A Comparative Study Between Symmetrical and Asymmetrical Inverters

Ahmed Talal Hashmat, Tahmid Tajwar, Mohsin Jamil Senior Member IEEE
Department of Electrical and Computer Engineering
Faculty of Engineering and Applied Science
Memorial University of Newfoundland, St. John’s, NL, A1B3X5
athashmat@mun.ca , tahmidt@mun.ca , mjamil@mun.ca

Abstract-- Inverters play a crucial role in modern power systems, converting direct current (DC) into alternating current (AC) for various applications. The choice between symmetrical and asymmetrical inverters can significantly impact system performance, efficiency, and cost. This paper presents a comprehensive comparative study of symmetrical and asymmetrical inverters, focusing on key parameters, design considerations, and their impact on system performance. Through extensive analysis and simulation, we aim to provide valuable insights for making informed decisions in selecting the appropriate inverter topology for their applications.

Keywords----Inverters, Symmetrical Inverter, Asymmetrical Inverter, Power Electronics, System Performance, Efficiency, Design Considerations.

I. INTRODUCTION

Inverter technology stands at the heart of numerous applications, enabling the conversion of DC power to AC power. The choice of inverter topology is driven by the specific requirements of an application, with symmetrical and asymmetrical inverters emerging as two key contenders in the realm of power electronics.

Symmetrical inverters, often referred to as conventional or standard inverters, generate sinusoidal output voltage waveforms that are symmetrical about the zero-crossing point. They have found extensive use in grid-tied solar inverters, industrial motor drives, and various

Power conditioning systems. In contrast, asymmetrical inverters, also known as multilevel inverters, offer a distinctive approach by creating multilevel output voltage waveforms. These inverters are gaining prominence in applications where high-voltage, high-power operation, or reduced harmonic distortion is paramount.

This comparative study investigates the essential characteristics of symmetrical and asymmetrical inverters, focusing on key parameters such as output waveform quality, efficiency, harmonic distortion, and voltage stress. It aims to provide valuable insights for engineers and researchers seeking to determine the most suitable inverter topology for a given application, thereby optimizing the performance and operational efficiency of the system.

II. CONTROL TECHNIQUES

Pulse Width Modulation is a technique used to control the average value of a voltage or current signal by modulating the width of its pulses. It involves switching a signal on and off at a high frequency and varying the duty cycle (the ratio of the on-time to the total period) to achieve the desired output. An H-Bridge is a circuit configuration that allows control of the voltage polarity and magnitude across a load. In a cascaded asymmetrical inverter, multiple H-Bridge modules are connected in series to generate a multilevel output voltage waveform.

The duty cycle determines the amount of time the H-Bridge module is on or off during each switching period. By adjusting the duty cycles of the individual H-Bridge modules, the desired output voltage waveform can be synthesized. The duty cycles are typically determined based on a reference signal, such as a sinusoidal waveform, which represents the desired output voltage.

The PWM signals are generated by comparing the reference signal with a high-frequency triangular waveform. The comparison between the reference signal and the triangular waveform generates the PWM signals with variable duty cycles. These PWM signals are then used to control the switching of the H-Bridge modules, which results in the generation of the multilevel output voltage waveform.[1]

III. ASYMMETRICAL INVERTERS

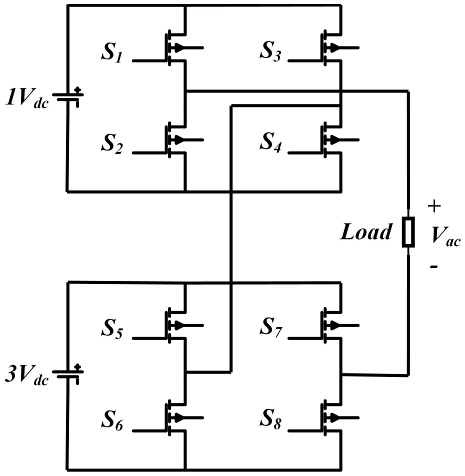

Fig. 1. Asymmetrical inverter

A. *Types and Operation*

Asymmetrical inverters, such as multilevel and cascaded inverters, offer a broader range of voltage levels compared to symmetrical inverters. These inverters can reduce harmonic distortion and improve efficiency by employing multiple voltage levels. Common types include the Multilevel Inverter and the Cascaded H-Bridge Inverter.[2-4]

B. *Characteristics of asymmetrical inverters:*

Capable of providing a wide range of output voltage levels. Reduced harmonic distortion and improved waveform quality. Suited for high-power applications and renewable energy sources.

