THD Analysis of Cascaded Mli for Various PWM Techniques

K.L.Dheeraj [1] M.Diwakar[2] M.DurgaRaj[3] M.Eswar[4] K.Naga Venkatesh[5]
[12345]Dept. of EEE, KLUniversity, Vaddeswaram, Guntur, A.P. India

***Abstract*: Cascaded inverters are ideal for connecting renewable energy sources with an AC grid, because of the need for separate dc sources, which is the case in applications such as photo voltaics or fuel cells. The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected. The modulation techniques are crucial in operating any inverter at desired conditions. In this paper different pwm techniques are implemented for three level and five level cascaded mli and THD variation is analysed with variation of modulation index.**

Keywords: cascaded mli, modulation techniques, modulation index, total harmonic distortion.

I. INTRODUCTION

A single-phase structure of an three level cascaded inverter is illustrated in Figure 1.1. Each H bridge inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by n = 2m+1, where m is the number of separate dc sources.

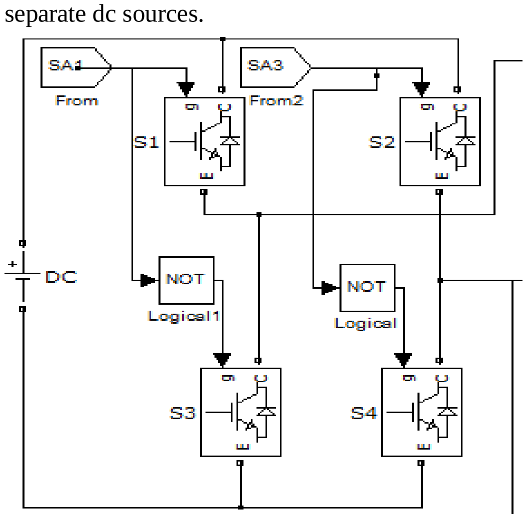

Fig.1 Single phase H-Bridge

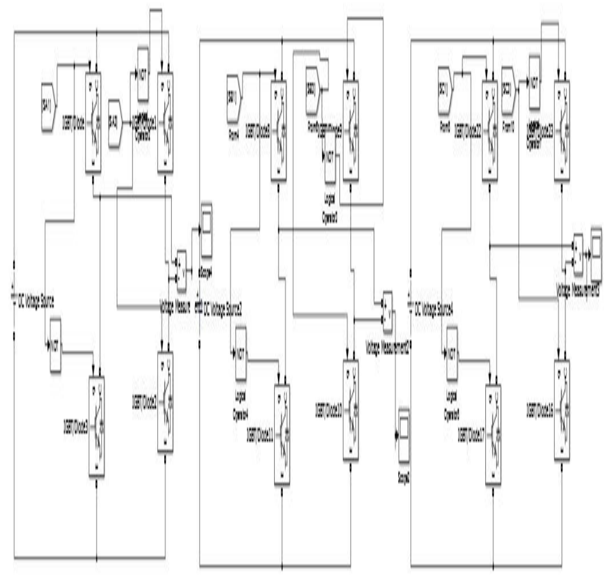

Fig.2 Three phase three level cascaded mli

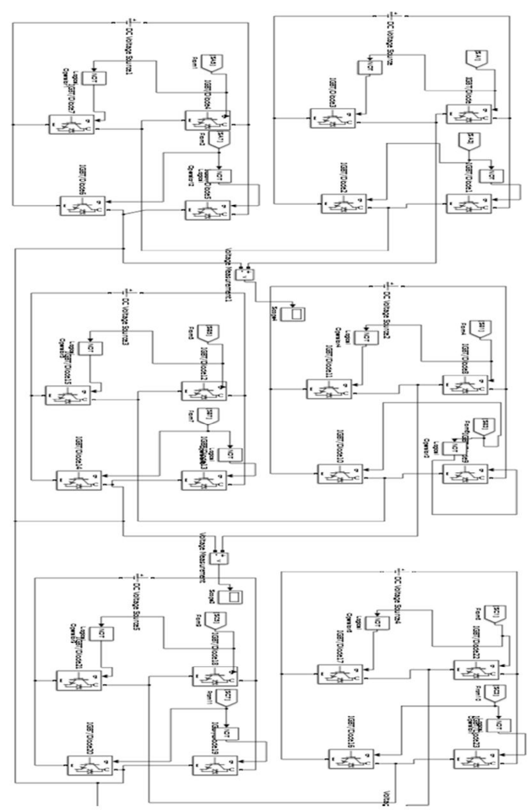

Fig.3 Three phase five level cascaded mli

II. CARRIER BASED PWM METHODS

The natural sampling techniques [2] for a multilevel inverter are categorized into two and they are:

a)Single-Carrier SPWM (SCSPWM)
b)Sub-Harmonic PWM (SHPWM)

Sub-Harmonic PWM is an exclusive control strategy for multilevel inverters and has further classifications. They are:

1. Phase Shifted Carrier PWM method (PSPWM)
