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# A Novel Hybrid Optimization Technique for Maximum Power Point Tracking under Partial Shading

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***Abstract:*** ***Optimum solar electric power generation is performed by the use of an optimum power point tracking technique. During different atmospheric environmental conditions such as normal shading and partial shading, the optimized maximum power point tracking (OPPT) is necessary. The latest algorithms for optimum power point tracking have shortcomings that will be overcome by an algorithm proposed in this paper. This algorithm is a hybrid algorithm called as overall distribution-weighted differential evolution (OD-WDE) OPPT algorithm. The OD-WDE finds out the correct optimum power point direction in a multiple power point scenario with a short time period. Two different shading conditions such as 20% shading and 40% shading have been considered for testing the ruggedness of OD-WDE. The performance of the proposed OD-WDE is compared with the other two latest algorithms such as particle swarm algorithm (PSO) and perturb and observe (P and O) algorithm. The simulation and experimental results show that the OD-WDE algorithm exhibits better performance on effectiveness and efficiency for tracking of a solar panel for optimum power generation point.***

***Index Terms*****:** ***weighted differential evolution algorithm, different shading conditions, multiple power points, Solar photo voltaic system.***

## I. INTRODUCTION

Nowadays the usage of electric power is increasing every day. The availability of fossil fuels and natural gases has become scarce. Renewable energy is an alternative option for increased usage in the modern world. One of the sources of renewable energy is solar energy which is abundantly available in nature. Therefore, it can be used to meet part of the electric power requirement. While using the solar electric power generation, obtaining optimum power generation in different environment condition is vital [1]. But solar rays will reach the solar panel through clouds and various other shading conditions due to earth objects. A suitable algorithm can be used to track the panel towards optimum solar flux, to fetch maximum solar electric power at different shading conditions [2]. Active types of solar tracking methods use gear, motor, and controllers which move panel towards the sun [3]. Solar power generation with the required electronic interface is becoming a challenge when the reliability and cost factors are taken in to account [4]. Present-day technical advancements have increased the efficiency of the electronic devices which are used at each and every weather condition. Several researchers have worked in solar power systems using boost converters and sepic-converters which have become prominent in all types of solar power applications like rural electrifications and microgrid etc. [5, 6].

By changing the duty cycle for changing the amount of power generation is one way of power control in a boost converter-based Photo Voltaic system [7]. The optimum power point tracking is always a challenge with respect to non-linear voltage behavior and sudden changes in the insolation. When there is uniform irradiance P and O algorithm will be used for tracking optimum power point. But this creates fluctuations which end in loss of power [8]. An adaptive particle swarm optimization method provides high performance without any unwanted oscillations during the maximum irradiance situations [9]. Taking into account of changes in current, voltage and power methods called modified perturb and observe algorithm has been created [10]. When there is only one optimum power point, the conventional method like incremental conductance and open circuit voltage can be used [11,12].

To avoid mismatch in energy and hotspots, it is necessary to use bypass diodes. Whenever conventional method fails in a partial shading environment, biologically related algorithms such as deterministic PSO [13] and Ant Colony Foraging algorithm [14] are used. When the number of particles incr eases, the time required for iterative execution of a population will be increased. Various methods have been formulated on reducing the time needed for tracking the optimum power point at different shading environment by searching optimum power points only. For uniform irradiance conditions, searching for voltage windows has been proposed [15,16]. Tracking period will be reduced, and then the duty cycle is changed during the tracking of the OPPT. When we consider a number of populations and iterations in those systems, it is found out that the tracking time is more and the efficiency of tracking is also less [17].

Artificial intelligence (AI) can be used to find out the OPPT [18,19]. Some of the algorithms which are using AI are Firefly and colony optimization. These algorithms use a smaller number of sampling points. It is computationally economical compared with another Global OPPT algorithm. The mathematical design of Flower pollination algorithm (FPA) is superior and its implementation is easy [20,21]. The drawbacks in FPA are in the determination of convergence in the OPPT which are pointed out in [22] and OPPT with complexity is explained. The

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OPPT tracking speed is decreased in Fireflies by changing movement rules [23]. In recent times Ant colony algorithm has been used along with the simulated annealing algorithm for finding OPPT [24]. Another algorithm Java OPPT has been proposed. It has no specified parameters. Algorithms which are based on AI prove that once the initial values are correct, then it leads to improving the speed in tracking. Finding the small area around OPPT and the necessary initial conditions for the algorithm implementation which use AI has increased the speed of tracking [25,26]. Many methods have been proposed to find out the region around Global OPPT. These methods give information regarding output voltage-current which are generated from the solar panel. Differential evolution algorithm (DEA) is a widely used robust optimization algorithm for solving real-valued numerical problems [26]. Various partial shading conditions have been verified using DEA combined with PSO for photovoltaic OPPT solution [28]. The WDE is a modified version of DEA which is used to solve different numerical problems with ease and efficient swarming process [29].

Due to the non-availability of prior hardware testing information, these above-said methods are facing difficulties in the implementation through hardware methods. After taking into account the drawbacks of these algorithms, an algorithm called OD-WDE OPPT technique is proposed here. This algorithm needs no prior hardware testing details. This method finds out the OPPT perfectly well, and in the shortest time. Particularly the OD OPPT identifies the nearby region of OPPT which leads into finding out the initial test readings which in turn are used by the WDE to identify the OPPT. Once initial values are found, the WDE algorithm will search a small area around OPPT very quickly. The remaining part of the paper has been structured in the following way. Section 2 describes the solar panel under partial shading conditions. Section 3 explains the OD-WDE OPPT algorithm. Section 4 provides simulation results. Section 5 describes experimental results under different shading conditions. The conclusion is presented in section 6.

