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A New Dragonfly Optimized Fuzzy Logic-based MPPT Technique for Photovoltaic Systems

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ABSTRACT- Photovoltaic (PV) power systems should be operated at the maximum power point (MPP) for best solar energy utilization, which can be achieved using maximum power point tracking (MPPT) techniques. Perturb & Observe (P&O) and Fuzzy logic MPPT approaches were two of the various strategies that were suggested as effective ways to achieve Maximum Power under Continuous Irradiation. When exposed to changes in environmental conditions, these approaches perform poorly dynamically and exhibit substantial steady-state oscillations around the MPP. To overcome this problem, this paper proposes the Dragonfly optimization-based fuzzy logic MPPT approach for maximum power extraction of photovoltaic (PV) systems. The approaches for implementing FL-based MPPTs that are currently available are not adaptable to the operating point, which varies widely in real-world PV systems with operational irradiance and ambient temperature. The proposed MPPT (DAFLC-MPPT) is straightforward, accurate, and offers quicker convergence to the optimal operating point. With consideration of various operating situations at slow and fast changes in solar radiation, the efficacy and viability verifications of the proposed AFL-MPPT approach are validated. The proposed strategy outperforms the standard P&O and fuzzy logic methods.

Keywords: Maximum power point tracking, Fuzzy logic control, Dragonfly, Photovoltaic, solar energy.

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1. INTRODUCTION

The research is shifting towards the development of Renewable energy sources (RES) as a result of the rising power demand, rising global warming effect, and rising pollution levels[1]. PV systems are regarded as one of the leading RESs because of their numerous advantages, including the absence of moving parts, a wide range of power scaling, abundant availability, costlessness, no fuel expenditure, unlimited and non-depleted, clean and safe energy[2].

Though, the PV systems have significant disadvantages, including higher installation costs and a range of power conversion efficiencies (14–19%) depending on the climate[3]. The ambient temperature, irradiances, and operating loads are three variables that affect the non-linear P-V and I-V characteristics[4]. Generally speaking, to achieve optimal efficiency and power extraction from the PV system, it must be operated at a specific location on the P-V curve[5]. To extract the MPP from the PV system, a proper MPPT controller is required.

An electronic system called the MPPT method gives the required duty cycle to the DC-DC converter in order to generate maximum power output[6]. The efficiency, execution, difficulty, irretrievable energy, and total cost are just a few of the important variables that need to be taken into consideration while constructing the MPPT method for PV systems. On the above basis these, various MPPT approaches turned out and categorized into three main groups[7, 8]. The first type of MPPT technique calculates MPP using a priori data rather than continuously monitoring the current and voltage[9, 10]. Less voltage and/or current sensors are needed, which is these approach's main benefit. However, those methods don't track exact MPPs for altering insolation and temperatures[11].

The second type of MPPT approach extracts the MPP regardless of prior data. Additionally, these methods are accurate for varying temperatures and insulations[10-13]. Conventional methods have a fixed step size, and their inherent oscillations reduce efficiency and also moves away the operating point from MPP. The third group includes hybrid MPPT methods and meta-heuristics methods that draw on both measurement and a priori data [10].

The drawbacks of metaheuristic methods are high initial oscillations at MPP and slow tracking speed[14]. However, these heuristic-based MPPT techniques track the MPP with better efficiency. Hence, considering the advantages of heuristic techniques and fuzzy logic control (FLC), this paper proposes a

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new dragonfly optimization of FLC approach-based MPPT. In this proposed method, the dragonfly optimization algorithm (DOA) tunes the scaling factors of membership functions of FLC. The efficiency of this dragonfly algorithm optimized (DAFLC) MPPT is compared and validated with the conventional FLC and P&O methods. The proposed can achieve MPP for any abnormal conditions and tracks with better efficiency, faster tracking speed, and fewer steady state fluctuations at MPP.

The remainder of this paper is summarized follows: The modelling of PV system is presented in the next section. *Section 3* gives the details of DC-DC converter. Additionally, *section 4* offers the FLC approach's overall framework for tracking MPPT. Also shows the proposed AFLC and the optimization of FLC parameters using the DA algorithm. The *section 5* deals the results and discussions. Finally, the last section provides conclusion.

