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A New DC-DC Converter Topology with Grey Wolf MPPT Algorithm for Photovoltaic System

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Abstract –This paper presents an implementation of Dc-Dc converter with a maximum power point tracking (MPPT) design for a photovoltaic (PV) system using a new optimization technique. The new optimization method which 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 problem of tracking the global peak (GP) of a PV array under partial shading condition is attempted employing to improve MPPT technique. The proposed scheme is called as Grey Wolf Optimization, which used 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 implemented on a PV 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 converter with MPPT algorithm outperforms both P&O and PSO MPPTs.

Index Terms –Grey wolf optimization (GWO), maximum power point tracking (MPPT), partial shading conditions (PSCs), photovoltaic (PV).

1. INTRODUCTION

Various maximum power point tracking (MPPT) algorithms were discussed in literature [1-3] 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 adaptabilityto 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) [4][5], 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 [6]–[9].Boththese 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 [10]. To reduce these oscillations and improve the module efficiency, the IC method was proposed [11] which reduced the oscillations but not completely. Both P&O and IC methods fail during those time intervals characterized by changing atmospheric conditions[12],[13].A few improved IC algorithms were also proposed to improve the MPP tracking capability during fast-changing irradiance level and load [14], [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 [15], 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 [16] 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 [17-26]. 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. Then finally, conclusion is provided in Section V.

2. CHARACTERISTICS OF A PV SYSTEM UNDER PSCS

2.1.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;

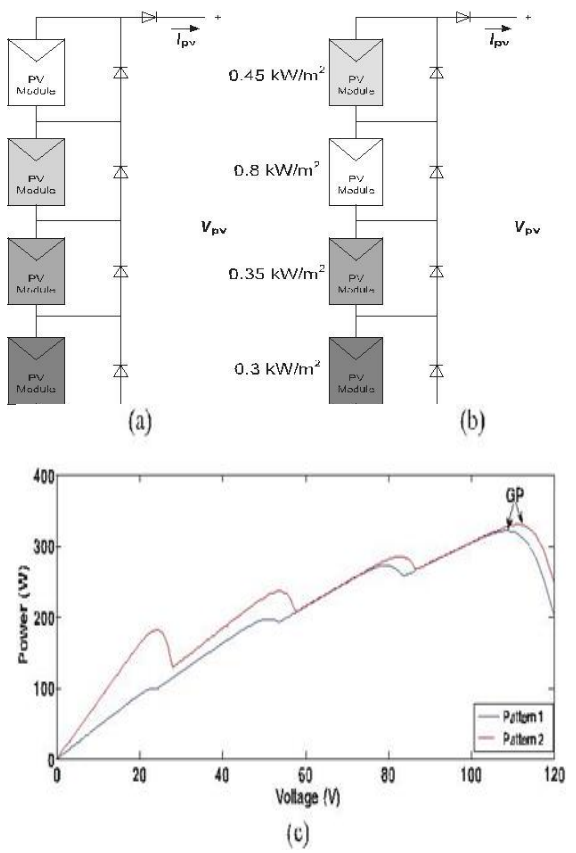

Fig.1.4S configuration under different shading patterns. (a)Pattern 1.(b) Pattern 2. (c) *P–V* curves under PSCs.

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,

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

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.

2.2.System Description

A PV array consists of several PV modules connected in series to produce a higher voltage and in parallel to increase the current. During PSCs, multiple peaks, i.e., local and global maxima points are observed in the P–V characteristics curve due to the presence of bypass diodes. 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.

