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A PSO – I GWO Algorithm Based MPPT for PV System under Partial Shading Conditions

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ABSTRACT

Solar photovoltaic (PV) is skyrocketing energy due to its advancement in technology. Nevertheless, PV energy face some difficulties under partial shading conditions (PSC) easily fall into local maxima instead of maximum peak power (MPP), oscillations around MPP when we used conventional algorithms. To avoid this problem a hybrid model of particle swarm optimization and improved grey wolf optimization (PSO – I GWO) based metaheuristic algorithm is used in this paper. It is developed and implemented in Matlab/ Simulink environment for different irradiation conditions. Moreover, the proposed algorithm is compared with another existing algorithm of cuckoo search optimization (CSO). Eventually, the hybrid model is superior to CSO in terms of convergence time, extracted power, and efficiency.

KEYWORDS: photovoltaic (PV), partial shading conditions (PSC), Maximum peak power (MPP), PSO –I GWO, CSO

INTRODUCTION

The generation of electricity plays a potential role to meet the required power demand through resources like conventional and non-conventional resources. The conventional resources are coal, oil, fossil fuel, and natural gases. Nevertheless, due to the lack of sources and increasing the cost of transportation, the total cost of electricity increases rapidly[1]. On the other hand, it was harmed the global environment due to the burning of fuels. To minimize the problems and reduce the cost of the system many researchers switch to non-conventional resources like solar, wind, tidal, and ocean energy. Amongst, solar photovoltaic (PV) energy plays a crucial role to incorporate the power demand. The cost of the photovoltaic (PV) system gradually decreasing due to the development of advanced technology[2]. In addition, the main factors have free from pollution, cleanness and noise-free. The PV system tracks the solar energy to generate electricity. However, the PV system faces numerous challenges for tracking the maximum power due to passing clouds, the shadow of buildings and partial shading conditions (PSC)[3].

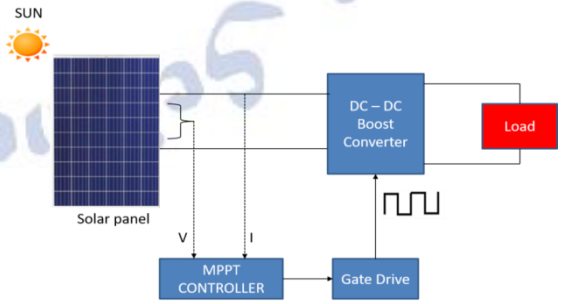

Fig1: Block diagram of PV system

To overcome the above problems, maximum power point tracking (MPPT) plays an important role which is

integrated into a DC-DC converter of the PV system as shown in Figure 1. In past decades the conventional MPPT algorithms are used to track global power. The conventional algorithms are perturbed and observe (P&O), incremental conductance (INC), and hill-climbing[4]. These algorithms can track the maximum power under uniform conditions, however; it has some oscillations around the maximum peak power (MPP) under PSC. The PV characteristics for uniform conditions and PSC are shown in Figure 2. In which only one peak for uniform condition and multiple peak power points (MPPP) is generated under PSC[5]. Amongst, one is global maximum peak power (GMPP) and the remaining are local peak power points (LPPP). The disadvantages of these algorithms have high oscillations, low accuracy and more settling time required under PSC to track the maximum power.