2. PV CELL MODELLING

The majority of PV cell is made of silicon which is a crystalline substance that conducts electricity whenever light strikes it, converting the light's energy into electrical energy[15]. PV cells are typically represented using electrical circuit equivalent models with one or two diodes. However, the one-diode model PV cell is widely used because of its simple construction and implementation[16]. *Figure 1* shows a similar model for solar cells.

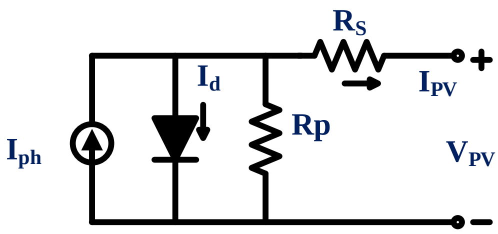

Figure 1: PV cell

We can find the load current shown in *equation (1)* by using Kirchhoff's current rule (KCL):

$$I_{PV} = I_{ph} - I_D - \frac{V_{PV} + R_S * I_{PV}}{R_P} \quad (1)$$

Where I_{ph} is the photo current, I_D is the current through diode, V_{PV} represents PV cell voltage, R_S is series and R_P is the parallel resistance of the PV cell[17].

The photocurrent, I_{ph} can be written as:

$$I_{ph} = \frac{G}{G_{ref}} \left[I_{phref} + \mu_{sc} \left(T_{cell} - T_{ref} \right) \right] \quad (2)$$

Where T_{cell} and T_{ref} represent PV Cell and standard temperatures in kelvin, G denotes Insolation, μ_{sc} represents temperature coefficient.

Also, the current, I_D can be stated as:

$$I_d = I_o \left(e^{\frac{V_{PV} + R_S * I_{PV}}{V_t}} - 1 \right) \quad (3)$$

Where, V_t represents thermal voltage

The current Io can be obtained as:

$$I_o = I_{o,ref} \left(\frac{T_{cell}}{T_{ref}} \right)^3 \exp \left[\left(\frac{q \varepsilon_G}{A.K} \right) \left(\frac{1}{T_{ref}} - \frac{1}{T_{cell}} \right) \right] \quad (4)$$

Where I_o represents diode saturation current.

3. DC-DC CONVERTER

The dc-dc boost converter is typically used as an interface between the inverter and PV array. *Figure 2* depicts the PV system with a common boost converter circuit schematic for MPP. Boost converters (BC) are used to increase the voltage of PV to the required level for grid connection synchronization and tracks the global MPP by using MPPT[18]. Here, a BC's output voltage is determined by the duty cycle. This duty cycle is tuned using the MPPT approach. The relationship between the input and output voltages of a BC are is represented as follows:

$$\frac{V_o}{V_i} = \frac{1}{1-D} \quad (5)$$

Where, V_O is the output Boost converter, V_i is the PV voltage input to boost converter, and D = duty cycle.

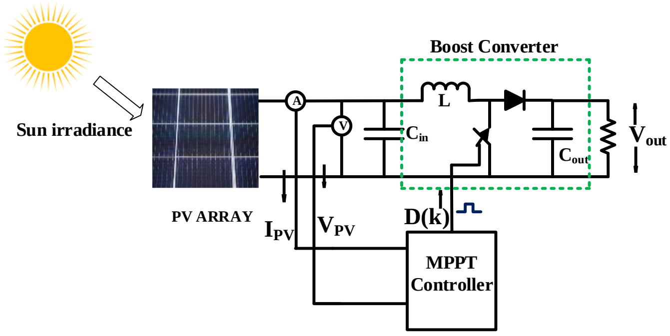

Figure 2: DC-DC Converter Model.

4. MPPT TECHNIQUE

The FLC-based MPPT approach for PV systems has gained in popularity during the past ten years. As shown in Figure 3, the FLC setup may be broken down into three phases: fuzzy inference engine, fuzzification, and defuzzification[19]. During the fuzzification stage, the defined Membership functions are used to convert the clean input variables into linguistic labels. The fuzzy inputs produced as a result of fuzzification are known as fuzzy outputs in the second stage, which is where a verbal choice is produced. On the basis of these fuzzy inputs, the fuzzy inference engine creates fuzzy output using the "if-then" idea included in the rule base. The final stage involves converting the fuzzy output into crisp values.

