South Asian Journal of Engineering and Technology Research Article

Open Access Full Text Article 131(2023) 83-89 DOI: 10.26524/sajet.2023.13.8

MATLAB Simulation of Sinusoidal Pulse Width Modulation based Three and Seven Level Current-Source Inverters

Dr. M.S. Priyadarshini [a*]

[a]Associate Professor, Department of Electrical and Electronics Engineering, K.S.R.M College of Engineering (Autonomous), Kadapa 516005, India

Corresponding author.
Correspondence: Dr. M.S. Priyadarshini
E-mail: **priyadarshini@ksrmce.ac.in**

Article info
Received 28thNovember 2022 Received in revised form 31 December 2023 Accepted 2 January 2023

Keywords
Inverter; Multilevel Inverter; Pulse width Modulation; Sinusoidal pulse width modulation

https://sajet.in/index.php/journal/article/view/253

Abstract
Here, a multilevel current-source inverter (MCSI) topology is analyzed. Here, the issue of constructing a novelmodular single-rating inductor MCSI has been explored. The proposed topology isbuilt with identical modules where all inductors carry the sameamount of current, simplifying the construction and operationof industrial applications with higher efficiency. A new state machine approach with a proper implementation of the phase-shifted carrier-sinusoidal pulse width modulation (PSC-SPWM) allows both current balancein all modules and effective switching-frequency minimization. The performance of the MSCI proposed is simulated with MATLAB. As a result of this topology and PSC-SPWM utilization, current balance was achieved in both main and sharing inductors, even under load and operating point changes. The switching frequency was drastically reduced with a new state machine approach, taking the advantage of the three different zero-states of the topology. The topology adopted allows operation with high efficiency by reducing the current through the inductors and the losses in the switches.

Introduction

The Inverter is an electrical device which converts direct current (DC) to alternate current (AC). The converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. The inverter is used for emergency backup power in a home. The inverter is used in some aircraft systems to convert a portion of the aircraft DC power to AC. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in

computers, to large electric utilityhigh-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries.

Multi-Level Inverter

The Multi-level inverter is used for industrial applications as alternative in high power and medium voltage situations. As the number of levels increases, the synthesized output waveform has more steps, which produces a staircase wave that approaches the desired waveform. In [1,11], design and implementation of power stages of forced commutated current source converter is explained. On state losses and switching losses-based design of devices is presented in [2,13]. In [3,12], it is described that Emitter Turnoff Thyristor (ETO) has a very good storage time dispersion of 100ns and can be further reduced through adjustment of the emitter switch gate resistance. It is evaluated in [4,14] that switching devices based on wide bandgap materials such as silicon carbide (SiC) offer a significant performance improvement on the switch level compared with Si devices. In [5,15], it is presented that the design and experimental analysis of a device, self-powered emitter turn-off thyristor (SPETO) which is high powered and different from the conventional high-power devices. References [6,16] to [10,11] explains about different concepts and topologies related to multilevel inverters.

Sinusoidal pulse width modulation (SPWM)

SPWM or sinusoidal pulse width modulation is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the on and off of the power switches. Here fig.1 represents a three level CSI in which the number of levels in the output current are three. A single module is arranged in order to obtain the three levels in the output level.

