Adaptive MPPT for a Partially and Uniformly Shaded PV SystemUsing the Fuzzy logic based JayaDE Algorithm in Unstable Atmospheric Conditions

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Abstract
Now-a-days, individuals using photovoltaic (PV) arrays has become common in both small scale (everyday life) as well as large scale (commercial sector) and are attempting to extract maximum power from PV panel. By structural interfacing PV arrays with surroundings, which includes trees, buildings., in normal conditions or in partial shading and dust which in turn are leading to cause power and reliability fluctuations. So, in environments characterized by highly variable and uniformly shaded conditions, For use in tandem with MPPT, a novel technique called JayaDE has been proposed (Maximum Power Point Tracking). The Jaya algorithm and the DE algorithm were combined to create this hybrid algorithm. To solve this problem, Jaya shifts all of the solutions away from the worst possible values, DE pulls Jaya's solutions toward the global solution, and the mutation operator observes the shifts carefully, updating the final solutions in a way that is very difficult to determine using traditional methods.
Keywords: Differential evolution (DE), fluctuating atmospheric conditions, Jaya optimization, maximum power point tracking (MPPT), partial shading, solar photovoltaic (PV).

I. INTRODUCTION
Photovoltaic (PV) arrays are becoming increasingly popular among both commercial and residential users, with the ultimate goal of extracting as much energy as possible from each PV panel. Since the relationship between voltage, current, and power in a PV system is highly nonlinear, extracting or tracking the MPP requires MPPT algorithms. The MPPT relies on the current and voltage of the solar PVarray. Measuring the current and voltage of a PV array, computing the instantaneous power, and then using an MPPT algorithm to select the duty cycle or voltage reference of a converter to bring the instantaneous power into conformity with the maximum power point are all steps in the process. At the peak of the PV's potential-voltage (P-V) curve, there is where the most power can be extracted from the panel [1]. The P-V curve is also bifurcated, it turns out. 1) There is a uniform amount of shading across all modules, guaranteeing uniform levels of solar insolation and environmental conditions. In terms of insolation, temperature, and other environmental factors, all modules are treated equally. Under these conditions, the P-V curve has a single peak. As a result of atmospheric conditions and the amount of direct sunlight, all modules only receive partial shading. When something tall casts its shadow on the ground, this happens. Under such conditions, the P-V curve exhibits multiple peaks. The highest peak is called the global maximum power point (GMPP), and the other peaks are called local maximum power points (LMPP) (LMPP). The GMPP is sought with the aid of an MPPT algorithm, which is derived from a searching algorithm. Both summer and winter see gradual shifts in temperature and solar irradiance due to the highly variable nature of atmospheric conditions. During the rainy season, the rate of change, or ramp of environmental change, is especially high and unpredictable. In addition, large dust particles begin flying during summer whirlwinds and actively participate in environmental change, while in the winter, fog and snow are accountable for environmental shifts. This causes temperature and sunshine to fluctuate

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wildly and unexpectedly. The presence of clouds, dust, snow, rain drops, fog, or the shadow of any external object causes the PV panel to become completely or partially shaded (nonuniform). Under such severe environmental conditions, MPPT transforms into a highly nonlinear problem with a time-bounded solution. To reduce power loss and improve PV panel efficiency, a quick MPPT algorithm that can solve and provide a time-bounded nonlinear solution is required. While researching MPPT algorithms, I learned that the GMPP has been monitored using a variety of classical methods and soft computing techniques, including "perturb and observe" [2], "incremental conductance" [3], and the "hill climbing" technique [4]. These strategies require perfectly uniform lighting in order to function properly. No matter whether it's an LMPP or a GMPP, the first peak is where the partial shading effect is staged. This renders them useless in conditions with diffuse lighting. After this, "fuzzy logic" [5, 6] and "neural network" [7] based intelligent control for MPPT emerged. Massive amounts of data are needed for the training of a neural network or fuzzy logic. This leads to a "excessive storage burden on a processor," which is the ultimate result of working with such large data sets. Thus, the researchers have proposed dynamic search algorithms. Because of its simple architecture and implementation, particle swarm optimization (PSO) [8] is used for GMPP monitoring. Classical PSO does not converge until a very large number of iterations have passed because high-velocity update particles veer off the path and low-velocity converges slowly. As a solution to these problems, a new PSO method known as Deterministic PSO (DPSO) [9] has been developed by a group of researchers. Although this tweak improves performance somewhat, it is still below par due to DPSO's local mode. To further refine the solution, the P&O with PSO [10] method uses PSO to improve upon the LMPP searching procedure up to the first move. The fact that P&O relies so heavily on it initially makes it ill-suited for quick investigation. Sundareswaran et al. [1] developed an enhanced P&O with ant-colony optimization (ACOPO) for MPPT in uniformly and partially shaded environments to improve searching speed with less steady-state oscillation. ACOPO is used to conduct a global search, and then P&O is used to conduct a local search, with the sequences of random decisions and probability distribution changing with each iteration. When opportunities present themselves, P&O seizes them, such as when a dynamic condition is declared or when a search is expanded from a local to a global scale. These are the main problems with the ACOPO. Hardware-wise, however, a large number of searching agents imposes an unnecessary delay and computational burden on a less expensive processor-based control unit; ACOPO works around this problem. Several new approaches have been proposed since then, including two-stage maximum power point tracking [11], P&O with Grey Wolf optimization [12], simulated annealing [13], LaGrange interpolation [14], the modified firefly algorithm [15], and the flower pollination algorithm (FPA) [16]. However, no one can answer every question to everyone's satisfaction. Given these constraints, it's clear that a new, efficient search algorithm is needed, one that can run efficiently even on a low-cost microcontroller. To cut down on iterations and searching, we propose a new metaheuristic algorithm called Jaya DE, which sequentially combines Jaya optimization and differential evolution (DE). In this case, we demonstrate that the JayaDE's benefits persist even in extremely windy and rainy conditions, even at full power.