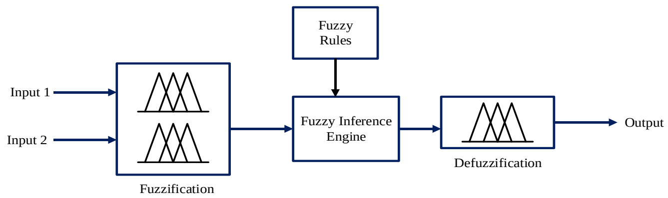

Figure 3: FLC setup

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Two inputs and one output make up the traditional FLC-based MPPT, which produces the PV system's MPP. The parameters specified in *equations (6)* through *eq. (8)* are

$$e(k) = \frac{dP}{dV} = \frac{P(k)-P(k-1)}{V(k)-V(k-1)} \quad (6)$$

$$de(k) = e(k) - e(k-1) \quad (7)$$

Also, the output is

$$dD(k) = D(k) - D(k-1) \quad (8)$$

Where e(k) is error *i.e.*, change in P-V slope

de(k) is the change in error

D(k) is the change in Duty

Figure 4 illustrates the input and output MFs of the FLC. Small Positive (SP), Big positive (BP), zero (ZE), Big negative (BN) and Small negative (SN) are the five MFs used in input1 (error), input2 (change in error) and output variables. At a stable state, oscillations and rapid tracking speed are reduced using the FLC rule base presented in *table 1*. In this study, the well-known and often used min-max approach is used. The centroid of area method is used in defuzzification approach, which is employed with FLC, is expressed as follows:

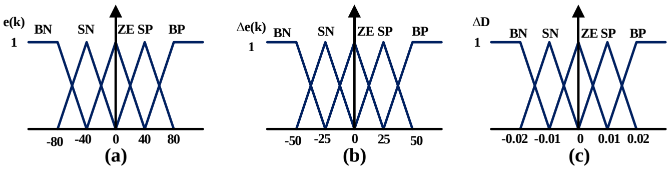

Figure 4: Input and output MFs of the FLC

Table 1. FLC rules for MPPT

e(k)	de(k)				
	BN	**SN**	**ZE**	**SP**	**BP**
BN	BN	BN	SN	BN	BN
SN	BN	SN	SN	SN	BN
ZE	SN	SN	ZE	SP	SP
SP	BP	SP	SP	SP	BP
BP	BP	BP	SP	BP	BP

The rule base and MFs that make up FLC's parameters have a significant impact on how well it performs. Without precise knowledge of the system, this parameter selection would not be adequate. As a result, conventional FLC might not perform at its best under fluctuating insolation and temperature. The scaling factors of MFs are optimized using a DA technique to address the aforementioned problem.

4.1 Proposed AFLC

There are some examples of the traditional FLC technique using the wrong MFs. The scaling factor of the input and output variables of the MFs were adjusted by numerous authors using swarm optimization approaches to address this issue. The tuning of fuzzy parameters can be done in a variety of ways[20, 21]. An innovative Dragonfly optimization algorithm (DOA) technique is employed in this paper to fine-tune the scaling factors of MFs of FLC depending on the difficulty and demands of MPPT technique of the PV system. The thorough description of DA provided in Reference. Figure 5 illustrates the proposed controller's construction. Because there are fewer variables to optimise, MF's scaling factors are tuned instead of ranges of fuzzy set. To achieve MPP with fast-tracking speed, the scaling factors of MFs are tuned. The cost function is used to determine the ITAE criterion, which is written as:

