

Multiple Carrier PWM Schemes for Multi-Level Cascaded H-Bridge Inverter

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Abstract—Multiple carrier pulse width modulation schemes are the popular managing techniques basically preferred in power electronic inverter circuits. And the pulse width modulation allows voltage regulation. To compare the performance of abundant modulation strategies, The CHBMLI is simulated in MATLAB. In this project, the %THD and basic line voltage have been intended to simulate in MATLAB with different modulation techniques like phase disposition pulse width modulation, alternate phase opposition disposition pulse width modulation, and phase opposition disposition pulse width modulation. The staircase types positioned can be generated by using a wide variety of switches within the multilevel inverters.

Keywords : CHBMLI, THD, PDPWM, PODPWM

I. INTRODUCTION

Nowadays we are mostly using multilevel inverters. The area of applications is high power and medium voltages because it may help to decrease the voltage stress on power switches [8]. Multilevel inverters are more popular in the area of power industry due to their ability to control high voltage and power drives with improved efficiency and reduced electromagnetic interference [1]. Neutral point clamped (NPC) inverters are commonly used in industrial applications, and multiple carrier PWM techniques can further enhance the performance of NPC inverters [2]. The use of multi-carrier pulse widths modulation techniques, such as phase disposition (PD), phase opposition and disposition (POD), and alternative phase-opposition disposition (APOD), can improve the power quality and reject common mode voltage, as well as address the issue of DC-link capacitor balancing in multilevel inverters. However, these techniques can also result in higher Total Harmonic Distortion (THD) compared to the other PDPWM techniques [3]. Enhancing the performance of a %THD of a 5- Phase, 3-Level Neutral Point Clamped (NPC) inverter is proposed in [4]. The goal is to achieve lower THD levels in the output waveform of the inverter, which can lead to improved efficiency, reduced losses, and higher-quality power output [5]-[6].

Multiphase inverters have gained popularity in high-power applications due to their advantages over single-phase inverters. These advantages include improved reliability, better output waveform quality, and reduced harmonic distortion. They have a wide range of applications, including high-power applications, uninterruptible power supply (UPS) systems, high-voltage DC transmission, variable frequency drives, pumps, and conveyors [7].

The MLI topologies are:

- Flying capacitor
- Diode clamped
- Cascaded H-Bridge [9].

Because of the disadvantages of diode-clamped and flying capacitors inverters, we are going with the Cascaded H-Bridge inverter [9]. The flying capacitor multilevel inverter has high-frequency switching so the switching losses are very high. And the tracking of voltage levels is very difficult [8]. The output voltage of diode-clamped multilevel inverter, the is decreased to half of the maximum input voltage and it has issues with capacitor voltage imbalance [8]. In this paper, we are comparing the three pulse width modulation techniques. Phase Disposition, Phase Opposition and Disposition, and alternate Phase Opposite Disposition [10]. In this paper, we have compared modulation techniques simulated in MATLAB. The Five-Level three-phase CHBMLI is being used in this simulation.

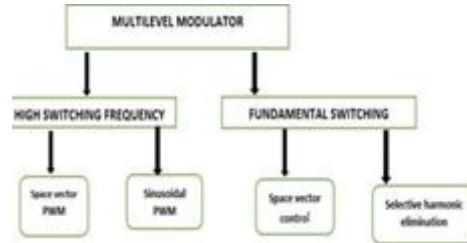


Fig.1 Different types of multilevel modulators.

II. DIFFERENT PULSE WIDTH MODULATION TECHNIQUES

There are many types of PWM techniques, but we are using only three PWM techniques in this paper.

