Levy_MPPT_rev2

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A Maximum Power Point Tracking Based on Levy Flight Optimization

ABSTRACT

This paper proposes a Levy flight global maximum power point tracking for solar photovoltaic (PV) system under partial shading conditions. The proposed method comes with merits such as simplicity, fast response and free of oscillation. This algorithm uses random search over the searching space and compares the previous and current states to obtain the best solution. For evaluation and comparative analysis, performance of the proposed method is also measured against Perturb and Observe (P&O) and Particle Swarm Optimization (PSO). All three algorithms are simulated in MATLAB/Simulink environment. Simulation results are satisfactory over the conducted tests under uniform and non-uniform irradiance. The proposed algorithm is able to track global maximum power point (GMPP) under partial shading conditions with fast tracking time and zero ripple at steady-state.

1. INTRODUCTION

Renewable energy is seen as a promising alternative in generating electrical power [1]. Solar is one of the potential candidates in power generation due to availability of the sun [2] and cleanliness [3]. Moreover, the operational and maintenance costs of solar photovoltaic (PV) are low compared to other renewable energy resources [4]. This emerging technology has gained a lot of interests from researchers in the area of grid integration, control and optimization [5]. However, this technology is still limited to its efficiency [6]. Efficiency of PV system is still low, less than 44% [3,7]. Additionally, non-linear parameters such as temperature and irradiance affect characteristics of current and voltage curves of the solar PV [1]. Thus, maximum power point tracking (MPPT) controllers are needed for harnessing the optimum power from PV modules [23].

Various MPPT methods have been proposed to obtain optimum power from solar PV. For instance, two MPPT methods are popularly used such as Perturbation and Observation (P&O) [9] and Incremental Conductance (IncCond) [10,11]. These methods work well under uniform irradiance. However, they faced some constraints under non-uniform irradiances across PV modules [12]. These conventional MPPT algorithms fail to distinguish in between global and local maxima, causimg the system to be trapped at local maxima power point [13].

Practically, connected PV arrays can be affected by environmental changes such as cloud, leaves and dust [14,15]. This phenomenon is inevitable and unpredictable which cause partial shading condition (PSC) to occur [16]. Soft computing methods are considered as the most potent candidates to mitigate the concern of non-uniform irradiance [17]. Nowadays, soft computing methods such as artificial intelligent network (ANN) [15,16], Fuzzy Logic Control (FLC) [16,18,19] and Particle Swarm Optimization (PSO) are most preferable among researchers [22]. PSO algorithm is one of the most leading MPPT techniques used to detect global maximum power point (GMPP) under PSC [2]. This method comes with great advantages due to its good performance, simplicity, easy to implement and less complex mathematical structure [16]. Conventional PSO algorithm works well under PSC. However, due to large searching area, this method suffers longer computational time [16] and steady-state oscillation. In addition, this algorithm also suffers from intermittent tracking since its requires an appropriate initial value to be able to detect certain changes of irradiance condition [23].

To solve the aforementioned problems, a Levy flight algorithm is proposed. The main feature of the proposed method is the absence of oscillation at steady-state condition, no specific initial value is required and fast computing time. This algorithm comes with ability to track extreme environmental condition such as PSC. Compared to other conventional techniques, Levy flight algorithm has fast tracking speed and is simple to be implemented.

The rest of this paper is organized as follows. Section 2, presents on PSC. Section 3, introduces the theoretical framework of Levy flight optimization. Section 4, discusses the simulation results. Finally, conclusion is presented in Section 5.

2. PARTIAL SHADING CONDITIONS

Typically under PSC, different photon current, I_{ph} is generated in conjunction with different irradiances penetrated at PV array. This phenomenon indirectly generates a hot spot in the shaded modules and might damage the modules. The solution to this aforementioned problem is done by introducing bypass diode which is connected in parallel to each module as shown in Figure 1. The presence of bypass diode in each module creates multiple peaks of P-V and I-V curves as shown in Figure 2 [6].

Figure 2. (a) P-V and (b) I-V curves under uniform condition (UIC) and PSC

PV module BPSX150 with specifications as shown in Table 1 is used to generate the pattern of partial shading conditions in this paper. The specifications are obtained under standard test condition (STC). There are three different patterns of partial shading conditions are generated as shown in Table 2. The same patterns are generated in MATLAB/Simulink for four PV modules BPSX150 connected in series under partial shading condition.

3. LEVY FLIGHT OPTIMIZATION

Paul Levy is a French mathematician who introduced Levy flight distribution in 1937 [24]. Levy flight is considered as a breakthrough over traditional Brownian motion by considering distribution for current and next jump using same mathematical form. Levy motion is diverged in motion. Nowadays, this motion is being widely explored in nature since Levy distribution can be applied in the most of analyses such as in physics, biology, finance and economics.

The behavior of animal searching for food is being observed. It is noticed that the animal behavior looking for food is classified as random or quasi-random manner. The decision of animal in next move for food search is based on current position and transition probability. Thus, this behavior can be modeled mathematically. It is observed that most animal and insects exhibit Levy flight behavior. Subsequently, this behavior is applied in optimization and optimal search.

Power law is used to mathematically model the distribution of Levy flight [24]. Random walk in Levy distribution is comprised of length, l drawn from power law function as in equation (4) [24],[25]. where l denotes by flight length and β is variance, $1<\beta< 3$.

