Dynamic and Steady State Modelling of Voltage-Output PSFB DC-DC LCLC Resonant Converter based on GAM

Chaouch Saad[1*], Kahla Sami[1], Boutaghane Amar[1], Hasni Mourad[2]

[1]Research Center in Industrial Technologies CRTI, Algeria

[2]Electrical Engineering, University of Science and Technology Houari Boumediene (USTHB), Algeria

*Corresponding author's e-mail: saad.yassin21@gmail.com

ABSTRACT

In this paper a new dynamic and steady state models of phase-shift full bridge (PSFB) DC-DC LCLC resonant converter with capacitive output filter based on generalized averaged modelling approach are presented. At first, the switched model is developed to derive the averaged model limited to sliding first harmonic. After, the steady state behaviour is obtained which is suitable for designing this type of converter in new field of applications such as arc welding power supplies. Finally, the predictions of the proposed dynamic and steady state models are examined and compared with experimental results available in dedicated literature. The discussion of the results demonstrates the accuracy and effectiveness of the obtained models for large range of switching frequency and load conditions.

Keywords: Generalized Averaged Modelling, Switched Model, LCLC resonant converter

1 Introduction

Most conventional power supplies used in industrial applications such as arc welding, induction heating and x-ray generators, contain step-down or step-up transformers. The existence of this transformer can play partially or completely the role of the resonant tank to insure soft switching techniques [1]. Hence, in addition to its low power high voltage application [2] and [3], to extend the application of the Voltage-Output PSFB DC-DC LCLC resonant converter (see Figure 1. (A)) in new areas such as arc welding power supplies, a novel dynamic and steady state models are required. Unfortunately, the state plan analysis approach cannot be used because the proposed topology is sixth order system which makes their modelling, analysis and design more complicated even say that is impossible. Since the generalized averaged modelling (GAM) approach gets well ready for resonant converter topologies whatever the system order [4]- [6], it is adopted to obtain the large signal model which is suitable for linearized feedback control and to develop the corresponding steady state model which is efficient for design and analysis purposes.

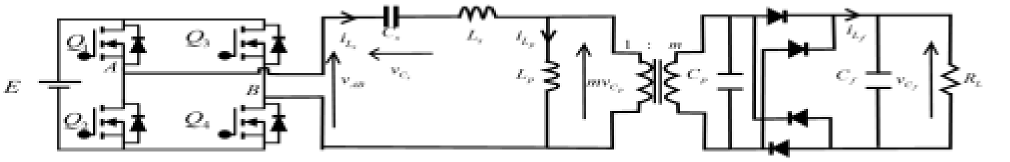
2 Generalized averaged model

Applying the two fundamental properties derived from the complex Fourier series on the switched model and defining the averaged state variables as $\langle i_{L_s}\rangle_1 = x_1 + jx_2$, $\langle i_{L_p}\rangle_1 = x_3 + jx_4$, $\langle v_{C_s}\rangle_1 = x_5 + jx_6$, $\langle v_{C_p}\rangle_1 = x_7 + jx_8$, $\langle v_{C_f}\rangle_0 = x_9$ and $\langle i_{L_f}\rangle_0 = x_{10}$, the averaged first order harmonic model can be obtained taking into account the main waveforms as illustrated in Figure 1.(B) and Figure 1.(C).

3 Simulation Results and Discussion

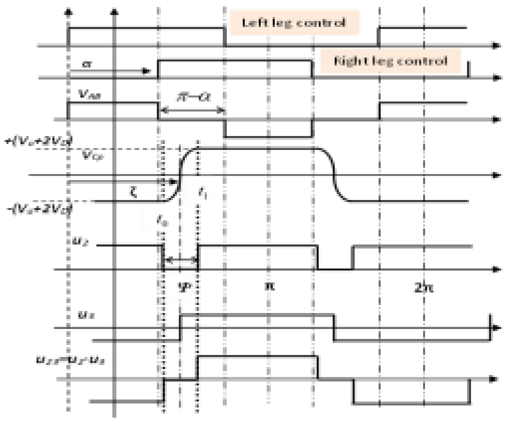
The developed switched model (SM) and the averaged model (AM) limited for first sliding harmonic are simulated and compared to circuit model (CM) using MATLAB/Simulink language. As illustrated in Figure 2.(A), Figure 2.(B) and Figure 2.(C), according to given waveforms such as the parallel resonant voltage, the output voltage and the rectified current of the converter, the obtained models show a great convergence.