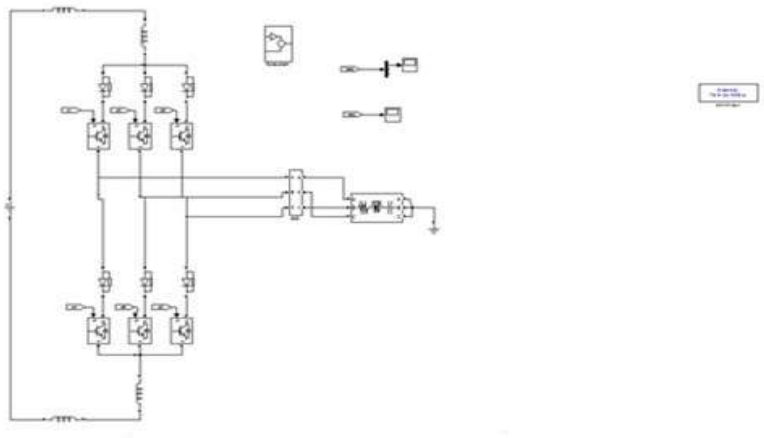

Fig.1 Simulation diagram of three level Current Source Inverter

To generate this signal, triangle wave as a carrier signal is compared with the sinusoidal wave, whose frequency is the desired frequency. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency. The frequency of reference signal determines the inverter output frequency and its peak amplitude controls the modulation index and output voltage. The number of levels n in the output current can be determined according to the number of modules m as, n=2m+1. **T**he three levels in output current are obtained from the number of modules by using the following formula n=2*m+1

Here n is the number of levels in the output current and m is the number of modules

Here m=1; n=2*1+1=2+1=3

Therefore, the number of levels in the output current=3 is obtained by using a single module

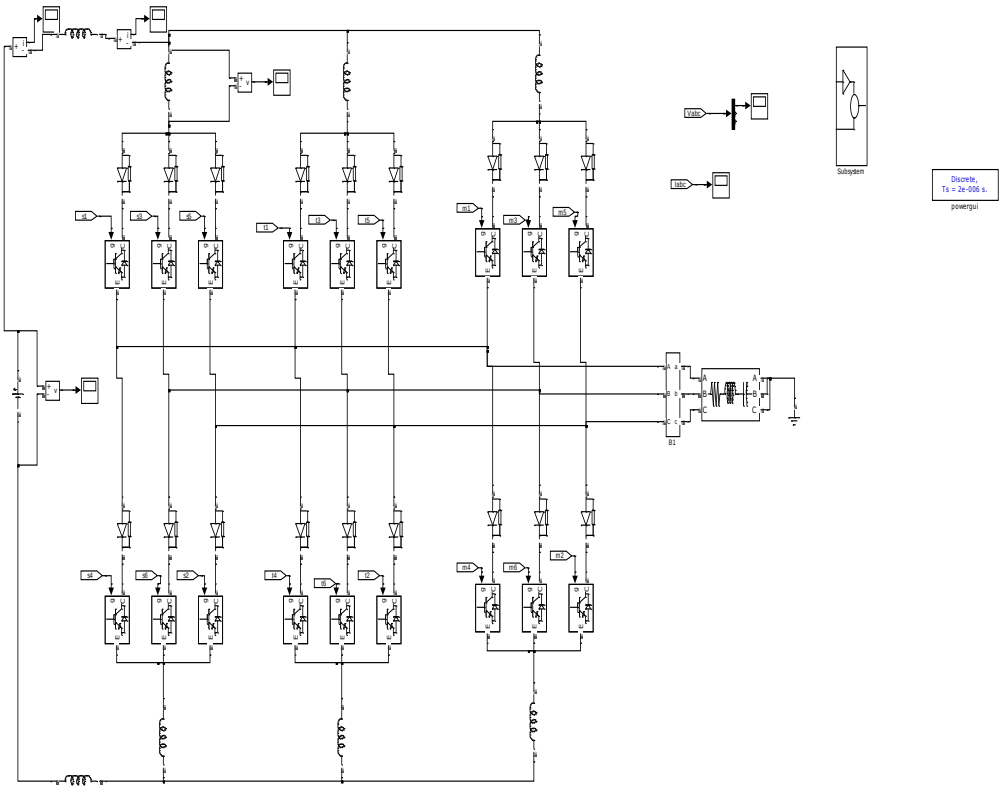

Fig.2 Simulation diagram of Seven level Current Source Inverter

Here fig.2 represents a seven level CSI in which the number of levels in the output current are seven.

In the above figure a three module is arranged in order to obtain the seven levels in the output level.

Here the seven levels in output current are obtained from the number of modules by using the following formula n=2*m+1 with n as the number of levels in the output current and m as the number of modules

Here m=3. So, n=2*3+1=6+1 =7.

Therefore, number of levels in the output current=7.