2. Carrier Disposition PWM methods
   - Phase Disposition (PD)
   - Alternative Phase Opposition Disposition (APOD)
   - Phase Opposition Disposition (POD)

An *m*-level multilevel inverter using level-shifted

Multicarrier modulation scheme requires **(*m* – 1)** triangular carriers, all having the same frequency and amplitude. The (*m* – 1) triangular carriers are vertically disposed such that the bands they occupy are contiguous. The frequency modulation index is given by $mf = fcr/fm$, which remains the same as the phase-shifted modulation scheme whereas the amplitude modulation index is defined as Where *Vm* is the peak amplitude of the modulating wave *vm* and ˆ*Vcr* is the peak amplitude of each carrier wave, $ma=V_m/(m-1)*V_{cr}$

A) PHASE SHIFTED MODULATION

All the triangular carriers have the same frequency and the same peak to peak amplitude. There is a phase shift between any two adjacent carrier waves, given by

$$Øcr = 360°/(m – 1)$$

$$\text{For } m=3,\ Øcr = 360°/2$$

$$Øcr = 180°$$

$$\text{For } m=5\ Øcr = 360°/4$$

$$Øcr = 90°$$

Comparision of carrier and modulating waves for three level are shown in fig.4

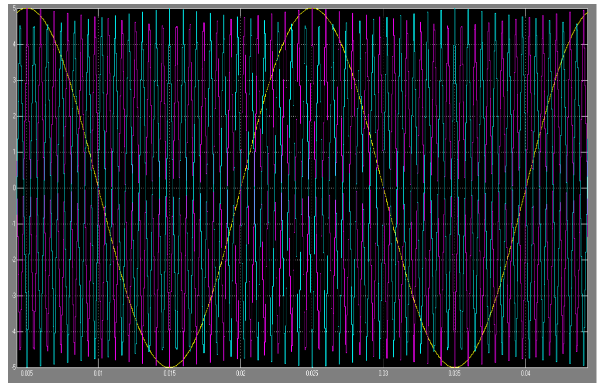

Fig.4.Comparision of reference wave and phase shifted carrier waves for three level

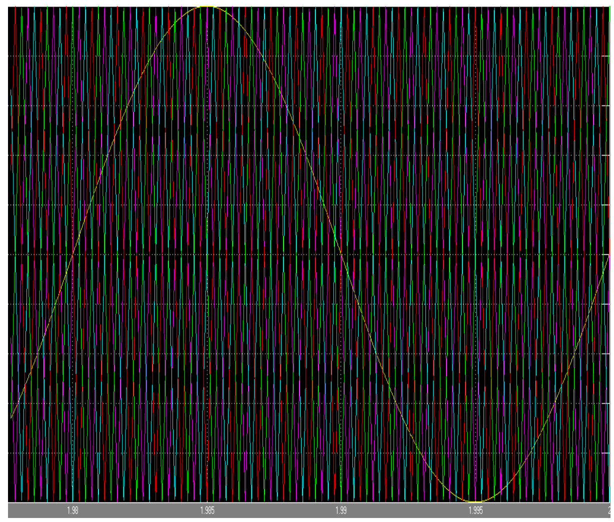

Fig.5 Comparision of reference wave and phase shifted carrier waves for five level

III. CARRIER DISPOSITION PWM METHODS

The widely used multi-carrier PWM methods are known as Phase Shifted (PS), Phase Disposition (PD), Phase Opposition Disposition (POD), and Alternative Phase

Opposite Disposition (APOD).