$$ITAE = \int_0^{\infty} t * |e(t)|dt \quad (9)$$

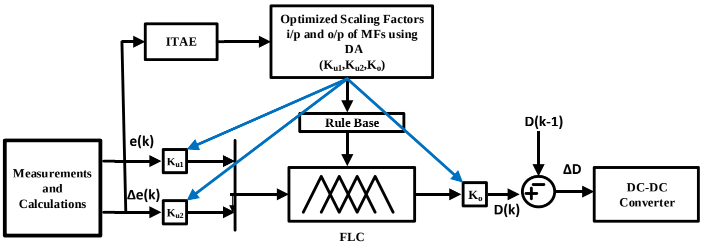

Figure 5: Proposed DA optimized FLC

4.2 Dragonfly Optimization Algorithm for MPPT

An initial duty cycle is the first step in the MPP tracking process. At this stage, the initial PV power is calculated by measuring the BC's input voltage and current. Now, the controller adjusts the duty cycle based on the initial fluctuations in power. New voltage and current measurements are made at this point, and the next power P_{PV} (k+1) is measured. At this stage, on the basis of historical and current data on the PV power, the MPPT controller chooses to rise or reduce the duty cycle. This tracking procedure continues till the MPP arrives.

An intelligent search-optimization method is the dragonfly optimization algorithm (DOA), a type of evolved algorithm[22]. The idea was inspired by the dynamic and static behaviors of these dragonflies. The dragonfly's little group that forages for food in a restricted area are referred to as static. The flying paths of each fly change abruptly and quickly throughout fly movement. A significant number of flies moving steadily across a large region to travel from one location to another is known as a dynamic swarm. Since the objective of dragonflies swarming behavior is similar to the optimization issue, the exploitation phase is described by their static behavior, or that of swarm dragonflies (DFs). This laid the ground work for DOA. Five characteristics of DFs separation, alignment, cohesiveness, food, and enemy are discussed to create the mathematical model for representing the dragonfly's movement in a cluster. The separation, alignment, cohesiveness, food, and adversary qualities of a single dragonfly in a cluster are represented by the Sep_i, Alg_i, Coh_i, Af_i, and Ee_i. The separation, alignment, cohesiveness, food, and adversary qualities of a single dragonfly in a cluster are represented by the Sep_i, Alg_i, Coh_i, Af_i, and Ee_i. The distance among adjacent DFs is essential to maximizing the search space and preventing collision within the given locality. The number of people in a group with 'n' neighbours is denoted by the symbol i. Equation (10), where x is the present position of the DFs and X_k is the position of the k^{th}

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neighbouring DFs, is used to illustrate the Separation Sep_i of *i* individual in a cluster.

$$Sep_i=\sum_{k=1}^{n}(x-x_k) \quad (10)$$

Where Sep_i - *Separation of the* i^{th} *individual DFs*

Alg_i, the alignment term shown in *Equation (11)*, is used to compare the individual's velocity to other DFs in the same region. The velocity of the k^{th} nearby DFs is represented here by V_k.

$$Alg_i = \frac{\sum_{k=1}^{n} Vk}{n} \quad (11)$$

Where Alg_i - *Alignment of the* i^{th} *individual DFs*

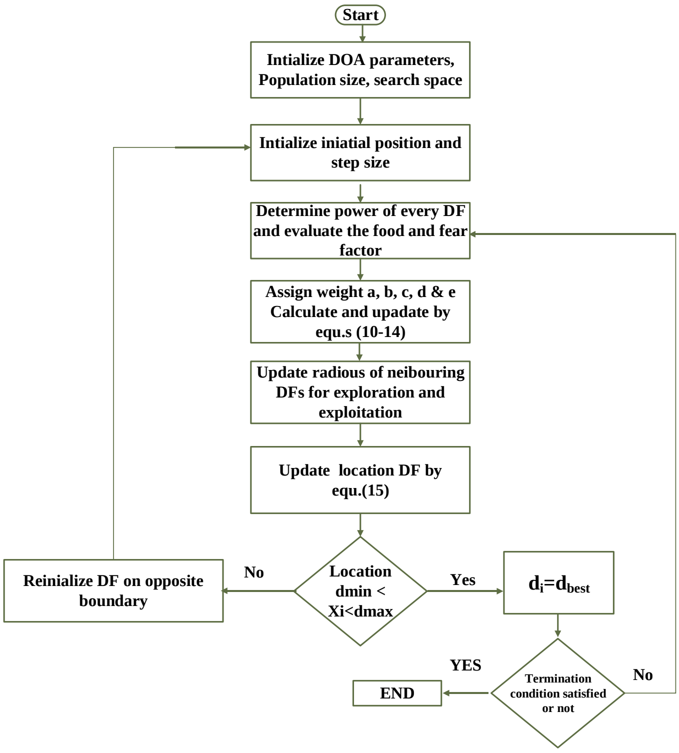

Figure 6: DOA Flow chart

The mass centre of nearby DFs is where all of the individuals in a cluster of DFs are prone to move. *Equation (12)* determines the DF's cohesiveness characteristic

