# A New MPPT Design using Grey Wolf Optimization Techniques with DC-DC Converter for PV System

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***Abstract-*** *This paper presents new approach for a maximum power point tracking (MPPT) design for a photovoltaic (PV) system using a new optimization technique. The new optimization method with SEPIC converter, overcomes the limitations such as lower tracking efficiency, steady state oscillations, and transients as encountered in perturb and observe (P&O) and PSO techniques, the new optimization is called as Grey Wolf Optimization (GWO).The problem of tracking the global peak (GP) of a PV array under partial shading condition is attempted employing the GWO-based MPPT technique. The proposed scheme is studied for a PV array under PSCs which exhibits multiple peaks and its tracking performance is compared with that of two MPPT algorithms, namely P&O-MPPT and PSO MPPT. The GWO MPPT algorithm was implemented on a P-V system using MATLAB. Furthermore experimental setup is developed to verify the efficiency of the proposed system. From the obtained simulation and experimental results, it is observed that the proposed MPPT algorithm with the converter outperforms both P&O and PSO MPPTs.*

## I. INTRODUCTION

Various maximum power point tracking (MPPT) algorithms were discussed in literature [1] about the occurrence of mismatched non uniform isolation resulting in decrease in photovoltaic (PV) output power, the hot-spot generated damages the PV cells. Since the dynamics of the PV system under partial shading is time varying, MPPT design for PV power system should be equipped with features such as tracking global maximum power point (GMPP) at different conditions, e.g., shading, degradation of PV cell, and adaptability to PV characteristics change in PV array, smooth, and steady tracking behavior.

There is number of MPPT techniques such as hill climbing (HC) [2], perturb and observe (P&O) [2][4], and incremental conductance (IC) [5] have been proposed for improving the efficiency of the PV system. The HC method uses a perturbation in the duty ratio of the power converter and the P&O method uses a perturbation in the operating voltage of the PV system [2]–[4]. Both these methods yield oscillations at maximum power point (MPP) owing to the fact that the perturbation continuously changes in both directions to maintain the MPP resulting in power loss.

The two influencing parameters in P&O algorithm, namely perturbation rate and perturbation size, are discussed in [4].To reduce these oscillations and improve the module efficiency, the IC method was proposed [5] which reduced the oscillations but not completely. Both P&O and IC methods fail during those time intervals characterized by changing atmospheric conditions [6], [7]. A few improved IC algorithms were also proposed to improve the MPP tracking capability during fast-changing irradiance level and load [8], [9].

To achieve a fast MPP tracking response, a simple trigonometric rule has been presented in[10] to establish relationship between the load line and I–V curve. A dynamic MPPT controller for PV systems under fast-varying insolation and PSCs is proposed in [11], which uses a scanning technique to determine the maximum power-delivering capacity of the panel at a given operating conditions.

Metaheuristic optimization methodologies such as particles swarm optimization (PSO)[12], and fire fly [13-19] have been extensively used for various engineering applications. Recently, Mirjalili et al. have developed a metaheuristic algorithm known as Grey Wolf Optimization (GWO).This algorithm is inspired by grey wolves to attack preys for hunting purpose.

Further, several works are reported in literature on an alternative soft computing method known as grey wolf optimization which is attracting considerable interests from the research community compared to other optimization techniques because it is more robust and exhibits faster convergence.

Furthermore, it requires fewer parameters for adjustment and less operators compared to other evolutionary approaches, which advantage when the rapid design process is considered. After a thorough literature survey, it is observed that GWO has not been exploited for designing an MPPT.

Hence, this work attempts to exploit the GWO for designing an MPPT to obtain efficient tracking performance under PSCs.

This paper is organized as follows. Section II describes about the characteristics of the PV system under PSCs and the system description showing I–V and P–V curves of partially shaded modules. Section III describes the proposed GWO-based MPPT algorithm to track the GP and Sections IV presents the simulation and experimental results.Finally ,conclusion is provided in SectionV.

