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# REFINED PARTICLE SWARM OPTIMIZATION FOR ENHANCED PHOTOVOLTAIC POWER GENERATION

**BILAL ARIF**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: bilal.arif@skt.umt.edu.pk

**MUHAMMAD MATEEN AFZAL AWAN ***
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. *Corresponding Author Email: mateenafzalawan@gmail.com

**NOUMAN ASHRAF**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: nouman.ashraf@skt.umt.edu.pk

**MUHAMMAD USMAN**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: ub4563928@gmail.com

**MUHAMMAD AHMED**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: muhammadahmed0134@gmail.com

**YAEESH AHMED**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: yaeeshmalik609@icloud.com

**ABDUL WADOOD**
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: abdulwadood0528@gmail.com

### Abstract

Considering the desired goal of shifting toward renewable energy by the world due to the swear issues of fossil fuel diminution that cause spiraling energy prices, and damage to the ozone layer due to the pollution caused by conventional energy-producing technologies and fuels, we have put our efforts in providing a solution to one of the most focused problems of solar renewable energy technology. Solar is one of the most focused and currently in use technology due to the reliable and free availability of the Sun as an energy source and the single-step conversion of sunlight into electricity (the most demanded form of energy) using the photoelectric effect. But its non-linear behavior bounds to avoid maximum power production due to the load. To solve the issue conventional algorithms came in and moved the operating power point to the position where maximum power could be delivered called maximum power point (MPP). However, under partial shading conditions tracking the MPP became impossible for conventional algorithms due to the disturbed power characteristic curve. The role of soft-computing algorithms begins here to efficiently track the real MPP among multiple arisen peaks in the power characteristic curve. One of the most prominent soft-computing algorithms is particle swarm optimization (PSO). It has the capability of efficiently tracking MPP but its weaknesses include complexity in structure, huge computations, hard implementation, and huge memory requirements. To overcome one or all existing weaknesses and improve the performance of the PSO algorithm we have modified its tracking strategy and found effective results.

The proposed revised PSO algorithm has been evaluated on the 3S PV system, specifically designed for the comparison of conventional and proposed PSO algorithms in MATLAB/Simulink.

**Keywords:** MPPT; Solar; Photovoltaics; Algorithms; PSO; Modified PSO.

## INTRODUCTION

Conversion of the world's research focus on renewable energy occurred due to the threat of the unreliability of fossil fuel reserves, health issues created by atmospheric damage made by toxic pollutants of conventional energy technologies, and hiking energy charges [1,2]. Renewable energy resources include Hydro, Wind, Solar thermal, Solar Photovoltaics, Tidal, Geothermal, biomass, biofuel, etc. [3]. Among renewables, the Sun is the only reliable energy source due to its presence all around Earth [4-6]. In solar technologies, the SPV is the only existing technology that directly converts sunlight into electrical energy using the photoelectric effect [7-9]. However, the SPV faces problems in producing the maximum possible energy due to its non-linear characteristics [10-12]. The electric load and weather force the SPV to operate far from its peak power point, which causes power loss [13-15]. To avoid this, MPP trackers guided by MPPT algorithms are hired [16-18]. The MPPT algorithms can be majorly categorized into conventional and soft-computing expressed in Figure 1.