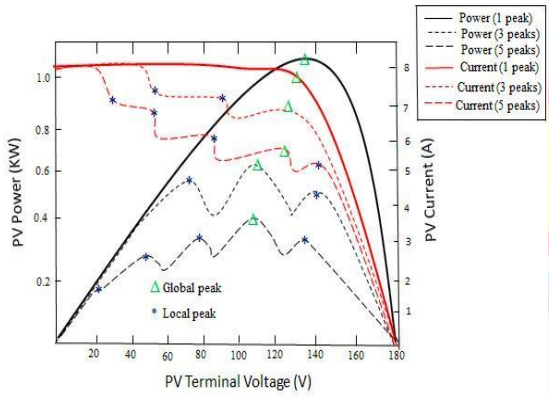

Fig 2: Characteristics of PV system

The above disadvantages can be avoided through soft computing algorithms and satisfy the required parameters of low convergence rate, least failure rate, and low oscillations under steady-state[6]. Again these soft computing algorithms can be divided into two types' artificial intelligence and bioinspired algorithms. However, the artificial intelligence methods have high computational complexity to track the GMPP and require qualified persons to operate. For example, a fuzzy-based method has different rules and is more complex when we apply it to PV systems[7]. Moreover, it is a difficult task while applying to different irradiations and temperatures. To accomplish these problems and avoid the complexity authors move forward to bioinspired algorithms[8]. Particle swarm optimization (PSO), ant colony optimization (ACO)[9], artificial bee colony (ABC)[10], bat (BAT)[11], cuckoo search optimization (CSO)[12], and grey wolf optimization (GWO) are bioinspired algorithms[13]. These algorithms can track GMPP in PV systems under PSC. Nevertheless, the PSO and CSO easily fall into local maximum instead of GMPP. Similarly, ABC and BAT also facing the same problems and require more convergence time to steady-state.

To mitigate the above problems hybrid PSO and I-GWO are presented in this paper. The mathematical model of the single diode model is presented in section 2 while the proposed hybrid model description is in section 3. In Section 4, Results and discussion are presented for the hybrid model and compared with another algorithm CSO. Eventually, the conclusion part is presented in section 5.

2. MATHEMATICAL MODEL OF SINGLE DIODE MODEL

The diode model can be classified into three type's single diode model, two diode models, and three diode models[14]. The single diode model is mostly preferred due to its simple construction and performance as compared to the other diode models[15]. In this paper single diode model is sufficient and the practical model consisting of one diode in parallel to the current source, series resistance (R_s) and shunt resistance (R_{sh}) are connected as shown in Figure 3.

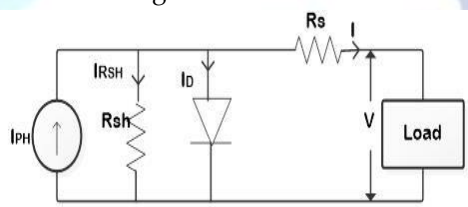

Fig 3: Practical single diode model

The diode current equation for the single diode model is shown below

$$I_D = I_{PH} - I_0\left[\exp\left(\frac{V+IR_s}{aV_T}\right) - 1\right] - \frac{V+IR_s}{R_{sh}} \quad (1)$$

Where I_D is the diode current, I_{PH} represents the photon current and I_O is the reverse saturation current.

$$I_O = I_{0.STC}\left[\frac{T_{STC}}{T}\right]^3 \exp\left[\frac{qE_g}{ak}\left(\frac{1}{T_{STC}} - \frac{1}{T}\right)\right] \quad (2)$$

Where E_g is energy gap and $I_{o.STC}$ is nominal saturation current at standard test conditions.

3.A HYBRID MODEL OF PSO AND I-GWO

The proposed algorithms PSO and I-GWO belong to bio-inspired algorithms which depend on the social behavior pattern. These algorithms can also be called nature-inspired algorithms.

A.PSO algorithm

The particle swarm optimization based on the population of candidate solutions is called particles[16]. In which each particle are surrounded for the best solution. Moreover, each particle having the memory for reserve the best location and is influenced by neighbour particles[17]. The displacement of each particle is shown in Figure 4.

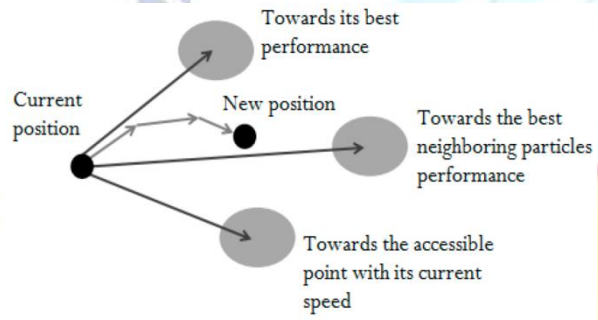

Fig 4: Displacement of a particle in PSO

In the PSO algorithm, the following three components inertia, cognitive, and social are mainly influenced. In which inertia particles move towards the current direction of movement, the particle moves the best location through cognitive component and social component reach the best location which is already reached by neighbour particles.