## II. CHARACTERISTICS OF A PV SYSTEM UNDER PSCS

### 1. Basic Characteristics of a PV Cell

A PV cell can be represented by an equivalent single diode model [2]. D a diode connected in parallel to the current source; Rs the sum of resistances due to all the components that come in path of current which is desirable to be as low as possible; Rp to represent the leakage across the P–N junction which is desirable to be as high as possible; I difference between the photocurrent Ipv and the diode current ID, which is given by,

$$I=I_{pv}-I_0[\exp(qV+qR_sI/N_sK_sTa-1)]-V+R_sI/R_p \quad (1)$$

where I0 is the saturation current, a is diode ideality factor, ks is Boltzmann’s constant, q is charge of an electron, T is temperature in kelvin, and Ns is the number of cells in series.

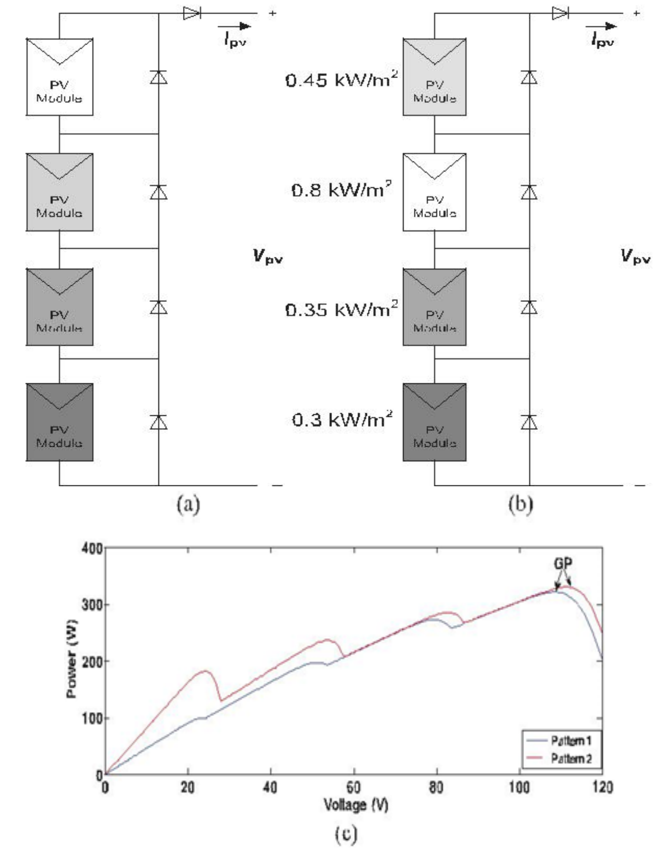


Figure 1. 4S configuration under different shading patterns. (a)Pattern 1.(b) Pattern 2. (c) P–V curves under PSCs.

