July – August 2020
ISSN: 0193-4120 Page No. 3200 - 3206

A Compendium of Nature Inspired MPPT Algorithm for Partial Shading in PV Systems

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Article Info
Volume 83
Page Number: 3200 - 3206
Publication Issue:
July - August 2020

Article History
Article Received*: 06 June 2020*
Revised*: 29 June 2020*
Accepted*: 14 July 2020*
Publication*: 25 July 2020*

Abstract: Electricity has a significant role to play in economy of country. Increasing populations and increasing industrial dependences of electricity are ultimatum demanding various renewable energy sources. Photovoltaic systems (PV) come up to gratify these electricity needs. PV system generates power for irradiance of the sun. Irradiance is intermittent as per the atmospheric conditions and thus PV system has fitful output. In PV system Maximum output is traced by Maximum Power Point Tracking (MPPT) algorithms as per atmospheric conditions. PV panels are coupled to form a PV array for meeting the demand of required voltage and current of the system. In PV array partial shading condition is one more challenge for tracking MPP (Maximum Power Point). Conventional MMPT algorithms expeditiously track the MPP for dynamic atmospheric condition but fail in case of partial shading. Partial shading creates multiple MPPs and it become more tedious to track MPP. Many nature inspired algorithm are put through under partial shading condition. Here a compendium of nature inspired MPPT algorithms for partial shading is done

Keywords: Global MPP, Photovoltaic system, Partial shading.

I. Introduction

In present circumstances of global warming, electricity plays a major role in the economic growth of a country. The non-renewable energy sources are getting exhausted and simultaneously the demand for the electricity is increasing rapidly. To meet this ever increasing demand renewable energy sources are accommodated for electricity generation. Renewable energy sources are available in great quantity also climate-friendly, non-polluting and ecological. Photovoltaic (PV) system is a common renewable energy source functioning on photovoltaic effect [1][2]. Sun irradiance fall on to the solar cell and cell generate clean and pollution free electricity. Solar cells are connected in series to sum up voltage and connected in parallel to sum up current and connection of solar cells made a PV module. Modules are connected in series and parallel as per the current and voltage requirements. Connection of PV modules will make a PV array [3]. PV system composed of PV array, DC to DC converter, and load and MPPT controller as shown in figure 1. As per the erratic atmospheric conditions, maximum power point changes and function of MPPT algorithm is to track that dynamic MPP. The Maximum Power Point Tracking (MPPT) algorithm works on the basis of delivering maximum power to load by means of matching the source impedance with the load impedance [4] [5]. In between the solar array

July – August 2020
ISSN: 0193-4120 Page No. 3200 - 3206

and load, there are dc to dc converters with pulse width modulation to achieve this impedance matching [6] [7].

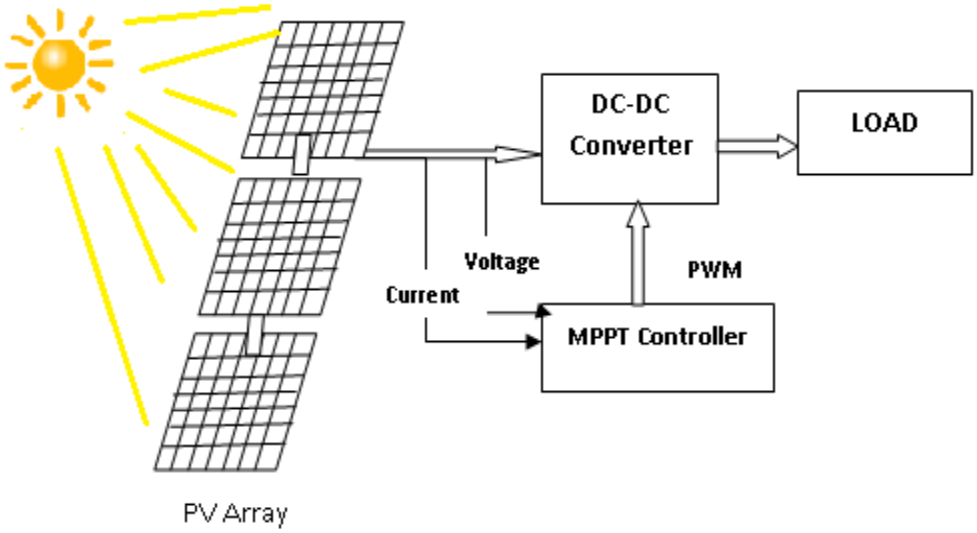

FIGURE 1.Photovoltaic system

Unequal irradiance level on PV modules creates partial shading as shown in figure 2. The Partially shaded Condition (PSC) has significant impact on the power output PV system. Under Partial shading PV system has multiple MPPs, out of that MPPs one MPP has maximum power called Global MPP [8] [9]. Position of MPPs is dynamic with respect to irradiance and temperature [my paper] this make more difficult to MPPT algorithm for tracking global MPP.

