"Analysis of Cascade Multilevel Inverter Using Sine PWM and Inverted Sine PWM Control strategy"

Jigarkumar V. Patel[1]*, Krishnakumari K. Wadiwala[2], Dr N.G. Mishra[3]

[1]Department of Electrical Engineering, Birla Vishvakarma Mahavidyalaya, India
[2]Department of Electronics and communication Engineering, A.D. patel institute of technology, india
[3]Department of Electrical Engineering, Birla Vishvakarma Mahavidyalaya, India

Abstract

This paper present cascade multilevel inverter using Sine PWM and Inverted sine PWM control strategy. The main advantages of these multilevel inverters is that they generate very less harmonics as compare to conventional inverter. This makes it very useful in the area of control and energy distribution, static reactive power compensation and adjustable-speed drives. This paper also present new PWM control strategy, called inverted sine PWM control strategy. This Inverted sine PWM control strategy generate very less Total Harmonic Distortion (THD), and switching losses as compare to conventional sine PWM control strategy, also This ISPWM method reduces the number of carriers as compare to conventional sine PWM method, so it increases the fundamental output voltage even modulation index is less This paper compares the % of THD for all level shifted and phase shifted sine PWM and inverted sine PWM control strategy of voltage and current for cascade multilevel inverter. The simulations for the five level cascade multilevel inverter using both inverted sine and sine PWM control strategy are carried out in MATLAB® software.

Keywords: *Sine and Inverted sine PWM control strategy, multilevel inverter, THD*

INTRODUCTION

Generally, the voltage source inverters generate an output voltage with a two level, if we use the high switching frequency along with various PWM control strategy, then we obtain quality output voltage and current with very less amount of ripple contact For the high power application and also for medium power application, but it operates at high frequency so this cause the switching losses, also this causes distorted output voltage and current and the total harmonic distortion of the voltage and current are very large in two-level single and three phase inverter [1]. therefore, multi-level inverters are utilizing to commute the overall THD as compare to simple two level inverter.

In this paper, sinusoidal pulse with modulation(SPWM) control strategy and inverted sine wane PWM control strategy is used and also present % of THD comparison using SPWM and ISPWM techniques for all the level shifted PWM (POD, APOD and PID) method and phase shifted PWM method. and the five- level cascade multilevel inverter simulation using Inverted sine PWM and sine PWM has been carried out in MATLAB software.

CONTROL STRATEGY

Sinusoidal Pulse with Modulation

The SPWM control strategy is used in the voltage source inverter. In this strategy triangular signals are compared with the sine signals, and if the amplitude of the sine wave is greater than the triangular wave then, it gives the pulse for the positive half cycle and if the amplitude of sine wave is less than the triangular wave then it gives the pulse for negative cycle [5]. The carrier signals frequency is twenty time more than the frequency of sinewave and it determines the number of pulses per half-cycle. The frequency of carrier signals is much larger than the frequency of reference signals, the reference signals frequency is 50Hz and it determine the output frequency.

Inverted Sinusoidal Pulse with Modulation

In this inverted sine PWM control strategy, inverted sine wave is used in the place of the triangular wave. So inverted sine wave is used as a carrier signals and sine wave is used as a reference signals, the inverted sine wave is shown in figure 1.

In this ISPWM strategy comparing the inverted sine wave with the sine wave and if the amplitude of the sine wave is greater than the inverted sinewave then switching signals are obtained. And it gives the pulses for the positive half cycle and if less than then it gives the pulses for negative half cycle. And inverted sine waves frequency defined the switching frequency and sine wave frequency defined the output frequency, and it is 50Hz. Inverted sine wave frequency is much larger than the reference signals frequency. This strategy generates less amount of THD as compare to conventional SPWM strategy. [8]

