Comparison of THD Values of Seven Level CHB Inverter with Single DC Source for various Multi Carrier PWM Techniques

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***Abstract*— Multilevel inverters are commonly used for high power applications because they cause less harmonic distortion. This paper compares the total harmonic distortions of the output voltage of the single-phase seven-level cascaded H-bridge multilevel inverter with a single DC source for various multi carrier pulse width modulation techniques. The total harmonic distortions of the output voltage of the inverter are compared for varying amplitude modulation index values. The simulated waveforms and the FFT analysis of the output voltage are shown for the various carrier disposition multicarrier pulse width modulation techniques. The simulation is carried out using MATLAB/ Simulink.**

Keywords*— *Cascaded H-Bridge Multilevel Inverter; Single DC source; Multi Carrier PWM techniques; Total Harmonic Distortion.

I. INTRODUCTION

Multilevel inverters (MLIs) are becoming popular for their high voltage and power levels. The capability of the multilevel inverters to produce high voltage with less total harmonic distortion at reduced switching frequency, using switching devices of low voltage ratings, makes them to be the best choice for medium and high voltage and power applications like solar and wind power applications [1-2]. These inverters are of three categories namely, 1. Neutral Point Clamped (NPC) multilevel inverter, 2. Flying Capacitor (FLC) multilevel inverter and 3. Cascaded H- Bridge (CHB) multilevel inverter. Of the three categories, the CHB inverter does not require any clamping diodes and capacitors and hence it is simple in construction. The only disadvantage of the CHB inverter is that it requires separate DC source for each H-bridge. To reduce the number of independent DC sources, methods were introduced in recent years; replacing reactors [3] or capacitors [4]. However, these approaches also need a minimum of three independent sources for three-phase inverter. The bidirectional switching method has been proposed [5] to ensure that the galvanic isolation between the input and the output; although it employs one input source, it has a complex circuit configuration because of the use of the bidirectional switches. This paper proposes a CHB inverter, which uses a single DC source and isolating transformers depending on the number of levels. For an m-level inverter, m-1 isolation transformers are required. The output of the inverter is connected through the transformer to the load. The paper also presents the comparison of THD values for the four carrier disposition techniques.

The paper is arranged as follows. Section II describes the proposed CHB MLI, while section III presents the multi carrier PWM techniques. Simulation and results are brought in section IV and the conclusions are brought out in section V.

II. PROPOSED CHB MULTILEVEL INVERTER

Figure 1 shows the proposed seven-level CHB MLI inverter. It uses a single DC source and three transformers. The output of the inverter is connected through the transformer to the load. The secondary winding of the transformers are connected in series and the load is connected to the series connected secondary windings [6-7].

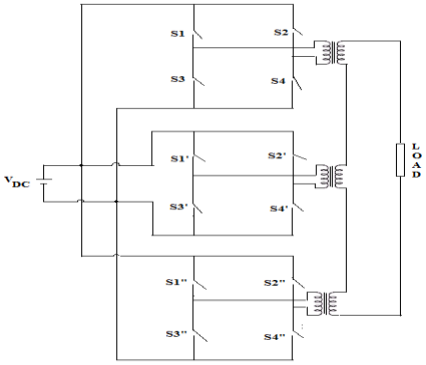


Fig. 1. Single-phase seven-level CHB inverter with a single DC source

III. MULTICARRIER PWM TECHNIQUE

The most popular control technique used in the MLI is the multicarrier PWM technique. It is more popular due to its simplicity and good results in all operating conditions. It can be used for any MLI and can be easily implemented. It can be categorized into two groups: carrier disposition methods (CD) and phase shifted (PS) methods [8].For an m-level inverter, m-1 carrier (triangular) waves with the same amplitude and frequency are required for this PWM technique.