The basic formula for PSO corresponds to the velocity

$$v_i^{k+1} = wv_i^k + c_1 r_1 (P_{besti} - x_i^k) c_2 r_2 (G_{be\pm i} - x_i^k) \quad (3)$$

Where w is the inertia weight and c_1, c_2 are the acceleration constant.

The detailed operation can be followed by a PSO flowchart as shown in Figure 5.

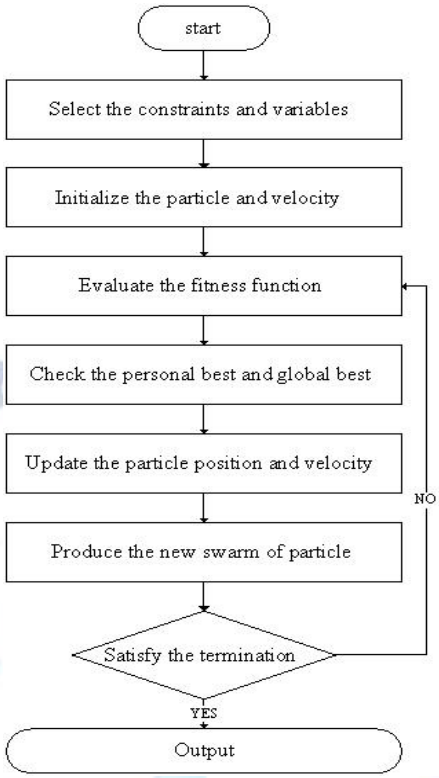

Fig 5: PSO flow chart

B. Improved Grey Wolf Optimization

In GWO, the four parameters α, β, δ, and ω can find the optimum solution however, it easily falls into local optimum due to lack of population diversity. To avoid this problem a novel new nature-inspired algorithm IGWO is considered in this paper[18]. It has three stages to operate like initializing, movement, and selecting and updating[19].

Initializing stage

In this stage, N wolves are randomly distributed in between the limits [l_i, u_j] through Equation 12.

$$X_{ij} = l_j + rand_j[0\ 1] \times (u_j - l_j),\ i \in [1, N],\ J \in [1,\ D] \quad (4)$$

Where the problem number of the dimensions is denoted by D and the total population is stored in a matrix with N number of rows and D number of columns. The fitness function calculated by $f(x_i(t))$.

Movement stage

Individual hunting's are added to group hunting to improve the behavior of the wolves hunting process is called dimension learning-based hunting (DLH)[20]. In DLH, the behavior of individual hunting learns by neighbor wolves for the updated position $x_i(t)$.

During this new learning, the updated position $x_i(t)$ is indicated by $x_{i\text{-}DLH}(t+1)$. For this individual hunting radius $R_i(t)$ is calculated using Euclidean distance as shown below. Moreover, it reduces premature convergence and balances the exploration and exploitation process.

$$R_i(t) = \|X_i(t) - X_{i-GWO}(T+1)\| \quad (5)$$

$$X_{i-DLH,d}(t+1) = X_{i,d}(t) + rand \times \left(X_{n,d}(t) - Xr,dt\right) \quad (6)$$

Selecting and updating stage

In this stage the best one is selected by comparing the fitness of these two $X_{i\text{-}GWO}(t+1)$ and $X_{i\text{-}DLH}(t+1)$ as shown below equation.

$$X_i(t+1) = \begin{cases} X_{i-GWO}(t+1) & if\ f(X_{i-GWO}) < f(X_{i-DLH}) \\ X_{i-DLH}(t+1) & otherwise \end{cases} \quad (7)$$

