Available online at www.sciencedirect.com
SciVerse ScienceDirect
Solar Energy 94 (2013) 28–36
SOLAR ENERGY
www.elsevier.com/locate/solener

A new approach in MPPT for photovoltaic array based on Extremum Seeking Control under uniform and non-uniform irradiances

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Received 17 February 2013; received in revised form 21 April 2013; accepted 29 April 2013
Available online 2 June 2013

Communicated by: Associate Editor H. Upadhyaya

Abstract

This work presents a Maximum Power Point Tracking (MPPT) based on analyzing the output characteristics of PV array under uniform irradiance and partial shading conditions. In order to carry out MPPT in PV panels, under partial shading conditions a method based on Extremum Seeking Control (ESC) is introduced. In contrast with classic ESC, in this method the double of dithering signal frequency is not used, consequently PV output power has a ripple of a lower frequency. Also the drop which occurs when MPPT system starts to operate in classic ESC method is minimized in this paper. The ESC approach for MPPT in this paper uses a series combination of a Low Pass Filter (LPF) and a High Pass Filter (HPF). These two filters act as a Band Pass Filter (BPF) and let a specific frequency of input power which includes the derivative of PV with respect to its voltage pass through. Finally, the system does not operate in local optimal points for efficient point will be global. The algorithm adds partial shadow judging conditions in ESC method. The system runs the variable step ESC method to realize MPPT when photovoltaic array is under uniform irradiance. Under Partial Shading Condition (PSC), the control method can eliminate the interference of local maximum power point (MPP) to make 23 the PV array running at global MPP. In addition, unlike other methods, the proposed MPPT operates on the global MPPs. The proposed MPP tracker does not add any extra complexity compared to the classical ones. However, it increases significantly the efficiency of the PV installation under PSC. We will show that under uniform irradiance, the proposed MPPT leads to faster performances than classical approaches.

Keywords: Boost converter; Extremum Seeking Control; Maximum Power Point Tracking (MPPT); Partial Shading Conditions (PSCs); Photovoltaic (PV) system

1. Introduction

The sun is a clean and renewable energy source, which produces neither green-house effect gas nor toxic waste through its utilization. Energy security of a nation, climate change, CO_2 mitigation and carbon credit can be earned by using photovoltaic (PV) or photovoltaic thermal (PV/T) technologies (Carbon Trading) (Tiwari and Dubey, 2009). Energy and environmental performances of PV systems become more interesting as the system design is more integrated with the whole building design, and as the module is more exploited as a dual-output device (Battisti and Corrado, 2005). Solar energy is convertible into electrical energy by means of photovoltaic arrays. Due to its high cost and low efficiency during energy conversion, it is necessary to optimize the performance of PV systems through the operation of conversion systems to increase the output efficiency of the overall system (Agrawal, 2012). So, it is

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http://dx.doi.org/10.1016/j.solener.2013.04.025

crucial to operate the PV-array systems near the maximum power point (MPP) to increase the efficiency of the PV system. The output voltage and current of PV is a nonlinear function of panel temperature, received radiation and loading conditions. The MPP can change under different conditions. As PV power generation systems become popular, the environmental conditions of PV panels become more complex. There are various approaches called Maximum Power Point Tracking (MPPT) for getting maximum power from PV panels. As PV power generation arrays become more popular in urban buildings, the surrounding tall buildings and trees may produce shadow on PV panels during the day (Agrawal and Tiwari, 2011). Under Partial Shading Conditions (PSCs), the current–voltage and power–voltage characteristic curves will appear multiple steps and peaks, and using MPPT control technology to track real MPP becomes a difficult task.

The Voltage-Feedback Method (Agrawal and Tiwari, 2011; Salameh and Taylor, 1990) is the easiest MPPT which adjusts the voltage of PV array terminals to a point that has maximum power. This approach is more appropriate for solar systems which have fixed radiation and temperature conditions. In Power-Feedback technique (Salameh and Taylor, 1990; Jain and Agarwal, 2007; Harada and Zhao, 1993), the dP/dV derivative is used as the reference for control system. In this control system, the controlled output voltage is adjusted in such a way that the aforementioned derivative gets closer and closer to zero, maximum power is obtained under this condition. However, this system needs complicated computations and makes it difficult to access MPPT.