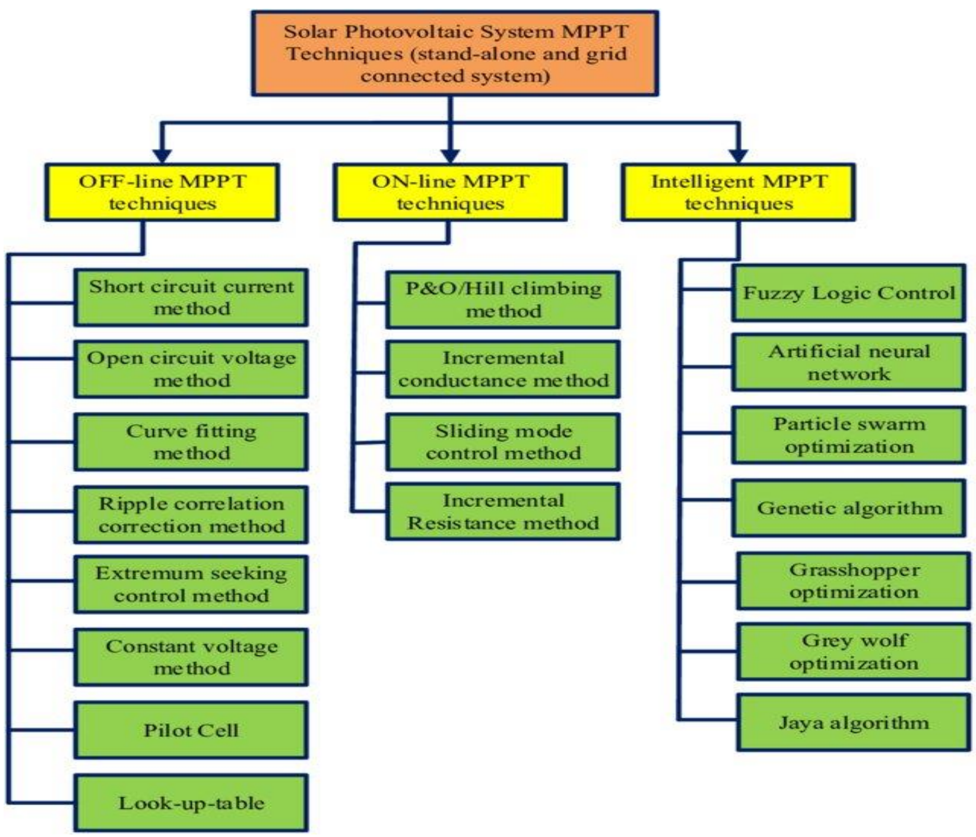


**Figure 1: Types of MPPT Algorithms [19]**

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Where the conventional follows the incrementing strategy that fails to identify the MPP among multiple crests under PSC, however, the soft-computing performs better due to the utilization of the randomization concept [20-22]. Each algorithm in soft-computing has a different strategy but it depends on randomization [20-22]. One of the most effective soft-computing algorithms is PSO [23-25]. It is known for its effective and efficient results [23-26].

The PSO has proved its dominance over renowned algorithms like Grey Wolf Optimization in [27], Genetic Algorithm in [27], and Firefly in [28] in MPPT efficiency and tracking speed/time.

Multiple researchers have optimized the PSO with multiple different approaches and have had success to some extent. A scientist in [29], has implemented the revised PSO. This attempt to improve the MPP tracking accuracy under shading scenarios. Another researcher [30] attempted to reduce the computational complexity of PSO by introducing an adaptive weighted delay velocity technique and observed valuable achievement. Researchers in [31] have attempted to implement the hybrid of PSO with slap swarm optimization algorithm to achieve stable and efficient results for battery charging and got 99.99% efficient results for battery charging. Another concept of hybridization of PSO with an adaptive neuro-fuzzy inference system was introduced by a researcher in [32], the researcher achieved a convergence speed of 34 times quicker than the PSO. Another effective hybrid technique was introduced in [33] by the researchers, here the PSO is integrated with EAG to get fast MPP tracking speed. The speed achieved was 2.6 seconds. Multiple other efforts have been made by various researchers that got reasonable development in tracking time and minor betterment in efficiency, as the PSO is already one of the top efficient algorithms.

Analyzing the strategy of PSO, we have revised its strategy to optimize its performance. The efficient utilization of pollination to avoid randomness to get the effective distribution of solutions throughout the power curve. The revised structure has outperformed the PSO in MPPT time.

The research article explains the PSO in section 2 and the revised PSO in section 3. Results are discussed in section 4 followed by the conclusion in section 5. Whereas, section-6 presents referred work.

**Revised PSO MPPT Algorithm:**

Observing the strategies of PSO has lightened the idea of better utilization of the tracking concept to get more efficient results. The PSO takes random solutions processes them through position calculation and assigns weights and velocities to converge towards MPP. To get better results, the optimal arrangement of solutions before processing is mandatory. This will reduce the settling time for each solution which in turn reduces the MPPT time.

The revised PSO initiates random solutions and processes them through each step of the PSO algorithm but does not apply them to the tracking circuit. Further, the produced

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solutions are arranged in descending order before applying to the circuit. This arrangement of solutions will be carried out through a hierarchical optimization approach to minimize the settling time. Finally, the retriggering of the algorithm is based on the change in weather, which is measured using the changing values of current and voltage. The application of the existing PSO strategy is optimized in this revised structure of PSO. The flowchart of the revised PSO (RPSO) is designed in Figure 2.

