



Technical Review of Partial Shading Detection and Global Maximum Power Point Tracking for Photovoltaic Systems Operated Under Shading Condition

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ABSTRACT

Photovoltaic (PV) technology is fast becoming prominent alternative source of energy due to its renewability and environmental friendliness. PV operations rely mainly on solar irradiation which determines the quantity of generated power. Partial Shading condition which is caused mostly by environmental factors such as passing cloud hinders PV from receiving optimum irradiation and consequent reduction in the power generated from the PV. Maximum Power Point Tracking (MPPT) has been studied and developed to obtain optimum power that PV could generate. This paper reviewed techniques of generating maximum power from a PV technology under shading conditions.

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INTRODUCTION

Photovoltaic technology (PV) is an essential technology that has the capacity of converting solar irradiance into electrical energy via a PV panel (Islam *et al.*, 2018). Solar energy is unquestionably one of the most promising sources of energy because it is readily available throughout the world and it is free of pollution (Alik & Jusoh, 2017). However, the efficiency of solar energy is mostly dependent on the level of solar irradiation and the temperature of the PV (Ellabban *et al.*, 2014). It is practically not feasible for solar PV to have uniform irradiation always, because the passing clouds, buildings, other high structures occasionally cover it totally or partially (Alik & Jusoh, 2017). Whenever a part of solar PV collects little irradiation from the sun, the unshaded cells will force the shaded cells to produce higher current than their short-circuit current and causes the shaded cells to function at a negative voltage (Alik & Jusoh, 2017). The shaded cells will eventually absorb power instead of producing power to the system. Moreover, there is an increase in the temperature of the shaded cells as it gives out power and heat, which eventually leads to thermal stress and complete failure of the PV cells (Alik & Jusoh, 2017). Partially shaded PV produces non-linear characteristic curves with multiple peaks. This makes it hard to obtain the maximum power from the solar PV. This condition is termed, Partial Shading Condition

(PSC) (Alik & Jusoh, 2017). Due to partial shading conditions, the output power of the PV array is reduced and thus the efficiency decreases, configuration complexity increases and the cost increases (Mohapatra *et al.*, 2017). In situation of uniform irradiance, the PV characteristic curve displays a single maximum power point, while in the case of PSC, multiple maximum power points are displayed. The Maximum Power Point Tracking (MPPT) is a conventional technique for extracting and sustaining maximum power available from the solar PV (Alik & Jusoh, 2017). A major problem of creating MPPT schemes is the necessity for rapidly detecting global maximum power points (GMPPs) rather than searching for other local maximum power points (LMPPs) under partial shading conditions (Islam *et al.*, 2018). There are two techniques of MPPT: conventional techniques and soft computing techniques (Alik & Jusoh, 2017). The conventional technique of MPPT includes fixed duty cycles, fractional open circuit voltage, fractional short circuit current, perturb and observe and incremental conductance; they are comparatively simple methods, cheap and have low efficiency (Alik & Jusoh, 2017). Alternatively, the soft computing techniques are fuzzy logic control, artificial neural networks and particle swarm optimization, which are complex method with high efficiency (Alik & Jusoh, 2017). Two peak

points occurs on a PV curve: Global and Local MPP. The global MPP is the real peak point extracted by the MPPT algorithm while the Local peak MPPT is another peak point that exists because of PSC (Alik & Jusoh, 2017).

Figure 1.1 displayed a PV string under uniform and non-uniform irradiance and the P-V peaks consisting of GMPP and LMPPs (Mohapatra *et al.*, 2017).

