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ORIGINAL ARTICLE

Bifurcation analysis of a Buck DC–DC converter applied to distributed power systems

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Abstract The aim of this paper is to investigate through a detailed analysis the stability and bifurcation pattern of the nonlinear phenomena in the Buck DC–DC converter. Such a study may lead to a better explanation of the dynamics behaviours of the converter. First, a nonlinear system modelling is derived for open-loop Buck converter with state variables of the input current and the output voltage. The large-signal time-domain nonlinear averaged model is used to understand the interaction on the slow scale using nonlinear analysis techniques. The model is extended for the closed-loop system while employing a proportional-integral control solution. After the initial analysis of this converter and stability region identification, we utilize the MATCONT and MATLAB packages to analyze the detailed bifurcation scenario as important parameters are varied. The analysis shows how instabilities can occur on the slow and fast scales. The simulation was performed to explore the dynamic performance.

Keywords DC–DC converters · Nonlinear systems · Bifurcation · Stability analysis

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1 Introduction

One of the necessities for the next generation of power supplies for distributed power systems (DPS) is to reach high power density with high efficiency (Hadri Hamida et al. 2004). In the conventional front-end converter based on the two-stage approach for high-power three phase DPS, the DC-link voltage coming from the power factor correction (PFC) stage penalizes the second-stage DC–DC converter (Hadri-Hamida et al. 2007; Allag et al. 2006). This DC–DC converter must insure the load exigencies. Besides that, it has to process energy economically, efficiently and with high reliability and power density (Hadri Hamida 2011, Hadri-Hamida et al. 2009).

The function of a DC–DC converter can be described basically as an orderly replication of the same sequence of circuit topologies. The conversion function of the converter is determined by the constituent topologies and the order in which they are repeated. The toggling between circuit topologies is achieved by placing switches at appropriate positions and turning them on and off so that the wanted sequence is created (Hadri Hamida et al. 2006, 2008).

Evidently, the absence of a fixed circuit configuration constitutes a serious problem to the study and modelling of DC–DC converters. The major difficulty lies in the fact that the manner in which the system works is highly nonlinear (Nayfeh and Balachandran 1995; Lee 1990; Zerouali et al. 2007, 2007). So far, most analytic techniques of modelling and analysis of DC–DC converters utilize different degrees of approximation and varying levels of restrictions in order to fit them into the framework of conventional linear system theory where there is a large body of standard theory for the analysis and design of linear feedback systems (Mazumder et al. 2001; Zerouali et al. 2006; Hadri Hamida