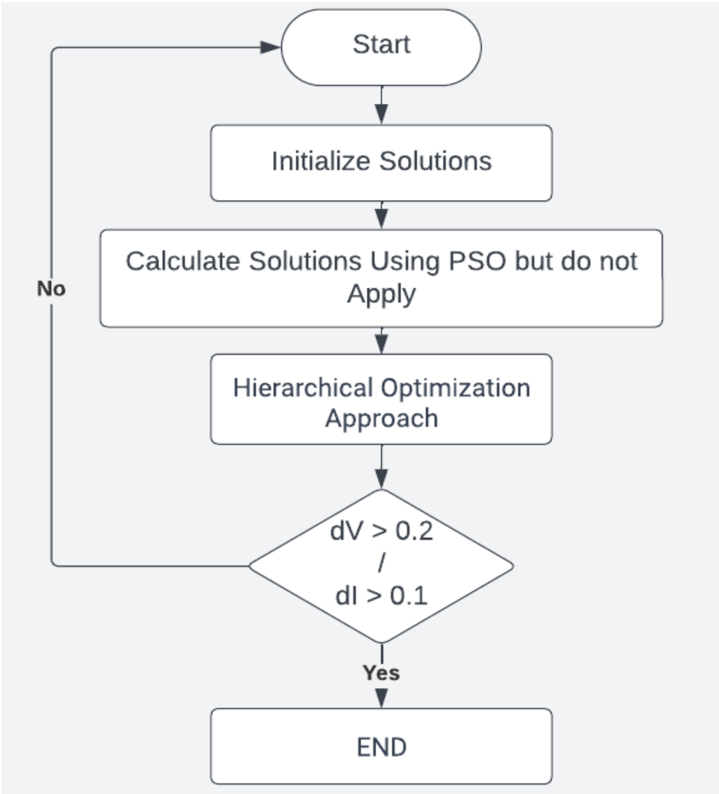


**Figure 2: Proposed Revised Flower Pollination Algorithm**

## Simulation's Result:

To validate the claim of RPSO, we have simulated a 90-watt SPV system that possesses a PV array connected with a load through a boost converter. The duty cycle to the boost converter is provided by the algorithm which in this case is the Flower pollination algorithm (FPA) and RPSO. The reason behind comparing the RPSO with FPA instead of conventional PSO is that the FPA is better in performance than conventional FPA. Therefore, this direct comparison can prove two achievements in a single step without complicating and lengthening the research paper. The weather effects have also been applied to the PV array in the simulation model presented in Figure 3.

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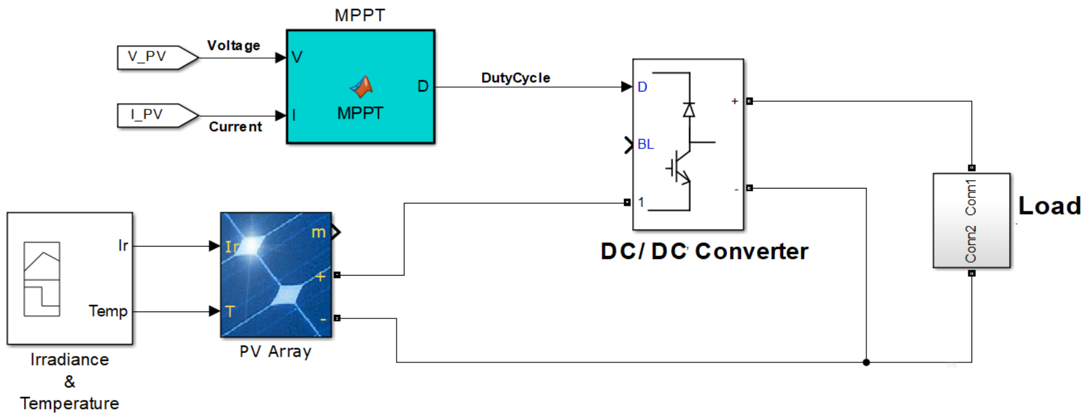


**Figure 3: Photovoltaic System's Structure**

The weather scenarios applied to the SPV system are standard test conditions (1000w/m$^2$, 25$^o$C), light shading (one panel of three is shaded 50%), and dark shading (two panels of three are shaded 50% and 25%). The three conditions are picturized in Figure **4**.