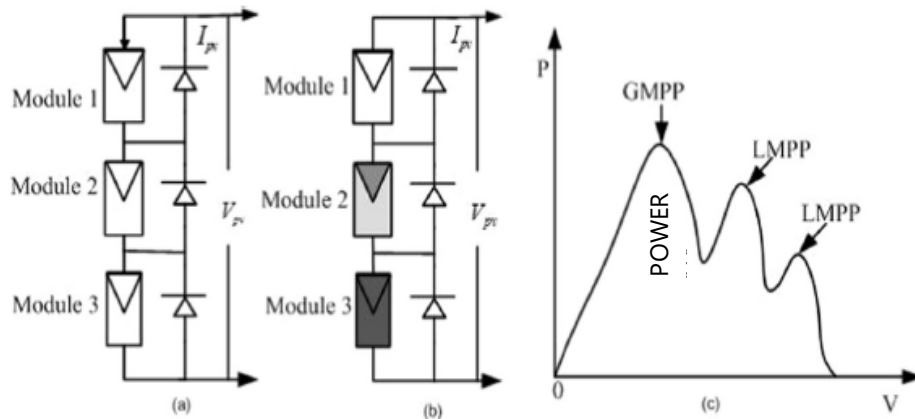


Figure 1.1: A Single PV String Showing: (a) Uniform Irradiance (b) Non-Uniform Irradiance Patterns (c) The P-V Peaks Consisting of GMPP and LMPPs (Mohapatra *et al.*, 2017)

Basic Units of a PV system

A typical PV system used for MPPT consists of the following sub-

components as shown in Figure 1.2 (Ghasemi *et al.*, 2015):

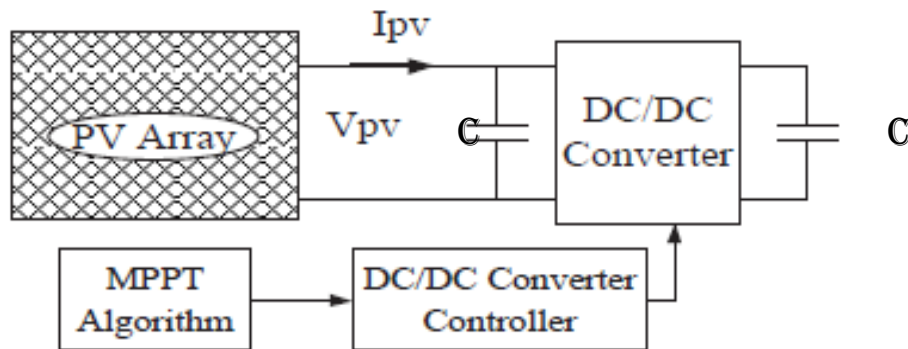


Figure 1.2: Overall Schematic Diagram of a PV System (Ghasemi *et al.*, 2015)

- i. **PV array:** this is the major component of a PV system in which PV modules are connected in series and parallel and it consists of solar cells. In a PV array, there is nonlinear relation between its voltage and current, and only in one operating voltage, maximum power is generated. This optimal operating point will vary as the environmental conditions change. Hence, finding this optimal point and extracting maximum power from a PV system in all environmental conditions are the main targets in this field.
- ii. **DC/DC converter:** A DC-DC converter is an electronic circuitry that converts a source of direct current (DC) from one voltage level to another voltage level. The commonly used DC-DC converters are given below:
- iii. **Single-Ended Primary Inductor Converter (SEPIC):** SEPIC is a type of



DC-DC converter allowing the output voltage to be greater than or less than the input voltage (Marodkaret *et al.*, 2018). The output of SEPIC can be controlled by duty cycle of switch. The SEPIC (Single Ended Primary Inductance Converter) has non-inverting buck-boost characteristics (Marodkaret *et al.*, 2018). This type of converter has limitations in terms of efficiency and cost, but it offers non-inverting polarity, and low input current ripple allows a high MPPT efficiency, which makes it suitable for PV applications (Mamarelis & Petrone, 2014).