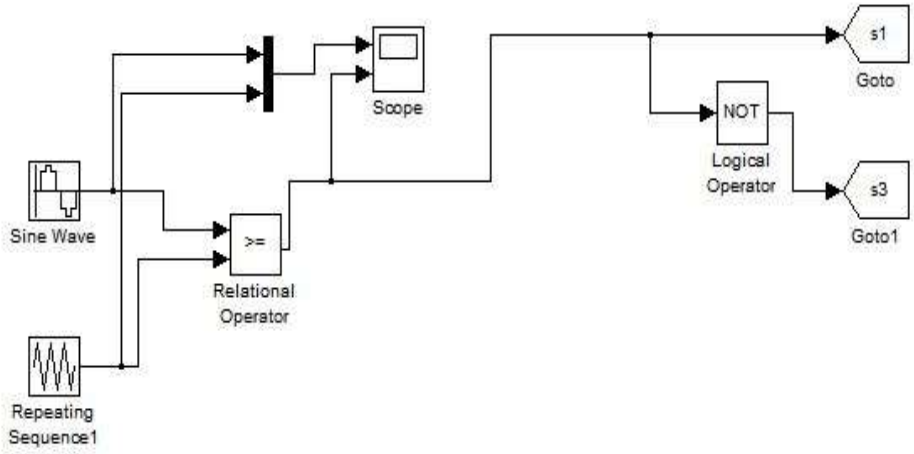

Fig.3 Sinusoidal pulse width modulation used in three and seven level inverters

The above fig.3 represents the sinusoidal pulse width modulation (SPWM) in which a repeating sequence i.e., a triangular carrier is compared with a sine wave and the comparison is carried out by using a logical operator are a relational operator which compare the two signals and produces the required output. Output currents for three and seven level current source inverters are shown in figures 4 and 5.

