March - April 2020
ISSN: 0193-4120 Page No. 2278 - 2283

Improved Performance of Single-Phase Seven-Level Grid-Connected Inverter for PV System

[1j] Mohideen Abdul Kadar, [2]Dr.A.Amudha[2], Dr.K.Balachander[3]Dr.G.Emayavaramban[4], Dr.Viyathukattuva[5] , Dr.M.Siva Ramkumar[6]P.Nagaveni[7],
[1]Dept of EEE,Faculty of Engineering, Karpagam Academy of Higher Education,Coimbatore,
[4,5,6,7]Asst Prof, Dept of EEE,Faculty of Engineering, Karpagam Academy of Higher Education,Coimbatore,
[2]Prof & Head, Dept of EEE,Faculty of Engineering, Karpagam Academy of Higher Education,Coimbatore
[3]Asso Pro, Dept of EEE,Faculty of Engineering, Karpagam Academy of Higher Education,Coimbatore
amudha.a@kahedu.edu.in

Article Info
Volume 83
Page Number: 2278 - 2283
Publication Issue:
March - April 2020

Article History
Article Received*: 24 July 2019*
Revised*: 12 September 2019*
Accepted*: 15 February 2020*
Publication*: 19 March 2020*

Abstract:

This article presents the performance of single phase seven level gtid connected inverter for PV system. The performance of the designed model is checked with help of MATLAB/Simulink. The results are presented to show the proficient of the designed model.

1. Introduction and Working of Proposed Inverter

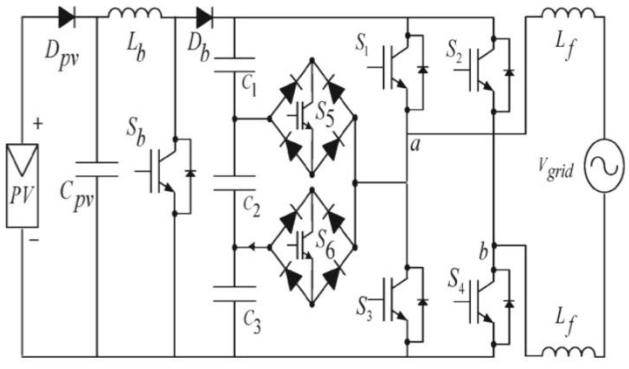

Fig. 1. Seven-level grid-connected inverter for photovoltaic systems

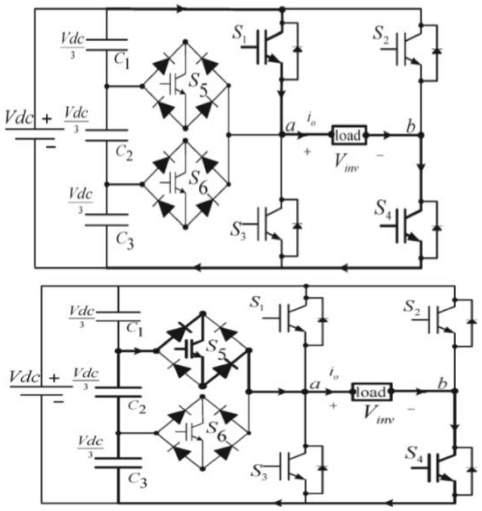

Table 3.1 shows the switching combinations that generated the seven output-voltage levels (0,−Vdc,−2Vdc/3, Vdc/3,Vdc,2Vdc/3,Vdc/3

