Methods of Pulse Width Modulation in Cascaded High Voltage Frequency Converters

Victor Busher
Dept. of Electrical Engineering and Electronics
National University "Odessa Maritime Academy"
Odessa, Ukraine
victor.v.bousher@gmail.com
https://orcid.org/0000-0002-3268-7519

Oleksii Chornyi
Institute of Electromechanics, Energy Saving and Automatic Control Systems
Kremenchuk Mykhailo Ostrohradskyi National University
Kremenchuk, Ukraine
alekseii.chornyi@gmail.com
https://orcid.org/0000-0001-8270-3284

Valerii Tytiuk
Kryvyi Rih National University
Kryvyi Rih, Ukraine
dinalt2006@gmail.com
http://orcid.org/0000–0003–1077–328

Oksana Glazeva
Dept. of Electrical Engineering and Electronics
National University "Odessa Maritime Academy"
Odessa, Ukraine
o.glazeva@gmail.com
https://orcid.org/0000-0002-4992-7697

Oleksandr Rozlutskyi
National University "Odessa Maritime Academy"
Odessa, Ukraine
razlutskyioleksandr@gmail.com
https://orcid.org/0000-0003-1920-927X

Vitaliy Kuznetsov
Dept. of the electrical engineering
Ukrainian State University of Science and Technologies
Dnipro, Ukraine
witjane20002014@gmail.com
http://orcid.org/0000-0002-8169-4598

***Abstract*— Purpose. The aim of this work is to compare the effectiveness of various methods for correcting cell failures in cascade high voltage frequency converters. These methods provide the smallest voltage drop on the motor, the least loads and oscillation of electromagnetic torque in an accident modes, and evaluate the effectiveness of pulse width modulation (PWM) methods with the injection of third harmonic and space-vector PWM in normal and emergency modes. Methodology. We use mathematical and geometrical interpretation of all analysed methods – Sinusoidal PWM (SPWM), Balanced sinusoidal PWM (BSPWM), Balanced PWM with injected 3rd harmonic (THPWM) and Balanced Space Vector PWM (SVPWM). Results. The method of balancing the phase-to-phase voltages by to such a shift of the zero point and rotation of the phase vectors, in which the amplitude of the phase-to-phase voltage decreases to the minimum possible value. Injection of the 3rd harmonic allows you to further increase the utilisation factor of power supplies in terms of voltage. But the violation of the symmetry of the phase voltages leads to the need to reduce the voltage amplitude to exclude saturation of the power supplies, which reduces this coefficient compared to the theoretically possible 15.6%. A distinctive feature of the method of balanced Space Vector PWM is that the amplitude of the 1st harmonic is always greater than the radius of the circle by 15.6%. Comparison of methods of space vector PWM (SVPWM), balancing of phase-to-phase voltage with the injection of the 3rd harmonic (THPWM) with sinusoidal PWM shows that SVPWM is the best method. Despite the more complex mathematical software for the implementation of this method, it provides the best performance in all considered emergency modes of 3…6 cascade converters. The Table of indicators for all methods are presented in the article. The use of a balanced SVPWM in combination with field oriented control makes it possible to obtain an electric drive in which, in the event of an accident, there are practically no shock mechanical and electromagnetic processes. After damage of cells the currents, electromagnetic torque and motor speed change along the required trajectory.**

REFERENCES

[1] Urbaniak M, Kardas-Cinal E and Jacyna M 2019 Optimization of Energetic Train Cooperation *Symmetry* 11(9), 1175; https://doi.org/10.3390/sym11091175

[2] Burdasov B K, Nesterov S A and Fedotov Yu B 2015 Frequency converters for high-voltage AC drives *APRIORI Series Natural and technical sciences* 4 pp 2–15

[3] Malinowski M, Gopakumar K, Rodriguez J and Pérez M A 2010 A Survey on Cascaded Multilevel Inverters I*EEE Transactions on Industrial Electronics* 57 7 pp 2197–2206

[4] Manimala V, Geetha N and Renuga P 2011 Design and simulation of five level cascaded inverter using multilevel sinusoidal pulse width modulation strategies *IEEE 3rd International Conference on Electronics Computer Technology* 2 pp 280–283. https://ieeexplore.ieee.org/document/5941701

[5] McGrath B P and Holmes D G 2002 Multicarrier PWM strategies for multilevel inverters I*EEE Transactions on Industrial Electronics* 49 4 pp 858–867

[6] Grahame D 2003 Pulse width modulation for power converters. *Principles and practice* (New Jersey: John Wiley & Sons, Inc.) p 724

[7] Kolpakov A 2009 Multilevel Converter Control Algorithms *Silovaya Elektron.* 2 pp 57–65. https://power-e.ru/wp-content/uploads/2009_2_57.pdf

[8] High voltage frequency converters series N5000 // http://www.tekhar.com/Programma/HYUNDAI/index_V_V_invert.html

[9] Frequency converters VEDADRIVE 315–25000 kVA // www.danfoss.ru/VLT

[10] Krishnapriya S and Unnikrishnan L 2015 Multilevel Inverter Fed Induction Motor Drives, *International Journal of Research in Engineering and Technology (IJRET)* 04 09 pp 60–64

[11] Rudyk T, Szczepański E, Jacyna M 2019 Safety factor in the sustainable fleet management model. *Archives of Transport*, 49(1), 103-114. DOI: https://doi.org/10.5604/01.3001.0013.2780

[12] PowerFlex 6000 Medium Voltage Variable Frequency Drive Firmware, Parameters, and Troubleshooting Manual Catalog Number 6000G // *Publication 6000-TD004E-EN-P* – September 2019. http://www.rockwellautomation.com/support

[13] High voltage frequency converters Robicon PERFECT HARMONY 225 kW–120 MW // www.siemens.com/robicon-perfect-harmony

[14] Puchkov A P and Osipov O I 2018 Correction of the Control System of a Multilevel Converter with a Defect in the Power cell of its Inverter *Electrotechnical Systems and Complexes* 3 40 pp 42–46

[15] Gorodny A, Dymerets A, Kut Y, Denisov Y, Natalia D 2020 Generalized method of commutation processes calculation in high-frequency switched-mode power converters *Advances in Intelligent Systems and Computing* 1019 pp 71–80

[16] V Busher et al 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* 985 012021. https://doi.org/10.1088/1757-899X/985/1/012021

[17] V. Busher, A. Shestaka, O. Chornyi, O. Glazeva, L. Melnikova and V. Tytiuk, "Method of Space Vector Pulse Width Modulation in High Voltage Cascaded Frequency Converter with Damaged H-cells," 2021 IEEE International Conference on Modern Electrical and Energy Systems (MEES), 2021, pp. 1-5, https://doi.org/10.1109/MEES52427.2021.9598782