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A Weighted SALP Swarm Optimization mpp Tracking Algorithm for the Solar Photovoltaic Systems

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ABSTRACT: Maximum Power Point Tracking (MPPT) is an important concept for both uniform solar irradiance and Partial Shading Conditions (PSCs). The system presents an Weighted Salp Swarm Algorithm (WSSA) for MPPT under PSCs. The proposed method benefits a fast convergence speed in tracking the Maximum Power Point (MPP), in addition to overcoming the problems of conventional MPPT methods, such as failure to detect the Global MPP (GMPP) under PSCs, getting trapped in the local optima, and oscillations around the MPP. The proposed method is compared with original algorithms such as Salp Swarm Optimization (SSO). The obtained results show that the proposed method can detect and track the MPP in a very short time, and its accuracy outperforms the other methods in terms of detecting the GMPP. The proposed WSSA algorithm has a higher speed and the convergence rate than the other traditional algorithms.

I. INTRODUCTION

Nowadays, the utilization of the renewable energy power systems is more in the domestic and industrial applications. The drawbacks of the non-renewable sources are, a drastic reduction of fossil fuel, more pollutant and exhaustive. The solar photovoltaic energy leads among the renewable energy power systems because of the advantage such as no fuel cost, no pollution, ease of maintenance, and zero gas emission. However, the solar power conversion efficiency is too low due to a various operating condition such as a change in the cell temperature, solar irradiation, and PSCs [1]. The PV array under the partial shading condition is shown in Fig. 1. The PSC is due to shading of the passage of clouds, dust, tree shadows etc. Under PSC, the PV system shows the multiple local MPP (LMPP), and one GMPP. The main effect due to the PSC is tracking of dynamic GMPP, and it is challenging too.

The conventional MPPT algorithms fail to locate the GMPP, and the modern optimisation methods are used to neutralize the effects due to the PSC by optimizing the duty ratio of the dc-dc converter to locate the MPP of the PV system under PSC. The PV power systems performance depends on the factors such as the PV panel conversion efficiency, the performance of the dc-dc converter, and the tracking efficiency of the maximum power point tracking (MPPT) algorithm. The conversion efficiency of the PV module and the dc-dc converter is depending on the recent developments which are out of the scope of this paper. Instead, the tracking efficiency of the MPPT can be improved efficiently with less cost, and it can directly update the conventional algorithm. The testing of the PV power system is straightforward in this way.

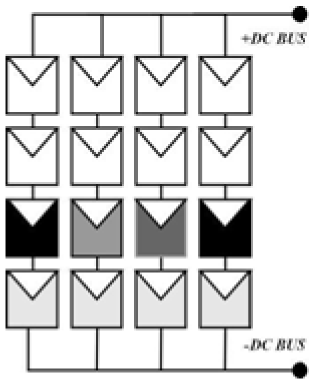

Fig. 1. PV array under partial shading condition

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The paper [2]-[3] discusses the conventional MPPT algorithm such as perturb & observation (PO), and incremental conductance (IC). The result exhibited by both the conventional algorithm is more or less same during both the static and dynamic condition as per the standard EN50530. The PO and IC algorithm fails to track the GMPP. Instead, it tracks the LMPP, and displays oscillated response while tracking the GMPP. The paper [4] proposed a modified PO MPPT algorithm for the PV energy systems. The modified PO provides faster convergence to GMPP during a change in operating condition. A modified IC algorithm proposed by [5] is suitable for the PV systems under PSC, and various loading condition to locate the GMPP, and thus power losses reduced. An improved IC algorithm proposed by [6] for the PV system to increase the speed of convergence to GMPP and reduces the steady-state oscillation. Whereas, modern soft computing techniques based MPPT algorithms uses meta-heuristics, heuristic and an evolutionary algorithm based on the artificial intelligence or bio-inspired such as Particle Swarm Optimization (PSO), Artificial Neural Network (ANN), fuzzy logic control, genetic algorithm, Tabu search, differential evolution, simulated annealing, firefly, teaching-learning based optimization, ant colony optimization, artificial bee colony, etc. [7] - [15].

The paper [16] proposed a PSO based MPPT technique for the PV system to locate the GMPP under PSCs. The PSO algorithm helps the dc-dc converter to track the MPP during the shading and PSCs. The author of [17] compares the swarm algorithm such as bat algorithm, and flower pollination algorithm (FPA), both the algorithms find the global operating point. The FPA’s tracking efficiency is more than the bat algorithm due to the less search space, and it leads to converge to LMPP instead of GMPP.

