ISA Transactions ■ (■■■■) ■■■–■■■

Contents lists available at ScienceDirect

ISA Transactions

journal homepage: www.elsevier.com/locate/isatrans

Research Article

Load estimator-based hybrid controller design for two-interleaved boost converter dedicated to renewable energy and automotive applications

Mohamed Bougrine [a,b], Mohammed Benmiloud [a], Atallah Benalia [a], Emmanuel Delaleau [c], Mohamed Benbouzid [b,d,*]

[a] University of Laghouat, LACoSERE Lab, Laghouat, Algeria
[b] University of Brest, FRE CNRS 3744 IRDL, Brest, France
[c] Ecole Nationale d'Ingénieurs de Brest, Mechatronics Department, Plouzané, France
[d] Shanghai Maritime University, Shanghai, China

ARTICLE INFO

Article history:
Received 8 June 2016
Received in revised form
14 August 2016
Accepted 6 September 2016
This paper was recommended for publication by Dr. Jeff Pieper

Keywords:
Interleaved boost converter
Hybrid dynamical system
Optimal limit cycle
Stabilization
Adaptive control
Fuel cell source

ABSTRACT

This paper is devoted to the development of a hybrid controller for a two-interleaved boost converter dedicated to renewable energy and automotive applications. The control requirements, resumed in fast transient and low input current ripple, are formulated as a problem of fast stabilization of a predefined optimal limit cycle, and solved using hybrid automaton formalism. In addition, a real time estimation of the load is developed using an algebraic approach for online adjustment of the hybrid controller. Mathematical proofs are provided with simulations to illustrate the effectiveness and the robustness of the proposed controller despite different disturbances. Furthermore, a fuel cell system supplying a resistive load through a two-interleaved boost converter is also highlighted.

1. Introduction

Climate change in the last century, mainly due to the increasing carbon dioxide (CO_2) released through human activities as shown in Fig. 1, brings to light serious issues like global temperature and sea level augmentation, ocean warming and acidification, shrinking ice sheets, etc. These facts have pushed the scientific community for renewable and clean energy solutions to supply various technological applications via switched converters.

Due to the power source and load constraints, the converter structures have to meet some practical challenges such as reliability, high power density, high efficiency, and low current/voltage ripples. Parallel connection of switched converters or specifically the interleaving approach meets the above requirements with better power scalability characteristics compared to the classical ones [2,3]. Fig. 2a depicts the topology of a DC–DC two-interleaved boost converter, the two-phase boost topology was proposed as an alternative to the classical single phase boost converter [4], and the two-phase buck topology as an alternative to the classical buck converter [5]. These interleaved topologies are widely used in varieties of applications and systems that incorporate solar panels or fuel cell sources, as reflected in the literature [6–11]. The interleaving technique is also investigated for the microprocessors power supply to achieve better computing performance using the topology in Fig. 2b, which is known as multiphase/multi-channel synchronous/interleaved buck converter [12–15]. The interleaved bidirectional topology, obtained by changing each diode with a controlled switching device in the interleaved boost converter, is also explored in systems with rechargeable energy storage elements like batteries or supercapacitors [16–20].

Research studies have discussed these topologies from different practical and fundamental points of view. The authors in [21] have discussed the number of phases that can be used to obtain a tradeoff among some indexes such as: the switching losses, the inductor volume, the input current ripples and the switches cost. Power management in fuel cell hybrid vehicles involving battery/supercapacitor as an auxiliary regenerative source is thoroughly

* Corresponding author at: University of Brest, FRE CNRS 3744 IRDL, Brest, France.
E-mail addresses: m.bougrine@lagh-univ.dz (M. Bougrine), med.benmiloud@lagh-univ.dz (M. Benmiloud), a.benalia@lagh-univ.dz (A. Benalia), delaleau@enib.fr (E. Delaleau), mohamed.benbouzid@univ-brest.fr (M. Benbouzid).

http://dx.doi.org/10.1016/j.isatra.2016.09.001
0019-0578/