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Photovoltaic Power Conversion System Based on Cascaded Inverters with Synchronized Space-Vector Modulation

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1. Introduction

Some of the perspective topologies of power converters are now cascaded (dual) two-level converters which utilize two standard three-phase voltage source inverters [1]-[3]. In particular, dual inverter-fed open-end winding motor drives have some advantages such as redundancy of the space-vector combinations and the absence of neutral point fluctuations [4]-[7].

Almost all versions of classical space-vector PWM are based on the asynchronous principle, which results in sub-harmonics (of the fundamental frequency) in the spectrum of the output voltage of converters, which are very undesirable in medium/high power applications [8]-[9]. In order to provide voltage synchronization in dual inverter-fed drives, a novel method of synchronized PWM has been applied for control of these systems with single dc voltage source [10], and for the systems with two dc sources: without power balancing between sources [11], and also with power balancing PWM algorithms in a linear control range [12].

Besides adjustable speed ac drives, photovoltaic systems are between perspective areas of application of the dual-inverter topology [13]. In particular, Fig. 1 presents dual inverter system supplied by two insulated strings of photovoltaic panels with the resulting dc voltages V_L and V_H [13]. Direct connection of photovoltaic modules to inverters, or their connection through dc/dc link (dashed lines in Fig. 1) is available in this case. Dual inverters are connected to grid by a three-phase transformer with the open winding configuration on primary side. So, this paper presents results of dissemination of novel method of synchronized pulsewidth modulation for control of cascaded-inverter-based power conversion system for photovoltaic high power/high current application.

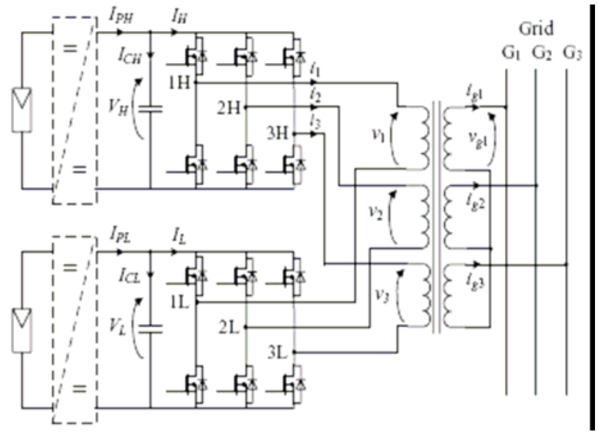

Fig. 1. Topology of dual-inverter photovoltaic system [13].

2. Features of the Method of Synchronized PWM

In order to avoid asynchronous operation of inverters with conventional space-vector modulation, novel space-vector-based method of synchronized PWM [14],[15] can be used for control of each inverter in a dual system for photovoltaic application. One of the basic ideas of the proposed PWM method is in continuous synchronization of the positions of all central switch-on signals in the centers of the 60^0 clock-intervals of three-phase inverters, and then – to generate symmetrically all other active signals together with the corresponding notches [14],[15].

3. Synchronous Operation of Dual Inverters

Synchronous control of the output voltage of each inverter of dual-inverter system with synchronized PWM provides synchronous symmetrical regulation of the phase voltages V_1, V_2 and V_3 of the system. Rational phase shift between output voltage waveforms of the two inverters is equal in this case to one half of the switching interval (sub-cycle) τ [1].

As an example of operation of the dual-inverter system with synchronized PWM, Fig. 2 presents basic voltage waveforms (period of the pole voltages V_{1H}, V_{1L} ($V_H=V_L$, $m_H=m_L=0.45$), line-to-line voltages V_{1H2H}, V_{1L2L} of the two inverters, and phase voltage V_1 (with its spectrum)) for the system with continuous synchronized PWM. The fundamental and switching frequencies are equal to 5*0Hz* and *1.35kHz*.

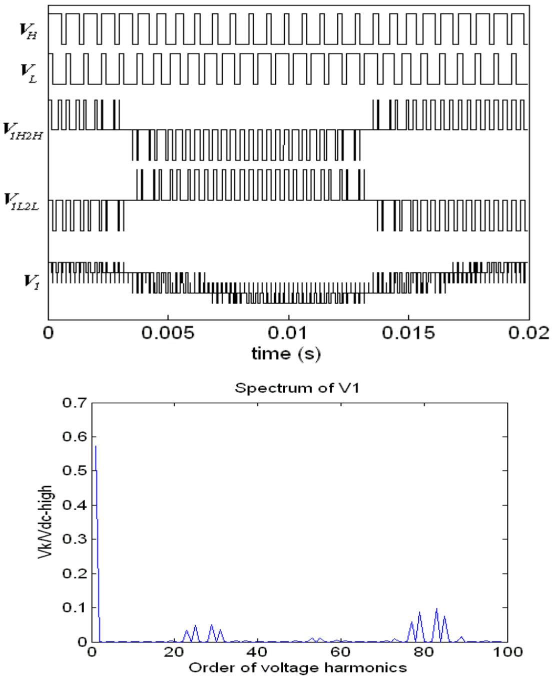

Fig. 2. Basic voltages waveforms and voltage spectrum.