March - April 2020
ISSN: 0193-4120 Page No. 2278 - 2283

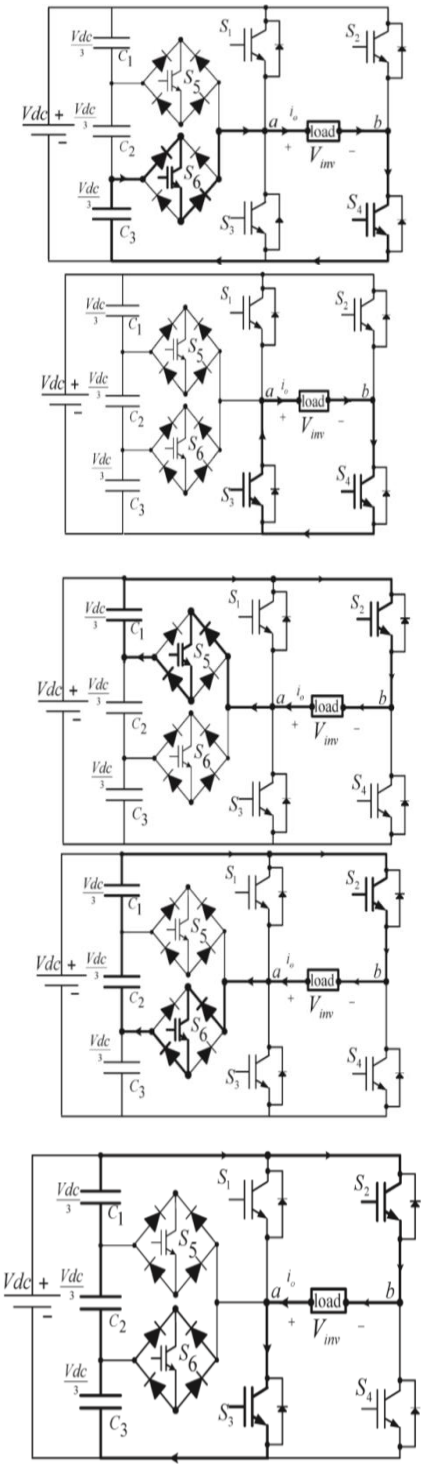

Fig. 2. Switching Pattern.

TABLE 3.1

OUTPUT VOLTAGE ACCORDING TO THE SWITCHES'ON–OFF CONDITION

v_0	S_1	S_2	S_3	S_4	S_5	S_6
V_{dc}	on	off	off	on	off	off
$2V_{dc}/3$	off	off	off	on	on	off
$V_{dc}/3$	off	off	off	on	off	on
0	off	off	on	on	off	off
0*	on	on	off	off	off	off
$-V_{dc}/3$	off	on	off	off	on	off
$-2V_{dc}/3$	off	on	off	off	off	on
$-V_{dc}$	off	on	on	off	off	off

3.3 PWM Modulation

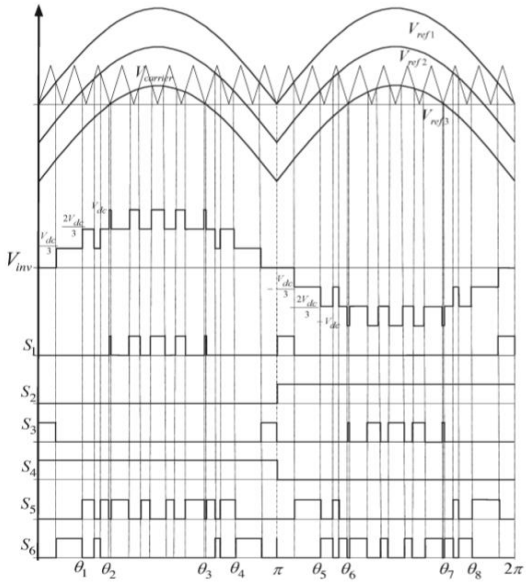

Fig. 3.3. Switching pattern for the single-phase seven-level inverter.

A novel PWM modulation technique was introduced to generate the PWM switching signals. Three reference signals (V_{ref1}, V_{ref2}, and V_{ref3}) were compared with a carrier signal ($V_{carrier}$). The reference signals had the same frequency and amplitude and were in phase with an offset value that was equivalent to the amplitude of the carrier signal. The reference signals were each compared with the carrier signal. If V_{ref1} had exceeded the peak amplitude of $V_{carrier}$, V_{ref2} was compared with $V_{carrier}$ until it had exceeded the peak amplitude of $V_{carrier}$. Then, onward, V_{ref3} would take charge and would be compared with $V_{carrier}$ until it reached zero. Once V_{ref3} had reached zero, V_{ref2} would be compared until it reached zero. Then, onward, Vr_{ef1} would be compared with $V_{carrier}$.

March - April 2020
ISSN: 0193-4120 Page No. 2278 - 2283

Fig. 3.3 shows the resulting switching pattern. Switches S_1, S_3, S_5, and S_6 would be switching at the rate of the carrier signal frequency, whereas S_2 and S_4 would operate at a frequency that was equivalent to the fundamental frequency.