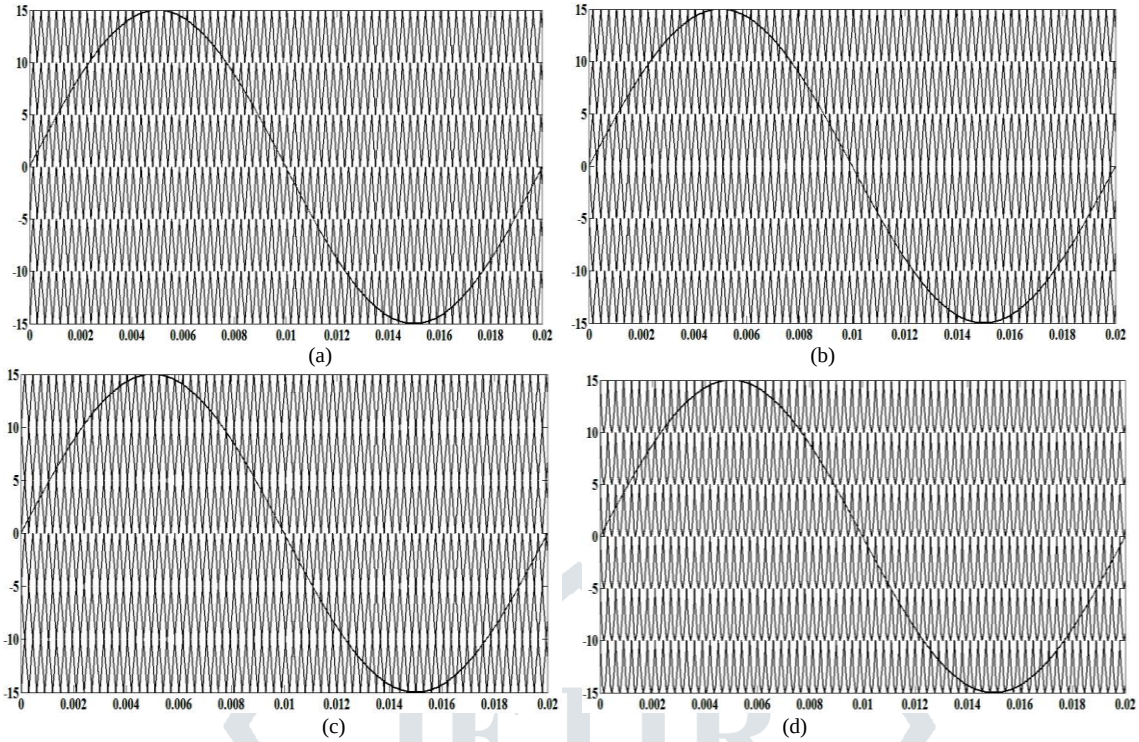


Fig. 2. (a) PD Technique, (b) POD Technique, (c) APOD Technique, (d) ISINE Technique

The frequency modulation index is the ratio of carrier signal frequency to the modulating signal frequency and is given by equation (1).

$$m_f = \frac{f_{cr}}{f_m} \quad (1)$$

Where, f_m is the modulating signal frequency and f_{cr} is the carrier signal frequency. The amplitude modulation index m_a is given by equation (2).

$$m_a = \frac{v_m}{v_{cr}(m-1)} \quad (2)$$

Where, v_m is the peak value of the modulating wave and v_{cr} is the peak value of each carrier wave. There are two major classifications of multi-carrier PWM techniques namely, carrier disposition and phase shifted techniques. In the carrier disposition techniques, the carrier waves are vertically shifted from each other. In the phase-shifted technique, the carrier waves have an horizontal phase shift. The various disposition techniques are [9-13]

1. Phase Disposition (PD)
2. Phase Opposition Disposition (POD)
3. Alternate Phase Opposition Disposition (APOD)
4. Inverted Sine PWM (ISPWM).

Phase Disposition (PD) employs (m-1) triangular carrier waves with all carrier waves in phase with each other.

For the seven-level inverter, six carrier waves are compared with the sine wave. The six carrier waves are arranged with a vertical shift. Figure 2(a) shows the PD modulation for seven level MLI

Phase Opposition Disposition (POD) employs (m-1) triangular carrier waves where all carrier waves above the zero reference are in phase, but shifted by 180˚ from those below the zero reference. The six carrier waves are arranged with a vertical shift. Figure 2(b) shows the POD modulation for seven level MLI.

Alternate Phase Opposition Disposition (APOD) employs (m-1) vertically shifted triangular carrier waves with each carrier wave shifted from the adjacent wave by 180˚. Figure 2(c) shows the APOD modulation for the seven-level MLI.

