New Hybrid MPPT Technique Using Honey Badger (HBA) and Coyote Optimizer (COA) for Partially Shaded PV systems

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ABSTRACT

The maximum production of electricity is needed to satisfy the consumption from renewable energy source such as solar energy. Solar cell is more appropriate energy source for long usage. The irradiance level is measured for finding the maximum earned power from solar energy so that several maximum power point tracking (MPPT) techniques have been introduced. Thus the performance of photovoltaic (PV) system is increased by using Honey Badger Algorithm (HBA) and Coyote Optimizer Algorithm (COA). The HBA is extracted from the foraging behavior of honey badger which is used to get maximum power from the PV panel. Additionally COA optimization is used for making efficient and accurate output power by analyzing the placement of PV panel in the whole process based on the social behavior of coyotes. From these algorithms, the maximum power is obtained in any climate change situations and also the efficiency and accuracy are maintained using the proposed optimization techniques. The novelty of this study is to produce maximum power and also maintain the efficiency and accuracy of output throughout the process. The simulation is carried out under Matlab/Simulink environment. The key results analyzed the performance of the proposed technique, in terms of steady state behavior, tracking speed, tracking efficiency, and distortions in waveforms and was compared to the most recent and effective MPPT algorithms as FPA, GSA and PSO, under different solar radiance levels, and the comparison showed that is superior to them, a faster tracking speed, higher tracking efficiency, and lower oscillations around the steady state.

I. Introduction

Electricity consumption is increasing, owing to the growth of technologies and population day by day, so that power generation is focused on renewable energy sources such as solar energy. This later is inexhaustible and affordable energy source that produces energy from sun light [1]. The disadvantages of traditional Perturb and Observe (P&O) algorithm can be reduced using the fractional short-circuit current (FSCC) method under different conditions. [2]. An adaptive perturbation size is achieved by multiplying 2D Gaussian function and Arctangent function then the PV system steady state is developed by duty cycle computed with variable perturbation frequency [3]. A high voltage gain DC-DC converter was implemented in P&O algorithm for low power applications [4]. The difference between successive powers with corresponding voltages was determined by analyzing the differential power algorithm to effectively track the maximum power [5]. To reduce the oscillation with high speed and good tracking accuracy, fractional order using fuzzy logic method was used [6]. The traditional variable step size is eliminated by changing the step size with the method of auto-scaling variable step-size [7]. In [8] it focuses on the generating speed by increasing the number of optimal blades in which impeller solidity is measured using the starting and stopping speed of blades.

The total harmonic distortion (THD) is reduced to improve the performance of the proposed PV system by integrating of conjoins three series connected full bridge inverters and a single half bridge inverter [9]. The main objective of this technology is to produce maximum power under different partial shading conditions (PSC) in which whale optimization and differential evolution algorithms are used to produce high quality output [10]. This method is used to produce maximum power by reducing the shading effect and atmospheric changes using voltage scanning technique within the short period of complex PSC [11]. This system is generated for low power applications that use single diode based PV systems to enhance accuracy and efficiency by a MPPT algorithm [12]. The maximum power depends on the radiance and temperature and the efficiency is achieved by a new P&O algorithm [13]. This system constantly generates the maximum power using array of PV cells with the MPPT algorithm of deep reinforcement and fuzzy mechanism [14].

The purpose of the proposed methodology is to improve the PV panel performance using a stability algorithm for producing maximum power; unlike conventional technologies where the maximum power is not stable for all types of loads. The remainder of this paper is organized as follows. In Section II, MPPT tracker using proposed algorithm to enhance the performance of the system is explained. In Section III, the key simulation results of the proposed technique are discussed and compared to existing algorithms as Flower Pollination Algorithm (FPA), Gravitational Search Algorithm GSA) and Particle Swarm Optimisation (PSO. Section IV ends with conclusion.

II. Design of the Proposed Methodology

The proposed system consists of PV panel, switched mode boost DC-DC converter, multilevel cascaded H-Bridge (CHB) inverter, HBA controller and COA controller. This approach is used to get maximum power and also enhance the efficiency and accuracy tracking. Fig.1 illustrates the block diagram of the overall PV system. The PV panel is integrated with MPPT block for getting maximum power. This latter is converted from DC to AC with the help of the inverter to supply AC loads [15-17].

The maximum power is obtained by using HBA based MPPT algorithm. Then, the stability is provided by the COA controller.

