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The performance of perturb and observe and incremental conductance maximum power point tracking method under dynamic weather conditions

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HIGHLIGHTS

- Stringent efficiency standards for maximum power point tracker (MPPT) are envisaged.
- Performance of MPPT under dynamic environmental conditions is very crucial.
- Dynamic performance of P&O and IC method is analyzed using European Efficiency Test, EN 50530.
- Both adopted methods are sensitive to its perturbation size, especially at low insolation levels.

GRAPHICAL ABSTRACT

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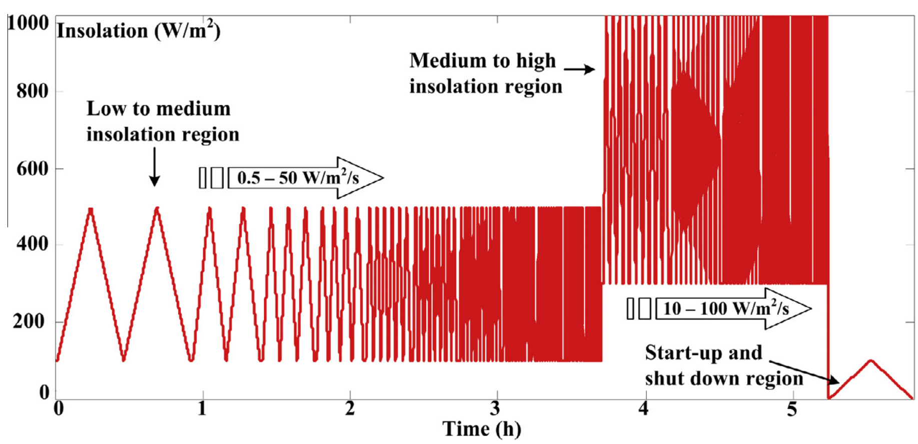

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ABSTRACT

With the rapid growth of photovoltaic (PV) systems, stringent standards are envisaged to ensure the safe and efficient generation of power. Therefore, the performance of maximum power point tracking (MPPT) element in PV system under dynamic environmental conditions is very crucial. Hence, this paper evaluates the performance of perturb and observe (P&O) and incremental conductance (IC) MPPT technique on the basis of European Efficiency Test, EN 50530, which is specifically devised for the dynamic performance of PV system. Both techniques are implemented in direct control structure and buck–boost converter is used as MPPT converter. Experiments are conducted using a custom designed PV array simulator. Results reveal that both methods yield almost equivalent dynamic MPPT efficiency. However, in average, the performance of IC method is found to be slightly better that gives 98.5% efficiency compare to 98.3% in P&O. It is also seen that the performance of IC method is very sensitive to its perturbation size, especially at low insolation levels.

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1. Introduction

Up to date, considerable number of PV power generation systems have been installed in many countries due to its potential long term economic prospects [1]. Seeing that, PV systems are known to be environmentally friendly, many large companies have taken the initiatives to be part of the green energy drive. Moreover, various attractive financial incentives; for example, feed-in tariff schemes [2] and subsidized policies [3] have been initiated by various countries, resulting in rapid growth of the industry. However, despite these tangible benefits, the main hindrance for public acceptance of PV system is still apparent, i.e. the high capital investment, due to the high module price. Thus, it is of utmost concern for PV designers to increase the efficiency in PV system so as to compensate the initial cost issue.

The efficiency of a PV system is mainly influenced by three factors: (1) the efficiency of the PV cell, which directly depends on the technology, is about 8–15% [4], (2) the efficiency of the power converters (dc–dc and/or dc–ac), which typically ranges between 95% and 98% [5] and (3) the efficiency of the maximum power point tracking (MPPT) algorithm, which in most of the cases can go beyond 98% [6]. There are also some efficiency looses due to cabling, mismatching between the array and the load/battery and energy deficiency in batteries [7]. To increase the efficiency of the cell, improved fabrication technologies and designs at silicon level is required [8–14]. Despite the fact that, this approach is meaningful, considerable amount of work and resources are certainly needed; typically, they are performed by large PV companies or well-established research institutions. On the other hand, improved converter topologies plus design can however increase the MPPT efficiency but in certain cases, it can significantly increase the overall cost of the installed PV system.