The genetic algorithm (GA) was employed in [18] to rapidly track the GMPP and to improve the accuracy of MPPT algorithm. In literature [19], artificial bee colony (ABC) algorithm was described to track the MPP under varying operating conditions, which requires very less defined parameters and the convergence is independent of the initial condition. In addition, cuckoo search algorithm (CSA) was proposed for the PV system to track the MPP efficiently under PSC [20]. Additionally, bat algorithm (BA) was proposed by [21] to provide dynamic performance and fast convergence rate by switching between exploitation and exploration during the process. The author of [22] proposed a moth-flame optimization (MFO) to rapidly find the GMPP under PSC. The author of [23] proposed a meta-heuristic grey wolf optimization (GWO) algorithm for the PV system reduces the problem such as steady-state oscillation, less tracking efficiency, and transients as in the conventional algorithms. The author of [24] applies a whale optimization algorithm (WOA) to locate the GMPP, and it offers high tracking speed and high accuracy under the PSCs. The WOA algorithm is superior in tracking speed and accuracy compared to PSO and GWO techniques.

The author of [25] combines the GWO and PO technique to achieve the better tracking efficiency under a rapid and extreme change in solar insolation. The GWO takes care of the initial stage, and final stage is taken care by the PO algorithm to achieve the fast convergence. The author of [26] combines the PO and artificial neural network (ANN) to achieve the faster convergence rate under PSC. The ANN finds the GMPP region and the PO located the MPP by varying/controlling the duty ratio of the dc-dc converter. The key motivation of this paper is to increase the tracking speed and tracking efficiency of the proposed algorithm under the PSCs by optimizing the duty ratio of the dc-dc converter. The author of [27] combines WOA and PO technique to achieve the better tracking speed and the efficiency under various environmental conditions. The WOA will find the initial global peak, and the PO will take the final stage for faster convergence rate.

An optimization method is not only used to rapidly find the quality power output, however, it also improves the stability during the convergence which reduces the power fluctuation of the system. The conventional optimization algorithms such as GWO, WOA, ANN etc. faces the problems to satisfy the above such requirements. Therefore, this paper discusses a new MPPT algorithm for the PV system under PSCs to rapidly find the GMPP and improves the stability during convergence. This paper is organised as follows. Section 2 discusses the PV mathematical modelling and its characteristics under the change in operating condition. The illustration of the SSO, modelling, and its application to develop the MPPT is discussed in section 3. Section 4 discusses the simulation and experimental results, and the performance comparison with the WSSA and PSO. Section 5 concludes the paper.

II. MATHEMATICAL MODELLING AND CHARACTERISTICS UNDER PARTIAL SHADING CONDITIONS

2.1. MATHEMATICAL MODELLING OF THE PV MODULE

The PV cell is modelled as per the single diode PV cell model, and the equivalent circuit of the PV cell is shown in Fig.2. The single diode PV model has current source to represent the photo-current in parallel with the diode,

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shunt resistance (Rsh), and series resistance (Rse) [28]. First, the model is developed for the PV cell and then extended to the PV module. The PV cell current of the model is presented in Eq. 1.

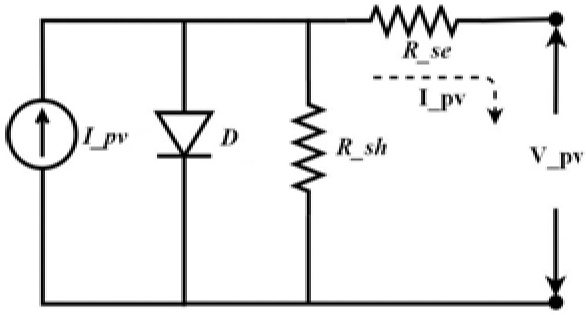

Fig. 2. The equivalent circuit of a single PV cell

Where I0 is the diode's reverse saturation current, n is an ideality factor of the diode, and VT is the thermal leakage voltage. The PV cell is subjected to the change in temperature and solar irradiation. The effect on the solar PV panel is given in Eq. 2.

Where Ipv_STC represents the photocurrent under standard test condition (STC), the change in cell temperature is represented by ΔT=T-TSTC, and TSTC=25°C, GSTC is the solar irradiation effect under nominal condition, i.e. 1000W/m², G is the solar irradiation effect on the PV cell, KI is the temperature coefficient of the short-circuit current and usually this value will be provided by the manufacturer. The diode reverse saturation current is given by the Eq. 3.

Where IO_STC represents the nominal diode saturation current, Eg is the band gap energy of the silicon diode, q is electron charge and, is equal to 1.6 x 10-19 C, the temperature of the diode p-n junction is T in Kelvin, and Boltzmann's constant, k= 1.38 x 10-23 J/K. The diode saturation current as a function of the junction temperature is presented in Eq. 4.