Fig. 3 presents the calculation results of Total Harmonic Distortion factor (*THD*) in the function of modulation index $m=m_H=m_L$ for the phase voltage V_1 ($THD=(1/V_{1_1})\sqrt{\sum_{k=2}^{1000}(V_{1_k})^2}$) of dual-inverter system with equal dc-links voltages ($V_H=V_L$), controlled by algorithms of continuous (CPWM) and discontinuous (DPWM) schemes of synchronized modulation. The fundamental and switching frequencies are equal to 5*0Hz* and *1.35 kHz*. The calculation results show that continuous scheme of synchronized PWM provides better spectral composition of the phase voltage in the systems with operating modulation indices $m<0.8$.

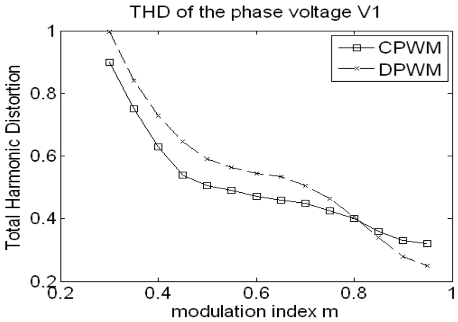

Fig. 3. *THD* factor of the phase voltage V_1.

4. Conclusion

Novel method of synchronized space-vector modulation, applied for control of dual-inverter system with two insulated photovoltaic dc-links, allows both continuous phase voltage synchronization and required regulation of the system by the corresponding control of modulation indices of two inverters.

The spectra of the phase voltage of photovoltaic systems with algorithms of synchronized PWM do not contain even harmonics and sub-harmonics for any control regime of the systems, with both equal and different voltages of two dc-sources, which is especially important for high power/high current applications.

References

[1] H. Stemmler and P. Guggenbach, "Configurations of high power voltage source inverter drives," in Proc. EPE'93, pp. 7-12.

[2] H. Stemmler, "High-power industrial drives," IEEE Proc., vol. 82, pp. 1266-1286, 1994.

[3] K.A. Corzine, S.D. Sudhoff and C.A. Whitcomb, "Performance characteristics of a cascaded two-level converter," IEEE Trans. Energy Conversion, vol. 14, pp. 433-439, 1999.

[4] E.G. Shivakumar, K. Gopakumar, S.K. Sinha, A. Pittet and V.T. Ranganathan, "Space vector PWM control of dual inverter fed open-end winding induction motor drive," in Proc. APEC'2001, pp. 399-405.

[5] E.G. Shivakumar, V.T. Somasekhar, K.K. Mohapatra, K. Gopakumar, L. Umanand and S.K. Sinha, "A multi level space phasor based PWM strategy for an open-end winding induction motor drive using two inverters with different dc-link voltages," in Proc. PEDS'2001, pp. 169-175.

[6] M.R. Baiju, K.A. Mohapatra, R.S. Kanchan and K. Gopakumar, "A dual two-level inverter scheme with common mode voltage elimination for an induction motor drive," IEEE Trans. Power Electr., vol. 19, pp. 794-805, 2004.

[7] G. Grandi, C. Rossi, A. Lega and D. Casadei, "Multilevel operation of a dual two-level inverter with power balancing capability," in CD-ROM Proc. IAS'2006, 8 p.

[8] J. Holtz, "Pulsewidth modulation – a survey," IEEE Trans. Ind. Electr., vol. 39, pp. 410-420, 1992.

[9] N. Mohan, T.M. Undeland and W.P. Robbins, Power Electronics, 3rd ed., John Wiley & Sons, 2003.

[10] V. Oleschuk, F. Profumo, G. Griva, R. Bojoi and A.M. Stankovic, "Analysis and comparison of basic schemes of synchronized PWM for dual inverter-fed drives," in Proc. ISIE'2006, pp. 2455-2461.

[11] V. Oleschuk, A. Sizov, F. Profumo, A. Tenconi and A.M. Stankovic, "Multilevel dual inverter-fed drives with synchronized PWM," in CD-ROM Proc. PESC'2006, 7 p.

[12] V. Oleschuk, R. Bojoi, G. Griva and F. Profumo, "Dual inverter-fed traction drives with dc sources power balancing based on synchronized PWM", in Proc. IEMDC'2007, pp. 260-265.

[13] G. Grandi, D. Ostojic, C. Rossi and A. Lega, "Control strategy for a multilevel inverter in grid-connected photovoltaic applications," in CD-ROM Proc. 2007 Aegean Conf. on Electrical Machine, Power Electron. and Electromotion, 6 p.

[14] V. Oleschuk and F. Blaabjerg, "Direct synchronized PWM techniques with linear control functions for adjustable speed drives," in Proc. APEC'2002, pp. 76-82.

[15] V. Oleschuk and F. Blaabjerg, "Quasi-linear algorithms of synchronous PWM for speed controlled induction motor drives," in CD-ROM Proc. ICEM'2002, 6 p.