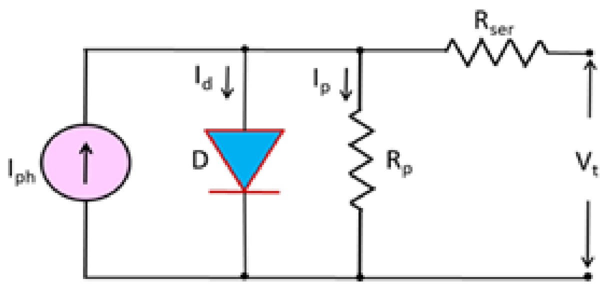


Fig. 1. Single diode model

## II. PV MODULE UNDER PARTIAL SHADING

The performance of the solar cell PV system depends on the solar cell model which is used in a particular system. To understand solar cell characteristics, two different cell models are widely used as test cases. One is a single diode model and the other is a two-diode model [30]. The single diode model is used to study the characteristics as it is simpler than the other one and is shown in Fig. 1. Using Kirchhoff's current law, the output current of a single diode solar PV cell is given as:

$$I_t = I_{Ph} - \left(I_R\left(e^{V_d/aV_T} - 1\right)\right) - \frac{V_t + I_t R_{Ser}}{R_P} \quad (1)$$

For a single diode model, there are 5 unknown parameters such as $I_{Ph}$, $R_{Ser}$, $R_P$, $I_d$ and 'a'. In these five parameters, $I_{Ph}$ denotes current of a solar cell; $R_{Ser}$ and $R_P$ refer to series and shunt resistance of a solar cell. The diode current $I_d$ which is equal to $I_R(e^{Vd/aVt}-1)$. $V_d$ is the diode voltage, $I_R$ refers to diode current at reverse saturation condition, diode ideality factor is 'a', and $V_T$ refers to the thermal voltage, $V_T = N_s kT/q$. Where $N_s$ is the total number of series cells, Boltzmann's constant is k, T refers to room temperature in Kelvin and q is the electron charge. The solar panel current ($I_t$) of the PV Model is given based on [31] as:

$$I_t = N_p - \left\{I_{tm} - I_R\left[exp\left(\frac{V_t + I_t R_{Ser}}{V_T N_S}\right) - 1\right]\right\} - \frac{V_t + I_t R_{Ser}}{R_P} \quad (2)$$

Here $I_{tm}$ refers to module current, $N_p$ and $N_s$ refer to a number of cells in parallel and series in the panel.

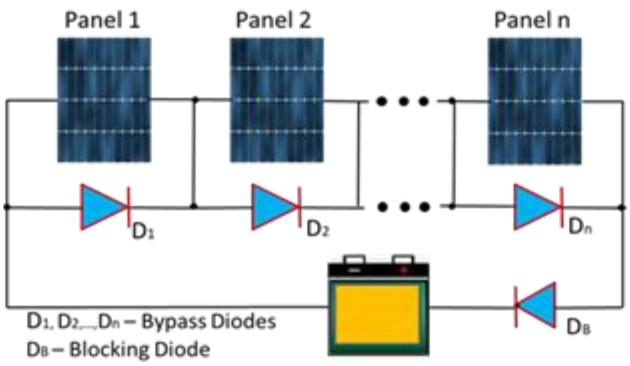


Fig. 2. Photo-Voltaic array with blocking diodes and bypass diodes

The shaded parts of the solar panel will not generate power. It becomes a load in that condition, which may generate heat, called hot spot heat which will damage the panel itself [32]. To overcome this hot spot heating effect, the panels will be connected with a diode in parallel, which is given in Fig. 2. This will protect the panel but generates multiple peaks in their characteristic curves for power versus voltage in a PV panel [33]. In this study, a hybrid technique, overall distribution combined with the weighted differential evolution algorithm for OPPT is implemented using four solar panels connected in series under three different shading conditions.

Three different shading conditions of this study are shown in Fig. 3 and the corresponding irradiance used in this study are listed in Table 1. In the first case, the illuminated solar intensity is the same for all four panels. The P-V characteristics are shown in the Figure4. These characteristics are simulated using Power SIM software. In the second and third cases, the solar array is illuminated by two or three different intensities of solar radiation respectively. The output voltages of the solar panel depending on the solar irradiance level [33].

In the first case, there will be no shading for any solar panel. Now only one OPP is available. It is given in Fig. 4, as $G_1$. In the second case,


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there are two optimum power points in the P-V characteristics graph which are shown in Fig 4. Now the global OPP is positioned in global position $G_2$. In the third case, four solar panels are illuminated with three different intensities. Now there are three OPP are obtained in the PV characteristics and the global OPP is positioned at global position $G_3$, which is shown in Fig. 4. From this study, it is found out that, number of optimum power points and maximum value of power-voltage characteristics, are different for these three cases. That is why the identification of the optimum power point is important in different conditions.

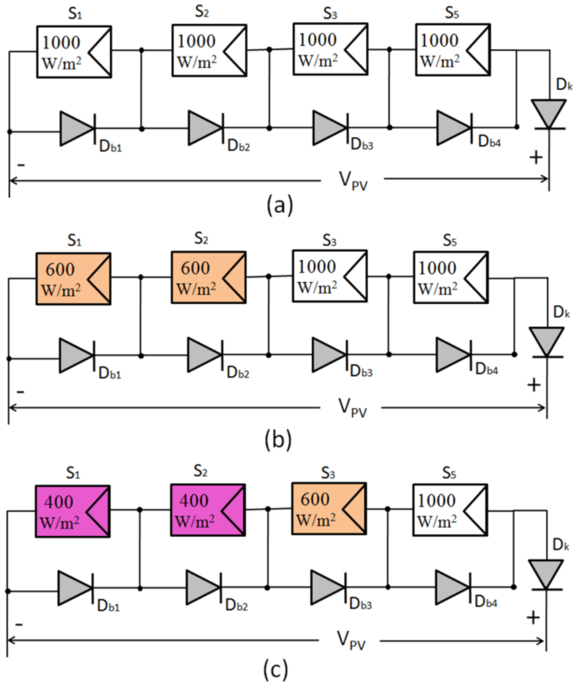


Fig. 3. PV array with different shading condition (a) No shading (b) 20 % (c) 40 %.

Table 1. Various irradiance used in this study.

| Category | PV panel irradiance (W/m$^2$) | | | |
|---|---|---|---|---|
| | Panel1 4 | Panel 3 | Panel 2 | Panel1 |
| Case 1 | 1000 | 1000 | 1000 | 1000 |
| Case 2 | 1000 | 1000 | 600 | 600 |
| Case 3 | 1000 | 600 | 400 | 400 |

## III. OD-WDEOPPT ALGORITHM

Optimum power point tracking (OPPT) algorithm based on Artificial Intelligence (AI) can be used to capture the global optimum power point (GOPP). It has the drawback of sensitivity character towards the initial value conditions. The performance of the AI-based algorithm will be improved by applying proper initial values [34,35]. An algorithm called hybrid OPPT, a combination of OD and WDE, is proposed here to improve its performance by decreasing the search region around the GOPP. These two algorithms complement each other for producing a better performance in tracking the solar panel system. This section describes the OD-OPPT and then its combination with WDE algorithm.

