Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

REVISION OF FLOWER POLLINATION ALGORITHM FOR OPTIMIZING PHOTOVOLTAIC SYSTEM

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

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

MUHAMMAD ASIM
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: 20007019002@skt.umt.edu.pk

ABDULLAH AKBAR
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: 20007019009@skt.umt.edu.pk

HANZILA-BIN-FAROOQ
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: 20007019008@skt.umt.edu.pk

MUHAMMAD IRFAN
Electrical Engineering Department, University of Management and Technology, Lahore, Sialkot-Campus, Pakistan. Email: 20007019007@skt.umt.edu.pk

Abstract

The renewable energy revolution is essential considering the depleting threats and greenhouse gas production of conventional energy resources. Solar has the priority among renewables due to the availability of the source almost everywhere. Further, solar photovoltaic (SPV) technology is prominent due to the direct conversion of sunlight into electricity. However, the non-linear characteristics do not allow the SPV cell to produce determined power. Therefore, the trackers driven by algorithms are hired to take the operating point to a maximum power point (MPP). Only soft-computing MPP tracking (MPPT) algorithms can survive under partial shading conditions (PSC). One of the most renowned soft-computing algorithms is the flower pollination algorithm (FPA) because it effectively distributes locally and globally. Optimal utilization of the strengths of FPA to improve its performance in MPPT for SPV cells has been performed in this research. Results have shown around 86% improvement in tracking speed which is a huge achievement. Simulations have been performed in MATLAB.

Keywords: MPPT, Solar, Photovoltaics, Algorithms, FPA.

INTRODUCTION

The renewable energy revolution occurred due to the problems of conventional energy unreliability, soaring costs, and environmental threats [1-3]. 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

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

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.

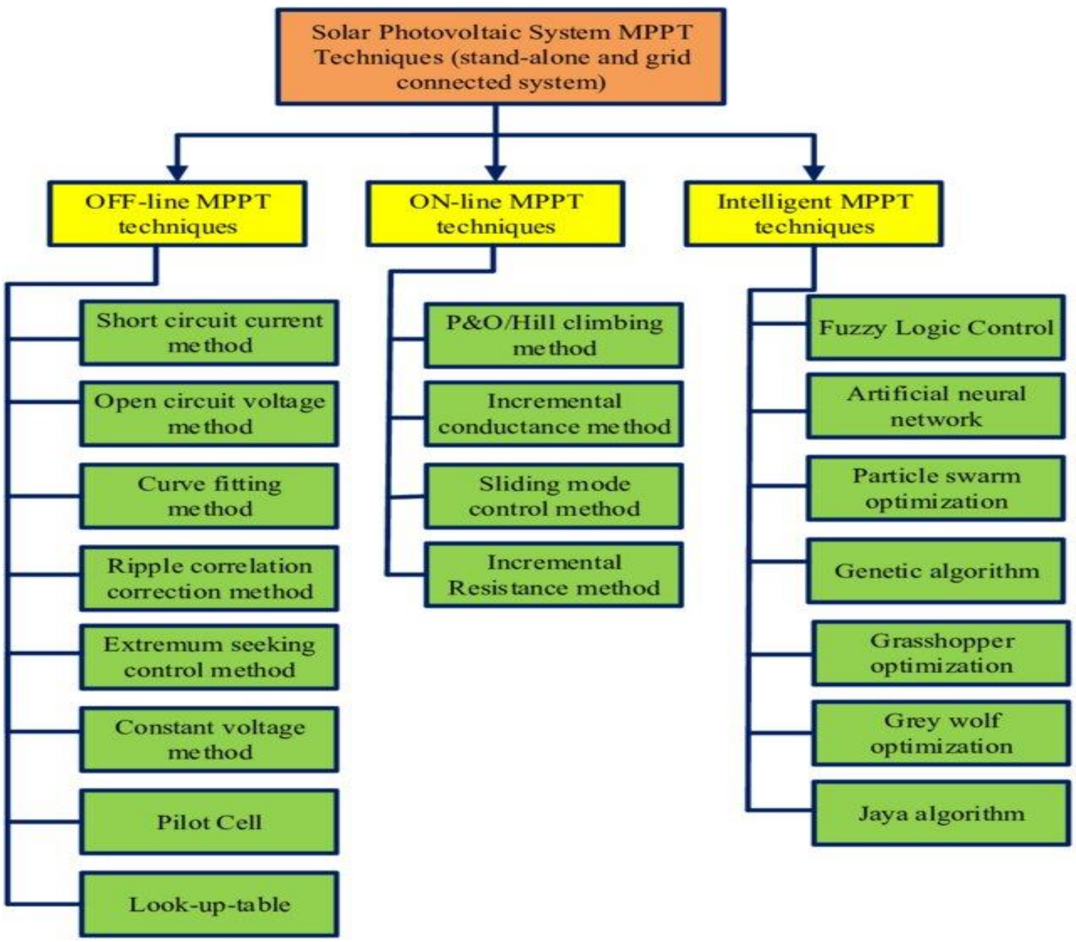


Figure 1: Types of MPPT Algorithms [19]

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 FPA [23-25]. It is known for its effective distribution of solutions across the search space [23-25].

