International Journal of Advances in Applied Sciences (IJAAS)
Vol. 14, No. 3, September 2025, pp. 751~760
ISSN: 2252-8814, DOI: 10.11591/ijaas.v14.i3.pp751-760

An innovative design and development of multilevel inverter for a wind energy conversion system

Rosaiah Mudigondla, Thiruveedula Madhu Babu, Supriya Dachepalli, Anudeep Punjala, Md Yousuf Ali, Bakam Anirudh
Department of Electrical and Electronics Engineering, Teegala Krishna Reddy Engineering College, Hyderabad, India

Article Info

Article history:

Received Nov 11, 2024
Revised May 14, 2025
Accepted Jun 8, 2025

Keywords:

Multilevel inverter
Permanent magnet synchronous generator
Shifted carrier–pulse width modulation
Total harmonic distortion
Wind power generation

ABSTRACT

The drawbacks of fossil fuel-based energy sources, including high costs, pollution, scarcity, and environmental damage, highlight how urgent it is to switch to renewable energy sources. Multilevel inverters (MLIs) are currently required for the production of wind electricity. In this research, to get a reduced harmonic distortion, use 31-level inverter based on shifted carrier-pulse width modulation (SC-PWM) is developed for wind power generation using MATLAB/Simulink. It aids in minimizing the total harmonic distortion (THD) to 3.20, and the output voltage is enhanced by the suggested MLI. Wind energy extraction is optimized by combining with a proportional integral derivative (PID) control system. MATLAB/Simulink has been used to make sure the MLI structure and look into the implementation of wind energy conversion systems using a permanent magnet synchronous generator (PMSG). In order to show that the suggested inverter architecture improves power conversion efficiency and stability in renewable energy systems, the study also examines power efficiency, system dependability, and the viability of large-scale applications. Additionally, the study investigates grid integration, modulation strategies, and switching losses to guarantee increased sustainability, dependability, and efficiency in wind energy applications while lowering operating costs.

Corresponding Author:

Rosaiah Mudigondla
Department of Electrical and Electronics Engineering, Teegala Krishna Reddy Engineering College
Meerpet, Medbowli, Hyderabad 500097, India
Email: rosaiah0228@gmail.com

1. INTRODUCTION

System engineers find it difficult to integrate the power supplied by wind turbines with the current power system. Wind power integration with the current system requires power electronic converters, which have an impact on the consumer's power quality. Power quality may be impacted by total harmonic distortion (THD), which can be produced when power electronic converters are added to the current system to integrate wind power. Therefore, it is essential to guarantee that the system operator will provide the customer with high-quality power. The most cost-effective distributed energy generation option is wind energy [1], [2]. For improved frequency and voltage regulation, conversion systems primarily use the double-fed induction generator (DFIG) [3] and permanent magnet synchronous generator (PMSG) [4] types of generators. Power electronics play a part in improving the efficiency of wind energy conversion and use [5]. Compared to the traditional voltage source inverter (VSI), multilevel inverters (MLIs) have been recognized for their capacity to manufacture high-quality output voltages coupled to reduced distortion and low blocking voltages of semiconductors in standalone wind energy conversion systems [6]. A new MLI topology for solar applications was created in [7] utilizing an H-bridge inverter and a DC link capacitor, which has been shown to result in fewer switches. Boosting power quality and compensating for reactive power by using an active power filter. A series active power filter (SAPF) is used particularly to equalize for voltage distortions such as sags, flickers, and notches, and to lower harmonics in low and medium-voltage electrical systems. SAPF reduces THD by injecting voltage enters the line to lessen distortions [8]. To create an AC voltage with minimal THD and power loss, a bridge inverter receives a DC voltage in the form of a staircase that roughly resembles the reinstated structure of a prescribed sinusoidal wave. The bridge inverter then switches the polarity [9]. Palani *et al.* [10] present a new cascaded multilayer inverter design that significantly reduces the number of switches and DC voltage sources. The cross-switched MLI is coupled to a switched-capacitor circuit, which further increases the input voltage while lowering it. The assortment of power supply and switching devices [11]. Reduced detached DC sources have been employed with series-connected capacitor-clamped MLI [12]. A novel optimal construction for MLI is suggested, which uses a lower blocking voltage capability and produces large voltages with fewer switches [13]. A comparison between a symmetric hybrid MLI that uses a customized H-bridge inverter and an asymmetric seventeen-level switching capacitor MLI has been made [14]. It has been suggested to use switching capacitors of the MLI type to increase the converter's capacity [15]. It is explained how to use a cascaded H-bridge MLI as a distribution static compensator (DSTATCOM) with a proportional-integral (PI) controller to lower source current harmonics in the distribution system [16]. In addition to compensating reactive power, the PI controller lowers source current harmonics and keeps the distribution system's power factor at unity.

