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A COMPARATIVE INVESTIGATION OF 13-LEVEL, 23-LEVEL AND 33-LEVEL CONVENTIONAL CASCADED H-BRIDGE MULTILEVEL INVERTERS BY USING SIMULINK / MATLAB

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ABSTRACT

This paper aims to extend the knowledge about performance of different Cascade H-Bridge multilevel inverters (CHB-MLI) through harmonic analysis. Large utility applications require advanced power electronics converter to meet high power demands. As a result, multilevel power converter structure has been introduced as an alternative for high power and medium voltage situations. A multilevel converter not only achieves high power ratings, but also improves performance of the whole system in terms of harmonics, dv/dt stresses, and stresses in the bearings of a motor [1].

Multilevel inverters are becoming more popular in the power conversion systems for high power and power quality demanding applications. The MATLAB based simulation on SIMULINK platform is presented for Cascade H-Bridge multilevel inverter (CHB-MLI) topology of Single Phase cascaded H-bridge Multilevel Inverter for 13, 23, and 33-levels. A detailed comparison of Cascade H-Bridge multilevel inverters (CHB-MLI) are presented in the paper based on number of power devices used, Total Harmonic Distortion [1].

KEYWORDS: Cascade H-Bridge Multilevel Inverter (CHB-MLI), Flying Capacitor Multilevel Inverter (FC-MLI), Neutral Point Clamped Multilevel Inverter (NPC-MLI), Total Harmonic Distortion (THD).

INTRODUCTION

Multilevel inverters have more applications in the field of high voltage and medium power applications due to advantages such as low voltage stress on power semiconductor devices, low harmonic distortions, good electromagnetic compatibility, reduced switching losses and improved reliability on fault tolerance. Therefore, the multilevel inverters also have lower dv/dt ratio to prevent induction or discharge failures on the loads. Recently low voltage applications also has been studied to apply the multilevel inverters for high efficiency such as in the uninterrupted power supply (UPS) and power inverter for solar photovoltaic system (PV) [2].

Several multilevel converter topologies have been developed; i) diode clamped, ii) flying capacitors, and iii) cascaded or H-bridge. Based on various literature reviews, the Cascade H-Bridge multilevel inverter (CHB-MLI) with separated DC sources is clearly the most feasible topology for use as a power converter for medium & high power applications due to their modularization and extensibility. The H-bridge inverter eliminates the excessively large number of (i) bulky transformers required by conventional multilevel inverters, (ii) clamping diodes required by multilevel diode-

clamped inverters, and (iii) flying capacitors required by multilevel flying-capacitor inverter. So the CHB-MLIs are mostly used for PV applications because each module of CHB-MLI requires separate DC sources which can be easily supplied by individual PV arrays. The number of levels of the output waveform can be increased by cascading the number of H-Bridge modules in series. Total Harmonic Distortion in output voltage decreases with increase in number of levels.

CONVENTIONAL CASCADED H-BRIDGE MULTILEVEL INVERTER

The cascaded H-Bridge multilevel inverters are the most advanced and important method of power electronic converters that analyses output voltage with number of dc sources as inputs. As compared to neutral point clamped multilevel inverter and flying capacitor multilevel inverter, the cascaded H-Bridge multilevel inverters requires less number of components and it reaches high quality output voltage which is close to sine wave. By increasing the number of output levels the total harmonic distortion in output voltage can be reduced. In cascaded H-Bridge multilevel inverter required AC output voltage is obtain by synthesizing number of DC sources. The number of H-Bridge units with different DC sources is connected in series or cascade to produce cascaded H-Bridge multilevel inverter [1].

Cascaded H-Bridge MLI is nothing but H-Bridges connected in a cascaded manner. By adding each H-Bridge module, we can increase the two levels in an output waveform. Normally for a single phase cascaded H-Bridge multilevel inverter, number of semi conductor switches required is 2(n-1), where n is the number of levels [2].