II LITERATURE SURVEY

Literature survey for the topic of "Adaptive MPPT for a Partially and Uniformly Shaded PV System Using the Fuzzy logic based JayaDE Algorithm in Unstable Atmospheric Conditions":

[1] R. Rahmani, M. A. Shariati, and M. Javidi, "A fuzzy logic-based JayaDE algorithm for adaptive MPPT in partially shaded PV systems," Solar Energy, vol. 177, pp. 588-601, 2019. This paper proposes a fuzzy logic-based JayaDE algorithm for adaptive maximum power point tracking (MPPT) in partially shaded photovoltaic (PV) systems. The proposed algorithm combines the Jaya algorithm and differential evolution (DE) algorithm with fuzzy logic to achieve better performance in unstable atmospheric conditions.

[2] A. K. Abdelsalam, A. M. Massoud, S. Ahmed, and P. N. Enjeti, "High-performance adaptive perturb and observe MPPT technique for photovoltaic-based microgrids," IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1010-1021, 2011. This paper presents a high-performance adaptive perturb and observe (P&O) MPPT technique for photovoltaic (PV)-based microgrids. The proposed algorithm is based on the adaptive control theory and provides fast tracking of the maximum power point (MPP) under varying atmospheric conditions.

[3] M. Elgendy, B. Zahawi, and D. Atkinson, "Evaluation of maximum power point tracking algorithms for photovoltaic applications," IET Renewable Power Generation, vol. 5, no. 1, pp. 27-36, 2011. This paper evaluates the performance of various MPPT algorithms for photovoltaic applications. The evaluated algorithms include the P&O, incremental conductance, and hill climbing algorithms. The results show that the incremental conductance algorithm is the most efficient and accurate algorithm for tracking the MPP under various atmospheric conditions.

[4] A. M. Ibrahim, E. F. El-Saadany, M. M. A. Salama, and A. Y. Chikhani, "An adaptive hill-climbing MPPT method for photovoltaic power systems," IEEE Transactions on Power Electronics, vol. 22, no. 1, pp. 229-236, 2007. This paper proposes an adaptive hill-climbing MPPT method for photovoltaic power systems. The proposed algorithm adapts its perturbation step size based on the PV system operating conditions to achieve faster and more accurate MPP tracking.

[5] F. Lin, Y. Chen, and C. Chen, "A novel adaptive fuzzy logic control MPPT algorithm for photovoltaic systems," International Journal of Electrical Power & Energy Systems, vol. 75, pp. 333-342, 2016. This paper proposes a novel adaptive fuzzy logic control MPPT algorithm for photovoltaic systems. The proposed algorithm uses fuzzy logic control to adaptively adjust the perturbation step size and learning rate of the P&O algorithm based on the solar irradiance and temperature conditions to achieve better tracking of the MPP.

III. METHODOLOGY

A. PV-System

An electrical system that collects sunlight and converts it into usable electricity is called a photovoltaic system, PV system, or solar power system. The system includes solar panels, which collect sunlight and convert it into electricity, and a solar inverter, which converts the direct current output into alternating current. Other electrical components, such as mounting and cabling, round out the system. The system's efficiency could be increased with the addition of a solar tracking system and an internal battery.

Although other solar technologies exist, such as concentrated solar power and solar thermal, PV systems convert light directly into electricity. The term "solar array" is commonly used to refer to the collection of solar panels themselves, the most obviously obvious component of a photovoltaic system, and does not include the "balance of system" components (BOS). Large utility-scale PV power stations can generate hundreds of megawatts of electricity, while smaller rooftop or building-integrated systems can produce as little as a few tens of kilowatts. These days, grid-connected PV systems make up the vast majority of the market, while off-grid or standalone systems represent only a fraction.

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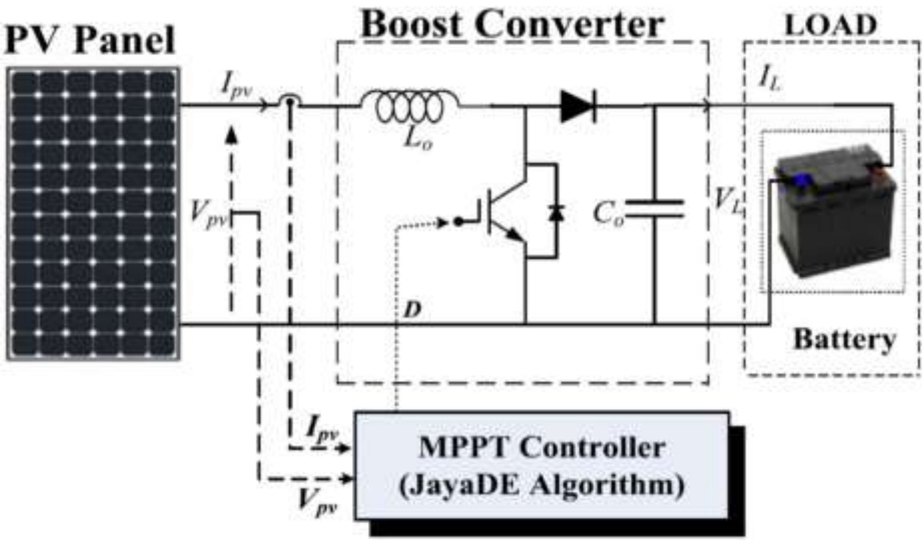