A multi-phase generator, a passive rectifier, a modular medium-frequency transformer-based converter, and a current source converter (CSC) are the components of a new CSC-based wind energy conversion system that has been presented [17]. Alskran and Simoes [18] provide a thorough explanation of how modular multilevel converters (MMCs) work in general. It demonstrates that an MMC can function in normal, step-down, or step-up modes by adjusting the arm DC component. When compared to previous voltage lift methods like super lift converters and classical boost converters, ultra-lift converters produce extremely high output transfer gains with geometric growth. Comparatively speaking, it also offers better efficiency and a smaller size. Continuous conduction mode is used to analyze the operation of ultra-lift converters [19]. In order to analyze and evaluate the performance of a wind energy conversion system, a wind turbine emulator (WTE) was designed and developed [20]. Sandeep *et al.* [21] provide a better model of a grid-connected wind power system (GCWPS) that uses artificial intelligence for control and is powered by a PMSG. It recruits two voltage source converters (VSC) based on insulated-gate-bipolar-transistor (IGBT); one is associated with the grid (inverter), and the other is correlated to the generator (rectifier).

Hong and Chen *et al.* [22] present sophisticated control methods based on an adaptive neuro-fuzzy inference system (ANFIS) are presented for optimal grid deployment of photovoltaics (PV) and wind energy in renewable energy systems. Maximizing the use of renewable energy, improving power management, and improving grid stability are the goals of the ANFIS control. ELmorshedy *et al.* [23] explain how to operate a PMSG wind energy conversion system on its own. Regarding certain working circumstances, such as wind-speed variation, load variation, in disproportionate circumstances, the control approach that is being described seeks to regulate the load voltage in magnitude and frequency. A disadvantage of the power converters employed in PMSG systems is that the lower energy generation region is restricted by the conventional inverter's worse DC bus utilization at minimum rates of wind. The generating system's lower limit is determined by the converters' pulse width modulation (PWM) algorithms, architecture, and rating. For the grid side converter, a new dual-level inverter-based architecture is proposed in [24] in order to increase DC bus utilization. Atifi *et al.* [25] resolved the issue of controlling the connection between the electrical grid and a wind system that uses a PMSG.

This study proposes and designs an MLI configuration based on shifted carrier pulse width modulation (SC-PWM) for windmill applications. The performance of the suggested MLI is analyzed using the SC-PWM approach. The output voltage can be improved, and THD can be decreased using the SC-PWM approach. Although the conversion efficiency of renewable energy sources is not as high as that of traditional energy sources, technology is constantly being improved to increase its efficiency to above 90%. Wind power plants generate electricity at a relatively lower cost than other methods of generation. A lot of major utility-scale wind power plants are assembled in a year. Among the several subsections of a wind energy conversion system, the generator type is the most crucial. Self-excited induction generators (SEIG), DFIG, and PMSG are among the various generator types that are employed.

2. MULTILEVEL INVERTER

MLI are advanced power conversion devices that produce output voltages with multiple discrete levels, improving waveform frequency versus traditional two-level inverters. Figure 1 implies a basic MLI schematic diagram. They achieve this by stacking several voltage levels using series-connected power semiconductor devices. By employing SC-PWM, these inverters synthesize a staircase-like output waveform that closely resembles a sinusoidal shape. This configuration reduces THD, resulting in cleaner power delivery and enhanced efficiency. An essential method for improving output waveform quality and lowering harmonic distortion in inverters, especially MLI, is SC-PWM.

Furthermore, MLI allows for lower voltage ratings and greater dependability by distributing voltage stress among several components. Applications, including electric cars, industrial motor drives, and renewable energy systems, make extensive use of them. They are crucial to contemporary power electronics because of their capacity to produce excellent power quality and effective energy conversion.

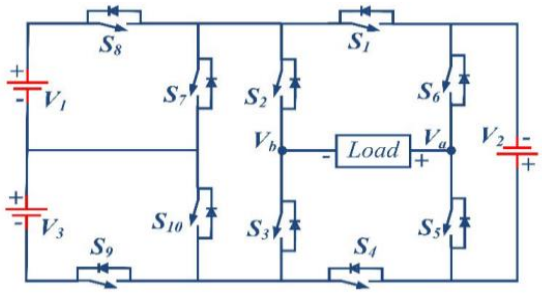

Figure 1. Basic MLI schematic diagram

3. WIND POWER ENERGY

A wind turbine model in Simulink consists of a wind input block to simulate varying wind conditions, a turbine model to convert wind energy into mechanical power, and a generator (synchronous or DFIG) to produce electrical power. Figure 2 depicts a block diagram of wind energy. A primary proportional integral derivative (PID) controller adjusts the blade pitch angle to regulate speed and maximize power output. Additional components, like power conversion and grid synchronization, can be included for grid-tied setups. Together, these components simulate dynamic wind turbine operations in varying conditions. Every subsystem wind, mechanical, generator, and controller is constructed and linked using the appropriate blocks in Simulink. In order to replicate genuine turbine behavior, simulation parameters such as initial circumstances, wind fluctuations, and tuning settings are set up.

