

# Single Phase Multilevel Inverters with Simple Control Strategy Using MATLAB

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**Abstract**-This paper presents the simulation of 3, 5, 7level inverters. The realization of these three different levels is done by cascading one, two, three H-bridges in series respectively in MATLAB. The use of simple control strategy which is applied for switching the switches at appropriate conducting angles with proper delays is presented in this paper. The reduction in harmonics is done with the help of multilevel inverter and high quality of voltage waveforms is produced with large no of steps in an inverter. The simulation of single phase 3, 5, 7level inverters done in MATLAB/ Simulink with FFT spectrum along with the THD value.Total harmonic Distortion (THD) and Fast Fourier Transform (FFT) spectrum analysis of multilevel inverter with the help of MATLAB/Simulink. It has been found that cascaded technique reduces the total harmonic distortion as compared to conventional multilevel inverters. The topology used in this technique reduces the number of power switches when compared to the conventional cascaded H-bridge multilevel inverter.

**Keywords**—Cascaded H-Bridge Inverters, Multilevel Inverters, MATLAB/Simulink, THD

## I. INTRODUCTION

The industrial and power system applications of multilevel inverters have become popular in recent years due to their advantages on two level inverters i.e. Low Harmonics, high power rating so as to give higher efficiency. These are the reasons why multilevel inverters are becoming popular day by day and have become a field of interest for researchers. In multilevel inverters the output voltage are generated at high frequency and low switching frequency with low distortion[1],[2],[3].In case of high power and medium voltage situations such as laminators, SVC, HVDC, pumps, blowers, compressors and so on, where multilevel inverters are introduced as an alternative. In the year 1975 the multilevel inverter concept was introduced. In the same year Cascaded multilevel inverter was introduced for the first time. For the synthesis of staircase AC output voltage a series DC sourced full bridge are placed [1].By increasing the number of separate DC voltage sources, the converter output voltage waveform approaches the sinusoidal waveform.[3],[5].The three level inverter was the first multilevel inverter .After this several topologies of multilevel inverters were developed. In 1981, Diode-clamped multilevel inverter topology was introduced

[4].In 1992, Capacitor-Clamped (or flying capacitor) multilevel inverter topology was introduced [1].Out of the above three topology cascaded H-bridge and Diode Clamped are most common [6].The rating of switching devices are highly reduced to the rating of each cell, this is the main advantage of both the topologies i.e. cascaded H-bridge and Diode clamped inverters. Both the topology have the drawback,that they require large numbers of switching devices which is equal to  $2(K-1)$ , where K denotes the number of levels .This number is large as a result the complexity increases and reliability and efficiency reduces [7].

## II. MULTILEVEL INVERTER

Demand for high power converters along with high voltage, which are capable of producing quality waveforms that utilizes low voltage devices with reduced switching frequency has led to the development of multilevel inverters. Multilevel inverters includes an array of voltage source, capacitors and power semiconductors, the generated output voltage is a stepped waveform.

The features of multilevel inverters are:-

[1] With lower distortion and lower  $dv/dt$  output voltage can be generated.

[2] With low distortion input current is drawn [4], [8].

There are many ways by which multilevel converters can be implemented. One of the simplest techniques involves series or parallel connection of conventional converters which led to the formation of multilevel waveforms.

The three types of multilevel topologies are [9];

[1] Diode clamped multilevel inverter

[2] Capacitor clamped multilevel inverter.

[3] Cascaded inverters with separate DC sources.

Out of the three multilevel inverters the cascaded H-bridge multilevel inverters are more reliable and have the best fault tolerance as compared to the other two topologies.

### A. CASCADED MULTILEVEL INVERTER

In recent year's cascaded configuration have become popular in speed drive applications and high power AC supplies. In case of cascaded configuration, each of the H-bridge (single phase full bridge) inverter consists of separate DC source. Cascaded configuration is formed by cascading the series H-bridges. Fig.3 shows the general configuration of single phase cascaded H-bridge inverter