The FPA has proved its dominance over renowned algorithms like Particle Swarm Optimization in [26], Revised Particle Swarm Optimization in [27], Grey Wolf Optimization in [27], Genetic Algorithm in [27], and Firefly in [28] in MPPT efficiency and tracking

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

speed/time. Multiple researchers have optimized the FPA with multiple different approaches and have had success to some extent. A scientist in [29], has implemented the revised MFPA with an introduction of a new equation to select the initial duty cycles. This attempt to improve the initial cycle boosted the tracking speed up to 35%. Another researcher [30] attempted to process the pollens through local and global in a single step. This strategy was applied to enhance the efficiency of FPA and remains successful with around 0.5% more efficient. Researchers in [31] used the root mean square error, mean relative error, and mean absolute error approaches to optimize the convergence efficiency of FPA and got 96% efficient results. Further another concept of cross-pollination was introduced by a researcher in [32] by merging the local and global searching and sharing their positions for further placements. The approach seems effective and achieved a 1% improvement in efficiency and around 32% improvement in tracking speed. Research conducted in [33] has utilized the concept of random walk to optimize the efficiency of FPA. The random walk is applied immediately after the pollination process to optimize the distribution of pollens to get more efficient results. This contribution has improved the MPPT efficiency of FPA by 0.9%. Multiple other efforts have been made by various researchers that got reasonable development in tracking time and minor betterment in efficiency, as the FPA is already one of the top efficient algorithms.

Analyzing the strategy of FPA, 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 FPA in MPPT time.

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

FPA MPPT Algorithm:

The FPA algorithm is one of the top-performing techniques. It has a distribution strategy for solutions (known as pollens in FPA) at close and far positions through a local and global pollination process respectively. A first set of randomly generated pollens is applied and pollen with the optimal result is kept as the best pollen of the set denoted by P_{best}. Further, each pollen in the set would be assigned a new value through local or global pollination that depends on comparing a random number in the range 0-1 and the probability switch. This ends up with a new set ready to apply and provide another P_{best}. The process repeats for a defined iteration number and P_{best} with the optimal value would be the best pollen among all P_{best}. Refereed as G_{best}. Afterward, the FPA searches for parameter changes (irradiance, temperature, etc.) to reinitiate the tracking process. The flowchart of FPA is placed in Figure 2.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

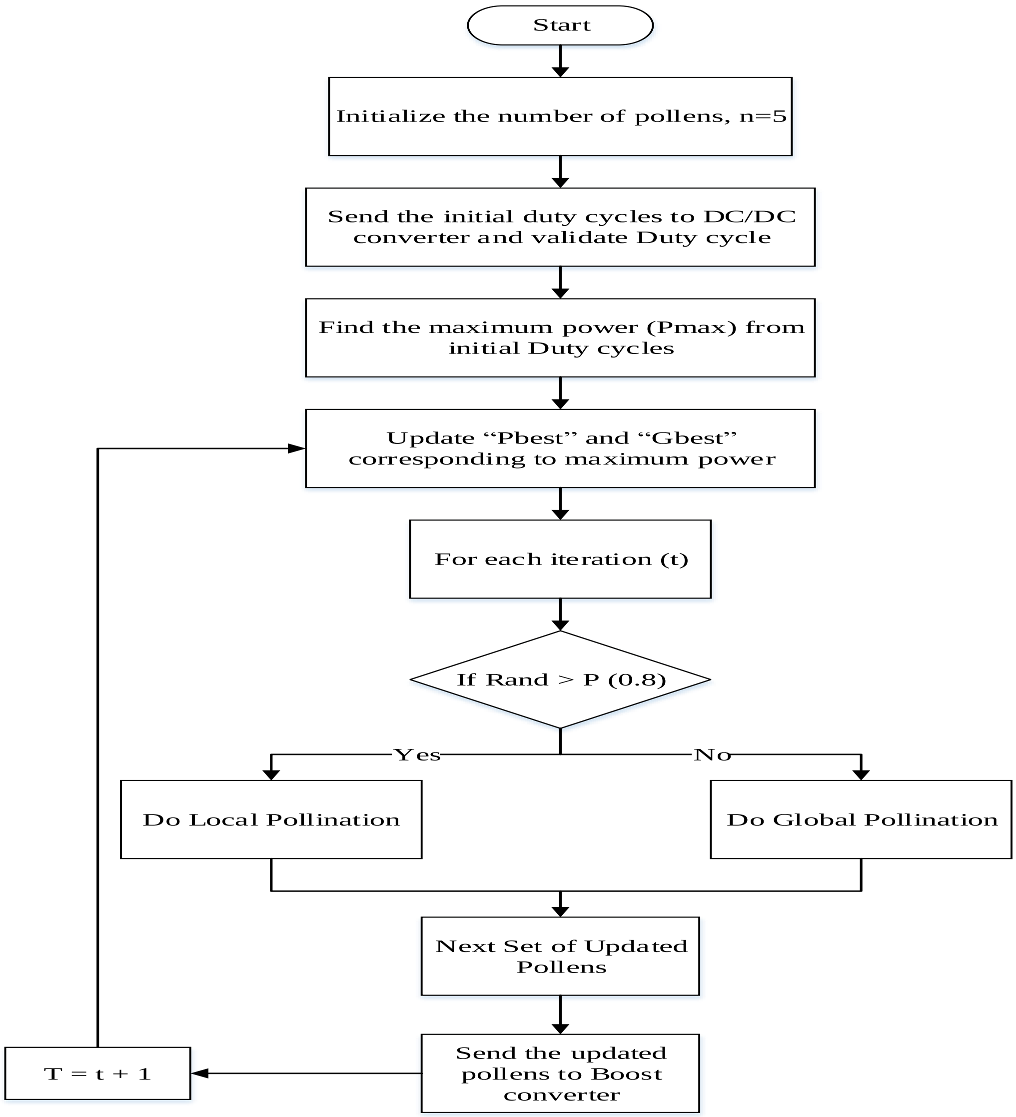


Figure 2: Flower Pollination Algorithm [23-25]

Revised FPA MPPT Algorithm:

Observing the strategies of FPA has lightened the idea of better utilization of the pollination concept to get more efficient results. The FPA takes random pollens and makes random placements before processing them through pollination which is the weak area. To get better results, the optimal placement of pollens before processing is mandatory, afterward the pollination selection would play a vital role in effective distribution to get the needed results.

