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Performance Analysis of Multicarrier SPWM Strategies for Three Phase Z - Source Seven Level Cascaded Inverter

V. Arun, [1] B.Shanthi, [2] S. P. Natarajan[3]
[1]Department of EEE, Arunai Engineering College, Thiruvannamalai, Tamilnadu, India
[2]Centralised Instrumentation and Service Laboratory, Annamalai University, Chidambaram, Tamilnadu, India
[3]Department of EIE, Annamalai University, Chidambaram, Tamilnadu, India

ABSTRACT: *This paper presents multicarrier PWM strategies for three phase cascaded seven level Z-source inverter. Multilevel inverters posses the advantage of reduced harmonics, high-power capability and high-voltage level. Impedance network in the cascaded multilevel inverter circuit will perform boost operation. This paper focuses on multicarrier sinusoidal pulse width modulation (MCSPWM) strategy for the three phase seven level Z source cascaded inverter. Performance parameters of three phase seven level Z source cascaded inverter have been analyzed. A simulation model of three phase seven level Z source cascaded inverter developed using MATLAB/SIMULINK and its performance has been analyzed.*

Keywords: *APOD, CO, POD, PD, SPWM.*

I. INTRODUCTION

Multilevel inverters have become an attractive choice as a partial solution to the improvement of the global conversion chain efficiency. Multilevel inverter is a switching converter where the appropriate control of an arrangement of switching devices allows combining diverse input voltages to synthesize a sinusoidal output voltage waveform. Carrara et al [1] discussed various multilevel PWM methods and theoretical analysis of PWM strategies. Huang et al [2] proposed Z-source inverter for residential photovoltaic applications. Loh et al [3] have used pulse-width modulated strategies for Z-source neutral point clamped inverter. Various pulse-width modulated strategies for Z source inverter was discussed by Loh et al [4]. Different control strategies for Z-source neutral-point-clamped Inverter and also for cascaded MLI were discussed in [5,6]. Malinowski et al [7] analysed various cascaded multilevel inverters. Three level Z source inverter topology was introduced by Peng in [8]. Rendusara et al [9] analysed common mode voltage and PWM strategies for adjustable speed drive. Shanthi and Natarajan [10] discussed various unipolar PWM strategies for single phase five level cascaded inverter. Zhou et al [11] discussed Z source inverter based single phase uninterruptible power supply.

II. Z-SOURCE SEVEN LEVEL CASCADED INVERTER

Figure1 shows the two-port network that consists of an inductors (L1, L2) and capacitors (C1, C2) and connected in X shape is employed to provide an impedance source (Z Source) coupling the inverter to the dc source.

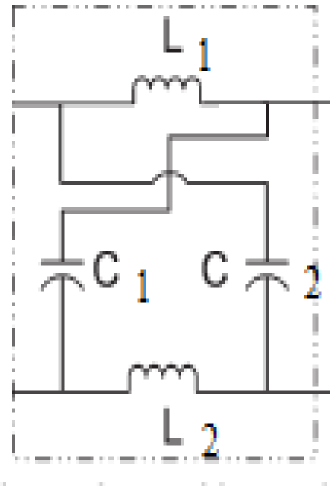

Figure 1 Impedance Network

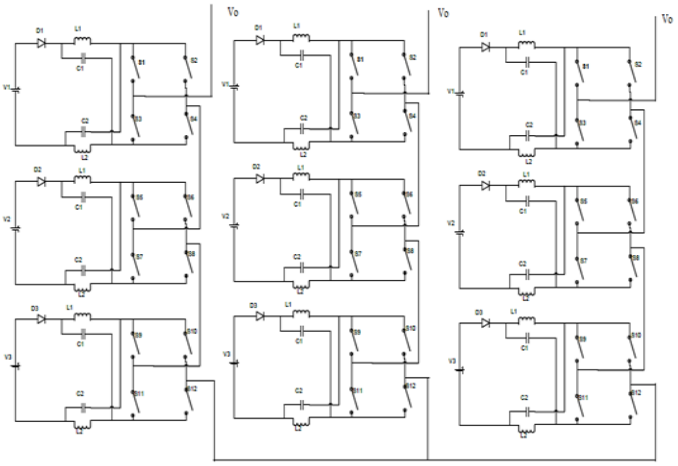

Figure 2 Three phase Seven Level Z source cascaded inverter

Figure2 shows the seven level Z source cascaded inverter. The inverter topology is based on the series connection of single-phase inverters with separate impedance dc sources. The resulting phase voltage is synthesized by the addition of the voltages generated by the different cells. The number of output voltage levels are $2n+1$, where n is the number of cells. The ac output of each H-bridge is connected in series such that the synthesized output voltage waveform is the sum of all the individual H-bridge outputs.