A. PDPWM:

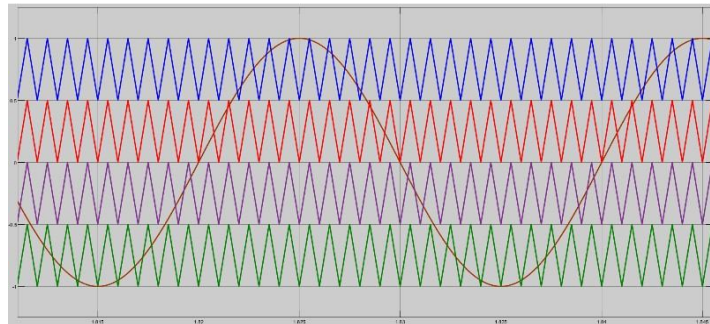


Fig. 2 PDPWM

In this phase disposition pulse width modulation. We are using repeating sequence values for four carrier signals are

1. 0.5, -1, -0.5
2. 0, 0.5, 0
3. -0.5, 0, -0.5
4. -1, -0.5, -1

These carrier signals are compared with the sine wave with a frequency of 50HZ.

B. PODPWM:

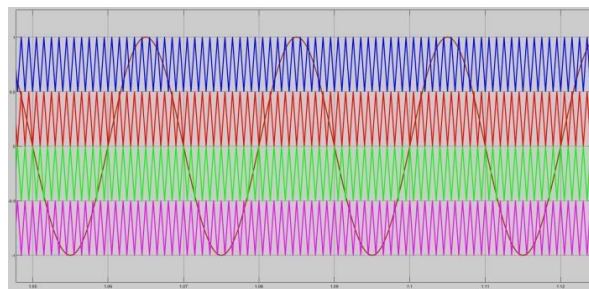


Fig. 3 PODPWM

In this phase opposition disposition pulse width modulation. We are using repeating sequence values for four carrier signals are

1. 0.5, 1, 0.5
2. 0, 0.5, 0
3. 0, -0.5, 0
4. -0.5, -1, -0.5

These carrier signals are compared with the sine wave with a frequency of 50HZ.

C. APODPWM:

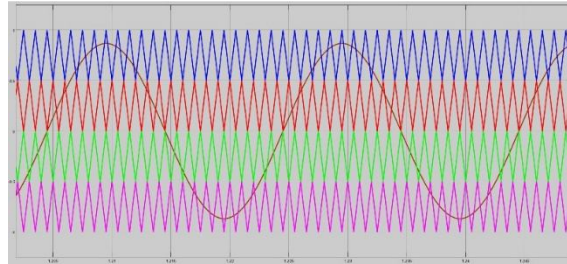


Fig 4. APODPWM

In this alternate phase opposition disposition pulse width modulation. We are using repeating sequence values for four carrier signals are

1. 0.5, 1, 0.5
2. 0.5, 0, 0.5
3. -0.5, 0, -0.5
4. -0.5, -1, -0.5

These carrier signals are compared with the sine wave with a frequency of 50HZ.

III. SIMULATION RESULTS AND DISCUSSIONS

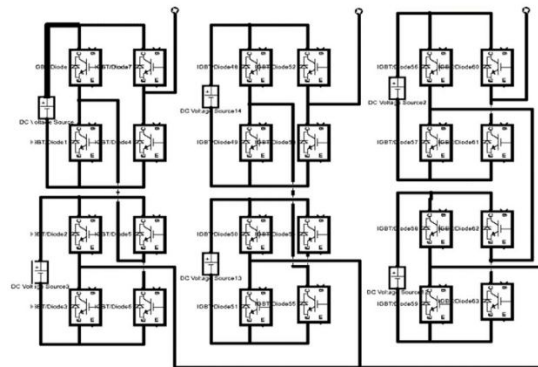
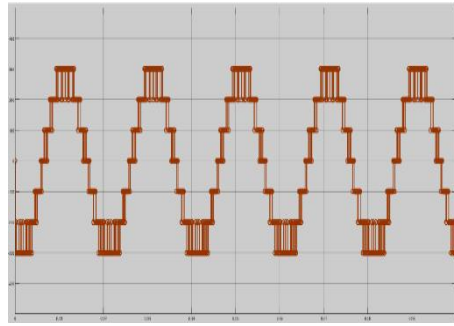