The revised FPA initiates five pollens at global positions and processes through local pollination to attain five positions at a reasonable distance. This would conduct the

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

repeated regional distribution of pollens at five local positions. To ensure efficient global positioning these locally pollinated solutions will be processed through global pollination to reduce the probability of missing GMPP, and require fewer computations and a smaller number of iterations due to the limited search area. Additionally, within a single iteration, the efficient utilization of local and global pollination is attained. Moreover, the arrangement of collected pollens 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 pollination concept strategy is optimized in this revised structure of FPA. The flowchart of the revised FPA (RFPA) is designed in Figure 3.

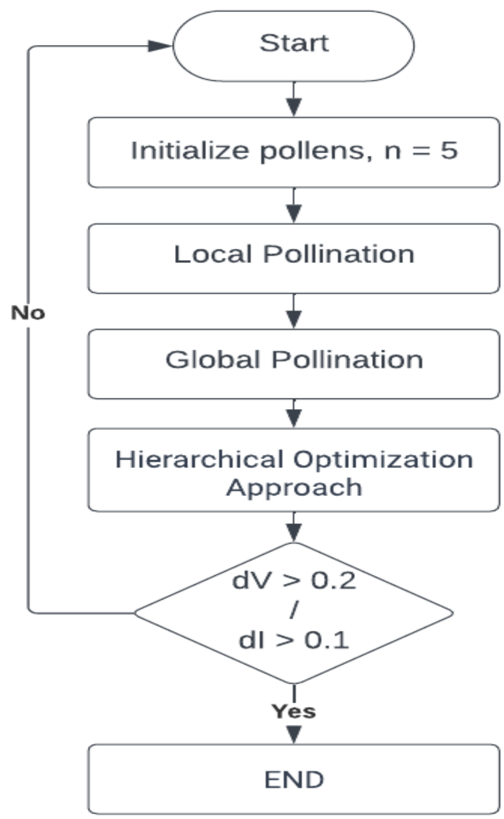


Figure 3: Proposed Revised Flower Pollination Algorithm

Simulation's Result:

To validate the claim of MFPA, 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 are FPA and MFPA. The weather effects have also been applied to the PV array in the simulation model presented in Figure 4.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

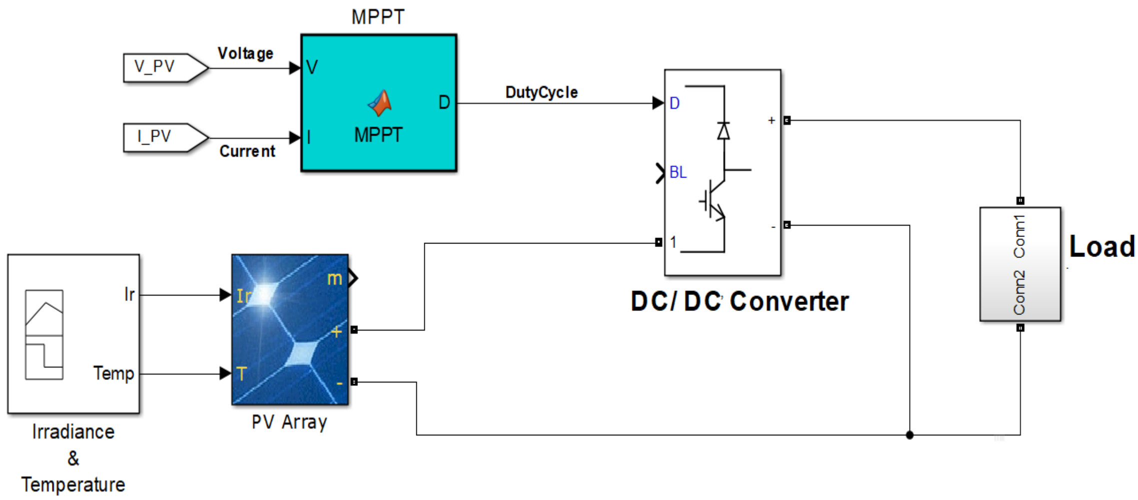


Figure 4: Photovoltaic System's Structure

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 **5**.