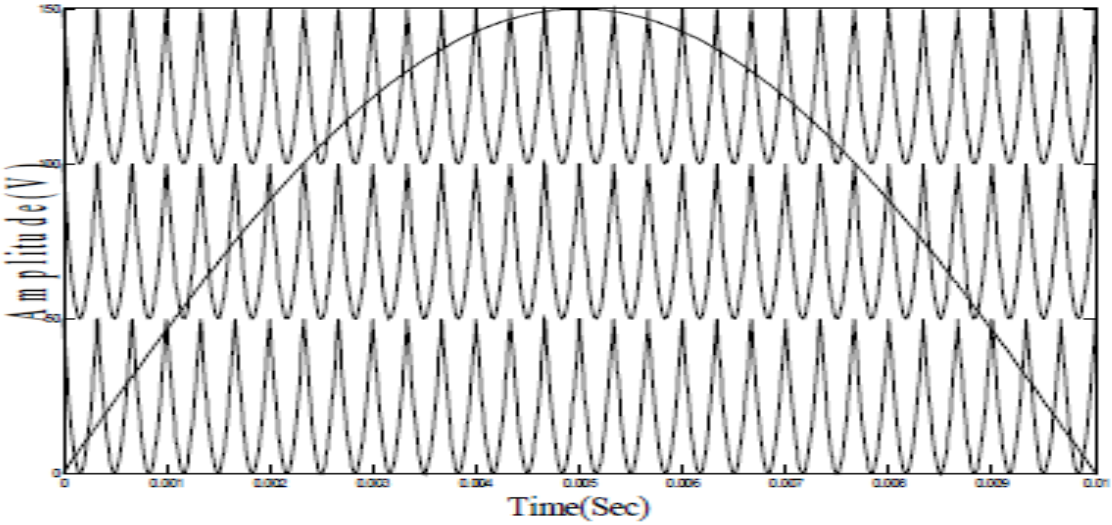

Fig. 1: Carrier and Inverted Sine Waveforms for ISPWM technique

FIVE-LEVEL CASCADE MULTILEVEL INVERTER

The single phase cascade multilevel inverter consists of 2(N-1) switches, (N-1)/2 DC sources, and (N-1)/2 H-bridges, where N is the number of level. Final output voltage is the sum of all the DC voltages sources, so the output voltage for five level is, V= Vdc1+Vdc2 Where, V= Total output voltage and direct current is convert in to alternating current with five voltage levels.

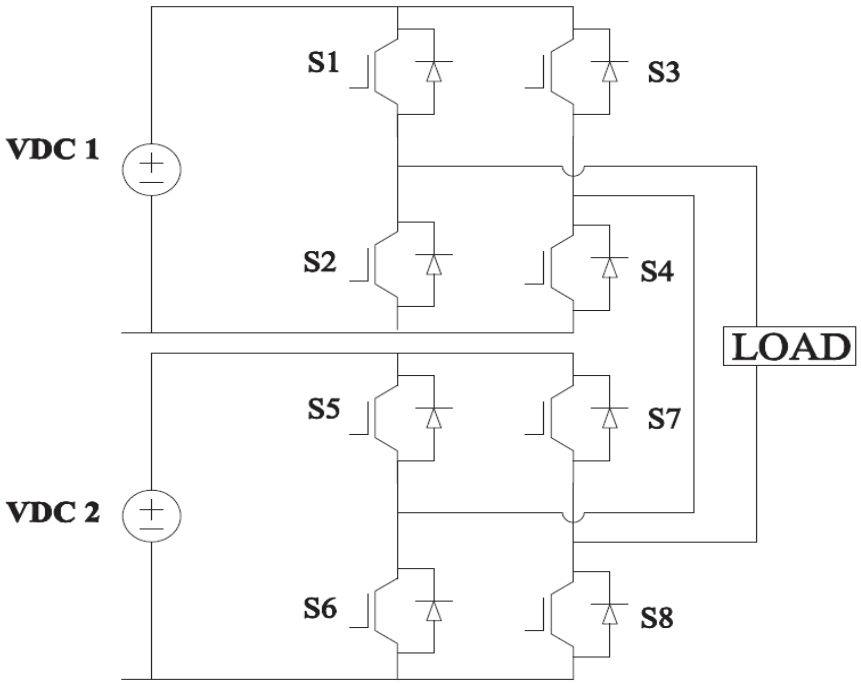

Fig. 2: Circuit diagram of five level cascade multilevel inverter

This five-level cascade multilevel inverter required eight power switches therefore, four pair of getting signal have to be produced to be fed to the switches. Switching are designed for each H-bridge cells such a way that only one pair of switches operated at a same time at a reference frequency and other pairs operated at a carrier frequency. Therefore, five level of output voltage is 0, +V, +2V, -V and -2V. In the first case, the switches 1,8 and 4 are conduct so only one DC source is conduct, so that +V level are generated. after that 1,8,4 and 5 these four switches are conduct so both the DC sources are utilizing, so +2V voltage level is generated.