- iv. **Boost Converter:** Boost converter is also called step up converter, because the output voltage of the Boost converter is always more than that of the input (Marodkaret *et al.*, 2018). It belongs to a category of switched mode power supply (SMPS) containing at least two semiconductors (a diode and a switch) and at least one energy storage element, a capacitor C, inductor L, or the two in combination (Marodkaret *et al.*, 2018). The boost converter has limited output voltage and possesses discontinuous current input flow (Islam *et al.*, 2018).
- v. **The Buck Converter:** The buck converter provides limited output voltage and possesses discontinuous current input flow (Islam *et al.*, 2018). A single buck converter can be applied in stand-alone PV systems due to its simple construction and high efficiency (Islam *et al.*, 2018).
- vi. **Buck-Boost Converter:** Buck-Boost Converter is a DC Converter that increases or decreases the output voltage more than the input voltage. This type of converter possesses a high efficiency and the short circuit protection of the output can be implemented easily (Pradhan *et al.*, 2013). However, it suffers from discontinuity in input current, excessive peak currents through power elements, and poor transient response. Figure 2.6, shows the diagram of the buck-boost converter. A buck-boost Converter consists of a switch which may be MOSFET or a Bipolar Joint Transistor, Inductor, Diode, Capacitor, and a Load which may be resistive or any other (Pradhan *et al.*, 2013).
- vii. **The CUK Converter:** CUK converter is a DC-DC converter that has output voltage magnitude that is either greater than or less than the input voltage magnitude (Marodkaret *et al.*, 2018). The CUK converter has low switching losses and a very high efficiency. It can provide better output current characteristics due to the inductor on the output stage (Marodkaret *et al.*, 2018). The CUK converter is the most widely used because of the fact that it achieves continuous input and output current, flexible output, and a low number of components (two inductors, one capacitor, one switch and one diode). However, it suffers from output voltage inversion (El Khateb & Rahim, 2015). The CUK converter has two modes of operation (Safari & Mekhilef, 2010). The first mode of operation is when the switch is closed (ON) and the second mode of operation is when the switch is opened (OFF). The comparison of the different topologies of DC-DC converters is shown in Table 1.1 (Mohapatra *et al.*, 2017)

Table 1.1: Comparison of Various Topologies (Mohapatra *et al.*, 2017)

Converter Topology	Efficiency
Buck converter	92%
Boost converter	97-98.2%
Buck-boost converter	99.5%
Cuk converter	> 96%
Sepic converter	> 90%

- i. **MPPT Algorithm:** The Maximum Power Point Tracking (MPPT) is a conventional technique for extracting and sustaining maximum power available from the solar PV (Alik & Jusoh, 2017). A major problem of creating MPPT schemes is the necessity for rapidly detecting global maximum power points (GMPPs) rather than searching for other local maximum power points (LMPPs) under partial shading conditions (Islam *et al.*, 2018). Generally, a good MPPT algorithm should track the GMPP in all conditions rapidly to get high efficiency. It should also have a simple implementation with a low computational load.
- ii. **DC/DC Converter Controller:** the main function of a DC/DC converter controller is in absorbing power from the PV array by controlling its voltage.
- iii. **Photovoltaic (PV) Module Equivalent Circuit:** The single diode equivalent circuit consisting of a current source I_{ph} connected antiparallel with a diode, including series resistor R_s and parallel resistor R_p , is as shown in Figure 1.3 (Gosumbonggot & Fujita, 2019)

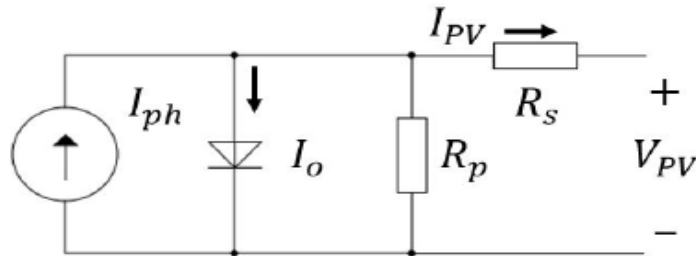


Figure 1.3: Photovoltaic (PV) Module Equivalent Circuit (Gosumbonggot & Fujita, 2019)