III. MULTICARRIER PWM STRATEGY

Multicarrier PWM strategy is the widely adopted modulation strategy for MLI. It is similar to that of the sinusoidal PWM strategy except for the fact that several carriers are used. Multicarrier PWM is one in which several triangular carrier signals are compared with one sinusoidal modulating signal. The number of carriers required to produce m-level output is m-1. All carriers have the same peak to peak amplitude A_c and same frequency f_c except for VF. The reference waveform has peak to peak amplitude of A_m and a frequency f_m .The reference is continuously compared with each of the carrier signals and whenever the reference is greater than the carrier signal, pulse is generated. There are many carrier arrangements to implement the PWM strategies. In this work the following strategies were carried out.

a. Phase disposition PWM strategy.
b. Phase opposition disposition PWM strategy.
c. Alternate phase opposition disposition PWM strategy.
d. Carrier overlapping PWM strategy.
e. Variable frequency PWM strategy.

The frequency ratio m_f is as follows: $m_f = f_c / f_m$

III.a. Phase Disposition PWM strategy (PDPWM).

Fig. 3 shows the sinusoidal pulse width modulation of an m-level inverter, (m-1) carriers with the same frequency f_c and same amplitude A_c are positioned such that the bands they occupy are contiguous. If the reference wave is more than a carrier signal, then the active devices corresponding to that carrier are switched on. Otherwise, the devices switch off.

Amplitude of modulation index $m_a = 2A_m/(m-1)A_c)$

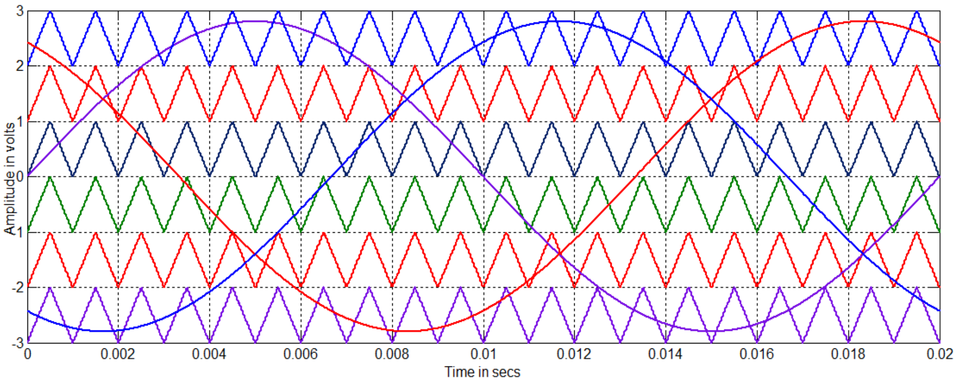

Figure 3 Carrier arrangement for PDPWM strategy (m_a=0.9 and m_f=20)

III.b. Phase Opposition Disposition PWM strategy (PODPWM).

In POD strategy the carrier waveforms above the zero reference are in phase. The carrier waveforms below are also in phase, but are 180 degrees phase shifted from those above zero as shown in Fig.4.

Amplitude of modulation index $m_a = 2A_m/(m-1)A_c)$

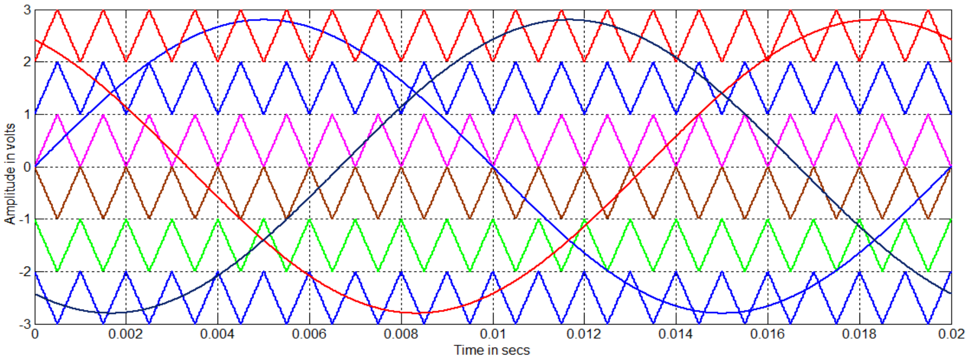

Figure 4 Carrier arrangement for PODPWM strategy (m_a=0.9 and m_f=20)