Where the temperature coefficient of the open circuit voltage is represented as KV, nominal short circuit current and open circuit voltage is represented as ISC_STC and VOC_STC respectively. The thermal voltage equation is presented in Eq. 5, in which Ns represents the series-connected PV cells in a PV panel.

Eqs. (1)-(5) represent the PV cell, and it can be extended to the PV panel. In PV panel, a number of the PV cells are connected in series/parallel to meet the voltage and power demand. The voltage demand met by connecting the cells in series, and the current demand met by connecting the cells in parallel. The total current of the PV panel is presented in Eq. 6. The number of series connected PV cells and the number of parallel connected PV cells represented as Ns and Np respectively.

Eqs. 1-6 are analysed and simulated using the simulation tool called MATLAB/Simulink, and the simulation result under PSC is shown in Figure 3. Figure 3 demonstrates the P-V and I-V characteristics of the PV array under partial shading conditions.

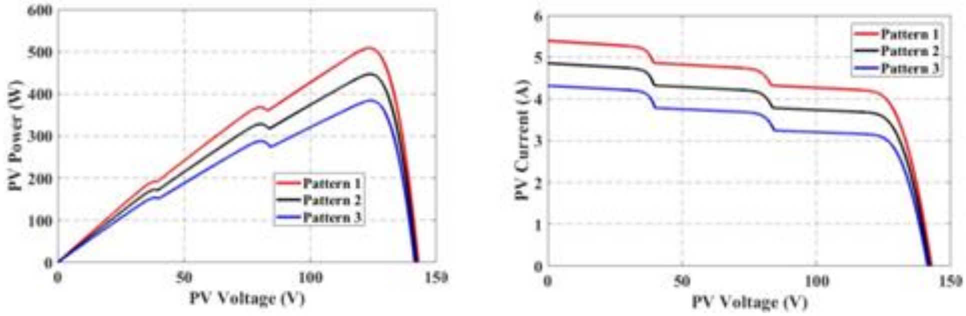

Fig. 3. PV characteristics under PSCs with patterns; (a) V-P characteristics, (b) V-I characteristics

EFFECT OF THE PSC ON THE PV ARRAY WITH DIFFERENT CONFIGURATIONS

The PV array is made with many modules connected in series and parallel combination. If the cells in the modules are partially shaded, the cell subjected to shading absorbs high energy due to the reverse voltage. This absorbed energy is converted as a hotspot and results in thermal stress and, finally damage the PV cell. The effect due

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to the hotspot reduced by the bypass diode, and is connected across the PV panel. So, the negative voltage is avoided as discussed in [29]. If the Eq. 7 is satisfied, the bypass diode starts to function.

The effect of PSC on the PV array configuration is shown in Fig. 3. From the Fig. 3(a), it is observed that V-P characteristic of the PV panel exhibits multiple peak points during shading condition, i.e. many LMPP and one GMPP. The various configuration of the PV systems is selected to validate the proposed algorithm such as 2S2P (two sets of the series connected panel are connected in parallel), and 3S configuration (three series connected panels). For simplification, the other PV array configurations such as total-cross-tied (TCT), honey-comb (HC), and bridge-linked (BL) is not discussed in this paper which are out of the scope. However, the proposed algorithm is also suitable for the above-said PV array configurations. The diagrammatic representation of the two different PV configurations is shown in Fig. 4.

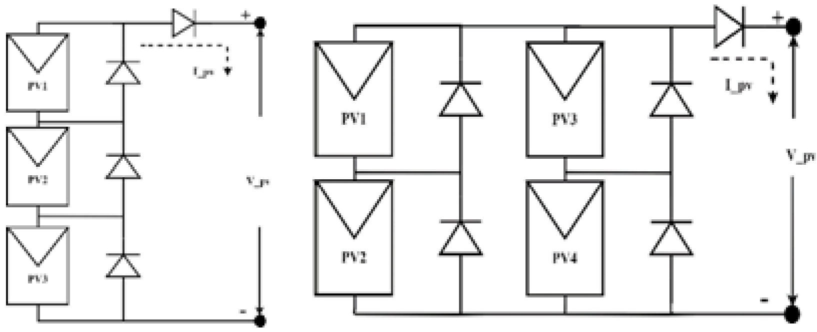

Fig. 4. Different PV configurations; (a) 3S configuration, (b) 2S2P configuration

Fig. 5 shows the simulated P-V characteristic for the two different PV formations under different shading conditions. The divergent GMPP is located in the P-V characteristics for each of the shading pattern and it is shown in Fig. 5. The power extraction from the panel is formulated as an augmented problem, and the Eq. 8 shows the optimized problem.

Where the duty ratio of the boost converter is d, dmin represents the minimum duty cycle; the maximum duty cycle represented by dmax, and is considered as 45% and 70% respectively. The maximum value is fixed at 70% to decrease the reverse recovery issue on the switching device, and diode.