DOI: 10.21467/abstracts.163 ISBN: 978-81-965621-5-1 (eBook)



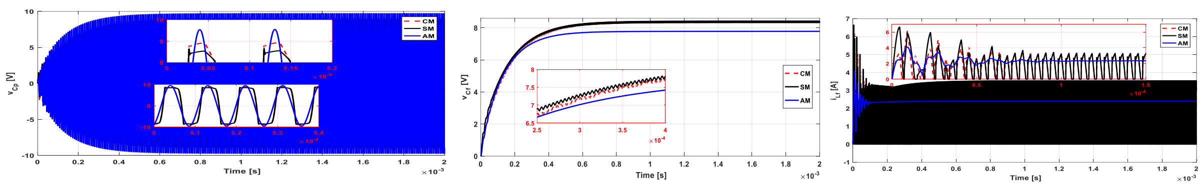
(A)

$$\begin{cases}\dot{x}_1 = -\frac{r_s}{L_s}x_1 + \omega_s x_2 - \frac{1}{L_s}x_5 - \frac{m}{L_s}x_7 + \frac{E}{L_s}\frac{\sin\alpha}{\pi}\\ \dot{x}_2 = -\omega_s x_1 - \frac{r_s}{L_s}x_2 - \frac{1}{L_s}x_6 - \frac{m}{L_s}x_8 - \frac{E}{L_s}\frac{(\cos\alpha - 1)}{\pi}\\ \dot{x}_3 = \omega_s x_4 + \frac{m}{L_p}x_7\\ \dot{x}_4 = -\omega_s x_3 + \frac{m}{L_p}x_8\\ \dot{x}_5 = \omega_s x_6 + \frac{m}{L_p}x_1\\ \dot{x}_6 = -\omega_s x_5 + \frac{m}{L_p}x_2\\ \dot{x}_7 = \frac{m}{C_p}x_1 - \frac{m}{C_p}x_3 + \omega_s x_8 - \frac{1}{C_p}\frac{2}{\pi}\cos\frac{\psi}{2}\sin\zeta\, x_{10}\\ \dot{x}_8 = \frac{m}{C_p}x_2 - \frac{m}{C_p}x_4 - \omega_s x_7 - \frac{1}{C_p}\frac{2}{\pi}\cos\frac{\psi}{2}\cos\zeta\, x_{10}\\ \dot{x}_9 = -\frac{1}{R_L C_f}x_9 + \frac{1}{C_f}x_{10}\\ \dot{x}_{10} = \frac{4}{\pi}\frac{\cos\frac{\psi}{2}}{L_f}[x_7\sin\zeta + x_8\cos\zeta] - \frac{a_\psi}{L_f}x_9 - \frac{r_f}{L_f}x_{10}\end{cases}$$



(B) (C)

Figure 1: *Voltage-Output PSFB DC-DC LCLC resonant converter (A), GAM (B) and the corresponding main waveforms (C).*



(A) (B) (C)

Figure 2: *Simulation using MATLAB/SIMULINK of Circuit Model (CM) with dotted red line, Switched Model (SM) with black line and Average Model (AM) with blue line: (A): Parallel resonant voltage v_{Cp} ,(B) Output voltage v_{Cf} and (C) Rectified current i_{Lf}.*

4 Conclusion

In this paper, a new dynamic and steady state models based on first harmonic GAM approach have been proposed for Voltage-Output PSFB DC-DC LCLC resonant converter. The obtained large signal dynamic model can be variable-frequency and/or phase shift controlled. Moreover, the derived steady state model is able sufficiently to predict the behaviour of the converter for large range of switching frequency and load conditions which facilitates its inclusion in design process for new field of industrial applications. The predictions of proposed dynamic and steady state models are examined, compared and validated with the experimental results available in the specialized literature.

How to Cite

C. Saad, K. Sami, B. Amar, H. Mourad, “Dynamic and Steady State Modelling of Voltage-Output PSFB DC-DC LCLC Resonant Converter based on GAM”, *AIJR Abstracts*, pp. 77–79, Feb. 2024.

References

[1] Crespin, A. N., Lopez,V. M., et all.: 'Digital control for an Arc welding machine based on resonant converters and Synchronous

ISBN: 978-81-965621-5-1
Series: AIJR Abstracts
DOI: 10.21467/abstracts.163

Rectification IEEE Transactions on Industrial Informatics| Vol: 9, No: 2 2013

[2] Lin, R. L.,Huang,L. H.:'Efficiency improvement on LLC resonant converter using integrated LCLC resonant transformer',IEEE Transactions on Industry Applications Vol: 54, No: 2, 2018

[3] Zhao,B., Wang, G.,and Hurley, W.G.:' Analysis and performance of LCLC resonant converters for high-voltage high-frequency applications', IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol: 5, No: 3, 2017

[4] Bacha S, , Brunello M., Hassan A. : "A general large signal model for DC-DC symmetric switching converters", Electric Machines and Power Systems, Vol 22, Nø 4, July 1994 ; pp 493-510

[5] Bacha, S., Munteanu, I., & Bratcu, A. I. (2014). Power electronic converters modeling and control. Advanced textbooks in control and signal processing, 454, 454.

[6] Chaouch, S., Hasni, M., Boutaghane, A., Kahla, S., Bacha, S., & Frey, D. (2022). Novel and simplified model representing current-output phase-shift full-bridge DC-DC LCLC resonant converter in arc welding application. International Journal of Modelling and Simulation, 42(5), 831-854.

ISBN: 978-81-965621-5-1

Series: AIJR Abstracts

DOI: 10.21467/abstracts.163