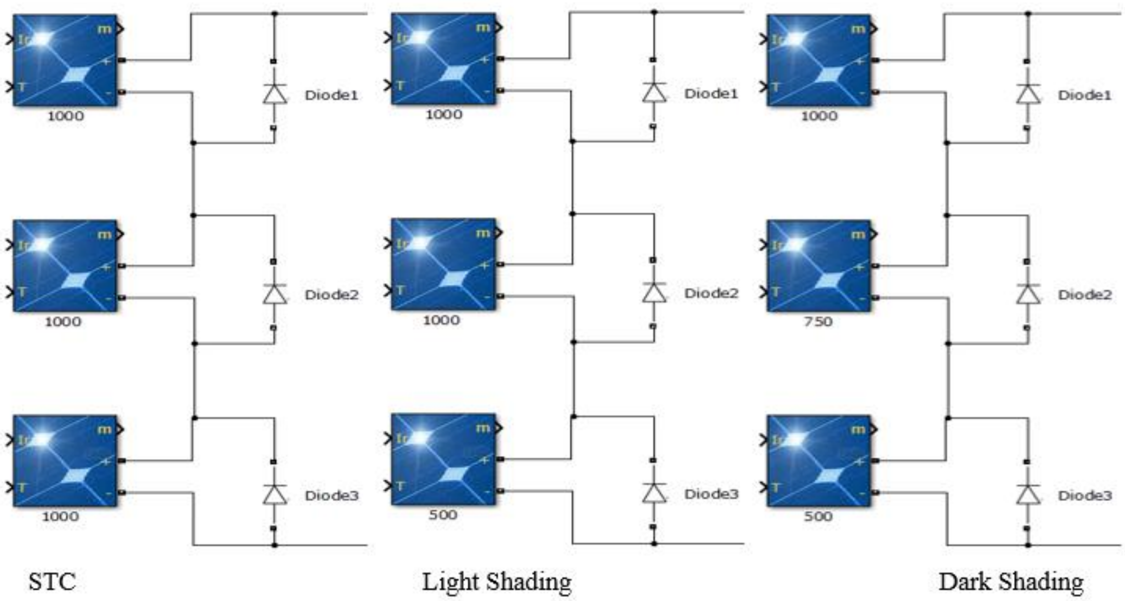


**Figure 4: Solar Photovoltaic System**

The characteristic curves of the designed SPV system for the three scenarios are depicted in Figure **5**. At full shine the PV array production capability is 90 watts, however, it reduces to 57.9 watts at light shading and drops down to 52.83 watts in the dark shading scenario.