III.OVERVIEW OF THE PROPOSED WEIGHTED SALP SWARM MPPT TECHNIQUE

3.1. MOTIVATION

Salps shape is like a barrel-shape and transparent body, and it belongs to the Salpidae family. The tissues of salps are like jellyfishes. The movement of salps is like jellyfish, and it is moving forward by pumping the water through the body, and it will act as propulsion. Fig.4(a) shows the shape of the salp. Keeping the salps in the laboratory environments is tough. The most exciting feature/ behaviour of the salp is the main motivation of this paper, i.e. the swarming feature of the salp. In the ocean, salp forms a swarm called as salp chain [30]-[31]. The salp chain is shown in Fig. 4(b). However, the reason for forming salp chain is yet unknown to the researchers. The few researchers believe that the chain is for better movement using foraging and change in coordination.

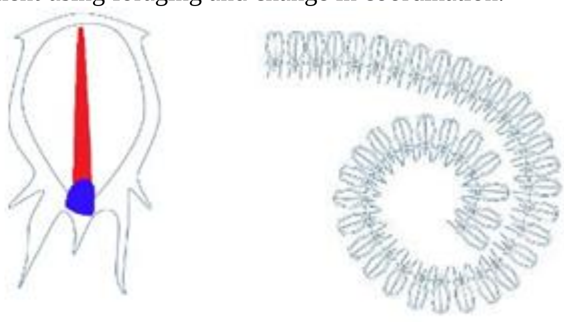

Figure 4. Shape of the Salp; (a) Single Salp, (b) Salp chain

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Mathematical Model for the Salp Chain

The mathematical model for the salp chain is proposed by [32]-[34], and this model is used for the optimization problem. The modeling is done by dividing the population into two groups such as follower and leader. The salp at the forward-facing is called a leader, and the remaining salps in the chain are considered as a follower. A leader guiding the swarm and the followers follow the leader. As with other swarm optimisation methods, the salp position is well-defined as n-dimensional search space, and n is called a number of variables. The salp position is stored in a two-dimensional matrix. Here, the swarm target is assumed as a food source in the search space. The leader position is updated as per the Eq. 9.

Where the leader position in the jth dimension is expressed as , the food source is represented as Fj, upper and lower bound is represented as ubj and lbj respectively, the random numbers are c1, c2 and c3. From the Eq. 9, it is observed that the position of the leader is updated concerning the food source. The random number, c1 is a significant coefficient in the salp swarm optimization algorithm, and this coefficient decides the exploitation and exploration. The Eq. 10 represents the coefficient, c1.

Where L represents the maximum iteration, the current iteration is represented as l. The coefficients such as c2 and c3 are generated randomly between [0,1]. The position of the followers is updated as per the Eq. 11.

Where the follower position in the jth dimension is expressed as ,i $\geq$ 2, the initial speed is represented as vo, a=vfinal/vo, and v=x-xo/t. Assume vo=0, a time in optimization is represented as an iteration, and inconsistency between the iteration equal to 1. The Eq. 11 is modified as the Eq. 12. Eqs. 9-12 is used to model and simulate the salp chain.

WEIGHTED SALP SWARM OPTIMIZATION (WSSO) ALGORITHM APPLICATION TO MPPT

The primary objective of the algorithm is to find the global optimum, i.e. GMPP. In the salp chain model, the follower follows the leader, and the leader goes towards the food source. If the GMPP replaces the food source, the salp chain moves towards the GMPP. The best solution so far is the GMPP, and the salp chain chases the food source. The flowchart for the proposed SSO algorithm is shown in Fig. 6. The steps to be followed for the proposed SSO algorithm are as follows.

The flowchart of the proposed MPPT technique starts with approximate global optimum by assigning the random position for the many salps. This optimum value finds the fitness, determines the best fitness salp, and the position of the best fitness salp is assigned as a food source. The variable F chased by the swarm of salps. The c1 coefficient is updated using the Eq. 10. At every dimension, the leader salp position is updated as per the Eq. 9, and the follower salp position is updated as per the Eq. 11. If the salp position is out of search space, it will come back to the boundaries.