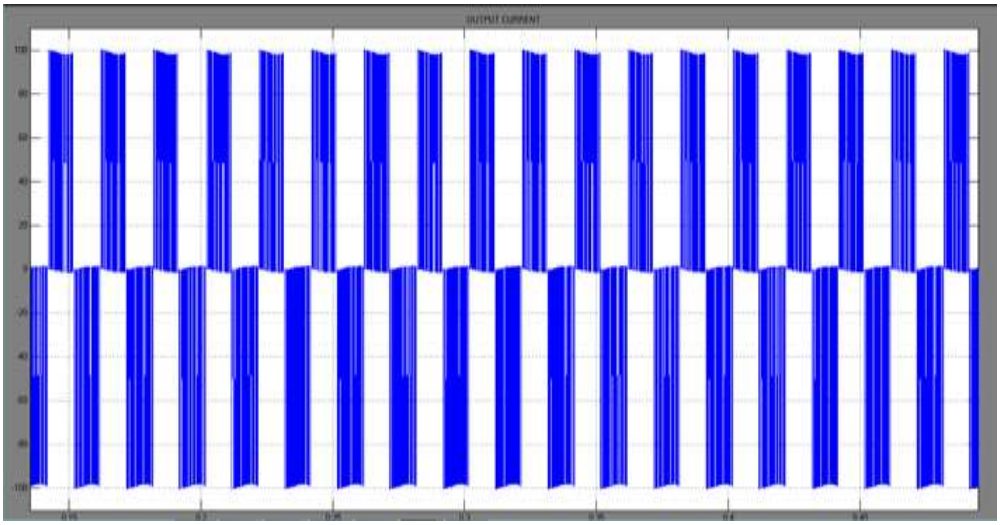

Fig.4 Output current waveform for a three level CSI

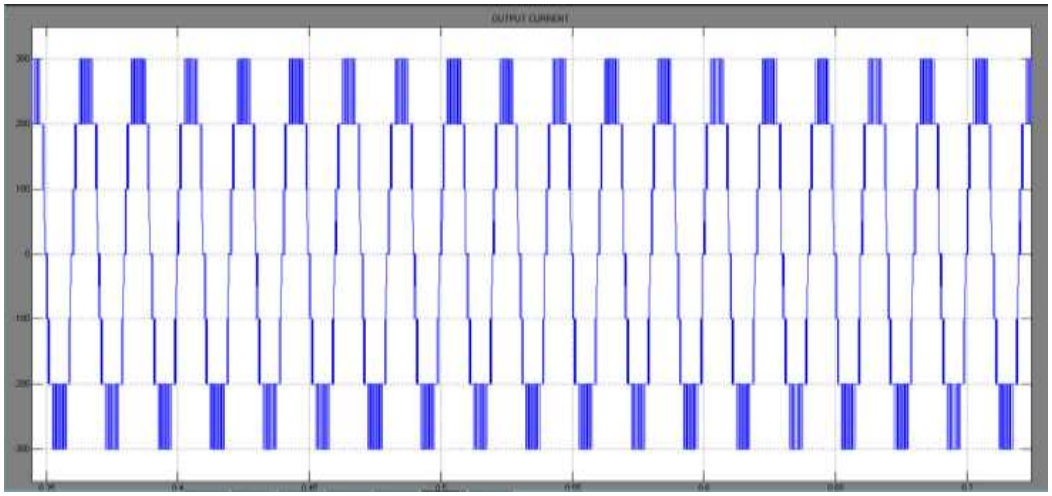

Fig.4 Output current waveform for Seven level CSI

Here Sinusoidal Pulse Width Modulation is comparing the sinusoidal signal and the triangular carrier and required output is generated as shown in fig.5.

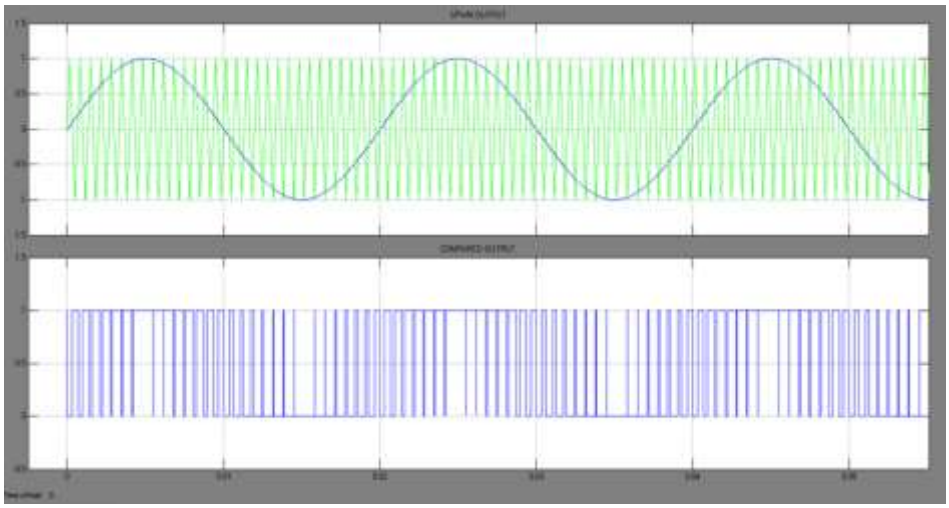

Fig.5 Simulation results of Sinusoidal Pulse Width Modulation (a) Triangular and sinusoidal signals (b) Generated pulses

Conclusion

Multilevel current-source inverter topology is analyzed. Three level and seven level multilevel inverters are simulated in MATLAB environment and output currents are obtained. Sinusoidal pulse width modulation with triangular carrier wave is also depicted. Sinusoidal pulse width modulation allows both current balance in all modules and effective switching frequency minimization. As a result of this topology current balance was achieved for both three level and seven level current source inverters.

References

[1] H. Bilgin and M. Ermis, "Design and implementation of a current-source converter for use in industry applications of D-STATCOM," IEEE Trans.Power Electron., vol. 25, no. 8, pp. 1943–1957, Aug. 2010.

[2] T. Butschen, J. Zimmermann, and R. W. De Doncker, "Development of a dual GCT," in Proc. IPEC, Jun. 21–24, 2010, pp. 1934–1940.