C. *Advantages and Limitations*

1) Advantages of asymmetrical inverters:

- Improved efficiency, especially at higher power levels.
- Reduced harmonic distortion and higher-quality AC waveforms.
- Greater scalability for high-power applications.

2) Limitations of asymmetrical inverters:

- Complex control algorithms and higher component count.
- Typically, costlier and may require more maintenance.
- May experience increased losses due to voltage clamping.

IV. SYMMETRICAL INVERTERS

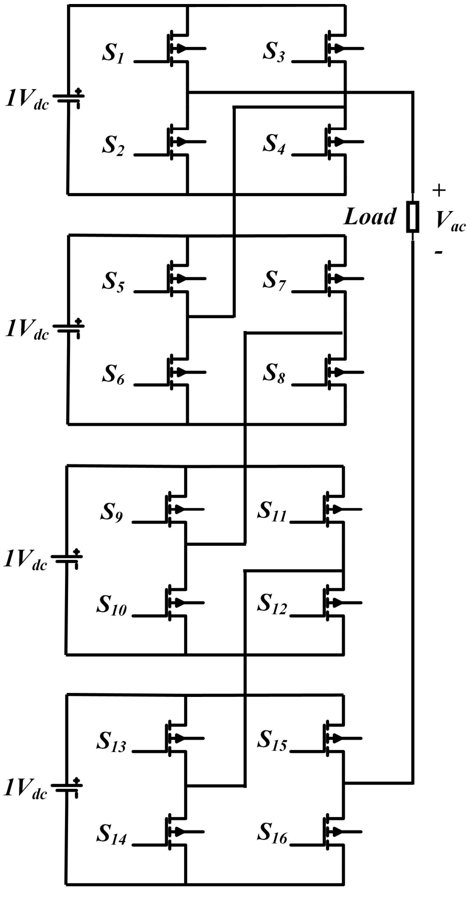

Fig. 2. . Symmetrical inverter

A. *Operation and Characteristics*

Symmetrical inverters, often referred to as two-level inverters, are widely used for their simplicity and reliability. They generate sinusoidal AC waveforms through pulse-width modulation (PWM) techniques. The most common type of symmetrical inverter is the Voltage Source Inverter (VSI).

B. *Characteristics of symmetrical inverters:*

Simple and well-established technology. Generates high-quality, low-harmonic AC waveforms. Suitable for a wide range of applications, including residential solar PV systems and uninterruptible power supplies.[3-5]

C. *. Advantages and Limitations*

1) Advantages of symmetrical inverters:

- Low harmonic distortion, making them ideal for sensitive applications.
- Well-understood control algorithms and commercial availability.
- Cost-effective and reliable for lower power ratings.

2) Limitations of symmetrical inverters:

- Limited scalability to higher power levels.
- Limited efficiency improvements compared to asymmetrical inverters.
- May experience higher switching losses at higher frequencies.

V. COMPARATIVE ANALYSIS

Symmetrical and asymmetrical are two different prevalent techniques for developing multilevel inverters, both offer their own unique benefits. In this paper, we model the multilevel inverter (9-level) using both techniques on MATLAB/Simulink and the results are compared.

The model of a symmetrical inverter consists of four H-bridges and each bridge is controlled by a set of four dedicated switches. The mathematical formula used to determine the number of H-bridges and corresponding levels is 2n+1 where n is the number of H-bridges. Further to this, a dedicated DC source is kept for each bridge with the same voltage level. The DC voltage considered here is 100V.

The model of an asymmetrical inverter consists of two H-bridges and each bridge is controlled by a set of four dedicated switches. The mathematical formula used to determine the number of H-bridges and corresponding levels is $2^{n+1}+1$ where n is the number of H-bridges. Although there is a dedicated DC source kept for each bridge but the voltage level for each bridge is different. The DC voltage ratio between H-bridges should be 1:3 or 1:2. In our case, we followed the convention of 1:3 which means one H-bridge is supplied with 100V whereas the other is provided with 300V.