Partial Shading Condition: the efficiency of solar energy is mostly dependent on the level of solar irradiation and the temperature of the PV (Ellabban *et al.*, 2014). It is practically not feasible for solar PV to have uniform irradiation always, because the passing clouds, buildings, other high structures occasionally cover it totally or partially (Alik & Jusoh, 2017). Whenever a part of solar PV collects little irradiation from the sun, the unshaded cells will force the shaded cells to produce higher current than their short-circuit current and causes the shaded cells to function at a negative voltage (Alik & Jusoh, 2017). The shaded cells will eventually absorb power instead of producing power to the system. Moreover, there is an increase in the

temperature of the shaded cells as it gives out power and heat, which eventually leads to thermal stress and complete failure of the PV cells (Alik & Jusoh, 2017). Partially shaded PV produces non-linear characteristic curves with multiple peaks. This makes it hard to obtain the maximum power from the solar PV. This condition is termed, Partial Shading Condition (PSC) (Alik & Jusoh, 2017). Due to partial shading conditions, the output power of the PV array is reduced and thus the efficiency decreases, configuration complexity increases and the cost increases (Mohapatra *et al.*, 2017). Figures 1.4 shows 4 different scenarios of a PV system covered partly or partially by clouds.

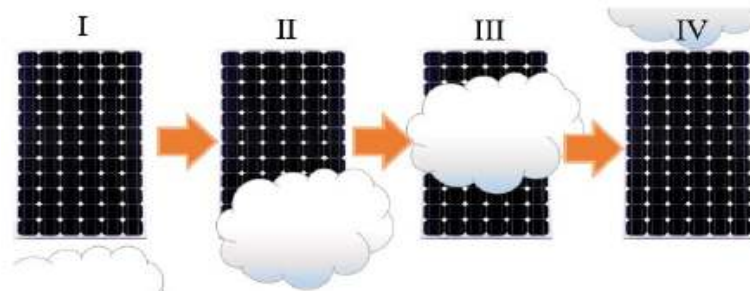


Figure 1.4: Showing Different Levels of Partial Shaded Conditions (Gosumbonggot *et al.*, 2018).



Review of MPPT algorithms under PSC conditions

Ahmed & Salam, (2015) proposed an improved perturb and observe (P&O) maximum power point tracking (MPPT) algorithm for higher efficiency. The author presented a technique to solve the oscillation problem of the conventional P&O close to MPP area and the loss of tracking direction causing it deviate from the MPP locus. The steady state oscillation problem was solved by utilizing dynamic perturbation step-size to decrease the oscillation. The problem of loss of tracking direction was mitigated by the use of a constraint introduced to prevent it from deviating from the MPP. In this method, the voltage interval of scanning was greatly reduced and only the vicinity of the approximate GMPP was required to be searched, which is less than that of the conventional method. The algorithm was implemented on a buck-boost converter and standardized using benchmarked MPPT efficiency calculation. Simulation results showed that the MPPT of the proposed P&O scheme is increased by almost two percentages. Another advantage of the proposed algorithm is the fact that it does not require the use of any hardware component, only the imputation of several lines codes to the traditional P&O MPPT control program. However, the steady state oscillation problem is not fully eliminated, which makes tracking the MPPT difficult and the best values for PIC was gotten by trial and error method.

Kwan & Wu, (2016), proposed power tracking using a variable antecedent fuzzy logic controller (FLC). The FLC is a technique that achieves a significantly improved performance over MPPT in terms of response speed and no oscillation around the maximum power point (MPP). A major issue that emanates from the classical FLC based algorithm is the lack of versatility due to quickly changing environmental conditions such as the applied irradiance. These challenges are mitigated by the author in proposing an alternative design of an adaptive MPPT fuzzy logic controller which utilizes simple formulae rather than a complex learning algorithm to adjust the antecedents. In order to verify the proposed MPPT system, a customized off the shelf solar panel is connected to a SEPIC converter and the entire system is simulated on both Simulink and experimentally verified. The emanating

response is shown to be fast and stable in comparison to previous designs which used fuzzy logic antecedents that need to be manually modified whenever the environmental conditions change or a different solar panel is used. However, the algorithm utilizes a SEPIC converter, which has a discontinuous output current, which reduces the efficiency of the system.