Inverted sine PWM employs (m-1) inverted sine carrier waves with all the carrier waves shifted vertically from each other. Figure 2(d) shows the inverted sine PWM for the seven-level MLI.

IV. Simulation And Results

The proposed seven level MLI is simulated in MATLAB using the four carrier disposition techniques by changing the amplitude modulation. The output voltages and their voltage THDs are obtained for different PWM techniques for m_a = 0.4, 0.5, 0.6, 0.7, 0.8. Figures 3-6 show the simulated output voltage and the FFT of output voltage for the four carrier disposition techniques.

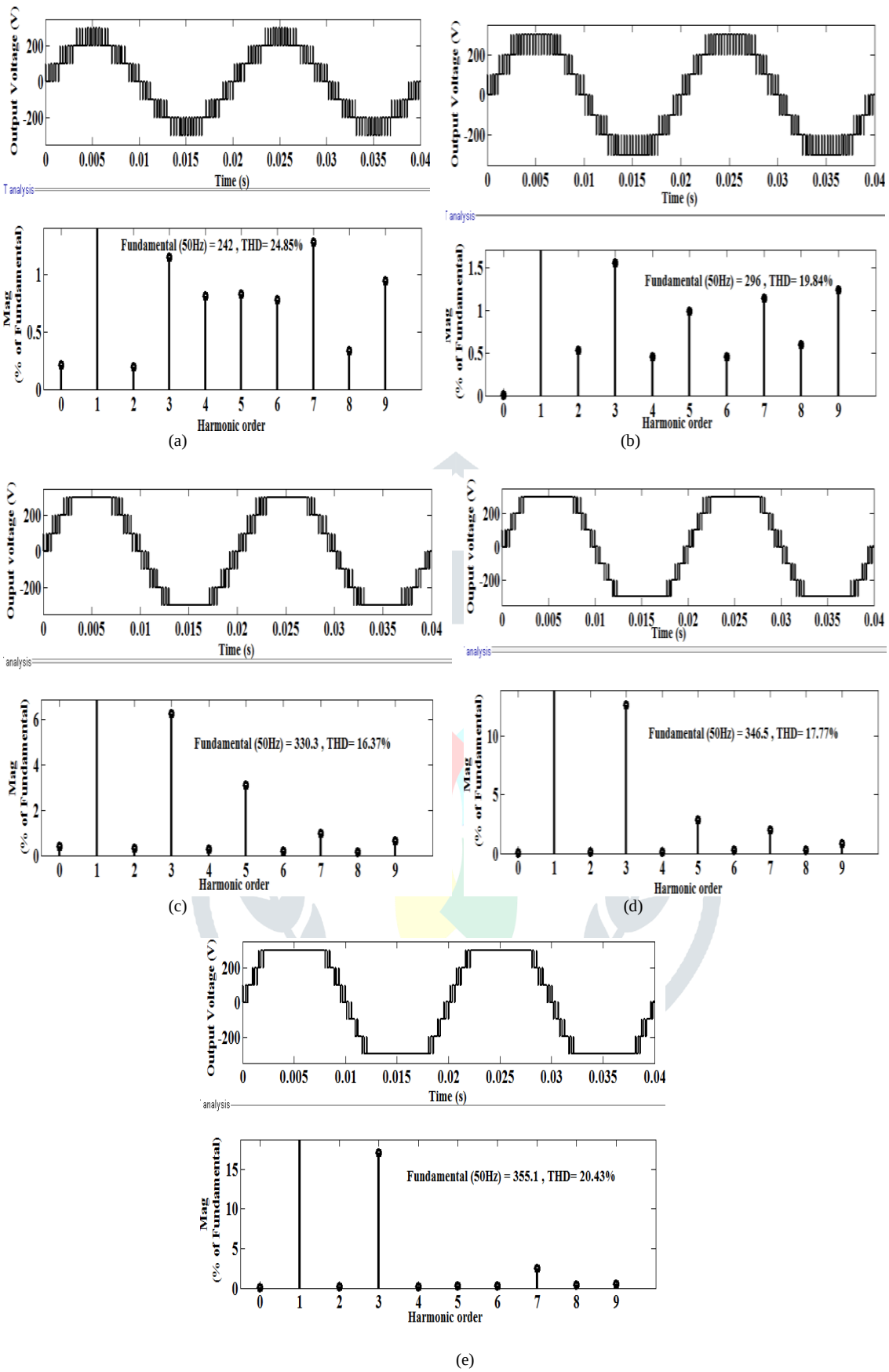


Fig. 3 Output Voltage and FFT analysis for PD Technique (a) ma= 0.4 (b) ma= 0.5 (c) ma= 0.6 (d) ma= 0.7 (e) ma= 0.8

