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Maximum power point tracking of single-ended primary-inductor converter employing a novel optimisation technique for proportional-integral-derivative controller

Ahmad El Khateb[1], Nasrudin Abd Rahim[1], Jeyraj Selvaraj[1], Mohammad Nasir Uddin[2]

[1]*UM Power Energy Dedicated Advanced Centre (UMPEDAC), University of Malaya, Kuala Lumpur, Malaysia*
[2]*Electrical Engineering Department, Lakehead University, Ontario, Canada*
E-mail: akhateb84@hotmail.com

Abstract: This study presents an optimisation technique for proportional-integral-derivative (PID) controller to achieve maximum-power-point tracking (MPPT) of single-ended primary-inductor converter (SEPIC). A new weight function is developed to optimise the PID parameters based on gradient-descent (GD) method by adding low-pass filter term. The proposed optimisation method does not stick in the local minima, which happens frequently with the traditional weight function used in GD method, where the low-pass filter term suppresses the noise and smooths the iteration process. The prototype of the proposed optimised PID-based SEPIC converter for photovoltaic inverter applications is built using DSP-based TMS320F28335. The performance of the proposed optimised PID-based MPPT scheme is tested in both simulation and experiment at different operating conditions. A performance comparison of the proposed GD method with the conventional GD PID is also made in real-time. It is found that the proposed optimised PID-based SEPIC converter is superior to the conventional GD PID controller in terms of power transfer and efficiency. Furthermore, the proposed optimised PID controller for two-level inverter can achieve a better total harmonic distortion (THD) level as compared to the multi-level inverter frequently used by researchers for the same purpose.

1 Introduction

Owing to its treatment to both transient and steady-state response, proportional-integral-derivative (PID) controller offers the simplest and most efficient solution to many genuine control problems. Over the years, PID controllers have been widely used in industry for converter control, motor drives and other process controls [1, 2]. The optimisation of the PID controller parameters reduces the error signal significantly and comprehensively controls the converter with maximum-power-point tracking (MPPT) operation while minimising overshoot, settling time, rising time and steady-state error.

A huge number of optimisation methods have been introduced for PID parameters tuning in the literature. Particle swarm, Taguchi, Chaos, gradient-descent (GD) and genetic algorithms all improve the steady state and the transient characteristics through the optimisation of the PID parameters [3–6]. However, methods like particle swarm, Taguchi and Chaos have some disadvantages. The particle swarm optimisation has problems of dependency on initial conditions and difficulty in finding the optimal design parameters of the final outputs because of the absence of the derivative. Taguchi optimisation method has difficulty in determining the interactions between parameters, where the results obtained are only relative and do not exactly indicate what parameter has the highest effect on the performance characteristic value [7]. Chaos is not a derivative-dependent optimisation method. It overcomes the difficulties of the derivative-based methods because it heavily depends on the gradient information but it has an advantage since it avoids falling in local minima [6].

GD optimisation is a reiterative technique that is given a starting point, and follows the negative gradient in order to move the point towards a specific solution, which is hopefully the desired value. GD method is popular for very large-scale problems because it is simple, easy to implement and it is guaranteed to find the minimum through numerous time of iterations as long as it exists [8, 9]. As the GD method is an effective optimisation method for solving the PID parameters problem, this work develops GD-PID controller to search for the optimal PID parameters. The GD method often becomes stuck in local minima, which is the most common problem in this method. Conversely, the improvement on this method by adding filter term to the weighting function suppresses the noise, fasten the process and avoid sticking in the local minima. Therefore the proposed method combines between the simplicity of the original method and the advantages of the additional filter term especially avoiding the local minima.