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A Review On Artificial Intelligence-Based MPPT And Total Harmonic Distortion Reduction In PV Grids: Insights For Cognitive Adaptation In Reattach Therapy

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Abstract

The increasing use of photovoltaic (PV) systems for sustainable energy faces two major challenges: tracking the global maximum power point (GMPP) during partial shading conditions (PSC) and mitigating Total Harmonic Distortion (THD) caused by fluctuating solar irradiance. These challenges impact the efficiency and performance of PV systems integrated into grid networks. Artificial Intelligence (AI) has proven effective in optimizing Maximum Power Point Tracking (MPPT), addressing both GMPP tracking and THD reduction. Interestingly, AI's adaptive strategies in PV systems parallel cognitive adaptation techniques in ReAttach Therapy, which fosters neuroplasticity and cognitive flexibility in individuals with developmental diversities. Both frameworks rely on timely, dynamic adjustments to optimize outcomes, whether in energy management or cognitive rehabilitation. This review examines AI-based MPPT algorithms and their role in THD reduction, drawing parallels with ReAttach Therapy's adaptive processes. Just as adaptive filters (AF) reduce noise and disturbances in PV systems, ReAttach techniques help individuals adapt to sensory stimuli and improve emotional regulation. The paper highlights how AI-based solutions can inspire advancements in therapeutic approaches by integrating adaptive strategies to enhance performance in both fields. By providing a multidisciplinary perspective, this review offers new insights into selecting optimal AI-based MPPT methods while promoting adaptive strategies applicable in both technological and therapeutic contexts.

Keywords: Artificial Intelligence (AI), Maximum Power Point Tracking (MPPT), Photovoltaic (PV) Systems, Total Harmonic Distortion (THD), ReAttach Therapy, Adaptive Filters (AF)

1. INTRODUCTION

The worldwide shift toward renewable strength assets has positioned photovoltaic (PV) systems as a critical solution for sustainable electricity technology. PV systems, which harness the sun's loose and considerable power, are increasingly more integrated into grid networks. However, regardless of their advantages, PV structures face massive technical challenges, along with the issue of monitoring the worldwide most power point (GMPP) underneath partial shading situations (PSC) and the technology of Total Harmonic Distortion (THD) caused by variable solar irradiance. These issues can avoid power efficiency and degrade the first-rate of electricity provided to the grid.
Artificial Intelligence (AI) has emerged as a transformative generation in addressing those challenges, mainly in enhancing the performance of Maximum Power Point Tracking (MPPT) systems. AI-based MPPT techniques can dynamically adapt to converting environmental conditions, enabling greater correct tracking of GMPP and improving power conversion efficiency. Furthermore, AI methods play a key function in decreasing THD, making sure the delivery of cleanser, extra strong strength to the grid.
Interestingly, the concept of adaptive optimization in AI-primarily based MPPT mirrors cognitive adaptation techniques used in ReAttach Therapy, which promotes neuroplasticity and developmental development in individuals with cognitive challenges. Both structures focus on dynamic edition to obtain choicest consequences, highlighting the interdisciplinary capability of AI solutions.
Conservative power resources are being changes by means of renewable electricity assets (RESs), consisting of tidal, wind solar, and lots of others. Additionally, due to the fact RESs are available, easy, and clean to achieve, they're getting used lots extra frequently. Furthermore, when RESs are used, favorable outcomes had been visible, including a lower in global warming and a lower in carbon dioxide emissions. As a end result, RESs are preferred over traditional assets. The addition of RESs to the modern power system can also meet the growing load call for [1]. Despite their many blessings, wind and sun strength assets are heavily area- and surroundings-established, that is one of the main drawbacks of employing RESs. These obstacles have a bigger effect on grid constancy, which can be abridged through integrating RESs with power garage systems (ESS).

The Static Compensator (STATCOM) in combination with ESS has progressed grid stability and THD [8]. Furthermore, FLC-based totally MPPT algorithms may be used to avoid the uncertainty in RESs. For the cause of lowering weather-related uncertainties when it comes to sun PV output energy, FLC-based totally MPPT has been implemented [13, 14]. The proposed approach, the authors' end, has outperformed the traditional tactics to enhancing strength best.
Study the strategies for harmonic discount inside the technology device and for decreasing THD inside the PV grid. Examine the ways artificial intelligence (AI) is utilized in sun power gadget MPPT. Look into the regions wherein AI is presently being utilized in MPPT development. Compare and compare the effectiveness of every AI set of rules used in MPPT approaches.
All conventional MPPT structures have similar troubles with strength fluctuation, oscillation across the MPP, negative overall performance under PSC and, trapping at a nearby MPP, and speedy irradiance variations [15, 16]. This paper offers a thorough expertise of the maximum current trends and advancements in AI which can be used within the MPPT for sun power structures. As a result, AI is employed to bypass those troubles [17, 18].