$$Coh_i = \frac{\sum_{k=1}^{n}(Vk)}{n} \quad (12)$$

where Coh_i - *Cohesion of the* i^{th} *individual dragonfly*

As food is necessary for survival, everyone in a cluster tends to go in its direction. *Equation (13)* is used to determine the location's attraction to food, or Afi characteristic.

$$Af_i = x_{food} - x \quad (13)$$

where Af_i - *Food attraction*

The entire group tends to flee from the adversary. *Equation (14)* can be used to determine the enemy feature Eei at the enemy x_e position.

$$Ee_i = x_e + x \quad (14)$$

Where Ee_i - *Enemy position*

Combining these five criteria has an impact on how DFs behave in a cluster.

Equation (15) represents the revised location of each individual DFs as determined by step Δxi.

$$x_i = x_i + \Delta x_i$$

$$\Delta x_i = w\Delta x_i + (a.Sep_i + b.Alg_i + c.Coh_i + d.Af_i + e.Eei) \quad (15)$$

Where *w - Inertial weight,* Δx_i *- Step size of DF movement, a - Separation of weight, d - Food factor, b - Alignment weight, c - Cohesion weight, e - Enemy factor.*

Where the alignment, separation, and cohesion weights are represented by letters *a, b,* and *c*, respectively; the food factor is represented by the letter *d*; and the adversary factor is represented by the letter *e*. The separation, alignment, cohesiveness, food, and adversary qualities of a single dragonfly in a cluster are represented by the *Sepi, Algi, Cohi, Afi*, and *Eei*.

By employing various values of the parameters, it is possible to realize the variance in the exploitative and explorative behavior of the DFs. In *figure 6*, you can also see the DOA flowchart.

5. SIMULATION RESULTS AND DISCUSSIONS

To test the efficacy of the proposed method, a PV system model was made using the MATLAB-Simulink. The PV system is made up of the resistive load seen in *figure 2*, a BC with MPPT technology, and a PV module. With different insolation and temperature profiles, it is shown how the proposed MPPT methodology outperforms existing techniques like traditional FLC and P&O FLC method in terms of tracking speed and efficiency. Pmax = 36.3W, Vmpp = 12.36V, Impp = 2.93A, Voc = 16V, and Isc = 3.11A are the simulation parameters taken into account to represent the PV module. L = 10mH, Cin = 100°F, and C = 300°F are the boost converter components that were selected for the simulation.

5.1 Uniform Irradiance

The input irradiance for the PV system under consideration in this instance is uniform (1000W/m2) at 25^{0}C. *Figure 7* depicts the PV system's output power with three MPPT approaches, and *table 2* presents a quantitative analysis of *figure 7*.

Table 2. Comparison of MPPT techniques

MPPT technique	Tracking speed (sec)	Maximum Power (KW)	Power at MPP (KW)	Tracking efficiency
P&O	0.22	36.34	36.185	99.57
FLC	0.18		36.24	99.72
Proposed DA optimized FLC	**0.093**		**36.27**	**99.81**

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Table 2 shows that the suggested DA-optimized FLC MPPT outperforms all previous MPPT algorithms documented in the literature, achieves an MPP of 36.27W with faster tracking speed. When the insolation level rises or falls, these output powers change.

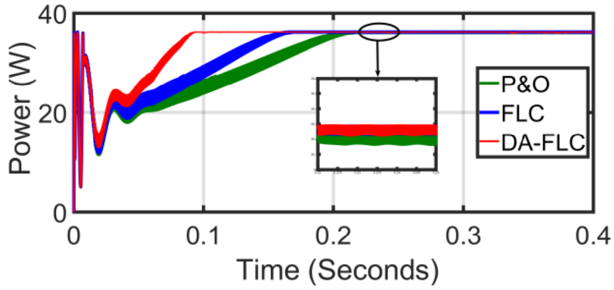

Figure 7: The PV system output power for DA-FLC, FLC, and P&O.