Several algorithms are being developed in to track the maximum power point among them the Perturb and Observe (P&O) method is most successful as well as simple as the controller here works on the principle of perturbing the PV array output voltage [10]. P&O method has the advantage of reducing the computation time and easy to implement [11]. Apart from this, P&O method has the drawback of high power loss and conversion efficiency. In case of partial shading scenario, P&O algorithm gets trapped at local MPP. Various approaches are there in literature to track global MPP. Here natures inspired approaches for maximum power point tracking under shading are discussed.

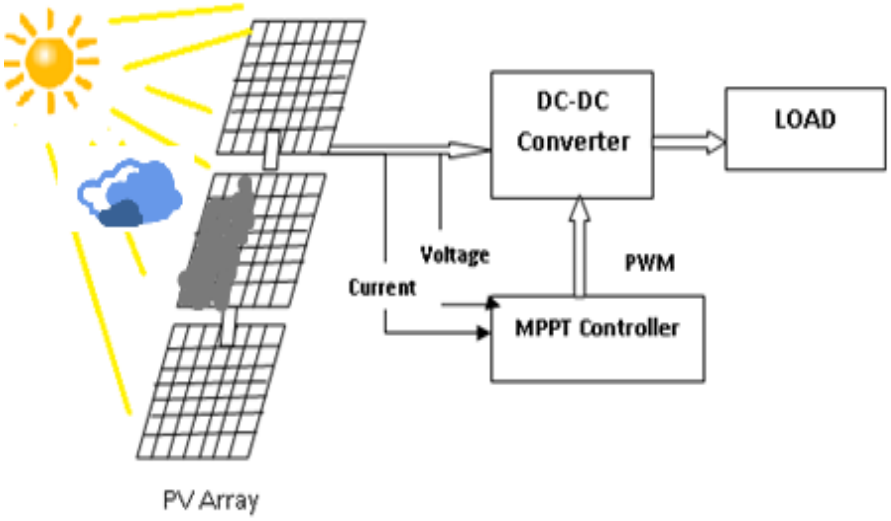

FIGURE 2.Photovoltaic system under Partial Shading

July – August 2020
ISSN: 0193-4120 Page No. 3200 - 3206

Diverse Biological systems and their way of operation are helpful to find the solutions to various problems and thus algorithms inspired with this are termed as nature inspired of or bio inspired algorithms. A variety of difficult optimization problems are solved by nature inspired algorithms and thus it is more accepted in various domains. Swarm intelligence is a one class of natured inspired algorithms and it is inspired from communal behavior of animal societies and insects [12]. Many nature inspired algorithms are applied to track dynamic global MPP in case of partial shading condition.

II. Nature Inspired MPPT Algorithms

1. Grey Wolf Optimization (GWO)

Grey wolves are counted in apex predators, that mean they are at the top of the food chain. Generally Gary wolves live in group of 5 to 12 averagely. Gary wolves strictly follow hierarchy. It has four types of wolves, like alpha, beta, delta and omega. Alphas is at top with highest priority, second is beta, third is delta and last is omega. Hunting phases are chasing and tracking the prey, encircling prey and then attacking prey [13].

Modified grey wolf optimization (GWO) for maximum power point tracking (MPPT) design technique referred as proposed GWO-MPPT algorithm in photovoltaic (PV) system [14]. This model helped in determining the global peak (GP) during partial shading conditions (PSCs). Here, GWO is merged with direct duty-cycle control with the decreasing the steady-state oscillations as well as power loss due to oscillations. This proposed model was compared with the existing techniques like perturb and observe (P&O) -MPPT improved PSO (IPSO) -MPPT and the resultant of GWO-MPPT algorithm exhibited lower tracking efficiency and steady-state oscillation.

2. Memetic Salp Swarm Algorithm (MSSA)

Salp are marine animals and they belongs to Salpidae family. They have transparent barrel shaped body. They contract band of muscles which ring their body and then they move in the water. In ocean salps form a salp chain called as blastozooids. They are always attached together when they are swimming and feeding so that each individual can grow in size. Memetic algorithm was proposed by Moscato in [15].

In [16] a novel optimization method is formulated and it is referred as memetic salp swarm algorithm (MSSA). It was developed by extending the conventional original salp swarm algorithm (SSA) having multiple independent salp chains. In between different salp chains, the global coordination was achieved using virtual population based regroup operation that in turn enhanced the convergence stability. MSSA helped in generating the global maximum power in photovoltaic (PV) systems in partial shading condition (PSC) and fast time-varying weather conditions

3. Artificial Bee Colony (ABC)

Honey bee colonies have very intelligent foraging activities. Artificial Bee colony (ABC) algorithm is inspired with foraging method of honey bees. There are three types of Bees first type is employed Bees then second type is onlookers Bees and third type is scouts Bees. Task of Employee bees is to search for food from sources which are in their memory. When employee bees come back from sources, they dance on dancing area. Onlookers bees observe the dance of employee bees and based on deices the best source of food. Some employed bees, which discard their food sources and look for new ones are the scout bees. Thus the task of scout bees is to discover new sources [17].