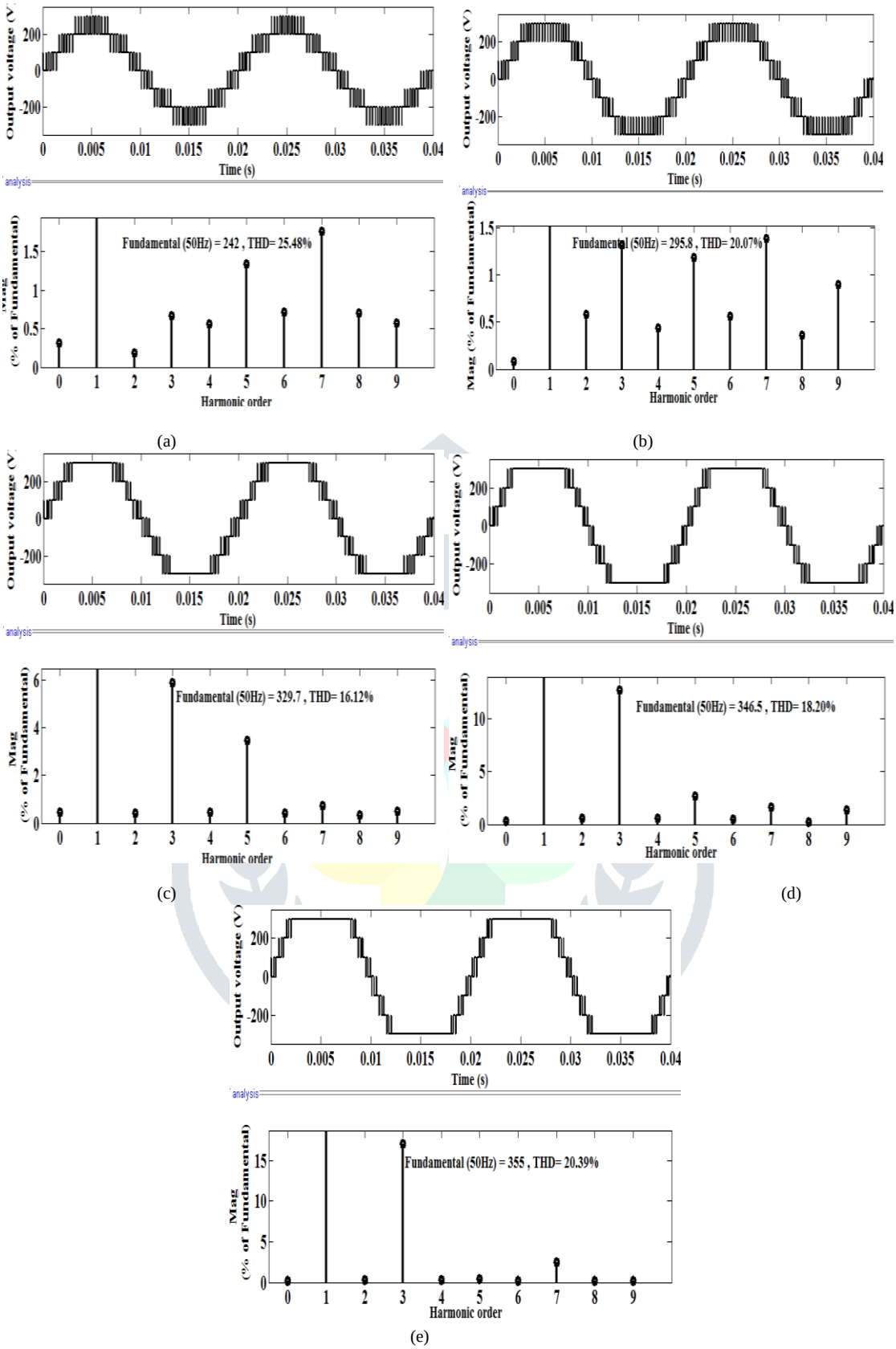
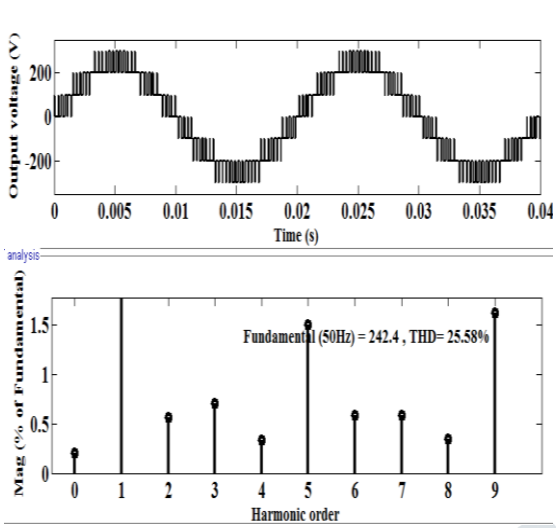