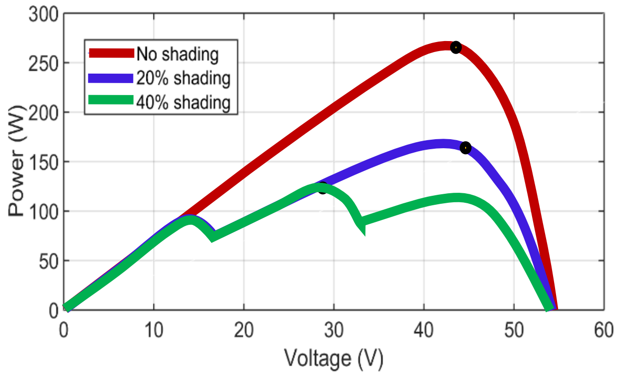


Fig. 4. P-V characteristic of PV array under three different shading condition (a) no shading (b) 20% shading (c) 40% shading.

### A. OD-OPPT algorithm

The OD-OPPT algorithm which was proposed in 2012 is an algorithm which has the function of intelligence characteristics. This has been used to solve the problem in a hydroelectric power system and thermal power system [36,37]. Here OD-OPPT algorithm is able to find out required region surrounding OPPT rapidly. The equation for OD - OPPT is as follows.

$$\begin{cases} F_i^{j+1} = OPPT_{Gbest}^{j} + R^{j+1} Cauchy_i^{j+1} \\ R^{j+1} = \beta R^{j} \\ Cauchy_i^{j+1} = -\mathcal{E}\tan(\pi . r1), i = 1,2,\ldots\ldots, N;\ Cauchy \in [-2,2];\ \ \beta \in (0,1) \end{cases} \quad (3)$$

Where $F_i^{j+1}$ is a place of the i$^{th}$ particle during iteration (j+1), $R^j$ is the radius during the j$^{th}$ iteration, α is the sharing co-efficient. $Cauchy_i^{j+1}$ is nothing but the random number of Cauchy distribution of i$^{th}$ particle at iteration (j+1). The random number, β which is the parameter of scale.

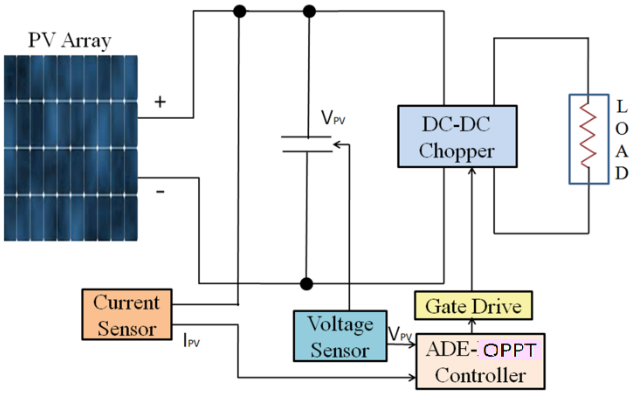


Fig. 5. OPPT Controller with DC-DC converter.

In the OD-OPPT algorithm, a number of particles around the OPP area are $F^i$. Using an adaptive method, this area will be reduced further into a very small region than Ɛ(Ɛ> 0). In a solar PV power generator, a PV array solar panel with a buck converter is used to introduce the OD-OPPT method. This is displayed in Fig. 5. Here the inverter includes a resistive load for easy understanding purpose. Representing the inverter in the form of resistive reflects the power transmission in the inverter for study purpose [34,35].

OD algorithm uses a buck converter duty cycle (d) of this power generator, as particles. $R^j$ is the Cauchy radius during the j$^{th}$ iteration of the algorithm execution process. The value of


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$R^j$ can be selected from 0 to 1. The $R^j$ $OPPT_{GBEST}$ and Cauchy will update particle position. The values $OPPT_{GBEST}$ term expresses the best position of the particle around the OPPT in the OD-OPPT algorithm before completing the $j^{th}$ iteration. The best place of the particle explains that the fitness level of the particle is greater among the particles. The fitness of a particle in an OD algorithm for the solar power system is given as

$$P(d^{j+1}) = V \times I \qquad (4)$$

V stands for output voltage and I represent output current value. Initialization of the duty cycle for a buck converter is the first step of the algorithm OD-OPPT. They will be expressed as $d_i^{J+1}$(i = 1, 2,...,N).

The duty cycle for the fitness value which has the maximum value is saved and that duty cycle will be denoted $I^k_{BEST}$. The $OPPT_{GBEST}$ must satisfy the below expression.

$$P(OPPT^i_{GBEST}) \geq P(I^K_{BEST}); k = (1,2 \ldots .j) \qquad (5)$$

Updating the generation of duty cycle will be used for tracking towards the OPP and the resulting duty cycle will be measured by the expression (3). The duty cycle will be distributed surrounding the $OPPT^i_{GBEST}$ in the R radius, and R€(0,1) is nothing but Cauchy distribution.

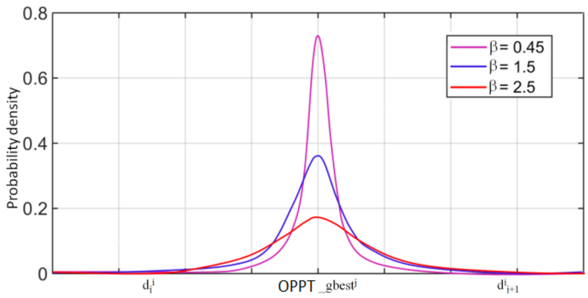


Fig. 6. Cauchy distribution function for various values of β.