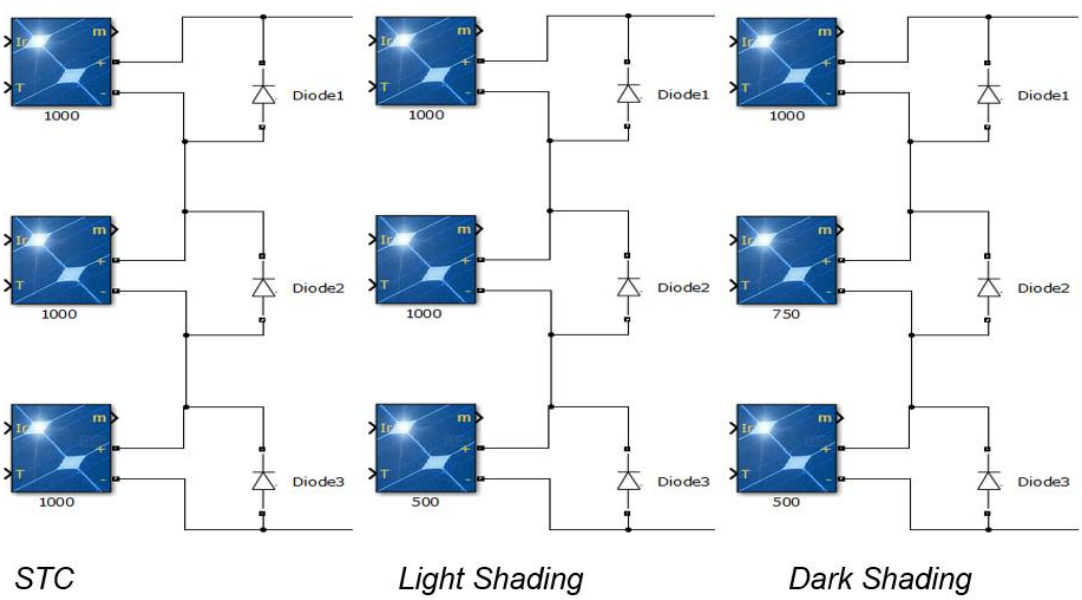
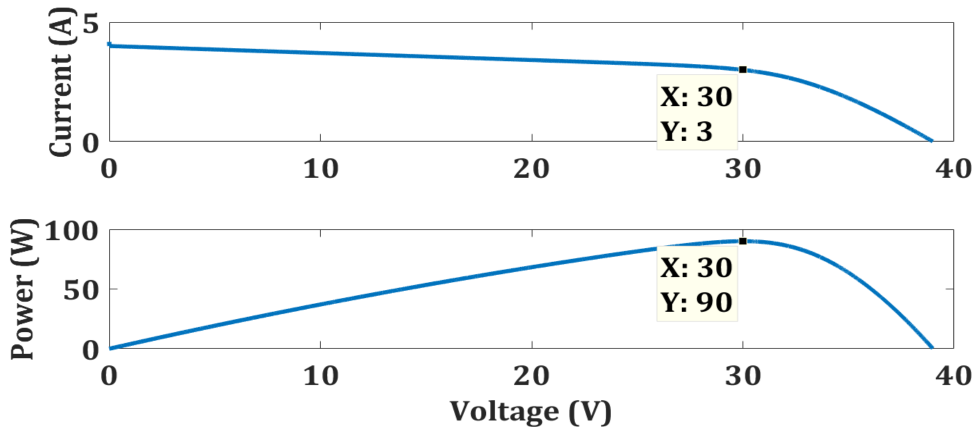


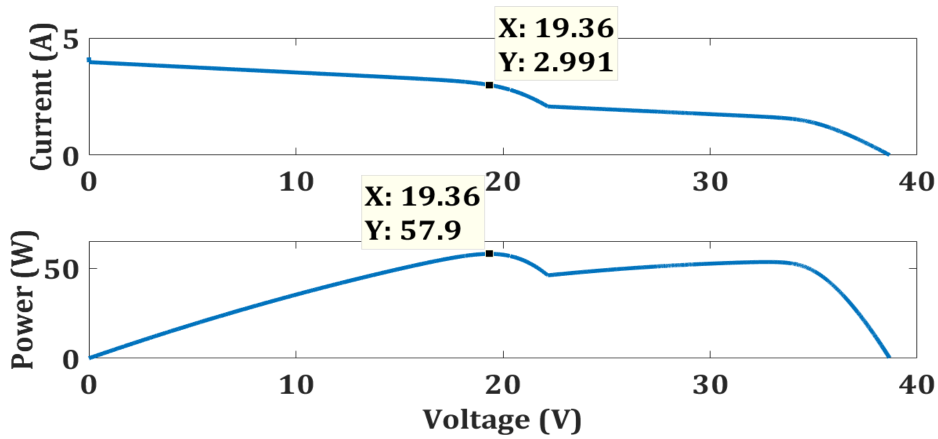
Figure 5: Solar Photovoltaic System

The characteristic curves of the designed SPV system for the three scenarios are depicted in Figure **6**. 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.

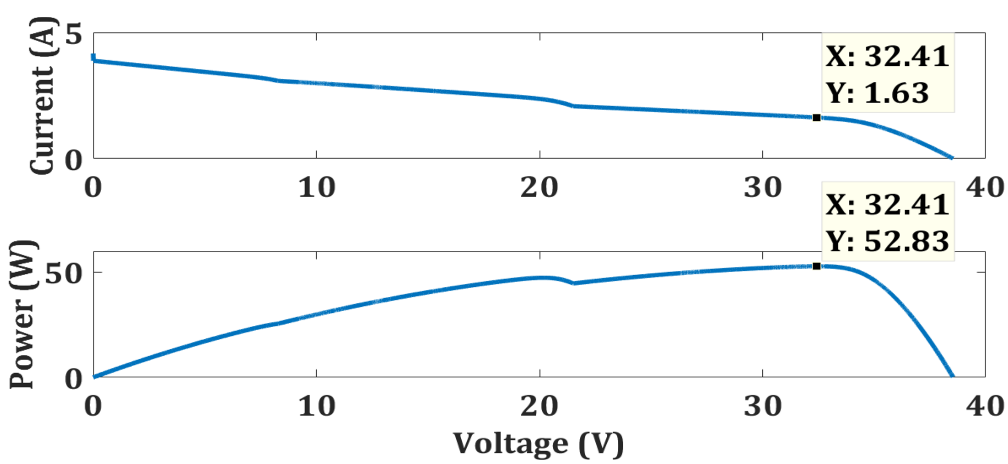
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631