Single Phase Conventional Cascaded H-Bridge Multilevel Inverter

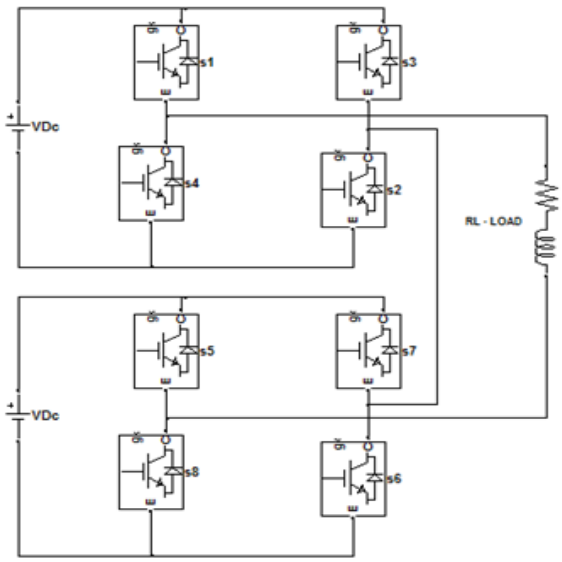

Figure 1: Single Phase Conventional 5-Level CHB-MLI

The figure 1 above shows the five levels cascaded H-Bridge MLI where two modules are connected in cascaded manner. The switching of the eight switches is done in such a way (as tabulated in Table 1) so as to get an output voltage waveform as shown in figure 2, which is a five level output.

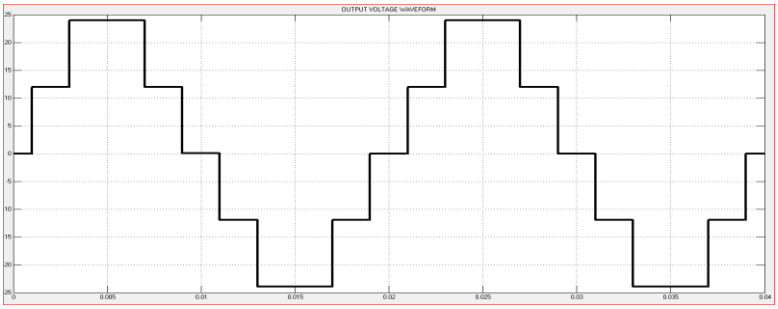

Figure 2: Output Voltage Waveform of 5-Level CHB-MLI

Table 1: Switching Table of the 5-Level Conventional CHB-MLI

Mode	Output Voltage	Status of the Power Device							
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
1	+2 V_{DC}	1	1	0	0	0	0	1	1
2	+ V_{DC}	1	1	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	- V_{DC}	0	0	1	1	0	0	0	0
5	-2 V_{DC}	0	0	1	1	1	1	0	0

SIMULATION RESULTS

The SIMULINK models of the 13, 23 and 33-level conventional CHB-MLI are shown in Fig 3, Fig 6, and Fig 9 respectively.

The SIMULINK models were made for 13, 23 and 33-level conventional CHB-MLI and it is observed that the THD reduces as the level increases. The output voltage waveforms of 13, 23 and 33-level MLIs are shown in Fig 4, Fig 7, and Fig 10 and THD with reference to fundamental component for 13, 23 and 33-level are shown in Fig 5, Fig 8, and Fig 11 respectively.