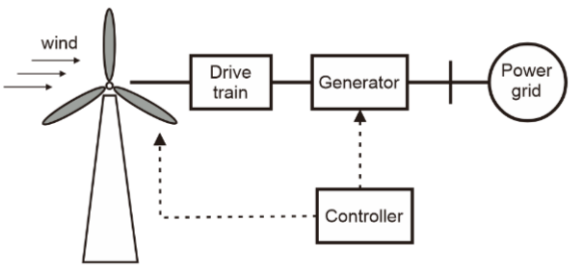

Figure 2. Basic block diagram of wind energy

3.1. Permanent magnet synchronous generator modeling

The circuit diagram for the working generator is shown in Figure 3. The flexible equation associated with the generating kind of maneuver can be stated mathematically as (1).

$$V_t = E_r - I_a(R_a + jX_L) \tag{1}$$

For each machine phase, X_L is the leakage reactance in series with the resistance between the terminal voltage and air gap e.m.f., and R_a is the machine resistance.

The model for PMSG is shown in Figure 3. A sinusoidal back e.m.f., negligible eddy current and hysteresis losses, and no dissemination are assumed by this dynamic model. Iron losses are taken into consideration, and the dynamic equations for the PMSG currents as in (2)-(7).

$$\frac{di_{md}}{dt} = \frac{1}{l_d}\left(v_d - R_{st}i_d + \omega L_q i_{mq}\right) \quad (2)$$

$$\frac{di_{mq}}{dt} = \frac{1}{L_d}\left(v_q - R_{st}i_q + \omega L_q i_{md} - \omega\varphi_{PM}\right) \quad (3)$$

$$i_d = \frac{1}{R_c}\left(L_d\frac{di_{md}}{dt} - \omega L_q i_{mq} + R_c i_{md}\right) \quad (4)$$

$$i_q = \frac{1}{R_c}\left(L_q\frac{di_{mq}}{dt} + \omega L_d i_{md} + \omega\varphi_{PM} + R_c i_{mq}\right) \quad (5)$$

$$i_{cd} = i_d - i_{md} \quad (6)$$

$$i_{cq} = i_q - i_{mq} \quad (7)$$

Where the d_q axes currents are denoted by i_d and i_q, the iron losses currents by i_{cd} and i_{cq}, the magnetising currents by i_{md} and i_{mq}, the d_q axes inductances by L_d and L_q, and the d_q axes voltages by v_d and v_q. If φ_{PM} is the mutual flux caused by magnets, then R_c is the resistance to iron losses and R_{st} is the resistance of the stator. The equation for the PMSG's electromagnetic torque as in (8).

$$T_e = \frac{2}{3}p[\varphi_{PM}i_{mq} + (L_d - L_q)i_{md}i_{mq}] \quad (8)$$

Where the symbol p represents the value of pole pairs.

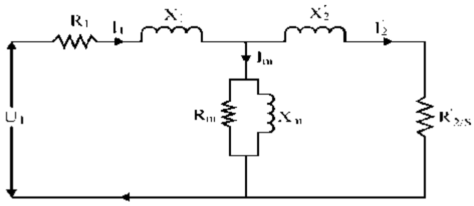

Figure 3. Circuit diagram of PMSG

4. MODULATION TECHNIQUE

The SC-PWM inquiry takes note of the technique; the SC-PWM waveform is displayed in Figure 4. For modulating each cell independently, bipolar and sinusoidal PWM are taken into consideration. The reference voltage signal is constantly compared with each cell of the shifted carrier signal. For every full bridge inverter in a multilayer phase leg, a 180° phase shift is introduced. This method's capacity to drastically reduce THD, which results in cleaner electricity and increased efficiency, is one of its main advantages. SC-PWM is also suitable for motor drives, renewable energy systems, and other high-performance applications since it may be used in a variety of topologies, such as cascaded MLIs.

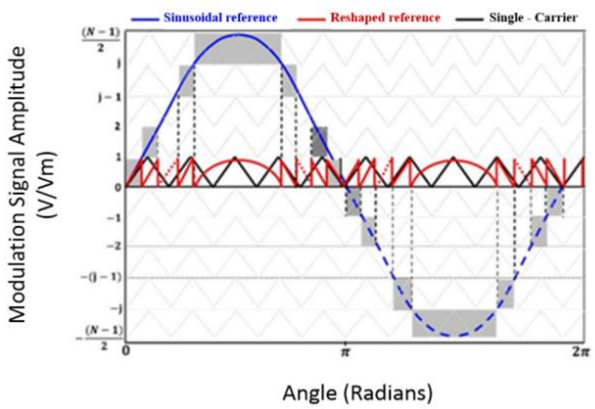

Figure 4. SC-PWM

The SC-PWM signal waveform is displayed in Figure 5. The n-level inverter generates the n-1 phase-shifted carrier signal. Simulations are run, and a 31-level inverter is designed. The following is their operating procedure, which takes into account the SC-PWM technique.

