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Two Level and Five Level Cascaded H-bridge Inverter Structure with Amplitude Modulation (AM) Technique with Reduction in Total Harmonic Distortion

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ABSTRACT
Inverters using pulse width modulation techniques generates common mode voltages in induction motor drives which can cause shaft voltages and bearing currents resulting into failure of motor. A two level and five level inverter topology with amplitude modulation technique is proposed in this paper which completely eliminates the above problems. Also losses in switching devices and stress is reduced. Using proposed topology total harmonic distortion (THD) is reduced and improved overall harmonic profile is achieved. The system is modelled with the help of MATLAB Simulink software for two level and five level inverter with proposed AM technique. Experimental results shown for the proposed topology which indicates lower total harmonic distortion.

Keywords: Amplitude Modulation (AM), Cascaded H-bridge Inverter, Multilevel Inverter (MLI), Total Harmonic Distortion (THD)

I. INTRODUCTION

In view to improve the quality of output waveforms generated, it is necessary to improve the performance of power electronics systems. In today's arena, to improve the performance of the system and increased power ratings, multilevel inverters are used [1]. Because of the significant advantages offered by it, multilevel inverters are preferred solution for high power applications. Improving the output voltage waveform of the multilevel inverter reduces its respective harmonic content and so, the size of filter used and the level of electromagnetic interference (EMI) generated because of switching operation [2],[3].

One of the topology used multilevel inverter is the cascaded multilevel inverter or series h-bridge inverter. This topology avoids the use of clamping diodes and capacitors used for voltage balancing [4]. To avoid short circuit of DC sources, the separate DC sources configuration is applied to the cascaded multilevel inverter [6]. Because of the structure of separate DC sources, cascaded multilevel inverter is well suited for various renewable energy sources such as photovoltaic cell, fuel cell etc. For active power conversion from AC to DC and then DC to AC as per requirement, the cascaded inverter is best suitable [8]. With its modularity and flexibility, the cascaded multilevel inverter shows supremacy in high power applications [5]. Compared to other topologies of multilevel inverters the proposed topology gives advantages like: reduced number of switches, optimization layout is possible because of same structure for all levels, simple control etc. The only disadvantage of h-bridge inverter is it requires separate DC sources [7].

While using h-bridge inverter various problems have been faced and these problems can be solved using cascading the h-bridge inverters. Summary of the problems associated with h-bridge inverter and their solution of the problem is given in the TABLE I below [8].

TABLE I: Comparison between h-bridge MLI and cascaded h-bridge MLI

H-bridge inverter demerits	***Solution using cascade MLI***
High electrical stress on device	More than one semiconductor switches in series is used. Hence electrical stress divide across all.
High total harmonic distortion	Low voltage appears across any switch so low harmonics are generated due to switching
Radio interference	Comparatively low voltage and current is chopped so radio interference is low.
Due to high THD, large, costly and complex filter circuit is required.	THD is low, so simple circuit can be used.
High cost of switching device, because of higher voltage rating	As low voltage will appear across each device, cost of devices will somewhat less.

II. PROPOSED TOPOLOGY

In proposed amplitude modulation technique, one reference wave is taken and according to requirement switching takes place. In this switching losses are less as compared to PWM technique. To generate appropriate gate pulse, it is required to calculate time interval for switching the individual device or switch. In pulse width modulation technique, to generate the gate pulse a reference wave is compared with a carrier wave and at the intersection or at the crossover gate pulse is generated according to the requirement of configuration. Calculation is little bit difficult in this case, but in amplitude modulation technique, the mathematical calculation for time interval is not as difficult as in pulse width modulation.

The mathematical formulae for finding out appropriate time interval in proposed scheme is as follows:

$$t_i = \frac{\sin^{-1}\{(i-0.5)/n\}}{(f * 360°)}$$

Where,
ti =time interval for ith level,
i = no. of output voltage level, where i ≤n
n =maximum output voltage level,
f =frequency of output voltage is to be generated

This equation can be used to find the time interval from zero to peak value, after it the time period can be found using wave symmetry of sinusoidal waveform.

