Electric Power Systems Research 134 (2016) 186–196

Contents lists available at ScienceDirect

Electric Power Systems Research

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

Four-phase interleaved DC/DC boost converter interfaces for super-capacitors in electric vehicle application based onadvanced sliding mode control design

Y. Ayoubi [a], M. Elsied [a], A. Oukaour [a,*], H. Chaoui [b], Y. Slamani [a], H. Gualous [a]

[a] LUSAC Laboratory, University of Caen—Basse Normandie, Cherbourg-Octeville, France
[b] Tennessee Technological University, Cookeville, TN, USA

ARTICLE INFO

Article history:
Received 8 July 2015
Received in revised form 15 January 2016
Accepted 26 January 2016
Available online 18 February 2016

Keywords:
Electric vehicles
DC/DC boost converter
Online controller
Super-capacitors
Four phase interleaved boost converter

ABSTRACT

Electric vehicles (EVs) has received an increasing interest from the power community and have become increasingly popular due to their importance in fighting climate change. An advanced power electronic converter remains the main and common topic for research in this area. In this paper, an advanced sliding mode control (ASMC) is designed for Four Phase Interleaved Boost Converter (FP-IBC). The novelty of the proposed controller relies on the use of an adaptive delay-time block with the conventional sliding mode control scheme which is designed based on chattering elimination method. The new scheme succeed to reduce the ripple contents in the converter's output voltage and inputs currents, and achieve fast convergence and transient response. An experimental comparison study has been investigated between the proposed controller and Self-tuning Lead Lag Compensator (SLLC). The comparison study is performed at different loading conditions using Super-Capacitor (SC) module. The experimental results show that the dynamic response of FP-IBC is significantly improved based on the proposed control design.
© 2016 Elsevier B.V. All rights reserved.

1. Introduction

The growing number of human population yields increased energy consumption and depletion of finite resources such as, oil and gas. Therefore, Electrical Vehicles (EVs) are seriously considered as an alternative to fossil-fueled vehicles specially in smart-grids applications [1–3]. In EVs, Fuel cells (FCs), Supercapacitors (SCs), and batteries are usually used as energy storage devices. Combining such energy sources leads to a FC/SC/battery hybrid power system (HPS) [4–6], as it is shown in Fig. 1. Unlike single-sourced systems, HPS has the potential to provide the load with high power quality, high reliability and efficiency.

In EVs, a DC/DC boost converter is a key element to interface HPSs to the EV's dc-bus. Various DC/DC boost converters topologies have been studied and analyzed for EV applications in the literature such as Conventional Boost Converter (BC), Two-Phase Interleaved Boost Converter (TP-IBC), and Multi-Device Boost Converter (MDBC) and Multi-Device Interleaved Boost Converter (MD-IBC) and Four-Phase Interleaved Boost Converter(FP-IBC) [7–11]. MD-IBC and FP-IBC are more powerful and more efficient than TP-IBC, MDBC and BC as admitted in [11,12]. The higher efficiency of MD-IBC and FP-IBC is realized by splitting the input current, substantially reducing I^2R losses and inductor AC losses [13]. Other than that, their input current and output voltage ripples using interleaved theory are reduced compared to conventional BC, TP-IBC and MDBC. Indeed, The voltage and current ripples are among the various phenomena that contribute to the lifespan's reduction of energy storage devices such as, FCs, SCs, and batteries [14–17].

For the FP-IBC, double pole and right half plane (RHP) zero are dependent on the duty cycle, load variation, and converter parameters which make the control design more challenging from the viewpoint of stability and bandwidth.

Many controllers are applied to boost converters to solve this problem. Among several robust control methods, variable structure control (VSC) scheme aims to provide as a popular robust strategy to treat system parameter uncertainties and external disturbances. The simplest VSC, sliding mode control (SMC), has received much attention due to its major advantages such as guaranteed stability, robustness against parameter variations, fast dynamic response and simplicity in implementation [18,19].

In [20], Sliding Mode Fuzzy Control (SMFC) has been designed and implemented to control the conventional boost converter and

* Corresponding author. Tel.: +33 233014611; fax: +33 233014135.
E-mail address: amrane.oukaour@unicaen.fr (A. Oukaour).

http://dx.doi.org/10.1016/j.epsr.2016.01.016
0378-7796/© 2016 Elsevier B.V. All rights reserved.

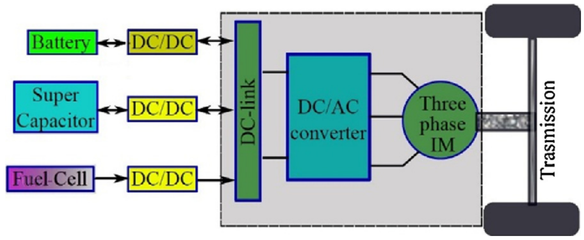

Fig. 1. Block diagram for the FC/SC/battery hybrid power system.

compared in the aspect of design and experimental results with PID fuzzy control. The results proved that the SMFC is able to achieve faster transient response with very little overshoot during startup, more stable steady-state response than PID and PI controller. In [21], a simple and systematic approach to the design of practical SMC has been presented aiming to improve the output voltage regulation of the converter subjected to any disturbance. The SMC introduced in [22] has the advantages of separate switching action and the sliding action, but the computation requirement of the inductor's current reference function increases the complexity of the controller. Besides the robustness of the aforementioned SMC algorithms against uncertainties in plants models and its rapidity of reaching the sliding surface by using the discontinuous components of the law control, there is a big problem facing this algorithm which is well known as chattering phenomenon or ripples in power electronics [23]. It shows finite frequency oscillations of the controlled variables, especially in inductance current.