Loukritz *et al.*, (2016), proposed simulation and experimental design of a new advanced variable step incremental conductance MPPT algorithm for PV systems. The author proposed a variable step size incremental conductance in order to mitigate the negative effect of the fixed step size. The conventional algorithm makes use of a fixed step size for tracking the MPP. This makes the tracking speed and accuracy to depend largely on the fixed step. The power extracted from PV array using a large step size contributes to faster dynamics, but increases the losses in steady state due to large perturbations around the MPP. Using small perturbation step size, oscillation can be reduced but the tracking speed stays lower. Thus, based on the operational condition, the corresponding designs should satisfactorily address the tradeoff between the dynamic and steady state oscillation. This gives rise to the use of a variable step size. The author presents the modeling and simulation of the different operational conditions of conventional incremental conductance. The proposed method was successfully developed and tested on a flyback converter and control circuit using DSPIC30F4011. A comparative study between the proposed variable step size and fixed step size ICMPTT method under similar operating condition is presented. The obtained result demonstrated the efficiency of the proposed MPPT algorithm in terms of speed in MPP tracking and accuracy. However, a flyback converter is utilized which has low efficiency.

Ahmed & Salam, (2017) proposed An Accurate Method for MPPT to detect the Partial Shading occurrence in PV System. This paper proposes an accurate detection scheme that effectively differentiates the partial shading from the uniform change of irradiance. By doing so, it avoids the unnecessary global peak search which results in a drop of the maximum power point tracker (MPPT) efficiency. The detection is



achieved by calculating the irradiance at two designated points on I - V curve namely, i.e. the short circuit (I_{sc}) and MPP (I_{mpp}) currents. Since the mismatch of irradiance at these two points differs greatly for the partial shading and uniform irradiance change, the occurrence of the former is easily discriminated. To prove its effectiveness, the scheme is integrated into perturb and observe (P&O) and particle swarm optimization MPPT algorithms using a buck-boost converter. Its performance under several partial shading and dynamic shading condition is simulated using Matlab/Simulink and validated using the dSpace DS1104 platform. It only requires 3 samples to determine if partial shading occurs; without the scheme, an unnecessary scans of the entire P - V curve is initiated. Consequently, MPPT transient efficiency is increased by 30-35%. In addition to this, the calculated irradiance is utilized to update the open circuit voltage of the array, thus eliminating the use of temperature and irradiance sensors. However, the use of PSO algorithm makes it difficult to implement.

Basoglu & Cakir, (2017) proposed experimental evaluations of global maximum power point tracking approaches in partial shading conditions. The author, realized the MPPT by adjusting the duty ratio of pulse width modulation signal (PWM) to an optimum value, to extract maximum power available from PVMs. Due to the fact that there are multiple peaks on V - P curve under PSCs, to determine the value of the correct peak region, the value of the duty cycle is changed from minimum to maximum or maximum to minimum by a fixed step size and power values are stored for each values of duty cycle ratio. Then the value of the duty cycle is initiated corresponding to the maximum value of power. Although, this method guarantees the GMPPT under all PSCs, scanning increases convergence time and decreases the tracking efficiency. The novel MPPT algorithm locates the GMPPs from the assertion that the number of MPP regions depends on the number of bypass diodes. On the other hand, full scanning and large scanning methods manages to track global MPPT (GMPPT). Performance of large scanning method is outstanding compared to the full scanning one since it limits the scanning interval. However, the algorithm utilizes a SEPIC converter, which has a discontinuous

output current, which reduces the efficiency of the system.