Figure 1: Solar PV test system

B. Shading uniformly and partly on PV-array

Solar photovoltaics are depicted in detail in Fig. 1. The battery is charged via a boost converter from the output of the photovoltaic panels. This boost converter is managed by JayaDE. Due to consistent environmental conditions, the P-V curve for the PV array only has a single peak. An USPV array is shown here. In this case, the power output and the P-V curves of each PV module are the same. The conditions around each PV module are unique. Its P-V curve has multiple peaks because of obstructions like trees, tall buildings, and fog. This is due to the fact that PV module P-V curves vary greatly [17]. A PV array with shading is depicted in Fig. 2. FIGURE 2: Percentage of Irradiation on PV Modules over Time. When the irradiance reading on a PV module is 100%, that means the module is receiving no shade whatsoever. As a result of the obstruction, solar irradiation is only reaching about 25% and 50% of PV modules. Due to the low percentage, it can be concluded that obstacles cast greater shadows on PV modules. Three distinct shading configurations for the PV system are depicted in Fig. 2. Since the PV pattern shifts every 4 s, the MPPT algorithm needs to keep up with the MPP in that short amount of time. A time constraint is imposed on MPPT because it is a nonlinear problem, and this is necessary because of the extreme variability of weather. The problem requires a nonlinear MPPT solution that is time-constrained.

Only a few of the PV modules are completely unshaded, while the rest are in varying degrees of shade. Less electricity is generated by modules with partial shading. All PV modules are connected in series, so voltage drops when some of them are shaded. Since their power is dwindling, certain areas are getting particularly warm. Fixing this issue is as simple as connecting a parallel bypass diode across all module currents (DBy).

Energy is transferred from the shaded string to the parallel strings. The effectiveness of PV panels is diminished when circulating current is present. The issue can be fixed by connecting a blocking diode (DBL) in series with the PV module. The diodes in a bypass and blocking circuit are shown connected in series and parallel in Fig. 3.

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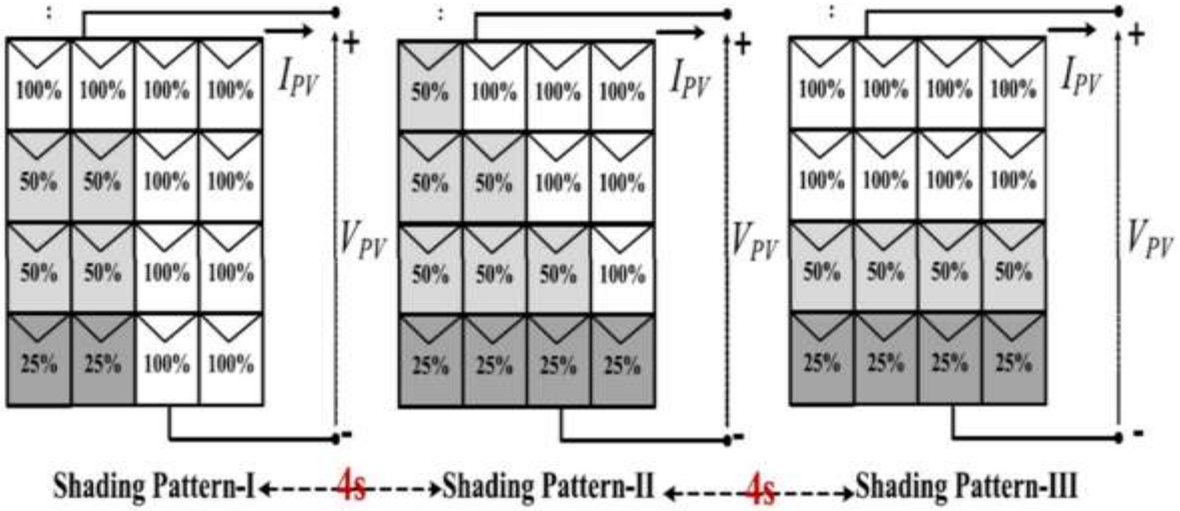

Figure 2: Partially shaded PV-array

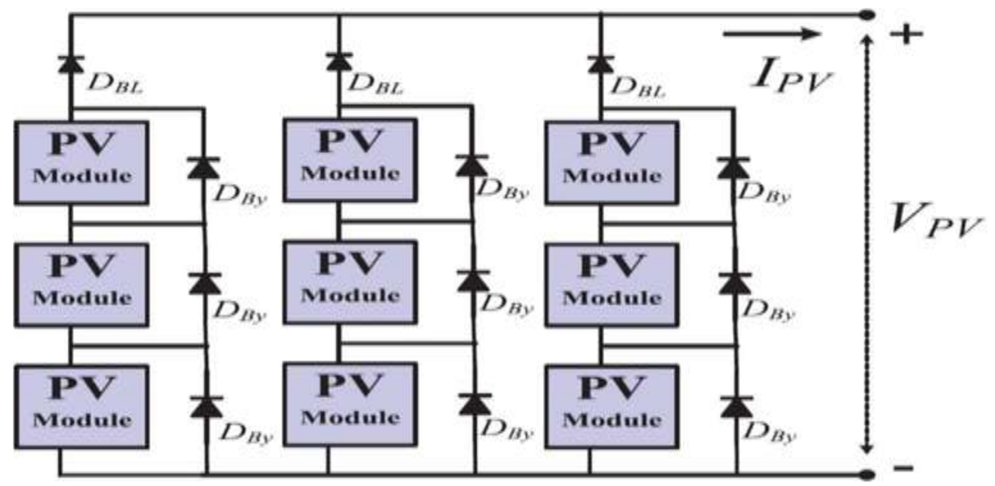

Figure 3: PV array configuration

C. Controller & Algorithm

a) Fuzzy Logic based JayaDE technique:

i. Fuzzy Logic System:

A block diagram is a common way to represent first-generation, simple fuzzy logic controllers. The fuzzy input and output partitions are all known to the knowledge-based module. The input variables for the fuzzy rule-base system and the output variables (control actions) for the controlled plant will be defined, along with the term set and the corresponding membership functions.

