Analysis Of Total Harmonic Distortion Using Multicarrier Pulse Width Modulation

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ABSTRACT

Cascaded H-Bridge Multilevel Inverters have become an effective and practical solution for reducing harmonics, switching losses and allows for higher output voltage and have many applications in electric utility and for industrial drives. In this paper 7, 9 and 11 levels of cascaded h-bridge multilevel inverters total harmonic distortion is analyzed using multicarrier pulse width modulation technique. These levels are employed to generate ac output voltage producing different magnitudes of THD indices for comparison purpose. In the analysis it is found that the THD in output voltage decrease and output voltage increase with increase in number of levels. The THD has been analyzed by the MATLAB/Simulink.

Keywords: Multilevel inverter, Cascaded H-Bridge multilevel inverter, Multicarrier pulse width modulation, Total harmonic distortion.

1 INTRODUCTION

A multilevel inverter is a power electronic converter that synthesizes a desired output voltage from several levels of dc voltages as inputs. With an increasing number of dc voltage sources, the converter output voltage waveform approaches a nearly sinusoidal waveform while using a fundamental frequency-switching scheme. The primary advantage of multilevel inverter is their small output voltage, results in higher output quality, lower harmonic component, better electromagnetic compatibility, and lower switching losses. [1] [2].

High magnitude sinusoidal voltage with extremely low distortion at fundamental frequency can be produced at output with the help of multilevel inverters by connecting sufficient number of dc levels at input side. There are mainly three types of multilevel inverters; these are a) diode- clamped, b) flying capacitor and c) cascade multilevel inverter (CMLI).Among these three, CMLI has a modular structure and requires least number of components as compared to other two topologies, and as a result, it is widely used for many applications in electrical engineering as HVDC, SVC, stabilizers, and high power motor drives.[2][3] The output waveforms of multilevel inverters are in a stepped form, therefore they have reduced harmonics compared to a square wave inverter. To reduce the

harmonics further, carrier-based PWM methods are suggested in the literature [4].

In this paper 7, 9 and 11 levels of cascaded h-bridge multilevel inverters total harmonic distortion is analyzed using multicarrier pulse width modulation technique. These levels are employed to generate ac output voltage producing different magnitudes of THD indices for comparison purpose. In the analysis it is found that the THD in output voltage decrease and output voltage increase with increase in number of levels. The THD has been analyzed by the MATLAB/Simulink.

2 CASCADED H-BRIDGE MULTILEVEL INVERTER

A cascaded multilevel inverter is made up of from series connected single full bridge inverter, each with their own isolated dc bus. This multilevel inverter can generate almost sinusoidal waveform voltage from several separate dc sources, which may be obtained from solar cells, fuel cells ,batteries, ultra capacitors, etc. this type of converter does not need any transformer or clamping diodes or flying capacitors.[5]

Each level can generate three different voltage outputs +Vdc, 0 and –Vdc by connecting the dc sources to the ac output side by different combinations of the four switches. The output voltage of an M-level inverter is the sum of all the individual inverter outputs. Each of the H-bridge's active devices switches only at the fundamental frequency, and each H-bridge unit generates a quasi-square waveform by phase-shifting its positive and negative phase legs switching t i m i n g s . Further, each switching device always conducts for 180˚ (or half cycle) regardless of the pulse width of the quasi-square wave so that this switching method results in equalizing the current stress in each active device .[6]

This topology of inverter is suitable for high voltage and high power applications because of its ability of synthesize waveforms with better harmonic spectrum and low switching frequency. Considering the simplicity of the circuit and advantages, Cascaded H-bridge topology is chosen for this work and harmonic

distortion is reduced due to more output levels.[9] An example phase voltage waveform for an eleven level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure.2. The phase voltage $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$.
For a stepped waveform such as the one depicted in Figure 2 with s steps, the Fourier Transform for this waveform follows [7,8].

