



Suppression of Harmonics in Cascaded H-bridge Inverter using Multicarrier Modulation Techniques

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Abstract - Multilevel Inverters are playing a vital role in today's industrial world. Initially, two level inverter systems were used to convert direct voltage to alternating current. But with the advancement in technology, higher levels of inverters are explored and designed. It has been found that on increasing the number of levels in inverter system; losses are reduced resulting in better output. In this research paper, a higher level of inverter system has been designed and its performance is compared using the pulse width modulation strategy. The main aim of the paper is to reduce the harmonics and losses of the designed inverter system. The methodology used in pulse width modulation technique. Using these techniques, inverters are fired at the optimum angles resulting in lesser distortions. Also, the number of required components is reduced making the overall system more compact and economical. It has been observed that the overall system results in harmonics that are in the accepted IEEE range i.e. less than 5%. This system is useful for industrial purposes, can be used to integrate renewable sources and to grid also.

Index Terms - Multilevel Inverter (MLI), Pulse Width Modulation (PWM), Total Harmonic Distortion (THD), Harmonics

1. Introduction

A multilevel inverter is a power electronic device that converts direct current (DC) into alternating current (AC) with multiple voltage levels. It provides a higher quality output waveform compared to traditional two-level inverter by synthesizing the output voltage several levels of voltage steps. The primary purpose of a multilevel inverter is to achieve higher voltage levels with reduced harmonic distortion and lower voltage stress on the power devices. This makes them particularly suited for high-power applications, such as renewable energy systems, electric vehicles, and industrial motor drives. The basic principle behind multilevel inverters involves the use of multilevel power semiconductor switches and energy storage elements, such as capacitor or dc sources, to synthesize the desired output voltage waveform. By controlling the switching states of these semiconductor switches, the multilevel inverter can generate stepped waveforms that approximate a sinusoidal waveform. Multilevel inverter can generate higher output voltage levels

without the need for excessively high voltage-rated switches, making them suitable for high-power applications. Compared to conventional two-level inverters, multilevel inverter typically operate at lower switching frequencies, reducing the switching losses and improving overall efficiency. Due to these advantages, multilevel inverters are widely used in various applications such as renewable energy systems (such as solar and wind power), electric vehicles, adjustable-speed drives, high-voltage direct current (HVDC) transmission systems, and other industrial and grid-connected applications.

There are numerous topologies of multilevel inverters, including diode-clamped inverters, flying capacitor inverters, cascaded H-bridge inverter. Each topology employs a different arrangement of power semiconductor switches and energy storage elements to achieve the desired output waveform.

II. Cascaded H-Bridge Multilevel Inverter

A Cascaded H-bridge multilevel inverter is another type of multilevel power converter used in high-power applications, similar to the diode-clamped multilevel inverter, it is known for its ability to produce even higher voltage levels and improved output waveform quality. The Cascaded H-Bridge multilevel inverter is composed of multilevel H-bridge cells connected in series. Each H-bridge cell consists of four power semiconductor switches (IGBTs or MOSFETs) arranged in a bridge configuration, along with a DC voltage source (usually a capacitor or a battery) for each cell. The key advantage of this inverter is its ability to produce multilevel voltage levels. The number of voltage levels depends on the number of H-Bridge cells in series. For an N-Level inverter, there will be $N/2$ H-bridge cells, providing 2^N Voltage levels. Each H-Bridge cell can independently generate a positive or negative voltage relative to its DC voltage source. By controlling the switching states of the power semiconductor switches in each H-bridge cell, the inverter can synthesize the desired output voltage levels. The magnitude of the output voltage is determined by the sum of the voltage levels generated by each H-bridge cell. Like other multilevel inverters, Pulse Width Modulation (PWM) is commonly used to control the output

voltage levels. By adjusting the duty cycles of the individual switches in each H-bridge cell, the inverter can create the required output voltage waveform with reduced harmonic content and improved voltage resolution.

It's important to note that the cascaded H-bridge multilevel inverter requires sophisticated control algorithms to manage the switching of multiple H-bridge cells effectively. Additionally, the choice of components, such as the type of power semiconductor switches and voltage sources, depends on the specific application and system requirements. Fig. 1 represents the basic structure of cascaded H-bridge inverter.