TABLE I. SYMMETRICAL INVERTER SWITCHING TABLE

Switch No.	**Voltage Levels (*Vdc*)**								
	+4	***+3***	***+2***	***+1***	***0***	***-1***	***-2***	***-3***	***-4***
S1	1	1	1	1	1	0	0	0	0
S2	0	0	0	0	0	1	1	1	1
S3	0	0	0	0	1	1	1	1	1
S4	1	1	1	1	0	0	0	0	0
S5	1	1	1	0	1	1	0	0	0
S6	0	0	0	1	0	0	1	1	1
S7	0	0	0	0	1	1	1	1	1
S8	1	1	1	1	0	0	0	0	0
S9	1	1	1	0	1	1	0	0	0
S10	0	0	0	1	0	0	1	1	1
S11	0	0	1	0	1	1	0	1	1
S12	1	1	0	1	0	0	1	0	0
S13	1	0	1	0	1	1	0	1	0
S14	0	1	0	1	0	0	1	0	1
S15	0	0	1	0	1	1	0	1	1
S16	1	1	0	1	0	0	1	0	0

There are a total of 16 Nos switches in the symmetrical inverter and their switching sequence is explained in Table I. At the same time, the 08 switches shall be ON and the rest of 08 shall remain OFF. The switching duration of all the switches is kept the same to ensure that the output is a uniform modified sine wave.

The important phenomenon in switching is that when one switch is ON its opposite side switch shall be OFF and the duration of their state is also the same, refer to Fig 3. It can be seen clearly that when S1 is ON during that particular duration S2 is OFF and the same convention is followed for S3 & S4.

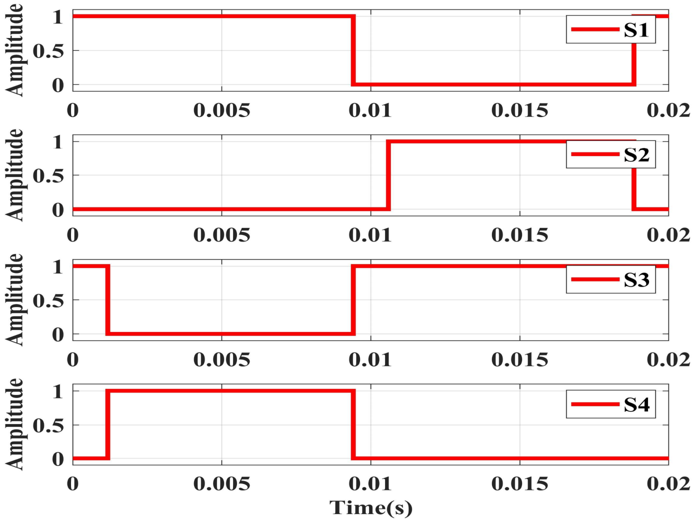

Fig. 3. Switching of H-Bridge 1

The output of the symmetrical 9-Level inverter is shown in Fig. 4 and the results show that the output of the inverter is a uniform and modified sine wave.

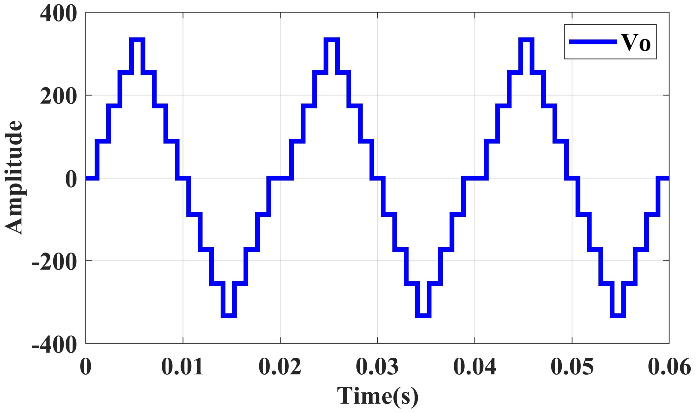

Fig. 4. 9-Level Output Voltage for Symmetrical Inverter

Total Harmonic Distortion (THD) is a measure of the distortion in the output waveform of an inverter or any electrical device that generates an AC (alternating current) output. In the context of inverters, THD is used to assess the quality of the AC waveform they produce. THD quantifies how much the inverter output deviates from a perfect sinusoidal waveform, which is the ideal AC waveform. Fig. 5 shows the resultant THD produced by the symmetrical inverter. As described above, the switching duration of the switches is the same therefore we can see its impact in the form of Efficiency as compared to the asymmetrical inverter.

