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Literature Review on Maximum Power Point Tracking Algorithm under Partial Shading Condition

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Abstract—*Problem of partial shading for Maximum Power Tracking in Photovoltaic system is a critical issue as it reduces the output power drastically. In this paper a detailed literature survey is carried out on various MPPT control techniques presented by researchers in literature under partial shading condition. This paper will be helpful for the beginners in ON grid or OFF Grid Photovoltaic systems as it provides an overview of research going on MPPT under partial shading condition.*

1. INTRODUCTION

Despite the relatively high cost of solar modules, PV power systems have been commercialized in many countries. One critical component of any PV is the effectiveness of its Maximum Power Point Tracker (MPPT). This area has been and is still attracting immense interest from PV research communities. Conceptually, MPPT is a simple problem-it is basically an operating point matching between PV array and power converter. However, because of non-linear I-V characteristics of PV curve and under condition known as partial condition, tracking of MPP becomes more challenging task. Conventional MPPT algorithms such as P&O, IC(to name a few) is likely to be trapped at one of the local peaks because it could not differentiate between local with Global point(GP). Numerous, MPPT techniques have been proposed by different authors published in different journals. In a short span of time, the body of knowledge related to this subject has grown tremendously. Clearly, it is difficult to keep track with literature unless a single reference with concise and accurate summaries of various MPPT schemes made available.

This paper presents brief of different latest research papers on MPPT operating under partial shading condition, it is envisaged that some background knowledge would be helpful for certain group of readers. However, since the number of papers related to one particular method is quite large, it is imperative that only works with significant contributions are cited. Papers that refer to previous works with minor modifications or improvements may not be included in the reference list. In that regard, apologies are offered to the respective authors.

2. PARTIAL SHADING PROBLEM

Considering a PV array in a series parallel configuration where the modules are connected in strings, with three modules per string. When one of the modules in the string experiences [1] less illumination due to shading it's voltage drops; thus it behaves as a load instead of a generator. A hot spot ensued and typically a bypass diode is connected in parallel with each PV module to protect the shaded module from being damaged. Additionally, a blocking diode is connected at the end of each string (combination of series modules in one current path) to provide the protection against reverse current caused by the parallel connected strings. In normal condition, i.e., when the solar insolation on the entire PV array is uniform, the P-V curve exhibits the unique MPP. During partial shading, when any part of PV module being less illuminated, the difference in insolation between two modules activates the bypass diode of that module. As a result, two stairs current waveform is created on the I-V curve. Consequently, the corresponding P-V curve is characterized by several local peaks and one global peak (GP). Furthermore, if the bypass diode is removed, the PV array exhibits only a single peak; but this is achieved at the expense of a significant reduction in power. Therefore, in general, the bypass diode is always installed to improve the power throughput of the P-V array, despite the complication that arises during partial shading.

3. LITERATURE REVIEW ON MPPT UNDER PARTIAL SHADING CONDITION

K. Punitha et al. [14] has proposed a neural network (NN) based modified IC algorithm for MPPT in PV system. IC algorithm comes under the category of model-free algorithm. The idea behind the IC method is to increase or decrease V_{ref} value based on the comparison of instantaneous conductance to incremental conductance. The advantage of this method is that it offers an effective solution under rapidly changing atmospheric condition. Under the variation in atmospheric condition this algorithm tracks the MPP by applying increments or decrements to V_{ref}. The disadvantage of IC algorithm is that size of increment or decrement value is

crucial. If the size is large, the algorithm finds MPP quickly but results in oscillation around the MPP. If size is small, the oscillation around the MPP is reduced but the convergence will decrease. Future scope of this algorithm is that it provides higher percentage of maximum power with less response time.

Abd kadir Mahammad, et al. [16] has compared conventional Proportional Integral Derivative(PID) and Fuzzy Logic(FL) under four different conditions which are : constant irradiation and temperature, constant irradiation and variable temperature, constant temperature and variable irradiation. After simulation results PID controller has shown better performance than FL controller under partially shaded conditions. PID controller has greater maximum power and average power compared to FL controller. A.Bouilouta, et al.[17] has introduced a new method to track the global maximum power point (GMPP) under partially shaded condition for standalone PV systems. Advantages are that PV systems have fast response and good stabilization at the real MPP, efficiency is high. The disadvantage is that under rapid changes in isolation (or under dynamic loads) it takes small amount of time to reach MPP and has small overshoots. Further work is being conducted on the overall system design and experimental implementation.