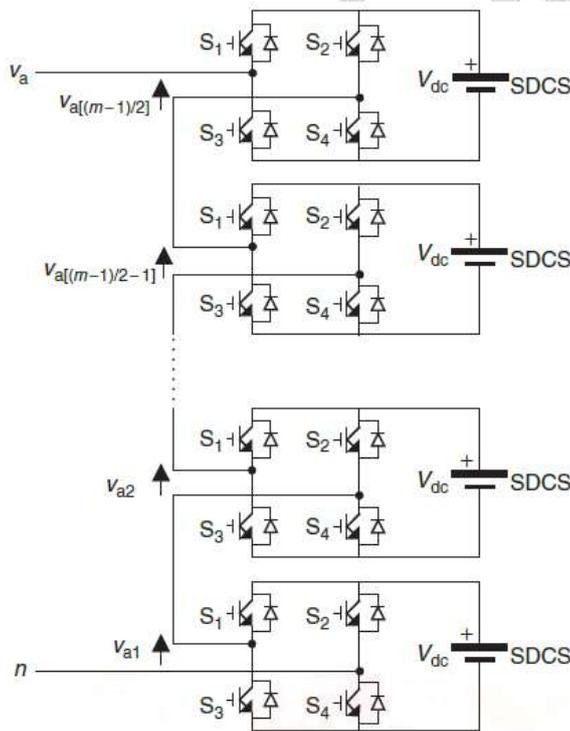


Fig.1 Basic Model of Cascaded H-Bridge Multilevel Inverter

III. Modulation Technique

Pulse Width Modulation (PWM) is a technique used in electronics and power systems to control the average voltage or power delivered to a load by varying the width of the pulses in a pulse train. PWM is widely used in applications such as motor control, audio amplifiers, lighting control, and power inverters. In power inverters used for DC to AC conversion, PWM is employed to generate an AC output. In power inverters used for DC to AC conversion, PWM is employed to generate an AC output. The width of the pulses determines the magnitude of the output voltage. PWM is a key component in SMPS to regulate the output voltage efficiently. SPWM modulates the width of the pulses to approximate a sine wave. It is commonly used in motor control and inverters to reduce harmonic distortion. Fig. 2 depicts the classifications of modulation techniques.

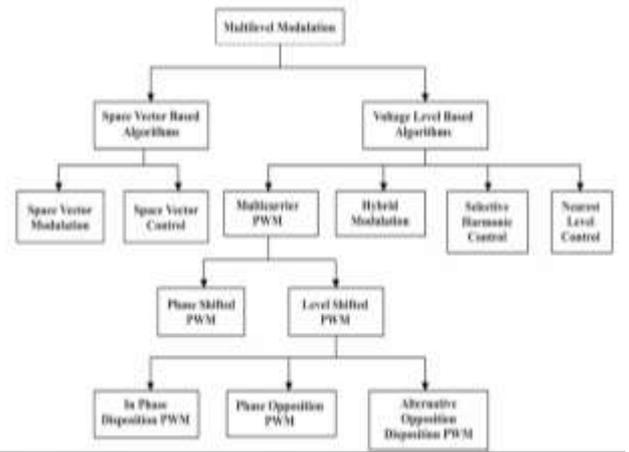


Fig.2 Classification of Modulation Techniques

In this research work, Level-shifted pulse width modulation (PWM) is being used, it is a technique used in power electronics to generate high-quality modulated waveforms. It involves shifting the reference voltage or signal level to improve the efficiency and performance of the power conversion system. This technique is often employed in voltage source inverters (VSIs) to control the output voltage waveform. In a basic PWM control, the reference voltage is compared with a triangular carrier wave, and the resulting pulse width is determined. In level-shifted PWM, the reference voltage or signal level is shifted to optimize the performance of the power electronic system. Level-shifting helps to maintain the relationship between the reference signal and the output voltage, ensuring a more precise and predictable modulation. Level-shifted PWM contributes to improved power quality by reducing harmonic distortion and providing more linear control over the output. The optimization of the PWM technique through level-shifting can lead to enhanced efficiency in power converters and inverters. There are three Types of Level Shifted Pulse Width Modulation Techniques i.e. In-Phase Disposition (IPD), Phase Opposite Disposition (POD) and Alternate Phase Opposite Disposition (APOD).