In. [18] a modified P&O MPPT by integrating both Artificial Bee Colony (ABC) algorithm and P&O algorithm under PSC is developed. The global MPP was tracked by ABC and local MPP was tracked by P&O algorithm. The optimum duty cycle is generated for the boost converter by combining local search ability of P&O as well as the global search ability of ABC.

July – August 2020
ISSN: 0193-4120 Page No. 3200 - 3206

4. Whale Optimization with Differential Evolution (WODE) Algorithm

Whale optimization algorithms are inspired from humpback whale hunting method. Size of an adult humpback whale is near about size of a school bus. krill and small fish herds are favorite prey of Humpback whale. Particular hunting method of Humpback whales is called as bubble net feeding method. It has three stages of hunting. First stage is search for prey. In this stage location of prey is recognized by whales. Second stage is Encircling prey. In this stage whale will encircle Prey with bubbles. Prey fish will get scared and will not cross the bubbles. Third stage is bubble-net feeding. In this stage whale will start shrinking the circle or it will create spiral bubble pattern and then attach on prey [19].

Combination of Differential equation (DE) and Whale optimization is done in [20] and it is termed as Whale optimization with Differential equation (WODE). WO method is best for finding global best and new best start point in every iteration is given by DE. The performance of the WO was enhanced by differential evolution (DE). Whale optimization with differential evolution (WODE) technique in photovoltaic (PV) system for the maximum power point tracking is proffered in [20]. The tracking of MPP was accomplished both in the dynamic as well as the steady-state conditions and within few steps the global best peak position was tracked without any oscillation. The Solar PV module was constructed using a single diode model.

5. BAT Algorithm (BA)

BAT uses echo in locating their foods and Bat algorithm inspired this feature. it is a population based optimization algorithm. [21] small bats are called microbats. These microbats find their primacy food insects using echo. At first bat overflies the area with sending ultrasonic waves of certain amplitude and density. Then bat receives its own signal in feedback by echolocation. When it got low intensity and strong rate signal is received, it indicates pray is detected. In bat algorithm N microbats are taken then each of them assign with velocity, position and varying loudness as per different pulses. Fitness function is designed for loudness. Random combination. The current global best location is decided by comparing with all N bats at each iteration. In [22] BAT algorithm is applied for tracking global MPP in case of partial shading. In this direct duty cycle control method is used. Optimization variable is defined in terms of PWM duty cycle.

6. Cuckoo Search (CS) Algorithm

Cuckoo birds are famous for their sweet sound and also popular for their aggressive reproduction tactic. Some species of cuckoos lays eggs in common nest and they try to remove other bird's eggs for increasing hatching probability of their own eggs. Some species are having brood parasitism of three different ways like cooperative breeding, nest takeover and intra specific brood parasitism. Cuckoo search has three basic steps [23]

- In randomly selected nest cuckoo will lay one egg at a one time
- The nest having high quality eggs will go to nest generation
- Available host nests are fixed and a host can notice a foreign egg with a probability

In [24] CS is applied for GMPP tracing in case of partial shading of PV system. Duty cycle of DC to DC converter is termed as number of cuckoos. In this Lévy distribution is used. Best duty cycle is choose for maximum output power.

III. Discussion on Nature Inspired MPPT Algorithms

In future, there is a requirement to have an optimal MPPT tracking technique for partial shading condition in photovoltaic system, such that it essential to know about have a look on the existing systems. In GWO-MPPT algorithm [14], steady-state oscillations are not available and hence the efficiency of tracking is high. On the other hand, it suffers from the issues like slow

July – August 2020
ISSN: 0193-4120 Page No. 3200 - 3206

convergence and high cost. MSSA has the advantages of high reliability and Simple and easy to use [16]. It has the disadvantages like high undesirable disturbance and high delay. In ABC-P&O [18], the noise is rejected and has Low peak overshoot. Apart from this, it suffers from the shortcoming like low energy extraction and inaccurate tracking of global MPPT. In WODE [20], the convergence and robust is high. It has the drawback of high computational complexity. The implementation cost is low and the stability of the model is high in GMPP [24]. In contrast to this, the convergence speed is low. The higher conversion rate is achieved in BA [22]. But, here the accuracy is low. Thus, before designing an innovative system for MPPT tracking under partial shading condition in photovoltaic system, all these challenges can be kept in mind and they can be overridden. Table 1 depicts the features and challenges of the existing MPPT tracking techniques under partial shading condition in photovoltaic system.

TABLE 1. Features and challenges of MPPT algorithms

MPPT Algorithm	Features	Challenges
GWO	Absence of steady-state oscillations High tracking efficiency	High cost Slow convergence
MSSA	High reliability Simple and easy to use	Unable suppress undesirable disturbance caused due to measurement
ABC-P&O	No noise Low peak overshoot	GMPP is not accurate Low energy extraction
WODE	High convergence speed Highly robust	High computational complexity
CS	Low implementation cost High stability	Low convergence speed
BA	Higher Conversion Rate	Low Accuracy

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July – August 2020
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