After that the switches 2,6 and 3 are conduct so only one DC source is used, but now the flowing current is in opposite direction of the first case, so –V voltage level is produced, after that switches 2,6,7 and 3 are conduct so both the DC source are used, but now the flowing current is in opposite direction of the first case so –2V voltage level is produced.

Table 1: switching sequence of five level cascaded H bridge multilevel inverter

Voltage level	S1	S2	S3	S4	S5	S6	S7	S8
+V	1	0	0	1	0	0	0	1
+2V	1	0	0	1	1	0	0	1
0	1	0	0	1	0	0	0	1
-V	0	1	1	0	0	1	0	0
-2V	0	1	1	0	0	1	1	0
0	0	1	1	0	0	1	0	0

SIMULATION AND RESULTS

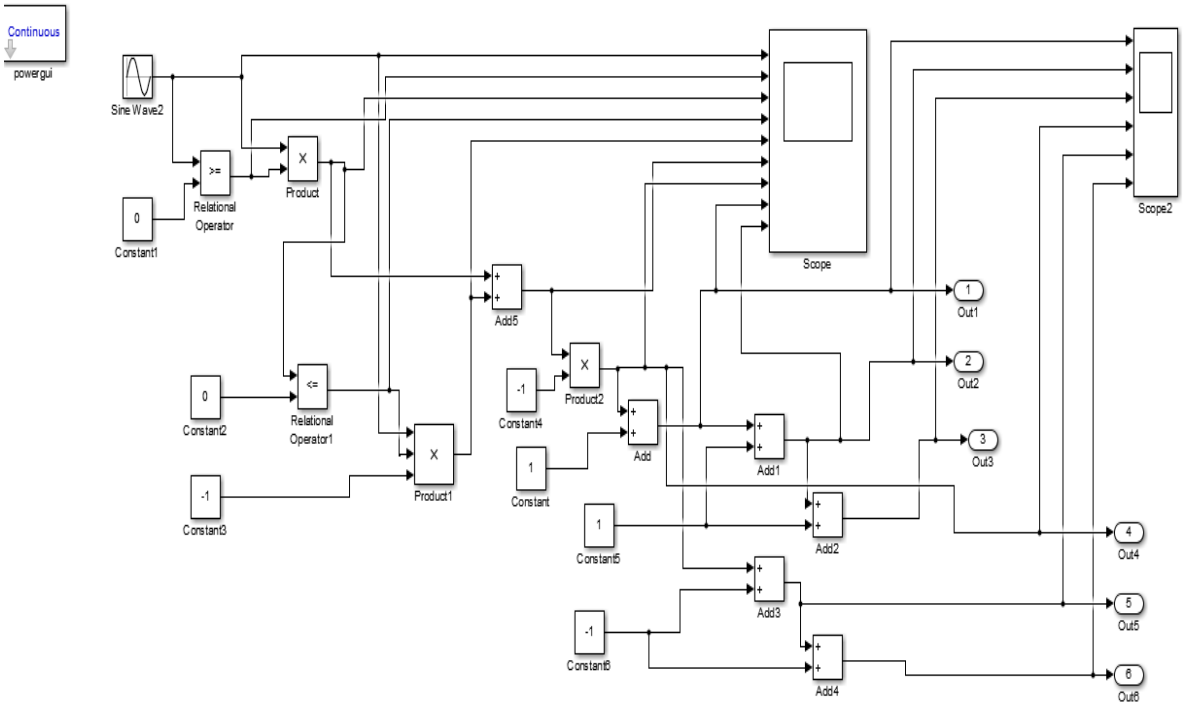

Fig. 3: Simulation circuit for generation ISPWM carrier signals in MATLAB

The inverted sine wave is generated using the above simulation circuit. This simulation circuit generate six inverted sine wave of 4000 Hz frequency, so for five level inverter we use four inverted

sine pulse and for seven level we use all six pulses, in which two inverted sine waves are compared with positive half of reference sine wave and other two inverted sine wave are compared with negative half of reference sine wave.