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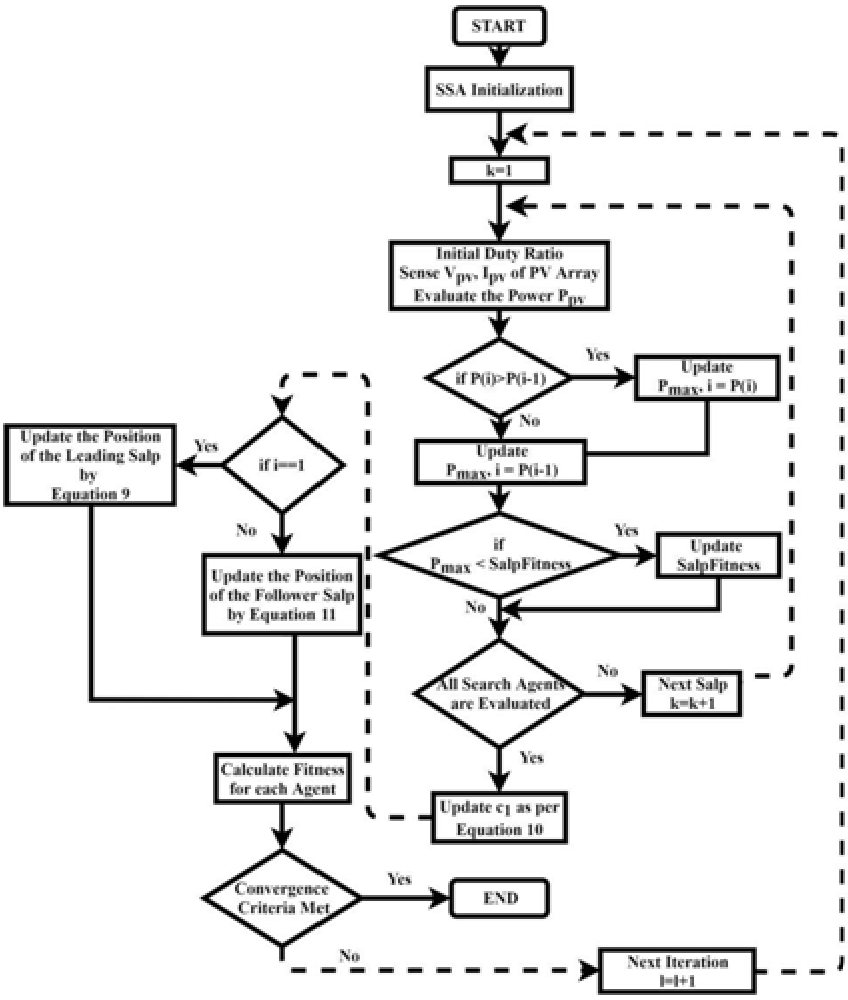

Fig6. Flowchart of the proposed WSSO MPPT

The steps are repeated until the convergence criteria met. The food source is updated because the swarm of salps is likely to determine the optimal solution by exploiting and exploration around the search space. The swarm of salps moves towards the GMPP that change over each iteration. The leader salp position represents the duty ratio for the converter which omits the usage of the proportional-integral control loop. It helps to reduce the burden on the controller gain tuning.

Fig. 8 shows the block diagram for the proposed MPPT technique. The output power of the PV module changes under the change in climatic condition. During the change in operating condition, the proposed algorithm is reinitialized by recalculating the PV output power. The tracking efficiency of the converter is increased by the selecting high number of salps. In this paper, the computation time is reduced by selecting 10 number of salps in a chain.