Because of simplicity of its control system and smaller number of measurement parameters, the Perturb-and-Observe Method (P&O) (Harada and Zhao, 1993; Karami et al., 2012; Piegari and Rizzo, 2010) approach is widely used in power trackers of PV cells. Despite the fact that maximum power point tracking is fulfilled by P&O approach, these points still are not optimal and PV array has some loss, also in this method, atmospheric conditions need to be fixed or have slow changes. The Incremental-Conductance Method (INC) method (Bianconi et al., 2013; Kish et al., 2012; Qin and Lu, 2012) is used to overcome losses of P&O method. In INC method, the output voltage or current of PV array is adjusted in such a way that the current to voltage ratio of PV is equal to augmented conductance, dI/dV. When any kind of deviation is observed, the current to voltage ratio changes in such a way that it becomes equal to dI/dV, because maximum power is obtained in this point. Another approach to overcome changing of maximum power point is the Three-Point Weight Comparison Method (Mei et al., 2011). In this method, three points are measured, compared and weighted. As soon as the weighting process results in receiving more power from PV array, weights become fixed. In this approach, the control system is complicated and consequently system response is slow. In Linear Approximation Method (Hsiao and Chen, 2002; Scarpa et al., 2009), maximum power point tracking is carried out by following an approximate straight line between maximum power points under different radiation conditions. This method of maximum power point tracking has higher speed but lower accuracy, also the effect of temperature on changing of maximum power point is not considered. In Neural-Network-Based Method (Shen and Tsai, 2012; Bahgat et al., 2005) and Fuzzy-Logic-Control Approach techniques (Kassem, 2012; Chiu, 2010; Chaouachi et al., 2010; Alajmi et al., 2011), MPPT is completely carried out by considering various conditions of atmospheric and PV array parameters, but calculations are complicated and microcontrollers are needed.

When the PV array is under PSC, these traditional MPPT methods can obtain the local MPP, but may not be able to extract global MPP and cause power loss.

When the PV array works in series under uniform irradiance, the load current is equal to output current of PV array. If one or more pieces of PV panels appear shadow, the output current of shadowed panels become lower and easily occur hot-spot phenomenon. Hot-spot can accelerate aging or even damage PV panel, so most PV panel is integrated with a bypass diode (Algazar et al., 2012; Renaudineau et al., 2011).

So far, the presented methods not only pay attention to the power electronic aspects but also depend on its control branch aspects. In control systems domain, a group of techniques for tracking optimum point of system performance which were developed in 1950 are known as Extremum Seeking Control (ESC).

In this paper, two optimum and real time techniques for tracking MPP in solar cells which are based on ESC method, are analyzed and compared. Also, it is proved by simulation – MATLAB/Simulink – that the proposed control systems outperform other ESC control systems and convergence and internal robustness of proposed control systems is guaranteed by using laboratorial samples.

As it is known, ESC methods are adaptive closed-loop control methods which are used to search for extreme points in random characteristics. Numerous attractive aspects of ESC method which caused it to be in the center of attention in last decade are expressed in Lei et al. (2011). As it is mentioned in Zhang and Ordóñez (2012) if ESC is used, the MPP tracking accuracy for solar cells is over 99.98%.

The aim of this article is to make a comparison between classic ESC methods and the proposed method in improving the speed of accessing MPP in solar cells under partial shading conditions.

In this paper, a new MPPT method for PV array under uniform irradiance and PSC is proposed. The operating principle takes advantage of the conditions for recognition of global MPP. In addition, unlike other methods, the proposed MPPT operates on the global MPPs. The proposed MPP tracker does not add any extra complexity compared to the classical ones. However, it increases significantly the efficiency of the PV installation under PSC. In addition, we