Ahmed & Salam, (2018) studied an Enhanced Adaptive P&O MPPT for Fast and Efficient Tracking under Varying Environmental Conditions. An enhanced adaptive perturb and observe (EA-P&O) algorithm for maximum power point tracking (MPPT) for photovoltaic (PV) system is presented in this work. The major aim of the work is to reduce the shortcomings of the conventional P&O. Namely, the steady state oscillation, diverged tracking direction and inability to detect the global peak during partial shading. The first two problems are mitigated by a smart oscillation detection scheme and a dynamic boundary condition. In the meantime, an intelligent prediction technique is employed to ensure that the global peak is always correctly tracked. A prominent advantage of the proposed technique is that the open circuit is determined without the use of sensors. Simulation of the proposed algorithm is carried out using Matlab by commanding a strict dynamic irradiance and partial shading tests. The algorithm is validated experimentally by using a buck-boost converter together with dSpace DS1104 DSP board. Validation of the performance of the algorithm is carried out by comparing it with four common MPPT techniques: the artificial bee colony, modified incremental conduction, cuckoo search and the hybrid ant colony Optimization-Perturb & Observe. The results show that the proposed method tracks the global peak successfully under distinctive patterns of partial shading, when other algorithms fail occasionally. In addition, it improves the tracking speed by 2 to 3 times, while efficiency is maintained over 99%. However, the use of intelligent prediction technique makes the system expensive and difficult to implement.

Gosumbonggot *et al.*, (2018), proposed Partial Shading and Global Maximum Power Point Detections Enhancing MPPT for Photovoltaic Systems Operated in Shading Condition. The author presents a novel technique called "Partial shading and global maximum power point detections" that contributes high efficiency and a quick tracking time for PV under partial shading condition. The author considered four different scenarios of shading and partial shading conditions. The algorithm consists of two main parts, the main program and global MPPT using slope



calculation. The main tracking program initiates from the measurement of the PV's current, voltage, power generated and dc load voltage for duty cycle calculation; including open-circuit voltage per one module and the number of PV panels connected in series for each string in which users can determine from the manufacturers specifications. The tracking is initiated with the conventional InC algorithm to determine in advance the initial power peak of the system and store its value. When changes in irradiation occur, the search is performed by measuring the value of the instantaneous power and calculating the difference with the previously stored value, setting the threshold 1% of the previously stored value. If the difference is greater than the threshold, it means there is a possibility of shading or changing of irradiation so that the global MPPT using slope calculation is invoked for the next tracking step. On the other hand, the system remains in the main program. This is called "Partial Shading Detection". After the first detection, the tracking system proceeds to global MPPT. Simulation results showed that the presented technique achieved 9.09% increase in generated power from PV compared to conventional tracking method with fast tracking response. However, the use of boost converter has limited output voltage and possesses discontinuous current input flow, which affects the performance of the system and the tracking efficiency.

Guichi *et al.*, (2018) proposed a new method for intermediate power point tracking for PV generation under partially shaded conditions in hybrid system. The author considered a PV system under a partially shaded condition that can alternate smoothly between maximum and limited power mode. The first mode made use of a particle swarm optimization (PSO) algorithm while the second mode utilized a novel intermediate power point tracker (IPPT) algorithm. The novel algorithm has the benefit of tracking intermediate power under regular or partial shaded condition with an increased speed and zero steady state oscillations. The advantage of the new technique is the ability of selecting the point of highest voltage and lesser current among several points presenting the same amount of power, which heightens the system efficiency by decreasing the power losses. The new algorithm could track IPP on the left or right side. The advantages of tracking

the IPP on the right side, outweighs that of the left side, making it to be adopted in this research work. Verification of the effectiveness of the proposed technique was done using simulation under partial shaded conditions and normal conditions. Different scenarios under normal and partially shaded conditions are verified. Finally, the combined control algorithm was implemented using a DSpace 1104 environment and extensively tested under various partially shaded patterns. The experimental results of the prototype have proven that the newly developed algorithm improves the capability of photovoltaic system to respond quickly and precisely to the supervisor of the hybrid power system under different partially shaded conditions. However, the use of PSO algorithm makes it difficult to implement and increases the commercial production cost of the system, thereby making it non-commercially viable.