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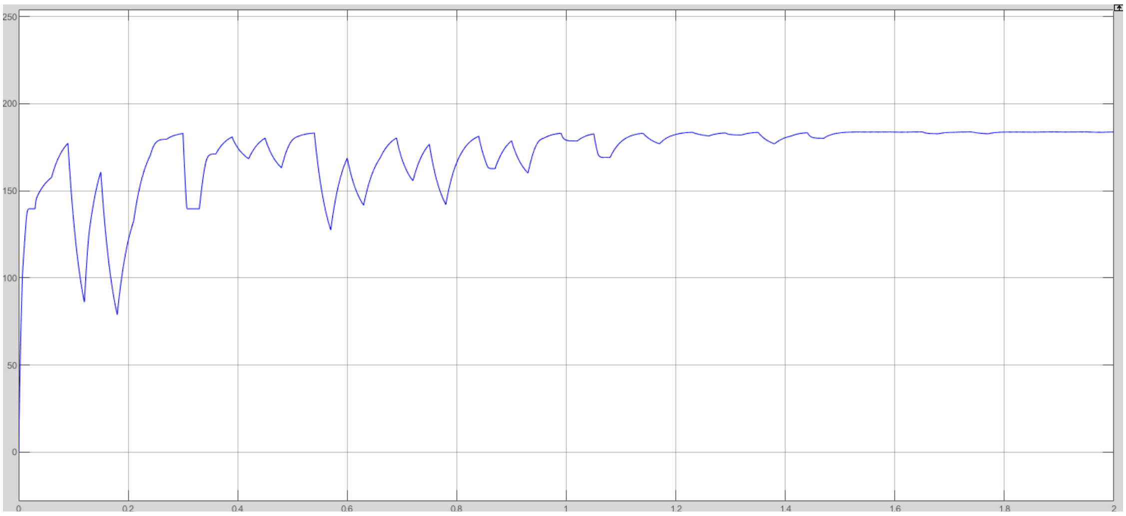
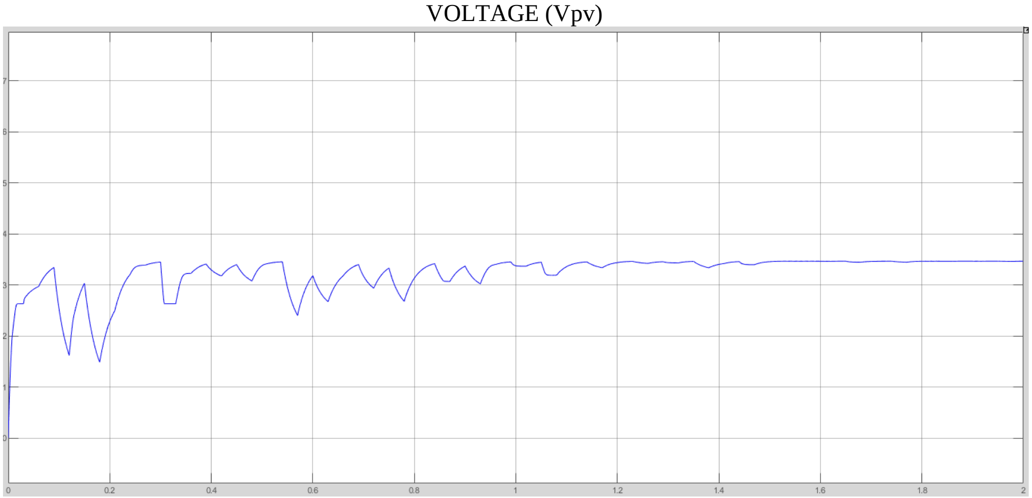
IV. RESULTS AND DISCUSSIONS

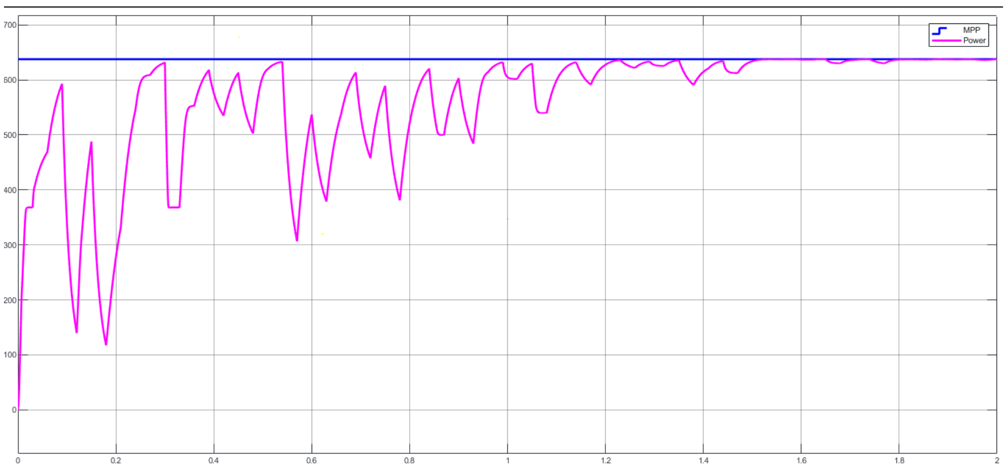
SIMULATION RESULTS



PARTICLE SWARM OPTIMISATION OUTPUT WAVEFORM OF VOLTAGE (Vpv)



PARTICLE SWARM OPTIMISATION OUTPUT WAVEFORM OF CURRENT (Ipv)