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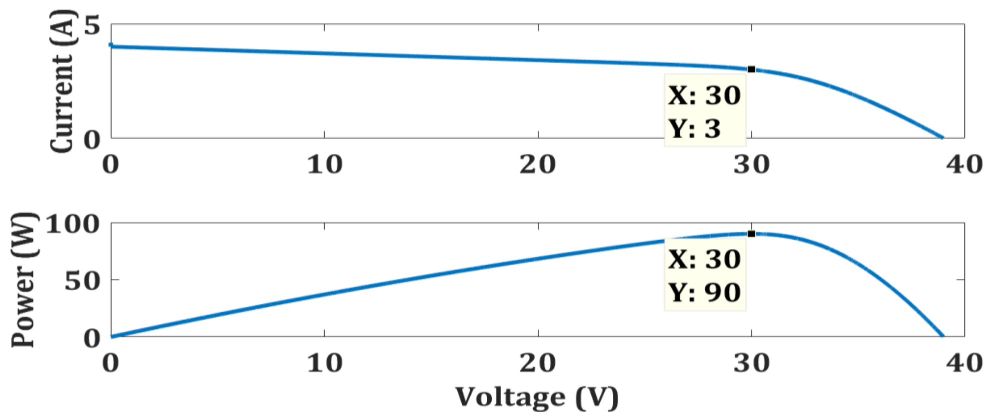
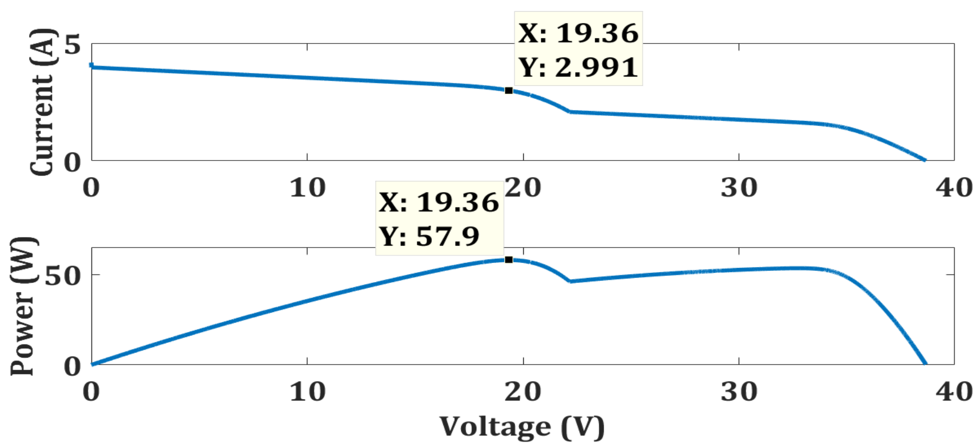
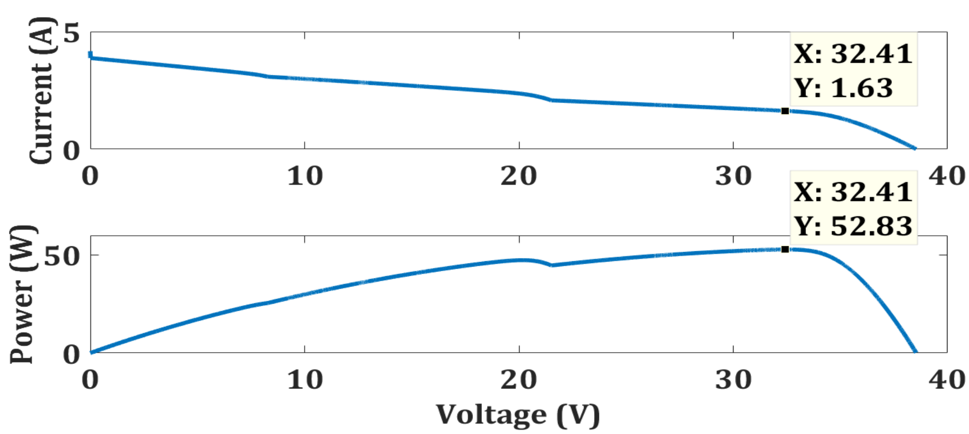