III. SIMULATION RESULTS

A. Two level H-bridge inverter with proposed AM Technique

Two level h-bridge inverter is modelled with the help of MATLAB Simulink software with and without amplitude modulation technique. Simulink model for 2-level inverter is shown in Fig.1. Fig.2 shows the output voltage waveform.

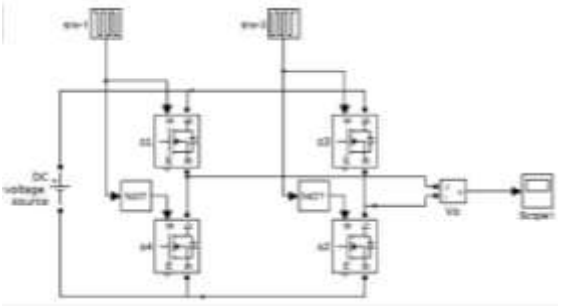

Fig.1 Simulink model (2-level)

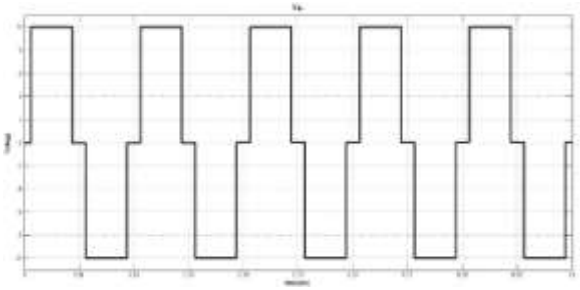

Fig.2 Output voltage waveform (2 level)

FFT spectrum and fourier analysis of two level inverter with amplitude modulation technique is shown in Fig.3 and Fig.4 repectively.

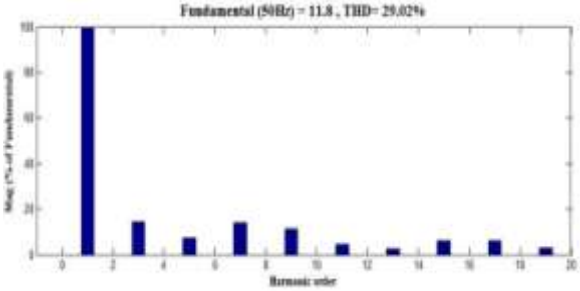

Fig.3 FFT spectrum for two level inverter

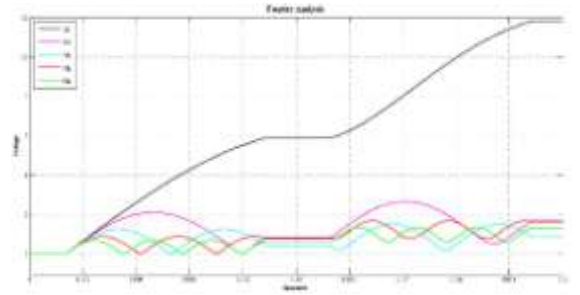

Fig. 4 fourier analysis for two level inverter

B. Five level h-bridge inverter with proposed AM technique

Simulation results of five level inverter with amplitude modulation technique is shown in this section. Fig.5 shows the MATLAB model of five level inverter. While output voltage waveforms of five level is shown in Fig. 6 below.