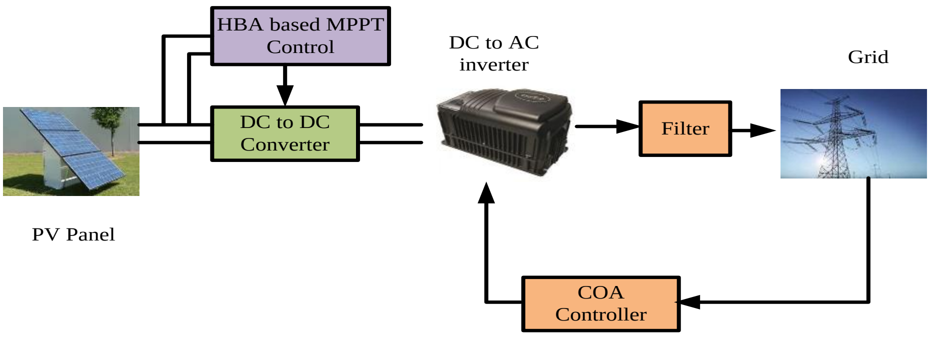

Figure . 1. Block diagram of the proposed PV system.

II.1. HBA based algorithm for maximum power generation

The power generated from PV panel should be maximized using HBA which is based on the hunting behavior of honey badger animal. It finds the prey location by smelling and digging or follows the honey guide bird to directly locate beehive in which it can dig fifty holes of radius forty kilometer in a day. In this algorithm, there are two phases, digging phase and honey phase. Each step of this algorithm is explained in [18]. This flowchart is shown in Fig. 2, it is based on exploration and exploitation phases, and the population candidate solution is given in equation (1)

$$\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1D} \\ x_{21} & x_{22} & \cdots & x_{2D} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nD} \end{bmatrix} \quad (1)$$

Honey badger is in the position of i which is expressed in equation (2),

$$x_i = x_i^1 + x_i^2 + \ldots + x_i^D \quad (2)$$

In initialization phase n is the number of honey badgers and badger's position is given by equation (3)

$$x_i = lb_i + r_1 \times (ub_i - lb_i) \quad (3)$$

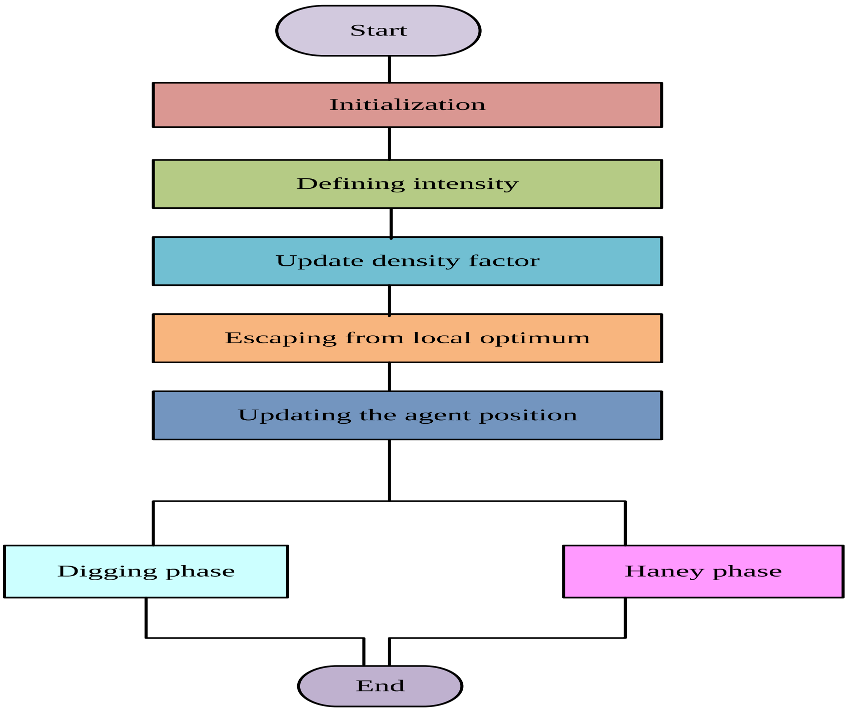

Figure. 2. Flow chart of HBA algorithm.

r_1 is a random number from 0 to 1, lb_i and ub_i are the lower and upper values, respectively, of search domain.