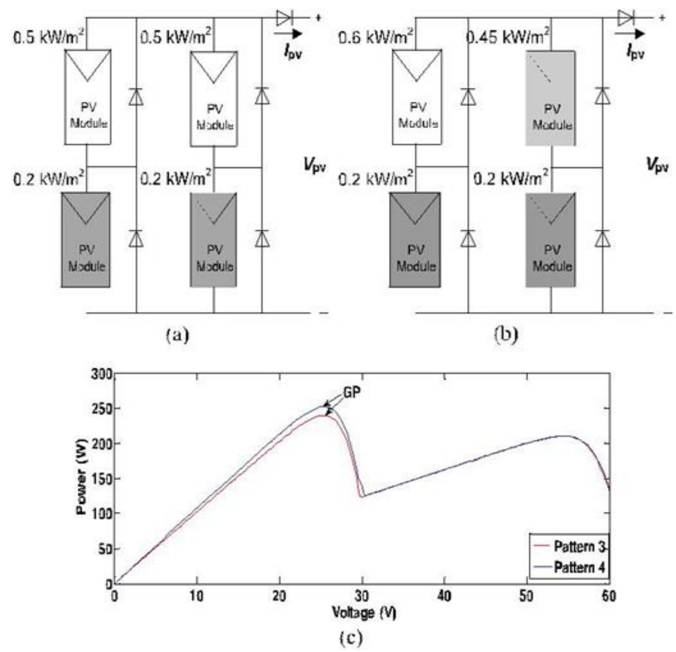

Fig.2. 2S2P configuration under different shading patterns. (a) Pattern 3.(b) Pattern 4. (c) *P –V* curves under PSCs.

3. 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.

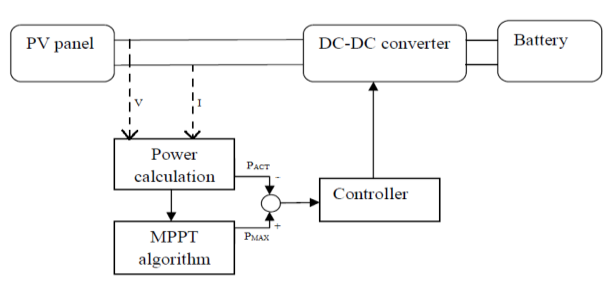

Fig.3.Block diagram

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 GWOoptimization. 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)

a-linearly decreases from 2 to 0, r1, r2-random vectors

3.1.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 V_{pv} and I_{pv} through sensors and computes the output power. The flowchart 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. 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

$P(d_i^k)>P(d_i^{k-1})$ (7)

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

4. RESULTS AND DISCUSSION

4.1.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. 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. 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.

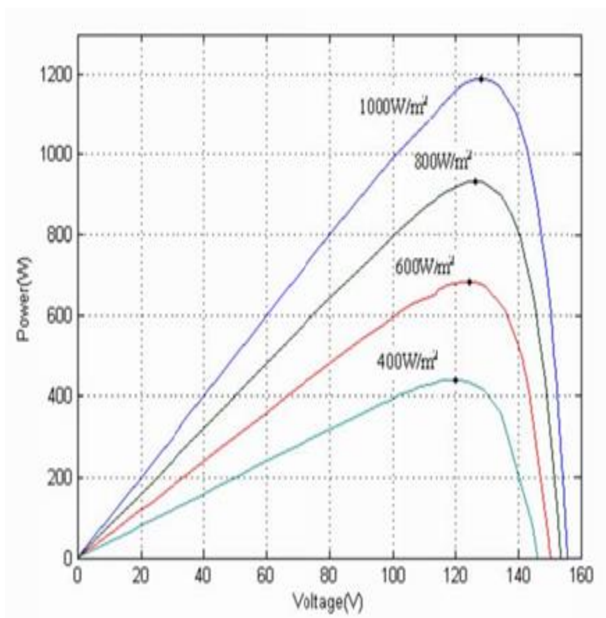

Fig.4.PVcurveofsolararrayfordifferentirradiationandconstanttemperatureof25`C

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.