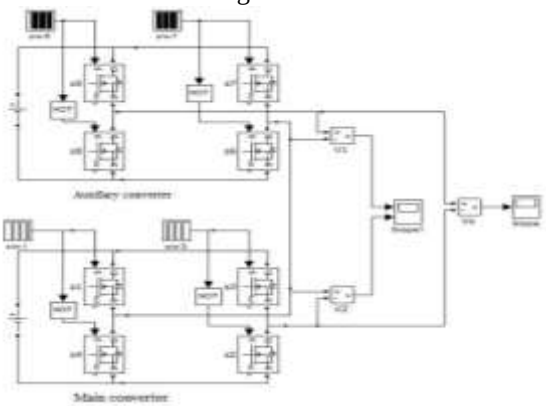

Fig.5 Simulink model of 5 level inverter

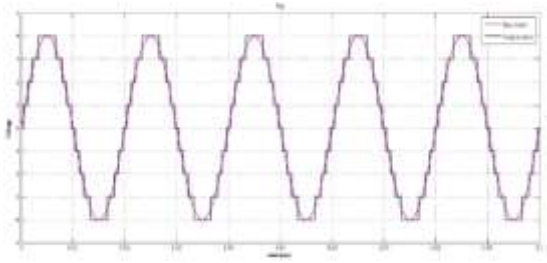

Fig.6 Output voltage waveform (five level)

From above Fig.6 it can be seen that output voltage waveform follows the sinusoidal waveform. Hence reduction in THD is there. FFT analysis of outout voltage waveform shows that there is a large reductin in THD compared to two level MLI. FFT spectrum for fove level inverter is shown in Fig.7 and fourier analysis is shown in Fig.8 below.

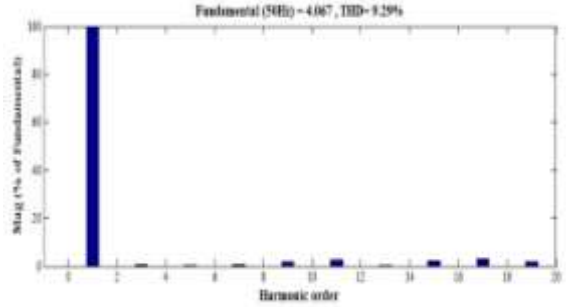

Fig.7 FFT spectrum of fivel level inverter

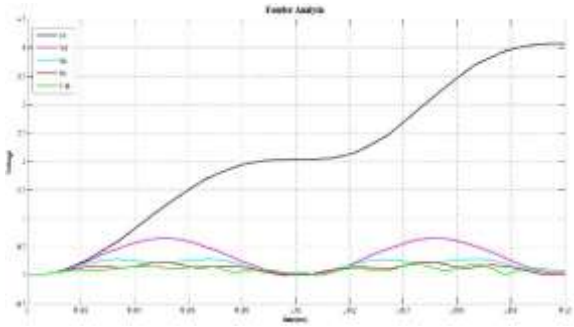

Fig.8 Fourier analysis of five level inverter

From above simulation study it can be concluded that as the level of output voltage increases, THD is reduced. Analysis of THD with and without amplitude modulation scheme for different output voltage leves is shown in TABLE II below.

TABLE II: % THD analysis with different levels of inverter

Cascade h-bridge inverter (levels)	% THD without using amplitude modulation	% THD using amplitude modulation technique
2 level	48.34 %	29.02 %
5 level	15.22 %	9.29 %

IV. EXPERIMENTAL RESULTS

Hardware implementation was done for two level and five level cascaded h-bridge inverter using proposed technique. According to output voltage requirement number of h-bridges can be connected in series. Microcontroller is used to generate the gate pulses. The gate pulses are applied to semiconductor devices through opto-coupler and driver ICs. Fig.9 shows the circuit configuration for one h-bridge. Similar h-bridges can be connected in series to increases the output voltage level.

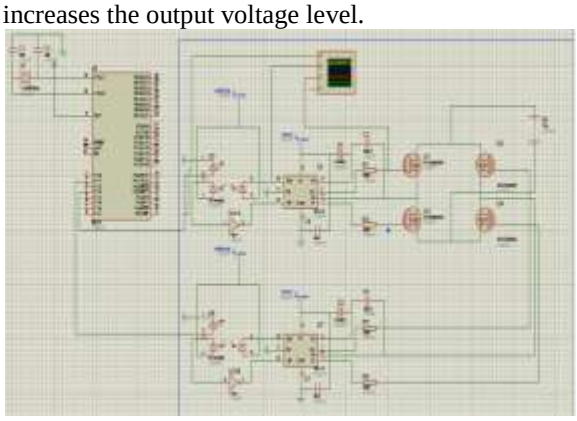

Fig. 9 Circuit configuration for single h-bridge

The hardware test setup is shown in Fig. 10. Fig.11 shows the output voltage waveform of two level inverter using AM technique.

