Control Method for Multi-leg Voltage-Source Inverters

Ph. Delarue[1], A. Bouscayrol[1], E. Semail[1], B. François[2],

[1] **L2EP Lille**, bât. P2, USTL, 59 655 Villeneuve d'Ascq cedex, France,
[2] **L2EP Lille**, Ecole Centrale de Lille, 59 655 Villeneuve d'Ascq cedex, France
Philippe.Delarue@univ-lille1.fr, Fax: 33-3-20-43-69-67,
URL: http://www.univ-lille1.fr/l2ep/

Keywords

Converter control, multi-converter

Abstract

In this paper, a general and simple control method is proposed for any multi-leg voltage-source inverters. This strategy is based on a specific coding technique of the switching patterns. It is validated on an original 5-leg inverter, which supplies two independent induction machines. Applications to 3-leg and 4-leg structures are also presented. Finally a comparison with a standard Pulse Width Modulation points out its characteristics.

I. Introduction

In the last decades numerous works have been proposed to optimize the control of voltage-source inverters (VSI) [1, 2]: third harmonic injection, space vector strategy, flat-top modulation... Most of these inverters are 3-leg structures in order to supply AC machines. Indeed, these drives are growing in industrial applications thanks to dynamic machine controls [3].
But other specific inverter structures are now studied: 4-leg inverter for three-phase four-wire systems [4, 5], 5-leg inverter for a two-induction drive [6]… Moreover studies of multi-machine multi-converter systems are developed in order to propose original solutions [7]. For each of these non-classical structures, a specific control has been developed.
In this paper, a general and simple control method is proposed for any multi-leg voltage-source inverters. The aim is to have a general algorithm, which can be quickly implanted and easily modified if the inverter topology changes.

II. Modelling of a multi-leg VSI

II.1. Structure of the studied VSI

The studied converter links a DC voltage source V_{DC} to n AC current sources i_1... i_n. (Fig. 1). It is so composed of n legs of two power switches (one transistor and one diode in parallel), which are assumed to be turn-on and turn-off controlled.
As the leg n° n is arbitrarily chosen as potential reference, the converter leads to $n-1$ modulated phase-to-phase voltages u_{1n}...$u_{(n-1)n}$ between current-sources. In another hand, the inverter yields a modulated current i_{inv} to the DC voltage-source.

references of phase-to-phase voltages in order to impose different frequencies on both stator windings of the machines (i.e. to obtain two independent and balanced systems of three phase-to-neutral voltages [6]).

Conclusion

A general control method has been proposed in order to control any multi-leg voltage-source inverter. It has been validated for different structures: original 5-leg and 4-leg inverters, and a classical 3-leg one.
A specific coding allows a global strategy for any leg number. It can be easily implemented in a table. But, in another hand, it leads to a worse harmonic spectrum than a classical PWM control. Another method to define the non-used modulation patterns could be found in order to reduce these drawbacks.
But for a number of leg higher than 3, optimum PWM are more complex [4, 5, 11]. So this multi-leg control strategy is very interesting in practical cases in case of the number of leg may change (modular power structures [13]) or for inverters for a great number of legs. Supply of multi-phase machines, which are growing in industrial process, are concerned.

References

1. J. Holtz, “Pulse width modulation - A survey”, *IEEE Trans. on Industry Applications*, vol. 39 no. 5, 1992, pp 410-419.
2. H. van der Broeck, “Analysis of the voltage harmonics of PWM voltage fed inverters using high switching frequencies and different modulations functions", *ETEP Journal*, vol. 2, no. 6, 1992, pp 341-349.
3. W. Leonhard., "30 years space vectors, 20 years field orientation, 10 years digital signal processing with controlled ac. drives", *EPE Journal*, vol. 1, no. 1, 1991, pp. 13-20.
4. S. Ali, M. Kazmierkowski, “Current regulation of four-leg PWM-VSI”, *IECON Conference*, Vol. 3/4, Aachen (Germany), August 1998, pp 1853-1858.
5. V. Soares, P. Verdelho, “A comparison of current controllers for three-phase four-wire PWM voltage converter”, *EPE'99 Conference*, Lausanne (Switzerland), September 1999, CD-ROM.
6. B. François, A. Bouscayrol, "Design and modelling of a five-phase voltage-source inverter for two induction motors", *EPE Conference*, Lausanne (Switzerland), September 1999, CD-ROM.
7. A. Bouscayrol, B. Davat, B. de Fornel, B. François, J. P. Hautier, F. Meibody-Tabar, M. Pietrzak-David, "Multi-machine multi-converter systems: applications to electromechanical drives", *EPJ Applied Physics*, vol. 10, no. 2, May 2000, pp-131-147.
8. J.P. Hautier, J.P. Caron, "Convertisseurs statiques : méthodologie causale de modélisation et de commande", *Edition Technip*, Paris, 1999.
9. B. François, J. P. Cambrone, "Design of logic connection controllers for three-phase voltage-source converters", *ISIE'97 Conference*, Guimaraes (Portugal), July 1997, Vol. 2, pp 543-548.
10. X. Guillaud, J. P. Hautier, "Modelling, control and causality: the Causal Ordering Graph", *16th IMACS World Congress*, Lausanne (Switzerland), August 2000.
11. A. Bouscayrol, M. Pietrzak-David, B. de Fornel, "Comparative studies of inverter structures for a mobile robot asynchronous motorization", *IEEE-ISIE Conference*, Warsaw, July 1996, vol. 1, pp 447-452
12. J. Houldsworth, D. Grant, "The use of harmonic distortion to increase the output voltage of a three-phase PWM inverter", *IEEE Ton Industry Applications*, vol. IA-20, no. 5, September 1984, pp 1224-1228.
13. Z. Ye, D. Boroyevich, F. C. Lee, "Parralelling non-isolated multi-phase PWM converter", *IEEE-IAS annual meeting*, Rome, October 2000, CD-ROM.