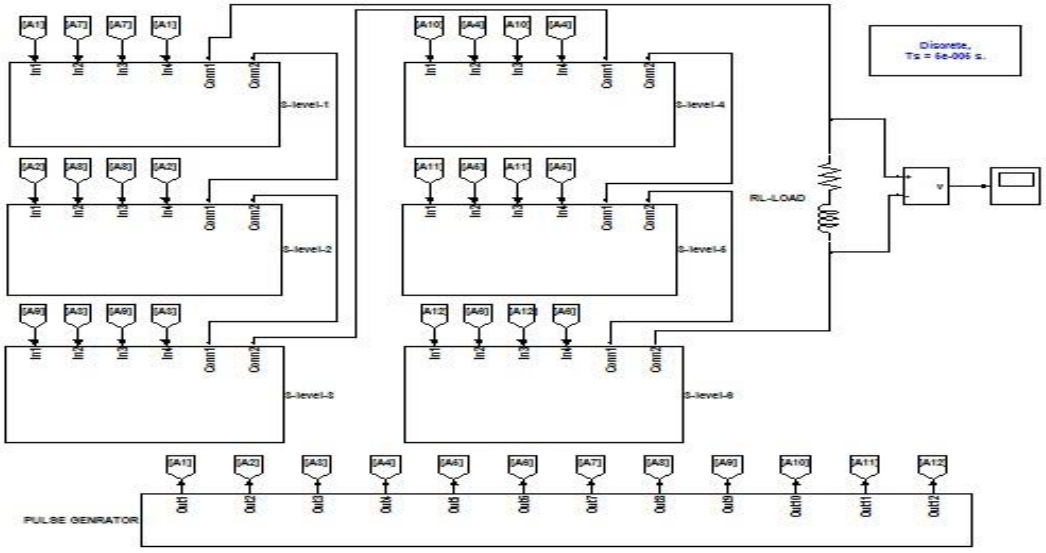

Figure 3: Simulink Model of Conventional 13-Level CHB-MLI

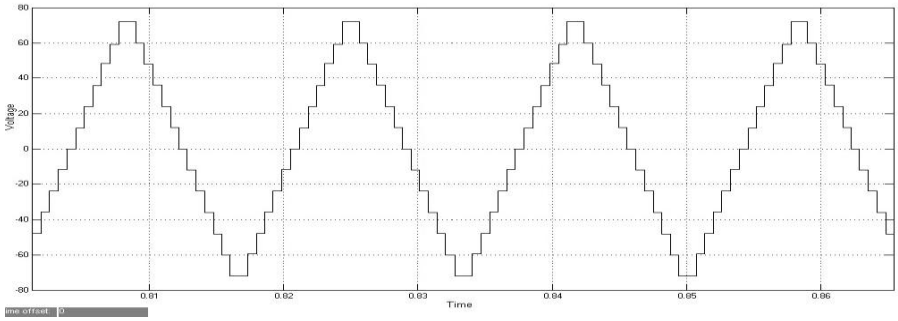

Figure 4: Output Waveform of a 13-Level CHB-MLI

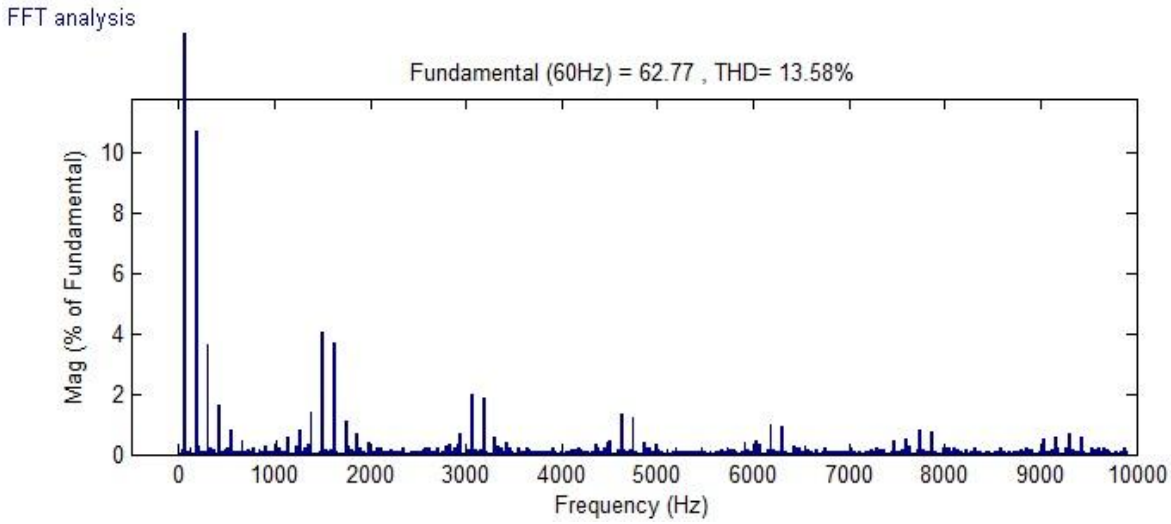

Figure 5: THD With Reference to Fundamental Component Of a 13-Level CHB-MLI

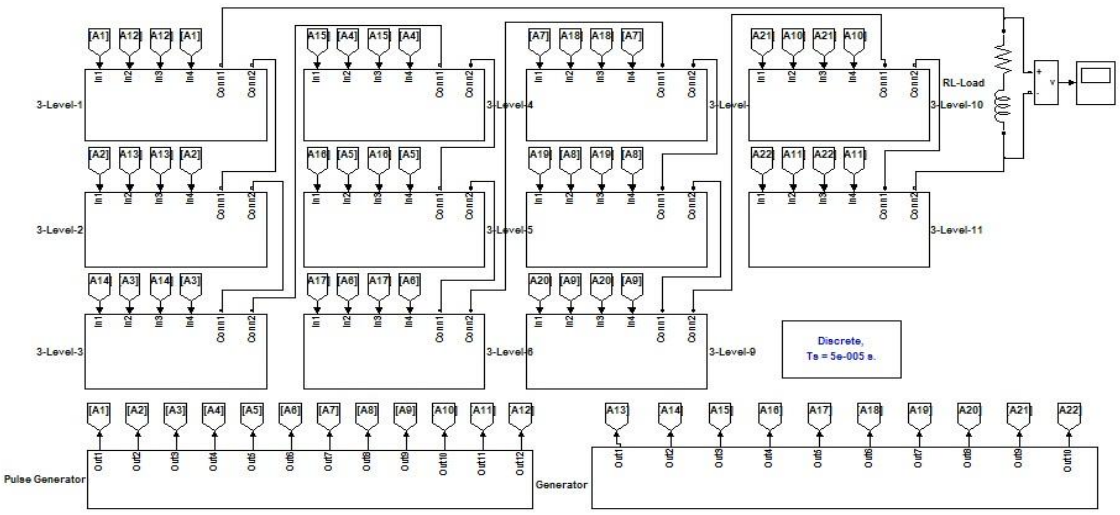

Figure 6: Simulink Model of Conventional 23-Level CHB-MLI

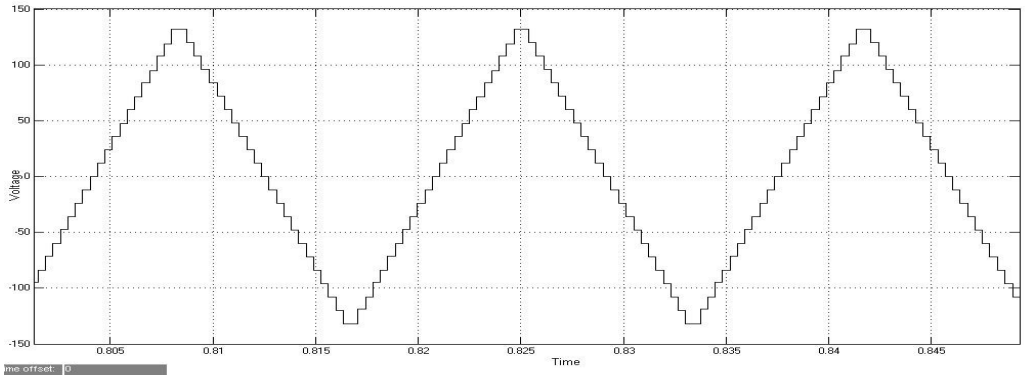

Figure 7: Output Waveform of a 23- Level CHB-MLI

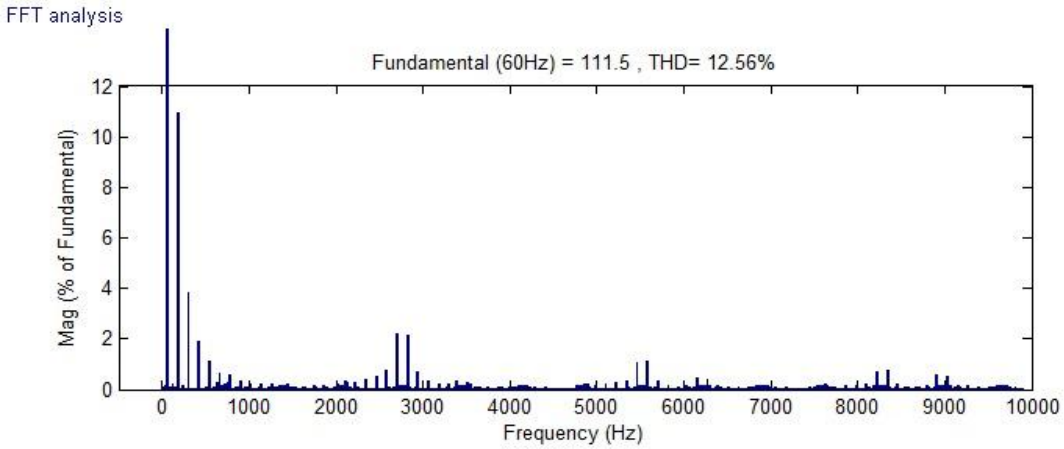

Figure 8: THD With Reference to Fundamental Component Of a 23- Level CHB-MLI