Fig.1.Single-phase structure   of   a   m level cascaded H bridge multilevel inverter

Fig.2.Output voltage waveform of a m-level cascaded H bridge multilevel inverter

The conducting angles, θ_1, θ_2, ..., θ_S, can be chosen such that the voltage total harmonic

distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5th,7th,9th and 11th are eliminated . [10]

3 MULTICARRIER PWM TECHNIQUE

The Multicarrier PWM uses several triangular carrier signals and only one modulating sinusoidal signal as reference wave. If an 'n' level inverter is employed , 'n-1' carriers will be needed. At every instant each carrier is compared with the modulating signal. Each comparison gives one if the modulating signal is greater than the triangular carrier , zero otherwise. The results are added to give the voltage level, which is required at the output terminal of the inverter.[10].

Frequency modulation ratio is defined as the ratio of carrier frequency and modulating frequency.

$$mf = fc / fm \quad .... (5)$$

Amplitude modulation ratio is defined as the ratio of amplitude of modulating signal and amplitude of carrier signal.

$$m_a = Am/(n-1)Ac \quad .... (6)$$

Using this technique THD value can be reduced with reduction in output voltage.

4 PROPOSED TOPOLOGY

The Proposed Cascaded Multilevel Inverter topology involves different levels. The circuit needs independent dc source. In case of seven level inverter , it consists of conventional three-level bridges, whose AC terminals   are simply connected in series to synthesize a three level square wave output voltage waveform.

In case of nine level inverter , it consists of conventional four-level bridges, whose AC terminals are simply connected in series to synthesize a four level square wave output voltage waveform.

In case of eleven level inverter , it consists of conventional five-level bridges, whose AC terminals are simply connected in series to synthesize a five level square wave output voltage waveform.

5 SIMULATION RESULTS

This paper presents comparison of output voltages at various levels and harmonic elimination for 7-level, 9- level and 11-level inverters of the proposed topology. Fig.3,4,5 and 6 shows the Simulink model for proposed Inverter
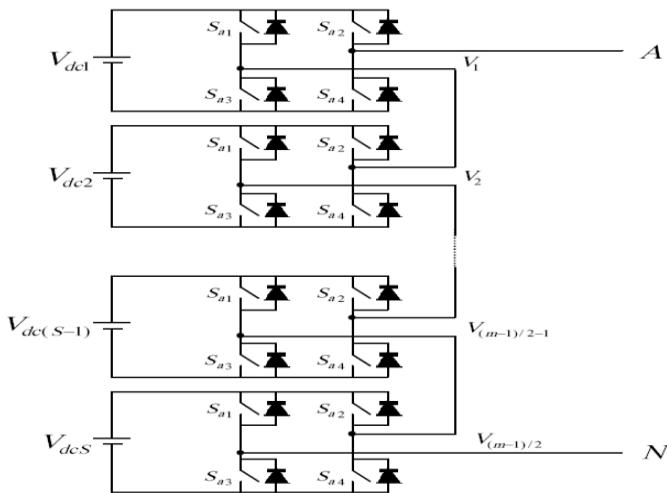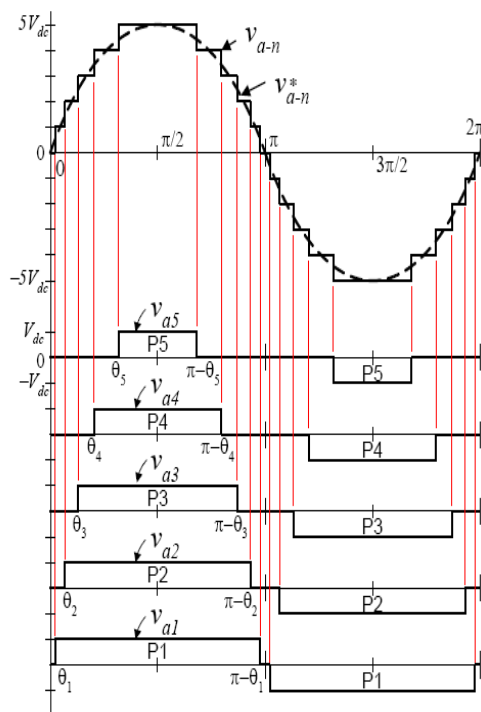
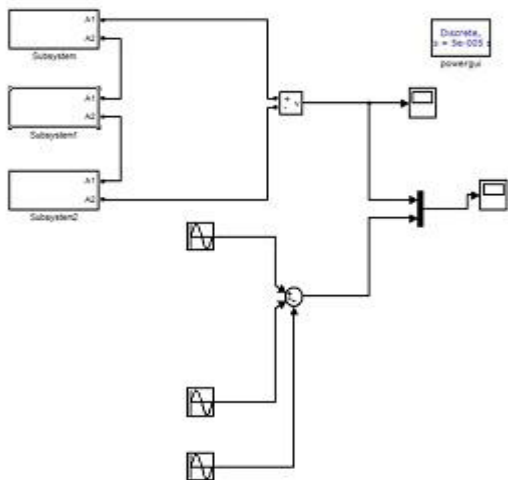topology. The generated output pulses from the pulse generator are shown in the Fig. 7. and Fig.8.,