A. Phase Disposition

If all carriers are selected with the same phase, the method is known as Phase Disposition (PD) method. It is generally accepted that this method gives rise to the lowest harmonic distortion in higher modulation indices when compared to other disposition methods. This method is also well applicable to diode clamped inverters. The waveform of carriers of this method is illustrated in Fig. 8.

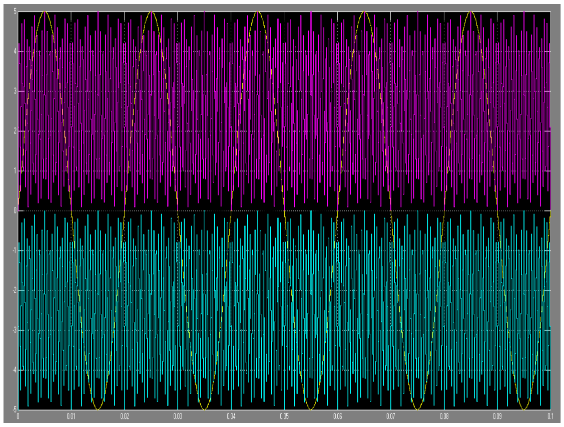

Fig.6 Comparision of reference wave and phase disposition carrier waves for three level

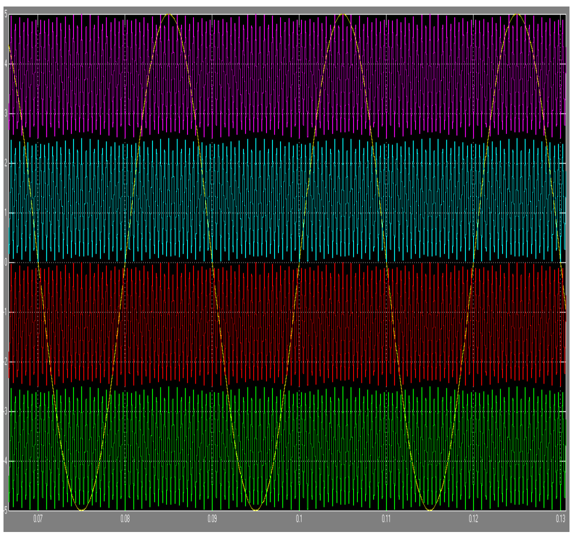

Fig.7 Comparison of reference wave and phase disposition carrier waves for five level

B. PHASE OPPOSITION DISPOSITION

The Phase Opposition Disposition (POD) method, having the carriers above the zero line of reference voltage out of phase with those of below this line by 180 degrees as shown in Fig. 12 is one another of the carriers' disposition group. Compared to the PD method, this method has better results from the viewpoint of harmonic performances in lower modulation indices. In POD method, there is no harmonic at the carrier frequency and its multiples and the dispersion of harmonics occurs around them.

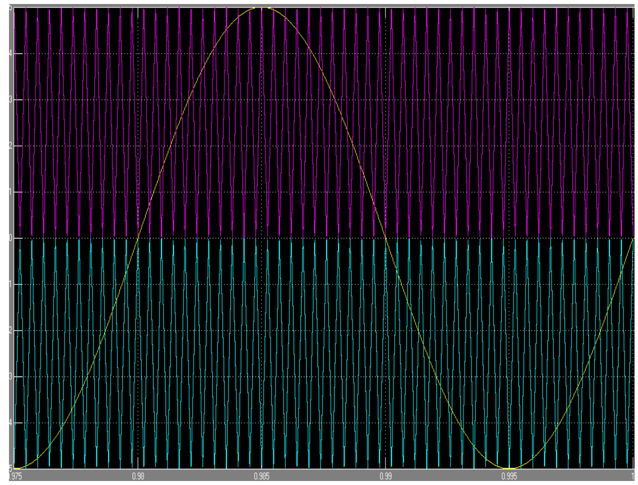

Fig.8 Comparison of reference wave and phase opposition disposition carrier waves for three level