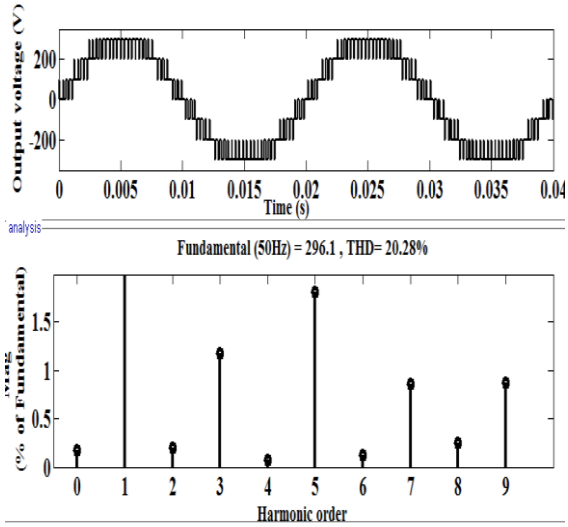
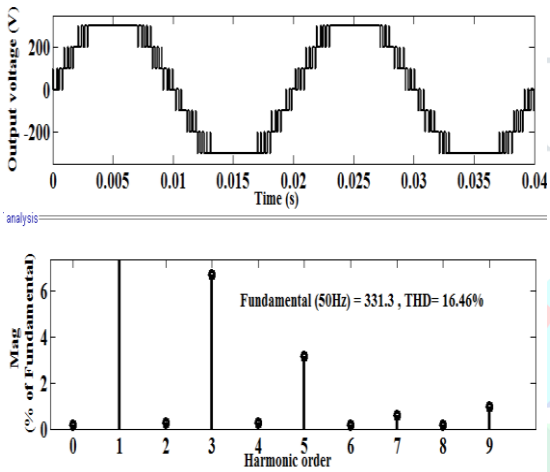