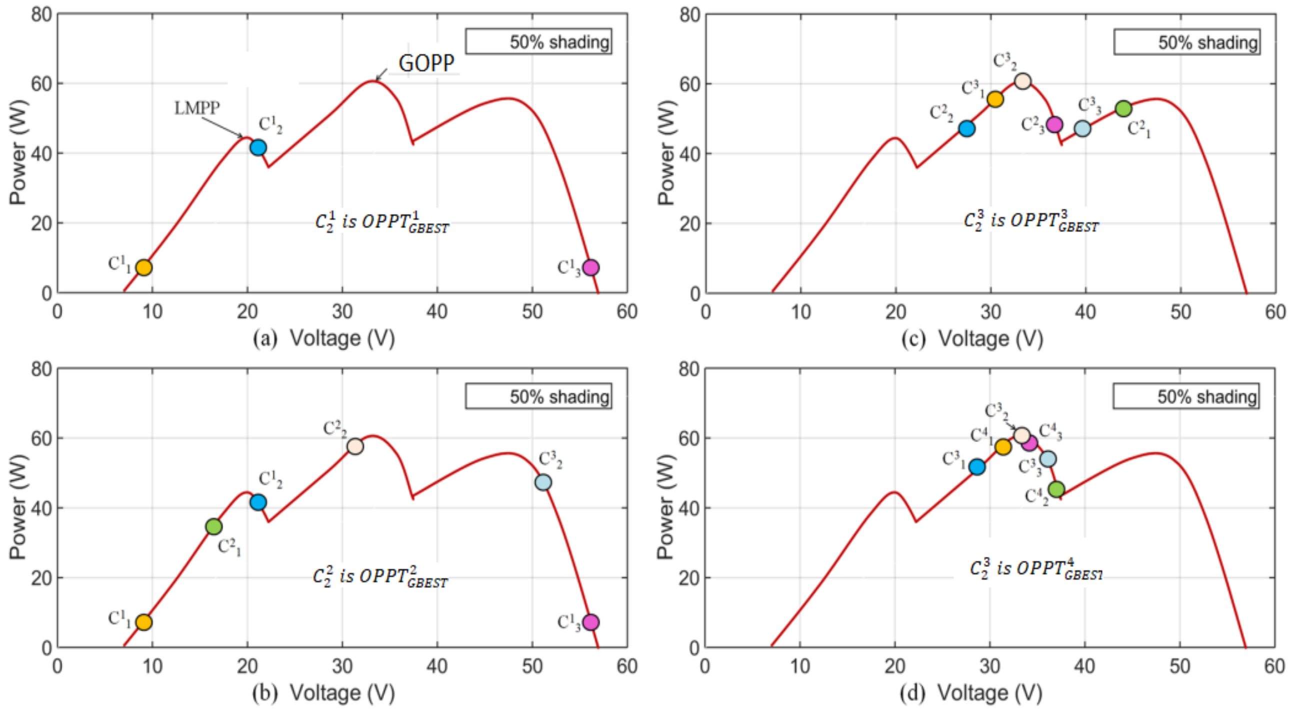


Fig. 7. Operation of OD-OPPT algorithm.

This radius will be reduced by a coefficient which is called as shrinking coefficient. The above process must be repeated many times before reaching conditions $R < \mathcal{E}$ and $(\mathcal{E} > 0)$. Updating particles will be made by this Cauchy distribution which is nothing but one type of probability distribution. Thus, Cauchy distribution will be expressed based on [35] as;

$$F(Cauchy) = 1/\pi(\arctan(Cauchy - X_0)/(\beta + \pi/2) \qquad (6)$$

Where $X_0$ is the position parameter, which defines the peak position in the distribution area, and β expresses the scale parameter. The PDF (Probability Density Function) will be given as equation 6, based on [35]. Here $X_0$is selected as 0.

$$f(Cauchy, x_0, \beta) = {}^{1}\Big/_{\pi.\beta\left(\frac{Cauchy - x_0)}{\beta}\right)^2} \qquad (7)$$

The particle position $F_i^j$is linearly changing a parameter in this proposed algorithm OD-OPPT. It is similar to the distribution of Cauchy. The Cauchy PDF is given in Figure 6. From figure 6, it is understood that when β is small, the PDF will concentrate more around the $OPPT_{GBEST}$. When β is greater than the Cauchy probability, it will be dispersedly distributed. That means very near to $OPPT_{GBEST}$, the particle probability density will be higher [36]. In this OD-OPPT algorithm, the distribution of particle closer to $OPPT_{GBEST}$ will be used for finding the GOPP very accurately. The particles which are away from the $OPPT_{GBEST}$ can be used to avoid LPP (Least Power Point) tracking. In this way, GOPP can be found from the overall distribution OPPT algorithm. To understand the outer distribution in the OPPT algorithm, multiple P



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distribution curves which consist of two OPPs are used as an example which is given in Fig.8. The iteration steps are as follows.

Firstly, N will be equal to 4 for the outer distribution OPPT algorithm. GOPP will not be available at d=0 and it will not also occur at d+1. The following 3 initial particles are expressed as $C_1$= 0.04, $C_2$=0.6, and$C_3$ = 0.94.