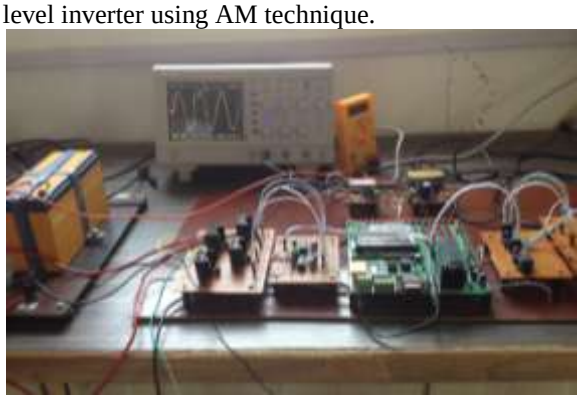

Fig.10 Hardware test setup

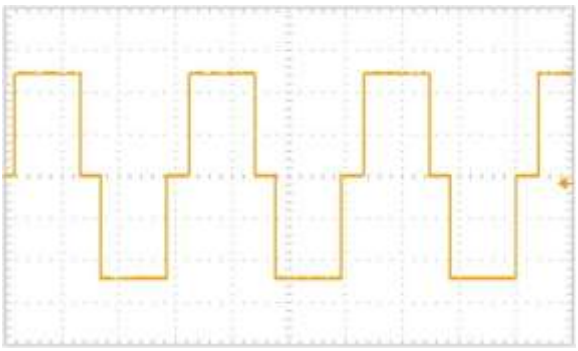

Fig.11 Output voltage waveform (two level)

Similarly, 5 level output voltage can be generated by connecting two h-bridges in series. One converter act as a main converter and another

converter act as an auxiliary converter. Each converter consist of four semiconductor switches. Gate pulses are generated using microcontroller and given to the main converter and auxiliary converter. Gate pulses generated for switch 1 & 4 of main converter are shown in Fig.12 and for switch 2 & 3 are shown in Fig. 13 below.

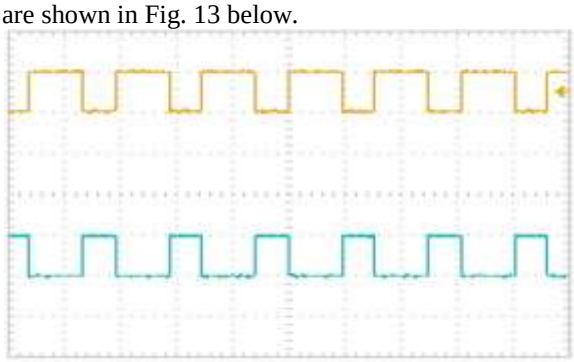

Fig.12 Gate pulses for switch 1 & 4

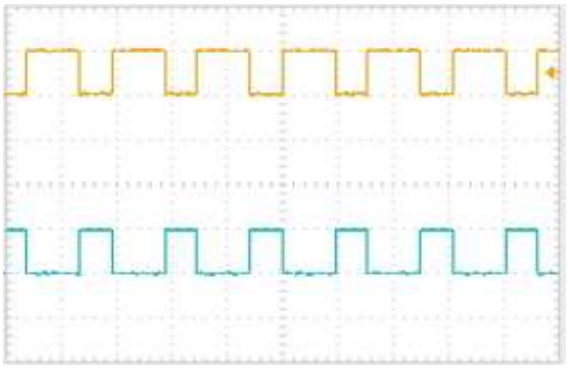

Fig. 13 Gate pulses for switch 2 & 3

Similarly, gate pulses for auxiliary converter switches are shown in Fig.14 and Fig.15.