Intensity is defined as the prey concentration strength at distance between prey and ith honey badger position. Here I_i is the smell intensity and if it increases, the speed will also increase, which is expressed as inverse square law in equations (4-6)

$$I_i = r_2 \times \left(\frac{S}{4\pi d_i^2} \right) \quad (4)$$

$$S = (x_i - x_{i+1})^2 \quad (5)$$

$$d_i = x_{prey} - x_i \quad (6)$$

S is the concentration strength of prey. The density factor (α) makes smooth transition by controlling time-varying randomization from exploration to exploitation. For decreasing the iteration with time, update α which is given in equation (7).

$$\alpha = C \times \exp\left(\frac{-t}{t_{\max}}\right) \tag{7}$$

where, t_{max} is the maximum iteration, C is a constant, C > 1 (default = 2).

The search direction is changed by flag F which alters search direction, as shown in Figure.3 to escape from local optima by scanning of the search space [17].

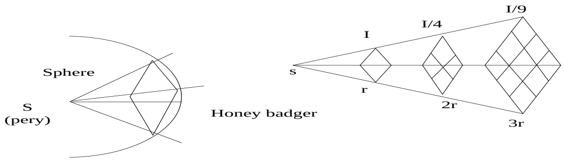

Figure. 3. Search direction of honey badger.

As mentioned in the above explanation, the update process (x_{new}) is divided as digging phase and honey phase. In honey phase, the movement of honey badger is in cardioid shape so the cardioidal motion is given in equation (8),

$$x_{new} = x_{prey} + F \times \beta \times I \times x_{prey} + F \times r_3 \times \alpha \times d_i \times \left|\cos(2\pi r_4) \times [1 - \cos(2\pi r_5)]\right| \tag{8}$$

where, x_{prey} is the best fit prey position, β is greater than or equal to 1 (default = 6), the distance between prey and i^{th} honey badger is denoted as d_i and r_3, r_4, and r_5 are three different random numbers between 0 and 1. Value of F is expressed in equation (9)

$$F = \begin{cases} 1 & if\ r_6 \le 0.5 \\ -1 & else \end{cases} \tag{9}$$

where, r_6 is a random number from 0 to 1. Moreover, in digging phase, any disturbance F received by badger is used to find better prey location. The equation (10) expresses the honey phase to reach the beehive.

$$x_{new} = x_{prey} + F \times r_7 \times \alpha \times d_i \tag{10}$$

The search is varied from time (α) and disturbance F at this stage.

II.2. HBA based algorithm for maximum power generation

In the proposed method, COA optimization is adopted for maintaining the efficiency of the system by considering the placement of PV panel. Its core idea is based on canis latrans species that locate in America. The balance between exploitation and exploration process is developed for optimization. The algorithm is explained by the flowchart in Fig. 4.

COA is developed based on the social behavior and hunting strategy of coyotes [19]. The latter are distinguished by cooperative functionalities as they head towards the prey in the close chain. The location of the prey is identified by the smelling sense, and they attack in groups. The social behavior of the coyote is defined in equation (11)

$$SOC_c^{p,t} = \vec{x} = (x_1, x_2, x_3, \ldots x_D) \tag{11}$$

The coyote social condition is denoted as $fit_c^{p,t} \in \Re$. The current social condition of coyotes behavior is assessed by equation (12):

$$fit_c^{p,t} = f\left(SOC_c^{p,t}\right) \tag{12}$$

Initially the coyotes are in random packs. After, they will move and change their packs. These packs are interchanged between coyotes increasing the consideration with their interaction, as expressed by alpha, given in equation (8).

$$alpha = \left\{ SOC_c^{p,t} \,\middle|\, \underset{c=\{1,2,\ldots N_c\}}{\arg} \min f(SOC_c^{p,t}) \right\} \tag{13}$$