Fig.4. Output Voltage and FFT analysis for APOD Technique (a) ma= 0.4 (b) ma= 0.5 (c) ma= 0.6 (d) ma= 0.7 (e) ma= 0.8





(b) (b)



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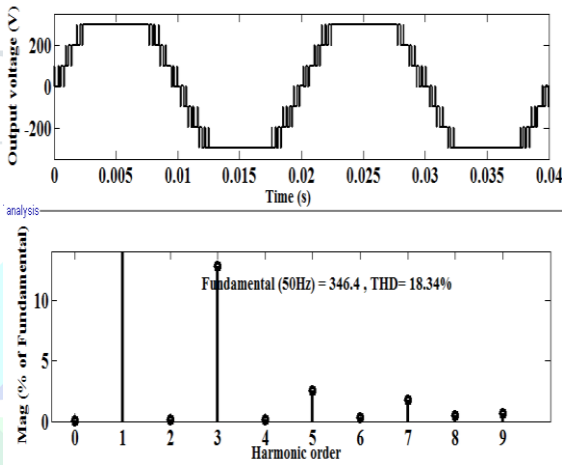

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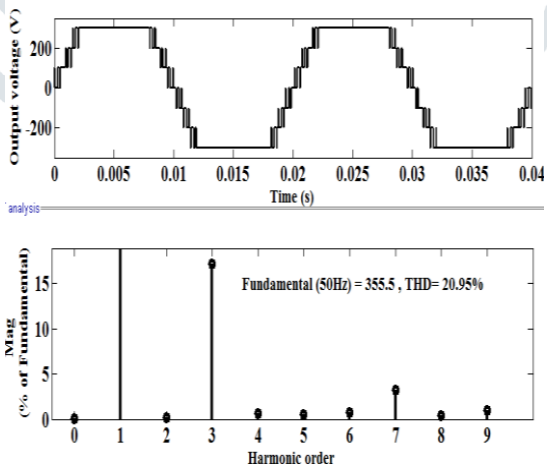
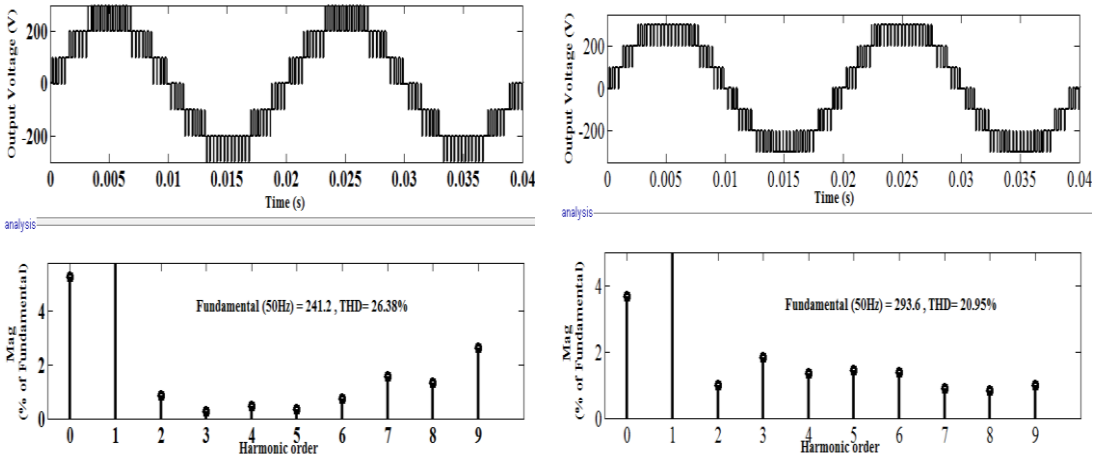


(e)

Fig. 5 Output Voltage and FFT analysis for POD Technique (a) ma= 0.4 (b) ma= 0.5 (c) ma= 0.6 (d) ma= 0.7 (e) ma= 0.8



(a)

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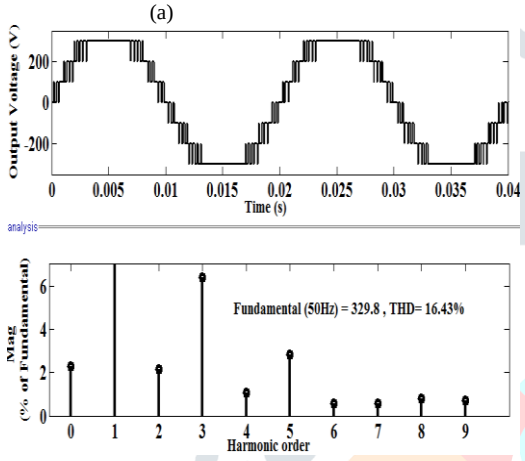

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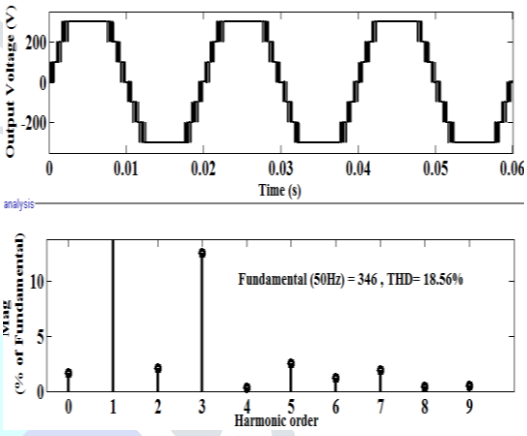