1.1 Objective and Contribution

This evaluation objectives to discover the mixing of AI in MPPT algorithms for improving strength performance in PV systems whilst addressing the essential difficulty of THD reduction. The key contributions of this review are:
1. Comprehensive Evaluation: A thorough contrast of the maximum distinguished AI-based totally MPPT algorithms, studying their performance below partial shading and their effectiveness in tracking GMPP.
2. THD Reduction Strategies: An exploration of AI-pushed answers for THD reduction, such as the potential of adaptive filters (AF) in minimizing harmonic distortions and enhancing electricity quality.
Three. Interdisciplinary Perspective: Drawing parallels among adaptive AI mechanisms in PV systems and cognitive edition strategies in ReAttach Therapy, imparting insights into how AI may be leveraged across diverse fields.

2. PV SYSTEM

The global electricity panorama is undergoing rapid changes with growing emphasis on renewable strength resources. Among these, photovoltaic (PV) systems have won prominence due to their ability to transform sunlight immediately into electrical strength. However, as PV structures continue to be integrated into grid networks, they face challenges associated with strength performance and energy satisfactory. Two key troubles that have an effect on PV structures are the correct monitoring of the worldwide most power factor (GMPP) during partial shading situations (PSC) and the mitigation of Total Harmonic Distortion (THD), that can lessen the first-class of the energy furnished to the grid. These challenges no longer simplest decrease the power output of the system but additionally compromise the stability of the grid.

2.1 The Role of MPPT in PV Systems

PV systems are subject to variable environmental conditions, consisting of fluctuations in solar irradiance and temperature, which affect their power output. The primary goal of an MPPT algorithm is to make certain that the PV system operates at its top of the line factor, the Maximum Power Point (MPP), to maximise energy conversion performance. However, in the course of partial shading conditions (PSC), more than one neighborhood maxima can seem inside the energy-voltage curve, making it difficult to pick out the genuine international maximum electricity factor (GMPP) the use of conventional MPPT techniques consisting of Perturb and Observe (PandO) or Incremental Conductance (IC) .
AI-based totally MPPT algorithms have shown extensive promise in overcoming the limitations of conventional MPPT strategies. Techniques consisting of synthetic neural networks (ANNs), fuzzy good judgment, and genetic algorithms have been applied to improve the accuracy of GMPP tracking, especially underneath PSC . These algorithms can adapt to real-time adjustments within the surroundings, making them more powerful in maximizing power output under complicated conditions.

2.2 Artificial Intelligence in MPPT: Techniques and Applications

AI-primarily based MPPT strategies leverage gadget gaining knowledge of and optimization algorithms to decorate the efficiency and flexibility of PV structures. The number one AI strategies hired in MPPT include:
1. Artificial Neural Networks (ANNs): ANNs mimic the structure and function of the human mind, letting them procedure complex, nonlinear relationships in PV structures. By training ANNs on historic records, these models can predict the ideal MPP beneath various conditions, outperforming traditional algorithms in accuracy and pace .
2. Fuzzy Logic: Fuzzy common sense systems use a rule-primarily based approach to approximate the MPP by using handling the uncertainties associated with fluctuating environmental conditions. Fuzzy good judgment controllers can manage nonlinearities inside the PV machine, making them greater strong underneath dynamic conditions like PSC .

Three. Genetic Algorithms (GA): GAs are optimization strategies stimulated through herbal selection. They are used to search for the most reliable MPP by means of iteratively enhancing candidate answers. GAs are particularly powerful in locating the global MPP in systems with more than one nearby maxima .
4. Particle Swarm Optimization (PSO): PSO is another optimization set of rules that models the behavior of a swarm of particles. In MPPT, debris represent ability answers, and the set of rules converges on the most fulfilling MPP via iteratively refining the particles' positions .
Each of those AI strategies offers precise advantages and change-offs in phrases of complexity, computational requirements, and flexibility to environmental changes.

2.3 Total Harmonic Distortion (THD) in PV Systems

THD refers back to the distortion within the waveform of an electrical sign due to harmonics, which are multiples of the fundamental frequency. In PV structures, THD may be caused by fluctuations in sun irradiance and mistaken switching in inverters . High stages of THD can result in bad power quality, decreased performance, and capability harm to electric components.
The integration of AI into MPPT structures has the potential to lessen THD through ensuring smoother transitions among energy states and enhancing the general stability of the machine. Adaptive filters (AF) are specially effective in reducing THD as they can dynamically regulate to clear out unwanted frequencies and harmonics .

2.4 AI-Based THD Reduction Strategies

Reducing THD in PV systems is important for retaining grid balance and making sure high power best. AI-primarily based processes, which include ANNs and fuzzy common sense, were applied to optimize the switching control of inverters, minimizing harmonic distortion. Additionally, adaptive filtering techniques can be integrated with AI algorithms to dynamically adjust the filtering procedure primarily based on actual-time information from the PV system.
One of the maximum promising AI-primarily based solutions for THD discount is using adaptive filters (AF). AFs can dynamically adapt to changing harmonic conditions and take away undesirable distortions within the electricity sign . By integrating AFs with AI-based MPPT systems, it is possible to simultaneously optimize strength extraction and reduce THD, ensuing in improved system performance .