with separate DC sources for each H-bridge (single phase full bridge). For a three level inverter we need only one H-bridge (single phase full bridge). The three level inverter consists of four switches and one DC source. For three level inverter, the three different voltages i.e.  $+V$ ,  $0$ ,  $-V$  is obtained by the different combinations of the four switches  $S_1$ - $S_4$ . On turning  $S_1$  and  $S_4$  we get  $+V_{dc}$ . When  $S_2$  and  $S_3$  are turned on we get  $-V_{dc}$  in the output. When switches  $S_1$ ,  $S_2$ ,  $S_3$ ,  $S_4$  or switches  $S_1$  and  $S_2$ , or switches  $S_3$  and  $S_4$  are turned on we get  $0$  at the output [1]. Fig.1 shows five level inverter which consists of eight switches and two DC source. For a five level inverter, five different output voltage levels are  $+2V_{dc}$ ,  $+V_{dc}$ ,  $0$ ,  $-V_{dc}$ ,  $-2V_{dc}$ . These different output voltages are obtained by different combinations of eight switches. By turning on switches  $S_1$ ,  $S_6$ ,  $S_5$ ,  $S_2$  we get  $+2V_{dc}$  at the output. By turning on the switches  $S_2$ ,  $S_6$ ,  $S_8$ ,  $S_2$  we get  $+V_{dc}$  at the output. By switching the switches  $S_1$ ,  $S_3$ ,  $S_5$ ,  $S_7$  we get  $0$  at the output. By turning on the switches  $S_3$ ,  $S_8$ ,  $S_7$ ,  $S_4$  we get  $-2V_{dc}$  at the output. By switching the switches  $S_3$ ,  $S_7$ ,  $S_5$ ,  $S_4$  we get  $0$  at the output [10]. Similarly any level of multilevel inverter can be formed by cascading a number of H-bridges. In multilevel inverter the synthesized voltage waveform is the sum of individual H-bridge output. In this configuration the output voltage level is defined as  $K=2M+1$ , where 'M' is the numbers of H-bridges and 'K' is the number of levels. For 15 level the output phase voltage is given by  $V_{an}=V_{dc1}+V_{dc2}+V_{dc3}+V_{dc4}+V_{dc5}+V_{dc6}+V_{dc7}$  [1].

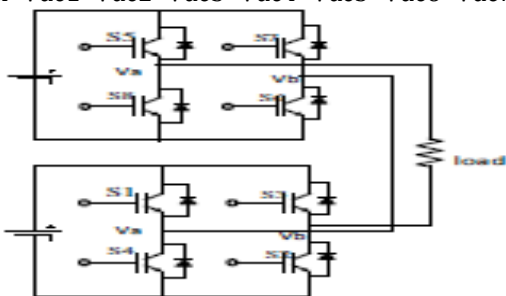


Fig1.Single Phase Five Level Inverter.

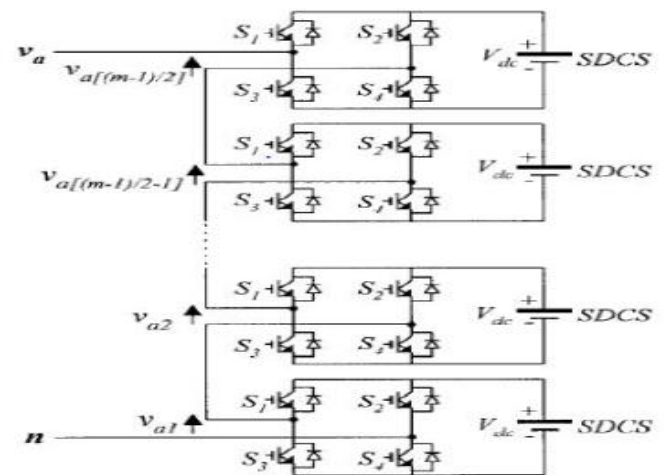


Fig1.Single phase cascaded H-Bridge inverter.

With the help of above configuration we can make any level of inverter i.e. 3 level, 5 level, 7 level and so on without any modulation technique.

### III. SIMULATION RESULT

The bridge circuit for three level inverter is shown below in Fig.3

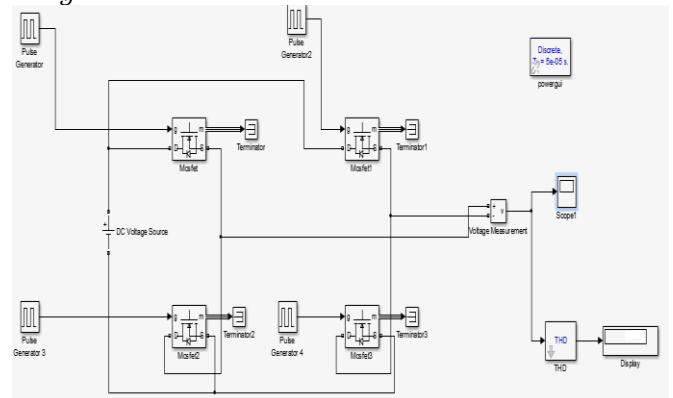


Fig.3 Simulation circuit for three inverter.