- n=level of the inverter.
- N-1. i.e., The arrangement is four carrier waveforms. The full bridge inverter's carriers are chosen with a 90° phase shift.
- The converter changes to +Vdc if the reference goes over all of the carrier wave forms.
- The converter converts to Vdc/2 if the context is more than all other carriers and lower than the highest carrier waveform.
- The converter flips to 0 if the reference is more than two lowermost carriers and less than the two largest carrier patterns of waves.
- This causes the converter to switch to -Vdc/2 if the reference has been elevated above the lowest carrier and lower than any other carrier.
- The converter changes to -Vdc if the reference is less than all carriers.

Particularly in MLIs or modular converters, phase-shifted PWM waveforms are achieved through the use of shifted carrier signal production. This technique entails producing a number of high-frequency carrier signals, usually uniformly distributed over the number of carriers, each phase-shifted by a particular angle.

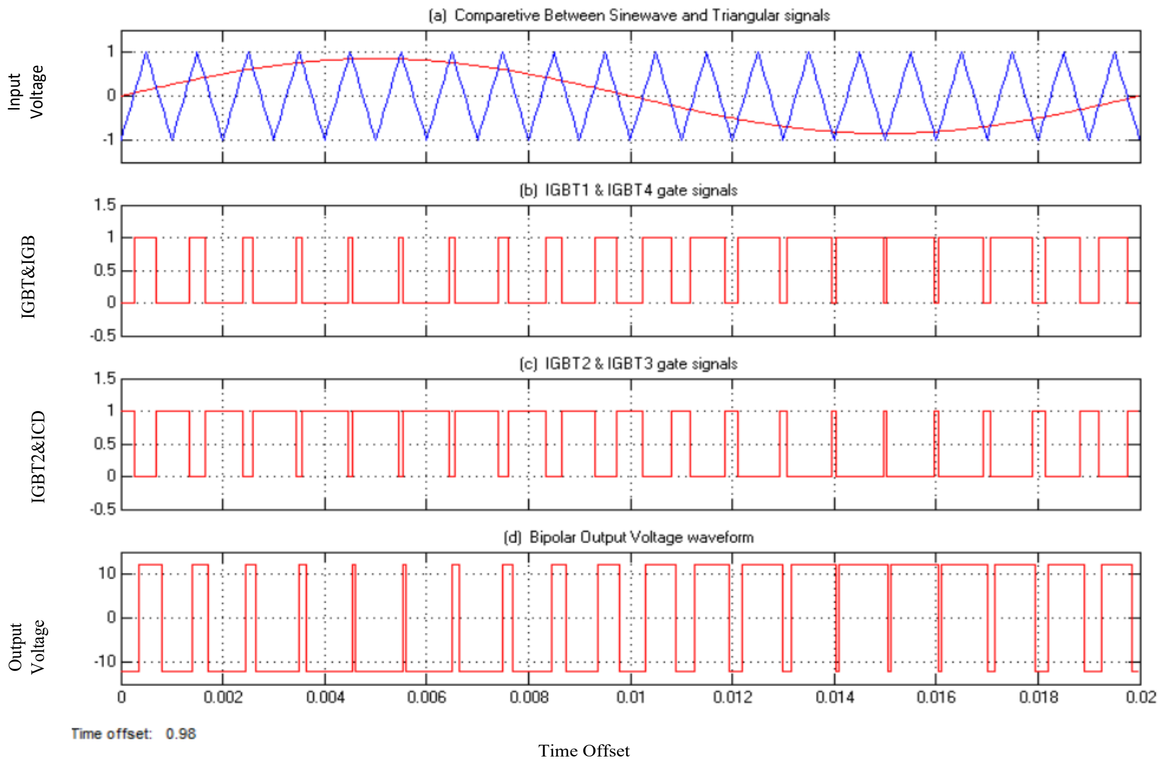

Figure 5. SC-PWM generation of signal

The phase shifting of the carrier frequency as in (9).

$$P_{cr} = \frac{(S-1)\pi}{n} \quad (9)$$

Where, S=S^{th} bridge, n=Number of inverters.

$$n = \frac{(P-1)}{2} \quad (10)$$

In each phase leg, P is the quantity of switched DC levels that can be obtained. The power cell's output voltage is determined by (11)-(13).