Cultural tendency is defined as the existing information shared by coyotes when all coyotes are arranged and exchange in social culture which is given in equations (14, 15),

$$cult_j^{p,t} = \begin{cases} O^{p,t}_{\left(\frac{N_c+1}{2}\right)} & ; \quad N_c \text{ is odd} \\ \dfrac{O^{p,t}_{\frac{N_c}{2} j} + O^{p,t}_{\left(\frac{N_c}{2}+1\right) j}}{2} & ; \quad otherwise \end{cases} \tag{14}$$

where $O^{p,t}$ is social condition ranking of all coyotes at instant t and the cultural tendency of considered pack is determines coyotes mean in the social condition from a specific pack. In this $age_c^{p,t}$ is the birth of new coyotes,

$$pup_j^{p,t} = \begin{cases} SOC_{r1,j}^{p,t} & ; rnd \,\alpha\, P_s \quad or\ j = j_1 \\ \dfrac{SOC_{r2,j}^{p,t}}{2} & ; rnd \,\alpha\, P_s + P_a \quad or\ j = j_2 \\ R_j & ; otherwise \end{cases} \tag{15}$$

where, $SOC_{r1,j}^{p,t}$ is the Social condition of coyote r_1, $SOC_{r2,j}^{p,t}$ is the Social condition of coyote r_2, j_1, j_2 are the dimensions of the optimization problem, Pa, Ps are the probability of association and probability of scatter respectively, R j is the number in the range of variable bounds.

The cultural variety of coyotes is calculated by Pa and Ps from pack which is given below,

$$P_s = \frac{1}{D}, \quad P_a = \frac{1-P_S}{D}$$

For simulation we have to consider two parameters. the fitness function w is the bad function and pack effect δ in which the coyotes quantity is denoted Q and the function is mentioned in equations (16, 17)

$$\delta = alpha^{p,t} - SOC_{cr2}^{p,t} \tag{16}$$

$$\delta = cult^{p,t} - SOC_{cr2}^{p,t} \tag{17}$$

The alpha and pack effect are important while updating coyotes which is shown in equation (18),

$$SOC_c^{p,t,new} = SOC_c^{p,t,old} + r1.\delta 1 + r2.\delta 2 \tag{18}$$

Update of social condition of coyotes is given by equation (14),

$$SOC_c^{p,t+1} = \begin{cases} SOC_c^{p,t,new} \; fit_c^{p,t} \alpha fit_c^{p,t} \\ SOC_c^{p,t} otherwise \end{cases} \tag{19}$$

Thus the output is maintained efficiently and accurately by using the above mentioned optimization technique. By using the simulated output of this system, the effectiveness of maximum power generation progress is verified.