**A. Characteristic Curve of 3S PV System for Zero PSC**




**B. Characteristic Curve of 3S PV System for Weak PSC**




**C. Characteristic Curve of 3S PV System for Strong PSC**

**Figure 5: Characteristic Curve of 3S PV System for Strong PSC**

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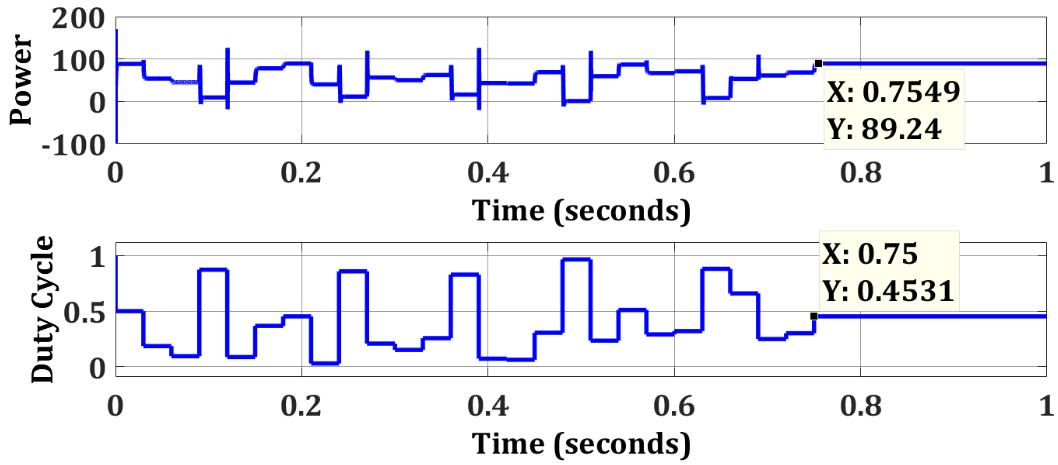
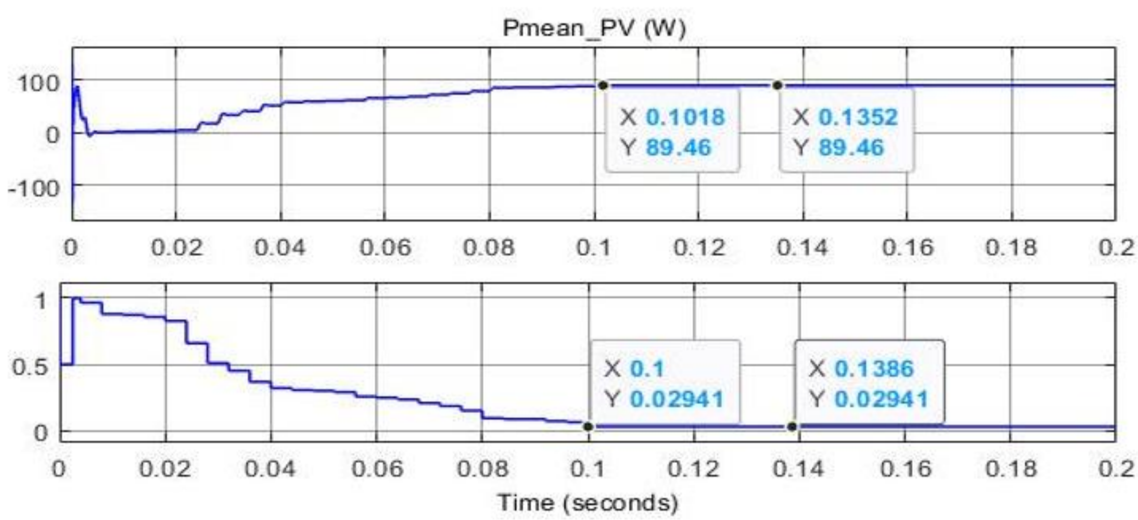
Application of PSO for STC presented in Figure **6** showed good results of 89.24 watts which is 99.15% efficient but the time it took is 0.7549 seconds due to the high number of iterations and large settling time between successive pollens. On the other hand, the RPSO extracted 89.46 watts from the SPV array which is 99.4% efficient. The efficiency is better but the main achievement is the time it took to get the GMPP which is only 0.1018 seconds which means 86.5 times faster (far better than PSO). The reason is the efficient use of concepts, which helped out in minimizing the iterations and settling time.




**A. PSO algorithm for Zero Shading**




**B. DA-PSO algorithm for Zero Shading**

**Figure 6: Simulation Results for 3S Configuration under Zero PSC**

Proceeding to the second test, we shaded one of three SPV modules by 50% (it receives 500W/m$^2$ illumination) and applied the algorithms. It can be easily observed from the results in Figure **7** that both the competitor algorithms attained 53.39 watts of power at

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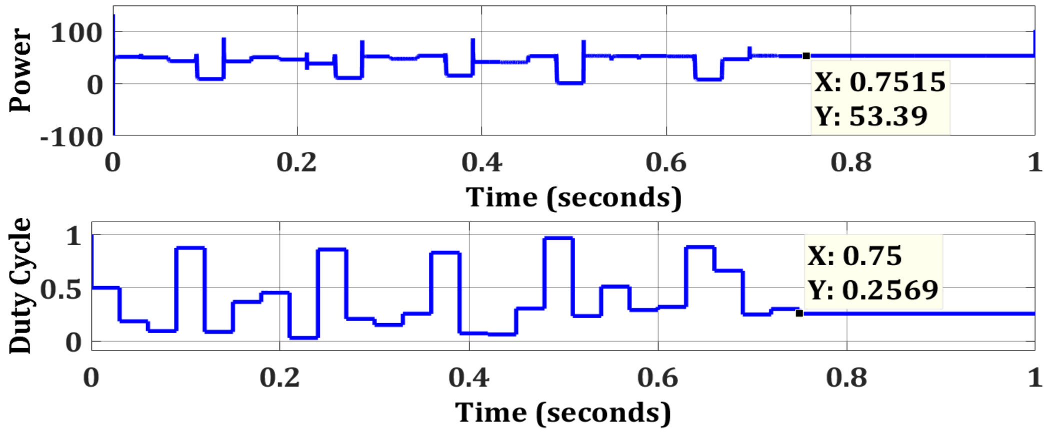
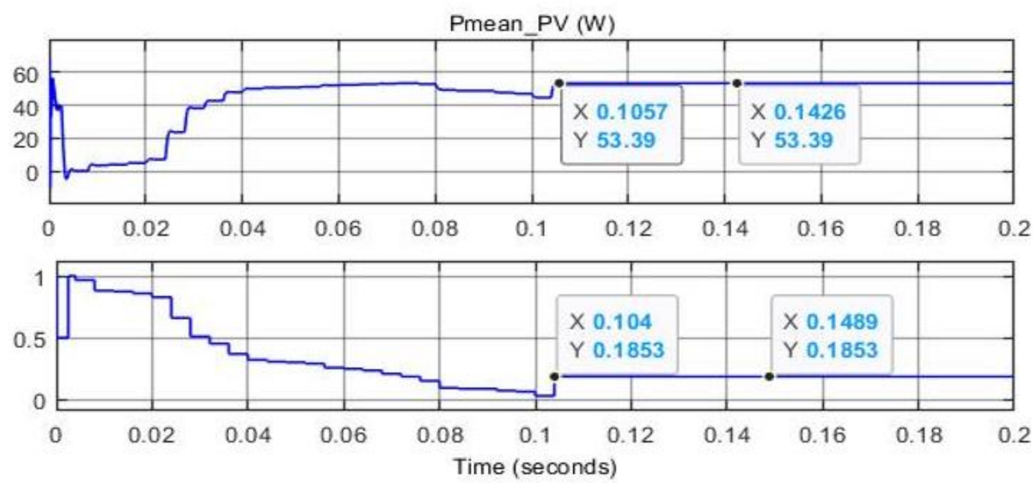
different speeds. The RPSO has proved 86 times faster than the PSO in tracking speed by capturing the target in just 0.1057 seconds. The PSO is slow with a big margin, it attains the same in 0.7515 seconds.