In the figure 3 compare this sine waves with the 0 constant and if the amplitude of sine wave is more than or equal to zero, then it gives the pulse at the output. And after that, we take product of this pulses with the sine wave, so positive half cycle of the sine wave is obtained. After that this positive half cycle is compare with the 0 constant, and if the amplitude of positive half cycle is less than or equal to zero, then it gives the pulses at output. And after that, we take the product of sine wave, new generated pulse and -1 constant, and after this process new carrier wave are generate, shown in figure 4 called inverted sine signal.

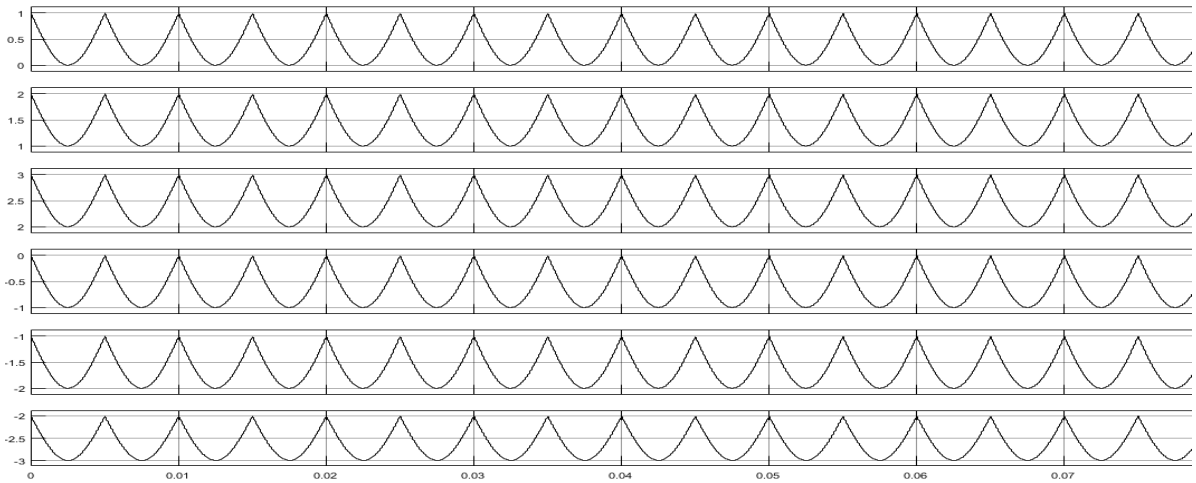