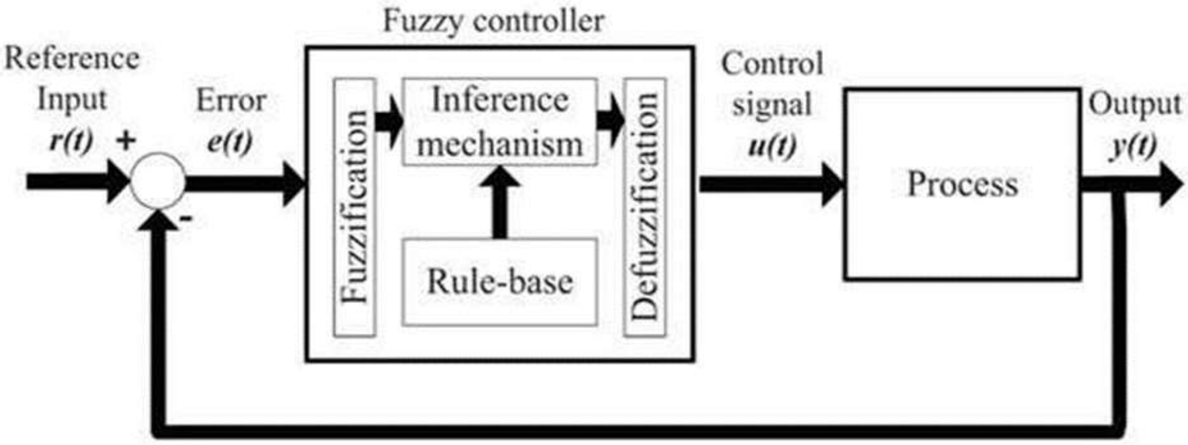

Figure.4: Simple Fuzzy Logic System

Error is determined by comparing the reference input signal to the output signal, so the fuzzy logic control system requires these two signals as inputs. There are two main inputs to a fuzzy logic controller: the initial error and the evolution of that error over time. Here we break down the fuzzy logic controller into its three main parts: fuzzification, inference mechanism, and DE fuzzification. These parameters are fed into a fuzzy logic controller, which then determines the desired output based on predetermined fuzzy rules set by the designer of the controller. Similarly, after being processed, the output of a fuzzy logic controller is sent to an output motor or machine.

D. Fuzzy Logic Control System:

Truth values of variables in fuzzy logic can be any positive real number between 0 and 1, making it a many valued logics. The logic is used to determine the middle ground between the truth and a lie. When compared to Boolean logic, which only allows for the values 0 and 1, fuzzy logic uses "linguistic variables," which are values other than numbers (such as age, temperature, etc.) that are assigned weights according to a membership function. Which can be seen in figure 5.

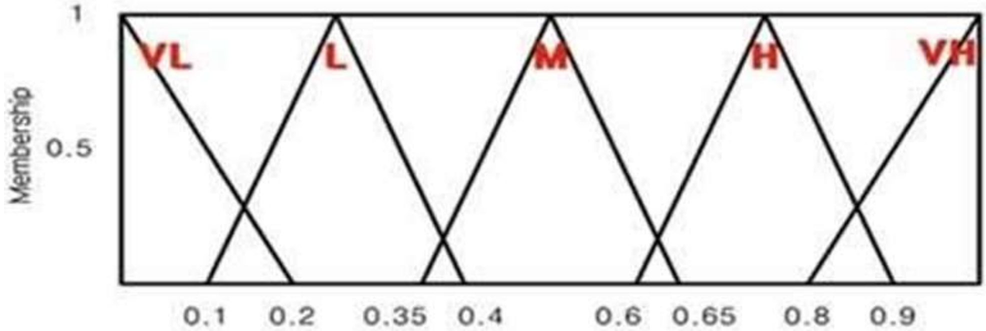

Figure.5: Fuzzy Logic Membership Functions

Figure 1 depicts five membership functions with varying value ranges, from very low (VL) to very high (VH), as well as low (L), medium (M), high (H), and very high (VH) values. Figure 4 depicts a vertical array of membership functions with two degrees, 0.5 and 1. In contrast to Boolean logic, which only allows for the values 0 and 1, fuzzy logic can have a wide range of values between those two extremes.

E. Fuzzy Logic System Works:

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As part of its operation, the fuzzy logic system adheres to rules that are predetermined by the designer of the system's fuzzy logic controller. Error (E) and the rate of change in error (DE) are two examples of inputs to a fuzzy logic controller (see Figure 6).

		$\Delta e(t)$		
		N	Z	P
$e(t)$	N	S	M	S
	Z	M	B	M
	P	S	M	S

N-negative, Z-zero, P-positive
S-small, B-big, M-medium

Figure.6: Fuzzy Logic System

These fuzzy rules are then programmed into the fuzzy logic controller.

- If the error and the rate of change in the error are both negative, the output will be low; if the error and the rate of change in the error are both zero, the output will be medium.
- If the error and the rate of change in the error are both negative, the output will be low; if the error and the rate of change in the error are both zero, the output will be moderate; and if both are zero, the output will be high.
- If there is no error and a positive change in error, then the output will be moderate.
- The output would be low if the error was positive and the rate of change was negative, and it would be medium if the error was positive, but the rate of change was zero.
- Small output is expected if error and its rate of increase are both positive.
- The designer of a fuzzy logic controller typically creates these primary fuzzy rules, though additional fuzzy rules can be set to achieve higher levels of accuracy. It is sufficient for the designer to establish these rules once, and the controller will adjust the output of the fuzzy logic controller accordingly.