In this paper, an advanced sliding mode control (ASMC) is designed, discussed, and analyzed for FP-IBC aiming to eliminate the chattering effects and reduce the voltage and current ripples is presented based on an adaptive gain control law. The proposed control law is able to achieve faster transient response with very little overshoot during startup, more stable steady-state response. The FP-IBC along with its controller is tested experimentally at different loading condition using two different power sources, i.e., Supercapacitor (SC) module. Results highlight that the proposed control scheme can successfully tune the controller parameters during the changes in system dynamics.

The paper is organized as follows. The proposed converter structure and its operating modes are presented in Section 2. The converter modeling and its control design are discussed in Section 3. Finally, an experimental setup is designed using a suitable SC module to supply load demand via the proposed converter in Section 4. An experimental test is carried-out for different loading conditions to verify the effectiveness of the proposed converter and its controller.

2. Structure of the proposed converter

Fig. 2a shows the structure of the proposed converter which consists of four DC/DC boost converter modules connected in parallel. Fig. 2b shows the switching device gate signals at $d = 0.25$, where d is the duty cycle. The gate signals are successively phase shifted by $T_S/(nxm)$, where T_S is the switching period, n is the number of phases, and m is the number of parallel switches per phase. For FP-IBC, $m = 1$ and $n = 4$. As such, the current delivered by the electric source is shared equally between each phase and has a ripple content of period $Ts/4$. Similarly, the frequency of the output voltage and the input current is n times higher than the switching frequency f_{SW}. The current sharing equally between each phase will provide tight sizing of power semiconductors, distribution of losses between modules and size's optimization of the converter. In addition, the system reliability and converter power rating will be also increased by using paralleling phases. These advantages are behind the use of FP-IBC as a good candidate for EV power systems in particular for high power applications.

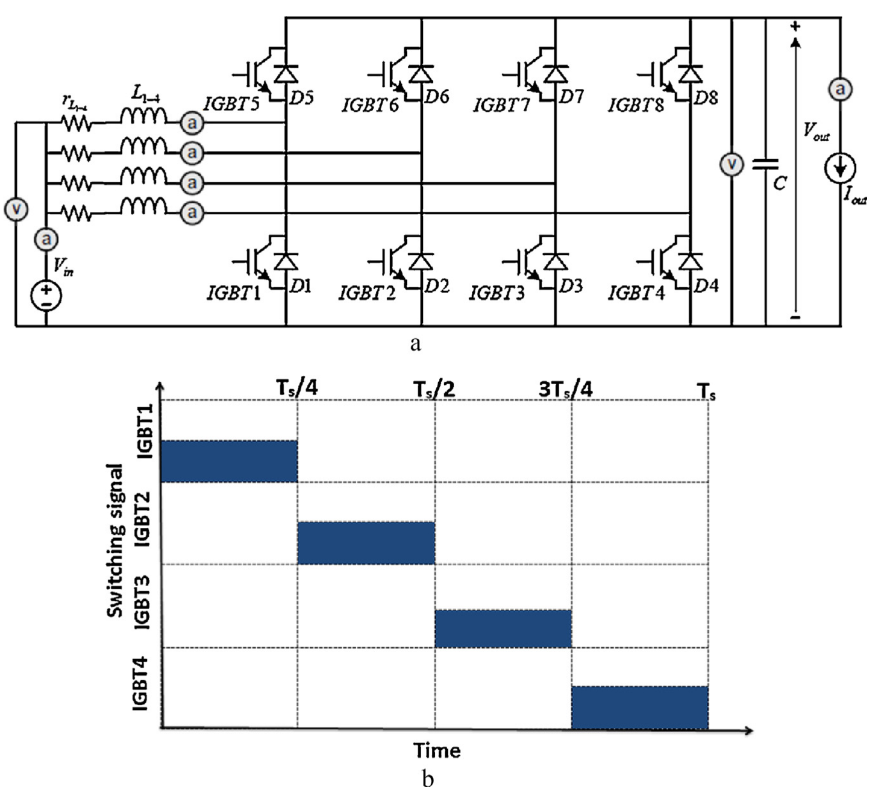

Fig. 2. (a) FP-IBC structure. (b) The switching pattern of FP-IBC at $d = 0.25$.

Download English Version:

https://daneshyari.com/en/article/704280

Download Persian Version:

https://daneshyari.com/article/704280

Daneshyari.com