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Maximum Power Point Tracking Based on Remora Algorithm under PSC

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Abstract: Full or partial shading conditions have a significant impact on power generation capacity and can lead to losses. It is necessary to get the maximum power that they can generate by reducing energy losses as much as possible; the power-voltage characteristic curve of PVG under the PSC (Partial Shading Condition) leads to multips power peak, the GMPP (Global Maximum Power Point) represents the peak with the higest value, the others are called LMPPs (Local Maximum Power Points). To extract the maximum power from a set of PV panels, an electronic controller (DC-DC converter) is incorporated between the PVG and the load, its main role is the continuous monitoring at all times of the point of MPP.
This paper proposes a bio-inspired metaheuristic algorithm named the Remora Optimization Algorithm (ROA), used to get the GMPP of the PV panel under the PSC. In this paper, to show the feasibility of the ROA, we propose two configurations, first, we have five PV panels connected in series as a source and resistance as a load, this configuration will be tested under three scenarios (without shading, under weak or strong shading), second, we will replace DC load by AC load (pumping system), this configuration will be tested under strong partial shading.

Keywords: *Remora algorithm; PV generator; global MPP; local MPP; DC load; AC load.*

Mathematics Subject Classification (2010): 70Kxx, 93C10, 93-XX.

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1 Introduction

The continuously increasing power demand is met by both the conventional and renewable electric power generation sources [1]. Solar energy is the most abundant source of energy among renewable energies. Photovoltaic electricity comes from the direct transformation of part of the solar radiation into electrical energy. This energy conversion takes place through the so-called photovoltaic (PV) cell based on a physical phenomenon called the photovoltaic effect which consists of producing an electromotive force when the surface of this cell is exposed to light. The power delivered by a PVG strongly depends on the level of sunshine, the temperature of the cells, the shade and also the nature of the load supplied. The power characteristic curve of the PVG has a maximum power point (MPP) corresponding to a certain operating point of coordinates, VMPP for the voltage and IMPP for the current. Since the position of the MPP depends on the level of sunshine and the temperature of the cells, it is never constant over time. An MPPT (Maximum Power Point Tracker) converter must therefore be used to track these changes. Under the partial shading condition, several maximums appear in this P-V curve, a global maximum (GMPP) and one or more local maximum values (LMPPs). An MPPT converter (Boost converter) is a power conversion system equipped with an appropriate control algorithm to extract the maximum power that the PVG can provide.

The main disadvantage of the classical techniques, for example, the hill climbing algorithm, is that it remains trapped in the first local optimum encountered. Methods of this type do not present any form of diversification. An improvement of this algorithm consists in restarting several times, when a local optimum is found, from a new randomly generated solution. The classical technique P&O (Perturb and Observe) as the second example can not differentiate between these points and fail in tracking the global maximum point (GMPPT). Several researchers are currently working on bio-inspired techniques that belong to a group of soft computing techniques known as meta-heuristic algorithms for the best operation of the MPPT technique [2], [3],namely PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization), ABC (Artificial Bee Colony), etc. The main objective of this paper is to propose one of very promising meta-heuristics named Remora, this technique is used to get this point (GMPPT) to show the effectiveness of the proposed method, and as cited bellow, the power delivered by a photovoltaic generator (PVG) strongly depends on the shade and also the nature of the load supplied. For this reason, this paper proposes five PV panels connected to DC load under three scenarios of Partial Shading Conditions (without shading, weak or strong shading). Then we will replace resistance (DC load) by a pumping system (AC load) by using the ROA with just one strong shading scenario.

2 MPPT Based on Remora Algorithm

2.1 Remora optimization principle

The ROA was recently proposed by Heming Jia et al. [4] in 2021. This algorithm is inspired by the intelligent behavior of the remora and random host replacement of the remora, see Figure 1c.

The remora is a fish that lives in warm waters. It is also known as a suckerfish (whalesucker, sharp-sucker and disc fish) because it gets into the habit of sticking itself using a natural suction cup to the skin of sharks in particular (as shown in Figure 1 a)). The remora feeds on the parasites and bacteria found there (as shown in Figure 1 b)). The sharks are thus preserved from various skin infections (their body is kept clean and safe from parasites – a service for which they are even ready to defend their remoras against predators). According to its behavior, the remora will follow algorithms for two hosts, the humpback whale and swordfish:

- The whale optimization algorithm (WOA),
- The swordfish optimization algorithm (SFA).

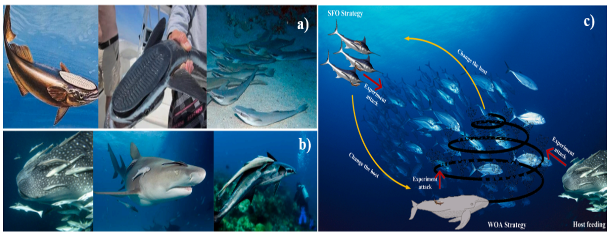

Figure 1: a) The individual remora, b) Remora parasitizes on different hosts, c) The different states of the remora [4].