4 Simulation Results

This part discusses about simulation results of seven level inverter (single phase). The dc-bus voltage was set at 900 V ; in this case, Vgrid was 900V peak -peak). Fs=5kHz. Fig. 4 show the MATLAB/Simulink model of the designed system. Figs. 3.5 to 3.8 simulated responses of the designed system.

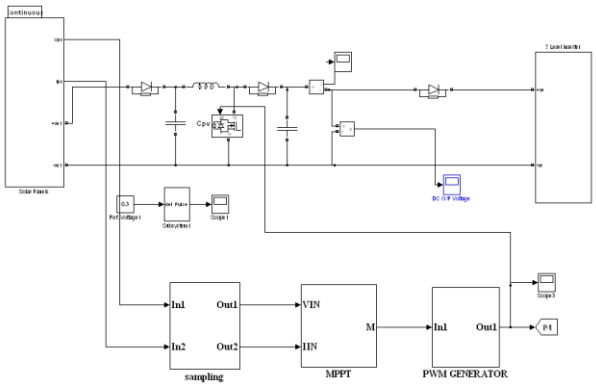

Fig. 4. MATLAB/Simulink model of the single-phase seven-level inverter.

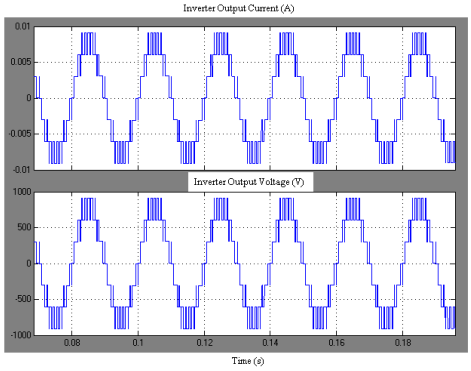

Fig. 5. Simulated response of single-phase seven-level inverter output voltage and current.

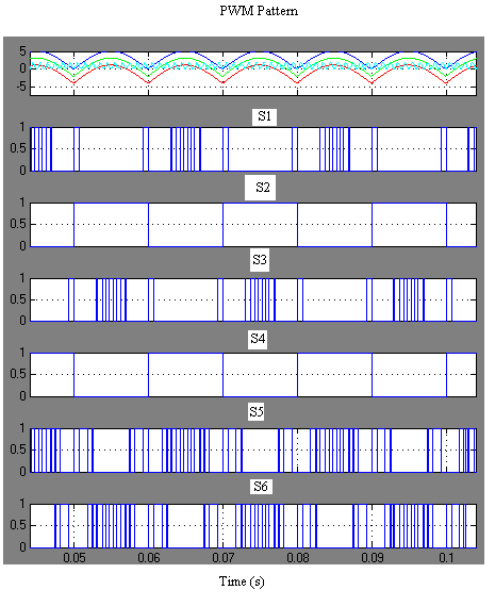

Fig. 6. Simulated response of gating pulse for single-phase seven-level inverter.

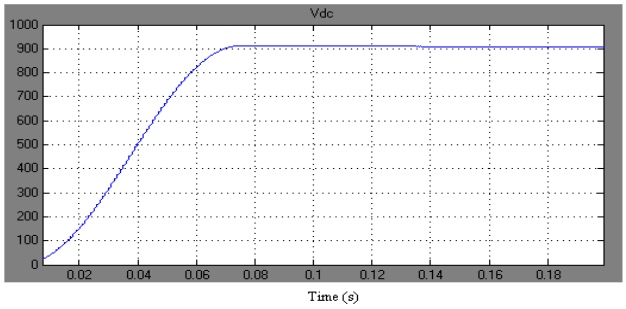

Fig. 7. Simulated response of gating pulse for single-phase seven-level inverter.

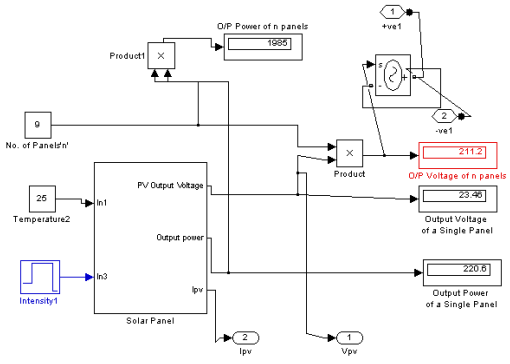

Fig. 8. Simulated response of PV details.

