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Performance analysis of the tracking of the global extreme on multimodal patterns using the Asymptotic Perturbed Extremum Seeking Control scheme

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ABSTRACT

This paper presents the capability of the Asymptotic Perturbed Extremum Seeking Control (aPESC) scheme to track the Global Extreme on multimodal patterns. The multimodal patterns are simulated based on power characteristics generated by a photovoltaic (PV) array under Partial Shading Conditions (PSCs). The aPESC scheme is tested to evaluate the performance of locating, searching and tracking of the Global Maximum Power Point (GMPP). The following performance indicators such as the searching resolution, tracking accuracy, tracking efficiency, and tracking speed are used to compare the performance of the GMPP tracking (GMPPT) algorithms. The aPESCH1 scheme proposed has been implemented in MATLAB/Simulink package to evaluate the performance indicators mentioned above. The results prove that the proposed aPESCH1 scheme is effective and simple to be implemented.

Introduction

The aPESC schemes were briefly introduced in Refs. [1–3] and its modeling, stability, and design rules were analyzed in Refs. [4,5]. According to literature, researches focus on the localization, searching and tracking of the Global Maximum Power Point (GMPP). The main performance indicators (searching resolution, tracking accuracy, tracking efficiency, and tracking speed [6–9]) will be evaluated in the present study for the proposed GMPPT algorithm.

The proposed GMPPT algorithm is compared with other GMPPT algorithms reported in the literature [6–9] to show its performance. Initially, the firmware-based GMPPT algorithms that are analyzed in reviews [6–9] operate in two stages, instead of the proposed GMPPT algorithm that may find the GMPP in one stage. Secondly, the firmware-based GMPPT

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algorithms use in first stage advanced algorithms based on Fuzzy Logic Controller (FLC) [10], Artificial Neural Network (ANN) [11], Genetic Algorithms (GAs) [12], Differential Evolution (DE) [13], Particle Swarm Optimization (PSO) [14], or Ant Colony Systems (ACSs) [15]), and chaotic search [16]. However, after the GMPP is located, the GMPPT is tracked in the second stage using a classical MPPT algorithm such as Perturb and Observe (P&O) [17], Incremental Conductance (IC) [18], and Hill Climbing (HC) [19]. It is worth to mention that the classical MPPT algorithm may fail in tracking of GMPP, if the shading coefficient is over 30% or high variations appear on the irradiance profile [20,21]. So, the main objective of any GMPPT algorithm should be to track the GMPP under dynamic irradiance profile as in reality, quickly and accurately in order to increase the PV power generated with up to 45% in comparison with classical MPPT algorithms [22].

The main findings of this study are: (1) A systematic analysis of the aPESCH1 scheme is performed in order to estimate the tracking accuracy and the searching resolution of the GMPP on multimodal patterns; (2) The robustness of the GMPP searching on PV patterns under partially shaded conditions was shown using dynamic sequences of shaded PV power characteristics; (3) The tracking efficiency and tracking speed was estimated based on these dynamic sequences; (4) The robustness analysis to dither shape reveals that this is not important and the performance remains almost the same.

Some performance obtained are mentioned as follows: (1) Ability to discern the GMPP among the Local Maximum Power Points (LMPPs) is 20 times lower that 5% resolution reported by other GMPPT algorithms [6–9], (2) the average value of the tracking accuracy is of 99.97%, and (3) tracking speed is given by about 23 dither periods. The performance will be validated by the simulation results shown in sections below.

The paper is structured as follows: The PV characteristics of 1Px3S and 1Px5S arrays are shown in Section 2 under PSCs. The parameters of the solar cell and PV panel used in simulation are also mentioned here. Thus, a generic PV pattern is defined to be used in the simulation. In Section 3, the performance indicators (the searching resolution, tracking accuracy, tracking efficiency, and tracking speed) are defined. The results obtained for the performance indicators and robustness to irradiance profile with dynamical change of the PSCs, PV pattern with noise, and dither's shape are mentioned in Section 4. Finally, last section concludes the paper.