IV. Results

A nine-level multilevel inverter using Level-Shifted Pulse Width Modulation (PWM) is a power electronics configuration that generates nine distinct voltage levels at the output. To measure the THD of the Analog Signal using FFT Function in the matlab, the FFT Analysis of Alternate Phase Opposite Disposition of Nine level is shown in Fig. 3, similarly Fig. 4 and 5 shows the FFT analysis of Phase Opposite Disposition, and Phase Disposition Technique.

THD% Of PWM Techniques			
Level	APOD	POD	PD
Nine	13.08%	13.16%	13.16%
Thirteen	7.99%	7.99%	8.29%

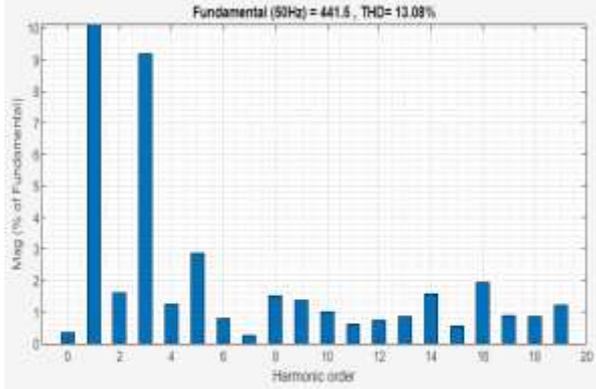


Fig. 3 FFT Analysis of Nine level for Alternate Phase Opposite Disposition Technique (APOD)

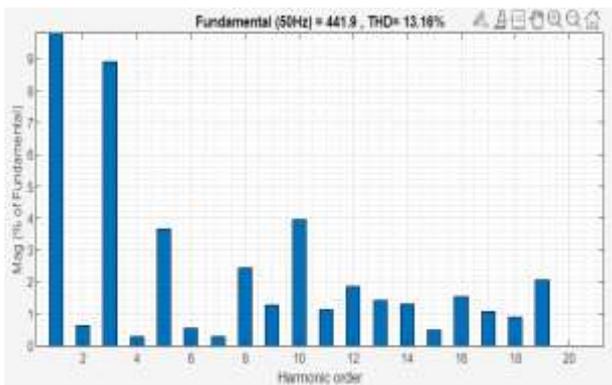


Fig. 4 FFT Analysis of Nine level for Phase Opposite Disposition Technique (POD)

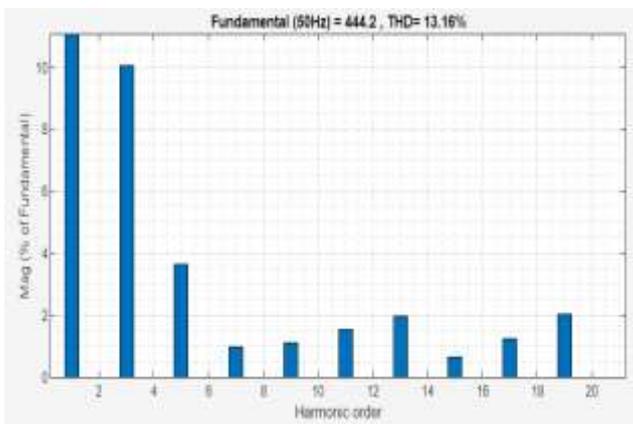


Fig. 5 FFT Analysis of Nine level for Phase Disposition Technique (PD)

A Thirteen-level multilevel inverter using Level-Shifted Pulse Width Modulation (PWM) is a power electronics configuration that generates thirteen distinct voltage levels at the output. To measure the THD of the Analog Signal using FFT Function in the matlab, the FFT Analysis of Alternate Phase Opposite Disposition of Thirteen level shown in Fig. 6, similarly Fig. 7 and 8 depicts the FFT analysis of Phase Opposite Disposition, and Phase Disposition Technique.