Conclusions

Multilevel inverters (MLI) offer improved output waveforms and lower THD. This work has

presented a novel PWM switching scheme of MLI. It utilizes three reference signals and a triangular carrier signal to generate PWM switching signals. The behaviour of the proposed multilevel inverter was analyzed in detail. By controlling the modulation index, the desired number of levels of the inverter's output voltage can be achieved.

REFERENCES

[1] Zhu. M., Luo.F.L., "Implementing of developed voltage lift technique on SEPIC, CUK and double-output DC–DC converters", *IEEE Trans. Ind. Electron. Appl*., Vol. 23, No. 25, pp. 674–681, 2007.

[2] M. Jinno, P. Y Chen, Y. C. Lai, and K. Harada, "Investigation on the ripple voltage and the stability of synchronous rectifier buck converters with high output current and low output voltage", *IEEE Trans. Ind.Electron.*, Vol. 57, No. 3, pp. 1008-1016, 2010.

[3] J. A. Morales-Saldana, R. Galarza-Quirino, J. Leyva-Ramos, E. E. Carbajal-Gutierrez and M. G. Ortiz-Lopez, "Modeling and control of a cascaded boost converter with a single switch", *IECON 2006 - 32nd Annual Conference on IEEE Industrial Electronics*, pp. 591-596, 2006.

[4] Luo, F.-L., Hong Ye, "Advanced DC/DC converters", CRC Press. London, 2006.

[5] F.J perez-Pinal and I. Cervantes, "Multi-objective control for cascade boost converter with single active switch", *2009 IEEE International Electric Machines and Drives Conference*, pp. 1858-1862, 2009.

[6] F. L. Luo, H. Ye, "Positive output cascade boost converters", in *IEE Proceedings - Electric Power Applications*, Vol. 151, No. 5, pp. 590-606, 2004.

[7] Davood Ghaderi, Mehmet Çelebi, "Implementation of PI controlled cascaded boost power converters in parallel connection with high efficiency", *Journal of Electrical Systems*, Vol. 13, No.2, pp. 307-321, 2017.

[8] Pinaa, P. Ferrãoa, J. Fournierb., B. Laca, "Small signal modeling of a DC-DC type double boost converter integrated with SEPIC converter using state space averaging approach", *Energy Procedia*, Vol. 117, pp. 835-846, 2017.

[9] Wan, X., Zhang, K., Ramkumar, S., Deny, J., Emayavaramban, G., Ramkumar, M. S., & Hussein, A. F. (2019). A Review on Electroencephalogram Based Brain Computer Interface for Elderly Disabled. IEEE Access, 7, 36380-36387.

[10] Sanjeevikumar Padmanaban, Emre Ozsoy, Viliam Fedák and Frede Blaabjerg, "Development of sliding mode controller for a modified boost Cuk converter configuration", *Energies*, Vol.10, No.1513, *2017*.

[11] Ahmed A. A.Hafez, "Multi-level cascaded DC/DC converters for PV applications", *Alexandria Engineering Journal*, Vol.54, No. 4, pp. 1135-1146, 2015.

[12] Ayhan Ozdemir, Zekiye Erdem, "Double-loop PI controller design of the DC-DC boost converter with a proposed approach for calculation of the controller parameters", *Systems and Control Engineering*, Vol. 232, No. 2, pp. 137–148, 2018.

[13] P.Nagaveni, M.Siva RamKumar, M.Nivetha, A.Amudha, G.Emayavaramban , "Electrical Energy Audit –An Experience in a Small Scale Textile Mill" International Journal of Innovative Technology and Exploring Engineering, 8(10) pp 4102-4107

[14] Balachander Kalappan, D., & Ponnusamy, V. (2013). Optimization of Cost of Energy of Real Time Renewable Energy System Feeding Commercial Load Case Study: A Textile Show Room in Coimbatore, India. Life Science Journal, 10(7s).

[15] Wan, X., Zhang, K., Ramkumar, S., Deny, J., Emayavaramban, G., Ramkumar, M. S., & Hussein, A. F. (2019). A Review on Electroencephalogram Based Brain Computer Interface for Elderly Disabled. IEEE Access, 7, 36380-36387.