$$V_{oi} = \frac{1}{T_{cr}} * \int V_{oi}\,(t)dt \quad (11)$$

$$V_{oi} = \frac{T_{on}}{T_{cr}} * V_{dc} \quad (12)$$

$$V_{oi} = V \quad (13)$$

5. SIMULATION RESULTS AND DISCUSSION

At the turbine speed, the maximum turbine power is 12 m/s. Figures 6 and 7 represent the output voltage and current waveforms of the wind energy, respectively, at their maximum levels. Figures 8 and 9 display the PMSG speed and torque characteristics of the wind power plant as specified by wind turbine specifications. The output voltage simulation results at level 31 are shown in Figure 10. In contrast to the asymmetrical input voltage of 1,500 V, the output voltage is 1,691 V, suggesting an increase in output voltage. This approach used the wind power converter system. The SC-PWM technique yields a lower THD value of 3.20%, this value is less compared with other existing methods. The THD value of the suggested 31 level of MLI linked to wind power generation is shown in Figure 11.

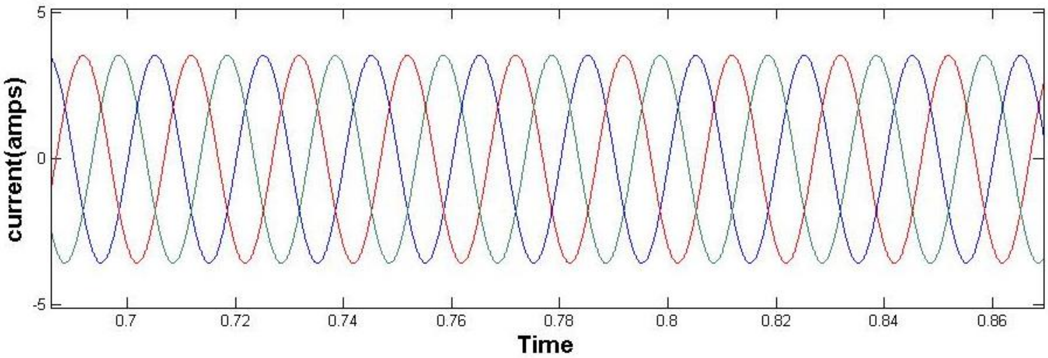

Figure 6. Windmill output current

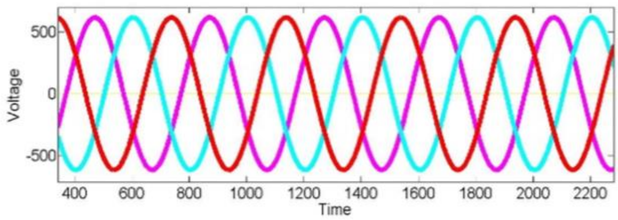

Figure 7. Windmill output voltages

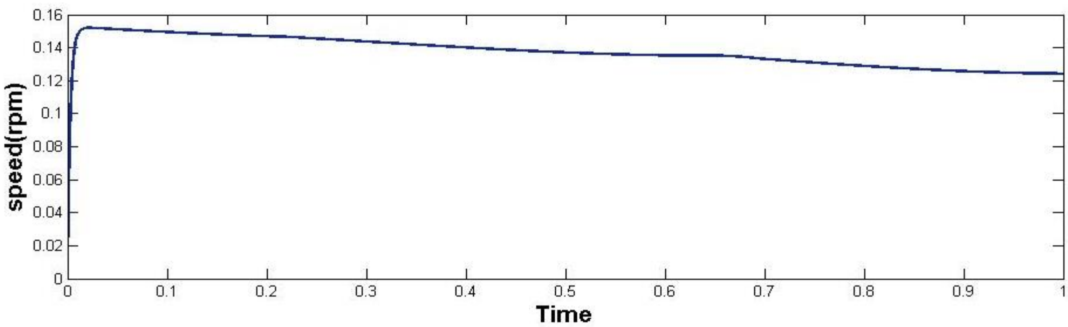

Figure 8. PMSG speed

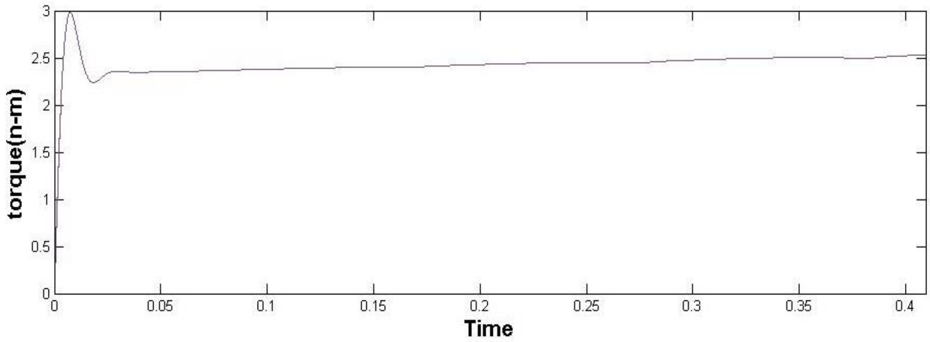

Figure 9. PMSG torque

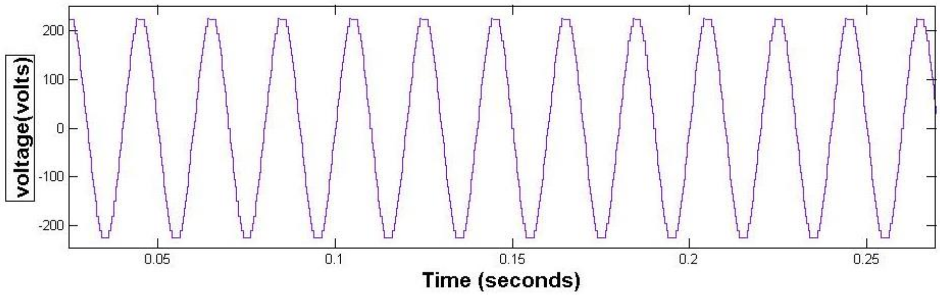

Figure 10. 31-level output voltage waveform

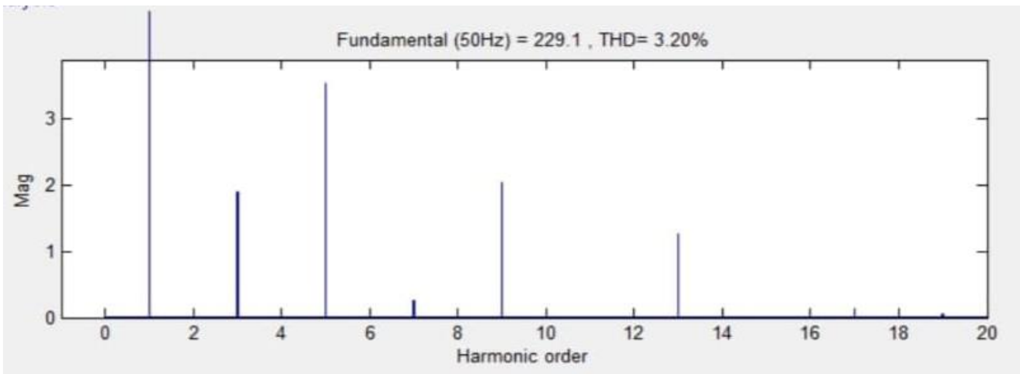

Figure 11. Harmonic voltage spectrum

6. CONCLUSION

Improved performance in terms of lowering THD value of 3.20 for a 31-level inverter linked to a wind mill using the SC-PWM approach. This simulation output gives 31 increasing and decreasing levels, which helps in reducing the THD value and obtaining the sinusoidal waveform as the output. The control approach that was implemented demonstrated a significant improvement in both system efficiency and output power. PMSG