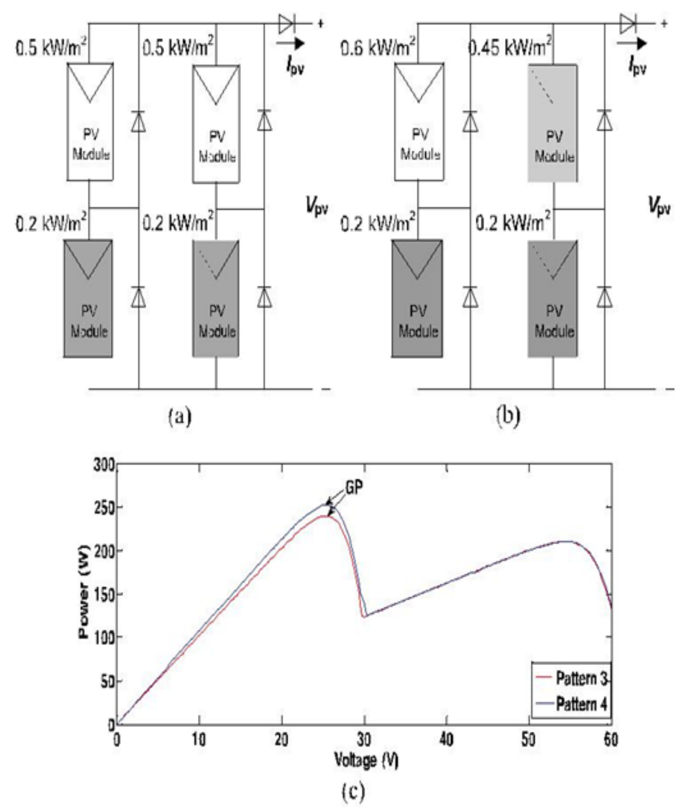


Figure 2. 2S2P configuration under different shading patterns. (a) Pattern 3.(b) Pattern 4. (c) P –V curves under PSCs.

The two different PV arrays are considered in this work and are shown in Figs. 1 and 2A configuration consisting of four modules in series (4Sconfiguration) having two different shading patterns with their P–V curves is shown in Fig. 1. The second PV configuration that has two series modules connected in parallel with another two series modules (2S2P configuration) having two different shading patterns with their respective P–V curves are shown in Fig. 2.

## III. GWO AND ITS APPLICATION IN MPPT DESIGN

The GWO algorithm imitates the leadership hierarchy and hunting mechanism of grey wolves in nature proposed by Mirjalili et al. [14]. Grey wolves are considered to be at the top of food chain and they prefer to live in a pack. Four types of grey wolves such as alpha(α), beta (β), delta (δ), and omega (ω) are employed for simulating the leadership hierarchy.

In order to mathematically model the social hierarchy of wolves while designing, GWO we consider the fittest solutions as the alpha. Consequently, the second and third best solutions are named as the beta and delta respectively. The rest of the candidate solutions are assumed to omega. fig 3 shows three main steps GWO algorithm, namely hunting, chasing and tracking prey, and attacking prey which are implemented to design GWO.

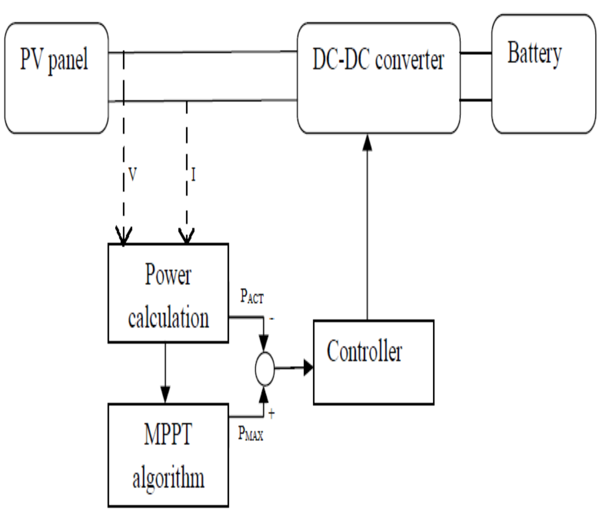


Figure 3. Block diagram

optimization. Grey wolves encircling behavior can be modelled by the following equations

.D=|C.Xp(t)-Xp(T)| (2)

X(t+1)=Xp(t)-A.D (3)

t-current iteration, D, A and C- coefficient vectors,Xp-position vector of prey,X-position vector of grey wolf

A=2a.r1-a (4)

C=2.r2 (5)

### 1. Application of GWO for MPPT Tracking

Fig.4 shows the block diagram of the proposed MPPT scheme for the PV system. For number of grey wolves, i.e., duty ratios, the controller measures Vpv and Ipv through sensors and computes the output power. The flow chart of the proposed GWO-based MPPT algorithm shown in fig 5. During partial shading, the P-V curve is categorized by multiple peaks having various local peaks(LPs) and one GP.It is to note that when the wolves find the MPP, their correlated coefficient vectors become nearly equal to zero. In the proposed method, an attempt has been made to combine GWO with direct duty-cycle control ,i.e ,at the MPP duty cycle is sustained at a constant value which is turn reduces the steady-state oscillations that exist in conventional MPPT techniques and lastly, the power loss due to oscillations is reduced resulting in higher system efficiency. To implement the GWO-based MPPT, duty cycle D is defined grey wolf. Therefore (3) can be modified as follows