Fig. 4: ISPWM carrier signals

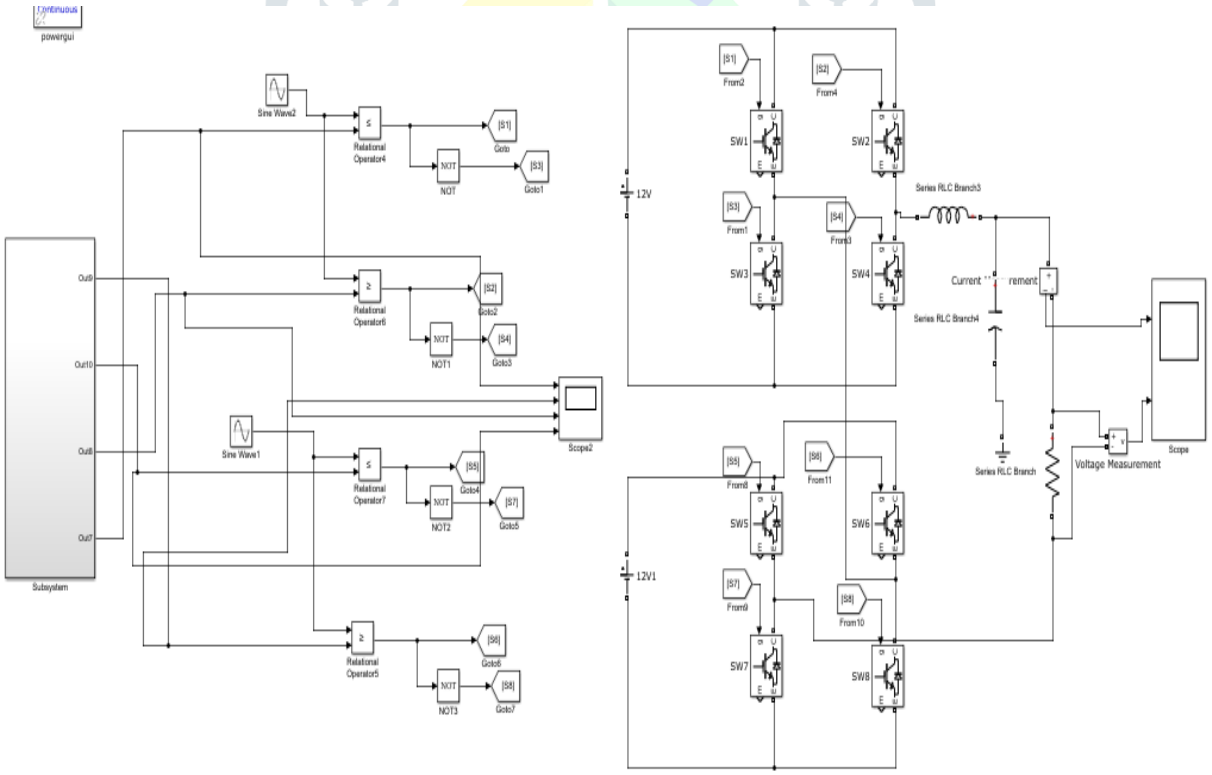

Fig. 5: simulation of five-level cascade multilevel inverter using ISPWM control strategy

The subsystem shown in figure five is the simulation of the generation of the ISPWM carrier signals and this inverted sine signals compare with the sine wave, so switching pulses are obtained, and this pulses are given to the IGBT. And after that the output voltage are obtained in five levels, shown in figure 6 using higher switching frequency and in figure 7 using lower switching frequency.

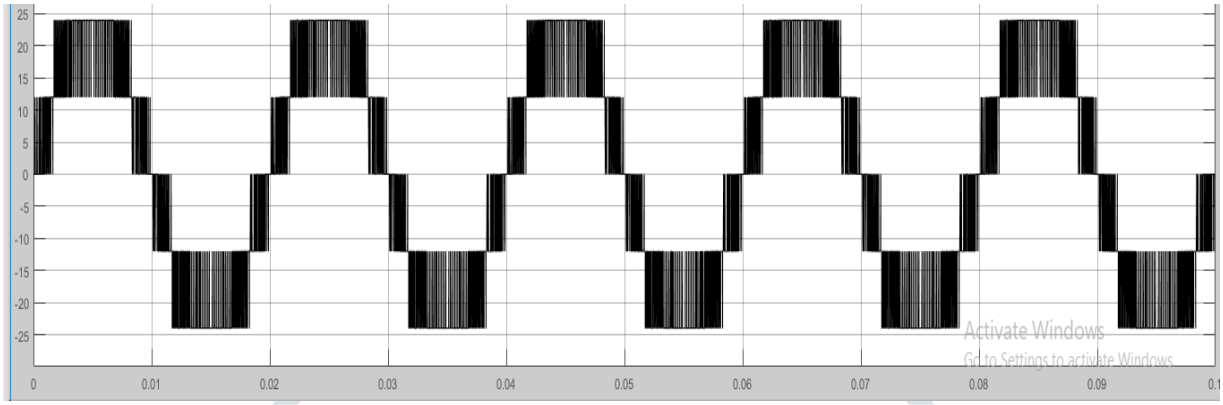

Fig. 6: five level output voltage waveform for 4000Hz inverted sine wave carrier frequency

