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STUDY ON REDUCTION OF HARMONICS IN 7-LEVEL CASCADED H-BRIDGE MULTILEVEL INVERTER

Jay Prakash[1], Prof. Eknath Borkar[2]

[1]Scholar M.Tech (Power System), Department of Electrical and Electronics Engineering,

Scope College of Engineering, Bhopal, India

[2]Guide & Professor , Department of electrical & Electronics Engineering, Scope College of Engineering, Bhopal, India

Abstract - This thesis presents the intensive analysis of total harmonic distortion (THD) of seven level of cascaded H-bridge multi level inverter (CHBMLI) on different controlling technique of sinusoidal pulse width modulation scheme (SPWM). The MLI has more advantageous over conventional two level inverter and wide spread used to compensate for energy shortage. It is used on low/medium level of voltage sources and produce amplified output with minimum DC component. As voltage level increases in output, the harmonics in output reduces and hence the power quality improved. In this paper, we will discuss harmonics obtained on different types of SPWM schemes like PD PWM, POD PWM & APOD PWM and compare with varying amplitude modulation indices from 0.5 to 0.8. Among techniques, PD PWM is frequently used in Multi level inverter due to less harmonics in output waveforms and widely used in big industries, solar power plant, power grid etc. In this model 12 IGBT switches, 3 separate voltage sources uses and form 3 H bridge cells. One H bridge cell includes the 4 IGBT switches with one voltage sources, voltage source may be positive +Ve, negative –Ve and Zero 0. The switches are decided by the formula K=2(S-1), where 'K' denotes the required power switches and 'S' denotes the level of outputs. Similarly required separate DC sources calculated by the formula M=2S+1, where 'M' denotes the indivisual DC sources. To get 7 level output voltages, 3 H bridge cell connected in cascade mode. In order to maintain the different level of voltage at particular period of time, the pulse width of gating pulses are maintained by the conduction time period of IGBT. Hence by contolling of pulse width, we get adequate output voltages which is square wave in nature. The word level in multi level inverter is described as the quantity of node to which the inverter can be reachable. With the increase in level of voltage to infinite value, the waveform of voltage of the content of THD decreases to zero as the pulse will be much sinusoidal in shape. We can compare the THD in output for these three techniques for modulation index 0.5 and 0.8. The Simulation model based on 7-level have been developed and THD found out in all three cases & compared. The interest for cascaded inverter has been remarkable due to the rise in demand of medium voltage high power inverter.

Keywords: Multilevel inverter (MLI), Cascaded, Total Harmonic Distortion (THD), Sinusoidal Pulse Width Modulation (SPWM), Phase Disposition (PD), Phase Opposition Disposition (POD), Alternate Phase Opposition Disposition (APOD)

1.INTRODUCTION:

In this chapter single-phase Seven Level Cascaded H-bridge Multilevel Inverter SPWM control is implemented using Sim-Power Systems toolbox in MATLAB/SIMULINK. The simulation model is shown in Figure 1. The most popular method of controlling the output voltage is by incorporating PWM control within the inverters. In this chapter simulation and modelling of CHBMLI topology has been discussed based on Phase Disposition (PD) SPWM, Phase Opposition Disposition (POD) & Alternate Phase Opposition Disposition (APOD) SPWM techniques and as per output voltage, analysed for best techniques. The three different modulation strategies are simulated in this work and the comparisons are made among them to choose the better technique which will be efficient and provides the output with improved power quality. The gate signals for chosen seven level cascaded H bridge Multilevel Inverter are simulated using MATLAB-SIMULINK. The simulation model developed is tested for various values of modulation index ma and for various PWM strategies. The simulation results presented in this work are compared and evaluated for different modulation index, i.e Amplitude modulation $M_a=A_m/(n-1)*A_c$ where A_m is amplitude of reference signal and A_c is amplitude of carrier signal & n is level of output waveform.

1.1 Advantages:

(i) All components are compatible to work on low and medium voltages.