[3] Y. Li, A. Q. Huang, and K. Motto, "Series and parallel operation of the emitter turn-off (ETO) thyristor," IEEE Trans. Ind. Appl., vol. 38, no. 3, pp. 706–712, May/Jun. 2002.

[4] J. Biela, M. Schweizer, S. Waffler, and J. W. Kolar, "SiC versus Si–Evaluation of potentials for performance improvement of inverter and DC–DC converter systems by SiC power semiconductors," IEEE Trans.Ind. Electron., vol. 58, no. 7, pp. 2872–2882, Jul. 2011.

[5] B. Zhang, A. Q. Huang, B. Chen, S. Atcitty, and M. Ingram, "SPETO: A superior power switch for high power, high frequency, low cost converters," in Conf. Rec. 39th IEEE IAS Annu. Meeting, Oct. 3–7, 2004, vol. 3, pp. 1940–1946.

[6] B. P. McGrath and D. G. Holmes, "Natural current balancing of multi cell current source converters," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1239–1246, May 2008.

[7] J. Rodriguez, L. G. Franquelo, S. Kouro, J. I. Leon, R. C. Portillo, M. A. M. Prats, and M. A. Perez, "Multilevel converters: An enabling technology for high-power applications," Proc. IEEE, vol. 97, no. 11, pp. 1786–1817, Nov. 2009.

[8] M. P. Kazmierkowski, L. G. Franquelo, J. Rodriguez, M. A. Perez, and J. I. Leon, "High-performance motor drives," IEEE Ind. Electron. Mag., vol. 5, no. 3, pp. 6–26, Sep. 2011.

[9] S. Kouro, M. Malinowski, K. Gopakumar, J. Pou, L. G. Franquelo, B.Wu, J. Rodriguez, M. A. Perez, and J. I. Leon, "Recent advances and industrial applications of multilevel converters," IEEE Trans. Ind. Electron., vol. 57, no. 8, pp. 2553–2580, Aug. 2010.

[10] J. Bao, W. Bao, Z. Zhang, and W. Fang, "A simple current-balancing method for a three-phase 5-level current-source inverter," in Proc. 35thIEEE IECON, Nov. 3–5, 2009, pp. 104–108.

[11]Sivakumar, S.A., Naveen, R., Ibrahim, S.J.A. et al. Two-ways chip to chip communications through 2-dimensional photonic structures via photonic integrated circuit. Opt Quant Electron 55, 661 (2023). https://doi.org/10.1007/s11082-023-04941-3

[12] Verma, P., Jyoti, K., Sahni, V. et al. Synthesized feature learning model on news aggregator for chatbot. Soft Comput (2023). https://doi.org/10.1007/s00500-023-08069-0.

[13] Chinnappan, C.V.; John William, A.D.; Nidamanuri, S.K.C.; Jayalakshmi, S.; Bogani, R.; Thanapal, P.; Syed, S.; Venkateswarlu, B.; Syed Masood, J.A.I. IoT-Enabled Chlorine Level Assessment and Prediction in Water Monitoring System Using Machine Learning. Electronics 2023, 12, 1458. https://doi.org/10.3390/electronics12061458

[14] N. Krishnaraj, R. Vidhya, R. Shankar and N. Shruthi, "Comparative Study on Various Low Code Business Process Management Platforms," 2022 International Conference on Inventive Computation Technologies (ICICT), Nepal, 2022, pp. 591-596, doi: 10.1109/ICICT54344.2022.9850581.

[15] J. Ramprasath, N. Krishnaraj & V. Seethalakshmi (2022) Mitigation Services on SDN for Distributed Denial of Service and Denial of Service Attacks Using Machine Learning Techniques, IETE Journal of Research, DOI: 10.1080/03772063.2022.2142163

[16] Natarajan Krishnaraj, Chirag Madaan, Sanjana Awasthi , Raggav Subramani , Harsh Avinashand Sankalp Mukim Common vulnerabilities in real world web applications, doors-2023: 3rd Edge Computing Workshop, April 7, 2023, Zhytomyr, Ukraine