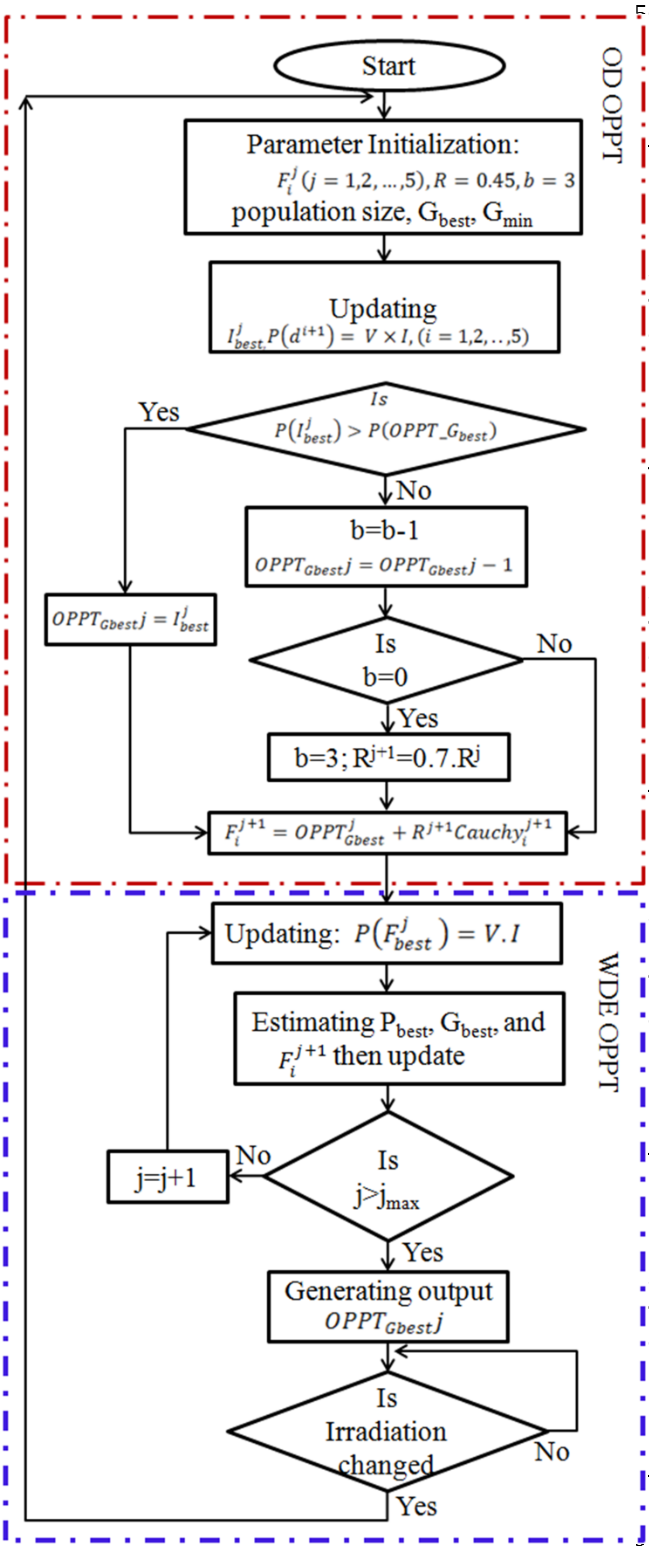


Fig. 8. Flow diagram of OD-WDE OPPT algorithm

In the Fig. 7, these three particles are denoted as the different color pattern. Now for explaining the proposed algorithm three fixed values will be used in the place of Cauchy ($I_i$ = 1,2,3). They are 0.04, 0.06 and 0.94. The half the interval of the initial particle is set as the starting values of Cauchy radius $R^I$. Therefore initial values of Cauchy radius is (0.94, -0.04)/2=0.45.

First Iteration: Initially three particles will be sent to buck converter then respective photovoltaic array output power is measured. From Fig. 7(a) $C_2$ particle is selected as the best one. This particle is denoted as $I^I_{BEST}$ and from the equation (4) this value is known as $OPPT^i_{GBEST.}$

Second Iteration: Next generation particles will be generated using equation (3). The distribution of particles is shown in Fig. 7(b). Fig. 8 shows that $X_1^I$ is $I^I_{BEST}$, after comparison with $OPPT^i_{GBEST}$, $I^I_{BEST}$ is known as the better particle. So $I^I_{BEST}$ replaces $OPPT^i_{GBEST,}$ based on the expression 2, radius R will be decreasing. To satisfy the tracking performance in this iteration, the shrinking coefficient α will be set as 0.7 and Cauchy radius $R^2$= 0.45 x .7 is 0.315.

Third iteration: Iteration 2 process will be repeated to generate the 3[rd] particle. These particles are distributed as in Fig. 7(c). At the end of iteration 3, $C_2^3$ is found to be the best particle. So $I_{BEST}^3$ will replace the $OPPT^2_{GBEST}$. Now P $(I^I_{BEST})$>P $(OPPT^2_{GBEST})$, $I_{BEST}^3$ will replace the $OPPT^2_{GBEST}$. The Cauchy radius has become nearly equal to 2 which is found from the expression $R^3$ = 0.3375x 0.75=0.253.

Fourth Iteration: Fig. 7(d) shows the fourth generation particles generated through the same process. $C_2^4$ will be the particle in this iteration. Therefore the $I_{BEST}^4$ will be $C_2^4$, this is $OPPT^i_{GBEST}$ particle in this OD-OPPT algorithm. Therefore$OPPT^4_{GBEST}$ will be called as $I_{BEST}^4$. Now the $R^4$ is equal to 0.2531x0.75<Ɛ, (Ɛ=0.2).

Initially, OD-OPPT is applied to get the particles rapidly. Then the WDE has used these particles as the initial particles for estimating the OPP. The OPP of the Photo Voltaic array is related to the irradiance level of solar flux. WDE algorithm taken from [29] and the flow diagram combined with OD OPPT is displayed in Fig. 8.

## IV. SIMULATION RESULTS

The usefulness of OD-WDE algorithm in optimum power point tracking applications is tested using four photovoltaic solar panels which are connected like a string. Photo -Voltaic characteristics show that convergence of duty cycles is necessary for obtaining the optimum value. A detailed comparison is done between OD-WDE, PSO algorithm and P and O algorithm using simulation results. Simulation has been performed using MATLAB, Intel i7 processor, 500 GB memory with 8 GB RAM. Table 2 shows the parameters of the PV module (KC200GT). This hybrid algorithm has been carefully coded for this study.

The simulation result shows that OD-WDE and PSO methods use 5 duty cycles randomly for initialization purpose. Fig. 5 shows the proposed OPPT with control structure for the boost converter. The duty cycle of the sample period with 0.033 is used with proper use of parameters for better performance in any optimization algorithms. The boost converter parameters are L=600 μH, R=1.65 Ω, C1=50 μF, C2=23 μF, and operating frequency is 20 kHz. Parameters used for the OD-OPPT based on [35] are as follows: ε=0.034 and β=0.1.