A- Characteristic Curve of 3S PV System for Zero PSC



B- Characteristic Curve of 3S PV System for Weak PSC

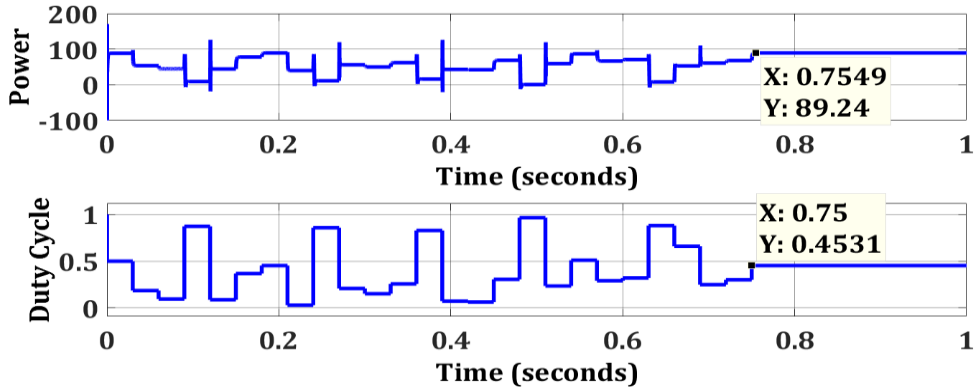


C- Characteristic Curve of 3S PV System for Strong PSC

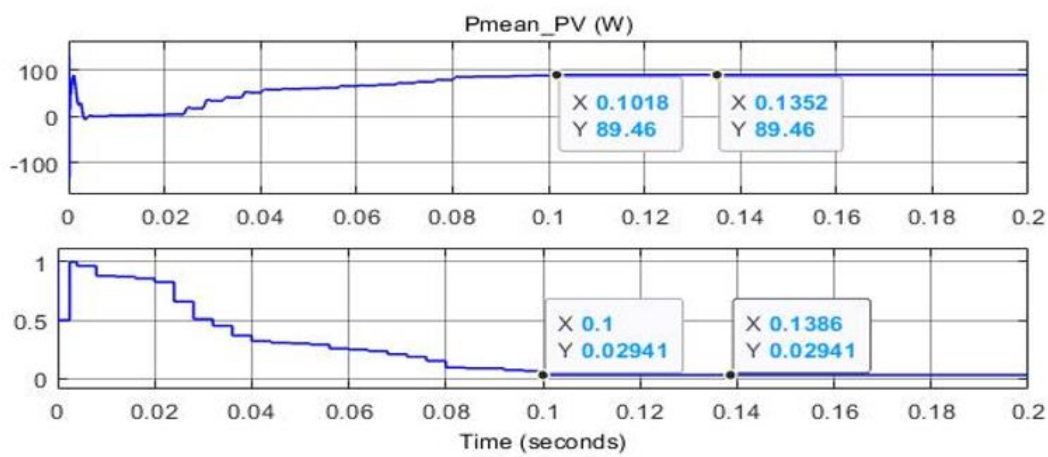
Figure 6: Characteristic Curve of 3S PV System for Strong PSC

Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

Application of FPA for STC presented in Figure **7** showed good results of 89.24 Watt 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 MFPA 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 FPA). The reason is the efficient use of concepts, which helped out in minimizing the iterations and settling time.