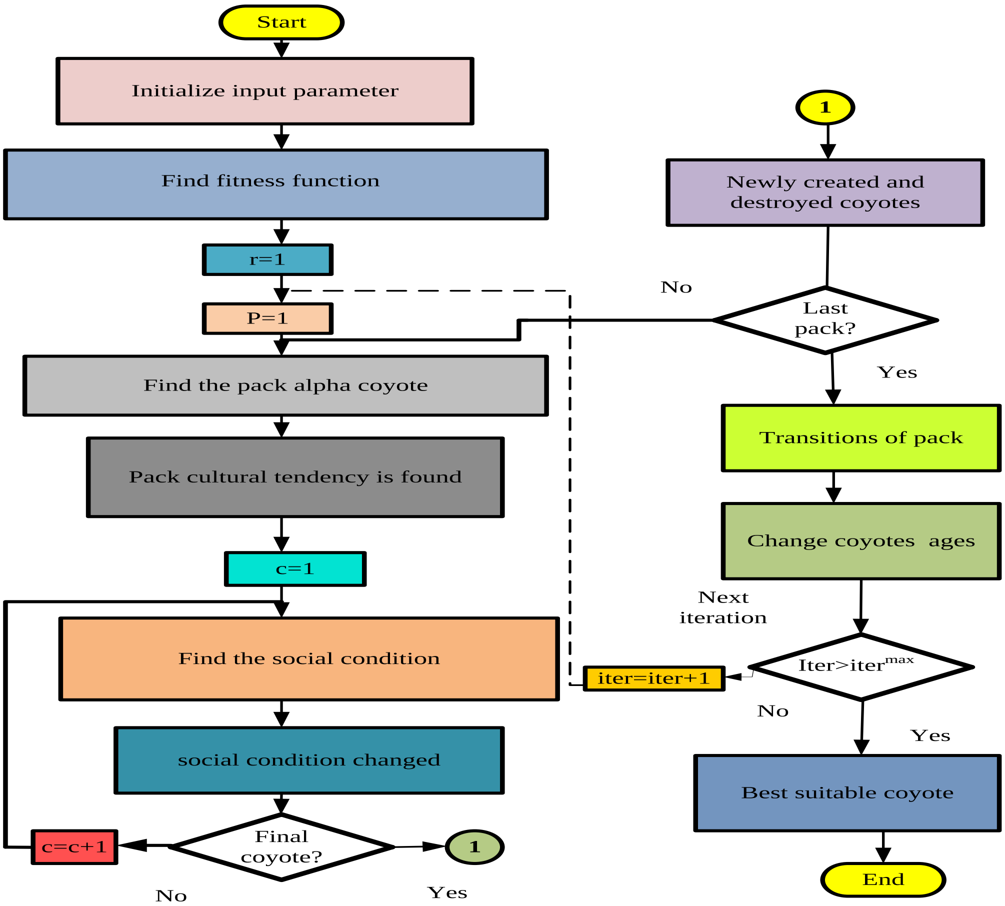

Figure. 4. Flow chart of COA algorithm.

III. RESULTS AND DISCUSSION

The proposed method is simulated under Matlab/ Simulink environment and the key results are shown. In this section, HBA technique is used for the MPPT controller to track the maximum power during a minimum time and COA provides high efficiency and stability as compared to others recent and efficient methods (FPA, GSA and PSO [20]). The simulation circuit of the proposed system consists of PV panel, HBA and COA controllers, boost DC-DC converter, CHB inverter. The PV panels with different irradiance levels are the input of the proposed system. In the proposed system the tracking efficiency is improved by using proposed technique in MPPT controller for tracking maximum power during minimum time. The key results show the PV panel output power, load and converter output voltage. The simulation parameters are given in table.1. For both the normal and abnormal state boundaries like voltage, current and power are utilized to evaluate. For the testing process, the simulation time is 0–5 s.

Table 2.Simulation parameters

Parameters	Values
PV	
PV panel Maximum Power (W)	9kW
Number of cells (Ncell)	96
Voc (V)	64.2
Isc (A)	5.96
Vmp (V)	54.7
Imp (A)	5.58
I_L (A)	6.0092
I_0 (A)	6.30e-12
Diode ideality factor	0.94504
Rsh (ohms)	269
Rs (ohms)	0.37
Three phase supply	
Nominal phase-to-phase voltage Vn (Vrms)	260
Nominal frequency fn (Hz)	50