Fig. 5 Three-Phase 5-level CHBMLI

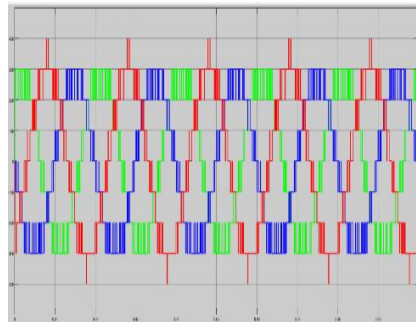
Here Fig.5 shows the circuit diagram of a 3-phase 5-level cascaded H- bridge inverter simulated in Matlab for PD, POD, and APOD. Here we are simulating the five-level three-phase cascaded H-bridge multi-level-inverter. And comparing the line voltages and THD%. for the three-phase 5-level cascaded H-bridge multi-level inverter, we are using 24 IGBT switches. For the RY phase 16 switches are acting with 400v, for the YB phase 16 switches are acting with 400v, for the RB phase 16 switches are acting with 400v. For the total three-phase 5-level cascaded H-bridge inverter, we are using 600v.

IV. PWM TECHNIQUES WITHOUT LOAD:

These are the simulated outputs of three phases cascaded H-bridge 5-level inverter and we are comparing the line-to-line voltage, phase voltage, and THD% of PD, POD, and APOD. By applying (0.8 and 0.3) modulation index for all three methods.



(a)



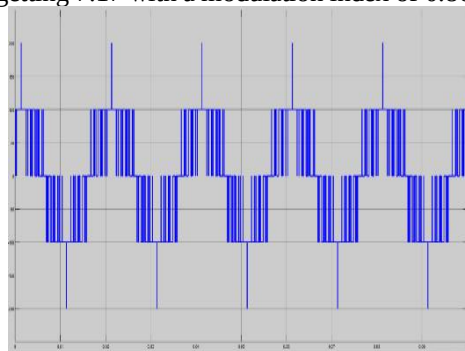
(b)



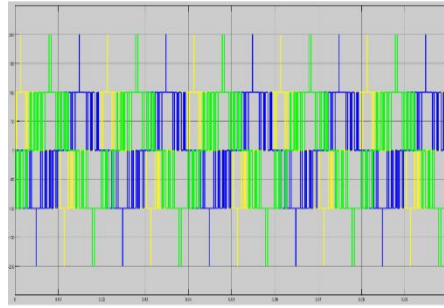
(c)

(i). Simulated waveforms for PDPWM (0.8)

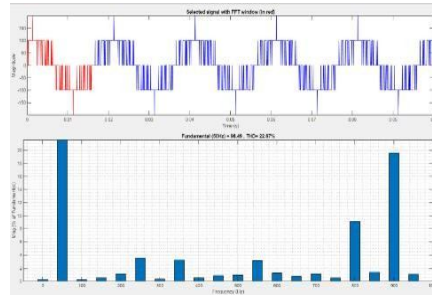
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 300v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 400v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 7.17 with a modulation index of 0.867 without load.



(a)



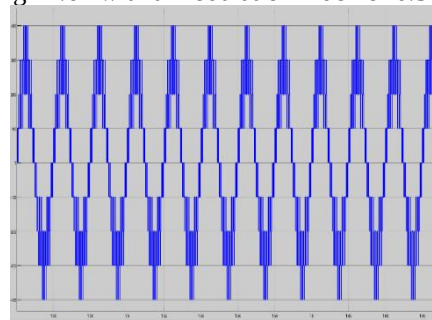
(b)



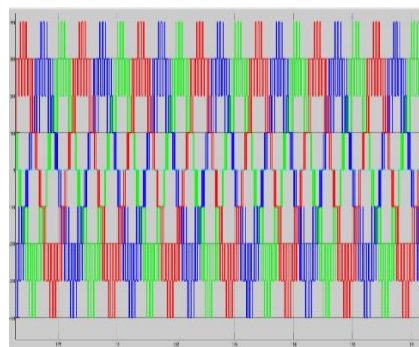
(c)

(ii). Simulated waveforms for PDPWM (0.3)

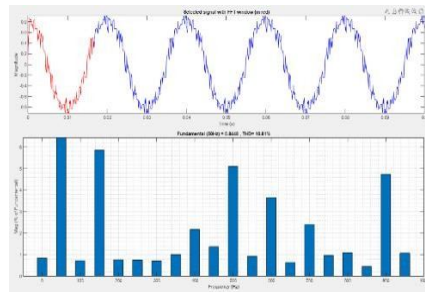
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 100.2v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 200v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 22.67 with a modulation index of 0.3 without load.