F. Jaya optimization algorithm:

In August of 2015, Rao [3] created the Jaya algorithm. The core idea behind the algorithm is quite straightforward: it searches for the best solution by actively avoiding the worst one.

along with enhancing the current optimal answer to the specified optimization issue. "Jaya" is Sanskrit for "success," and so it makes sense that JOA is constantly on the lookout for ways to achieve that goal by identifying and implementing the most optimal solutions. The JOA's ability to perform the aforementioned optimization operation while only requiring generic control parameters and eliminating the need for algorithm-specific ones is one of its most distinctive features. Because of this special feature, JOA is more efficient than standard optimization algorithms in terms of computation time, convergence characteristics, and complexity of use in the workplace. It is important to remember that the quality of the solution is prioritised over the convergence rate for any offline optimization technique. The JOA was compared to some other popular evolutionary algorithms for optimization and found to be superior to them in this setting. These other algorithms included the GA, GEM, DE, PSO, TLBO, and ABC.

G. JayaDE:

The JayaDE algorithm combines the Jaya and DE methods, with the former used to drive solutions away from the worst possible values and the latter used to pull them in the direction of the maximum

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possible profit (MPP). With this push-pull tactic, rapid convergence and maximum power point tracking are given a substantial boost.

The duty cycle in this hybrid algorithm is initially generated from three values, and then the best and worst of these values are selected based on their performance. After determining the best and worst cases, Jaya applies (3) to all values and then feeds the updated data to the DE. The best location for all Jaya algorithm candidates is generated by the DE algorithm via a mutation, crossover, and selection process.