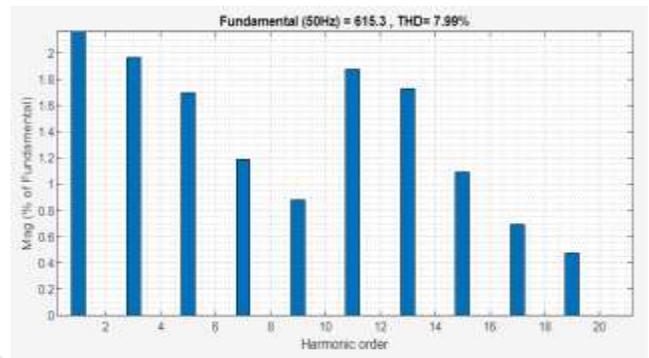


Fig. 6 FFT Analysis of Thirteen level for Alternate Phase Opposite Disposition Technique (APOD)

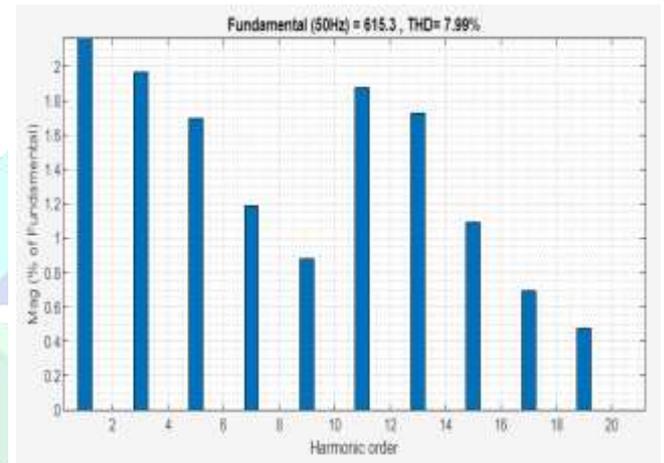


Fig.7 FFT Analysis of Thirteen level for Phase Opposite Disposition Technique (POD)

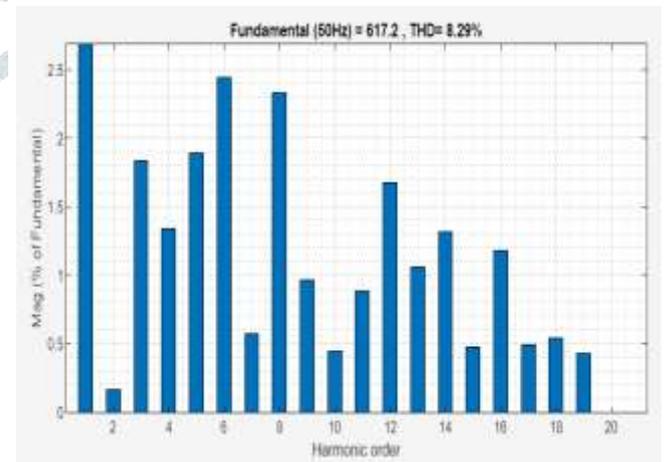


Fig. 8 FFT Analysis of Thirteen level for Phase Disposition Technique (PD)

Different levels of multilevel inverters and PWM techniques can have varying effects on THD. Table 1 shows a comparison of the THD of different levels of multilevel inverters using different PWM technique.

Table1 Comparison of THD of different PWM techniques

V. Conclusion

It is concluded that the Multilevel Inverter with Cascaded H-Bridge configuration requires (N-1) submodules and (2N-2) switches for N-Level Inverter. In this research we discussed the output waveform of voltage and the produced Total

Harmonic Distortion (THD) of different level of MLIs. For 9 and 13 level of multilevel inverter, three PWM techniques are applied and result obtained were used for the comparison study. The three PWM techniques are In Phase Disposition (IPD), Phase Opposite Disposition (POD), Alternate Phase Opposite Disposition (APOD). The simulation results obtained proves that Alternate Phase Opposite Disposition Technique PWM technique gives the better Total Harmonic Distortion (THD) for the different levels of cascaded H-bridge multilevel inverter.

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