and converter components are included in the suggested model, which can be used to research and evaluate the fundamentals of wind energy generation. The MLI structure is deemed suitable for recruits for sustainable energy sources based on the results. Furthermore, we may decrease THD by increasing the number of levels of inverters using various techniques and deploying renewable energy alternatives such as solar, hybridized systems.

FUNDING INFORMATION

This research was funded by Teegala Krishna Reddy Engineering College.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Rosaiah Mudigondla	✓	✓		✓	✓	✓	✓			✓		✓	✓	✓
Thiruveedula Madhu Babu	✓	✓		✓	✓	✓	✓			✓		✓	✓	✓
Supriya Dachepalli	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Anudeep Punjala	✓			✓	✓		✓	✓	✓		✓	✓	✓	✓
Md Yousuf Ali	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓
Bakam Anirudh	✓		✓	✓		✓	✓	✓		✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are openly available in [Iranian Journal of Science and Technology] at doi: 10.1007/s40998-023-00661-2, reference number [10].

REFERENCES

[1] V. Krishnakumar, P. Anbarasan, J. Pradeep, and M. Vijayaragavan, "Modified dual input dual output DC-DC converter for bladeless wind energy harvesting system," in *2021 12th International Symposium on Advanced Topics in Electrical Engineering*, IEEE, 2021, pp. 1–6. doi: 10.1109/ATEE52255.2021.9425186.

[2] Y. Zhang, X. Yuan, and X. Wu, "Analysis of the medium-frequency oscillation issue in a medium-voltage high-power wind energy conversion system," *IEEE Transactions on Industrial Electronics*, vol. 66, no. 9, pp. 7043–7054, 2019, doi: 10.1109/TIE.2018.2878118.

[3] P. S. Barendse and P. Pillay, "A doubly-fed induction generator drive for a wind energy conversion system," *SAIEE Africa Research Journal*, vol. 97, no. 4, pp. 274–280, 2006, doi: 10.23919/saiee.2006.9487880.