[16] Sivaram Krishnan, M., Amudha, A., & Siva Ramkumar, M. (2018). Execution Examination Of Three Phase Ac To Three Phase Ac Matrix Converter Using Distinctive Transporter Based Exchanging Algorithms. International journal of Pure and Applied Mathematics, 118(11), 609-617.

[17] Amudha, D. A., Ramkumar, M. S., & Krishnan, M. S. DESIGN AND SIMULATION OF ZETA CONVERTER WITH ZVZCS SWITCHING TECHNIQUE. Journal of Engineering and Applied Sciences, 14(9), 2764-2774.

[18] Ali, M. V. M., Babar, M., Nguyen, P. H., & Cobben, J. F. G. (2017). Overlaying control mechanism for solar PV inverters in the LV distribution network. *Electric Power Systems Research*, *145*, 264-274.

[19] Mawarni, D. E., Ali, M. V. M., Nguyen, P. H., Kling, W. L., & Jerele, M. (2015, September). A case study of using OLTC to mitigate overvoltage in a rural european low voltage network. In *2015*

March - April 2020
ISSN: 0193-4120 Page No. 2278 - 2283

50th International Universities Power Engineering Conference (UPEC) (pp. 1-5). IEEE.

[20] Ali, M. V. M., Nguyen, P. H., & Cobben, J. F. G. (2016, October). Coordinated control to mitigate over voltage and under voltage in LV networks. In *2016 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe)* (pp. 1-5). IEEE.

[21] Ali, M. V. M., Paterakis, N. G., Nguyen, P. H., & Cobben, J. F. G. (2017, June). A LV network overvoltage mitigation strategy based on epsilon-decomposition. In *2017 IEEE Manchester PowerTech* (pp. 1-6). IEEE.

[22] Ali, M. V. M., Nguyen, P. H., & Cobben, J. F. G. (2016, December). Internet of things in LV grids: Framework and experiments. In *2016 Saudi Arabia Smart Grid (SASG)* (pp. 1-5). IEEE.

[23] Viyathukattuva, Mansoor & Amudha, Alagarsamy & Ramkumar, M.Siva & Gopalakrishnan, G Emayavarmban. (2019). Relation between Solar PV Power Generation, Inverter Rating and THD. International Journal of Advanced Manufacturing Technology. 9. 4570-4575.

[24] T. Kalimuthu, M. Siva Ramkumar, Dr.A. Amudha, Dr.K. Balachander and M. Sivaram Krishnan "A High Gain Input-Parallel Output-Series DC/DC Converter with Dual Coupled-Inductors" Journal of Advanced Research in Dynamical and Control Systems, (12), pp 818-824

[25] S. Tamil Selvan, M. Siva Ramkumar, Dr.A. Amudha, Dr.K. Balachander and D. Kavitha "A DC-DC Converter in Hybrid Symmetrical Voltage Multiplier Concept" Journal of Advanced Research in Dynamical and Control Systems, (12), pp. 825-830

[26] M. Jayaprakash, D. Kavitha, M. Siva Ramkumar, Dr.K. Balacahnder and M. Sivaram Krishnan, "Achieving Efficient and Secure Data Acquisition for Cloud-Supported Internet of Things in Grid Connected Solar, Wind and Battery Systems" Journal of Advanced Research in Dynamical and Control Systems, (12), pp 966-981 .

[27] D. Kavitha, M. Siranjeevi, Dr.K. Balachander, M. Siva Ramkumar and M. Sivaram Krishnan "Non Isolated Interleaved Cuk Converter for High Voltage Gain Applications" Journal of Advanced Research in Dynamical and Control Systems, 10(5), pp 1256-1261

[28] S.Vivekanandan, M. Siva Ramkumar, Dr.A.Amudha, M. Sivaram Krishan, D. Kavitha "Design and Implementation of Series Z-Source Matrix Converters" Journal of Advanced Research in Dynamical and Control Systems, 10(5) , pp 1095-1102

[29] N. Eswaramoorthy, Dr.M. Siva Ramkumar, G. Emayavaramban, A. Amudha, S. Divyapriya, M. Sivaram Krishnan, D. Kavitha "A Control Strategy for A Variable Speed Wind Turbine with A Permanent Magnet Synchronous Generator Using Matrix Converter with SVPWM" International Journal of Recent Technology and Engineering, 8(1S4) pp 178-186