III.c. Alternate Phase Opposition Disposition PWM strategy (APODWM)

In APOD strategy the carriers of same amplitude are phase displaced from each other by 180 degrees alternately. The carrier arrangement is shown in Fig.5.

Amplitude of modulation index $m_a = 2A_m/(m-1)A_c)$

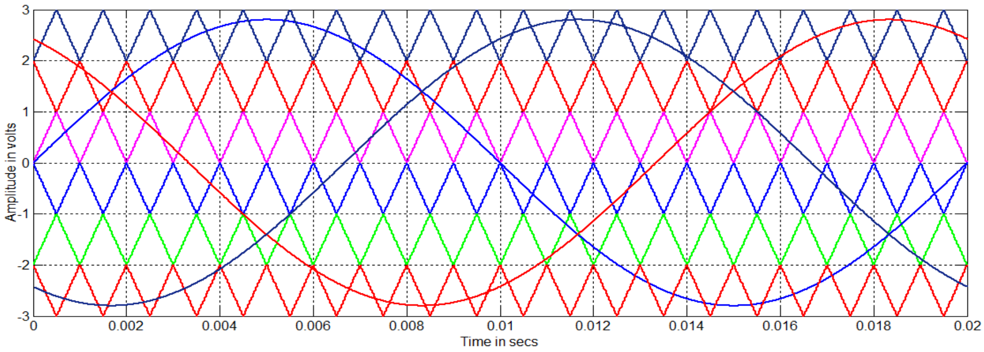

Figure 5 Carrier arrangement for APODPWM strategy (m_a=0.9 and m_f=20)

III.d. Carrier Overlapping PWM strategy (COPWM).

In COPWM strategy, carriers with the same frequency f_c and same peak-to-peak amplitude A_c are disposed such that the bands they occupy are overlap each other; the overlapping vertical distance between each carrier is $A_c/2$. The reference waveform is centered in the middle of the carrier set as in Fig.6.

The amplitude modulation index m_a for carrier overlapping method as follows:

$$m_a = A_m / 2A_c$$

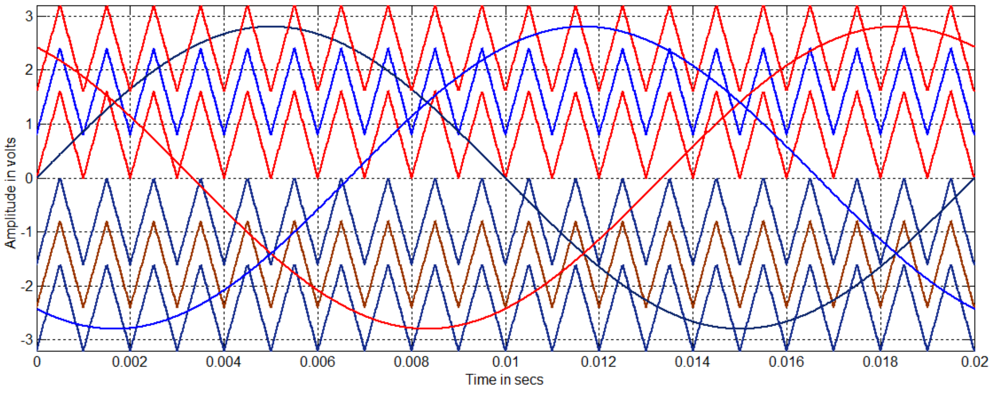

Figure 6 Carrier arrangement for COPWM strategy (m_a=0.9 and m_f=20)

III.e. Variable frequency PWM strategy (VFPWM)

The number of switching for upper and lower devices of chosen MLI is much more than that of intermediate switches in other PWM using constant frequency carriers. In order to equalize the number of switching for all the switches, variable frequency PWM strategy is used.