2.1.1 Initialization

In the proposed ROA, it is assumed that the candidate solution is the remora. Initialize the population location and memory location X_{pre}, initialize the optimal solution X_{best} and corresponding optimal fitness $f(X_{best})$.

2.1.2 Free travel (Exploration)

- *SFO Strategy.*
The remora is stuck to the sworfish, the formula of its location update was improved and got the following equation:

$$X(t+1) = X_{best}(t) + rand.(\frac{X_{best} + X_{rand}}{2}) - X_{rand}. \tag{1}$$

- *Experience attack.*
To know whether it is necessary to change the host or not, the remora must continuously take small steps around the host, this behavior is modeled by the following equation:

$$X_{att} = X_i(t) + randn.(X_i(t) - X_{pre}), \tag{2}$$

X_{pre} represents the previous position, X_{att} represents the tentative position. If the cost function value obtained by the attempted solution is smaller than the current solution

$$f(X_i(t)) > f(X_{att}(t)), \tag{3}$$

the remora then chooses a different feeding method for local optimization shown in the next section. However, if it is not the case, see Eq.(4), the remora returns back to the host selection,

$$f(X_i(t)) < f(X_{att}(t)). \tag{4}$$

2.1.3 Eat thoughtfully (Exploitation)

- *WOA Strategy.*
To update the remora position in the reseach space for the WOA strategy, we use the following equations:

$$X_i(t+1) = D * \exp(\alpha) * cos(2\pi\alpha) + X_i(t). \tag{5}$$

$$D = |X_{best}(t) - X(i)|, \tag{6}$$

$$b = -(\frac{1 + Current_{iteration}}{Max_T}), \tag{7}$$

$$\alpha = rand * (b-1) + 1, \tag{8}$$

D represents the distance between the best candidate and the remora, α is a random number in [-1, 1], and b is a linear decrease from (-1 to -2).
- *Host Feeding.*
The solution space can be minimized to the position space of the host. The movement of the remora on or around the host can be considered as small steps, which can be presented mathematically as follows:

$$X_i(t) = X_i(t) + A, \tag{9}$$

$$A = B * (X_i(t) - C * X_{best}, \tag{10}$$

$$B = 2 * V * rand - V, \tag{11}$$

$$V = 2 * (1 - \frac{1}{Max_{it}}). \tag{12}$$

2.2 Module

2.2.1 Proposed structure

The power chain of a PVG, where the load (a resistance or pumping system) is supplied by a generator through a static converter controlled by an MPPT, can be represented as shown in Figure 2. The MPPT command varies the duty cycle of the converter so that the power supplied by the PVG is the P_{MAX} available at its terminals. The MPPT algorithm can be more or less complicated to find the PPM, but in general, it is based on the variation of the duty cycle of the static converter until it is placed on the PPM. When we design a photovoltaic installation, we must ensure the electrical protection of this installation in order to increase its lifespan, in particular by avoiding destructive breakdowns linked to the association of the cells and their operation in the shading event. For this, two types of protection are conventionally used in current installations: protection in the case of the parallel connection of PV modules to avoid negative currents in the PVG (anti-return diode) and protection during the series connection of PV modules to avoid losing the entire chain (bypass diode) and avoid hot spots.

In this work, we propose, on one hand, DC load as a resistance and five panels as a source, this configuration is tested under three patterns, the first under zero shading (1000 W/m^2), the second under weak partial shading (1000-1000-500-1000-1000W/m^2) and the third under strong shading (400-1000-200-800-1000W/m^2).

On the other hand, we replace DC load by AC load. In this work, the pumping system (AC load) is containing the induction motor related to the centrifugal pump,

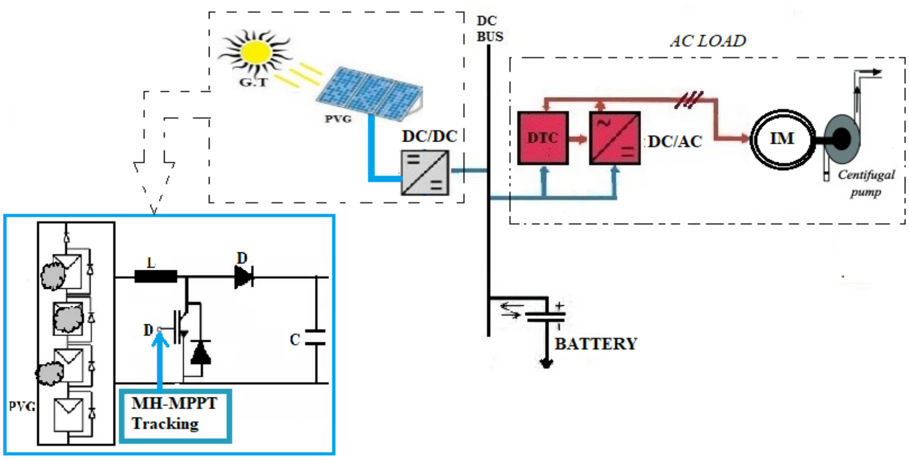

Figure 2: Proposed System with Boost Converter DC/DC.