(a)



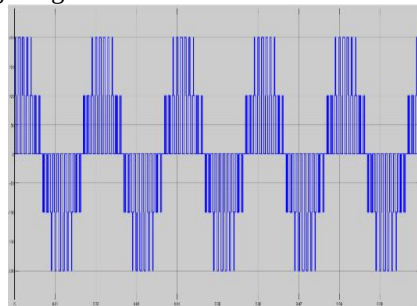
(b)



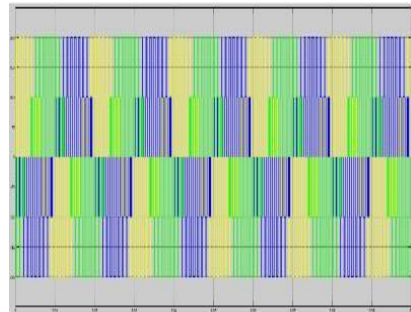
(c)

(iii). Simulated waveforms for PODPWM (0.8)

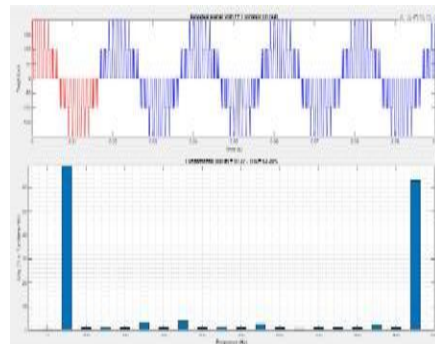
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 400v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 400v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique we are getting 10.81 with a modulation index of 0.867 without load.



(a)



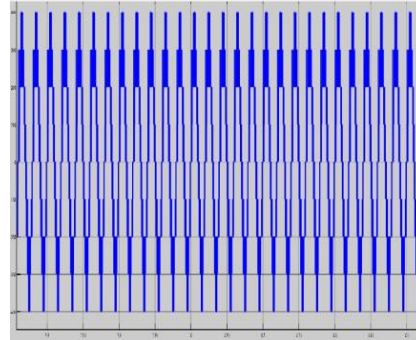
(b)



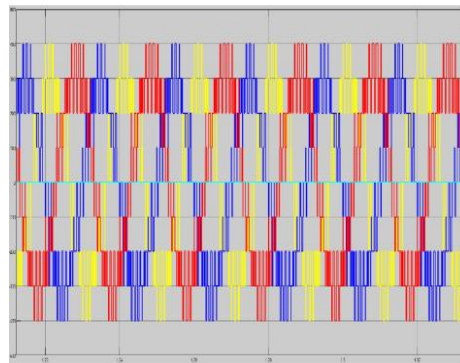
(c)

(iv). Simulated waveforms for PODPWM (0.3)

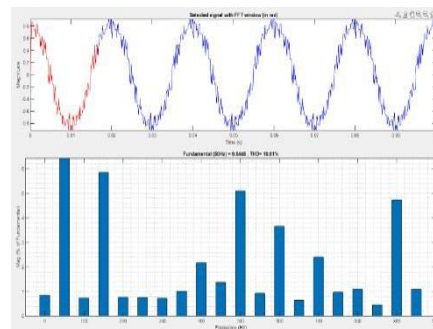
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 200v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 200v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 63.38 with a modulation index of 0.3 without load.