POWER WAVEFORM OF PARTICLE SWARM OPTIMISATION

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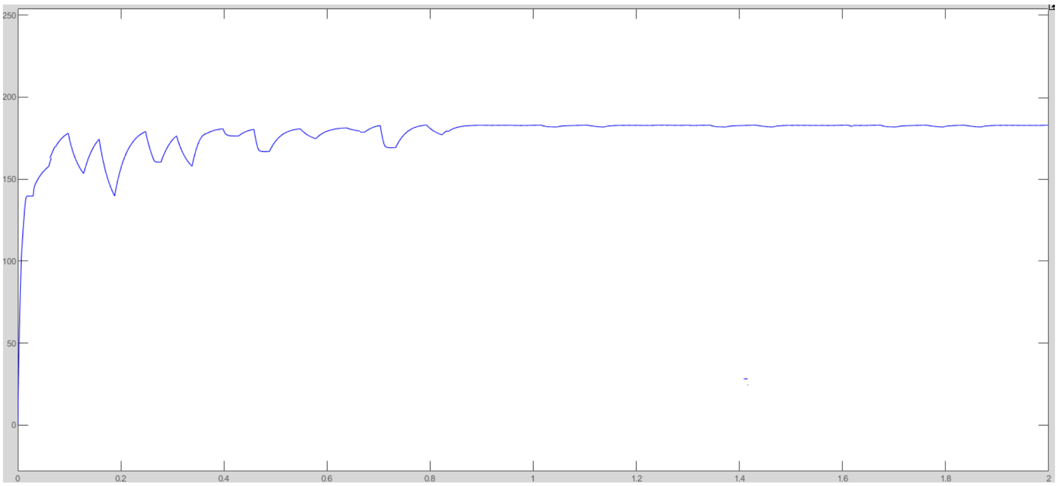
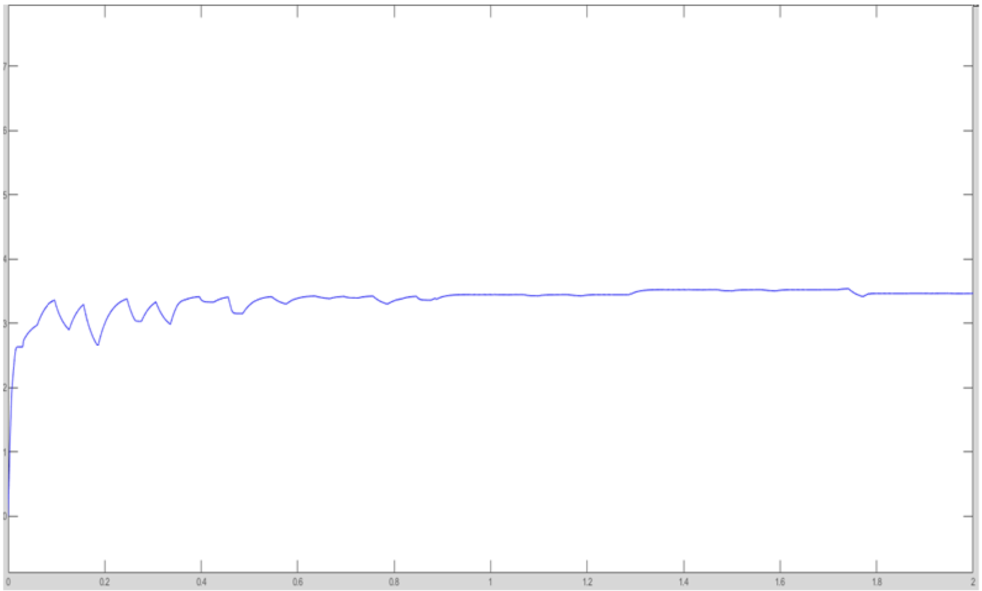
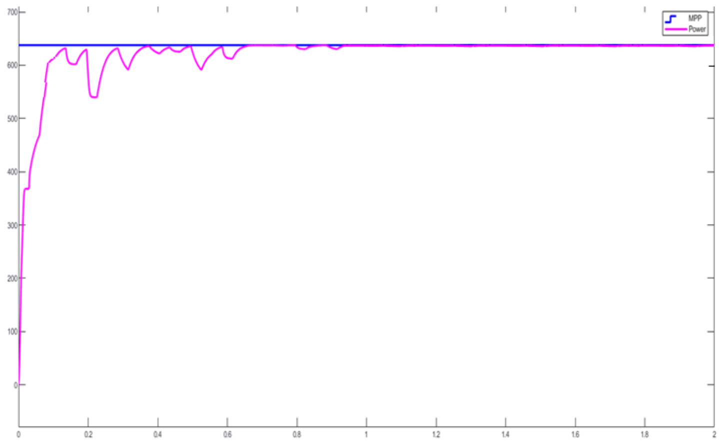


WEIGHTED SALP SWARM OPTIMISATION OUTPUT
WAVEFORM OF VOLTAGE (Vpv)



WEIGHTED SALP SWARM OPTIMISATION OUTPUT
WAVEFORM OF CURRENT (Ipv)



POWER WAVEFORM OF WEIGHTED SALP SWARM

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OPTIMISATION

From the simulation results, it is clear that with less oscillations, the GMPP is
reached in 0.9 second compared to 1.4 seconds in existing system
66 Parallel strings
Series Connected Modules Per String 5
Maximum Power 305.226W
Voltage At Maximum Power Point 54.7 V

A new SSO MPPT algorithm is proposed in this paper to trace the GMPP when the solar PV energy system is subjected to different shading patterns. The proposed algorithm is tested for two different PV array configurations under a rapid change in insolation, PSCs and an extreme change in insolation conditions. When the PV systems show multiple peak points, the SSO algorithm traces the GMPP with high tracking efficiency, high accuracy, and fast tracing speed under all the testing conditions. From the results and further discussions, the SSO MPPT technique is superior in tracking accuracy, time, and the efficiency. The computation burden on the SSO algorithm is reduced by selecting the lesser number of search agents with less iteration. The search agents and iterations are restricted to 10 and 20 iterations for the simulation and hardware testing.