the inverter (as shown in Figure 2) is controlled by direct torque control, this system is related to the battery. The excellent dynamic torque-control capabilities of traditional DTC are well-known in the literature for the permanent magnet synchronous motors, induction motor and for other motor types as well [5]. The first application of DTC to the asynchronous machine appeared in 1985 and was proposed by Takahachi and Depenbrock [6], [7]. The stator flux vector can be estimated using the measured current and voltage vectors [8], [9], [10]. We calculate the current and voltage in the axes $[\alpha, \beta]$ by using the Concordia transformation, for more details about this type of control, see [8], [9]. To get the needed value of DC voltage to feed the induction motor (514V), we use in this case twelve panels in series, these systems are tested under the PSC with strong shading (the first three panels under 900 W/m^2, the second three panels under 500 W/m^2, the third three panels under 200 W/m^2 and the fourth three panels are without shading).

2.2.2 Proposed ROA-MPPT

The maximum power point tracking by the ROA method is used to get the optimum power, the input of MPPT block is represented by the power (Vpv*Ipv) and the output by the duty cycle of DC-DC converter. Figure 3 represents the flowchart of the ROA used in this work with the initial position 0.1, 0.3, 0.5, 0.7, 0.9, the population number 50 and the maximum number of iterations 300.

3 Digital Simulation

The pumping system is built using MATLAB/SIMULINK. In this simulation, the induction machine parameters and PV panel parameters are listed in Tables of Reference [11].

4 Discussion of Results

In the first part, Figure 4 represents the Duty Cycle and PV Power responses (of the output of the DC-DC converter connected to the resistance load). It can be noticed

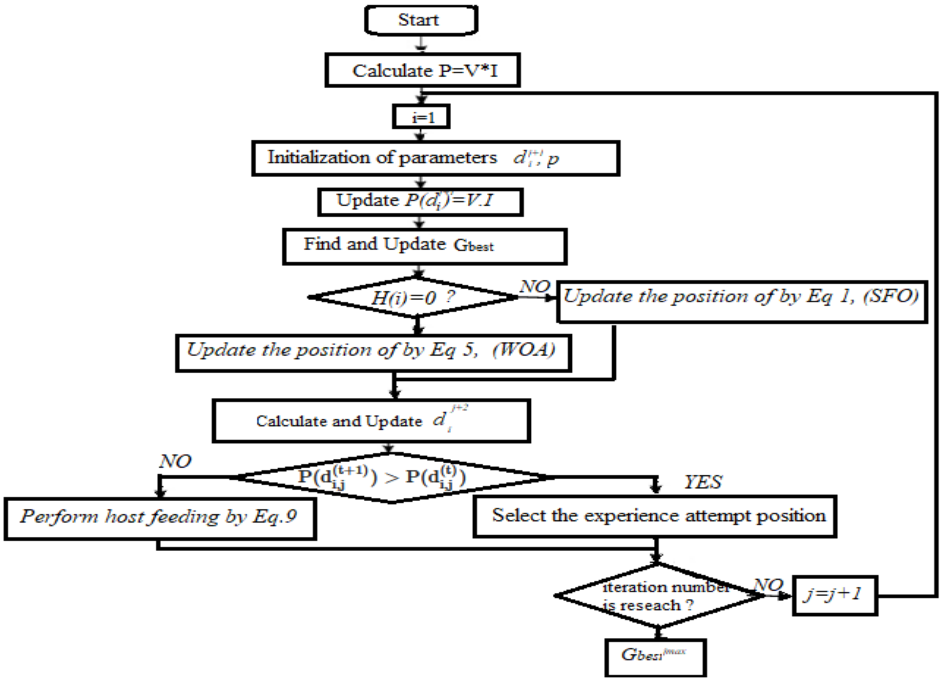

Figure 3: Flowchart of ROA.