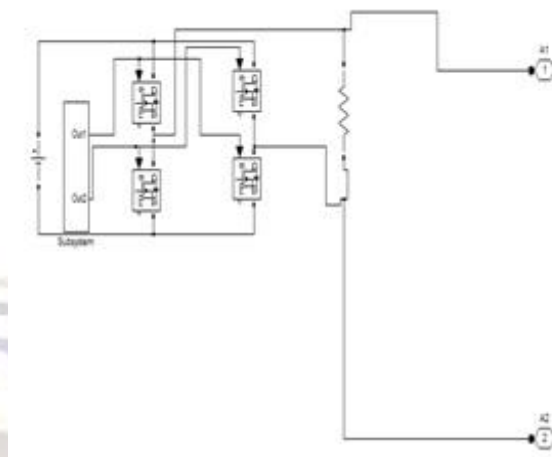Fig.3.Simulation circuit of the proposed method
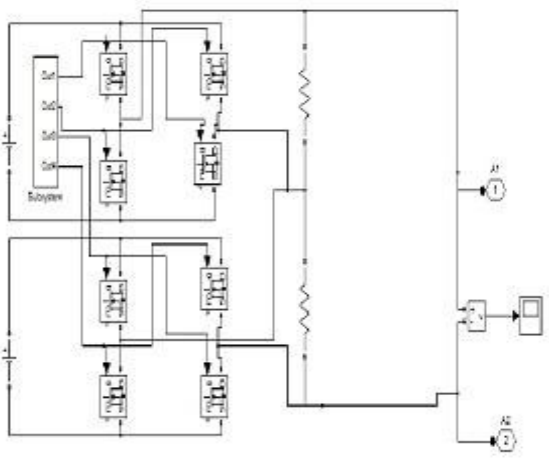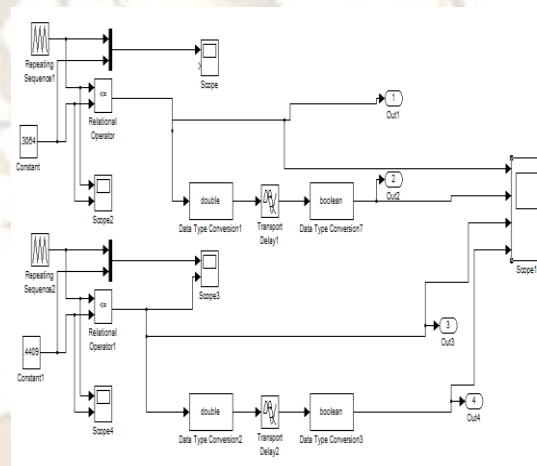