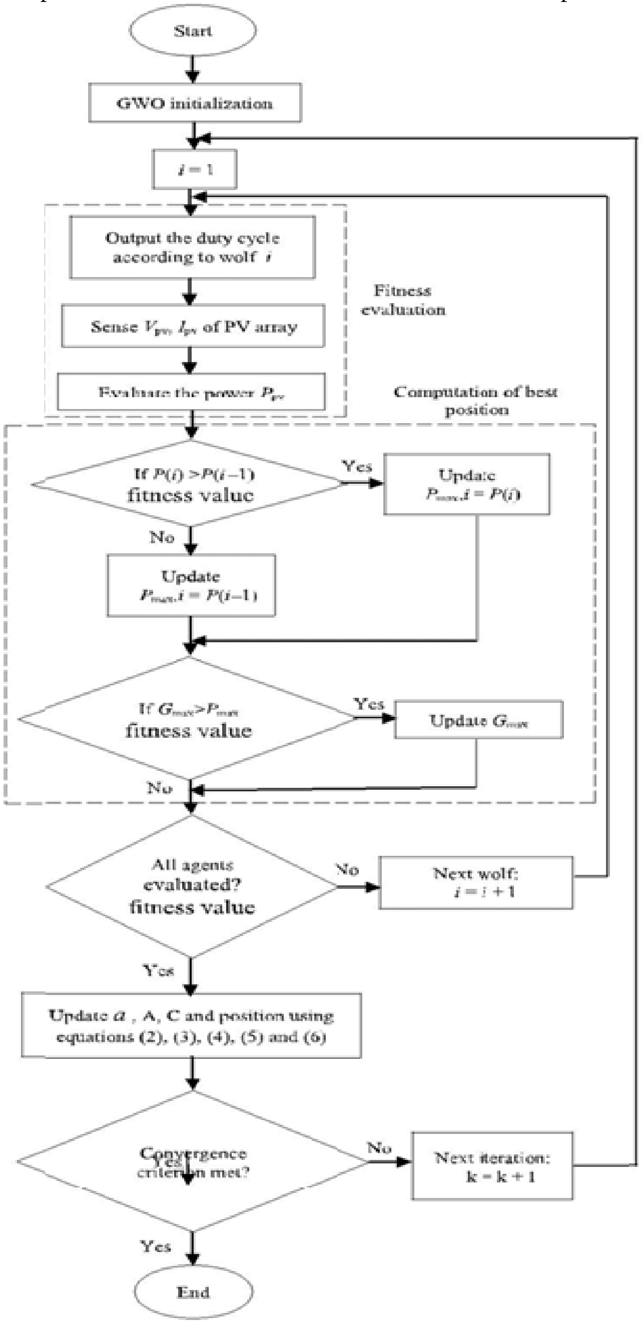

Fig.5.Flow chart

4.2.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 MPPfrom 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.

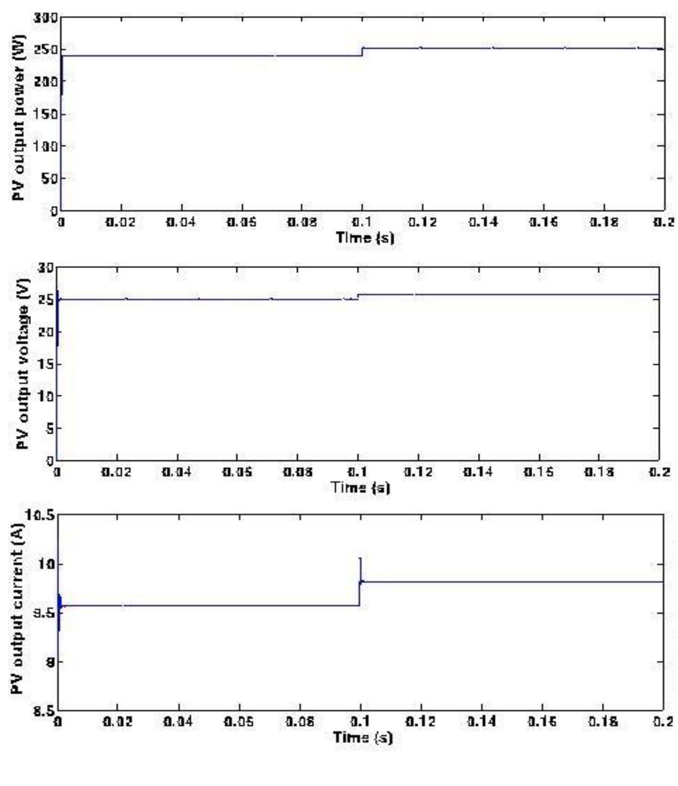

Fig.6. GWO-based MPPT.

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.

Table: 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.

5. CONCLUSION

This paper proposed a new approach is called grey wolf optimization to design a maximum power extraction algorithm for PV systems to work under PSCs condition. 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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