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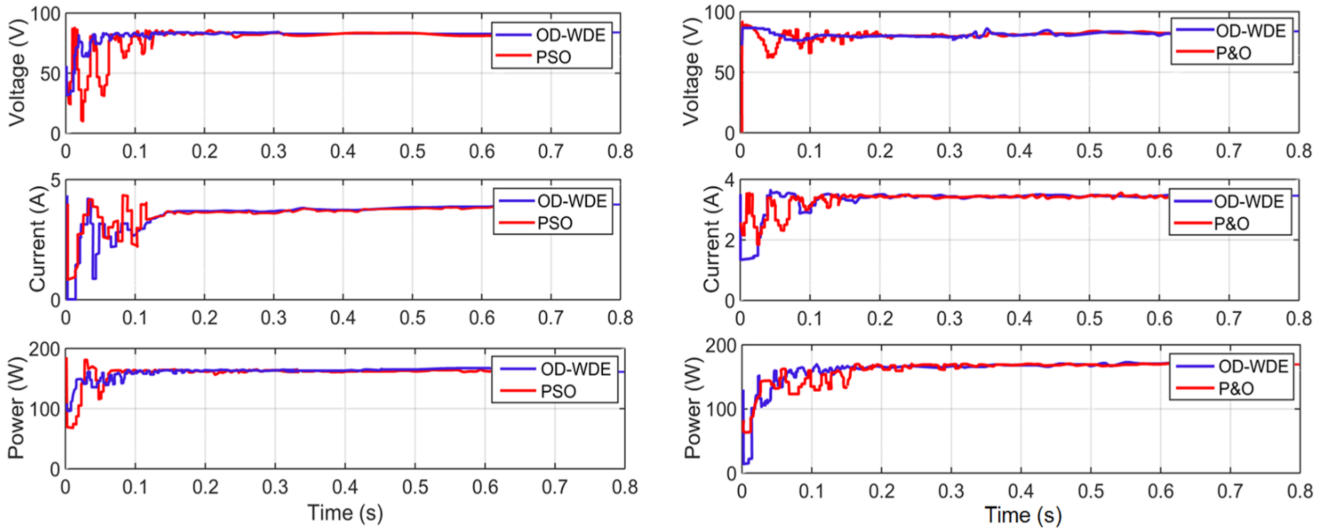


Fig. 9. Output curve of the PV under case 1 (a) the OD-WDE and PSO algorithm [21] (b) the OD-WDE and P and O algorithm [19].

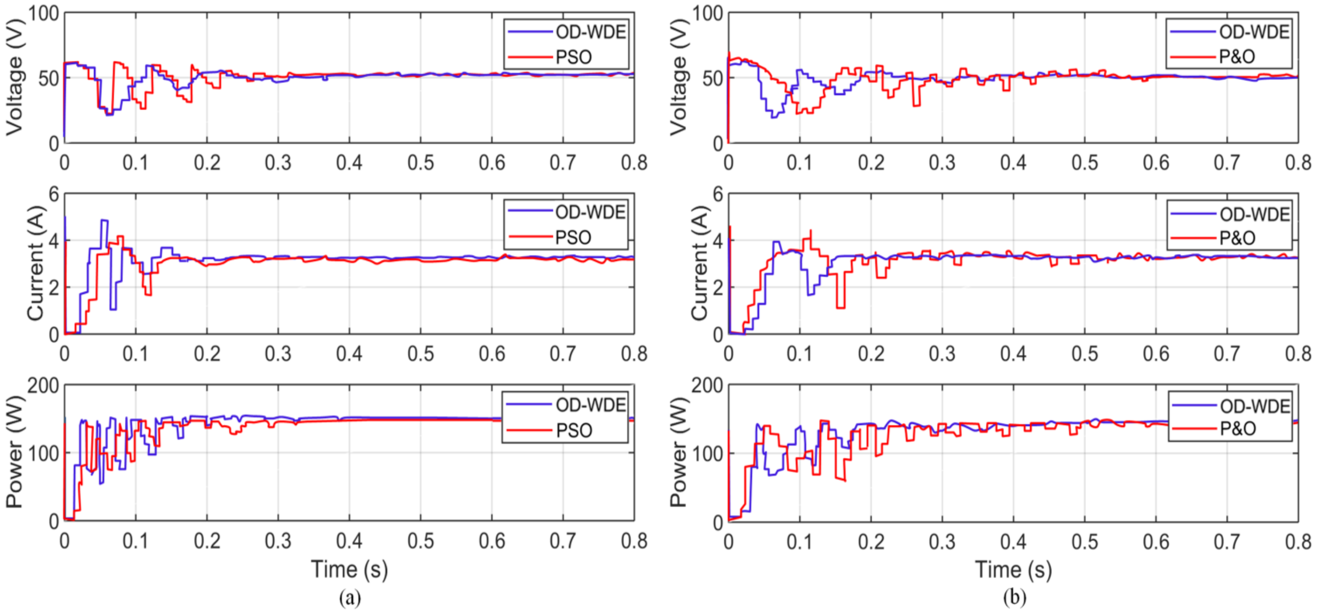


Fig. 10. Output curve of the PV under case 2 (a) the OD-WDE and PSO algorithm [21] (b) the OD-WDE and P and O algorithm [19].

### A. Case 1: No shading

Here, solar rays are falling on all the areas of the panel at the same level. Characteristics of OPPT are analysed. This is shown in Fig. 9. Current, voltage and power characteristics of the proposed OD-WDE and PSO algorithms are shown in Fig. 9(a). There is only one peak at 148.6 watts. From the graph, it is found out that convergence speed and speed of tracking is faster in the proposed OD-WDE in comparison with the other two algorithms. The V,I and P characteristics of proposed OD-WDE and P&O methods are illustrated in Fig. 9(b). It is understood that the OD-WDE algorithm reaches a peak at 0.5 s, the PSO algorithm reaches it at 1.2 s and P and O algorithm reaches it at 1.5 seconds. That means OD-WDE is very quick in reaching the optimum position compared with the other two methods. It is noted that P and O depend on its initial values for its convergence [19].

Table 2. Parameters of PV panel KC200GT

| Parameters | Values |
|---|---|
| Open circuit voltage ($V_{oc}$) | 32.9 V |
| Short circuit current ($I_{sc}$) | 8.21 A |
| Maximum power ($P_{max}$) | 200W |
| Voltage at $P_{max}$ | 26.3 V |
| Current at $P_{max}$ | 7.61 A |
| Temperature coefficient of $V_{oc}$ | $-1.23\times10^{-1}$ V/°C |
| Temperature coefficient of $I_{sc}$ | $3.8\times10^{-3}$ A/°C |

### B. Case 2: 20% Shading

The weak shading is illustrated in Fig. 10. The V, I and P curves for OD-WDE and PSO for 20% shading is shown in Fig. 10 (a). Here optimum power GOPP is 69.1 watts for the OD-WDE. It is reached in less than 0.5 seconds. But 1 seconds will be taken by the PSO method. PSO senses the GOPP in the first iteration itself, but the convergence takes more time due to the higher velocity generated by the way of