2.5 Parallelism Between AI Adaptation in PV Systems and ReAttach Therapy

An thrilling interdisciplinary connection can be drawn between the adaptive mechanisms in AI-based MPPT structures and the cognitive adaptation strategies utilized in ReAttach Therapy. In each instances, adaptive structures are hired to optimize performance in dynamic environments. Just as AI-primarily based MPPT algorithms adapt to fluctuations in sun irradiance, ReAttach Therapy makes a speciality of assisting people with developmental diversities adapt to sensory stimuli and environmental adjustments, fostering progressed emotional law and cognitive flexibility .
This parallel highlights the capacity for cross-disciplinary learning, in which the improvements in AI-primarily based adaptation for PV structures may want to inspire new therapeutic techniques in cognitive version, and vice versa. Both fields depend on non-stop remarks and adjustment to gain optimum effects, emphasizing the importance of dynamic, actual-time variation in complicated structures.

3. PV GRID WITH TOTAL HARMONIC DISTORTION

The UPQC largely achieves the majority of the specified capabilities, consisting of gadget-extensive voltage, harmonic discount, and modern-day and universal electricity best improvements [19]. UPQC is used to enhance the satisfactory of the energy produced via the PV-WE-ESS-EV machine whilst paired with EVs and ESS. Additionally, UPQC for solar PV structures has been implemented, and its examination beneath an imbalanced loading state has been carried out [21]. The UPQC outperforms opportunity electricity electronic-primarily based FACTS procedures mainly in SVC, DVR, and STATCOM. The authors came to the belief that the UPQC may enhance harmonic mitigation as well as electricity exceptional. It has been mentioned [23, 24] how the NN technique is being used in PV-UPQC and FLC method to enhance electricity quality [19, 22].
It is believed that the UPQC-FLC-EVA technique additionally prevents adjustments to voltage and contemporary waveforms. The IEEE-519 (1992) fashionable's THD threshold restriction is satisfied with the aid of this technique, which yields THD of load and supply-facet voltages and currents which are much less than five% [25].
The system is found to be strong with irradiation versions among 1000W/m2 and 600W/m2. It may be visible that PV-UPQC, which combines distributed technology with electricity first-class improvement, is a promising answer for modern distribution systems [26].

3.1 PV device DC-DC converters

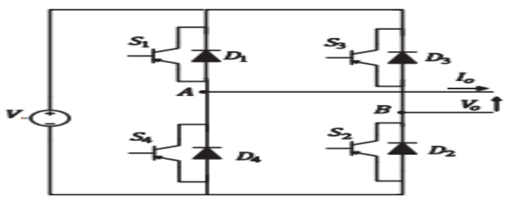
Due to its more capability to preserve the output DC signal at a particular degree and decrease THD caused by conversion, in PV systems dollar-increase converter has been used more regularly than others. The DC output voltage is substantially encouraged by means of the PWM control signal's switching frequency. [29, 31, 32] The appropriate DC-DC converter architecture have to be followed on the way to growth the harvest electricity of sun PV systems. This choice is influenced by way of the PV array configuration [29]. These topologies can manipulate and alter the DC output voltage to a appropriate stage with the aid of functioning as switching mode regulators. Table 1 provides a summary of some of the essential works inside the place of DC-DC converters.

Table 1 Summary of the conversion section's reduction

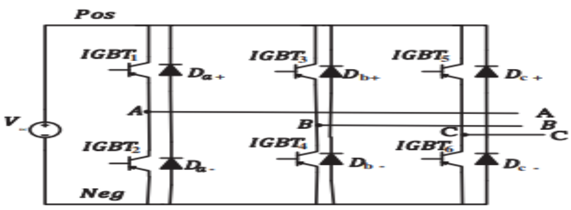
Reference	Contribution	Shortcomings
33	Investigated the buck-boost converter's nonlinear behavior, which caused distorted converter output voltage and rippling PV output voltage.	Only decreased the alteration caused by the conversion and PV cell components
35	In order to create a new interleaved and isolated boost converter suitable for low to high DC-DC converter applications and minimise the pressure on the voltage and current during power changes.	Condensed the alteration caused only by the converter and PV cell elements.
36	The grid-connected PV system employs a full-bridge DC-DC converter with zero voltage switching modes and high frequency switch loss reduction.	Only decreased the alteration caused by the conversion and PV cell components
37	Push-pull converter architecture was developed to evaluate the needs of a PV system and lessen the voltage strain on power switches.	Neglected to take into account the increased conduction power loss caused by the push-pull converter configuration
38	Under varied operating conditions, it was anticipated that integrating the MPPT controller and boost converter would maximise the output of the solar cell.	Only reduced the distortion brought on both the conversion and the elements of the PV cell

