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Specialized schemes of space-vector modulation of VSI for synchronous voltage control of PV stations

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Abstract

This paper briefly reviews the development and widespread use of an alternative method of synchronous pulsewidth modulation (PWM), based on a space vector approach, for the control of voltage source inverters (VSIs) and inverter-based photovoltaic grid-tied (PV) installations with low switching frequency of inverters. It assures providing synchronization and symmetry of winding voltage of power transformer for any operation conditions including cases of fluctuation of grid frequency, of unequal voltages of dc-sources (PV panels), etc. Examples of the use of this PWM method to control several topologies of VSI-based photovoltaic stations with multi-winding power transformer are presented.

Keywords: *modulation strategy, photovoltaic system, voltage harmonic composition, voltage source inverter*

References:

1. H. Abu-Rub, M. Malinowski and K. Al-Haddad, "Power Electronics for Renewable Energy Systems", Transportation and Industrial Applications, 2014. Google Scholar
2. P. Sanjeevikumar, M.S. Bhaskar, P.K. Maroti, F. Blaabjerg, P. Siano and V. Oleschuk, "Hextuple-inverter configuration for multilevel nine-phase symmetrical open-winding converter", Proc. of IEEE Int'l Conf. on Power Electronics Intelligent Control and Energy Systems (ICPEICES'2016), pp. 6, 2016. View Article Google Scholar
3. B.K. Bose, "Power electronics smart grid and renewable energy systems", Proc. of the IEEE, vol. 105, no. 11, pp. 2011-2018, 2017. View Article Google Scholar
4. N. Kannan and D. Vakeesan, "Solar energy for future world: a review", Renewable Sustainable Energy Reviews, vol. 62, pp. 1092-1105, 2016. CrossRef Google Scholar
5. E. Kabir, P. Kumar, S. Kumar et al., "Solar energy: potential and future prospects", Renewable Sustainable Energy Reviews, vol. 82, pp. 894-900, 2018. CrossRef Google Scholar

6. *E. Asmelash and G. Prakash, "Future of Solar Photovoltaic: Deployment Investment Technology Grid Integration and Socio-Economic Aspects", 2019.* Google Scholar

7. *N. Mansouri, A. Lashab, D. Sera, J.M. Guerrero and A. Cherif, "Large photovoltaic power plants integration: A review of challenges and solutions", Energies, vol. 12, no. 3798, pp. 16, 2019.* CrossRef Google Scholar

8. *A.O.M. Maka and J.M. Alabid, "Solar energy technology and its roles in sustainable development", Clean Energy, vol. 6, no. 3, pp. 476-483, 2022.* CrossRef Google Scholar

9. *J. Jana, H. Saha and Das K. Bhattacharya, "A review of inverter topologies for single-phase grid-connected photovoltaic systems", Renewable Sustainable Energy Reviews, vol. 72, pp. 1256-1270, 2017.* CrossRef Google Scholar

10. *R. Dogga and M.K. Pathak, "Recent trends in solar PV inverter topologies", Solar Energy, vol. 183, pp. 57-73, 2019.* CrossRef Google Scholar

11. *N. Mansouri, A. Lashab, D. Sera, J.M. Guerrero and A. Cherif, "Large photovoltaic power plants integration: A review of challenges and solutions", Energies, vol. 12, no. 3798, pp. 16, 2019.* CrossRef Google Scholar

12. *D. Kolantla, S. Mikkili, S.R. Pendem and A.A. Desai, "Critical review on various inverter topologies for PV system architectures", IET Renewable Power Generation, vol. 14, pp. 3418-3438, 2020.* CrossRef Google Scholar

13. *G. Grandi, C. Rossi, D. Ostojic and D. Casadei, "A new multilevel conversion structure for grid-connected PV applications", IEEE Trans. Ind. Electron, vol. 56, no. 11, pp. 4416-4426, 2009.* View Article Google Scholar

14. *Y. Park, S. Ohn and S-K. Sul, "Multi-level operation with two-level converters through a double-delta source connected transformer", Journal of Power Electronics, vol. 14, no. 6, pp. 1093-1099, 2014.* CrossRef Google Scholar

15. *S. Ohn, Y. Park and S.-K Sul, "Multi-level operation of triple two-level PWM converters", Proc. of IEEE Energy Conversion Congress and Exposition (ECCE'2015), pp. 4283-4289, 2015.* View Article Google Scholar