A simplified Levy flight is expressed in equation (5).
In here, x^{t+1} is the next state, x^t is current state, α is step size and $\otimes$ is product of entrywise multiplications.
A simplified step size, s sample generation is expressed in equation (6).
where k denotes as Levy multiplying coefficient, β is 1.5 , while u and υ are from normal distribution. Given equation u as expressed in equation (7).
while σ_u is expressed in (8).

Given equation υ denotes by expression (9).
While σ_υ is expressed with equation (10).

Figure 3(a) shows the flowchart of Levy flight optimization (LFO). In this algorithm, a set of particles is chosen. One best-known location is selected as starting. A whole new generation is produced with Levy flight motion with random distribution. The new generation is evaluated with best-known location. This process is continuously executed until one promising point is attained which is the best solution.

The same basic idea of LFO as discussed previously is applied to track maximum power point of PV module. A flowchart of LFO GMPP is as shown in Figure 3(b). A full PV system is shown in Figure 4. In here, this algorithm is functioned to extract global maximum power by comparing with existing power points and identifying photovoltaic power which is needed to regulate the duty cycle of boost converter.

Levy flight algorithm is applied in solar power system to trace global maximum power point under partial shading conditions. The main program starts by sensing the voltage and current of PV module as shown in the flowchart Figure 3 (b). Each of the duty cycle is randomly distributed among the search space. The fitness of each duty cycle is evaluated and the best duty cycle, pbest is found. Then, for each duty cycle position is updated based on random probability. The position of duty cycle is updated based on equation (5). If the current duty cycle is more than current pbest, then current duty cycle becomes pbest. By employing Levy flight in global power search, it enhances the search capability to perform global exploration throughout the search space. In Levy flight, the main key factor in searching is determined by β parameter. In here, β value of 1.5 is chosen.

4. SIMULATION RESULTS

In this study, a solar power system is modeled in MATLAB/Simulink to verify the effectiveness of the proposed algorithm as depicted in Figure 5. It shows a dc supply system powered by PV as input source connected to a boost converter and dc load. In this simulation, the PV model is represented as a current source parallel with a single diode, a parallel shunt resistor and a series resistor.

Boost converter having specifications in Table 3 is designed and modeled in MATLAB/Simulink. The boost converter is controlled by a power MOSFET. PWM switching is varied based on duty cycle. A constant load of 32 Ω is applied. The duty cycle is adjusted by the proposed algorithm to get global maximum power point. Firstly, the proposed algorithm is tested under uniform irradiance and later under non-uniform irradiances.

Figure 6 shows results of PV power, voltage and current under varying irradiances. Based on the results, all algorithms are able to track maximum power point under changing irradiances. However, P&O algorithm suffers from losses at certain irradiance. The oscillations occur at certain irradiance contributed to power losses. As can be seen, P&O algorithm has oscillation, slower time response and unstable. PSO algorithm shows low oscillation, fast respond time and stable. However, the proposed LFO shows the best performance as compared to both P&O and PSO since LFO has the lowest oscillation, fastest respond time and the most stable.

Next, the performance of the algorithm is tested under partial shading conditions. Three different patterns of partial shading conditions with different irradiances are penetrated at four series PV modules. It is well known that P&O algorithm has tendency to trap at local maxima during its search. Thus, this algorithm may fail to detect global maxima under partial shading conditions. Figure 7 shows results for PSO and LFO algorithms. It can be clearly observed that both algorithms are able to detect global maximum power point. In terms of oscillation, both have low steady state oscillation. Further analysis is done in terms of respond time, it shows that LFO has faster tracking time compared to PSO, and both algorithms are stable.

Partial shading condition 2 is tested where maximum power of each peak is closed to each other. The testing is done to gauge the intelligence of both algorithms in distinguishing between very closely peaks

to each others. Figure 8 shows simulation results under PSC 2 for power, voltage and current. Based on the simulation results, both algorithms are able to distinguish global maximum power peak even though the peaks are closed to one another. Both algorithms also produce low steady-state oscillation and stable. In terms of respond time, it shows that LFO has faster respond time compared to PSO.

Similarly, the test is repeated for PSC 3. In this condition, the global peak is at the right side of the curve. Both algorithms are tested under this condition. Based on results shown in Figure 9, PSO algorithm can detect the global maximum power point with some changes on the initial value of duty cycle being made. However, for LFO, the same initial values are used and this algorithm is able to detect global maximum power point. Both have low steady-state oscillation. However, in terms of respond time, LFO has faster respond time compared with PSO, and both algorithms yield stable results.

Table 4 provides a comparison between conventional P&O, PSO and LFO methods in terms of oscillation, respond time and stability.

5. CONCLUSION

In this paper, LFO algorithm has been proposed. In this algorithm the search was randomly executed in between the searching space, and no specific initial value was required. In this study, a standalone PV system with boost converter was modeled in MATLAB/Simulink to verify the effectiveness and the performance of the algorithm. In here, the proposed algorithm was tested under two test conditions which were under uniform and non-uniform irradiances. The algorithm was compared with conventional P&O and PSO. Further studies were carried out under non-uniform conditions with three different patterns of PSC. Based on the results, it can be noted that LFO algorithm is able to work well under uniform and non-uniform irradiances. In addition, this algorithm has low oscillation, fast respond time and stable. It is expected in future work, this algorithm will be deployed in the hardware and experiment to further validate its performance and effectiveness.

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