5.2 Step change Irradiance

In this case, the suggested DA-optimized FLC is tested against the traditional FLC and P&O MPPT approaches using the step-change insolation profile presented in *figure 8*. It is evident from the simulation results shown in *figure 9* that the suggested MPPT method surpasses both traditional FLC and P&O in terms of MPP convergence, tracking speed, oscillations at MPP, and efficiency. It can continuously manage the maximum power under irradiance conditions that change quickly. It is undeniable that changes in irradiance have less of an impact on PV voltages.

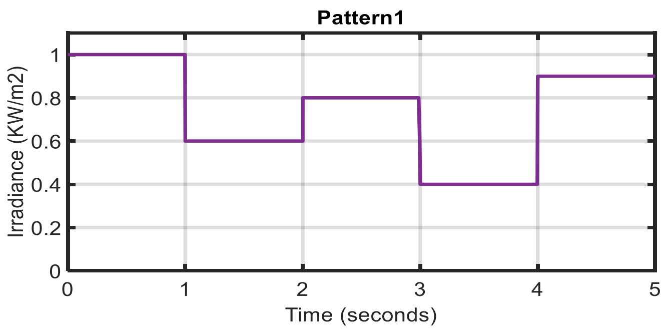

Figure 8: Step changing insolation profile.

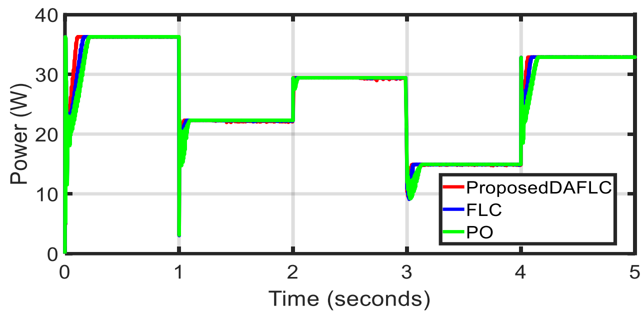

Figure 9: The PV system output power using DA-FLC, FLC, and P&O for step changing irradiance.

5.3 Linear and Step changing Irradiances

In this case, the linear and step changing irradiances shown in *figure 10* are employed to assess the efficacy of the suggested DA-optimized FLC. The output power for this linear and step changing insolation profile is shown in *figure 11*. In every linear and step change in irradiance, the suggested DA-optimized FLC achieves MPP more quickly than traditional MPPT techniques, and it also continuously tracks MPP in linear changing insolation without any oscillation at the MPP.

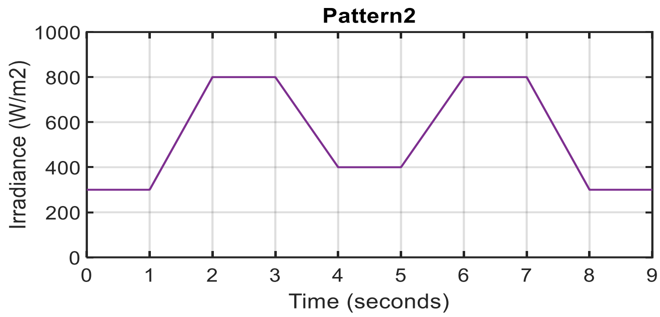

Figure 10: Linear and step changing insolation profile.

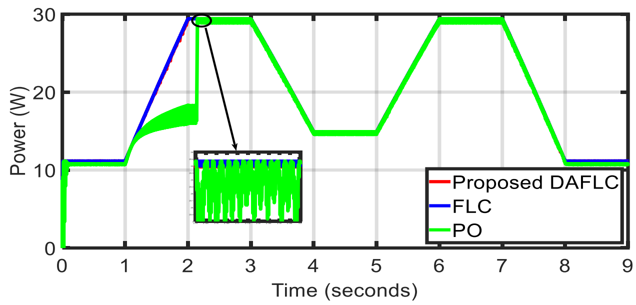

Figure 11: The PV system output power using DA-FLC, FLC, and P&O for linear and step-changing irradiance.