Yihao Wan *et al.*, (2019), in this paper, a novel nature-inspired Salp Swarm Algorithm with Grey Wolf Optimizer (SSA-GWO) MPPT method was proposed to track the GMPP quickly and accurately under static and dynamic partial shading conditions. In the proposed algorithm, the basic SSA algorithm is optimized by the Grey Wolf Optimizer (GWO) algorithm to improve the leader structure. Particularly, different from the single leader in SSA algorithm, half the salps are selected into a leader group, where the special hierarchy of GWO algorithm is introduced to help the population search globally and rapidly converge to the global optimal region. Moreover, the proposed algorithm still maintains the adaptive mechanism of the basic SSA algorithm, which is able to avoid stagnating in local best solutions. The numerical simulation was tested on 13 benchmark functions to evaluate the performance of the proposed SSA-GWO algorithm. The PV system with the proposed SSA-GWO MPPT method was simulated under static and dynamic partial shading conditions and compared with conventional P&O, PSO, and basic SSA MPPT methods to validate the effectiveness of this novel MPPT method in terms of mean, best, and standard deviation of fitness value. It can be observed that the proposed SSA-GWO algorithm outperforms the other algorithms in most test functions. However, a soft computing algorithm such as Grey wolf Optimizer (GWO) makes the whole



tracking system complex thereby increases the implementation cost and reduces the commercial viability of the model.

Wenfan Li, et al., (2019) proposed and analysed a novel Lipschitz optimization (LIPO) MPPT algorithm, which is effective under PSCs. Its tracking speed is very fast and tracking efficiency is above 98%, this algorithm was implemented with a boost converter. The characteristics of a PV array under PSCs are first analyzed and then the working principle of the proposed LIPO MPPT algorithm is explained. In order to validate the performance of the proposed algorithm, two popular MPPT algorithms, i.e., the modified particle swarm optimization (M-PSO) algorithm and the modified firefly optimization (M-firefly) algorithm were chosen to compare with it. All three algorithms are fulfilled and compared with each other through both simulations and experiments and the results show that the proposed MPPT algorithm has good performance. The findings of this study suggested that the efficiency of the M-PSO MPPT algorithm is a little higher than the LIPO and the M-firefly MPPT algorithms, though, the overall performance of the M-PSO MPPT algorithm is limited by its slowly tracking speed. Comparing the experimental results of the proposed LIPO MPPT algorithm and the M-firefly MPPT algorithm, it is obvious that the proposed LIPO MPPT algorithm has both faster tracking speed and higher efficiency than the M-firefly MPPT algorithm. Taken all the above analysis together, the proposed LIPO MPPT algorithm has good overall performance. However intelligent based MPPT algorithm such as Lipschitz Optimization is complex to implement and the use of Boost converter has limited output voltage and discontinuous input current flow which has adverse effect of the overall performance of the system.

Majad Mansoor et al., (2020), proposed a novel grasshopper optimization (GHO) technique, implemented to the MPPT controller under fast varying irradiance and PS conditions. A thorough comparison was made with well-established techniques, such as P&O, ABC, PSO, DFO, PSOGS, and CS optimization techniques under 5 different cases of weather conditions. The shortcomings of existing techniques are exposed under complex partial shading (CPS). An adaptive search and skip method is incorporated into GHO to enhance its robustness. GHO mimics the natural behaviour

of grasshoppers and its life cycle consists of 2 sub cycles namely nymph and adult cycle. In the nymph cycle, the motion is constrained. It provides better local exploration. In the adult cycle, abrupt fast jumps at random intervals help to avoid predators and explore more areas. The optimization is done for minimizing or maximizing a cost function. The corrective pattern between individual particles in a GHO swarm was established, and the distance between two consecutive particles is balanced by a comfort zone, which affects social interaction, attraction, and repulsion. The analysis confirmed the effectiveness of the proposed GHO over existing bio inspired MPPT techniques. Results show that the proposed GHO is highly robust with the tracking efficiency of up to 99.5%. The oscillation reduction of up to 85% is achieved along with 14–60% faster tracking. However, implementation of intelligent algorithm such as grasshopper optimization (GHO) techniques is highly complex increasing the system cost, rendering it not commercially viable, and the use of a boost converter also limits the tracking efficiency of the system as it has limited output Voltage.