(ii) Since output voltage waveform levels are more, THD is comparatively less.

(iii) Output voltage is almost sinusoidal without using filters.

(iv) It doesn't requires diode for clamping.

(v) Among three techniques, PD SPWM technique is more efficient.

(vi) Obtained output voltage is amplified.

1.2 Disadvantages:

(i) It requires separate DC sources for each H-bridge cell.

(ii) Due to use of indivisual DC sources, cost increases as output voltage level increases.

2. DEVELOPMENT OF SIMULATION MODEL:

In this chapter, the modelling and simulation of different Multilevel Inverter topologies, some of the modulation scheme is discusses. To explain the concept of Multilevel Inverter a Seven level Multilevel Inverter has been discussed in detail. The following model gives a general idea of developing the simulation models for any level Inverter. Figure 1.1 shows the complete simulation model of a Single Phase Cascaded H-bridge Multilevel Inverter.

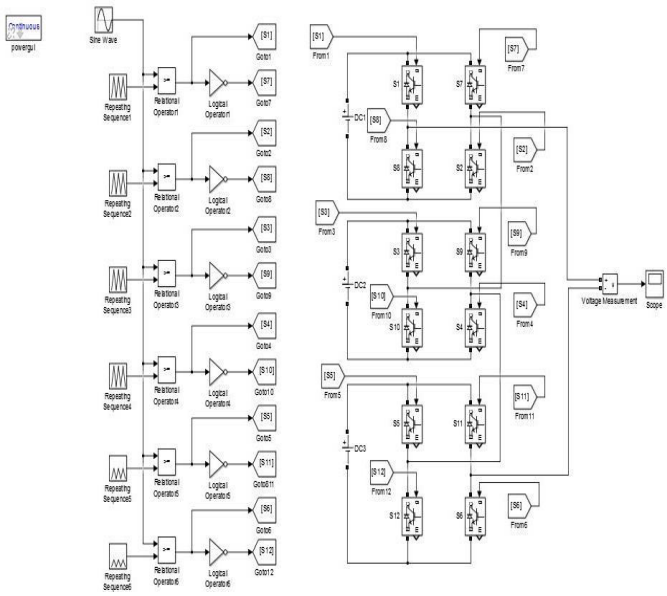

Figure:1.1, Seven Level Cascaded H-bridge Multilevel Inverter

It can be seen from the figure:1, that it consist of 3 H-bridge cell connected in cascade & controlling with 12 IGBT switches. The carrier frequency of the carrier waveform is captured 2500 Hz which makes the frequency modulation index to be 50.Similarly the amplitude modulation index for the present case is taken as 0.9 for simulation. The DC link voltage for a single level is taken as 100 Volts. The output waveform of 7 level is shown in figure 1.2, Clearly from the fig. that output voltage is approximately 3 times to input voltage.

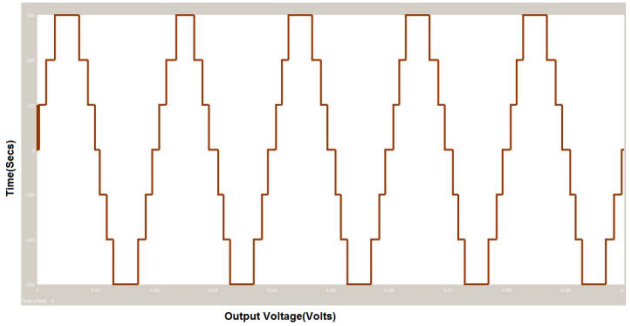

Figure:1.2, output waveform of cascaded H bridge multilevel inverter

2.1 SIMULATION MODEL OF CARRIER WAVE MODULATION SCHEME

To investigate further on the different modulation scheme of Seven Level Cascaded H-bridge Multilevel Inverter the carrier based modulation scheme is investigated in detail. To study their capabilities of harmonic elimination for Cascaded H-bridge Multilevel Inverter. This has been implemented on Seven level modulation scheme which has been followings:

2.2 PHASE DISPOSITION PWM SCHEME (PDPWM):

The Figure 2.1 shows the waveforms of carrier and the reference where modulation index is taken as unity while M f =80. Here all six carrier signals have equal magnitude and no phase difference is selected by controlling of firing for six switches. Carrier arrangement for this scheme is shown in Figure 2.1

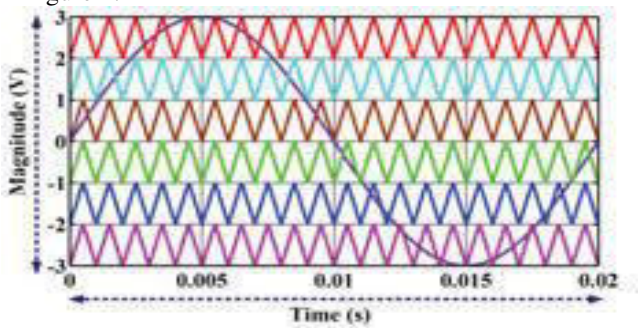

Figure:2.1, Modulating and carrier waveforms for PDPWM scheme

2.3 PHASE OPPOSITION DISPOSITION PWM SCHEME (PODPWM):

The Figure2.2 shows the waveforms of carrier and the reference signal where modulation index is taken as unity while M f =80. This scheme is similar to the PDPWM scheme but the two groups are opposite in phase with each other i.e signals above the x-axis is in positive and signals below the x-axis is 180 degree shifted. Carrier arrangement for this scheme is shown in Figure 2.2

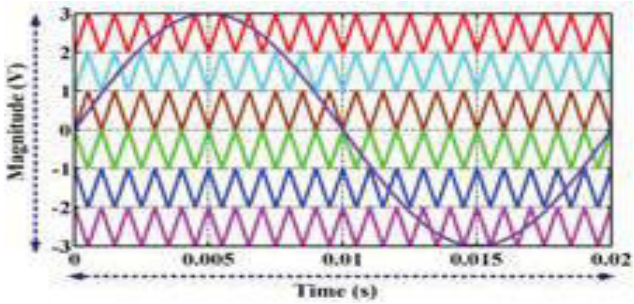

Figure:2.2, Modulating and carrier waveforms for PODPWM scheme

2.4 ALTERNATE PHASE OPPOSITION DISPOSITION PWM SCHEME (APODPWM):

The Figure2.3 shows the waveforms of carrier and the reference signal where modulation index is taken as unity while M f =80. In This scheme, adjacent signals are 180 degree shifted to each other which is arranged by controlling of switches. Carrier arrangement for this scheme is shown in Figure 2.3

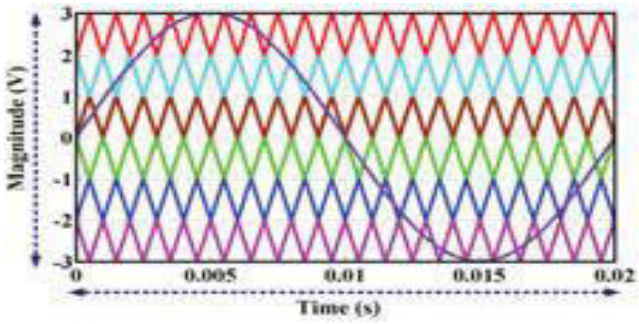

Figure:2.2, Modulating and carrier waveforms for APODPWM scheme

3. RESULT ANALYSIS:

To show the performance of the proposed Cascaded H-bridge Multilevel Inverter is studied. The proposed converter synthesizes a single-phase multilevel waveform from the calculated switching angles. The converter thus generates the variable-amplitude, variable frequency voltage waveforms from DC sources. The MATLAB-Simulink is used to simulate 7-level H bridge Multilevel Inverter and THD is shown in figure for different modulation techniques for unity modulation index viz. Figure 3.1 shows the THD of Phase disposition schemes, Figure 3.2 shows the THD of Phase opposition disposition schemes and Figure 3.3 shows the THD of Alternate Phase opposition disposition schemes. Similarly Figure 3.4 shows the THD of Phase disposition schemes for modulation index 0.6.