The output of three level inverter is shown in Fig 4.

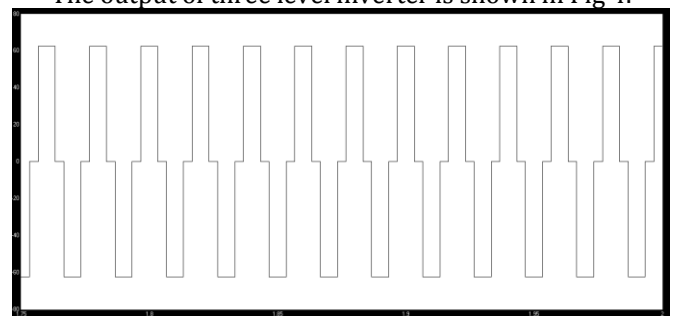


Fig.4 Simulation result of three level inverter.

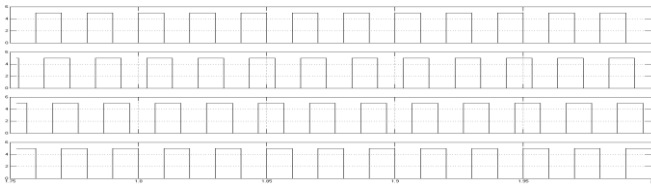


Fig.5 Gate pulses for various switches.

FFT spectrum for three level inverter is shown in Fig.6

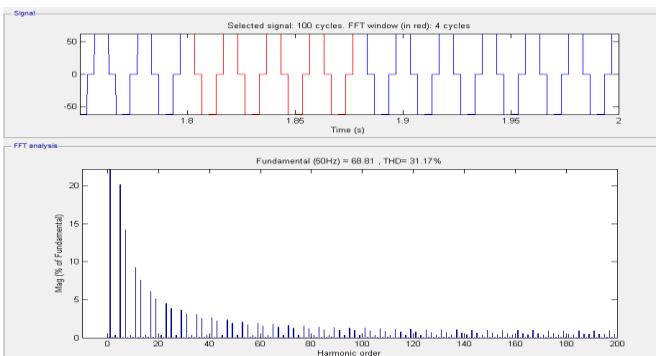


Fig.6 FFT spectrum for three level inverter.

The simulation circuit for five level is shown in Fig.7.

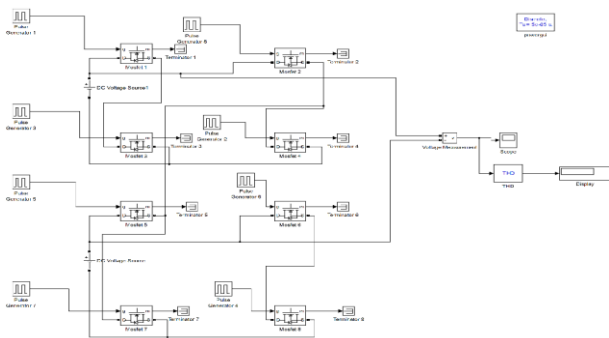


Fig.7 Simulation circuit for five level inverter.

The simulation result is shown below in Fig .8

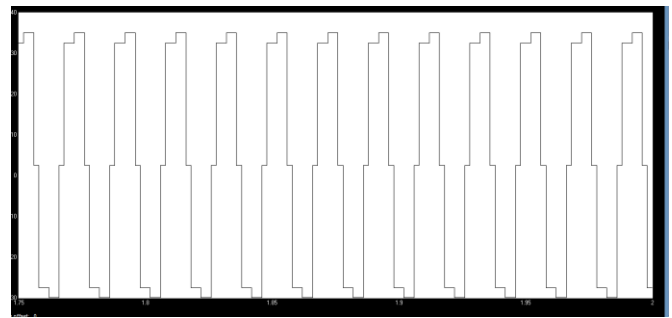


Fig.8 Simulation output for five level inverter.