[30] P. Jeyalakshmi, Dr.M. Siva Ramkumar, IR.V. Mansoor, A. Amudha, G. Emayavaramban, D. Kavitha, M. Sivaram Krishnan, "Application of Frequency based Matrix Converter in Wind Energy Conversion System Employing Synchronous Generator Using SVPWM Method" International Journal of Recent Technology and Engineering, 8(1S4) pp 187-195

[31] Charles Stephen, .A. Amudha, K. Balachander, .Dr.M. Siva Ramkumar, G. Emayavaramban, IR.V. Manoor, "Direct Torque Control of Induction Motor Using SVM Techniques" International Journal of Recent Technology and Engineering, 8(1S5) pp 196-202

[32] N. Saravanakumar, A. Amudha, G. Emayavaramban, Dr.M. Siva Ramkumar, S. Divyapriya, "Stability Analysis of Grid Integration of Photovoltaic Systems Using Partial Power Converters" International Journal of Recent Technology and Engineering, 8(1S5) pp 203-210

[33] S.Divyapriya, K.T.Chandrasekaran, A.Amudha, Dr.M.Siva Ramkumar, G.Emayavaramban, "Low Cost Residential Micro Grid System based Home to Grid Backup Power Management" International Journal of Recent Technology and Engineering, 8(1S5) pp 303-307

[34] N. Thiyaagarajan, Dr.M. Siva Ramkumar, A. Amudha, G. Emayavaramban, M. Sivaram Krishnan, D. Kavitha, "SVPWM based Control of SCIG-Matrix Converter for Wind Energy Power Conversion System" International Journal of Recent Technology and Engineering, 8(1S5) pp 211-218

[35] N. Seethalakshmi, A. Amudha, S. Divyapriya, G. Emayavaramban, Dr.M. Siva Ramkumar, IR.V. Mohamed Mansoo, "Voltage Frequency Controller with Hybrid Energy Storage System for PMSG Based Wind Energy Conversion System" International Journal of Recent Technology and Engineering, 8(1S5) pp 219-229

[36] G. Suresh, A.Amudha, Dr.M. Siva Ramkumar,G. Emayavaramban, IR.V.Manoor, "Bidding Strategy of Electricity Market Considering Network

Constraint in New Electricity Improvement Environment" International Journal of Recent Technology and Engineering, 8(1S5) pp 230-234

[37] G. Krishnan, M. Siva Ramkumar, A. Amudha, G. Emayavaramban,S. Divyapriya, D. Kavitha, M. Sivaram Krishnan, "Control of A Doubly Fed Induction Generator for Wind Energy Conversion System Using Matrix Converter with SVPWM Technique" International Journal of Recent Technology and Engineering, 8(1S5) pp 235-243

[38] S. Viswalingam, G. Emayavaramban, Dr.M. Siva Ramkumar, A. Amudha, K. Balachander, S. Divyapriya, IR.V. Mohamed Mansoor "Performance Analysis of a Grid Connected PV-Wind with Super Capacitor Hybrid Energy Generation & Storage System" International Journal of Recent Technology and Engineering, 8(1S5) pp 658-666

[39] N.Pandiarajan, G.Emayavaramban, A.Amudha, Dr.M.Siva Ramkumar, IR.V.Mohamed Mansoor, K.Balachander, S.Divyapriya, M..Sivaram Krishnan, "Design and Electric Spring for Power Quality Improvement in PV-Based Dc Grid" International Journal of Recent Technology and Engineering, 8(1S5) pp 242-245

[40] V.Jayaprakash, S.Divyapriya, A.Amudha, G.Emayavaramban,Dr.M.Siva Ramkumar, "Nano - Grid Smart Home With Plug-in Electric Vechicle using a Hybrid Solar-Battery Power Source" International Journal of Recent Technology and Engineering, 8(1S5) pp 246-248

[41] K.T.Chandrasekaran, S.Divyapriya, A.amudha, Dr.M.Siva Ramkumar, G.Emayavaramban, "Modeling and Control of Micro Grid Based Low Price Residential Home to Grid Power Management System" International Journal of Recent Technology and Engineering, 8(1S5) pp 261-265.