Di(k+1)=Di(k)-A.D. (6)

Thus the fitness function of the GWO algorithm is formulated as

P(dik)>P(dik-1) (7)

Where p represents power, d is duty cycle ,I is the number current grey wolves, and k is the number of iterations.

## IV. RESULTS AND DISCUSSIONS

### 1. Simulation Results:

To evaluate the performance of the proposed GWO based metaheuristic. MPPT algorithm, its performance were compared with P&O and PSO MPPT algorithms. All the above three algorithms were implemented under PSCs and rapidly changing insolation level for both 4S and 2S2P configurations. The power, voltage, and current for configurations with PSCs employing GWO,PSO and the second pattern appears for next 0.1s.In pattern 1 is made to exist for first 0.1 s and the second pattern appears for next 0.1s.In pattern 1,GWO based MPPT converges to the GP of 319.4W,PSO to LP of 100.2W as it is unable to differentiate between local and GPs resulting in steady-state oscillations.

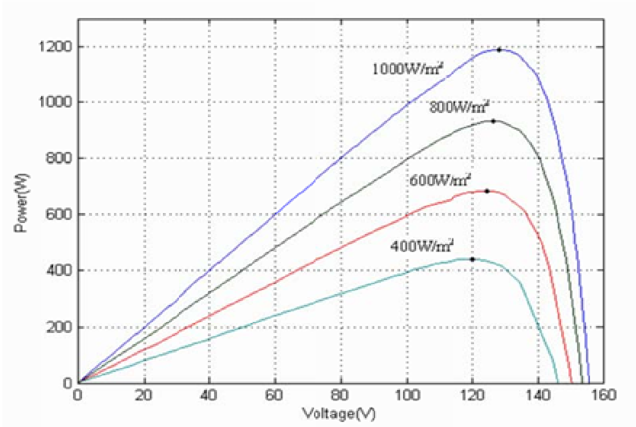


Figure 4. pv curve of solar array for different irradiation and constant temperatureof 25`C

i.e, the operating point oscillates around the MPP gives rise to power loss and also results in slowing down the speed of response of the algorithm and reduces the efficiency of the PV system. The simulation is now repeated for 2S2P configuration is having two major different patterns, namely patterns 3 and 4. The GWO based MPPT GP reaches 239.1 W, PSO tracks GP mostly as it tracks the peak which comes in contact first, i.e., it may be a GP or LP resulting in oscillations around MPP. All the above findings are implemented for existence of pattern 3 which appears for 0.1s.