A) FPA algorithm for Zero Shading

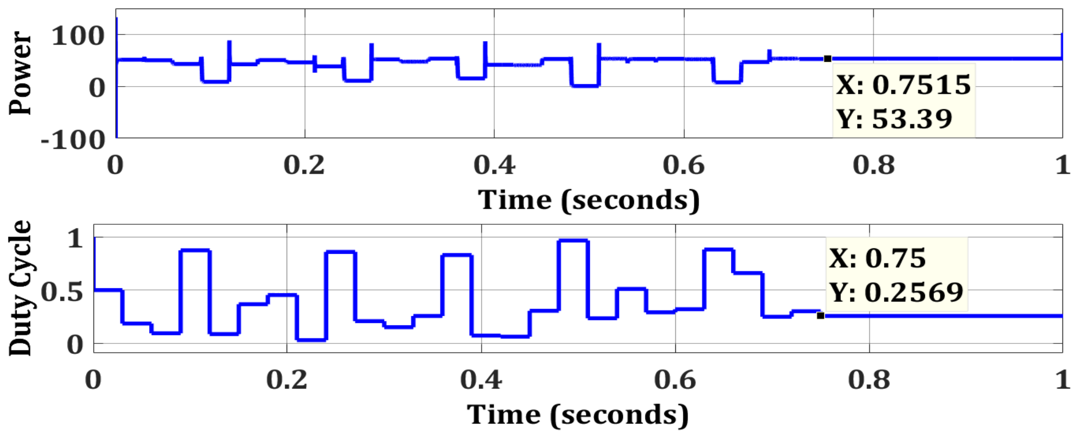


B) DA-FPA algorithm for Zero Shading

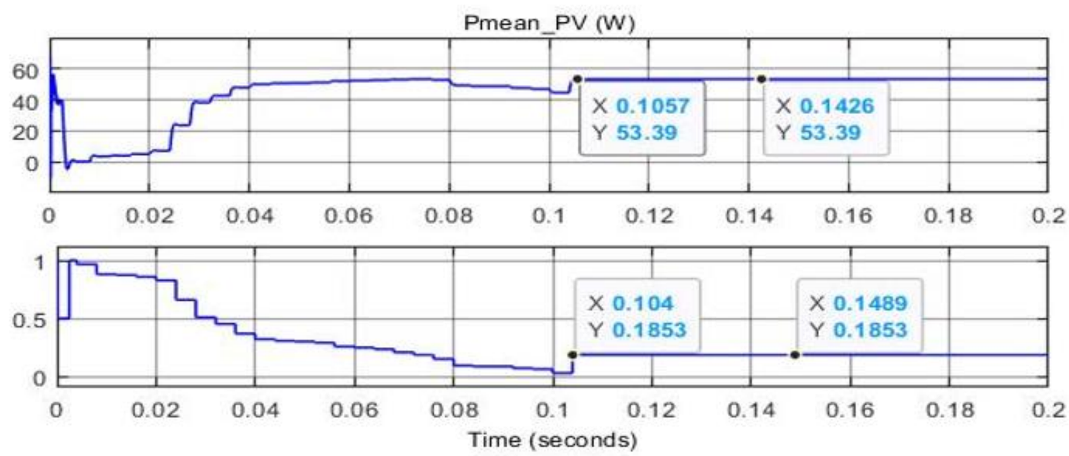
Figure 7: Simulation Results for 3S Configuration under Zero PSC

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 **8** that both the competitor algorithms attained 53.39 watts of power at different speeds. The MFPA has proved 86 times faster than the FPA in tracking speed by capturing the target in just 0.1057 seconds. The FPA is slow with a big margin, it attains the same in 0.7515 seconds.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631



A) **FPA algorithm**

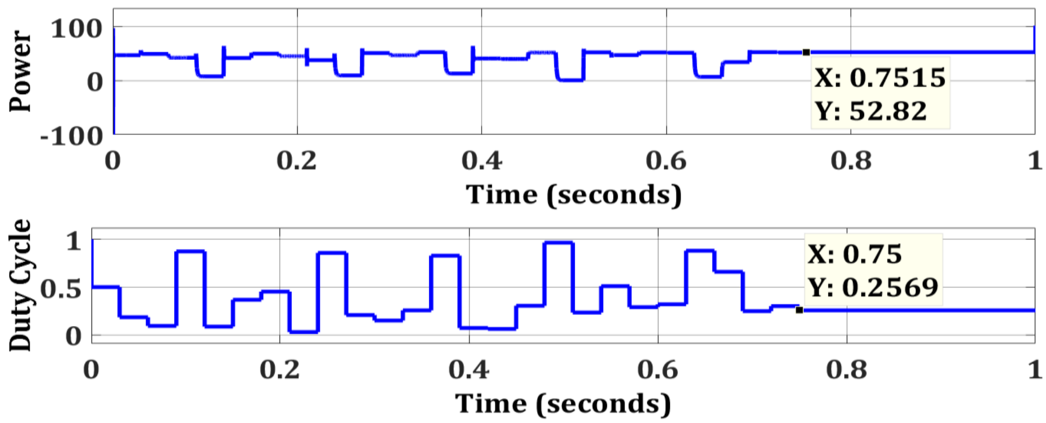


B) **DA-FPA Algorithm**

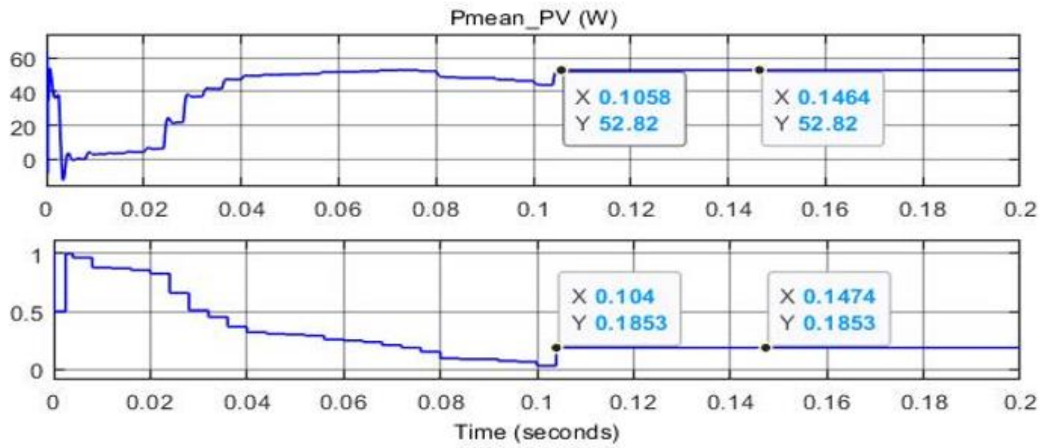
Figure 8: Simulation Results for 3S Configuration under Weak PSC

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 MFPA has outpaced the FPA with 86 times faster results in achieving the same goal of 52.82 watts. The simulation outcomes explain the results in Figure 9.

Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631



A) FPA algorithm



B) DA-FPA algorithm

Figure 9: 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	FPA	89.24	90	99.15	0.7549	**86.5**
	DA-FPA	89.46		99.4	0.1018	
Weak Partial Shading	FPA	53.39	57.9	92.21	0.7515	**86**
	DA-FPA	53.39		92.21	0.1057	
Strong Partial Shading	FPA	52.82	52.83	99.98	0.7515	**86**
	DA-FPA	52.82		99.98	0.1058	

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

Finally, the changing scenarios are analyzed to check if the algorithm can detect weather swings. The simulated output in Figure 10 confirms the change detection ability of MFPA to maintain its routine under numerous environments.

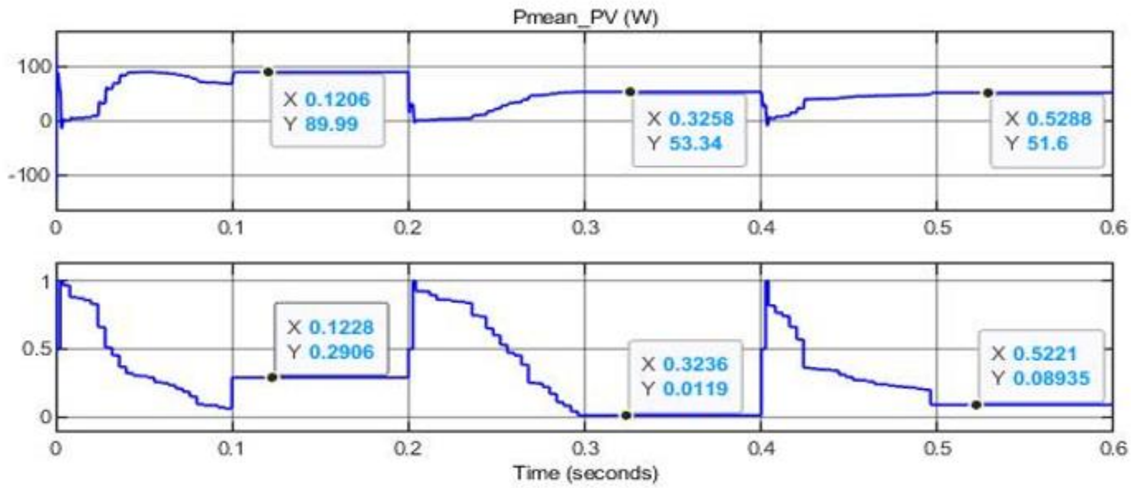


Figure 10: Performance of DA-FPA Algorithm Under Changing Weather Conditions for 3S PV system

CONCLUSION

After analyzing the searching strategy of FPA 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 FPA. 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 MFPA is compared with the FPA 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.

References

1) Díaz, A.V. and Moya, I.H., 2024. Urban wind energy with resilience approach for sustainable cities in tropical regions: A review. *Renewable and Sustainable Energy Reviews*, *199*, p.114525.

2) Ayorinde, O.B., Daudu, C.D., Okoli, C.E., Adefemi, A., Adekoya, O.O. and Ibeh, C.V., 2024. Reviewing the impact of LNG technology advancements on global energy markets.

3) Shabur, M.A., 2024. A comprehensive review of the impact of Industry 4.0 on the development of a sustainable environment. *Discover Sustainability*, *5*(1), p.97.

4) Chen, G. and Ji, Z., 2024. A Review of Solar and Wind Energy Resource Projection Based on the Earth System Model. *Sustainability*, *16*(8), p.3339.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

5) Ukoba, K., Yoro, K.O., Eterigho-Ikelegbe, O., Ibegbulam, C. and Jen, T.C., 2024. Adaptation of solar power in the Global South: Prospects, challenges and opportunities. *Heliyon*.

6) Alam, K.S., Kaif, A.D., Das, S.K., Abhi, S.H., Muyeen, S.M., Ali, M.F., Tasneem, Z., Islam, M.M., Islam, M.R., Badal, M.F.R. and Ahamed, M.H., 2024. Towards net zero: A technological review on the potential of space-based solar power and wireless power transmission. *Heliyon*.

7) Li, X., Wang, Q., Sun, Y., Sun, S. and Ge, L., 2024. Photogenerated charge carriers' regulation strategies: Structure design, mechanism, and characterization technology. *International Journal of Hydrogen Energy*, *69*, pp.1341-1365.

8) Chen, R., Ni, C., Zhu, J., Fan, F. and Li, C., 2024. Surface photovoltage microscopy for mapping charge separation on photocatalyst particles. *Nature Protocols*, pp.1-33.

9) Song, L., Fan, Y., Fan, H., Yang, X., Yan, K., Wang, X. and Ma, L., 2024. Photo-Assisted Rechargeable Metal Batteries. *Nano Energy*, p.109538.

10) Bennagi, A., AlHousrya, O., Cotfas, D.T. and Cotfas, P.A., 2024. A comprehensive study of the artificial intelligence applied in renewable energy. *Energy Strategy Reviews*, *54*, p.101446.

11) Gunawan, D., Zhang, J., Li, Q., Toe, C.Y., Scott, J., Antonietti, M., Guo, J. and Amal, R., 2024. Materials Advances in Photocatalytic Solar Hydrogen Production: Integrating Systems and Economics for a Sustainable Future. *Advanced Materials*, p.2404618.

12) Varshnry, A., Lather, J.S. and Dahiya, A.K., 2024. Supply energy management methods for a direct current microgrid: A comprehensive review. *Energy Storage*, *6*(1), p.e578.

13) Sharma, D., Jalil, M.F., Ansari, M.S. and Bansal, R.C., 2024. A Review of Maximum Power Point Tracking (MPPT) Techniques for Photovoltaic Array Under Mismatch Conditions. *Photovoltaic Systems Technology*, pp.85-102.

