Robust DC/DC Converter Controllers using PSO

(Full text in English)

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Abstract

As inevitable power electronic devices, DC-DC converters have been receiving great attention for their extensive use in a myriad of applications starting with basic calculators to photovoltaic systems to sophisticated weaponry. Several control methods were developed for DCDC converters control mostly with asymptotic convergence. Sliding mode, Synergetic control are a proven robust controllers approach and will be used here in a so called terminal scheme to achieve finite time convergence thus enhancing the already established technique robustness. An adaptive non-singular terminal synergetic control approach to handle uncertainties is provided resulting in enhancing robustness as well as a better transient performance compared to adaptive terminal sliding mode control. Lyapounov synthesis is adopted to assure controlled system stability. Furthermore, a PSO algorithm will be used to optimize controller's parameters using an ITAE criterion. Simulation of adaptive terminal synergetic control of a DC-DC converter is carried out for different operating conditions and results are compared to adaptive terminal sliding mode control showing good performance of the proposed approach.

Keywords: nonlinear control, ATSMC, ATSYC, DC-DC converters, swarm; finite time; PSO

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1. Introduction

As inevitable power electronic devices, DC-DC converters seem to be used in so many different scientific, industrial, space and military domains for their versatility and efficiency. Very versatile converters require robust control algorithms to handle unknown load values and/or line variation efficiently. Great emphasis realizing this task has been put on the control community. Converter design control with high performance is a challenge because of its nonlinear and time variant nature. Generally, linear conventional control fails to accomplish robustness under nonlinearity, parameter variation, load disturbance and input voltage variation.

Thus nonlinear approaches such as SMC, one of the most important approaches to handling systems with nonlinearities and uncertainties [1-2]. Generally, the linear sliding mode has been widely used, that is, the system state variables reach the system origin asymptotically in linear sliding mode [1-2]. However, the system states in the sliding mode cannot converge to zero in finite time.

Recently, the terminal sliding mode control has been developed to achieve finite time convergence of the system dynamics in the terminal sliding mode. Instead of using linear hyper planes as the sliding surfaces, the terminal sliding mode control adopts nonlinear sliding surfaces. But there exist singular points in conventional terminal sliding mode control [2]. Non-singular terminal sliding mode control can avoid the singularity, but the upper bounds of the disturbances usually must be known for calculating the switching gain[2-3]. Dangerous chattering ever present in SMC due to the discontinuous law component [1-4]. Many approaches have been proposed to reduce the latter but mostly at the expense of robustness performance [3-4]. Synergetic control like sliding mode control is based on the basic idea that if we could force a system to a desired manifold with designer chosen dynamics using continuous control law, we should achieve similar performance as SMC without its main inconvenient: chattering phenomenon [5-6]. Terminal Synergetic control (TSYC) has the advantage of finite time convergence and tiny steady state error [6]. The strong robustness of this control plays a very important role in guaranteeing the normal operation of DC converter.

To make the controlled system realize finite time convergence even in the condition of unknown boundary disturbance and overcome the singular problem in designing terminal SMC, terminal SYC synchronously [2-7], Adaptive control techniques have also successfully advanced in tackling control problems for uncertain nonlinear systems. A kind of adaptive estimation method was integrated to non-singular terminal SMC and non-singular terminal SYC. To weaken the chattering caused by SMC, the switching item in controller was eliminated. The selection of adaptive nonsingular terminal synergetic coefficients affects the performance of the controller in terms of transient response. Proper selection of these coefficients causes the system to become robust, stable and achieve fast response. We intend to apply this new technique to a DC-DC buck converter control in which PSO is used to improve overall performance.