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A review on maximum power point tracking for photovoltaic systems with and without shading conditions

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ABSTRACT

This paper discusses maximum power point tracking (MPPT) methods of PV system for normal and partial shading conditions (PSC). The selected MPPT methods were classified as artificial intelligent, hybrid, and other MPPT methods. The comparison of researches on MPPT methods under normal condition and PSC reveals that researchers have concentrated more on shading conditions since the last few years mainly due to the need of power output and efficiency improvements. It is believed that the information contained in this piece of work will be of great use for the researchers in the field under consideration.

Contents

1. Introduction

Among the renewable energy resources, solar PV is the most common application in the world. Fluctuation of weather conditions and PSC are proved to be the popular problems for PV systems rendering them yielding lower power output. Therefore, enhanced operation of PV is required to extract maximum power under these conditions [1]. Statistic and Parallel Testing Procedures have been laid for effective evaluation of the MPPT

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algorithms of PV Systems [2]. Low-power energy harvesting systems have also been designed with better MPPT techniques to improve the power output of PV systems [3]. Likewise, the power output of partially shaded PV systems can also be maximized using optimization of the interconnections of its modules [4]. Efficient energy harvesting and MPPT is also possible with the use of electromagnetic energy transducers and active low-voltage rectification [5]. This ensures improved power levels and wide supply voltage ranges especially in wireless sensor nodes such as those applied in medical implants. Another approach to enhance the power output of the shaded PV array is to arrange the physical position of modules in totally cross tied configuration, without altering the electrical connection of the modules in the array, so that the power output of the PV system increases [6]. In addition, energy can be recovered from shaded PV modules by applying a simple energy recovery scheme during PSC [7]. Maximum utilization of power from PV systems is also ensured by employing energy storage systems that backup energy from the PV array. Such systems include a compressed air accumulator which is controlled to enable compression and expansion modes under maximum efficiency point tracking (MEPT) and at the same time an MPPT power converter is connected to the PV system [8].

Self-shading losses also affect the output power of the fixed PV array which is standing freely. The rows formed by the modules in PV arrays can also shade the rows of the module behind each other. Parameter modifications based on location-independent experimental equation for the module-to cell width ratio were used to determine the self-shading losses [9]. Fault diagnosis with distributed MPPT for PV systems is necessary especially at module level and micro-inverters. To address this matter, an approach to diagnose the PV systems faults was presented in [10]. The advantage of this method is that monitoring of the PV plant parameters such as voltage and current at the working power point is possible.

MPPT has been carried out on different PV system configurations. For stand-alone PV system configurations, an MPPT based three-point-weighting method and mid-point tracking was conducted [11]. An MPPT control method developed for stand-alone system was applied to a power conditioning system whereby the I-V characteristics are scanned with detection interval control at specified intervals. The effectiveness of this method was demonstrated for PSCs [12]. Another MPPT technique for stand-alone PV systems under PSC was introduced to ensure the achievement of the global MPP for varying PSC [13]. Performance enhancement of solar PV systems has been achieved by designing a novel MPPT algorithm that uses short circuit current and open circuit voltage, sampled from a reference solar PV system. The method was checked for its performance in local environmental conditions [14].

Some research directed towards the control strategies for the optimization of distributed MPPT in PV applications is also necessary for proper operation of PV systems [15]. Therefore, optimum MPPT Controllers for PV systems during PSC can for example be achieved with conventional proportional integral derivative (PID) and Fuzzy Logic (FL) [16]. A novel MPPT technique for PV modules based on power plane analysis of I–V characteristics was proposed. The power region in the I-V characteristics was determined by examining the effects of the characteristic resistances of the PV module [17].

Similarly, MPPT methods for grid connected PV systems have been analyzed such as the enhanced MPPT that uses voltage-oriented control, which has improved tracking capability under fast changes in irradiance [18]. Exact MPPT of grid-connected partially shaded PV systems was introduced using current compensation concept [19] while an FL based MPPT algorithm was tested for grid-connected PV system under PSC [20]. Furthermore, some MPPT methods for three-phase PV system have also been presented in which a three-phase single-stage PV system with improved MPP tracker was tested with increased power rating [21].

A method designed for optimal arrangement of PV array with converterless matching to a given linear load revealed the difference between MPP matching and MPPT for solar generators. It was found out that for a pure resistive load, the PV system with MPPT has undoubted benefits. For a load represented by internal resistance and voltage source, the long term power output from the system using a practical MPPT operated converter is at the same level or even lower than a converterless system in term of power output [22]. In one study, the experimental investigation was carried out to assess the performance of a global MPPT and to analyze the effect of geometrical installation parameters of flexible PV modules, such as the tilt angle, bending angle and orientation, on the shape of the P-V characteristic [23]. The power loss during MPP search process was minimized whereas the output power for the flexible PV array was maximized.

MPPT techniques for PV systems have been classified and compared by some researchers [24–27]. For example, according to [25], conventional methods include incremental conductance (IC), perturb and observe (P&O), and hill climbing methods. The variant of these three methods have also been used in literature for MPPT of solar PV systems. A comparative study on MPPT techniques for PV systems available until January 2012 details the classification and description of MPPT techniques [28].

Intelligent methods and their hybrids have also been utilized to study MPPT of PV under both uniform and non-uniform irradiance. Intelligent techniques are sometimes referred to as soft computing (SC) techniques and are known to have the ability and flexibility to solve non-linear tasks and are suitable for handling different challenges arising out of adverse environmental conditions like rapid changes in irradiance and PSC [29]. It has also been observed that conventional control methods sometimes operate the PV system at local maxima. Hence, performance enhancement of PV array may be achieved with the aid of intelligent techniques especially under non-uniform irradiance conditions [30]. Partially shaded PV array have been optimized using Fuzzy MPPT which is inserted in conventional MPPT algorithms to adjust the size of the perturbed voltage [31]. Authors in [32] performed the analysis and comparison of stochastic and conventional MPPT methods based on the real MPP tracker ability, cost consideration, complexity of design, convergence speed and responsiveness to changing environmental conditions. Relatively, the artificial intelligence and stochastic algorithms show excellent tracking performance.

Laboratory prototype for the emulation of PV systems for both dynamic and PSC plays a significant role in determining the accuracy and efficiency of the proposed methods before they are practically implemented for commercial applications [33]. Experimental investigation of partial shading scenarios on different types of PVs such as mono-crystalline and poly-crystalline is paramount [34]. Software packages have also been developed that are being used to study the PV system performance under various conditions. For example, a CAD package for simulation and modeling of PV arrays under PSC is one of them [35].

The application of PV system in the buildings commonly known as building integrated PV (BIPV) is also very popular. Research directed towards this field to estimate the performance of PV arrays under PSC has intensified [36]. For instance, a novel MPPT algorithm combining the improved P&O and scanning technique to track the global MPP under PSC for BIPV was developed [37].

In this paper, a brief review of research work based on the study of PV parameters will be done followed by a compressive review of MPPT for PV systems under uniform insolation and PSC. The emphasis is given to the documentation of the latest research works on MPPT for PSC.