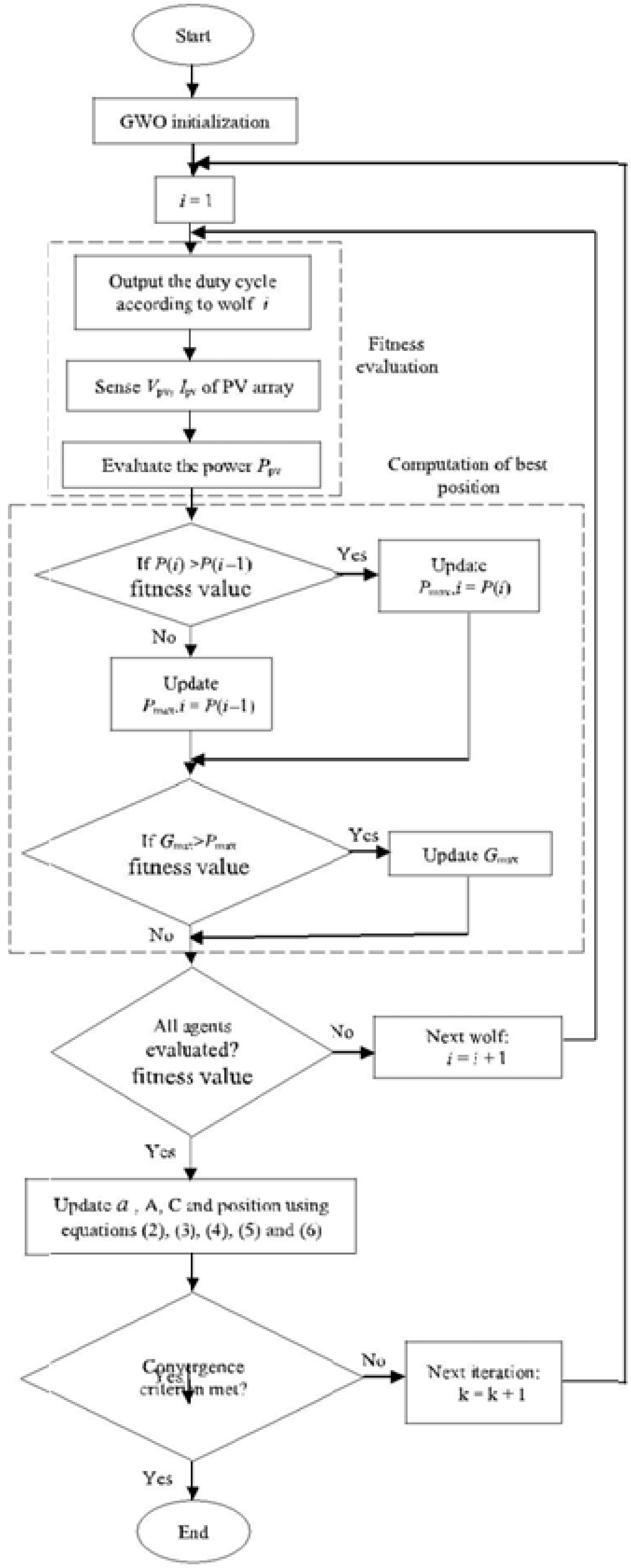


Figure 5. Flow chart

for pattern 4,the GWO-based on the MPPT locates the GP of 251.6W,PSO locates GP at 251.5w,and P&O gets settled to the GP of 247W as before in pattern 3 resulting in oscillations around the MPP. The tracking curves are shown in fig.7. The simulation results presented in figs.6 and 7 envisage that the GWO-based MPPT can handle partial shading efficiently and it outperforms both P&O and PSO with respect to faster convergence to GP, tracking speed, reduced steady state oscillations, and higher tracking efficiency. The simulation results presented in figs 6 and 7 are briefly summarized in Tables I and III. The MPPT tracking efficiency is calculated as the ratio between average output power obtained at steady state and maximum available power of the PV array under certain shading pattern [13].Furthermore a qualitative comparison among various fast converging MPPT methods is presented in Table II. From Tables III and I, it is seen that the GWO based MPPT outperforms over the other two MPPT methods. To ensure the effectiveness of the proposed MPPT algorithm, different loads such as an RL load (50Ω, 15mH) are connected in place of resistive load and are studied for pattern 1.

Fig.6 compares the response of two different types of loads (R and R-L load) from which it is seen in both the cases, the proposed MPPT is efficient enough converge GP successfully. Usually, for R load fast response is observed compared to any other loads.