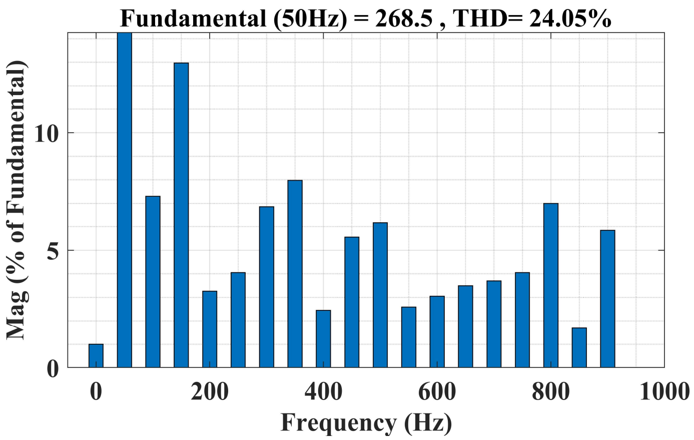

Fig. 5. Symmetrical inverter THD Analysis

The switching sequence of the Asymmetrical inverter is shown in Table II and it can be seen that there are 08 switches and at any particular time 04 switches shall be ON and the rest of 4 shall be OFF. To the contrary of the symmetrical inverter, the switching duration of the switches is random and does not follow the pattern.

TABLE II. ASYMMETRICAL INVERTER SWITCHING TABLE

Switch No.	**Voltage Levels (*Vdc*)**								
	+4	***+3***	***+2***	***+1***	***0***	***-1***	***-2***	***-3***	***-4***
S1	1	1	0	1	1	0	1	0	0
S2	0	1	1	0	0	1	0	0	1
S3	0	0	1	0	1	1	0	1	1
S4	1	0	0	1	0	0	1	1	0
S5	1	1	1	0	1	1	0	0	0
S6	0	0	0	1	0	0	1	1	1
S7	0	0	0	0	1	1	1	1	1
S8	1	1	1	1	0	0	0	0	0

As we can see from figs 6, Symmetrical Inverters lose a lot of their efficiency when operating at a high power, on the other hand, Asymmetrical Inverters have the same response to and power level, depending on the topology used. Symmetrical inverters, while efficient at lower power levels, tend to exhibit lower efficiency as power levels increase.

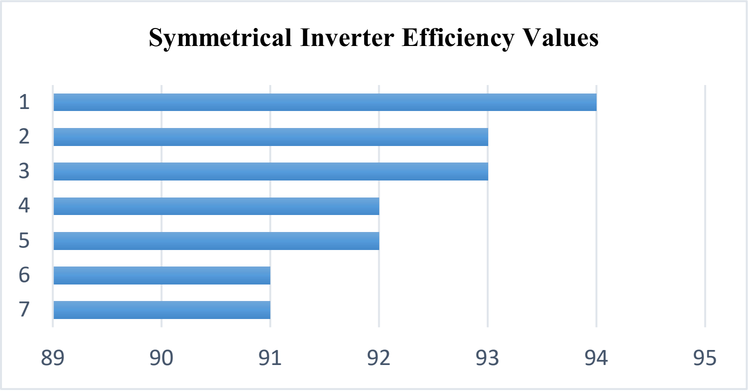

Fig. 6. Symmetrical Inverter Efficiency values

The switching duration and pattern of switches are shown in Fig 7. The output waveform of the asymmetrical inverter is quite similar to the symmetrical inverter and is a modified uniform sine wave.