In contrast to former two factors, improving the MPPT algorithm is much easier, less expensive and can be easily retrofitted in existing PV system plants. The aim of MPPT is to ensure that, at any environmental condition, the maximum power is extracted from the PV modules by matching its *I–V* operating point with the corresponding power converter. Generally, a PV array operates in conjunction with dc–dc power converter, whose duty cycle is adjusted to appropriately track the MPP of the array. However, because of the non-linear *I–V* characteristics of the PV source and the consequence of the varying environmental conditions, tracking of correct maximum power point (MPP) can sometimes be a challenging task.

Accordingly, several MPPT schemes have been proposed [15–25]; among the more popular ones are the perturb and observe (P&O) [15], incremental conductance (IC) [16,17], ripple correlation [18], short circuit current [19] and open-circuit voltage [20]. Many of these, particularly the first two, are the most commonly implemented methods in existing PV systems. The former is based on the perturbation in the voltage/current/duty cycle of the associated power converter, while later works by incrementally comparing the ratio of derivative of conductance with the instantaneous conductance. More recently, various researcher also employed soft computing techniques for the MPPT rationale such as, fuzzy logic control [21], neural network [22] and evolutionary algorithms [6,23–27].

It is interesting to note that, in most of the aforementioned works, the results are validated on the basis of static efficiency analyses i.e. the ability of the tracker to find and hold onto the MPP once the insolation and temperature conditions are steady. Typically, the converter efficiency numbers are quoted in peak efficiency [28] or sometimes in weighted efficiency, such as European weighted [28]. Such approach is quite satisfactory when dealing with certain environmental variations, which are almost static in nature. However, the performance of these methods under dynamic weather conditions could not be sufficiently quantified. This situation is more severe in the tropical regions, where the weather fluctuations are very frequent. In such circumstances, the MPPT needs to be tested under rapid changes of insolation, which unfortunately the static efficiency methods are not able to provide. Besides, for a non-specialist, it is taken for granted that the efficiency figures provided by the manufacturers/system designers (which assumes that the PV system always operates at the MPP) is the accurate value. However, this might not always be the case; therefore, a more comprehensive MPPT efficiency that encompass the dynamic behavior of the system need to be proposed. Until now, measurements of actual MPPT-performance of a PV system based on the above-mentioned criteria (using the traditional equipment) is almost impossible. Therefore, with the aid of a sophisticated measuring system as used in this work, (known as the PV array simulator – PVAS), the testing of MPPT methods under dynamic weather conditions can be successfully achieved.

In effort to propose such thorough test, an alternative efficiency computational method i.e. the European Standard EN 50530 Test [28] is drafted, which can be considered as a more suitable and realistic approach to quantify the performance of PV system in such conditions. The test is much more stringent and has rapidly become the benchmark test to validate the MPPT performance of grid connected inverters with respect to steady state (static) and dynamic efficiency. Since, this test method is relatively new, not many literatures can be found on the performance of the existing MPPT methods when subjected to this test.

With this view in sight, this work is carried out to compare the dynamic performance of the two well accepted MPPT techniques i.e. P&O and IC when tested using the EN 50530 Test. Both methods are widely used in existing PV system; hence their performance under rapid changes of weather will give a clear picture about the robustness of these MPPT techniques. To implement these practically, a dc–dc buck–boost converter is configured as MPPT in a direct control structure. Both methods are implemented using a Dspace DS1104 [29] Digital Signal Processor (DSP) which is explicitly configured to optimize the control actions.

The remainder of the paper is organized as follows: the next section discusses about the background knowledge of EN 50530 Test. Section 3 describes the MPPT structure of both methods. This is followed by a brief overview of P&O and IC techniques. While in Section 5, the experimental setup of the whole efficiency test is shown. Tracking results of EN 50530 Test are discussed in the next section. Finally, the conclusions are made in the last section.

2. The EN 50530 Test sequence

The dynamic test EN 50530 standard defines a test procedure for the measurement of MPPT efficiency of the grid-connected PV systems with the help of a PV array simulator that simulates the output characteristics of a PV source. Although, this test is geared for inverters, it can be readily used for dc–dc converters because the main aim is to evaluate the performance of the MPPT algorithm, rather than conversion efficiency itself [28].

The dynamic MPPT efficiency test under rapid changes of weather conditions is characterized by the combination of various ramp profiles over a certain span of time. More specifically, the complete profile consists of insolation ramp with different slopes as well as insolation levels, to include all dynamic conditions and to examine, whether and how successfully the MPPT algorithm can follow the insolation dynamics.

In this test, for an entire time range, three different types of insolation regions are used to characterize three types of insolation