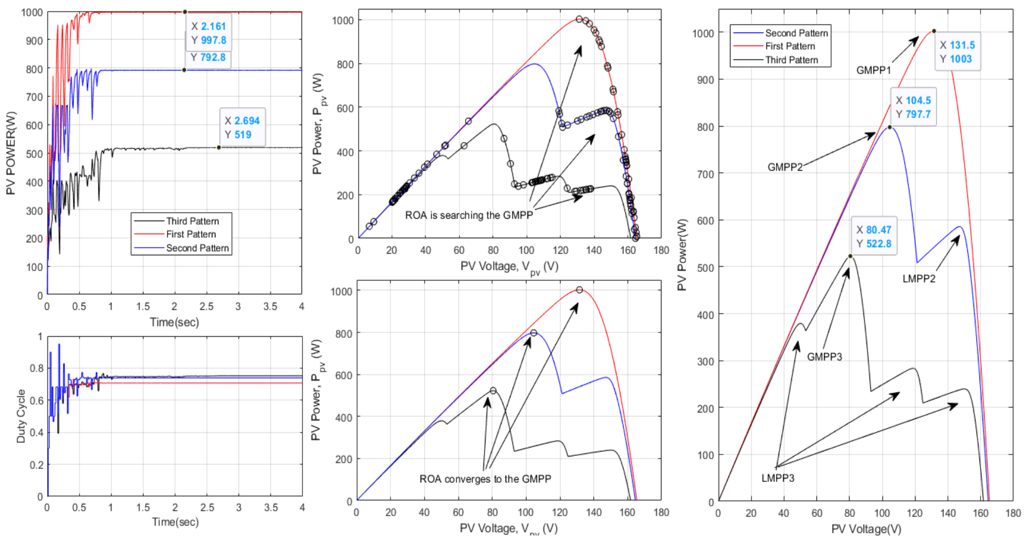

Figure 4: Duty Cycle and PV power responses using PV connected to the resistance load and based on the MPPT-ROA method under three scenarios of PSC(First: Without Shading, Second: Weak Shading, Third: Strong Shading).

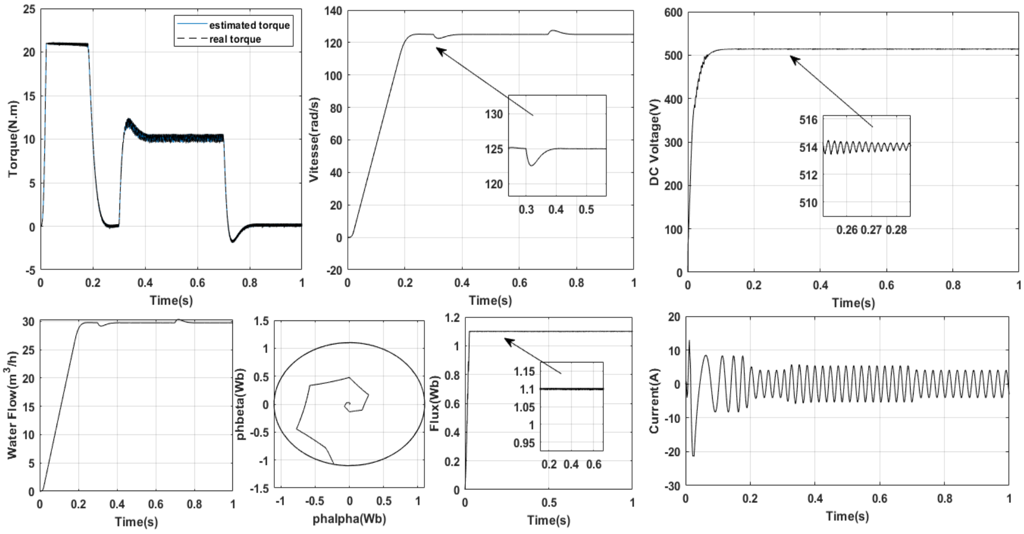

Figure 5: Current, Flow of water, Flux, Torque and Rotor Speed responses of a hybrid (PV-battery-IM-Pump) system based on the Remora method under the PSC.

that the proposed algorithm converges to the GMPP in three scenarios as shown in the same figure, the ROA (with 997.8W) converges to GMMP1 (1003W), the ROA (with 792.8W) converges to GMMP2 (797.7W) and the ROA (with 519W) converges to GMMP3 (522.8W).

In the second part, the pumping system is simulated with a constant load torque (10N.m) applied between 0.3sec and 0.7 sec under strong shading as cited above (at the end of the third paragraph of the proposed structure), and a simulation was run in a closed loop as shown in Figure 5, where it can be observed that the DC voltage, flux and rotor speed track their references (Vdc*=514V, Flux*=1.1Wb, w*=125 rad/ sec).

5 Conclusion

This paper has proposed the ROA to get MPPT under the partial shading condition, according to the results, the proposed method offers a better performance with both DC load and AC load and it can get nearly the GMPP of the proposed configuration cases, under the PSC or without shading regardless of the location of the global MPP.

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