Koray Sener Parlak [18] has offered a new novel method of Global MPPT operating under partially shaded conditions. A capacitor is connected to the array as load, and, its current and voltage parameters are sensed while charging from PV array. Advantages are ability to find GMPP in partial shading configuration, no need of multiple MPPT devices, very short computation time. In future challenges of application for the proposed MPPT method will be investigated since there may occur some technical difficulties in widely ranging irradiance level and for large scale system.

Jun Qi, Youbing Zhang [20] has proposed AMPPT algorithm based on conventional MPPT method by introducing two more steps. They are change detection for partial shade and search for GPA. The proposed method is satisfactory in real global MPP tracking under a large number of different partial shade conditions; less number of sensors is needed. If implemented generation efficiency for PV power system will improve.

A. Elnosh, et al.[21] has proposed Extremu-Seeking Control(ESC) to track the global power peak under non uniform irradiance conditions. It relies on the measurements of power and estimation of the power gradient to iteratively determine the segment of the PV characteristics in which the global peak lies, without converging at the local maxima. The proposed method can reach the global peak with a faster convergence rate and higher tracking efficiency than conventional approaches. Venkateswarlu, et al.[22] has presented a method to quickly draw the characteristics and recording the result using an electronic load. Also a method to add the characteristics of individual panels to obtain the combined characteristics has also been presented.

Kok Soon Tey et al. [23] has proposed a Differential Evolution (DE) based optimization algorithm to provide the globalized search space to track the GMPP. The direction of mutation in the DE algorithm is modified to ensure that mutation always converges to best solution among all the particles in the generation. The proposed algorithm has benefits of rapid convergence to GMPP and higher efficiency than conventional approaches. Mohammad Mehdi Seyed Mahmoudian, et al.[24] has presented MATLAB-programmed modeling and simulation of PV systems, by focusing on the effects of partial shading on the output of the PV systems. The proposed model simulates the behavior of different ranges of PV systems from a single PV module through the multidimensional PV structure.

Nicola Femia, et al. [25] has shown that negative effects of drawbacks of P&O can be limited by customizing P&O MPPT parameters to the dynamic behavior of the specific converter adopted. Also, theoretical analysis has been provided. Hiren Patel and Vivek Aggarwal [26] has presented a MATLAB-based modeling and simulation scheme suitable for studying the I-V and P-V characteristics of a PV array under partial shading, also , it can be used for developing new MPPT techniques. It can also be used as a tool to study the effects of shading patterns on PV panels with different configurations.

Hiren Patel and Vivek Aggarwal[27] has proposed a new algorithm to track the GMPP under partially shaded conditions. The algorithm works in conjunction with a dc-dc converter to track GP. Also, to accelerate the tracking speed, a feedforward control scheme for operating the dc-dc converter is proposed, it uses the reference voltage information from the tracking algorithm to shift the operation toward the MPP. As compared to conventional controller, tracking time is reduced to one-tenth. Also entire P-V curve is not scanned. Shahariar Kabir, et al. [28] has presented detailed analysis of impact of irradiance and temperature variations caused by partial shading condition. Also, an innovative MPPT scheme has been proposed which employs the Fractional Open-Circuit Voltage technique. Also, variable perturbation size concept is introduced. The proposed algorithm along with variable size control results in reduction of energy loss due to the fluctuation of tracker near MPP.

N. Jumpasri et al. [29] has discussed swarm optimization algorithm using average model. The algorithm has benefits of simple topology and accurate calculation, also response is fast. J. Salam et al.[30] has compared six important SC based MPPT technique. Emphasis is on technological aspects, merits/drawbacks and their comparative performance. K. Sundareswaran et al.[31] has reported the development of firefly algorithm. The major advantages of the proposed

method are simple computational steps, faster convergence, and its implementation on a low-cost microcontroller.