16. *A. Sinha, K.C. Jana and M.K. Das, "An inclusive review on different multi-level inverter topologies their modulation and control strategies for a grid connected photo-voltaic system", Solar Energy, vol. 170, pp. 633-657, 2018.* CrossRef Google Scholar

17. *V.F. Pires, A. Cordeiro, D. Foito and J.F. Silva, "Three-phase multilevel inverter for grid-connected distributed photovoltaic systems based in three three-phase two-level inverters", Solar Energy, vol. 174, pp. 1026-1034, 2018.* CrossRef Google Scholar

18. *R.V. Zaitsev, M.V. Kirichenko, G.S. Khrypunov, D.S. Prokopenko and L.V. Zaitseva, "Hybrid solar generating module development for high-efficiency solar energy station", Journal of Nano-and Electronic Physics, vol. 10, no. 6, pp. 06017-1-0617-5,*

2018. [CrossRef Google Scholar](#)

19. *R.V. Zaitsev, M.V. Kirichenko, K.A. Minakova, G.S. Khrypunov, I.V. Khrypunova and D. S Prokopenko, "DC-DC converter for high-voltage power take-off system of solar station", Proc. of IEEE Ukrainian Conf. on Electr. and Computer Engg. (UKRCON'2019), pp. 6, 2019. [View Article Google Scholar](#)*
20. *K. Minakova and R. Zaitsev, "Optimization of a basic solar collector model for combined photo-energy systems", Energy: Series "Modern problem of power engineering and ways of solving them", vol. 96, no. 4, pp. 114-119, 2020. [Google Scholar](#)*
21. *M. Qawaqzeh, R. Zaitsev, O. Miroshnyk, M. Kirichenko, D. Danylchenko and L. Zaitseva, "High-voltage dc converter for solar power station", Int'l Journal of Power Electronics and Drive Systems (IJPEDS), vol. 11, no. 4, pp. 2135-2144, 2020. [CrossRef Google Scholar](#)*
22. *K. Minakova and R. Zaitsev, "Photovoltaic Thermal PV/T systems: increasing efficiency method", Proc. of IEEE 2021 Int'l Conf. KhPI Week on Advanced Technology, pp. 303-306, 2021. [View Article Google Scholar](#)*
23. *V. Oleschuk and G. Griva, "Simulation of processes in synchronized cascaded inverters for photovoltaic application", International Review of Electrical Engineering, vol. 4, no. 5, pp. 975-982, 2009. [Google Scholar](#)*
24. *G. Griva and V. Oleschuk, "Dual inverters with synchronized PWM for grid-connected photovoltaic systems", Proc. of IEEE Int'l Conf. on Clean Electrical Power (ICCEP'2009), pp. 420-425, 2009. [View Article Google Scholar](#)*
25. *V. Oleschuk, G. Griva and F. Spertino, "Dual neutral-point-clamped converters with synchronized PWM for photovoltaic installations", International Review of Electrical Engineering, vol. 5, no. 1, pp. 123-131, 2010. [Google Scholar](#)*
26. *V. Oleschuk, G. Grandi and F. Dragonas, "Cascaded neural-clamped inverters with flexible synchronized PWM for photovoltaic installations", Proc. of IEEE Int'l Symp. on Ind. Electron. (ISIE'2011), pp. 989-993, 2011. [View Article Google Scholar](#)*
27. *V. Oleschuk and V. Ermuratskii, "Dual-inverter-based photovoltaic system with discontinuous synchronized PWM", Proc. of IEEE Int'l Conf. on Intell. Energy and Power Systems (IEPS'2014), pp. 86-89, 2014. [View Article Google Scholar](#)*
28. *V. Oleschuk, M. Cernat, M. Pastor and P. Sanjeevikumar, "Synchronous PWM control of triple transformer-connected inverters for photovoltaic system", Proc. of IEEE Int'l Conf. on Power Electron. and Motion Control (PEMC'2016), pp. 216-220, 2016.[View Article Google Scholar](#)*
29. *V. Oleschuk and V. Ermuratskii, "Two-inverter-based photovoltaic installation adjusted by the modified scheme of space-vector modulation", Technical Electrodynamics, no. 5, pp. 26-30, 2020. [CrossRef Google Scholar](#)*
30. *V. Oleschuk, I. Vasiliev, G. Griva and F. Spertino, "Schemes and techniques of*

synchronous modulation of PV inverters with high modulation indices: A survey", Proc. of IEEE Int'l Symp. on Advanced Topics of Electrical Engineering (ATEE'2021), pp. 6, 2021. View Article Google Scholar