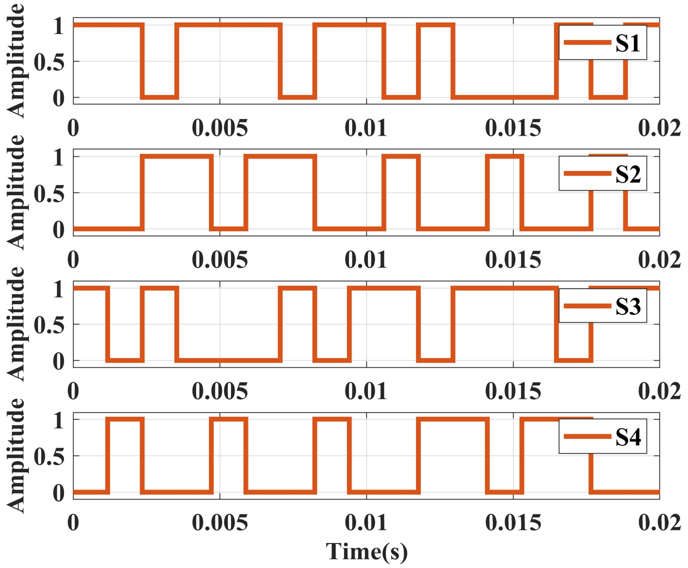

Fig. 7. Switching of H-Bridge 1

The output of the Asymmetrical 9-Level inverter is shown in Fig. 8 and the results show that the output of the inverter is a uniform and modified sine wave.

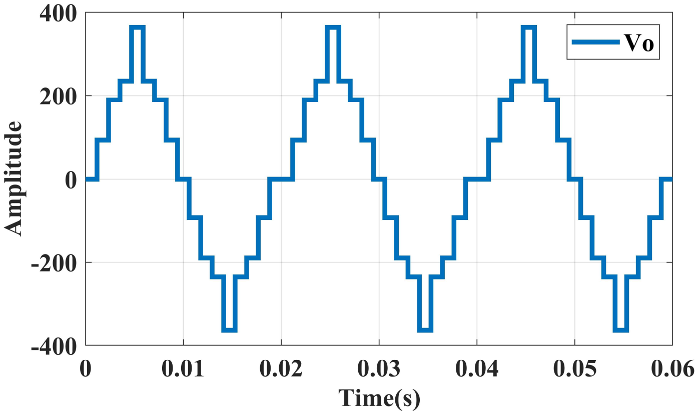

Fig. 8. 9-Level Output Voltage for Asymmetrical Inverter

The THD analysis of the Asymmetrical inverter is presented in Fig 9 and it clearly shows that the magnitude of THD is relatively lower than symmetrical inverter due to irregular switching.

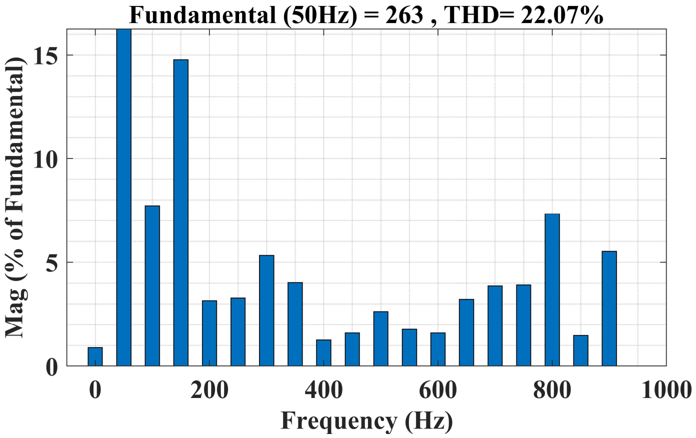

Fig. 9. Symmetrical Inverter THD Analysis

From Fig 10, Asymmetrical inverters, especially multilevel inverters, demonstrate higher efficiency, making them more suitable for high-power applications and renewable energy sources