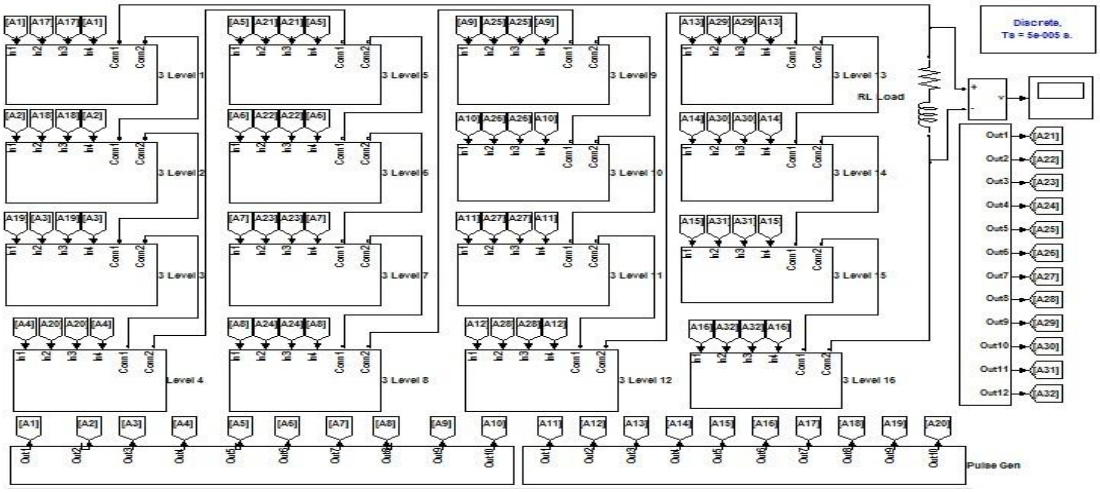

Figure 9: Simulink Model of Conventional 33-Level CHB-MLI

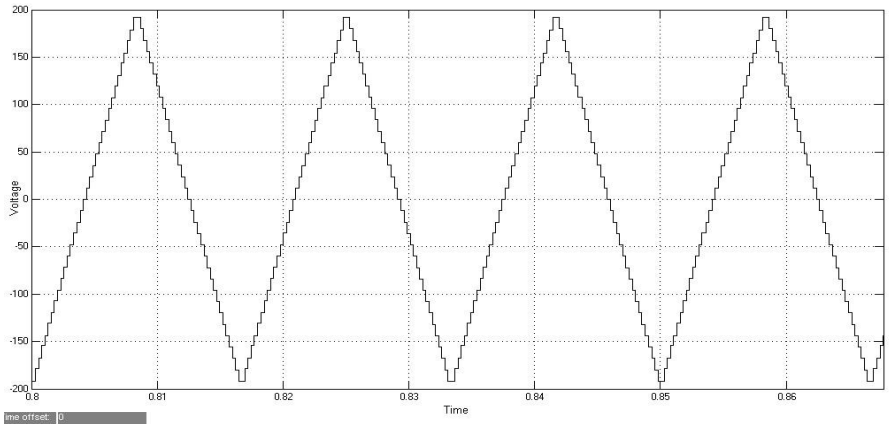

Figure 10: Output Waveform of a 33- Level CHB-MLI

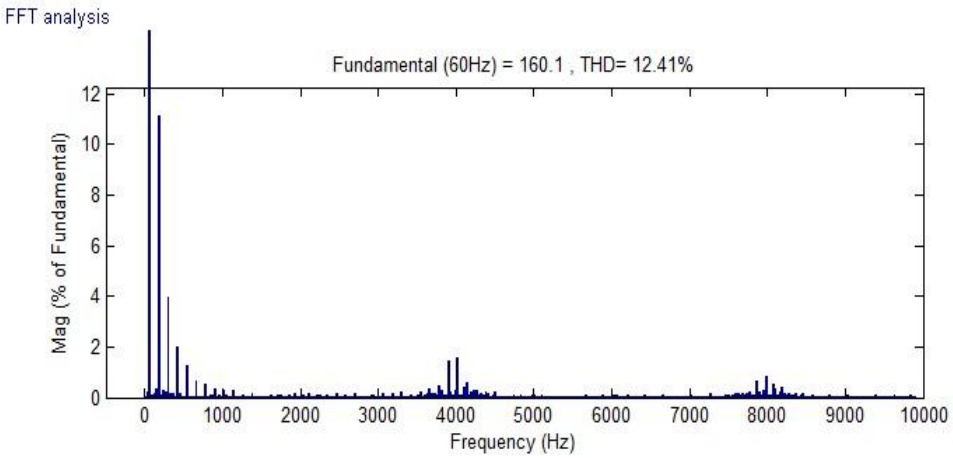

Figure 11: THD With Reference to Fundamental Component of a 33- Level CHB-MLI

COMPARATIVE ANALYSIS

The comparison of number of power devices required for 5-level [1], 9-level [1], 11-level [1], 13-level, 23-level and 33-level conventional CHB-MLI's are tabulated in Table 2.

Table 2: Comparison of Number of Devices

MLI Topology	Number of Devices					
	5-Level [1]	9-Level [1]	11-Level [1]	13-Level	23-Level	33-Level
Conventional CHB	8	16	20	24	44	64

The THD is calculated for 5-level [1], 9-level [1], 11-level [1], 13-level, 23-level and 33-level conventional CHB-MLI's are tabulated in Table 3. It is observed that THD reduces as the number of level increases.

Table 3: Comparison of THD

MLI Topology	THD in %					
	5-Level [1]	9-Level [1]	11-Level [1]	13-Level	23-Level	33-Level
Conventional CHB	20.64	15.17	14.44	13.58	12.56	12.41

CONCLUSIONS

In this paper a detailed comparison of conventional CHB-MLI has been presented. Thus the single phase 5-level [1], 9-level [1], 11-level [1], 13-level, 23-level cascaded H-Bridge inverters are compared with single phase 33-level cascaded H-Bridge inverter using MATLAB simulation on the basis of switches, THD with RL load. The total harmonic distortion in 5-level [1], 9-level [1], 11-level [1], 13-level, 23-level inverters are more as compared to 33-level inverter. As the number of level increases, THD decreases. This investigation will help the design engineer for selection of appropriate multilevel inverter for further applications.

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