Zhuoli Zhao et al., (2020), proposed a novel dynamic particles maximum power point tracking (MPPT) method to track global maximum power point (GMPP) for photovoltaic (PV) systems under partial shading conditions (PSCs). The method was combined with cuckoo search (CS) algorithm. Based on the investigation of the transient characteristic of the boost converter, the concept of dynamic sample time is introduced and deployed to decrease system tracking time with a fuzzy positioning mechanism. In the proposed two-mode searching strategy, numbers of particles, which are gradually abandoned through several iterations in global mode, rapidly position the area near the GMPP. Then the local mode is activated to accurately track the GMPP. The success rate of tracking GMPP is maximized with shorter tracking time and lower tracking power loss under PSCs. Comprehensive simulations and experiments were performed to verify the better effectiveness of the proposed dynamic particles MPPT method in comparison to other existing advanced optimization algorithms based MPPT techniques in PV systems under PSCs. Seven different MPPT methods including the proposed one under different parameter setting were tested, and the



simulated results showed that the proposed method, S-Jaya method, DPSO method and MFA method perform better tracking effects with higher success rate. Experiments have proved that the proposed method actualizes superior effectiveness including faster convergence and less power loss with higher success rate, compared to the established MPPT methods. However, the use of Boost converter which has limited output voltage and discontinuous input current flow limits the tracking efficiency. In addition, the combination of the novel dynamic particles maximum power point tracking method with cuckoo search algorithm greatly increased the system complexity.

Haidar Islam et al., (2021), in this study, an improved proportional-integral (PI) coordinated Maximum Power Point Tracking (MPPT) algorithm was designed to enhance the conversion efficiency of a PV system under PSC with fast-tracking speed and reduced power oscillations. Here, peripheral Interface (PI) controllers are used to mitigate the steady-state errors of output voltage and current of PV system that are later on passed through an incremental conductance (InC) algorithm to regulate the duty cycle of a DC-DC boost converter in order to ensure fast MPPT process. The PV system is integrated with the grid through an H-bridge inverter, which is controlled by a synchronous reference frame (SRF) controller. Tracking speed and steady-state oscillations of the proposed MPPT are evaluated in the MATLAB/Simulink environment and validated via a laboratory experimental setup using Agilent solar simulator and dSPACE (DS1104) controller. Results showed that the proposed MPPT technique reduces the power fluctuations of PV array significantly and the tracking speed of the proposed method is 13% and 11% faster than the conventional InC and perturb and observe (P&O) methods respectively under PSCs. However, the use of Boost converter which has limited output voltage and discontinuous input current flow had adverse effect on the overall performance and efficiency of the system.

CONCLUSION

This paper presents a technical review of partial shading detection and global maximum power point tracking for photovoltaic systems operated under shading condition. The MPPT is a conventional method of extracting

and sustaining maximum power from the solar PV. A major problem of creating MPPT schemes is the necessity for rapidly detecting global maximum power points (GMPPs) rather than searching for other local maximum power points (LMPPs) under partial shading conditions. There are two techniques of MPPT: conventional techniques and soft computing techniques. The conventional technique of MPPT includes fixed duty cycles, fractional open circuit voltage, fractional short circuit current, perturb and observe and incremental conductance; they are comparatively simple methods, cheap and have low efficiency. Alternatively, the soft computing techniques are fuzzy logic control, artificial neural networks and particle swarm optimization, which are complex method with high efficiency. Two peak points occurs on a PV curve: Global and Local MPP. The global MPP is the real peak point extracted by the MPPT algorithm while the Local peak MPPT is another peak point that exists because of PSC.

The following are recommended for further work:

- i. The development of a new technique for MPPT should focus on attaining high tracking efficiency while retaining design simplicity and low cost of implementation.
- ii. Utilization of an easily implementable converter with high efficiency.

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