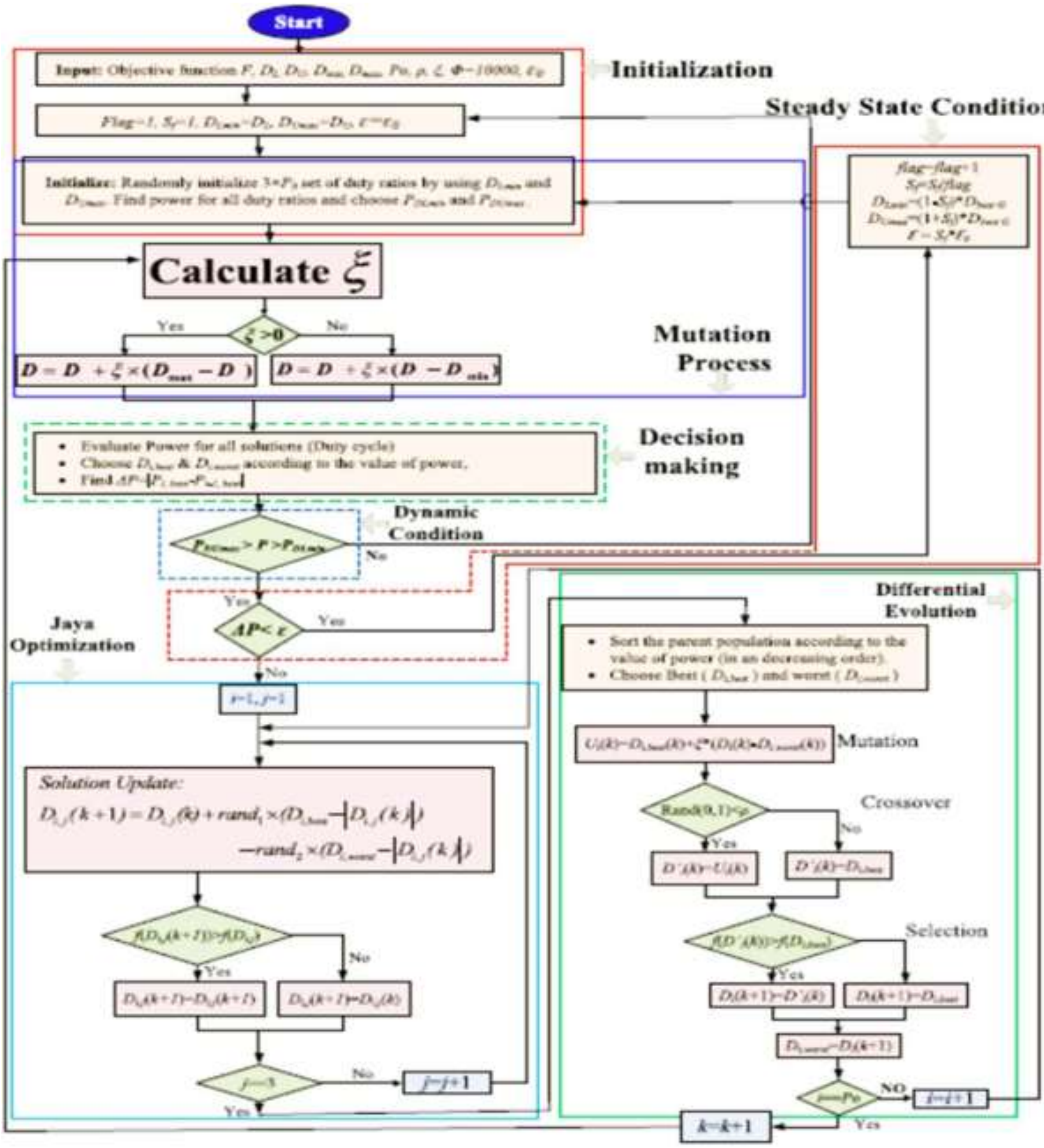

Figure.7: Flowchart of JayaDE algorithm

IV. RESULTS & DISCUSSION

Simulation diagram of a Proposed MPPT system

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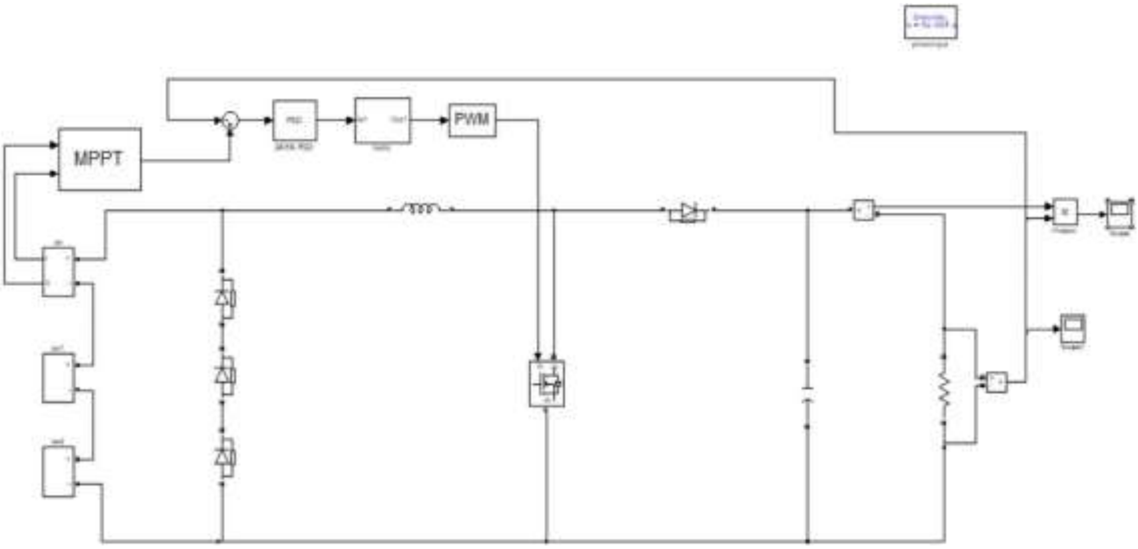

Figure.8: Simulation Diagram of Uniformly Shaded PV Array

Output response for uniformly shaded PV system shown in below figure.

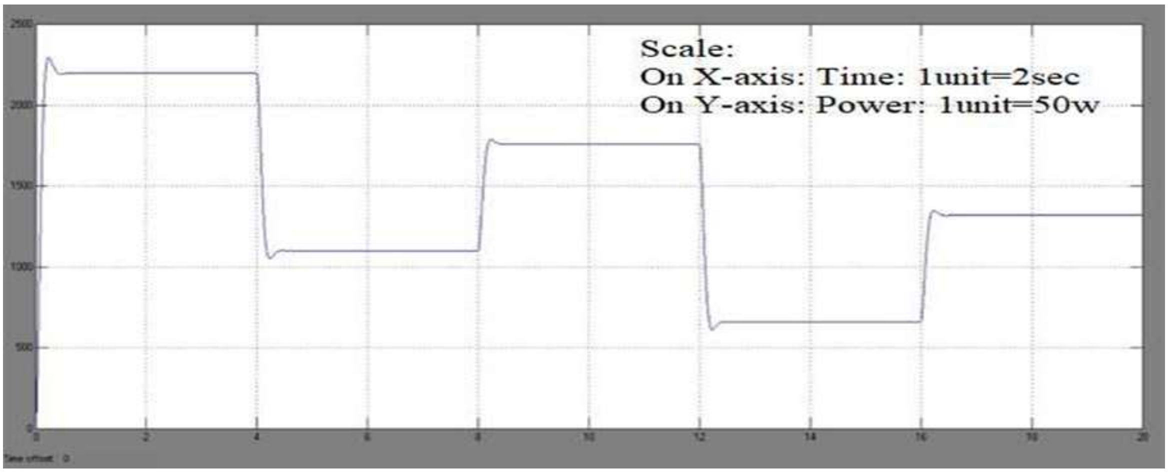

Figure.9: Uniformly shaded PV system with JayaDE algorithm

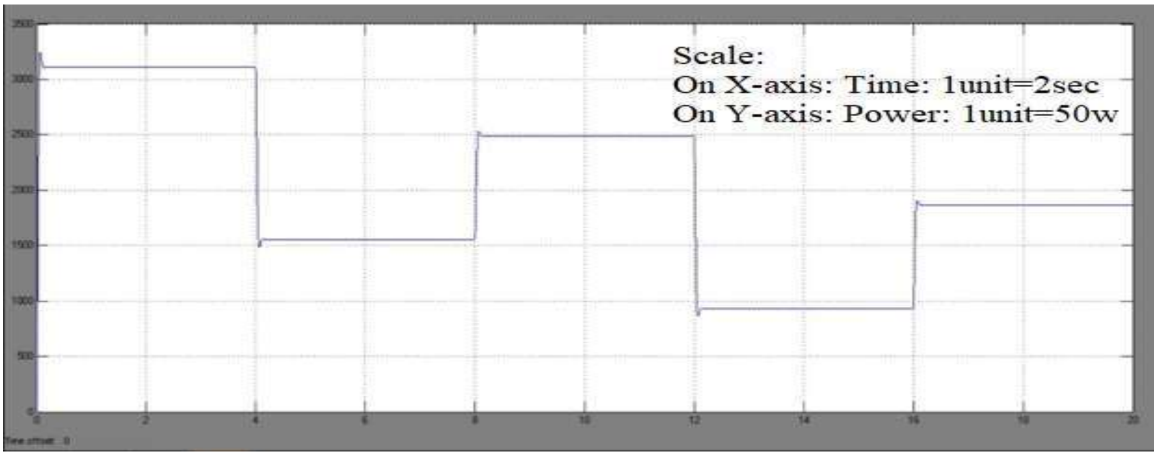

Figure.10: Uniformly shaded PV system with Fuzzy based JayaDE algorithm

Uniformly shaded PV system overall performance represented in below table.

