocity during the } j \text{ stage}, w_j^l \text{ relates the mayfly's positioning during the } l \text{ stage, } q_{ns} \text{ relates to, amongst other factors, the difference in velocity between the male and female mayflies, and } f_l \text{ stands for a sporadic factor.} \]

3.3.2. Mayfly mating

The act of male and female populations merging is the essence of MA. Two groups' combined location number is used to carry out crossover operations under the previous concept of male enticing female. Equations (6) and (7) illustrate its method.

\[ \text{offspring } 1 = K * \text{ male } + (1 - K) * \text{ female} \quad (6) \]
\[ \text{offspring } 2 = K * \text{ female } + (1 - K) * \text{ male} \quad (7) \]

Where \( L \) denotes a chance value falling inside a predetermined range, male denotes a particular male mayfly, female denotes a particular female mayfly, and descendants denote unique descendant mayfly animals.

3.3.3. Fitness Assessment of Mayflies

The later-generation population might take over if it obtains more fitness ratings. of the associated variable in the preceding community on the assumption that its overall size would remain equal; alternatively, the earlier iteration community will persist. The target population should be assessed and chosen at this point using the objective function, \( f(x) \). The problem that needs to be solved has an impact on the choice of the objective function. The third part of this paper's objective function provides a detailed explanation.

\[ u_{\text{max}} = \text{ rand } * (w_{\text{max}} - w_{\text{min}}) \quad (8) \]

The mayfly's particular velocity can easily climb to a high value during the operation of MA, rendering the algorithm useless. Small-speed beings will aid in the method's convergence, hence it is vital to set a speed upper limit and zero beginning speed for newly born everybody.

The computation might be impacted if the individual speed is too low and results in a decrease in the area's optimal rate. As a result, the maximum speed is set under someone's location.

The speed must still be reduced when needed though the highest achievable rate has been set. Thus, the addition of the gravity constant \( g \), that is similar to an MMO's gravity ratio.

The velocity of the male mayfly is calculated by including an enticement part:

\[ u_j^{l+1} = h * u_j^l + b_2 * f^{-\beta q \delta} (obest_j - w_j^l) + b_2 * f^{-\beta q \delta} (hbest - w_j^l) \quad (9) \]

\[ u_j^{l+1} = \begin{cases} 
(h * u_j^l + b_2 * f^{-\beta q \delta} (w_j^l - z_j^l)), \quad e(z_j) > e(w_j) \\
(h * u_j^l + b_2 * f^{-\beta q \delta} (w_j^l - z_j^l)), \quad e(z_j) \leq e(w_j) 
\end{cases} \quad (10) \]

In optimization management, the mayfly's erratic motion factor is useful for escaping the nearby optimum capture, but due to its high beginning value, it will also cause the mayfly to fly across an underdeveloped sector. The new random movement coefficient consequently has to be closely monitored throughout an iterative process in order in decreasing it.

\[ e_i = e_i \delta_i, \quad 0 < \delta < 1 \quad (11) \]
\[ ek_i = ek_i \delta_i, \quad 0 < \delta < 1 \quad (12) \]

Progeny-level variation techniques are introduced to address potential local optimum converging. A mutation in the progeny could force the mayfly to expand to discover the territory.

\[ \text{offspring}_m = \text{offspring}_m + \sigma M_m (0,1) \quad (13) \]

Where, \( \sigma \) denotes a normal distribution \( d \)'s variance, and \( N_m (0, 1) \) denotes a standard normal distribution with a mean.

4. Simulation Results

Simulations of the PV panel, transformer, and the FLC-MMO MPPT control system can be exemplified by the simulation's structure and using Bullet Cluster Optimising Techniques with MPPT fuzziness in Controls built in Matlab/Sim
and illustrated in Fig 2 The final shout shape is the final electricity, the goods produced electricity from the PV in comparison to standard ones, and the result produced power for the FLC under varying environmental conditions, specifically the climate, and sunlight, are shown in Fig 2 to fig 4. The buck-boost converted monitors its voltage, and FLC creates a command signal for the conversion's activity cycles. Since the traditional P&O approach converges slowly, it is disregarded.

The MPP is determined using the Fuzzy-MMO regulator. The power conversion, the PV component, and the suggested MPPT algorithm are all shown in the suggested approach’s graphic. The enhanced a direct-current is used for some reasons, including the fact that it consistently maintains the MPP regardless of sun-shielding or array heat and displays higher standards with the performance of PV arrays’ MPP. The situation of fluctuating solar insulation and the temperature was modelled to replicate the workings of the entire system. The effectiveness is examined using various swarm sizes and repetitions. The algorithm’s completion is dependent on speed and variable randomness. When the radiation level is varied owing to external factors, MMO captures the worldwide ideal value. The Figures 2, 3 and 4 display the various ideal voltage and power spectrum values that apply to each repetition.

![Figure 2 Fuzzy-MMO control of PV system.](image1)

![Figure 3 PV output voltage for different considered control.](image2)
5. Conclusions

In this paper, a better alternative to the MPPT approach using (FLC-MMO) algorithms for solar panels is presented. This technique can monitor the MPP value for challenging settings such as high irradiance as variations. Once the (MPP) is discovered, the continuous oscillation is reduced, which is the approach’s principal benefit. Additionally, the suggested technique can track the MPP in harsh environments, such as those caused by significant irradiance intensity variations. This proposed technique, which addresses a common problem with the traditional MPPT, is based on an optimized approach. The suggested approach outperforms the traditional direct duty cycle method under all temperatures. The findings show that the suggested fuzzy-MMO device surpasses and offers Advantages including improved tracking velocity, absence of oscillations at the MPP, and ability to locate the MPP for any circumstance as well as alterations of protection, and this method is simple to use and can be calculated very quickly; thus, its implementation using a cheap processor is practicable.

Ethical considerations

Not applicable.

Declaration of interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

References


Figure 4 PV output Power for different considered control.