3.2 Solar power system DC-AC inverters

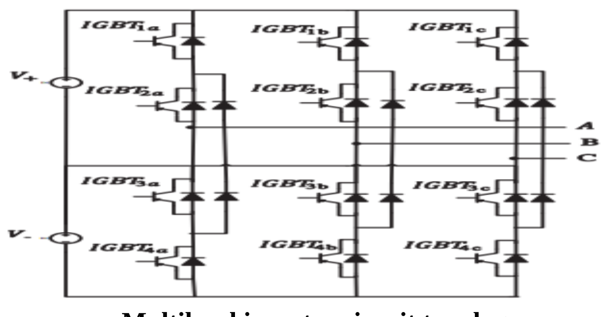
Many diverse forms of inverters have been integrated to connect PV arrays with the functional grid. These inverters must convert the DC signal produced by the PV array or the DC-DC converter into the desired frequency and amplitude of the AC signal required by the load. DC-AC inverters are the third source of THD in PV systems because they often switch operations at different switching frequencies [39]. [40, 42] There are now three different types of inverters: single-phase, three-phase, and multilevel, as shown in Figures 1(a), (b), and (c) (MLI).



a. An inverter using a single phase's circuit topology



b. A three-phase inverter's circuit topology



c. Multilevel inverter circuit topology

Figure 1(a, b, c) Different circuit topology of inverter

The DC supply may be taken into consideration during inverter design. PWM techniques are used to obtain the appropriate output amplitude. Space Vector PWM (SVPWM), [45, 46] discontinuous PWM, [47] and three-dimensional PWM, were formerly in use [48]. For illustration, when provided is a current source, a current source inverter (CSI) is utilized, and when the supply is a current source, a voltage source inverter (VSI) is used. While a CSI employs a big inductor, a VSI uses a huge capacitor across the DC bus. Voltage- or current-controlled VSIs and CSIs can be used, depending on the inverter output type. Early studies used VSIs [43] and provided a full explanation of CSIs [44]; the output voltage was almost entirely free of harmonics. Table 2 provides an overview of some of the most important studies in these two research areas.

Table 2 Summary of the inverter section decrease

Reference	Contribution	Shortcomings
49	Suggested a responsive current management technique to reduce the three-phase utility grid-connected PV inverter's current harmonic distortion.	It is impossible to completely remove the distortion that led to the anomalous voltage behaviour at the load level.
52	presented a contrast between the two-level inverter and the MLI and a pulse PWM control strategy for the MLI to eliminate THD.	To minimise the THD produced by this PV system component, only two types of inverters may be used.
53	SVPWM and SPWM were used to reduce harmonics on three-phase VSIs.	Focuses on the generated THD under particular conditions.
54	To maximize THD reduction, it was suggested utilizing GA in a 13-level cascaded MLI with an uneven DC source..	The inverter's architecture was slightly more complex than typical with the single objective of lowering the THD produced by the inverter section.
55	Projected a method that is ideal for removing certain harmonics at the output voltage of a 15-level cascaded single-phase stand-alone PV MLI.	The inverter's planning is intricate and only concentrates on certain harmonics.
56	A step variable inductor system was used to manage THD at the output of the VSI adjustable hysteresis band control.	Although a variable inductor reduced the inverter's switching frequency, it may not be a good idea to use one for THD reduction.

Various methods are available to prevent the rise in system complexity. Figure 2 [57], adaptive selective harmonic elimination (ASHE) is the first. Attacking a single particular harmonic at a chosen frequency is the main idea of ASHE. Usually, the third harmonic is the one to be removed. The fundamental flaw in this strategy is that it can only eliminate one harmonic. Utilizing adaptive filters, as illustrated in Figure 3, is another option. The fundamental objective of this method [40], which differs slightly from the conventional adaptive filter seen in Figure 5, is to minimize all of the harmonics present in the signal, regardless of their strength or frequency.