Modulation index $m_a = 2A_m/(m-1)A_c)$

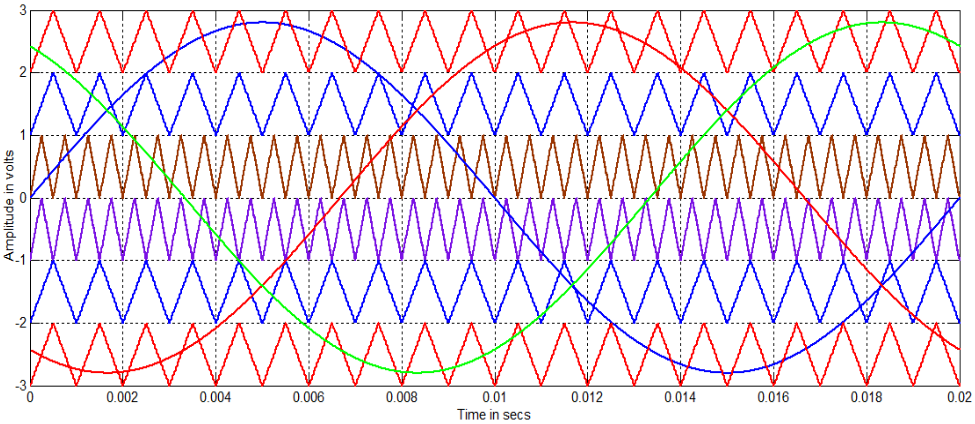

Figure 7 Carrier arrangement for VFPWM strategy (m_a=0.9 and m_{f1}=20,m_{f2}=40)

IV. SIMULATION RESULTS

The Z-source cascaded seven level inverter is modeled in SIMULINK using power system block set. Switching signals for cascaded multilevel inverter using MCSPWM strategies are simulated. Simulations are performed for different values of m_a ranging from 0.8 to 1 and the corresponding %THD are measured using the FFT block and their values are listed in Table I. Figure 8-17 show the simulated output voltage of Z source CMLI and their harmonic spectra. Figure 8 displays the seven level output voltage generated by PDPWM switching strategy and its FFT plot is shown in Figure 9. Figure 10 shows the seven level output voltage generated by PODPWM strategy and its FFT plot is shown in Figure 11. Figure 12 shows the seven level output voltage generated by APODPWM strategy and its FFT plot is shown in Figure 13. Figure 14 shows the seven level output voltage generated by COPWM strategy and its FFT plot is shown in Figure 15. Figure 16 shows the seven level output voltage generated by VFPWM strategy and its FFT plot is shown in Figure 17. Tables II and III displayed the V_{RMS} (fundamental) of the output voltage and Crest Factor (CF) for various modulation indices of Z -Source seven level cascaded inverter respectively.

The following parameter values are used for simulation: V_1 =50V, V2=50V, V_3=50V, R (load) = 100 ohms, f_c=1000 Hz and f_m=50Hz.