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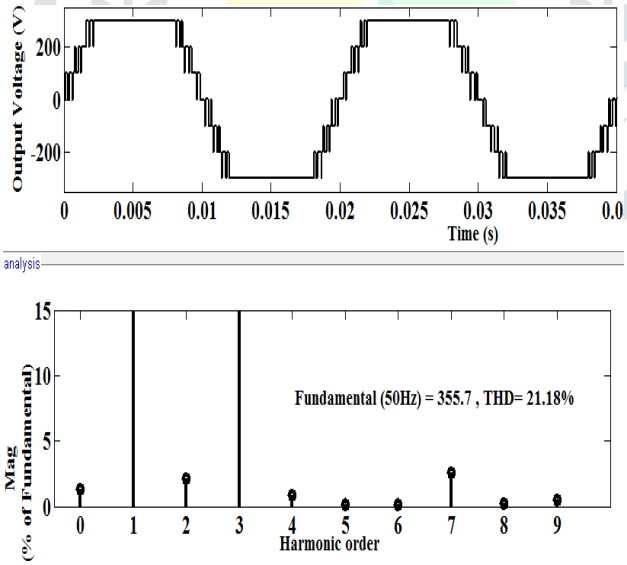

(e)

Fig. 6. Output Voltage and FFT analysis for ISINE Technique (a) ma= 0.4 (b) ma= 0.5 (c) ma= 0.6 (d) ma= 0.7 (e) ma= 0.8

Table 1 shows the voltage THD values of the MLI for varying m_a for the four carrier disposition techniques

TABLE 1. VOLTAGE THDS OF THE MLI FOR FOUR DIFFERENT m_a FOR THE FOUR DIFFERENT PWM METHODS.

m_a	0.4	0.5	0.6	0.7	0.8
Voltage THDs for the PD	24.85%	19.84%	16.37%	17.77%	20.43%
Voltage THDs for the APOD	25.48%	20.07%	16.12%	18.2%	20.39%
Voltage THDs for the POD	25.58%	20.28%	16.46%	18.34%	20.95%
Voltage THDs for the ISPWM	26.38%	20.95%	16.43%	18.56%	21.18%

Fig 7 shows the graph of the voltage THDs vs. m_a for the five techniques. From the Table 1 it is found that the voltage THDs are better for PD method for all the values of m_a. In addition, it can be seen that for m_a =0.6, the THD value is the least for all the PWM techniques.

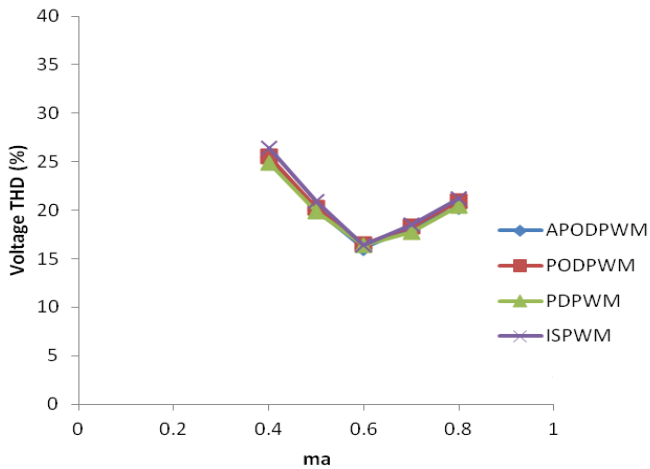

Fig. 7. Voltage THDs vs. m_a for APOD, POD, PD, ISPWM techniques

V. CONCLUSION

Cascaded H-Bridge Inverter is widely used because of its many advantages. The only disadvantage of requiring separate DC sources is eliminated in this paper with the proposed CHB inverter. The various carrier disposition techniques have been discussed. The proposed topology is simulated with the various carrier disposition techniques for varying amplitude modulation indices. The voltage THDs for the five carrier disposition PWM techniques are compared for varying modulation indices and the phase disposition technique produces the least THD value. In addition, it is found that the voltage THD is the least for m_a=0.6 for all the five PWM techniques. Hence, the phase disposition technique may be used in the Cascaded H-Bridge Inverter

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