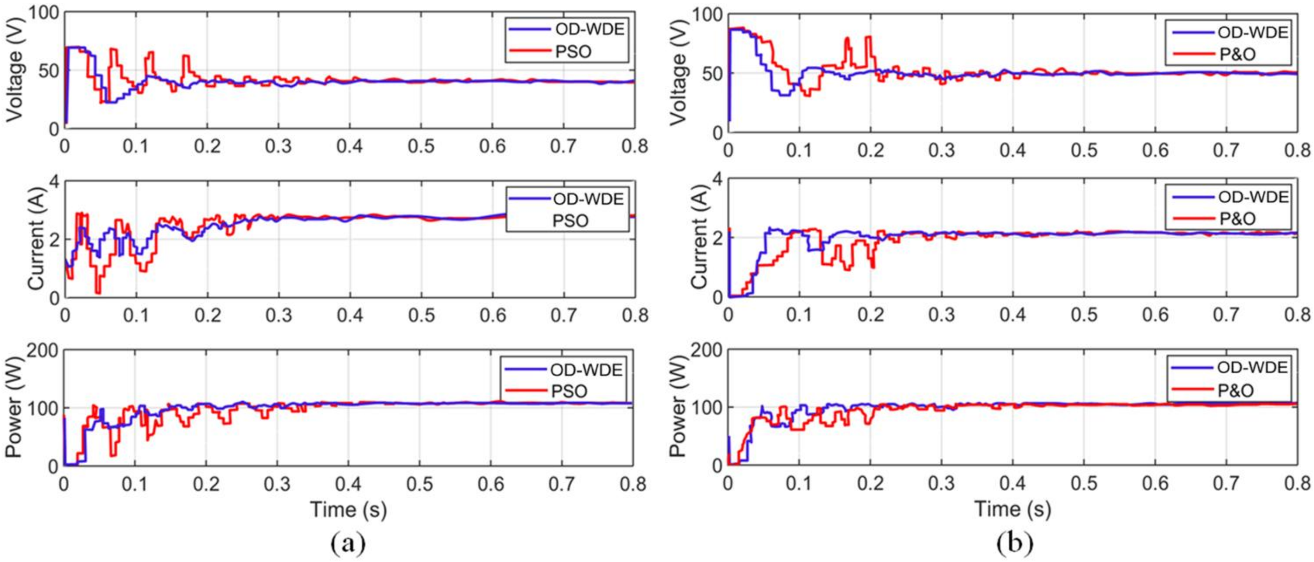


Fig. 11. Output curve of the PV under case 3 (a) the OD-WDE and PSO algorithm [21] (b) the OD-WDE and P and O algorithm [20].

updating the particles. Therefore, it takes more iteration. In the case of Perturb and Observe algorithm which made the GOPP on the optimum power point takes a longer period for convergence due to constant step sizes. The voltage, current, and power characteristics of proposed OD-WDE and Perturb and Observe algorithms are shown in Fig. 10(b). When P and O are wrongly initialized, it will settle on the local peak. this is one of the drawbacks of this algorithm.

### C. **Case 3: 40% Shading**

This kind of shading is produced due to different solar irradiance (1000, 600, and 400 W/m$^2$) has been focussed on the solar panels. Fig. 11 show this shading and the characteristics of V, I and P of the proposed OD-WDE and PSO algorithms are illustrated in Fig. 11(a). This strong shade has created 3 peaks of different ranges. Three power points occur at 30, 49, and 55 W respectively. This V,I, and P characteristics of proposed OD-WDE and the P and O algorithms are illustrated in Fig. 11(b). Thus figure 11 shows that P and O method and PSO methods settle at a local peak, while the OD-WDE reaches the GOPP rapidly.

## V. EXPERIMENT RESULT

Separate experiments have been conducted for uniform, 20%, and 40% shading on the solar panel. The boost converter has been added for obtaining similar results in a hardware model experiment. The converter output ripple values will be brought down for better performance. Figure 12 shows the hardware set up with a DC-DC boost converter connected with real-time photovoltaic cell panel. Literature survey shows that WDE method does not require different mutation process and control parameters. So the convergence speed is faster than the other two methods such as PSO and P and O [20]. Therefore, this algorithm was tested for different shading conditions with various duty cycles for each iteration.

Fig. 12. Experimental setup of the proposed OPPT scheme.

It was found out that 5 duty cycles are a more suitable one for WDE algorithm. The duty cycle with a 300 ns interval was utilized for stable state conditions. Figure 13 shows experimental results of case 1, with current, voltage and power. The experimental result shows that OD-WDE reaches global power point peak at 143.5 watts in less than 0.6 second. PSO method reached a maximum peak at 143.5 watts with the convergence time of 1.55 s. In this case, no shading is applied. Perturb and Observe method reaches the OPP in less than 1 s time.

In the second case, the photovoltaic panels are under the partially shaded condition, which generates two peaks and the result is compared with two other methods. Figure 14 shows the voltage, current, and power characteristics for three different methods such as OD-WDE, P and O method, and PSO method. It shows that OD-WDE reaches its global OPP very quickly. This algorithm reaches the GOPP within 6 s. PSO method reaches the OPP of 71.14 W with the convergence time of 1.25 s and when duty cycle initiates with 0.75 on the photovoltaic curve, then it reaches OPP with a convergence time of 0.543. When the duty cycle starts at the right side area of the photovoltaic characteristic curve, the value will be trapped in a local OPP.