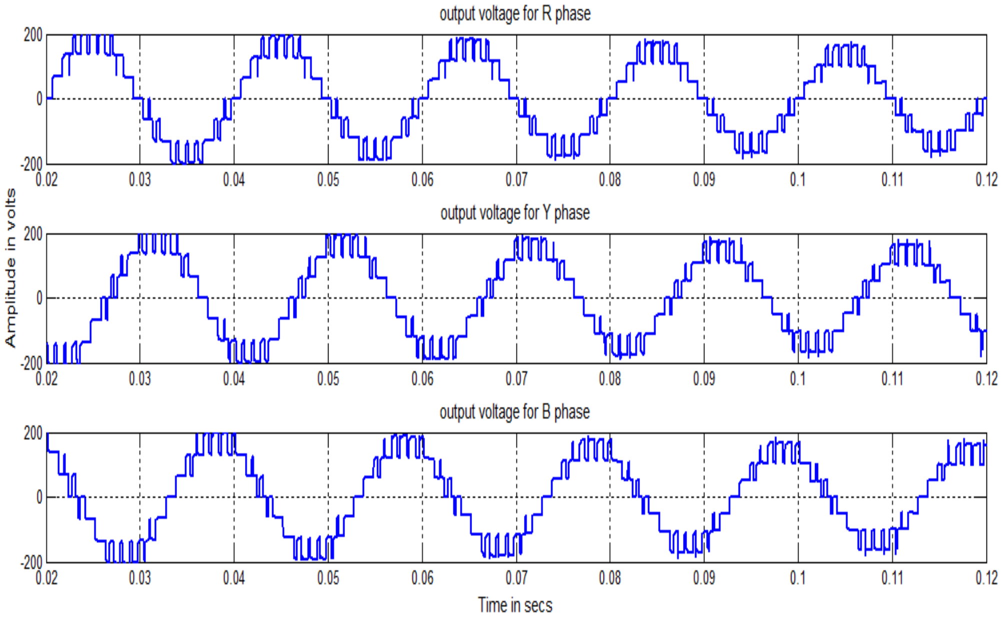

Figure 8 Output voltage generated by PDPWM

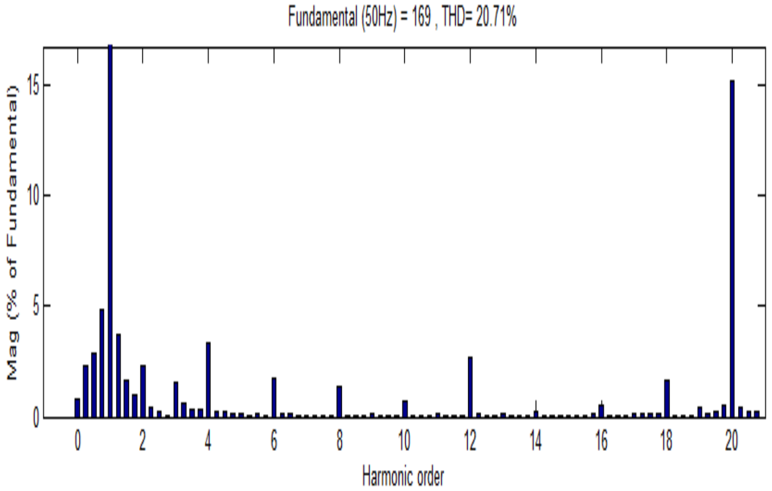

Figure 9 FFT plot for output voltage of PDPWM

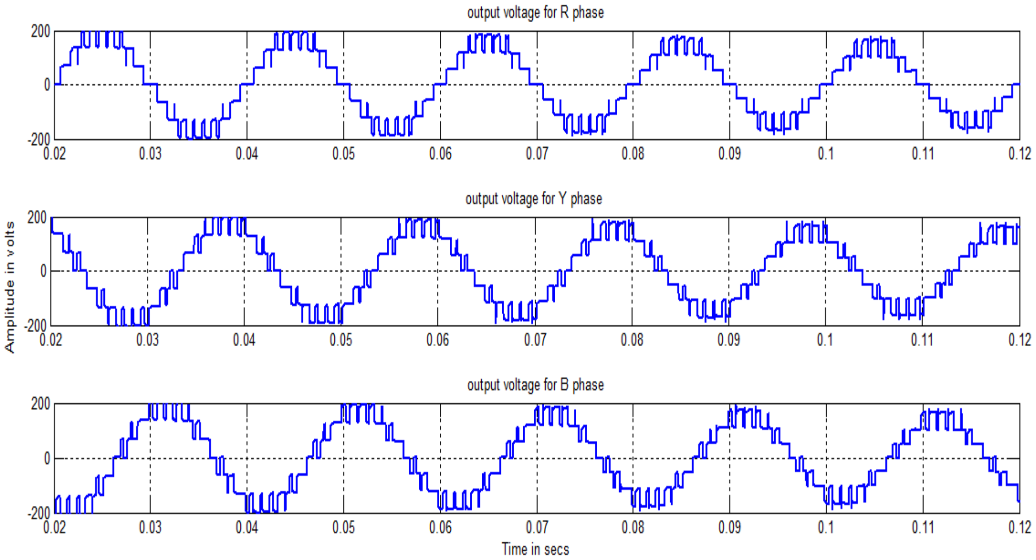

Figure 10 Output voltage generated by PODPWM

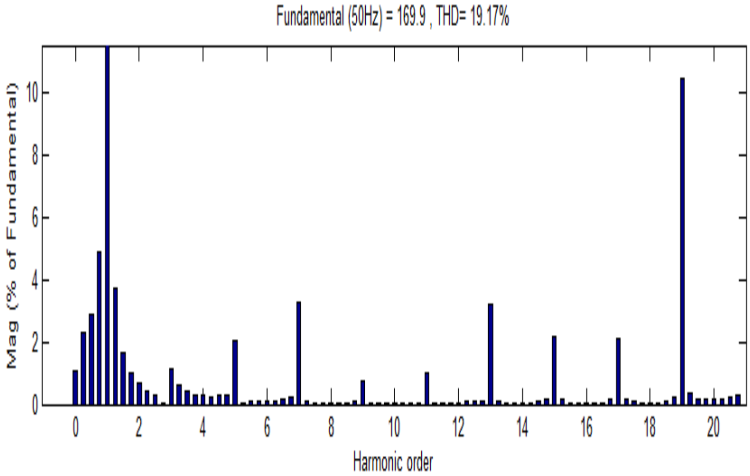

Figure 11 FFT plot for output voltage of PODPWM

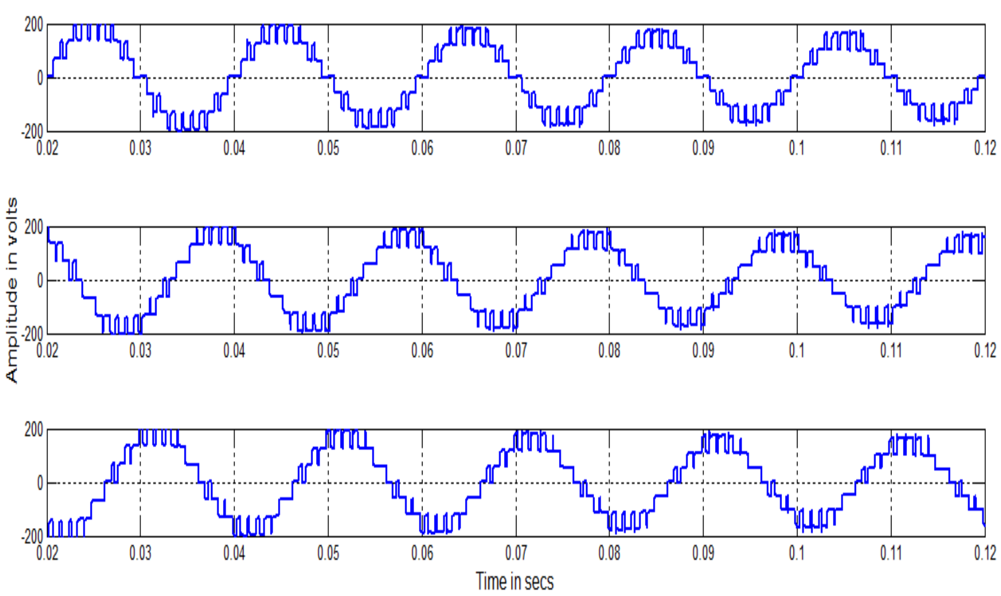

Figure 12 Output voltage generated by APODPWM

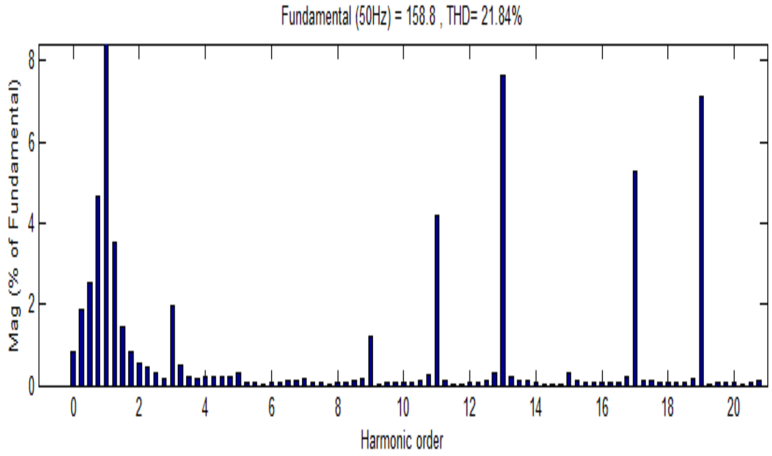

Figure 13 FFT plot for output voltage of APODPWM