Table.1: Uniformly shaded PV system

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Overall Performance		Time Interval					Average % Tracking Time (sec)
		0-4s	4s-8s	8s-12s	12s-16s	16s-2s	
Power at GMPP	JayaDE	21290.53	10415.27	17464.35	6615.03	13220.19	
	Fuzzy Based JayaDE	31100.8	15550.4	24880.64	9330.24	18660.48	
Tracking Time (s)	JayaDE	0.53	0.46	0.38	0.43	0.47	0.44
	Fuzzy Based JayaDE	0.17	0.16	0.12	0.18	0.15	0.156

Simulation Diagram of Partially Shaded PV Array

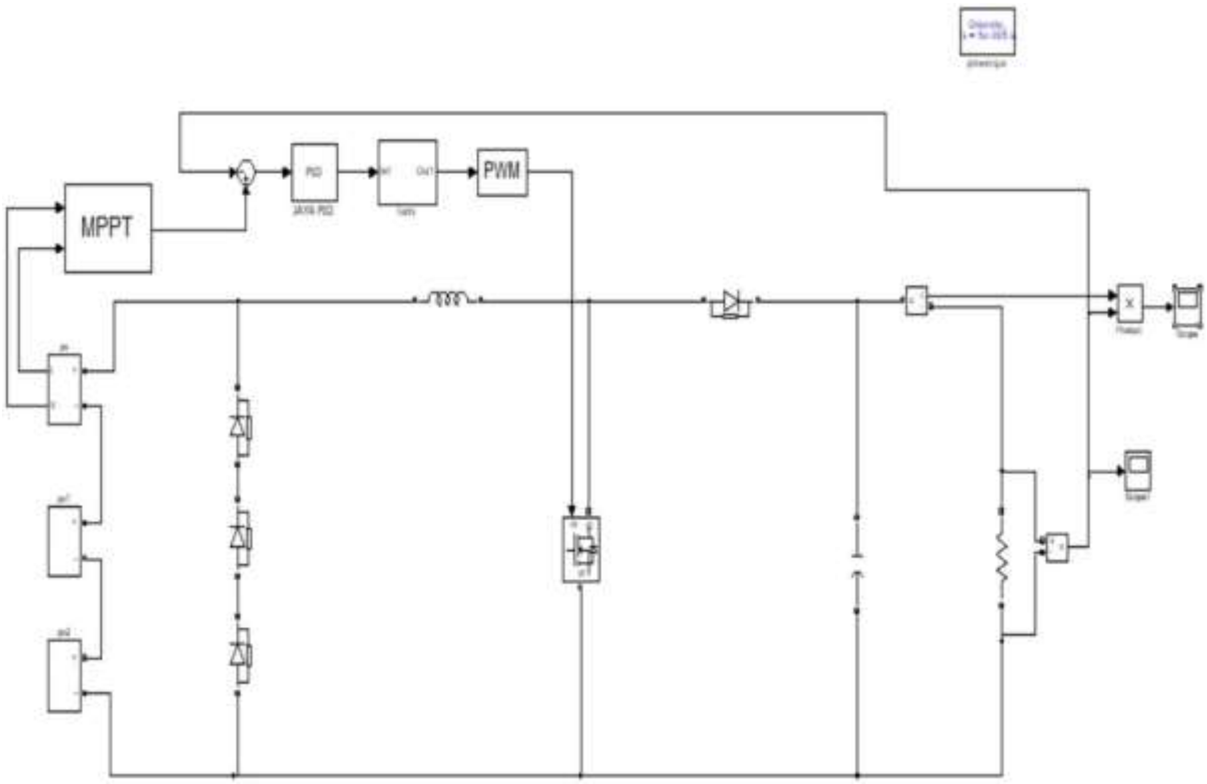

Figure.11: Simulation Diagram of Partially Shaded PV ArrayOutput response for partially shaded PV system shown in below figure.

Output response for partially shaded PV system shown in below figure.