[4] J. Hui, A. Bakhshai, and P. Jain, "An energy management scheme with power limit capability and an adaptive maximum power point tracking for small standalone PMSG wind energy systems," *IEEE Transactions on Power Electronics*, vol. 13, no. 3, pp. 1–1, 2015, doi: 10.1109/TPEL.2015.2478402.

[5] H. Liu, M. S. A. Dahidah, J. Yu, R. T. Naayagi, and M. Armstrong, "Design and control of unidirectional DC–DC modular multilevel converter for offshore DC collection point: theoretical analysis and experimental validation," *IEEE Transactions on Power Electronics*, vol. 34, no. 6, pp. 5191–5208, 2019, doi: 10.1109/TPEL.2018.2866787.

[6] M. Malik and P. R. Sharma, "Power quality improvement in hybrid photovoltaic and wind power system using 3 levels inverter," in *2020 International Conference on Advances in Computing, Communication and Materials*, IEEE, 2020, pp. 253–260. doi: 10.1109/ICACCM50413.2020.9212821.

[7] V. Arun, P. Sundaramoorthy, and B. Shanthi, "A dual DC link novel nine-level inverter (N9LI) with reduced components and on-state switches," *IEEE Canadian Journal of Electrical and Computer Engineering*, pp. 1–10, 2025, doi: 10.1109/ICJECE.2023.3273283.

[8] T. Madhubabu, A. Anireddy, N. Sahithi, K. S. K. Suman, S. Vikas, and K. Chenchireddy, "Reduction of harmonics to improve power quality in distribution lines using a series active power filter," in *2023 7th International Conference on Trends in Electronics and Informatics*, IEEE, Apr. 2023, pp. 123–128. doi: 10.1109/ICOEI56765.2023.10126006.

[9] D. P. Garapati, V. Jegathesan, and M. Veerasamy, "Minimization of power loss in newfangled cascaded H-bridge multilevel inverter using in-phase disposition PWM and wavelet transform based fault diagnosis," *Ain Shams Engineering Journal*, vol. 9, no. 4, pp. 1381–1396, 2018, doi: 10.1016/j.asej.2016.09.008.

[10] A. Palani *et al.*, "A novel design and development of multilevel inverters for parallel operated PMSG-based standalone wind energy conversion systems," *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, vol. 48, no. 1, pp. 277–287, Mar. 2024, doi: 10.1007/s40998-023-00661-2.

[11] L. Nanda, C. Jena, B. Panda, and A. Pradhan, "A cross-connected switch capacitor multilevel inverter: a proposed topology and its analysis," in *Recent Trends in Communication and Intelligent Systems*, Singapore: Springer, 2022, pp. 45–54. doi: 10.1007/978-981-19-1324-2_6.

[12] A. Dekka, O. Beik, and M. Narimani, "Modulation and voltage balancing of a five-level series-connected multilevel inverter with reduced isolated direct current sources," *IEEE Transactions on Industrial Electronics*, vol. 67, no. 10, pp. 8219–8230, 2020, doi: 10.1109/TIE.2019.2949537.

[13] S. Laali, K. Abbaszadeh, and H. Lesani, "A new algorithm to determine the magnitudes of DC voltage sources in asymmetric cascaded multilevel converters capable of using charge balance control methods," in *2010 International Conference on Electrical Machines and Systems*, 2010, pp. 56–61.

[14] C. Dhanamjayulu and S. Meikandasivam, "Implementation and comparison of symmetric and asymmetric multilevel inverters for dynamic loads," *IEEE Access*, vol. 6, pp. 738–746, 2017, doi: 10.1109/ACCESS.2017.2775203.

[15] H. K.-Jahan *et al.*, "Switched capacitor based cascaded half-bridge multilevel inverter with voltage boosting feature," *CPSS Transactions on Power Electronics and Applications*, vol. 6, no. 1, pp. 63–73, 2021, doi: 10.24295/CPSSTPEA.2021.00006.

[16] T. M. Babu, K. Chenchireddy, K. Sreevarsha, B. Praveen, T. Mohammad, and G. Kashinadh, "CHBMLI based DSTATCOM for power quality improvemt in a three-phase three-wire distribution system with PI controller," *International Journal of Advances in Applied Sciences*, vol. 13, no. 2, Jun. 2024, doi: 10.11591/ijaas.v13.i2.pp325-332.

[17] L. Xing, Q. Wei, and R. Li, "An improved current source converter-based series-connected wind energy conversion system," *IEEE Transactions on Industrial Electronics*, vol. 71, no. 5, pp. 4818–4829, 2024, doi: 10.1109/TIE.2023.3283700.

[18] F. Alskran and M. G. Simoes, "Step-up modular multilevel converters for transformerless grid connection of large wind turbines," in *2018 IEEE Texas Power and Energy Conference*, IEEE, 2018, pp. 1–6. doi: 10.1109/TPEC.2018.8312101.