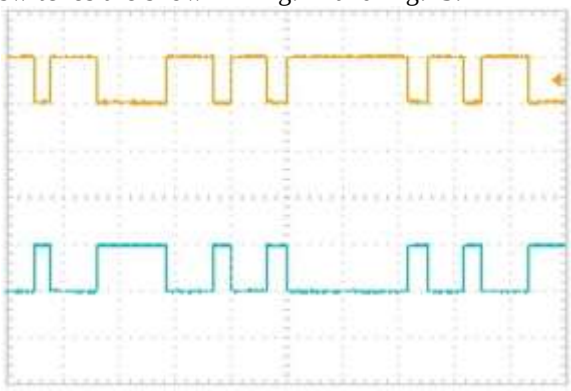

Fig.14 Gate pulses for switch 5 & 8

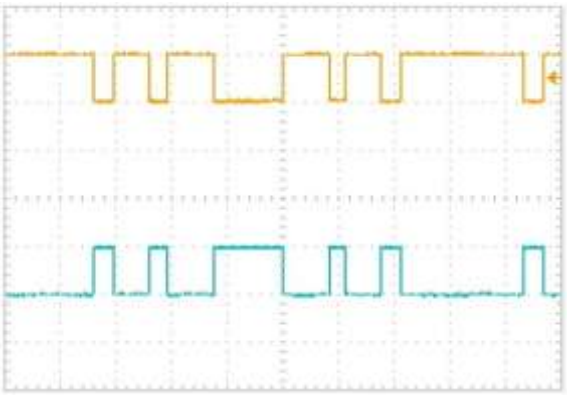

Fig. 15 Gate pulses for switch 6 & 7

Output voltage waveform of main converter and auxiliary converter is shown in Fig. 16 and Fig.17 respectively. Fig. 18 shows the total output voltage waveform of 5 level cascaded h-bridge multilevel inverter using amplitude modulation (AM) technique. Fourier analysis of output voltage waveform proves that using proposed AM technique percentage THD is reduced to a great extent.

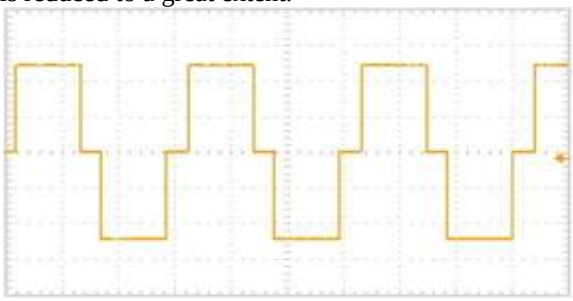

Fig.16 Main converter output voltage

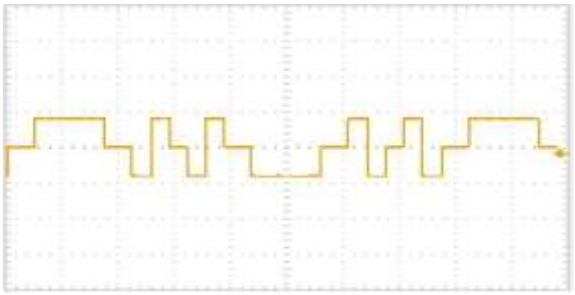

Fig. 17 Auxiliary converter output voltage

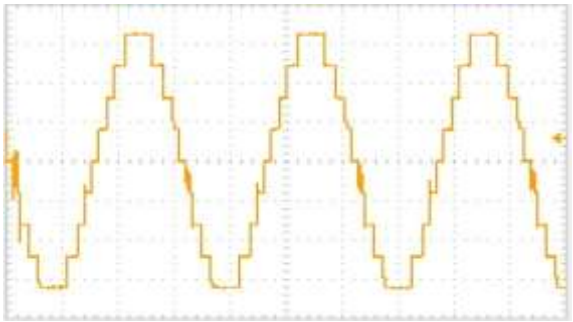

Fig. 18 Output voltage waveform (5 level)

V. CONCLUSION

This paper presents a cascaded multilevel h-bridge inverter using amplitude modulation technique. Different levels of inverter have been studied using different modulation strategies. Simulation results and hardware results shows that total harmonic distortion can be reduced by using AM instead of PWM. As number of switches are reduced, conduction losses will be less and overall cost of converters will reduce.

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