Table 3 compares the proposed DA optimized FLC MPPT's performance to other well-known MPPT methods that have been reported in the literature. In comparison to the conventional FLC and P&O approaches, the suggested MPPT technique offers higher tracking efficiency, less oscillations at MPP, rapid tracking speed, and greater reliability. The proposed DA optimized FLC MPPT tracks MPP with faster tracking speed and less oscillations than the Ant colony optimized (ACO) fuzzy controller.

Table 3. A qualitative comparison of MPPT techniques

Creteria	P&O	FLC	Fuzzy-PSO	ACO-FLC	Proposed DA-FLC
Tracking speed	Slow	Moderate	Moderate	Moderate	Fast
Tracking efficiency	Less	Medium	Medium	Medium	High
Complexity	Less	Less	Moderate	Moderate	Less
Tracking accuracy	Medium	Medium	Medium	Medium	Accurate
Reliability	Low	Moderate	High	Low	High
Oscillations at MPP	High	Medium	High	moderate (constant oscillations at MPP)	Less

Furthermore, ACO-FLC MPPT has more complexity because it has more algorithmic parameters, which increases the

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possibility of local best convergence. The PSO algorithm is utilized in the Fuzzy-PSO to modify the scaling factors of the MFs of FLC in order to track global MPP. However, the PSO technique has a sluggish convergence rate due to the larger number of initialization parameters (r1, r2, c1, c2), and if the initialization values are chosen incorrectly, it could result in divergence. As a result, compared to Dragonfly optimization, the PSO requires greater processing time. Consequently, under changing irradiance conditions, the proposed DA optimized FLC MPPT has a rapid response time, less oscillations, and a fast-tracking speed. The proposed technique is a little difficult for implementation concerning P&O or IC due to the fuzzification and defuzzification process.

CONCLUSION

In this paper, a new DOA tuned FLC based-MPPT method is proposed for extracting the MPP of the PV system. The proposed MPPT, traditional FLC and P&O methods were tested using MATLAB/Simulink software for various sudden changing irradiance conditions. The input and output variables of the FLC are modified with a DOA to enhance the performance of the MPPT to extract maximum PV power output. The proposed MPPT method performance is compared with traditional FLC and P&O based MPPT techniques. The results of the simulation led to the following conclusions. With less steady-state oscillations and quick tracking speed and efficiency, the proposed approach was proven to have good tracking performance even under a variety of environmental situations. Thus, in order to attain greater energy conversion efficiency, the proposed method can also be applied to hybrid solar-wind systems.