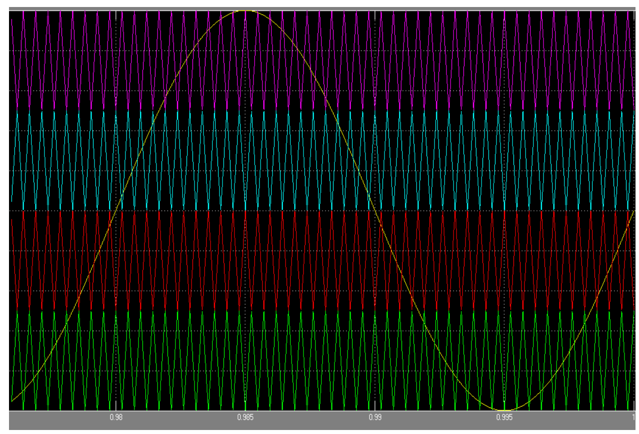

Fig.9 Comparison of reference wave and phase opposition disposition carrier waves for five level

C. ALTERNATE PHASE OPPOSITION DISPOSITION

The third member of the carriers' disposition group is known as Alternative Phase Opposition Disposition (APOD) method. Each carrier of this method is phase shifted by 180 degrees from its adjacent one. It should be noted that POD and APOD methods are exactly the same for a 3-level Inverter. This method gives almost the same results as the POD method. The major differences are the larger amount of third order harmonics which is not important because of their cancellation in line voltages. Thus, this method results in a better THD for line voltages when comparing to the POD method. The carrier waveforms of this method are illustrated in Fig 16.

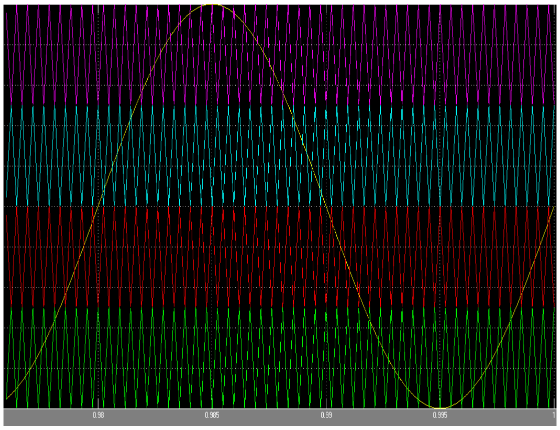

Fig.10 Comparison of reference wave and alternate phase opposition disposition carrier waves for five level

SIMULATION RESULTS

The variation of harmonic distortion with modulation index is as follows.

Total Harmonic Distortion for three phase five level Cascaded MLI

Modulation index	PWM Technique	THD (%)
0.35	phase disposition	23.34
	phase opposition	38.75
	alternate phase opposition disposition	39.83
0.5	phase disposition	17.07
	phase opposition	20.85
	alternate phase opposition disposition	25.16
0.833	phase disposition	14.57
	phase opposition	12
	alternate phase opposition disposition	15.36
1	phase disposition	12.03
	phase opposition	11.68
	alternate phase opposition disposition	14.87

Total Harmonic Distortion for three phase three level Cascaded MLI

Modulation index	PWM Technique	THD (%)
0.35	phase disposition	63.02
	phase opposition	65.93
0.5	phase disposition	51.03
	phase opposition	52.63
0.83	phase disposition	36.01
	phase opposition	38.34
1	phase disposition	33.12
		35.45

CONCLUSION

Three phase three level and five level cascaded multilevel inverter configuration are simulated using SIMULINK. The different modulation schemes like phase shifted, phase disposition, phase opposition, alternate phase opposition disposition are implemented and corresponding voltages for each configuration are obtained. The variation of harmonic distortion with modulation index is analysed.

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