(a)



(b)

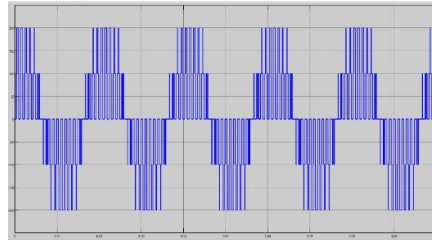


(c)

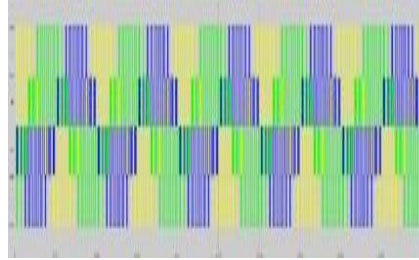
(v) Simulated waveforms for APODPWM (0.8)

Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the APODPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 400v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 400v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 10.81 with a modulation index of 0.867 without load.

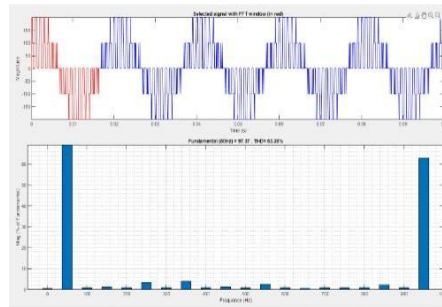
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 200v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 200v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 63.38 with a modulation index of 0.3 without load.



(a)



(b)



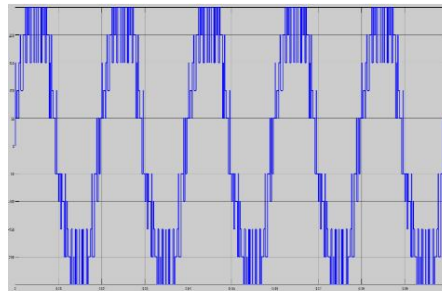
(c)

(v i) Simulated waveforms for APODPWM (0.3)

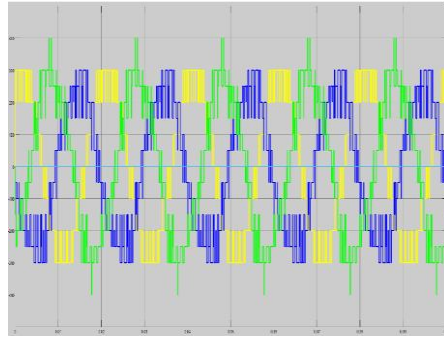
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 200v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 200v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 63.38 with a modulation index of 0.3 without load.

V. PWM TECHNIQUES WITH LOAD:

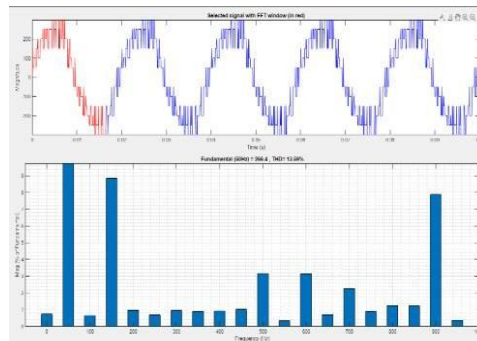
These are the simulated outputs of three phases cascaded H-bridge 5-level inverter and we are comparing the line-to-line voltage, phase voltage, and THD% of PD, POD, and APOD. By applying (0.8 and 0.3) modulation index for all three methods.