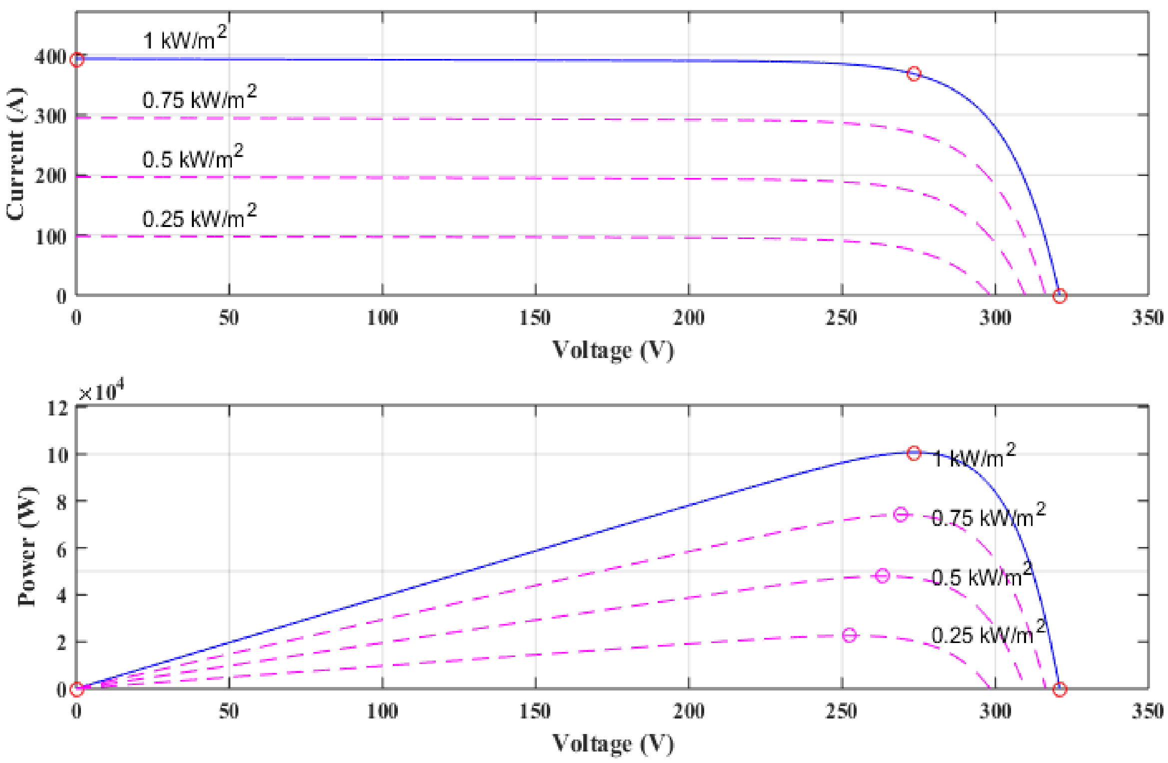

Figure. 5. IV and PV characteristics of PV panel.

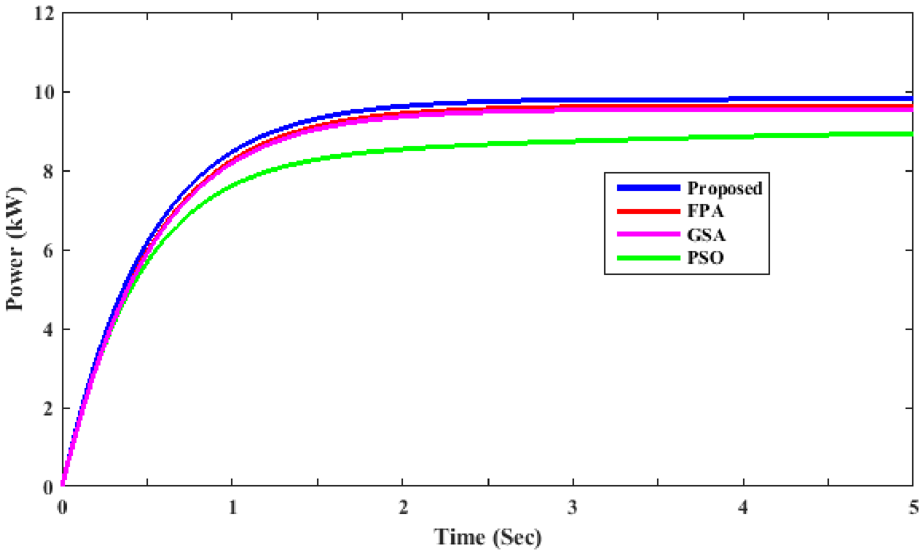

Figure. 6. Comparison analysis for different partial shading conditions.

Table 2.Key simulation results for tracking time and efficiency

Optimization Technique	Tracking time (sec)			Tracking Efficiency (%)
	Irradiance = 1000 (W/m^2) Pmpp = 2490.75 W	Irradiance = 900(W/m^2) Pmpp = 2235.4 W	Irradiance = 700 (W/m^2) Pmpp = 1728.23 W	
PSO	8.20	8.01	7.92	85.73
FPA	4.26	3.77	4.15	95.86
GSA	3.65	3.15	2.87	99.38
Proposed	1.25	1.53	1.55	99.49

I-V and P-V characteristics of PV pannel are represented in Fig. 5. The generation of maximum power is improved with the help of the boost DC-DC converter on the basis of HBA algorithm. The generated power comparison analyses the proposed technique with others recent techniques are illustrated in Fig. 6. The induced power and the tracking efficiencies are described in table 2. As well as the induced power is transmitted to the grid by means of the VSI and three phase filter. The comparison analysis proves that the proposed hybrid technique provides a very short tracking response (less than 1.5 s), very high efficiency (more than 99.5 %) with low distortion, and very low oscillations around the steady state (less than 2 W). From the above analysis, it can be concluded that the proposed method offers better results to manage power among generation side and grid side.

IV. Conclusion

This paper proposes a hybrid HBA-COA technique to enhance the performance of the MPPT of a grid-tied PV system under PSC conditions and climate changes. The proposed method provides a very short tracking response (less than 1.5 s), very high efficiency (more than 99.5 %) with low distortion, and very low oscillations around the steady state (less than 2 W).

The performance of the proposed method was evaluated using the platform of Matlab/Simulink, and compared to other recent and effective techniques, namely PSO, FPA, GSA and proved its superiority over these techniques in terms of tracking speed, efficiency, stability, distortions of the PV response.

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