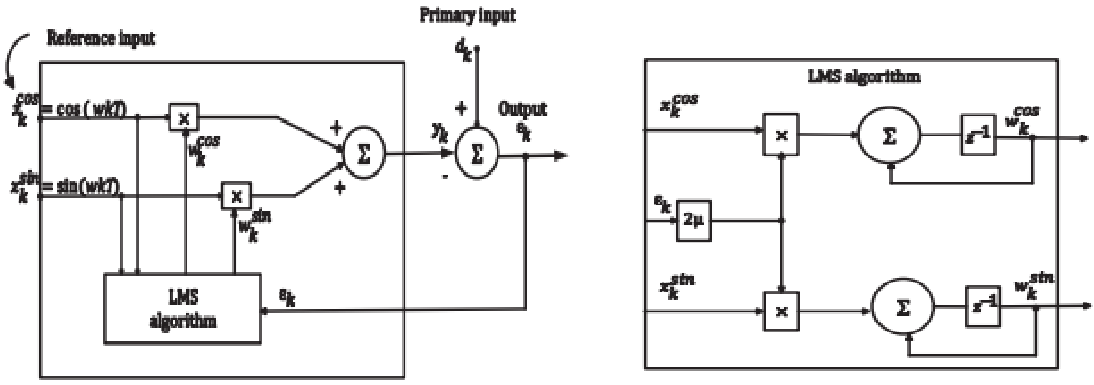


Figure 2 Block diagram for adaptive selective harmonic elimination

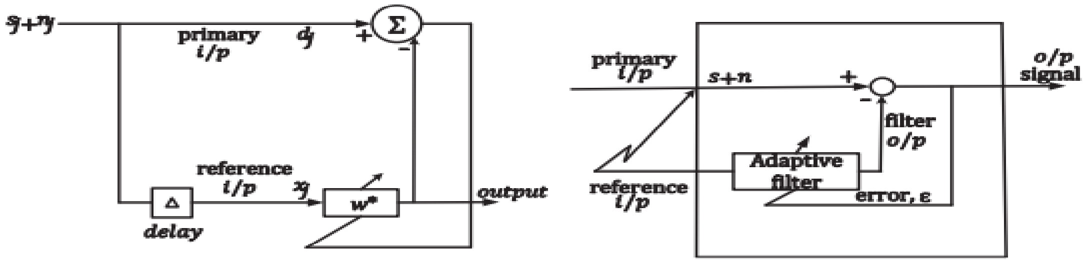


Figure 3 An adaptive filter's noise-cancelling block diagram

4. AI BASED MPPT

Because the designer must first mathematically model the plant before it can be managed, the design of a conventional control (CC) system requires mathematical modelling, also referred to as the mathematician's technique. On the other hand, in order to create an IC system, the inputs must account for the system behavior, and the IC system is in charge of autonomous and abstract modeling [58].

4.1 Fuzzy Logic Controller (FLC)

The FLC control machine converts non-stop digital values among 0 and 1 from analogue inputs the use of fuzzy good judgment [59]. It was evolved to remedy the drawbacks of conventional MPPT techniques, which include regular-state accuracy troubles, prolonged settling instances, and oscillation round MPP (SSE). It is easy to construct for the motive that it performs no longer necessitate expertise of a precise MPPT representation. Thus, FLC has gained popularity during the last ten years [60]. HC approach much like PandO and IC can incorporate FLC [61]. Fuzzy policies are created with the aid of FLC the use of the HC set of rules [62]. When there may be a trade in irradiance and a load modern, it's been established to offer superior electricity performance than the HC algorithm [63].

$$dP_{PV} = E_{rr} = \frac{P_{PV}(k) - P_{PV}(k-1)}{V_{PV}(k) - V_{PV}(k-1)} \quad (1)$$

$$\Delta \frac{dP_{PV}}{dV_{PV}} = \Delta E_{rr} = E_{rr}(k) - E_{rr}(k-1) \quad (2)$$

Where Err is the wide variety of errors and PPV and VPV are the energetic strength and voltage outputs of PV panels, respectively; DP stands for the energy trade ratio; DV stands for voltage version; DErr stands for mistakes change fee; Any low- to medium-powered microcontroller can create a fuzzy controller to adjust the output responsibility cycle D of the DC-DC converter based totally on T and Ee, which appears for the MPP of the sun energy gadget [64]. Examples of such microcontrollers consist of the Arduino Mega and Microchip. The dynamic of solar irradiance influences sun power [65]. A subject-programmable gate array (FPGA) can be used to reprogram FLC, making it very flexible and adaptable [66].

Reduced-rule FLC (RR-FLC), some other version of FLC, increases FLC's simplicity by lightening its computing burden [67]. Additionally, there are TakagiSukeno (T-S) and Mamdani design techniques for FLCs, the latter of which is extra broadly used [68]. Fuzzification, fuzzy policies, and defuzzification are the three steps that make up FLC in maximum cases [69]. Using loads of membership features that have been installed, the enter variables are first transformed into linguistic variables [70]. The machine's favored conduct is then implemented to these variables inside the following level, which is primarily based at the "if-then" policies. These variables are eventually transformed into mathematical variables [58]. The pace and accuracy of FLC are notably impacted by way of the club features [71].

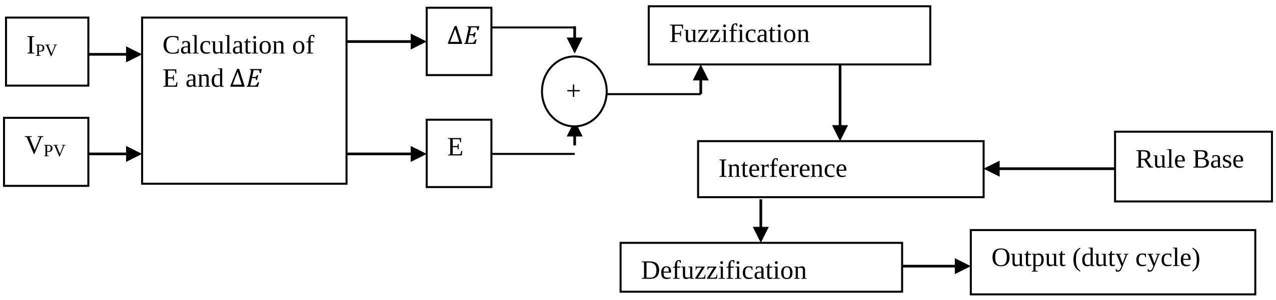


Figure 4 FLC block diagram in general.

Figure 4 demonstrates that Err and Err are essential FLC enter variables whereas D of a DC-DC converter is the yield changeable to be adjusted by FLC [72].