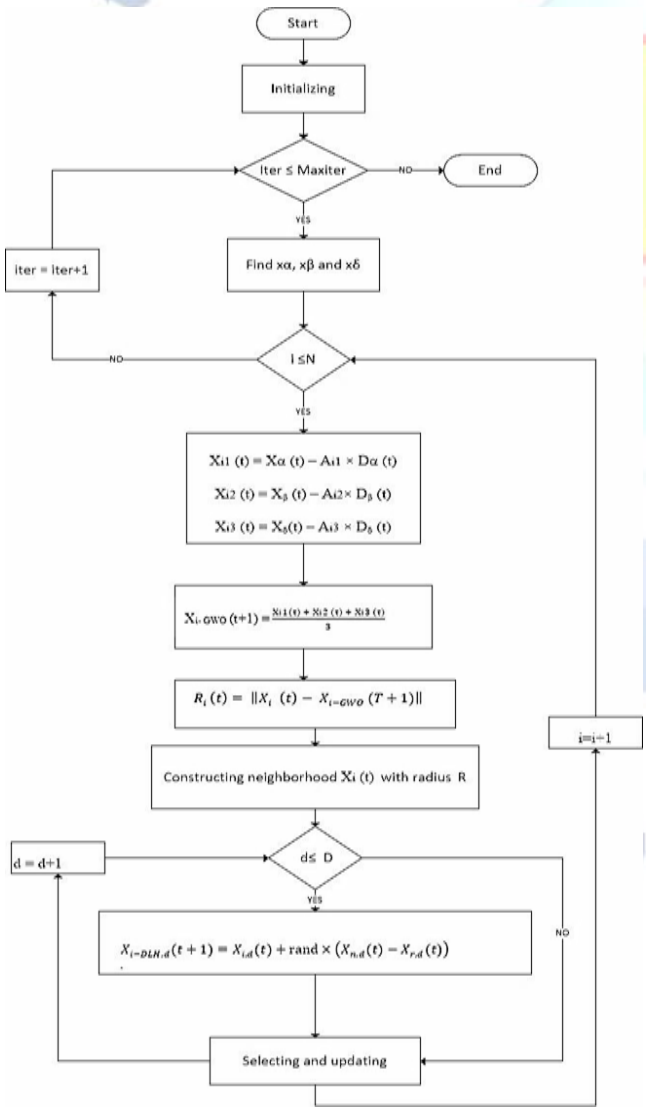

Fig 6: IGWO Flowchart

Eventually, the iteration value is increased by one for all individual values and the searching is continued until the predetermined value is reached. The total procedure can be described by the flow chart of I-GWO as shown in Figure 6.

In this paper hybrid models of PSO and I-GWO are applied to the PV system to overcome the challenges of slow convergence and efficiency problems.

4. RESULTS AND DISCUSSION

The proposed hybrid model was developed inMatlab/Simulink environment and applied to different cases moreover, it was comparedwith another algorithm of CSO.The performance of the PV system can be checked by considering three cases as shown in Table 1.

Table 1. Different cases for PV system

Type of case	Irradiation level W/m²
Case 1	Uniform irradiation 1000
Case 2	600, 600, 1000, 1000
Case 3	200, 300, 700, 1000

For the above cases, we are considered four PV modules that are connected in series and parallel.

Case 1: The uniform irradiation of 1000 W/m² is applied to each of four PV modules and check the performance through power, voltage, current and duty cycle w.r.t time as shown in Figure 7. From this figure, we can find the time to reach MPP and efficiency are 0.07 and 99.82% for the hybrid model of PSO- I GWO. The proposed algorithm performance is high as compared to CSO.

*Case 2:*In this case 600, 600, 1000, and 1000 W/m²are applied to the proposed PV system. The time is taken for MPP and efficiency of PSO - I GWO are 0.06 sec and 99.86% while 0.10 sec and 99.82% for CSO as shown in Figure 8