S. Taheri et al.[32] has proposed a maximum power point tracking technique based on Differential Evolution which is capable of finding global MPP under partial shading conditions. The benefits of this algorithm is that it tracks global MPP accurately, fast and with zero oscillation. Kai Chen et al.[33] has presented a new method to track GMPP of PV. The method proposed has advantages of determining whether partial shading is present, calculating number of peaks on P-V curves and predicting the locations of GMPP and LMPP. The new method can quickly find GMPP, and avoid energy loss due to blind scan. Lianlian Jiang et al.[34] has proposed a hybrid MPPT method to optimize the power output for the PV system under non-uniform conditions. It samples the operating point at locations on the I-V curve. When partial shading is detected and uses these values to predict GMPP region. After that, conventional MPPT algorithm efficient for unimodal functions, such as P&O or ESC is applied to local area so that system reaches the GMPP. Advantage is that no irradiance sensors are required, low cost, fast response, and simple structure.

R. Kotti et al. [35] has developed a high performance control to track MPPT of PV module under partial shading condition. A DC-DC boost converter has been selected as Power Conditioning Unit (PCU) to coordinate the operating point of the system MPP of PV array. The proposed algorithm uses a scanning technique to measure maximum power delivering capacity of panel and proposed control makes the system to operate at MPP. The algorithm is simple to implement, has high efficiency. V. Phimmasone et al.[36] has verified Initialization and Repulsion PSO(IR-PSO) in multiple PV arrays under various types of change in insolation and partial shading condition. This results in low cost, high efficiency and simple implementation. Also, detailed comparison with I-PSO and R-PSO is presented.

K. Ishaque et al.[37] has proposed a deterministic PSO to improve the maximum power point tracking. The main idea is to remove the random number in the accelerations factor of the conventional PSO velocity equation. Advantages include, consistent solution achieved, only inertia weight to be tuned and MPPT structure is simple. Algorithm has been implemented on a buck-boost converter. Tang Xao et al.[38] has proposed a new algorithm which relies on voltage measurements on each substring of PV module. The substring with highest voltage is set as the guiding unit and GMPP is determined based on it. The proposed algorithm is referred as maximum-voltage-unit-guided MPPT (MVUG-MPPT) and is simple to implement, results in superior performance of MPPT accuracy and speed.

Kashif Ishaque et al.[39] presented a paper To reduce computational time of simulator, they used only four parameters that are extracted for the model. The values of Rp and Rs are computed by an efficient iteration method The accurateness of the simulator is verified by applying the model to five PV modules of different types (multi-crystalline, mono-crystalline, and thin-film) from various manufacturers.

M. Muthuramalingama et al.[41] presented a paper in which they presented a unique combination of an interleaved soft switched boost converter (ISSBC) run by a set of two photovoltaic panel (PV) with a distributed MPPT, suitable to guarantee MPPT even under partial shadowed conditions, managed by an adaptive neuro fuzzy inference system The ISSBC is followed by a, single phase cascaded H bridge five-level inverter (CHI) to eliminate typically the seventh order harmonics The use of the ISSBC guarantees mitigation of ripple and it is meant to handle higher currents with minimal switching losses The ISSBC with PSO–ANFIS can provide the overall efficiency higher than ANN and P&O–ANFIS algorithms.

Jubaer Ahmed et al. [42] proposed a Maximum Power Point Tracking (MPPT) for PV system using Cuckoo Search (CS) method. CUCKOO SEARCH exhibits several advantages which include fast convergence, higher efficiency using fewer tuning parameters. Results show that CUCKOO SEARCH is capable of tracking MPP within 100–250 ms under various types of environmental change. Besides, the power loss in steady state due to MPP mismatch is only 0.000008%. Furthermore, it can handle the partial shading condition very efficiently. Due to these excellent features, it is envisaged that the CS can be suitably used as a MPPT, particularly for large PV system

Sreekumar A V et al.[43] presented a paper which discusses about an improved technique for tracking global maximum power point of photovoltaic arrays that has better performance under partial shading conditions. The first stage in this method is to find out global maximum power point among the local maxima. Once the global maximum power point is found then by adjusting the duty ratio, the voltage corresponding to maximum power can be found out. The control is then transferred to perturb and observe algorithm stage. This technique could be applied for both stand alone and grid connected PV system. They compared study between SEPIC converter and a BUCK BOOST converter with the above mentioned algorithm in order to verify the performance of both the converters.