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Merit: • Simple concept and implementation • Error-free operation • Quick monitoring velocity with brief irradiance adjustments • Good dynamic performance • Combination with every other algorithm
Due to their hard and prolonged derivation method, difficult calculation, unable to naturally analyze from the surroundings, and damaging show below PSC, fuzzy guidelines have an immediate impact on device overall performance, that's a drawback.

Table 3 FLC-BASED MPPT IMPLEMENTATIONS

Reference	Generated power	Work done
73	PV module (EP) 30W	In a microgrid, MPPT is managed by FLC. Comparing the improved steady-state performance to the traditional PandO approach
77	230 Watt polycrystalline Si	It is shown that the upgraded M5P model (FLC-based MPPT) can speed up calculation and result in energy loss.

4.2 Artificial neural network (ANN)
With more precision and easier converter implementation, ANN can be used to breed FLC designs [79]. By feeding the temperature, solar irradiances, and voltage or contemporary of the solar strength machine into the ANN and obtaining the right Pmax or Vmax output, Figure 5 demonstrates how the dataset is obtained from the simulation or hardware configuration. Artificial neural networks, regularly known as ANNs, are modelled after natural neural networks, also referred to as "connectionist systems." This technique is used to investigate and educate the nonlinearity of the relationship among I-V and PV. These inputs are derived by the ANN using enter present day, input voltage, irradiance, temperature, and metrological statistics [78], that's continuously getting to know to modify the behaviour of the solar electricity system for max output. It can guide Sequential Monte Carlo (SMC) filtering-based country estimation and MPP prediction. A country-space version for the sequential estimation of MPP may be outfitted further to the IC MPPT framework, and the ANN model forecasts GMPP the use of information on voltage, contemporary, or irradiance to enhance the SMC prediction [81]. These data are modified into education information before being fed into the newly evolved ANN. The overall performance of the meant ANN is evaluated using take a look at datasets after training, and the mistakes are sent lower back into the ANN for in addition satisfactory-tuning [80].

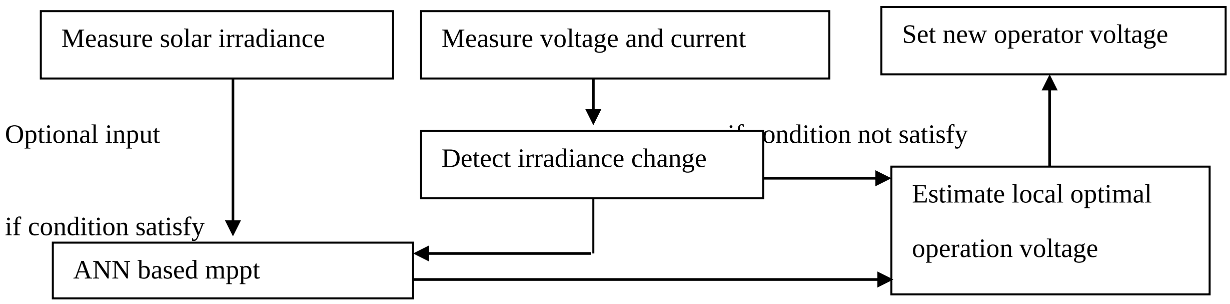

Figure 5 A MPPT with an ANN-based structure.

However, in order for the ANN to perform at its peak stage with out a primary training mistake, a precise, consistent, and good enough training set of statistics is a important want [82]. On the other hand, following accuracy is impacted by means of the PV panel model (gadget established), that's tough and time-ingesting. Fast responsiveness and monitoring velocity; small constant-country variation; and no need for reprogramming are the benefits. The most current implementation of ANN in MPPT is proven in Table 4.

Table 4 Periodic tweaking is necessary owing to environmental change and ageing.

Reference	Work done
83	A so-called solar power system's operational variations are being learned using an ANN model. PSO is used to determine the best ANN model's initial weights.
84	A simpler implementation and improved fault tolerance are displayed by MPPT based on ANN-modeled FLC.
85	The MPP of a PV panel can be precisely predicted using backpropagation trained neural network work. Compared to PandO-based MPPT, it offers accurate and quicker results.
86	An ANN model forecasts GMPP based on input voltage, input current, and irradiance using knowledge learned from training data.
87	The "nntool" is used to train the ANN in the MATLAB/Simulink model. In comparison to PandO and IC, an ANN-based MPPT controller reacts quicker to sudden changes in solar temperature and irradiance and has a reduced steady-state error.

4.3 Genetic Algorithm (GA)

When the voltage-step assortment GA approach is used, GA frequently well-knownshows minor oscillations, brief convergence, and brief dynamics [88]. GA is a complete AI-based optimization technique that may be applied to a whole lot of optimization problems. Through using MPPT, it's miles frequently possible to alternate a population of character answers and trade the voltage reference of a PV panel. A modified GA has a smaller populace length, greater efficient mutation approaches, and simpler crossover computation [89]. GA-based MPPT may additionally search the worldwide MPP, in comparison to traditional MPPT, which will become caught inside the nearby MPP.