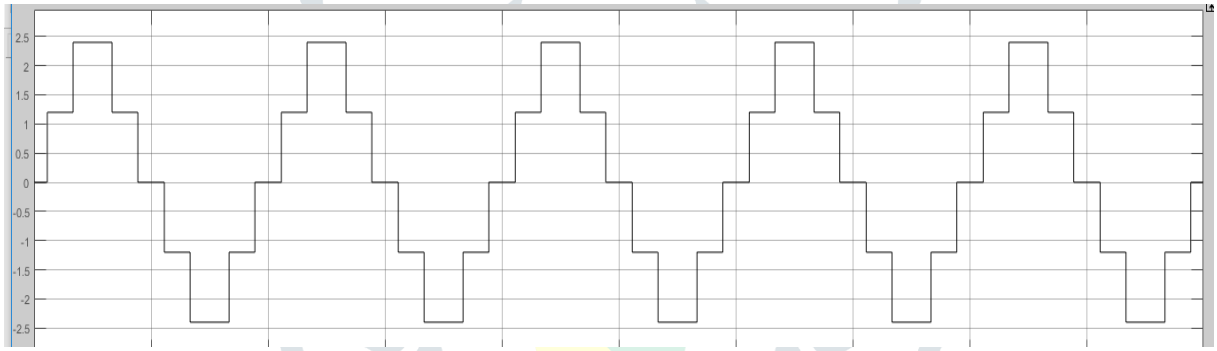

Fig. 7: five level output voltage waveform for 100Hz inverted sine wave carrier frequency

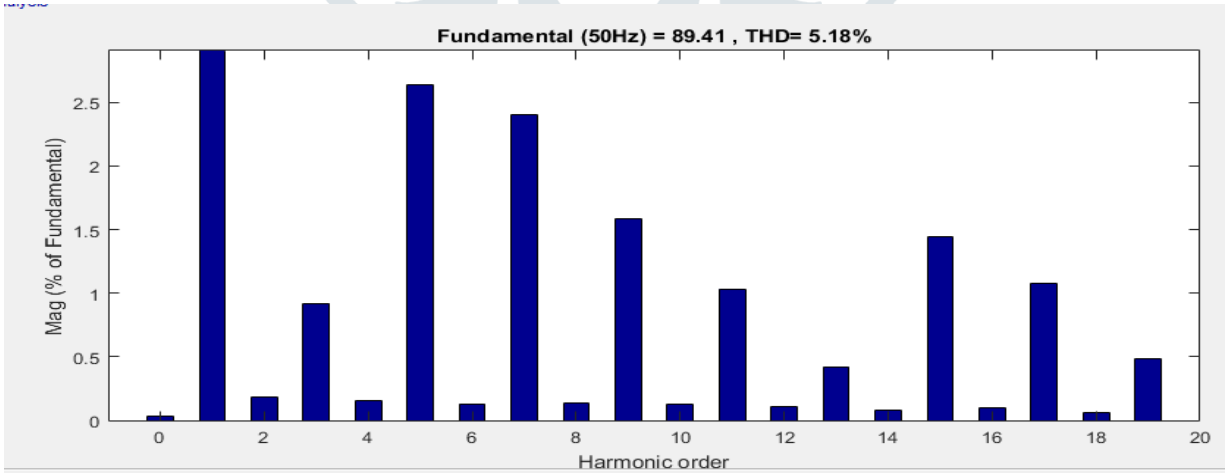

Fig. 8: FFT analysis for ISPWM

The proposed unipolar ISPWM control strategy, the obtain output voltage wave form shown in figure 6 for 4000Hz carrier frequency, and figure 7 for 100Hz carrier frequency. And also figure 8 shows the overall THD (5.18%) using phase shifted ISPWM technique and figure 9 shows overall THD (9.86%) using phase shifted SPWM technique.