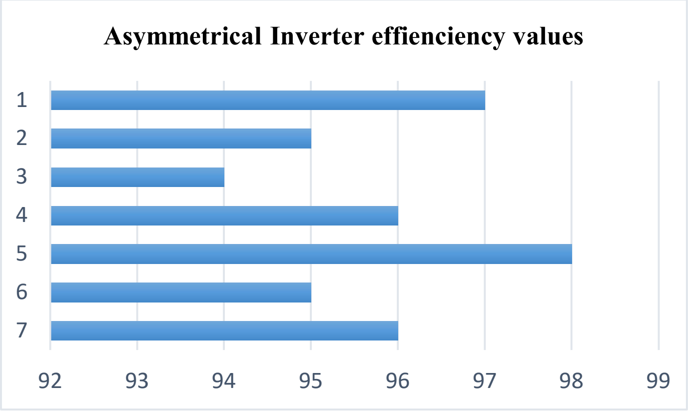

Fig. 10. Asymmetrical Inverter Efficiency values

The choice between symmetrical and asymmetrical inverters depends on factors such as the desired output waveform, the specific load requirements, and system efficiency. Symmetrical inverters are preferred when a clean and balanced AC output is essential, while asymmetrical inverters are chosen when the application benefits from tailored or unbalanced output waveforms. Researchers and engineers often investigate and compare these inverter types to determine the most suitable solution for a given application. As shown in Table III.

TABLE III. EFFICIENCY COMPARISION LOW POWER(LP) VS HIGH POWER(HP)

Ref No.	Symmetrical Inverter Efficiency	Asymmetrical Inverter Efficiency
[2]	91% LP	95% LP
[3]	93% LP	94% LP
[4]	90% HP	96% HP
[5]	88% HP	93% HP
[6]	91% LP	92% HP
[7]	91% HP	96% HP
[8]	90% HP	98% HP
[9]	91% HP	97% HP
[10]	94% LP	95% LP
[11]	92% LP	94% LP
[12]	91% HP	96% LP
[12]	90% HP	97% HP
[14]	93% LP	96% LP

Symmetrical inverters, which operate on the principles of Pulse Width Modulation (PWM), excel in producing AC waveforms with reduced harmonic content. This attribute arises from the precise control techniques employed in symmetrical inverter designs. The symmetrical inverters endeavor to generate AC output signals that closely resemble ideal sinusoidal waveforms. This endeavor results in relatively low harmonic distortion, making them an excellent choice when the emphasis is on obtaining a clean and balanced power output.

In contrast, asymmetrical inverters, especially those based on multilevel topologies, offer an even more advanced solution for mitigating harmonic distortion. Multilevel inverters achieve this by synthesizing the output voltage from a series of stepped voltage levels, which significantly reduces the presence of harmonics in the output waveform. This leads to power output that is exceptionally clean and low in harmonic content.

Symmetrical inverters are typically characterized by lower switching losses, especially when operating at lower frequencies. This attribute is a result of the well-established control techniques employed in symmetrical inverter designs, which are particularly efficient in managing switching transitions at these lower frequencies. Symmetrical inverters excel in maintaining power conversion efficiency, making them the preferred choice for applications where lower-frequency operation is the norm.

Conversely, when the operating frequency and power levels increase, asymmetrical inverters may demonstrate an advantage in terms of lower switching losses. This advantage becomes more pronounced as the frequency and power requirements escalate. Asymmetrical inverters, due to their unique design and control strategies, can efficiently handle high-frequency switching scenarios, resulting in reduced switching losses. Consequently, at higher frequencies and elevated power levels, asymmetrical inverters tend to exhibit superior efficiency compared to their symmetrical counterparts..

VI. CONCLUSION

In conclusion, the choice between symmetrical and asymmetrical inverters depends on the specific requirements of the application. Symmetrical inverters offer simplicity and reliability, making them well-suited for lower power and cost-sensitive applications. Asymmetrical inverters, on the other hand, provide greater efficiency, reduced harmonic distortion, and scalability for high-power and renewable energy applications. Engineers and researchers must carefully consider these factors when making their selection, ensuring that their chosen inverter topology aligns with their application's needs.

The selection between symmetrical and asymmetrical inverters is contingent upon variables including the targeted output waveform, particular load constraints, and overall system efficiency. Symmetrical inverters are favored when necessitating a pristine and equilibrated AC output, whereas asymmetrical inverters are selected when the application accrues advantages from customized or imbalanced output waveforms. Consequently, researchers and engineers routinely engage in comprehensive analyses and juxtapositions of these inverter classifications to discern the optimal solution commensurate with a specific application. As mentioned in Table IV