K. Divya et al.[44] proposed an improved Maximum Power Point Tracking of Photo Voltaic system using Deterministic Particle Swarm Optimization technique. This method has the ability to track the maximum power under varying environmental conditions i.e partial shading conditions. The advantage of this method is that particles moves in the restricted value of velocity to achieve the maximum power. SEPIC converter is employed to boost up the voltage of PV

system. To estimate the value of the propose method, MATLAB simulation carried out under partial shading condition. Donny Radianto et al.[45] proposed a method in which PV array is connected using TCT (total cross-tied) configuration including sensors tomeasure voltage and currents. The sensors provide inputs for MPPT controller in order to achieve optimum output power. The Adaptive Neuro Fuzzy Inference System (ANFIS) is utilized in this paper as the controller methods. Then, the output of MPPT controller is the optimum power duty cycle to drive the performance DC-DC converter. The simulation shows that the proposed MPPT controller can provide PV voltage (VMPP) nearly to the maximum power point voltage.

Young-Hyok Ji et al. [47] presented a paper in which they showed that Conventional popular maximum power point tracking (MPPT) methods are effective under uniform solar irradiance. However, under solar irradiance mismatching conditions [partially shaded conditions (PSCs)], these MPPTs can fail for real MPPT (RMPPT), because multiple local maxima can be exhibited on the power-voltage characteristic curve. A novel MPPT method capable of RMPPT under PSCs was proposed. The performance of the proposed MPPT method is analyzed according to the RMPP position and is verified by simulation and experimental results.

E.Roman et al.[48] presented the intelligent PV module concept, a low-cost high-efficiency DC-DC converter with maximum power point tracking (MPPT) functions, control, and power line communications (PLC). In addition, this paper analyses the alternatives for the architecture of grid-connected PV systems: centralized, string, and modular topologies. The proposed system, i.e., the intelligent PV module, fits within this last group. Its principles of operation, as well as the topology of boost dc-dc converter, are analyzed. Besides, a comparison of MPPT methods is performed, which shows the best results for the incremental conductance method. Regarding communications, PLC in every PV module and its feasibility for grid-connected PV plants are considered and analyzed in this paper. After developing an intelligent PV module (with dc-dc converter) prototype, its optimal performance has been experimentally confirmed by means of the PV system test platform. This paper describes this powerful tool especially designed to evaluate all kinds of PV systems. Weidong Xiao et al.[51] presented a paper that looks at the performance of photovoltaic modules in nonideal conditions and proposes topologies to minimize the degradation of performance caused by these conditions. It is found that the peak power point of a module is significantly decreased due to only the slightest shading of the module, and that this effect is propagated through other nonshaded modules connected in series with the shaded one. Based on this result, two topologies for parallel module connections have been outlined. In addition, dc/dc converter technologies, which are necessary to the design, are compared by way of their dynamic models, frequency characteristics, and component cost. Out of this comparison, a recommendation has been made.

E. Koutroulis et al.[54] presented a new method to track the global MPP which is based on controlling a DC/DC converter connected at the PV array output, such that it behaves as a constant input-power load. The experimental results verify that the proposed global MPP method guarantees convergence to the global MPP under any partial-shading conditions. Compared with past-proposed methods, the global MPP tracking process is accomplished after far fewer PV array power perturbation steps.

R.Candela et al.[55] presented a paper in which , the research of the optimal layout of photovoltaic (PV) modules in a PV array giving the maximum output power under different shaded working conditions is carried out. The particular condition of non uniform solar exposition of the modules is analyzed. The study of the different configurations has been carried out starting from a circuital model used for the design of PV cells and for the simulation of the working behavior of PV arrays. B.N .Alajmi et al.[57] presented a modified fuzzy-logic controller for maximum power point (MPP) to increase photovoltaic (PV) system performance during partially shaded conditions. Instead of perturbing and observing the PV system MPP, the controller scans and stores the maximum power during the perturbing and observing procedures. The controller offers accurate convergence to the global maximum operating point under different partial shadowing conditions. A mathematical model of the PV system under partial shadowing conditions is derived. To validate the proposed modified fuzzy-logic-based controller, simulation and experimentation results are provided.

4. CONCLUSION

Going by the amount of research work, it can be concluded that the MPPT is continuously being researched. This implies that improvements and new techniques are destined to happen in near future. In uniform isolations conditions there is no as such problems and only efficiency is being increased by improving or combining existing technique. But the real concern is for partial shading condition where still new techniques are being developed. In new techniques PSO shows the greatest viability. But research will continue to get the maximum power from PV system.

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