(a)



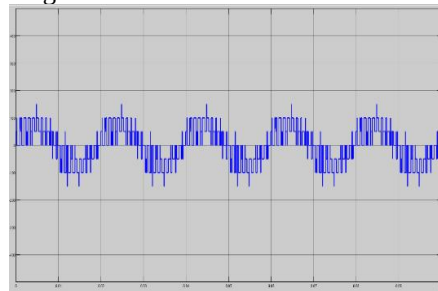
(b)



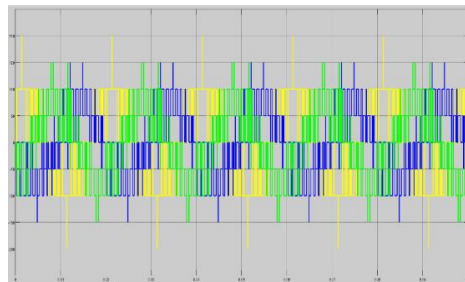
(c)

(i) Simulated waveforms for PDPWM (0.8)

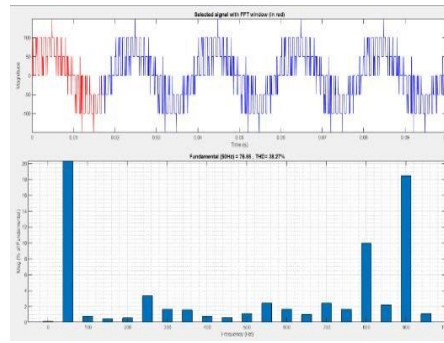
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 200v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 300v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 13.59 with a modulation index of 0.867 with load



(a)



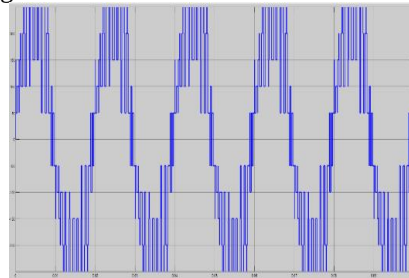
(b)



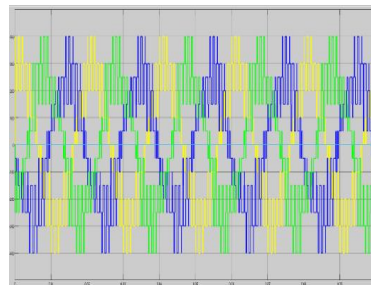
(c)

(ii) Simulated waveforms for PDPWM (0.3)

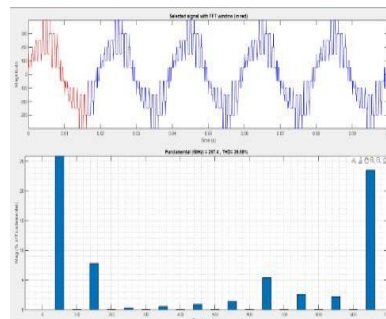
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 100v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 150v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 38.27 with a modulation index of 0.3 with load.



(a)



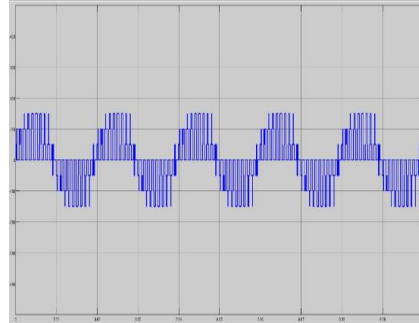
(b)



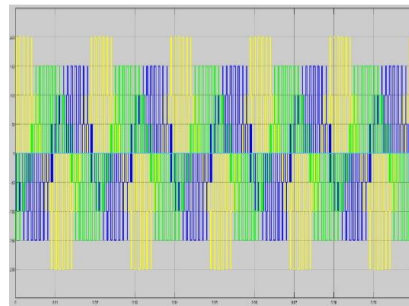
(c)

(iii). Simulated waveforms for PODPWM (0.8)

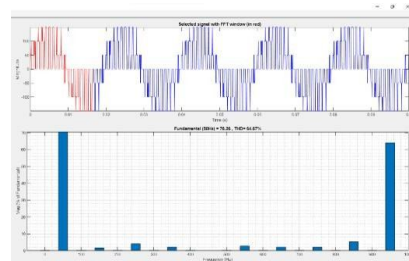
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 100v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 400v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique we are getting 25.68 with a modulation index of 0.867 with load.