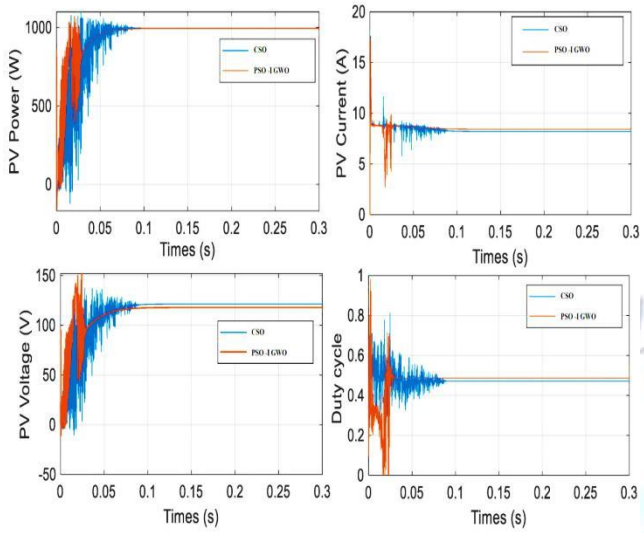

Fig 7: Uniform irradiation conditionfor PV characteristics under case 1.

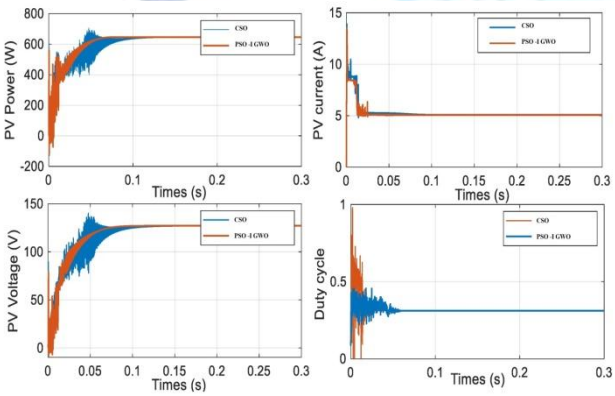

Fig 8: Partial shading conditions for case 2

Case 3:The irradiation levels for this case are 200, 300, 700, and 1000 W/m² are applied to the PV system. From Figure 9 we can observe the performance of the system are 0.04 sec for the time taken to MPP and efficiency is 98.84% for the proposed hybrid model.

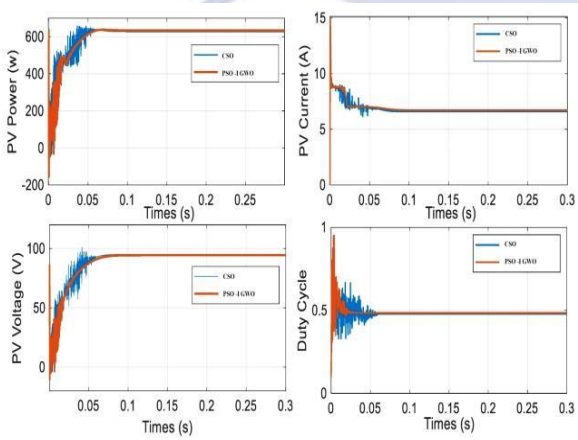

Fig 9: PV characteristics (power, voltage, current and duty cycle) for case 3

The comprehensive comparison for all the cases is shown in Table 2. This Table indicates the performance in terms of time to track MPP, extracted MPP, and efficiency.

Type of case	MPPT Techniques	Time to reach MPP (sec)	Extracted Power at MPP (W)	Efficiency (%)
Case1	PSO – I GWO	0.07	994.8	99.82
	CSO	0.09	993.2	99.76
Case2	PSO – I GWO	0.06	654.2	99.86
	CSO	0.10	653.8	99.82
Case3	PSO – I GWO	0.04	364.2	98.84
	CSO	0.10	358.2	98.46

The above table clearly describes both the algorithms of PSO –I GWO and CSO. Moreover, the proposed algorithm easily apply to practical applications also however it requires sensitive microprocessors for implementation.

5.CONCLUSION

This article provides the study and discussion of bio-inspired algorithms that belong to the metaheuristic algorithm i.e PSO- I GWO, CSO. The proposed PSO-I GWO algorithm offers superior performance in terms of time to reach MPP, extracted power at MPP and efficiency as compared to the CSO algorithm. Moreover, it is applied to different irradiation conditions for three cases. However, the bio-inspired algorithm is better for tracking MPP instead of conventional algorithms like perturb and observe (P&O), and incremental conductance (INC). Compare more metaheuristics algorithms and integrated them into the grid via an inverter for future work.

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