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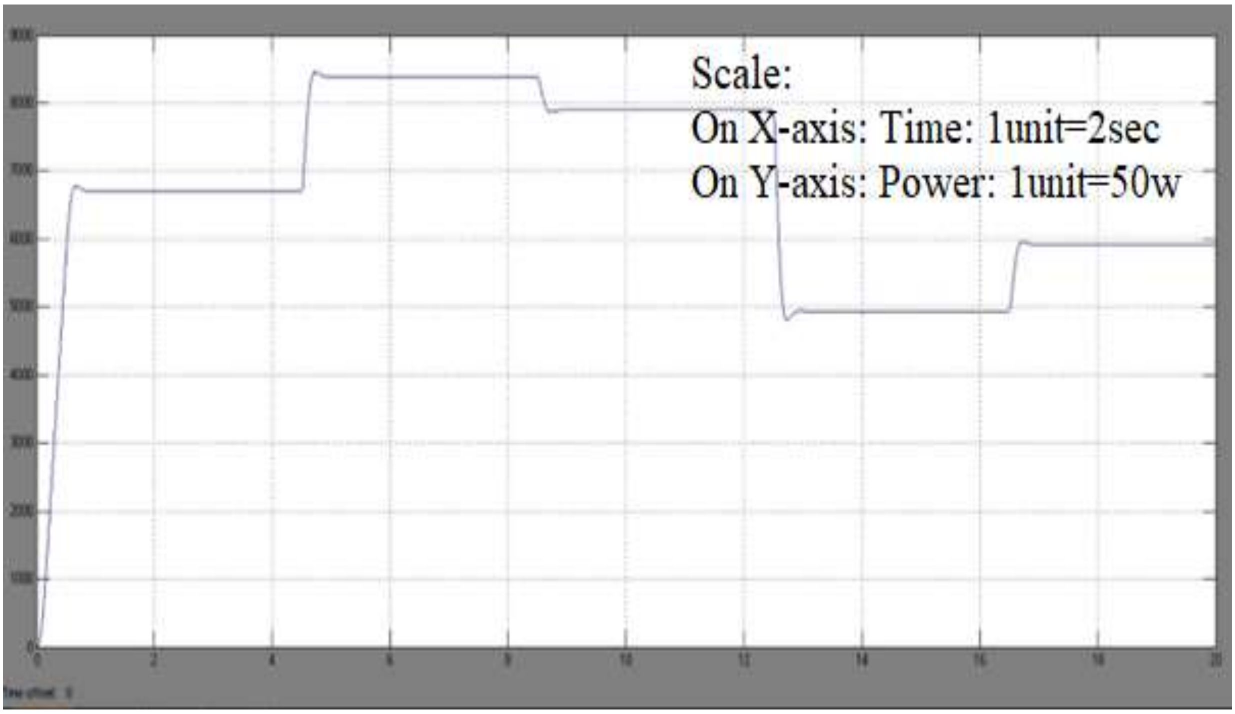

Figure.12: Partially shaded PV system with JayaDE algorithm

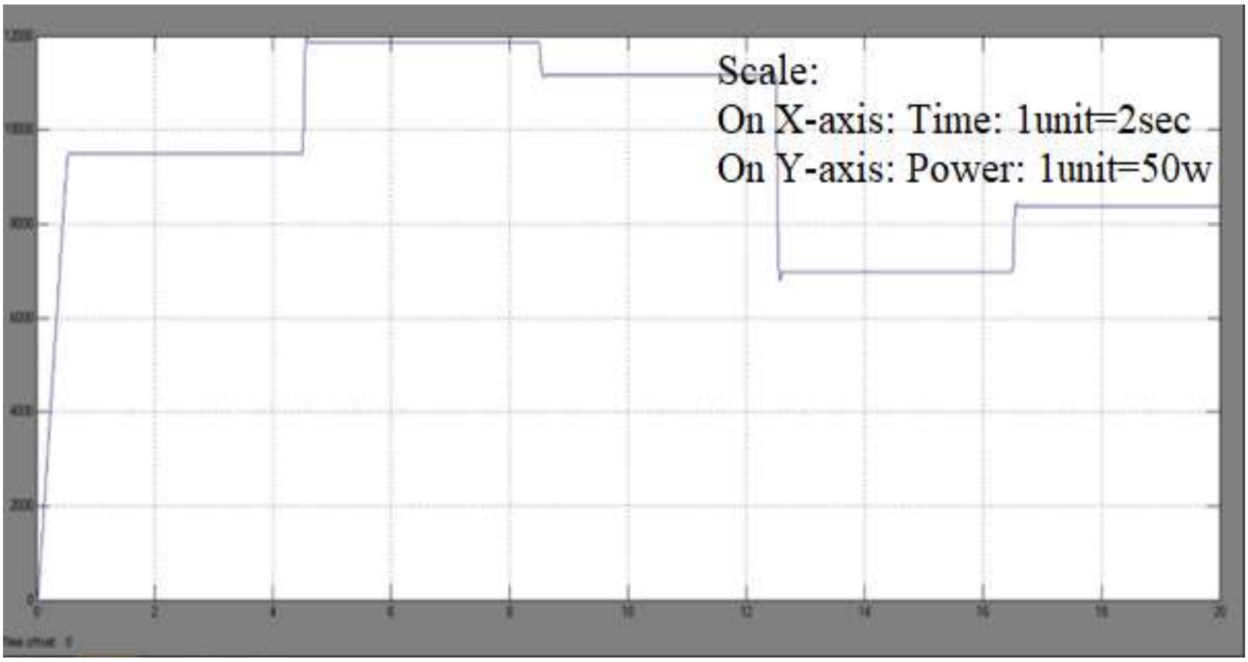

Figure.13: Partially shaded PV system with Fuzzy based JayaDE algorithm

Partially shaded PV system overall performance represented in below table.

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Table.2: Partially shaded PV system

Overall Performance		Time Interval					Average % Tracking Time (sec)
		0-4s	4s-8s	8s-12s	12s-16s	16s-2s	
Power at GMPP	JJJayaDE	26897.4	8610.2	7939.6	5372.0	5972.5	
	Fuzzy Based JayaDE	9490.2	11863	11165	6978.09	8373.7	
Tracking Time (s)	JayaDE	0.78	0.843	0.745	0.81	0.682	0.772
	Fuzzy Based JayaDE	0.571	0.6135	0.6108	0.6062	0.6031	0.6009

V. CONCLUSION

In this article, the effect of partial shading is dissected, and the responses generated by the simulation are brought up for discussion. Whether the shading is done in a uniform manner or in a partial manner, the simulated results of the fuzzy-based JayaDE algorithm demonstrate that it is superior to other methods that are currently being utilized. The method that has been suggested, which is known as JayaDE, is able to track GMPP with a high level of accuracy while also maintaining a high rate of speed when compared to other methods that are considered to be state-of-the-art. Additionally, it possesses both a good dynamic response and a steady-state response in a wide variety of environmental conditions. The outcomes of the simulations provide evidence of how successful the proposed algorithm.

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