FFT spectrum for five level inverter is shown in Fig.9

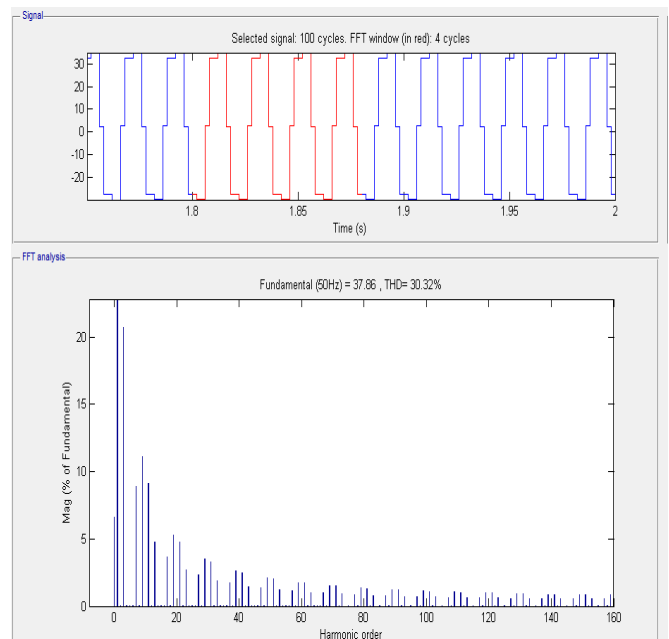


Fig.9 FFT spectrum for five level inverter.

The figure below shows the simulation circuit for seven level inverter

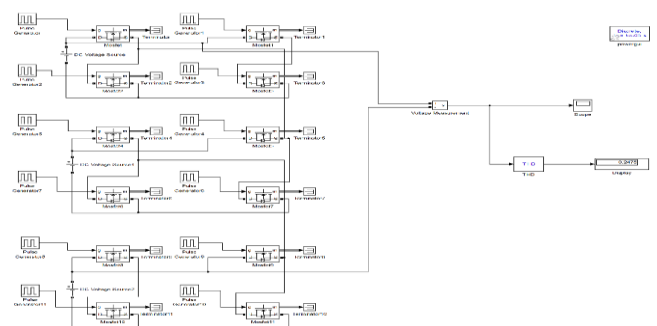


Fig.10 Simulation circuit for seven level inverter.

The simulation result for seven level is shown in Fig.11

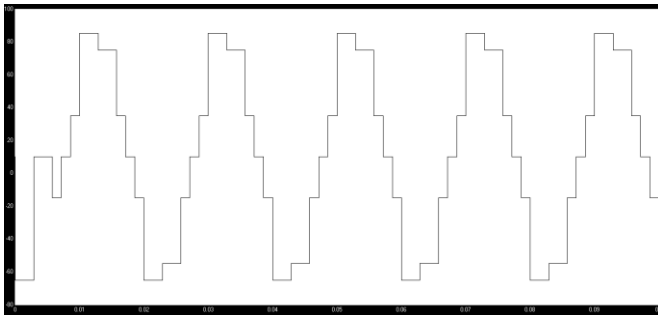


Fig.11 Simulation output for seven level inverter.

FFT spectrum is shown in figure 12.

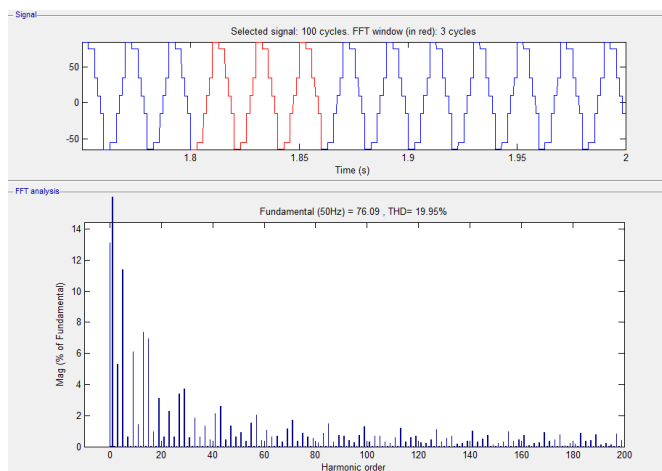


Fig.12 FFT spectrum for seven level inverter.

The analysis of lowering the harmonics is done by examining the output of three levels, five levels, and seven levels using FFT spectrum.

The results are shown in Table 1 below:

TABLE 1

THD FOR THREE LEVEL, FIVE LEVEL, SEVEN LEVEL

Parameter	Multilevel Inverter		
	Three level inverter	Five level inverter	Seven level inverter
THD for voltage	31.17%	30.32%	19.95%

#### IV. CONCLUSIONS

With the help of Matlab/Simulink the simulation of three level, five level, seven level were carried out with the help of a simple control strategy. A simple control strategy was used to trigger the switches at appropriate firing angle with suitable delay. The total harmonic distortion was calculated for each level and it was found that the THD decreases with the increase in the number of levels.

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## BIOGRAPHIES



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