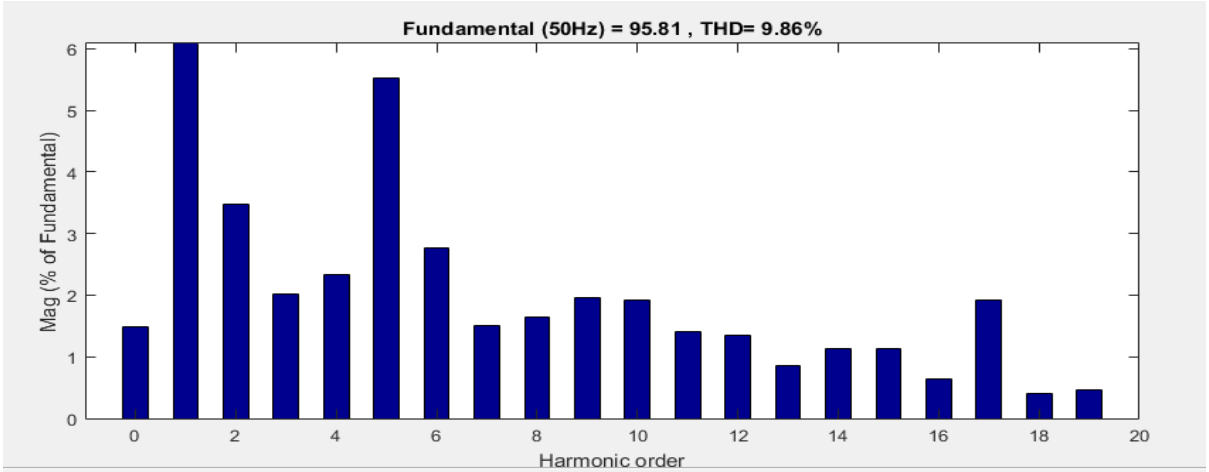

Fig. 9: FFT analysis for SPWM

TOTAL HARMONIC DISTORTION

In the five level cascade multilevel inverter overall THD is less as compare to conventional inverter. And if we increase the number of levels then output wave is obtaining as like a sinusoidal. if we increase levels more and more then %THD is very less. therefore, we obtain pure sinusoidal waveform without any filtering by using multilevel inverter. And also if we use inverted sine PWM in the place of Sine PWM strategy, then overall THD is also less.

Table 2: overall THD comparison for ISPWM and SPWM techniques

	Modulation index	**Sine PWM**	**Inverted sine PWM**
Phase shifted	1	9.86	5.18
	0.9	8.67	7.81
	0.8	7.52	6.92
IPD	1	13.92	12.77
	0.9	16.71	16.29
	0.8	20.05	18.35
APOD	1	13.59	12.01
	0.9	17.34	15.95
	0.8	19.28	16.67
POD	1	14.08	12.55
	0.9	15.94	14.8
	0.8	20.85	19.38

CONCLUSIONS

In this research paper simulation model of five level cascade multilevel inverter is done, with two PWM control strategy, this two control strategy, i.e. inverted sine PWM strategy compared with the conventional sine PWM strategy and this reduces the need for output filter. The simulation results of all the level shifted and phase shifted PWM method for both the inverted sine and sine PWM control strategy with the different modulation index are compared and observed that the overall THD is less in inverted sine PWM strategy as compare to sine PWM strategy, and if number of levels are going on increasing, the THD is decreasing and quality output voltage & current waveforms are obtained.

REFERENCES

[1] Dr. Asha Gaikwad, Pallavi Appaso Arbune, "Study of Cascaded H-Bridge Multilevel Inverter",2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT)

[2] Mohammad Ahmad and B.H. Khan, Senior Member, IEEE, "New Approaches for harmonic reduction in solar inverters"2012.

[3] Akshay B. Zade, Asha Gaikwad, "Design and simulation analysis of seven level cascaded grid connected inverter for pv system", International journal of innovations in engineering research and technology [ijiert]

[4] S. Daher, J. Schmid, and F. L.M. Antunes, "Multilevel inverter topologies for stand-alone PV systems," IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2703–2712,Jul. 2008

[5] Lei, Li, Wang Tian-yu, and Xu Wen-guo. "Application of sinusoidal pulse width modulation algorithm in the grid-connected photovoltaic system." Information Technology, Computer Engineering and Management Sciences (ICM), 2011 International Conference on. Vol. 2. IEEE, 2011.

[6] Zope, Pankaj H., et al. "Design and Implementation of carrier based Sinusoidal PWM Inverter." International Journal of advanced research in electrical, electronics and instrumentation engineering.

[7] Barge, Sonal Arvind, and S. R. Jagtap. "Harmonic Analysis of Sinusoidal Pulse Width Modulation." International Journal of Advanced Electrical and Electronics Engineering Advanced Electrical and Electronics Engineering

[8] R.seyezhai, 2 dr. B.l.mathur" performance evaluation of inverted sine Pwm technique for an asymmetric cascaded Multilevel inverter" Journal of Theoretical and Applied Information Technology