## 2. Experimental Results

To validate the effectiveness of the proposed GWO based MPPT, experiments were carried out on real PV array for both 4S and 2S2P configurations. The Processor running at 250 MHz and a slave DSP subsystem based on TMS32oF240 DSP and Hall effect sensor is used to sense the voltage and current of the PV array before sending it to the controller.Fig.9 shows the experimental setup of the system. New MPP from the new PV curve. The tracking curves of GWO and PSO based MPPT reach GP of 143.5W, whereas P&O gets trapped to LP of 65.32W. In order to validate the effectiveness of the proposed MPPT for a different random pattern, experiments were carried out for 2S2P configurations having two types of shading and pattern 7 having GP of 77.98W and LP of 47W and pattern 8 are having the GP of 58.25W,respectively.The experimentally determined MPPT curves employing with the proposed and existing methods. The tracking curves of the proposed GWO and PSO MPPT are able to converge to GP of 77.98W and P&O by chance settles to the GP resulting in oscillations. After sometimes when the shading pattern changes to a new P-V curve marked as pattern 8,once again the three algorithms search the PV curve for a new MPP. The curves of the proposed MPPT and PSO based MPPT converge of the GP of 58.25W and P&O gets trapped at a local optimum value of 46.64W.

To verify that the effectiveness of the proposed MPPT algorithm is working accurately under RL load, experiments were carried out for pattern 5. Fig.6 shows that the settling time increases, but the performance of the proposed MPPT remains the same for convergence toward the GP.

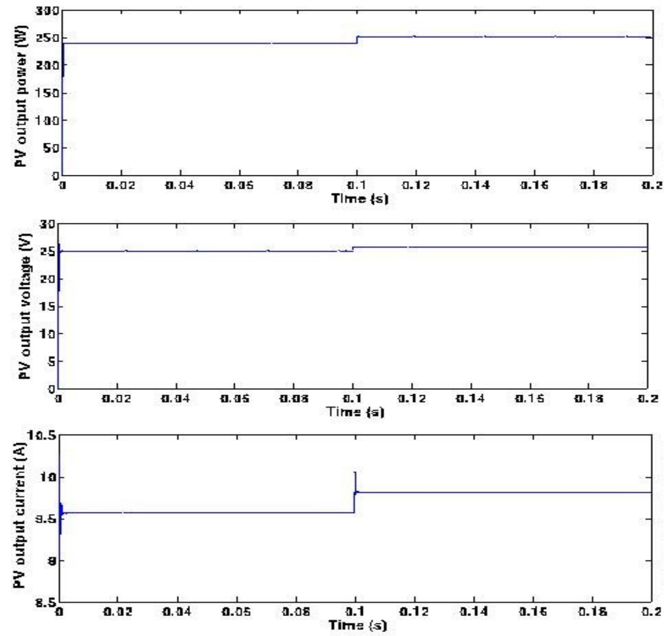


Figure 6. GWO-based MPPT.

Table 1. Performance comparision of proposed MPPT method

| Shading pattern | Maximum power from P–V curve (W) | Tracking techniques | Maximum power (W) | Maximum voltage (V) | Maximum current (A) | %Tracking efficiency |
|---|---|---|---|---|---|---|
| 3 | 239.3 | P&O | 234 | 24 | 9.75 | 97.78 |
| | | IPSO | 239.05 | 25 | 9.562 | 99.89 |
| | | GWO | 239.1 | 25.01 | 9.56 | 99.91 |
| 4 | 251.8 | P&O | 247 | 23.9 | 10.3 | 98.09 |
| | | IPSO | 251.5 | 25.64 | 9.808 | 99.88 |
| | | GWO | 251.6 | 25.64 | 9.812 | 99.92 |

The proposed method can used successfully detect the shading pattern in variations and re initialize the MPPT process exhibiting superior of the performance in terms of faster convergence to that of GP, reduced steady-state oscillations, and faster tracking in PV system under PSCs.

## V. CONCLUSION

This paper proposed a new computing approach is called grey wolf optimization to design a maximum power extraction algorithm for PV systems to work under PSCs. In these view of assessing the effectiveness of this new MPPT (grey wolf-based MPPT), its performance was compared with two existing MPPTs, namely P&O and PSO-based MPPT methods and from the obtained results, it was found that the GWO based MPPT exhibits superior performance compared to other two MPPTs.

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