REFERENCES

[1] I. Hanif, B. Aziz, and I. S. Chaudhry, "Carbon emissions across the spectrum of renewable and nonrenewable energy use in developing economies of Asia," *Renewable Energy*, vol. 143, pp. 586–595, 2019.
[2] E. Alsema, "Energy payback time and CO2 emissions of PV systems," in *Practical Handbook of Photovoltaics*, Elsevier, 2012, pp. 1097–1117.
[3] A. Sahu, N. Yadav, and K. Sudhakar, "Floating photovoltaic power plant: A review," *Renewable and sustainable energy reviews*, vol. 66, pp. 815–824, 2016.
[4] T. M. Chung, H. Daniyal, M. H. Sulaiman, and M. S. Bakar, "Comparative study of P&O and modified incremental conductance algorithm in solar maximum power point tracking," 2016.
[5] B. Yang *et al.*, "Comprehensive overview of maximum power point tracking algorithms of PV systems under partial shading condition," *Journal of Cleaner Production*, vol. 268, p. 121983, 2020.
[6] Himabindu Eluri,M.Gopichand Naik,"Energy Management System And Enhancement Power Quality With Grid Integrated Micro-Grid Using FuzzyLogic Controller",International Journal Of Electrical And Electronics Research (IJEER),Vol.10,Pp.256-263,2022
[7] C. Xu, K. Itako, T. Kudoh, K. Koh, and Q. Ge, "Proposal for an active PV array to improve system efficiency during partial shading," *IEEE Access*, vol. 9, pp. 143423–143433, 2021.
[8] H. F. Hashim, M. M. Kareem, W. K. Al-Azzawi, and A. H. Ali, "Improving the performance of photovoltaic module during partial shading using ANN," *International Journal of Power Electronics and Drive Systems*, vol. 12, no. 4, p. 2435, 2021.
[9] M Rupesh, Dr. Ts. Vishwanath, "FUZZY And ANFIS Controller to Improve the Power Quality of Grid Connected PV System with Cascaded Multilevel Inverter", 2022 International Journal of Electrical and Electronics Research (IJEER), vol.9, pp.89-95, 2022.
[10] L. Bhukya, N. R. Kedika, and S. R. Salkuti, "Enhanced maximum power point techniques for solar photovoltaic system under uniform insolation and partial shading conditions: a review," *Algorithms*, vol. 15, no. 10, p. 365, 2022.
[11] L. Bhukya and S. Nandiraju, "A novel photovoltaic maximum power point tracking technique based on grasshopper optimized fuzzy logic approach," *International Journal of Hydrogen Energy*, vol. 45, no. 16, pp. 9416–9427, 2020.
[12] L. Bhukya, N. R. Kedika, and S. R. Salkuti, "Enhanced maximum power point techniques for solar photovoltaic system under uniform insolation and partial shading conditions: a review," *Algorithms*, vol. 15, no. 10, p. 365, 2022.
[13] R. B. Bollipo, S. Mikkili, and P. K. Bonthagorla, "Critical review on PV MPPT techniques: classical, intelligent and optimisation," *IET Renewable Power Generation*, vol. 14, no. 9, pp. 1433–1452, 2020.
[14] S. Vijai Ananth and S. Singaravelu (2023), Modelling and Simulation of MPPT Based Solar Photovoltaic System for Voltage Lift LUO Converter. IJEER 11(1), 90-96. DOI: 10.37391/IJEER.110112.
[15] A. Upadhyay and A. Chowdhury, "Solar Energy Fundamentals and Challenges in Indian restructured power sector," *International Journal of Scientific and Research Publications*, vol. 4, no. 10, pp. 1–13, 2014.
[16] N. Barth, R. Jovanovic, S. Ahzi, and M. A. Khaleel, "PV panel single and double diode models: Optimization of the parameters and temperature dependence," *Solar Energy Materials and Solar Cells*, vol. 148, pp. 87–98, 2016.
[17] K. A. Kim, C. Xu, L. Jin, and P. T. Krein, "A dynamic photovoltaic model incorporating capacitive and reverse-bias characteristics," *IEEE Journal of photovoltaics*, vol. 3, no. 4, pp. 1334–1341, 2013.
[18] S. Padmanaban, M. S. Bhaskar, P. K. Maroti, F. Blaabjerg, and V. Fedák, "An original transformer and switched-capacitor (T & SC)-based extension for DC-DC boost converter for high-voltage/low-current renewable energy applications: Hardware implementation of a new T & SC boost converter," *Energies*, vol. 11, no. 4, p. 783, 2018.
[19] Y. Soufi, M. Bechouat, S. Kahla, and K. Bouallegue, "Maximum power point tracking using fuzzy logic control for photovoltaic system," in *2014 International conference on renewable energy research and application (ICRERA)*, 2014, pp. 902–906.
[20] S. A. Osman, R. G. Mohamed, M. A. Ebrahim, and F. A. Bendary, "Optimal tuning of fuzzy logic controller parameters for incremental conductance mppt controller based on grey wolf optimizer algorithm," *Journal of Al-Azhar University Engineering Sector*, vol. 12, no. 45, pp. 1417–1426, 2017.
[21] M. Adly and A. H. Besheer, "An optimized fuzzy maximum power point tracker for stand alone photovoltaic systems: Ant colony approach," in *2012 7th IEEE conference on industrial electronics and applications (ICIEA)*, 2012, pp. 113–119.
[22] M. Mafarja, A. A. Heidari, H. Faris, S. Mirjalili, and I. Aljarah, "Dragonfly algorithm: theory, literature review, and application in feature selection," Nature-Inspired Optimizers: Theories, Literature Reviews and Applications, pp. 47–67, 2020.