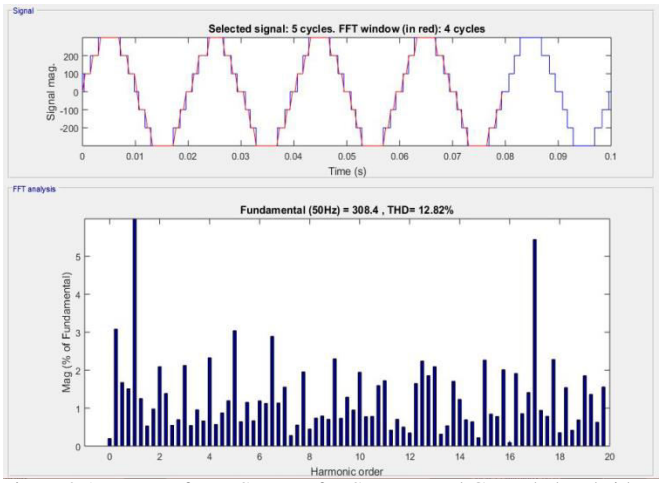

Figure:3.1, THD of PDSPWM for Seven Level Cascaded H-bridge Multilevel Inverter

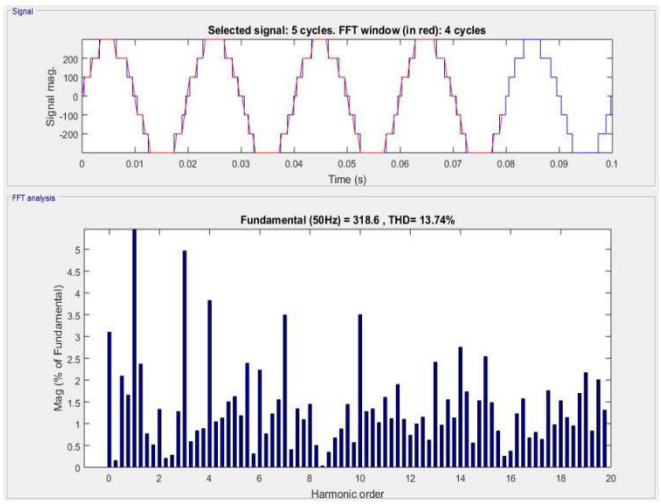

Figure:3.2, THD of PODSPWM for Seven Level Cascaded H-bridge Multilevel Inverter

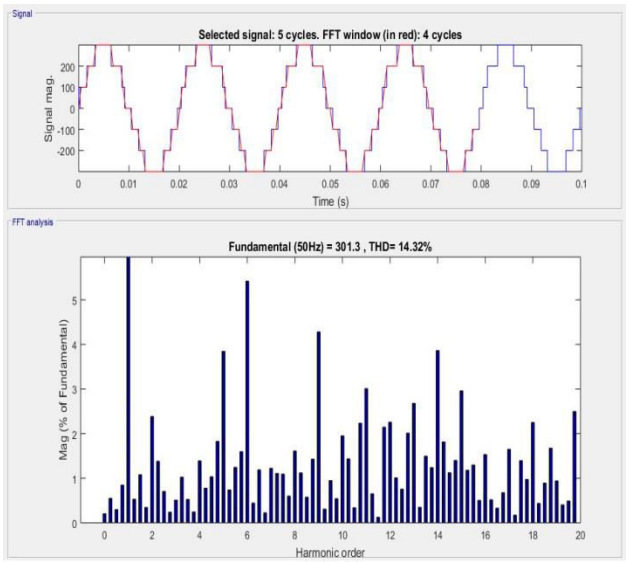

Figure:3.3, THD of APODSPWM for Seven Level Cascaded H-bridge Multilevel Inverter