The scheme of aPESCH1 and power characteristics under partially shaded conditions

The robustness of the aPESCH1 scheme (see Fig. 1) are tested for rapid change of the shading coefficients for the PV irradiance profiles' sequences, noise on the PV irradiance profile, and use of different shapes for the dither signal.

The power characteristics generated by PV panels in series (S) and parallel (P) that are integrated into a large array of pPxsS structure, where p and s represent the number of panels that are connected in parallel and series, have multiple peaks if the panels are shaded. The power characteristics for PV array having the structure 1Px3S (top) and 1Px5S (bottom) are shown in Fig. 2 for different irradiance sequences.

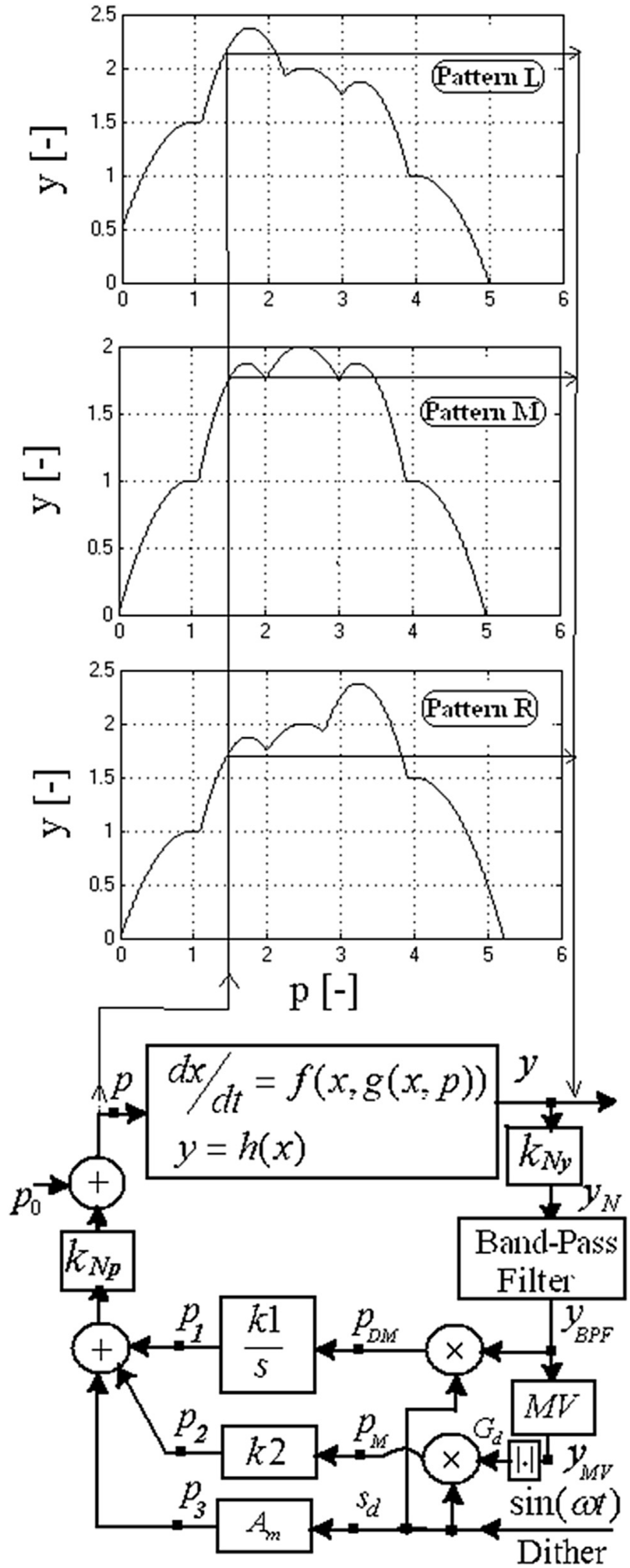

Fig. 1 – The aPESCH1 scheme and their operation using three shading patterns.

The functions, variables and parameters used in aPESCH1 scheme are the as following:

- the multimodal pattern is defined by function y = h(x),

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