TABLE IV. COMPARATIVE SUMMARY

Efficiency Considerations	**Symmetrical Inverters**	**Asymmetrical Inverters**
Efficiency at Low Power Levels	High	Comparable
Efficiency at High Power Levels	Moderate	High
Efficiency at Variable Load Conditions	May degrade more rapidly	Maintains better efficiency
Efficiency at Different Voltage Levels	Limited flexibility	Can provide a broader range of output voltage levels
Overall Efficiency	Suitable for low to medium power applications	Ideal for high-power applications
Cost-Efficiency	Cost-effective for smaller applications	May require higher initial investment
Applications	Residential solar PV systems, UPS	High-power renewable energy systems, grid-tied inverters
Common Topologies	Two-level inverters	Multilevel inverters, cascaded inverters

REFERENCES

[1] P. S. Rani, K. V. S. Prasadarao and K. R. N. V. Subbarao, "Comparison of symmetrical and asymmetrical multilevel inverter topologies with reduced number of switches," 2014 International Conference on Smart Electric Grid (ISEG), Guntur, India, pp. 1-5, 2014.

[2] K. Thakre and K. B. Mohanty, "Comparative analysis of THD for symmetrical and asymmetrical 17 level cascaded H-bridge inverter using carrier based PWM techniques," 2015 International Conference on Industrial Instrumentation and Control (ICIC), pp. 306-310, 2015.

[3] B. S. Tekpeti, X. Kang and M. Kheshti, "Particular PV grid-connected system under symmetrical and asymmetrical faults analysis," 2017 IEEE Electrical Power and Energy Conference (EPEC), Saskatoon, SK, Canada, pp. 1-6, 2017.

[4] R. S. Goopta and A. Bhattacharya, "Reduced Switch Multilevel Inverter with Symmetrical & Asymmetrical DC Sources for Solar PV Applications," 2020 IEEE Region 10 Symposium (TENSYMP), Dhaka, Bangladesh, pp. 1468-1473, 2020

[5] [N. Agrawal, A. Agarwal and T. Kanumuri, "Performance Analysis of 7-Level Cascade H-Bridge Multilevel Inverter with Symmetrical & Asymmetrical Configuration," 2022 IEEE 10th Power India International Conference (PIICON), , pp. 1-6, 2022.

[6] S. K. Maity and T. Roy, "A study of symmetrical and various asymmetrical DC source configurations of a novel cascaded multilevel inverter topology," 2018 Technologies for Smart-City Energy Security and Power (ICSESP), pp. 1-5, 2018.

[7] P. S. Rani, K. V. S. Prasadarao and K. R. N. V. Subbarao, "Comparison of symmetrical and asymmetrical multilevel inverter topologies with reduced number of switches," 2014 International Conference on Smart Electric Grid (ISEG), pp. 1-5, 2014.

[8] M. Rao A., V. Srinivas and B. Srividya, "Multilevel Inverter Topology with Symmetrical and Asymmetrical Sources for Distributed Energy Resources," 2019 8th International Conference on Power Systems (ICPS), pp. 1-5, 2019.

[9] S. S. Bharatkar, R. R. Bhoyar and S. A. Khadtare, "Analysis of three phase cascaded H-bridge multilevel inverter for symmetrical & asymmetrical configuration," 2014 First International Conference on Automation, Control, Energy and Systems (ACES), pp. 1-6, 2014.

[10] M. D. Siddique et al., "Single phase symmetrical and asymmetrical design of multilevel inverter topology with reduced number of switches," 2018 IEEMA Engineer Infinite Conference (eTechNxT), pp. 1-6, 2018.

[11] L. Nanda, C. Jena and S. Samal, "Symmetrical and Asymmetrical Conventional Cascaded Multilevel Inverter with SPWM Technique," 2021 International Conference on Intelligent Technologies (CONIT), pp. 1-5, 2021.

[12] S. D, J. G. R, P. K, N. A. A, S. D and N. S, "Symmetrical and Asymmetrical Multilevel Inverter with configurational parameters for power quality applications," 2020 IEEE 7th Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), pp. 1-5, 2020.

[13] S. R, P. S, P. E and S. K, "Comparison between Symmetrical and Asymmetrical 13 Level MLI with Minimal Switches," 2022 International Conference on Automation, Computing and Renewable Systems (ICACRS), pp. 187-191, 2022.

[14] K. Thakre, K. B. Mohanty, V. Kommukuri and R. N. Mishra, "Symmetrical and asymmetrical multilevel inverter using less number of switches," TENCON 2017 - 2017 IEEE Region 10 Conference, pp. 1032-1036, 2017