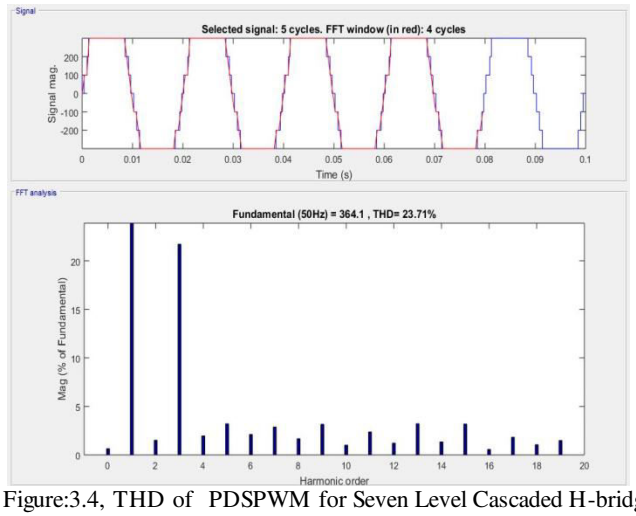

Figure:3.4, THD of PDSPWM for Seven Level Cascaded H-bridge Multilevel Inverter for M_a 0.6

Here pulse generator is modelled where reference wave (sine wave) First triangular wave is applied across the cycle of the sine wave Based on the concepts explained in modulation techniques, twelve pulses are generated. These pulses are given to the switches of seven level inverter. The controlling angles are such a manner that the output waveform is based on the three techniques viz. Phase Disposition SPWM, Phase Opposition Disposition SPWM & Alternate Phase Opposition Disposition SPWM. Hence THD is analysed for above three techniques. And as per the result, Phase Disposition techniques have high efficiency that means lower THD of output voltage. Also it is analysed as per Amplitude Modulation index M_a which is shown in Table 3.1. We can observe from the Table that unity modulation index have better THD than lower modulation index.

Table – 3.1: THD values of three SPWM techniques for different Modulation Index

S.No	Different Schemes of SPWM	M_a=1.0	M_a=0.6
1.	PD SPWM	12.82 %	23.71 %
2.	POD SPWM	13.74 %	26.96 %
3.	APOD SPWM	14.32 %	27.38 %

4. CONCLUSION:

In the proposed thesis an extensive investigation on Cascaded H-bridge multilevel Inverter has been carried out for the following cases:

- At different techniques of SPWM schemes.
- At different Amplitude modulation index.

Finally it can be concluded that the number of levels when increases helps to reduce the T.H.D. of the output voltage waveform from 31% to 12.82% but cost of device increases. It can be concluded that Phase Disposition SPWM scheme for seven level Inverter has least TH.D. of the output waveform. From the Table 3.1, it concluded that as Modulation Index increase, THD decrease and gives better efficiency. At the same time it can be also concluded that for high power application requirement increase in number of level may be a viable solution .but if the priority is of complexity of control and reduce device count then a proper compromise have to be made on number of levels. In this dissertation a single phase Seven level H bridge multilevel inverter is designed, developed and investigated for improve voltage quality in terms of harmonic distortion with different techniques and different modulation index. An exhaustive literature survey is carried out on different multilevel inverter to review the state of art of multilevel inverter technologies based on topologies, modulation schemes, and application techniques. A seven level H bridge multilevel inverter is then investigated through simulation using different multilevel modulation schemes such as sinusoidal pulse width modulation (SPWM). An improved performance of the inverter is obtained with PDSPWM in terms of load side power quality such as sinusoidal load voltages and current with their THD. Thus it can be finally concluded that the aim of the thesis, which was focussed on an extensive investigation on H bridge multilevel inverter has been achieved. Today, multilevel inverters have found wide area of applications, specifically high power medium voltage drives, HVDC transmission, distributed generation, static var compensation, electric vehicular technology, and grid connected renewable energy systems and many more. In fact, some researchers are suggesting their employment even for low power applications (e.g. aircraft systems).

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