REFERENCES

1. M. Premkumar, N. Dhanasekar, R. Dhivakar, and P. Arunkumar, ―Comparison of MPPT algorithms for PV systems-based DC-DC converter‖, Advances in Natural and Applied Sciences, Vol. 17, No. 09, pp. 212-221, March 2015.
2. D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, and R. Teodorescu, ―On the perturb- and-observe and incremental conductance MPPT methods for PV systems,‖ IEEE Journal of Photovoltaics, Vol. 3, No. 3, pp. 1070-1078, July 2013.
3. Tan, S.T.Adrian, and S. Iqbal, ―Implementation of INC MPPT and CV Charging Using LLC Resonant Converter for Solar Streetlight System‖, Journal of Circuits, Systems and Computers, Vol. 27, No. 03, pp. 1850043, 2018.
4. B. N. Alajmi, K. H. Ahmed, S. J. Finney, and B. W. Williams, ―Fuzzy-logic-control approach of a modified hill-climbing method for maximum power point in microgrid standalone photovoltaic system,‖ IEEE Transactions on Power Electronics, Vol. 26, No. 4, pp. 1022-1030, April 2011.
5. K.S. Tey, and S. Mekhilef, ―Modified incremental conductance algorithm for photovoltaic system under partial shading conditions and load variation,‖ IEEE Transaction on Industrial Electronics, Vol. 61, No. 10, pp. 5384-5392, October 2014.
6. T. K. Soon, and S. Mekhilef, ―A fast converging MPPT technique for photovoltaic system under fast varying solar irradiation and load resistance,‖ IEEE Transaction on Industrial Information, Vol. 11, No. 1, pp. 176–186, February 2015.
7. M.A. Ramli, S. Twaha, K. Ishaque, and Y.A. Al-Turki, ―A review on maximum power point tracking for photovoltaic systems with and without shading conditions‖, Renewable and Sustainable Energy Reviews, Vol. 67, pp. 144-159, 2017.
8. K. Ishaque, Z. Salam, and G. Lauss, ―The performance of perturb and observe and incremental conductance maximum power point tracking method under dynamic weather conditions‖, Applied Energy, Vol.119, pp. 228-236, 2014.
9. L. Liu, X. Meng, and C. Liu, ―A review of maximum power point tracking methods of PV power system at uniform and partial shading‖, Renewable and Sustainable Energy Reviews, Vol. 53, pp. 1500-1507, 2016.
10. N.A. Kamarzaman, and C.W. Tan, ―A comprehensive review of maximum power point tracking algorithms for photovoltaic systems‖, Renewable and Sustainable Energy Reviews, Vol. 37, pp. 585–598, 2014.
11. E. Kandemir, N.S. Cetin, and S. Borekci, ―A comprehensive overview of maximum power extraction methods for PV systems‖, Renewable and Sustainable Energy Reviews, Vol. 78, pp. 93-112, 2017.
12. A. Mohapatra, B. Nayak, P. Das, and K.B. Mohanty, ―A review on MPPT techniques of PV system under partial shading condition‖, Renewable and Sustainable Energy Reviews, Vol. 80, pp. 854-867, 2017.
13. K. Cao, J.Zhou, T.Wei, M.Chen, S.Hu, K.Li, ―A survey of optimization techniques for thermal-aware 3D processors‖, Journal of Systems Architecture, pp. 1-25, 2019.
14. Y. Li, Z. Zhu, Y. Yang, Y. Sun and X. Wang, ―A novel interface circuit with 99.2% MPPT accuracy and 1.3% THD for energy harvesting, Journal of Circuits, Systems and Computers, vol. 26, no. 11, pp. 1750176, 2017.
15. M. Premkumar, and T.R. Sumithira, ―Design and implementation of new topology for non-isolated dc–dc micro-converter with effective clamping circuit‖, Journal of Circuits, Systems and Computers, Early Access, pp. 1950082, 2019.
16. K. Ishaque, Z. Salam, M. Amjad, and S. Mekhilef, ―An improved particle swarm optimization (PSO)–based MPPT for PV with reduced steady-state oscillation,‖ IEEE Transactions on Power Electronics, Vol. 27, No. 8, pp. 3627-3638, August 2012.