Despite its efficiency, because of its streamlined method, GA isn't always suggested for optimizing specifically difficult, detailed, and excessive issues. The first discern population of the GA is started as an array during the MPPT optimization technique.

$$\mathrm{Xi} = [\mathrm{parent\ n}, \mathrm{parent\ n} + 1] \quad (3)$$

Where parent I (I = 1, 2,...,, n) represents the initial voltage readings at the start of the optimization process and n is the population size. Creating output electricity is the solar power system's primary goal (Xi). The objective function assesses the fitness values for each place. Following that, the population is employed to evolve over numerous generations and become fitter. In contrast to regular GA, the MPPT application requires the algorithm to be repeated because of sudden changes in load, solar irradiance, or PSC. Once the conditions in (4) and (5) are met, the GA-based MPPT approach is reactivated (5).

$$| \mathrm{V}(\mathrm{k} + 1) - \mathrm{V}(\mathrm{k})| < \mathrm{DV} \quad (4)$$

$$| \mathrm{P}(\mathrm{k} + 1) - \mathrm{P}(\mathrm{k})\, \mathrm{P}(\mathrm{k}) | > \mathrm{DP} \quad (5)$$

Where k denotes the current dimension and k + 1 denotes the following measurement iteration.

Low demand for computation a system of widespread and uniform implementation MPPT uses function values rather than calculations are befits of the method. High levels of steadiness and speed are Demerits due to the series format, tracking moves slowly.

Table 4 Depending on the state in the beginning

Reference	Work Done
90	In order to understand the temperature and irradiance data patterns, It uses a GA with huge variation radial basis functions. After dataset training, the programmed predicts MPP with excellent accuracy.
88	The voltage reference of the PV panels in solar power systems with MPPT and consistent power generation is established using GA. Its fast dynamics and slight power oscillations replicate the PandO MPPT's functioning.
91	GA is used to increase efficiency, particularly under PSC, which reduces energy loss generally.

4.4 Particle Swarm Optimization (PSO)

The PSO algorithm is the maximum extensively used SI-based MPPT. It is a heuristic method to the MPPT optimization difficulty. Potential answers are indicated by using a particle's role, whilst the solution space is proven with the aid of the duty ratio [92]. PSO, that is based totally on the concept of fowl flocking and has been found to present a better-equipped output with each new release. The best candidate particle is followed by means of each particle in PSO. PSO shows a population of debris and compares their locations to both the neighborhood and the global perfect locations. The first-class reaction is then found through rearranging these debris inside the search space [93]. The particle search process is improved by way of a non-linear lowering inertia weight and an advanced PSO [95]. PSO and normal distribution (OD) can be mixed to discover the general place of GMPP right away [94].The mastering issue and weighting price lower with the each new release for other modified PSO. However, it's far projected that the social mastering issue will growth. According to modifications to the slope and electricity characteristic curves, the weighting percent is also changed. Both tracking pace and stability are elevated by using these adjustments [96]. A discrete PSO (DPSO) is a greater straightforward shape than a normal PSO, with better overall performance and a greater dependable solution for fewer debris. There is simplest one parameter that needs to be set for the inertia weight [97]. Grey Wolf optimization (GWO) The life-style of gray wolves has an impact on one of the contemporary heuristic optimization strategies, known as GWO. The function of power is denoted with the aid of the terms "leader," "sub-chief," "lowest rank," and "lowest rank." A GWO-based MPPT follows the hierarchy of and is primarily based at the hunting strategies of gray wolves. The prey, in this example GMPP, will eventually be reached by means of the algorithm.

Artificial Intelligence (AI) has emerged as a promising device for addressing those challenges. By integrating AI into Maximum Power Point Tracking (MPPT) algorithms, PV systems can improve their potential to dynamically alter to converting environmental conditions, ensuring foremost power extraction even below difficult circumstances like PSC. Additionally, AI-based procedures offer potential solutions for reducing THD, thereby improving power exceptional. This assessment provides a comprehensive evaluation of the contemporary nation of AI-based MPPT algorithms and

their function in THD reduction, while also drawing parallels among adaptive mechanisms in PV structures and the cognitive variation techniques utilized in ReAttach Therapy.
The overview is dependent to offer insights into the type and overall performance of AI-primarily based MPPT techniques, their effectiveness in THD reduction, and the way adaptive mechanisms can inform each technological improvements and therapeutic strategies.