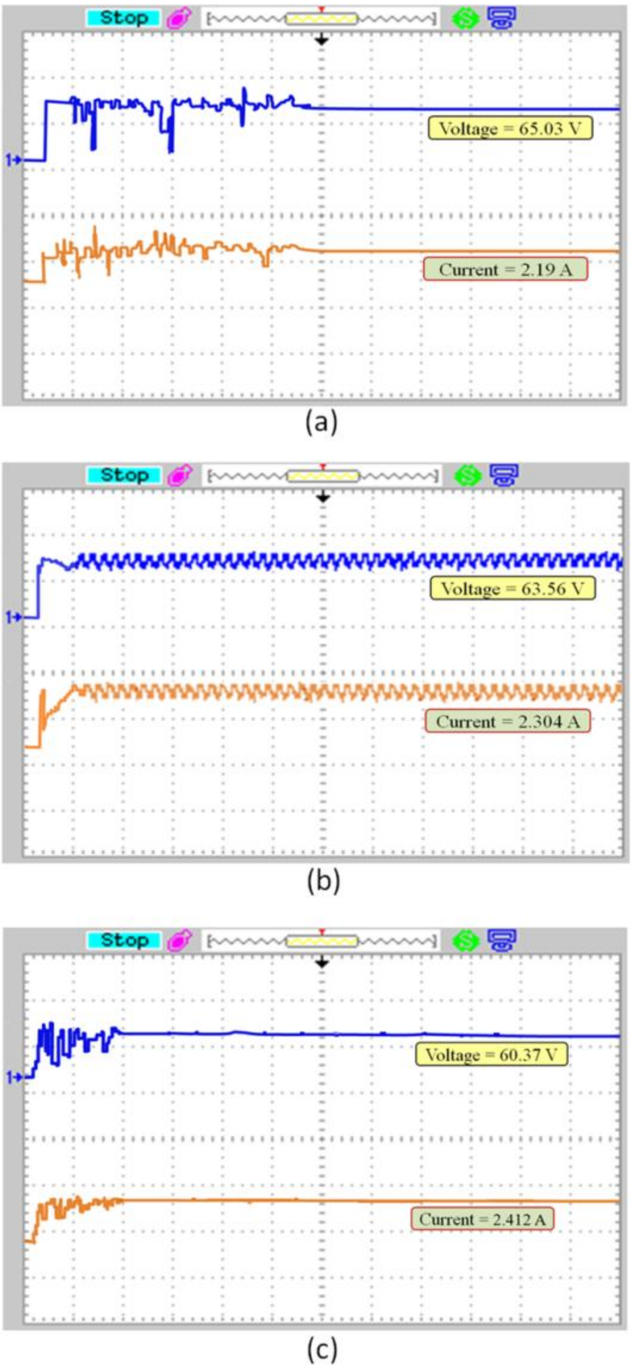


Fig. 13. Experimental output under 20% shading condition (a) PSO (b) P and O (c) OD-WDE

Another study is conducted for these 3 algorithms at multiple peak conditions. In this study, the results are the same as that of simulation results. OD-WDE reaches its global peak at 0.45 s. PSO was trapped at a local peak. It was not able to reach GOPP. P and O method also was trapped in local peak value of 35.31 W.

Figure 14 shows the waveform of the hardware implementation for the step change in the shaded condition. This figure shows that the OD-WDE is more superior in reaching the global peak very rapidly and it shows the more sensitivity in detecting OPP. For a partially shaded condition, OD-WDE method reaches OPP with shorter time. So the convergence time is shorter than other Optimization methods such as PSO and P and O methods.

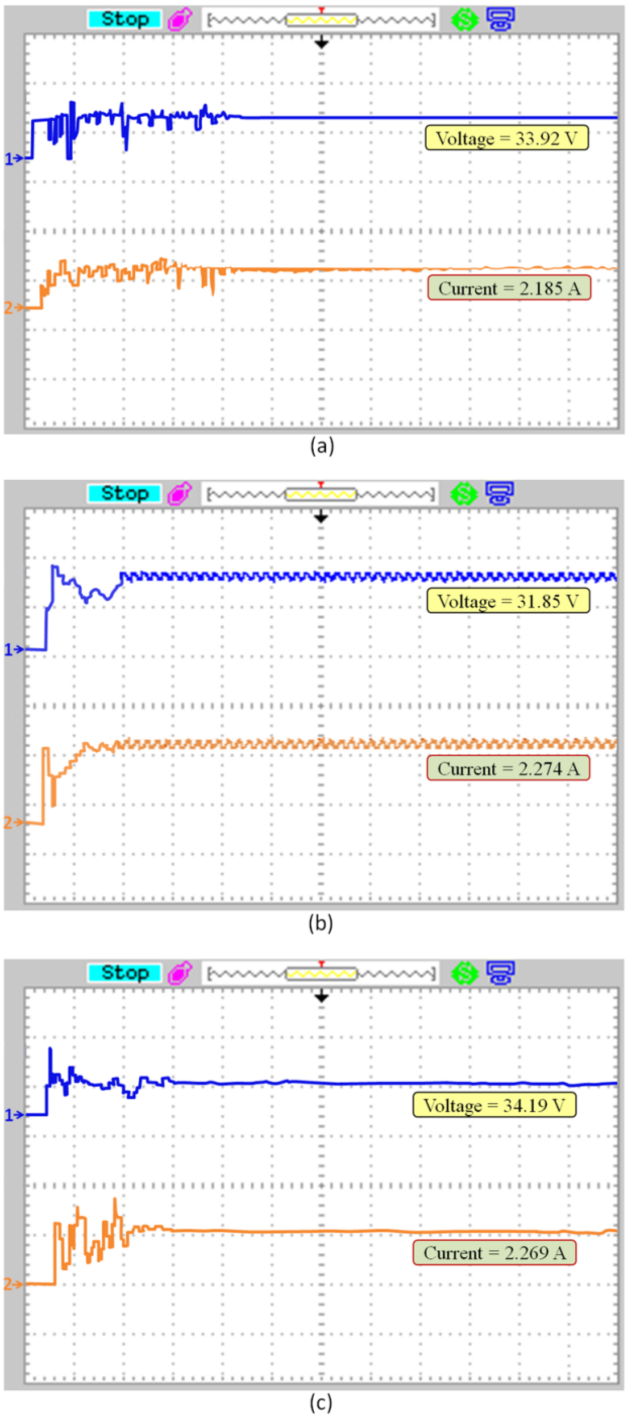


Fig. 14. Experimental output under 40% shading condition (a) PSO (b) P and O (c) OD-WDE

The experimental results provide the following statements: 1) For all the three cases such as uniform, 20% shading and 40% shading scenarios, occupying the smallest area around the OPP represents the more reliable and best performance. 2) A large area around the OPP indicates low performance. 3) Thus OD-WDE proves itself as a superior method compared with the PSO method and P and O methods.

## VI. CONCLUSION

A hybrid algorithm combined with overall distribution and weighted differential evolution has been studied and analysed for reaching solar OPPT under different shading conditions. OD-WDE hybrid algorithm obtains the GOPP rapidly. It does not require detailed information of the photovoltaic panel; as a result, the speed will increase. Moreover, OD-WDE algorithm helps the PV solar power system to generate more power and it also has a smaller number of power fluctuations compared with contemporary methods. Experimental and simulation results illustrate that proposed OD-WDE provides less oscillation, and take less time to find GOPP. OD-WDE algorithm is compared with PSO and P and O algorithm for its performance. Results prove that the proposed method outperforms PSO and P and O algorithms. The experimental, as well as simulation results show that the proposed OD-WDE algorithm is superior to the other two.

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