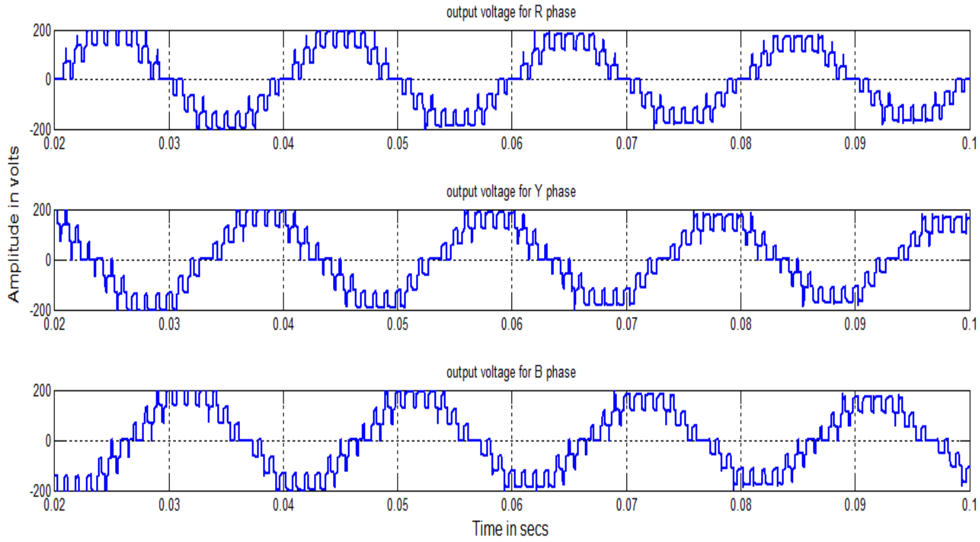

Figure 14 Output voltage generated by CODPWM

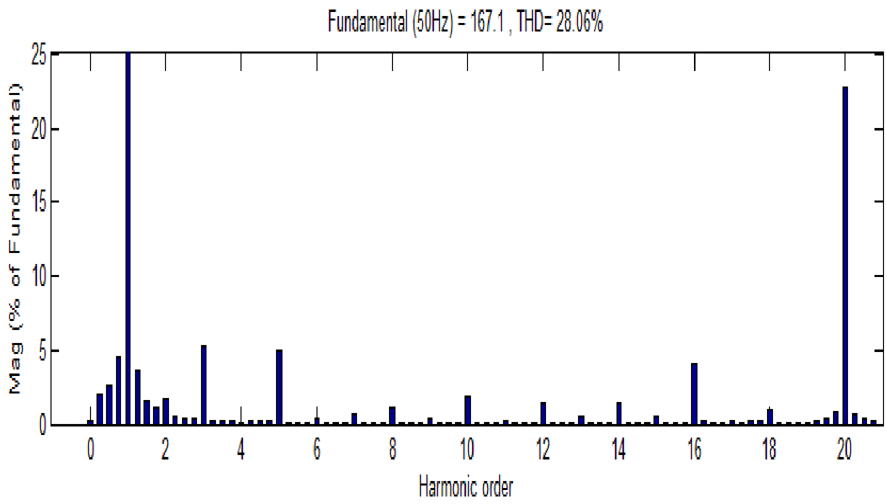

Figure 15 FFT plot for output voltage of COPWM

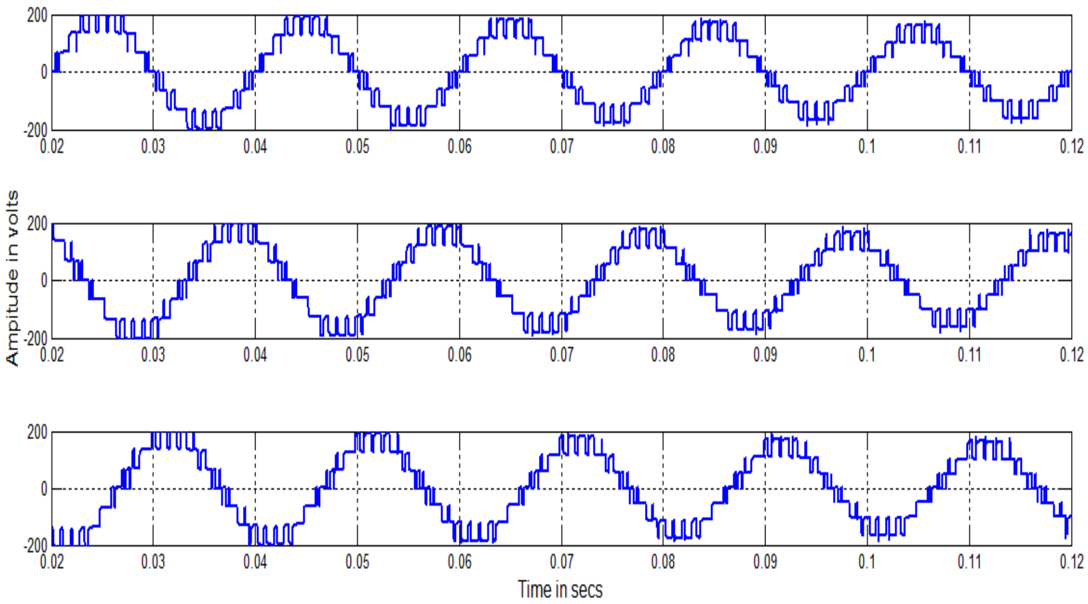

Figure 16 Output voltage generated by VFPWM

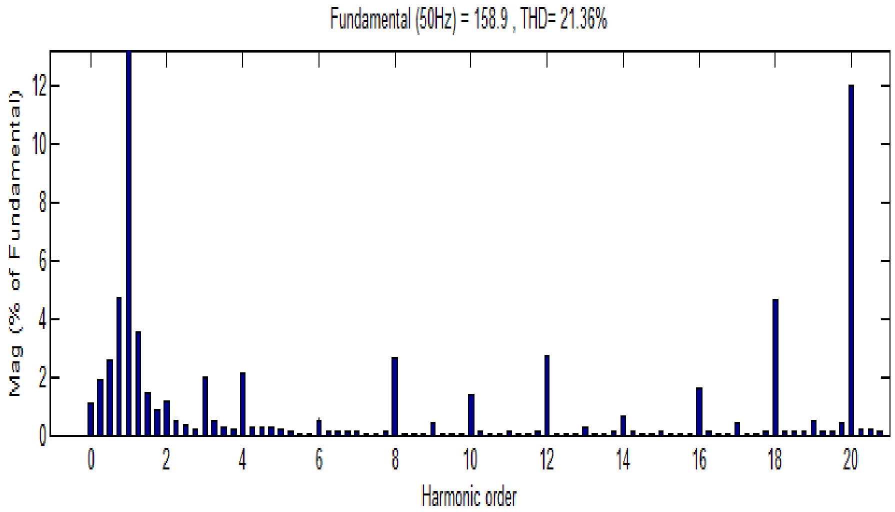

Figure 17 FFT plot for output voltage of VFPWM

TABLE I.
% THD For Different Modulation Indices

m_a	PD	POD	APOD	CO	VF
1	17.34	15.70	18.22	25.38	17.94
0.8	20.71	19.17	21.84	28.06	21.36
0.9	23.11	22.01	22.87	32.04	23.78

TABLE II.
V_{RMS} (Fundamental) For Different Modulation Indices

m_a	PD	POD	APOD	CO	VF
1	126.2	126.3	118.3	123.8	118.2
0.8	119.5	120.1	112.3	118.1	112.4
0.9	112.5	112.5	105.9	110.8	106

TABLE III.
Crest Factor for Different Modulation Indices

m_a	PD	POD	APOD	CO	VF
1	1.4136	1.4140	1.4150	1.4135	1.4145
0.8	1.4142	1.4146	1.4140	1.4149	1.4137
0.9	1.4142	1.4133	1.4145	1.4142	1.4141

V. CONCLUSION

In this paper, MCSPWM strategy for three phase Z source seven level cascaded inverter have been presented. Z source multilevel inverter gives higher output voltage through its Z source network. Performance factors like %THD, V_{RMS} and CF have been measured, presented and analyzed. It is found that the PODPWM strategy provides lower %THD and higher V_{RMS} and less number of dominant harmonics than the other strategies. DC source can be replaced by renewable energy sources and this Z source seven level cascaded inverter can be used for distributed generation systems.

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