Fig.6. Subcircuit

Fig.4. Subcircuit
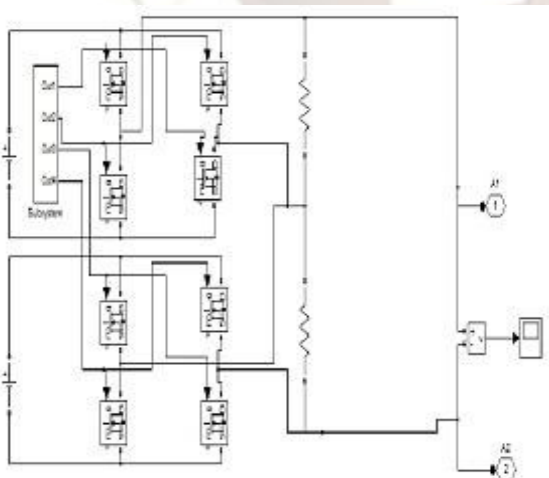

Fig.7. Pulse Generator with Multi CarrierPWM
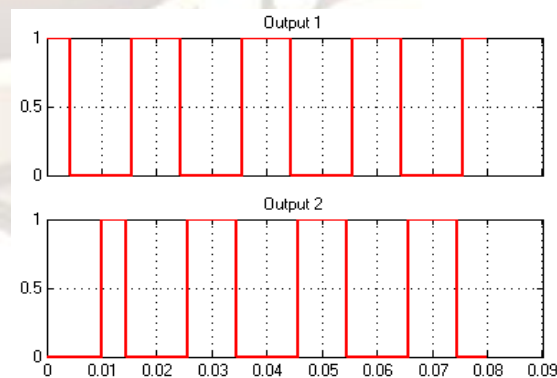

Fig.5. Subcircuit
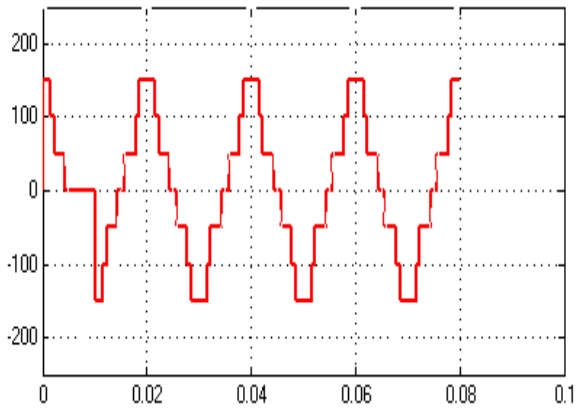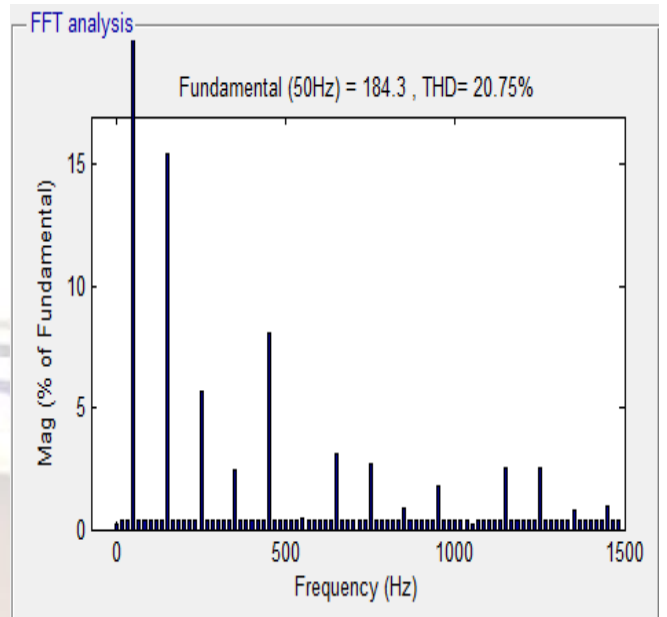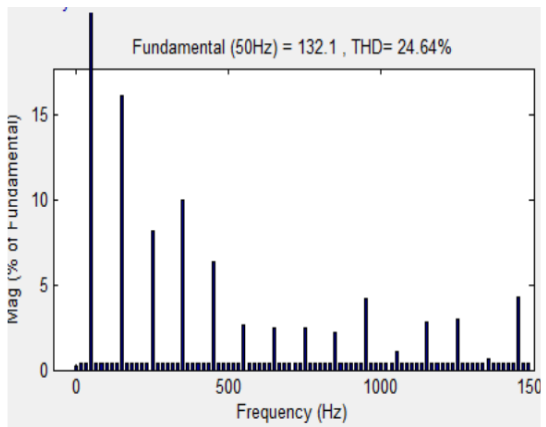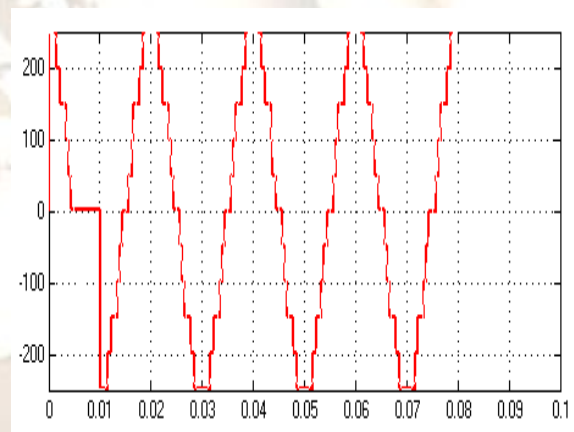