[19] T. M. Babu, K. Chenchireddy, J. Rohini, and M. S. Suhas, "High voltage DC-DC converter with standalone application," *International Journal of Applied Power Engineering*, vol. 12, no. 4, pp. 384–390, 2023, doi: 10.11591/ijape.v12.i4.pp384-390.

[20] A. Hazzab, H. Gouabi, M. Habbab, M. Rezkallah, H. Ibrahim, and A. Chandra, "Wind turbine emulator control improvement using nonlinear PI controller for wind energy conversion system: design and real-time implementation," *International Journal of Adaptive Control and Signal Processing*, vol. 37, no. 5, pp. 1151–1165, May 2023, doi: 10.1002/acs.3566.

[21] V. Sandeep, B. M. Krishna V., K. K. Namala, and D. N. Rao, "Grid connected wind power system driven by PMSG with MPPT technique using neural network compensator," in *2016 International Conference on Energy Efficient Technologies for Sustainability*, IEEE, Apr. 2016, pp. 917–921. doi: 10.1109/ICEETS.2016.7583879.

[22] C.-M. Hong and C.-H. Chen, "Intelligent control of a grid-connected wind-photovoltaic hybrid power systems," *International Journal of Electrical Power and Energy Systems*, vol. 55, no. 3, pp. 554–561, Feb. 2014, doi: 10.1016/j.ijepes.2013.10.024.

[23] M. F. ELmorshedy, S. M. Allam, A. I. A. Shobair, and E. M. Rashad, "Voltage and frequency control of a stand-alone wind-energy conversion system based on PMSG," in *2015 4th International Conference on Electric Power and Energy Conversion Systems*, IEEE, 2015, pp. 1–6. doi: 10.1109/EPECS.2015.7368494.

[24] K. R. Sekhar, R. Barot, P. Patel, and N. V. Kumar, "A novel topology for improved DC bus utilization in PMSG based wind energy generation system," in *2015 International Conference on Renewable Energy Research and Applications*, IEEE, 2015, pp. 525–530. doi: 10.1109/ICRERA.2015.7418469.

[25] Y. Atifi, M. Kissaoui, A. Raihani, K. Errakkas, and A. Khayat, "Nonlinear control of a wind turbine system connected to the grid," *IFAC-PapersOnLine*, vol. 58, no. 13, pp. 563–568, 2024, doi: 10.1016/j.ifacol.2024.07.542.

BIOGRAPHIES OF AUTHORS

Rosaiah Mudigondla received his B.Tech. degree in Electrical and Electronics Engineering from Arjun College of Technology and Science, Telangana, India, in 2010. M.Tech. degree in Power Electronics and Electric Drives from Ayaan College of Engineering and Technology, JNTUH, Hyderabad in 2014. He is currently working as an Assistant Professor at Teegala Krishna Reddy Engineering College, Telangana, Hyderabad, India. His research areas are power electronics and drives, and power systems. He can be contacted at email: rosaiah0228@gmail.com.

Thiruveedula Madhu Babu has received B.Tech. from JNTU Hyderabad, India, in 2010 and M.Tech. from NIT Calicut in 2013, respectively, and pursuing a Ph.D. at Annamalai University, India. He is presently working as an Assistant Professor and HOD at Teegala Krishna Reddy Engineering College, Hyderabad, India. He has presented technical papers in various national and international journals and conferences. He can be contacted at email: madhumk448@gmail.com.

Supriya Dachepalli is presently a UG student in Electrical and Electronics Engineering at Teegala Krishna Reddy Engineering College, Hyderabad, Telangana, India. She has presented technical papers at various international conferences. Her areas of interest include semiconductors, power electronics, power quality, and multilevel inverters. She developed a single-phase inverter at Teegala Krishna Reddy Engineering College, Hyderabad. She can be contacted at email: supriyadachepalli18@gmail.com.

Anudeep Punjala is presently a UG student in Electrical and Electronics Engineering at Teegala Krishna Reddy Engineering College, Hyderabad, India. He has presented technical papers at various national and international conferences. His areas of interest include renewable energy, power electronics, power quality, and multilevel inverters. He can be contacted at email: punjalaanudeep@gmail.com.

Md Yousuf Ali is presently a UG student in Electrical and Electronics Engineering at Teegala Krishna Reddy Engineering College, Hyderabad, India. He has presented technical papers at various national and international conferences. His areas of interest include controlling techniques, power electronics, power quality, and multilevel inverters. He can be contacted at email: mohd9515yousuf@gmail.com.

Bakam Anirudh is presently a UG student in Electrical and Electronics Engineering at Teegala Krishna Reddy Engineering College, Hyderabad, India. He has presented technical papers at various national and international conferences. His areas of interest include electrical machines, power electronics, power quality, and multilevel inverters. He can be contacted at email: bakamanirudh321@gmail.com.