14) Gyamfi, S., Aboagye, B., Obeng, M. and Peprah, F., 2024. Criticality and Severity of Adverse Effects of the Sun on Performance of Solar PV Systems. *Solar Energy Advances*, p.100058.

15) Zhang, R., 2024, March. Recent advances in maximum power point tracking for energy harvest in solar photovoltaic systems. In *Second International Conference on Physics, Photonics, and Optical Engineering (ICPPOE 2023)* (Vol. 13075, pp. 746-755). SPIE.

16) Al Dodaev, Z., Aziz, T., Rahman, M.S. and Joy, T.A., 2024. Comparative Analysis of the MPPT Algorithm in a Residence and a Grid-Connected Solar PV System Under Partial Shade Conditions-A Review. *Control Systems and Optimization Letters*, *2*(1), pp.135-143.

17) Mazumdar, D., Sain, C., Biswas, P.K., Sanjeevikumar, P. and Khan, B., 2024. Overview of solar photovoltaic MPPT methods: a state of the art on conventional and artificial intelligence control techniques. *International Transactions on Electrical Energy Systems*, *2024*(1), p.8363342.

18) Zhang, R., 2024, March. Recent advances in maximum power point tracking for energy harvest in solar photovoltaic systems. In *Second International Conference on Physics, Photonics, and Optical Engineering (ICPPOE 2023)* (Vol. 13075, pp. 746-755). SPIE.

19) Bhukya, L., Kedika, N.R. and Salkuti, S.R., 2022. Enhanced maximum power point techniques for solar photovoltaic system under uniform insolation and partial shading conditions: a review. *Algorithms*, *15*(10), p.365.

20) Ishrat, Z., Gupta, A.K. and Nayak, S., 2024. A comprehensive review of MPPT techniques based on ML applicable for maximum power in solar power systems. *Journal of Renewable Energy and Environment*, *11*(1), pp.28-37.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 08 | 2024
DOI: 10.5281/zenodo.13284631

21) Mazumdar, D., Sain, C., Biswas, P.K., Sanjeevikumar, P. and Khan, B., 2024. Overview of solar photovoltaic MPPT methods: a state of the art on conventional and artificial intelligence control techniques. *International Transactions on Electrical Energy Systems*, *2024*(1), p.8363342.

22) Tariq, M., Rihan, M. and Ayan, M., 2024. A comprehensive review of the application of recently introduced optimization techniques obtaining maximum power in the solar PV System. *Renewable Energy Focus*, p.100564.

23) Prithi, S. and Sumathi, S., 2024. A technical research survey on bio-inspired intelligent optimization grouping algorithms for finite state automata in intrusion detection system. *International Journal of Engineering, Science and Technology*, *16*(2), pp.48-67.

24) Chen, C., Cao, L., Chen, Y., Chen, B. and Yue, Y., 2024. A comprehensive survey of convergence analysis of beetle antennae search algorithm and its applications. *Artificial Intelligence Review*, *57*(6), p.141.

25) Tomar, V., Bansal, M. and Singh, P., 2024. Metaheuristic Algorithms for Optimization: A Brief Review. *Engineering Proceedings*, *59*(1), p.238.

26) Alshareef, M.J., 2023. A New Flower Pollination Algorithm Strategy for MPPT of Partially Shaded Photovoltaic Arrays. *Intelligent Automation & Soft Computing*, *38*(3).

27) Murdianto, F.D., Efendi, M.Z., Setiawan, R.E. and Hermawan, A.S.L., 2017, October. Comparison method of MPSO, FPA, and GWO algorithm in MPPT SEPIC converter under dynamic partial shading condition. In *2017 International Conference on Advanced Mechatronics, Intelligent Manufacture, and Industrial Automation (ICAMIMIA)* (pp. 315-320). IEEE.

28) Suyanto, S., Mohammad, L., Setiadi, I.C. and Roekmono, R., 2019, October. Analysis and evaluation performance of MPPT algorithms: Perturb & observe (P&O), firefly, and flower pollination (FPA) in smart microgrid solar panel systems. In *2019 International Conference on Technologies and Policies in Electric Power & Energy* (pp. 1-6). IEEE.

29) Awan, M.M.A. and Mahmood, T., 2022. Modified flower pollination algorithm for an off-grid solar photovoltaic system. *Mehran University Research Journal of Engineering & Technology*, *41*(4), pp.95-105.

30) Alghamdi, M.A., Khan, M.F.N., Khan, A.K., Khan, I., Ahmed, A., Kiani, A.T. and Khan, M.A., 2021. PV model parameter estimation using modified FPA with dynamic switch probability and step size function. *IEEE Access*, *9*, pp.42027-42044.

31) Roland Kobla Tagayi, Jongbok Baek, Jonghoon Kim, “Flower pollination global peak search algorithm for partially shaded solar photovoltaic system”, Journal of Building Engineering, Volume 66, 105818, 1 May 2023

32) Awan, M.M.A. and Awan, M.J., 2022. Adapted flower pollination algorithm for a standalone solar photovoltaic system. *Mehran University Research Journal Of Engineering & Technology*, *41*(4), pp.118-127.

33) Awan, M.M.A. and Mahmood, T., 2020. Optimization of maximum power point tracking flower pollination algorithm for a standalone solar photovoltaic system. *Mehran University Research Journal of Engineering & Technology*, *39*(2), pp.267-278.