5. DISCUSSION

The extensive comparison and analysis of different AI-based MPPT algorithms have clearly demonstrated that each algorithm possesses unique benefits and drawbacks. Similarly, in the field of ReAttach Therapy, various therapeutic approaches are tailored to individual needs, highlighting the importance of customization based on specific developmental diversities. Just as AI models must adapt to the unique characteristics of photovoltaic (PV) systems—including variations in solar irradiance, temperature, and shading—ReAttach Therapy relies on personalized strategies that consider the cognitive and emotional profiles of individuals with developmental diversities.
In the context of AI-based MPPT, an adaptive filter's input signal is a delayed version of the original signal, accounting for the unpredictability of the MPPT input and the nonlinearity of the relationship between current-voltage (I-V) and power-voltage (P-V) characteristics. AI is utilized to predict current and voltage outputs based on this data. Similarly, ReAttach Therapy employs adaptive techniques that respond to the sensory and cognitive fluctuations of individuals, facilitating improved emotional regulation and adaptive behavior.
For AI-based MPPT systems, training AI models necessitates comprehensive data collection, including solar irradiance, temperature, meteorological data on humidity, and shading conditions. This data-driven approach parallels the strategies used in ReAttach Therapy, where therapists gather detailed information about a participant's sensory preferences and triggers to create a responsive therapeutic environment. Both fields highlight the critical role of monitoring and data assessment: in MPPT systems, rapid changes in irradiance must be used as inputs to evaluate the MPPT's responsiveness to fluctuations; in ReAttach Therapy, real-time feedback is essential for adjusting interventions to meet the individual's needs.
Moreover, the inverter functions as the primary conduit between a solar power system and the electrical grid, much like how the therapeutic techniques in ReAttach Therapy serve as the bridge connecting individuals with developmental diversities to their environments. A more efficient inverter not only maximizes energy extraction from PV systems but also ensures high-quality AC output, analogous to how effective therapeutic approaches enhance the quality of life for individuals by optimizing their adaptive skills and resilience in social settings.

5.1 Challenges and Future Directions

While AI-based MPPT techniques and THD reduction strategies have shown great promise, several challenges remain. The computational complexity of AI algorithms can limit their real-time applicability in resource-constrained environments, such as off-grid PV systems. Additionally, the integration of AI into PV systems requires careful consideration of cost, scalability, and reliability .
Future research should focus on developing lightweight, energy-efficient AI models that can be deployed in low-power environments. Additionally, further exploration is needed into how AI-based techniques can be integrated with other renewable energy systems, such as wind or hybrid PV-wind systems, to improve overall energy efficiency and grid stability .
This review has highlighted the critical role of AI-based MPPT techniques in improving the efficiency and performance of PV systems, particularly under partial shading conditions. By dynamically adjusting to changing environmental conditions, AI algorithms outperform traditional MPPT techniques in tracking the global maximum power point (GMPP). Additionally, AI-driven approaches offer promising solutions for reducing Total Harmonic Distortion (THD), ensuring higher power quality and grid stability.
The interdisciplinary parallels between AI-based adaptation in PV systems and cognitive adaptation in ReAttach Therapy offer new insights into how adaptive mechanisms can be applied across diverse fields. As AI continues to advance, its potential to optimize both technological and therapeutic systems will only grow, opening new avenues for research and application.

5.2 Recommendations for Future Research

Future research in AI-based MPPT should focus on developing standardized design procedures to optimize algorithm performance while minimizing complexity. Just as the integration of various therapeutic techniques in ReAttach Therapy is tailored to individual needs, the development of hybrid AI-based MPPT systems could enhance performance by combining strengths from different methodologies, such as Fuzzy Logic Control (FLC), Artificial Neural Networks (ANN), and Genetic Algorithms (GA).
Theoretically, voltage fluctuation is described as a continuous voltage shift occurring when equipment or appliances with a higher load are used frequently. Therefore, linking a DC-DC-AC converter, or MPPT, with a synchronverter in

grid-connected solar power systems can maximize power extraction and generate virtual inertia. This synergy ensures stabilization of output voltage and frequency on the AC grid, much like how adaptive strategies in ReAttach Therapy provide a stable environment for individuals to thrive.
The focus on understanding voltage fluctuation and mini-frequency grids is essential for ensuring high power efficiency in solar systems, just as understanding sensory fluctuations is crucial for effective ReAttach interventions. Collaborative research between these fields can provide valuable insights, allowing for innovative solutions that leverage adaptive algorithms to address both energy efficiency and developmental support.

6. CONCLUSION

While the majority of AI-based MPPT techniques are more expensive, complex, and data-intensive than traditional methods, they offer significant advantages in tracking MPP under challenging conditions such as rapid changes in irradiance or partial shading (PSC). However, these advanced techniques can be less acceptable due to their inherent complexities, ongoing tuning requirements, and limitations in traditional architectures like Artificial Neural Networks (ANN) and Fuzzy Logic Control (FLC).
By conducting a comprehensive analysis of Total Harmonic Distortion (THD) mitigation options across PV systems, this review emphasizes the need for continued exploration and innovation in AI-based MPPT strategies. Major categories for AI-based MPPT approaches—including FLC, ANN, Soft Computing Intelligence (SI), hybrid methods, and Machine Learning (ML)—reveal their potential to achieve quick junction, minimal oscillation at steady state, and precise rate tracking.
Furthermore, a deeper understanding of recent advancements in THD reduction and AI-based MPPT techniques will not only benefit solar power applications but also enhance our knowledge of adaptive mechanisms in ReAttach Therapy. Insights from one field can inspire novel approaches in the other, fostering interdisciplinary collaboration that ultimately improves outcomes for individuals with developmental diversities.

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