(a)



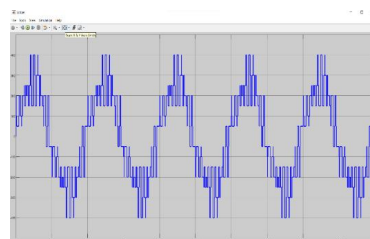
(b)



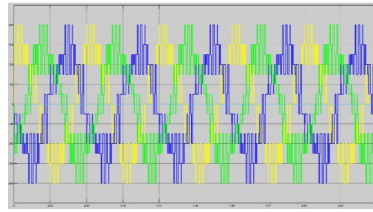
(c)

(iv). Simulated waveforms for PODPWM (0.3)

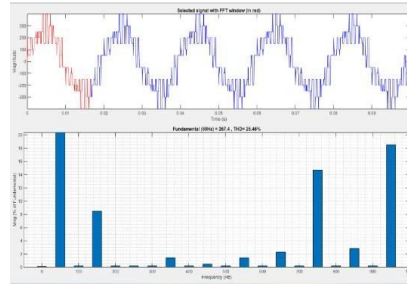
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 100v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 150v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 63.67 with a modulation index of 0.3 with load.



(a)



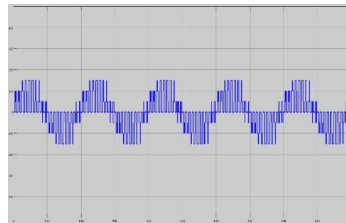
(b)



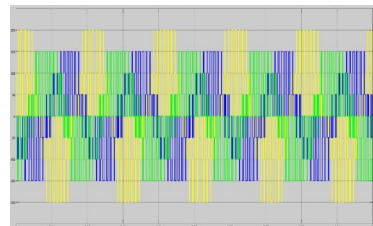
(c)

(v). Simulated waveforms for APODPWM (0.8)

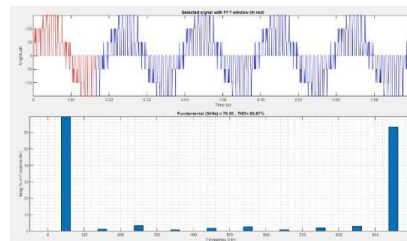
Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique with a modulation index of 0.867. we are getting a 9-level output voltage of 300v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 400v with modulation index of 0.867. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 25.46 with a modulation index of 0.867 with load.



(a)



(b)



(c)

(vi). Simulated waveforms for APODPWM (0.3)

Here Fig. (a) represents the line voltage of the three phases cascaded H-bridge 5-level inverter of the PODPWM technique with a modulation index of 0.3. we are getting a 3-level output voltage of 100v. Fig. (b) represents the phase voltage of three phases cascaded H-bridge 5-level inverter 150v with modulation index 0.3. Fig. (c) represents the percentage of total harmonic distortion of the three phases cascaded H-bridge 5-level inverter of the PDPWM technique we are getting 63.67 with a modulation index of 0.3 with load.

TABLE I. COMPARISON OF THD AND LINE-TO-LINE VOLTAGE FOR VARIOUS PWM METHODS ON THREE PHASE FIVE LEVEL CHBMLI

PWM TECHNIQUES WITHOUT LOAD				
PWM technique	Total harmonic distortion (%)		Line voltage(V)	
	$a=0.867$	$m=0.3$	$a=0.867$	$m=0.3$
PWM	7.17	2.67	0	0.2
DPWM	10.81	3.38	0	00
ODPWM	10.81	3.38	0	00
PWM TECHNIQUES WITH LOAD				
PWM	13.59	3.27	0	00
DPWM	25.68	3.67	0	00
ODPWM	25.46	3.67	0	00

IV. CONCLUSION

This paper presents a differentiation of various Pulse Width Modulation (PWM) techniques based on their ability to minimize Total Harmonic Distortion (THD). The study involved the simulation of different PWM techniques to identify the most effective method for reducing THD. The PDPWM technique has been recorded with less %THD compared to PODPWM and APODPWM. We are comparing the percentage THD and line voltages of different Pulse Width Modulation techniques.

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