**A. PSO algorithm**




**B. DA-PSO Algorithm**

**Figure 7: Simulation Results for 3S Configuration under Weak PSC**

To assess the performance under more complex situations, we applied dark shading to the SPV system and blocked 50% of the light of one module and 75% of the light of the second module. This putrefies the power-voltage curve to challenge the algorithms proving their capabilities. As in light shading, the RPSO has outpaced the PSO with 86 times faster results in achieving the same goal of 52.82 watts. The simulation outcomes explain the results in Figure 8.

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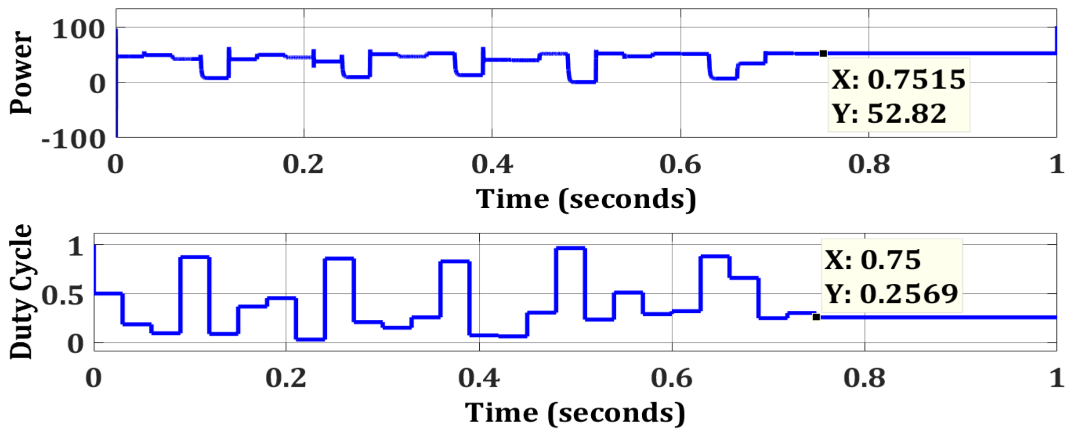
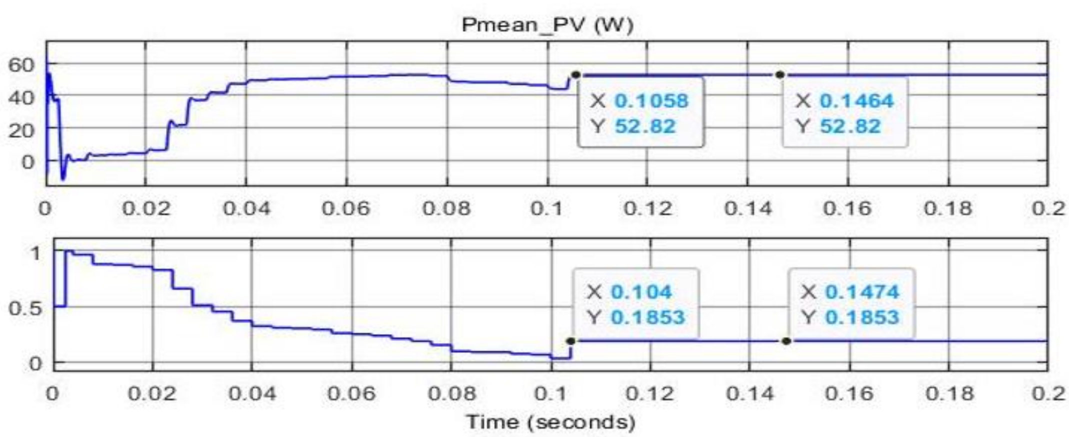