Fig.8.Gate pulses

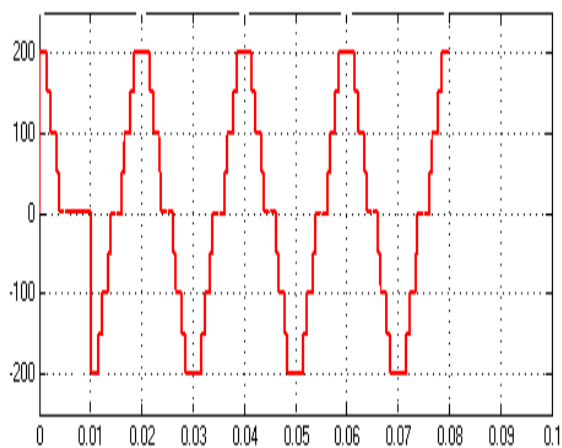**Fig.9. Output Voltage Waveform of seven level inverter**

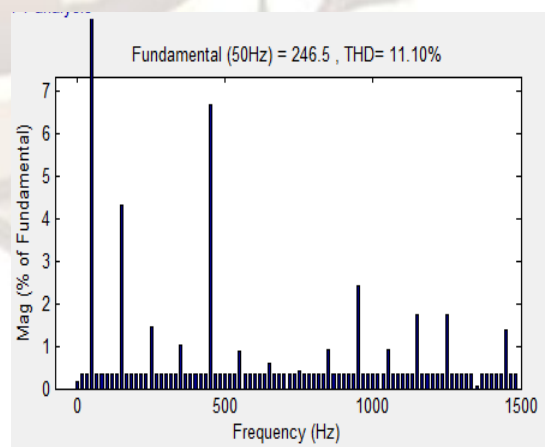**Fig.12.Harmonic spectrum**

Fig.10. Harmonic Spectrum

Fig.13. Output Voltage Waveform of eleven level inverter

Fig.11. Output Voltage Waveform of nine level inverter

Fig.14. Harmonic Spectrum

Table .1. THD at various levels

	Number of Switches		
Inverter Type	7- level	9- level	11-level
Cascaded H Bridge	12	16	20
% THD Reduction	24.64	20.75	11.1

In case of seven level inverter requires 12 switches to get the seven level output voltage and the output voltage is shown in fig.9.The corresponding FFT analysis is also shown in fig.10.
In case of   nine level   inverter requires 16 switches to get the nine level output voltage and the output voltage is shown in fig.11.The corresponding FFT analysis is also shown in fig.12.
In case of eleven level   inverter requires 20 switches to get the eleven level output voltage and the output voltage is shown in fig.13.The corresponding FFT analysis is also shown in fig.14.
For proposed topology the harmonic spectrum of the simulation system are compared and presented in the Table 1 at various levels.

6 CONCLUSION

In the Present work , the THD of different levels of   Cascaded H-Bridge Multilevel Inverter has been analyzed using MATLAB/Simulink. It has been found that the total harmonic distortion is low for higher levels of Cascaded H-Bridge Multilevel Inverter.

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