**A. PSO algorithm**




**B. DA-PSO algorithm**

**Figure 8: Simulation Results for 3S Configuration under Strong PSC**

To summarize the results and discussion, we have generated Table 1. A detailed performance presentation of both competing algorithms for each scenario is covered along with a comparison in tracking speed and efficiency. The Table 1 is sufficient to know the difference between presented algorithms in all aspects.

**Table 1: Performance Comparison for 3S PV System**

| Partial Shading | Algorithms | Power Output (W) | Rated Power (W) | Efficiency (%) | Tracking Speed (sec) | Improvement in Tracking Speed (%) |
|---|---|---|---|---|---|---|
| **Zero Shading** | PSO | 89.24 | 90 | 99.15 | 0.7549 | **86.5** |
| | DA-PSO | 89.46 | | 99.4 | 0.1018 | |
| **Weak Partial Shading** | PSO | 53.39 | 57.9 | 92.21 | 0.7515 | **86** |
| | DA-PSO | 53.39 | | 92.21 | 0.1057 | |
| **Strong Partial Shading** | PSO | 52.82 | 52.83 | 99.98 | 0.7515 | **86** |
| | DA-PSO | 52.82 | | 99.98 | 0.1058 | |

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Finally, the changing scenarios are analyzed to check if the algorithm can detect weather swings. The simulated output in Figure 9 confirms the change detection ability of RPSO to maintain its routine under numerous environments.

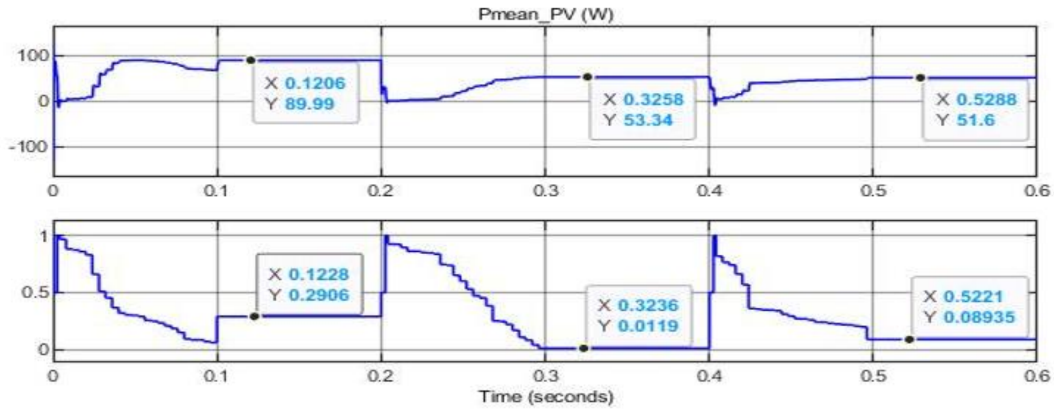


**Figure 9: Performance of DA-PSO Algorithm under Changing Weather Conditions for 3S PV system**

## CONCLUSION

After analyzing the searching strategy of PSO algorithms, we understood its core strength which is the efficient distribution of solutions at local and global pollinations. Further optimizing the effective utilization of its strengths to get more accurate and quick results, we revised the structure of PSO. Despite random pollens, we generated global positions for pollens to distribute solutions locally across each position. This improves the search quality by covering the maximum area and reducing the probability of avoiding GMPP. The RPSO is compared with the PSO at different persistent and varying weather and found the be more efficient and 86 times faster. Performance is summarized in Table 1 for both algorithms under each weather scenario.

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