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Research paper

Comparative analysis of various multilevel inverter symmetrical topologies with minimum number of components

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Abstract

Multilevel inverters (MLI) are frequently used in different fields like, oil and gas sectors, installations of power supply, high power and medium voltage applications and in FACTS (flexible AC transmission system) devices to improve power quality. Lot of topologies has been developed in the literature regarding multilevel inverters such as diode clamped type, flying capacitor type and cascaded H-bridge type multilevel inverters. However, several challenges are being faced while implementing these topologies like more number of switches, more losses and cost. The optimized construction of multilevel inverter is to get more number of levels with less number of switches and low total harmonic distortion. In this paper, three different existing multilevel inverter topologies have been considered and analyzed for five level output voltage. A comparison table is given for number of switches, extra diodes and voltage sources. The total work is carried by using Matlab/simulink software and results are presented.

Keywords: *Inverters; Multilevel Inverter; Cascaded H-Bridge Inverter; Total Harmonic Distortion (THD).*

1. Introduction

The renewable energy sources (RES) [1-2] are becoming more popular in the recent electrical energy system. The available renewable energy sources are solar, wind and fuel cell. Out of these sources solar energy is the widely used source because of its flexibility. To integrate the renewable energy sources to the grid or to use it for domestic and industrial loads, The DC output of PV system [3-4] must converted to AC. For this purpose inverter is used. Connecting renewable energy sources to the existing system is known as distributed generation (DG) [5-6]. The basic inverter used to convert DC to AC is two level inverter. This two level inverter can give the alternating supply, but the output voltage wave shape is square wave. As per fast Fourier transform analysis, the square wave consists of more number of harmonic components along with the fundamental component. The total harmonic distortion will be very high. The presence of harmonics causes for more heat losses, develops parasitic torques in case of rotating machines, the input current drawn also contains ripples. Therefore, to overcome these drawbacks multilevel inverter [7-8] topology has been developed which gives us the stepped output voltage waveform with comparatively low THD [9-10].

There are lot of multilevel inverter topologies has been developed like diode clamped multilevel inverter, flying capacitor type multilevel inverter and cascaded H-bridge (CHB) [10-12] multilevel inverter. The diode clamped type inverter requires more number of diodes and flying capacitor type inverter requires more number of capacitors. And the cascaded H-bridge type inverter got its popularity because of its advantages. In this type, the number of H-bridges is connected in cascade and the number of voltage levels is based on the number of H-bridges followed by a formula 2n+1. Here, n is the number of H-bridges. As the bridge count increases, the voltage levels also increases. But, the major limitation is increasing of bridges require more number of power switches. In this paper, three different topologies for five level output voltage is analyzed and compared. The topologies are symmetrical cascaded H-bridge inverter topology, five level six switch topology and five level five switch topology. The work is done using Matlab/simulink software. The results are analyzed for total number of switch count, number of gate driver circuits, number of extra diodes and number of voltage sources. The comparison table is also given.

2. Five level MLI with 8 switches

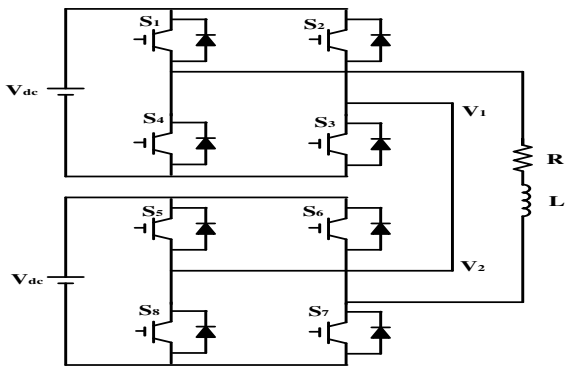


Fig. 1: 5 Level Symmetrical CHB.

Figure 1 shows the circuit diagram for five level MLI with 8 switches. The circuit contains two voltage sources of equal magnitude therefore, this topology is known as symmetrical configuration. The semiconducting switches are IGBT devices. The topology contains two H-bridges connected in cascade with 8 switches.

Table 1: Switching Sequence

Voltage Levels	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
$2V_{DC}$	on	off	on	off	on	off	on	off
V_{DC}	on	off	on	off	off	off	on	on
0	on	on	off	off	on	on	off	off
$-V_{DC}$	off	on	off	on	off	off	on	off
$-2V_{DC}$	off	on	off	on	off	on	off	off

The switching sequence for five level output voltage is shown in table 1

3. Five level MLI with six switches

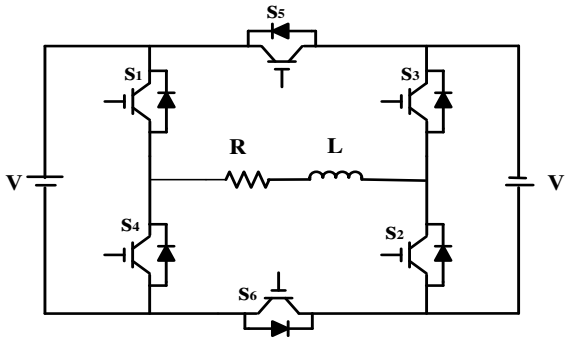


Fig. 2: Five Level MLI with Six Switches.

Five level multilevel inverter topology with six number of switches is shown in figure 2. It has two voltage sources of same magnitude with six switches.

Table 2: Switching Sequence

Voltage Levels	S_1	S_2	S_3	S_4	S_5	S_6
$2V_{DC}$	on	off	on	off	off	on
V_{DC}	on	on	off	off	off	on
0	on	off	on	off	on	off
$-V_{DC}$	off	off	on	on	on	off
$-2V_{DC}$	off	on	off	on	on	off

The switching sequence for five level MLI with six switches topology is given in table 2.

4. Five level MLI with five switches

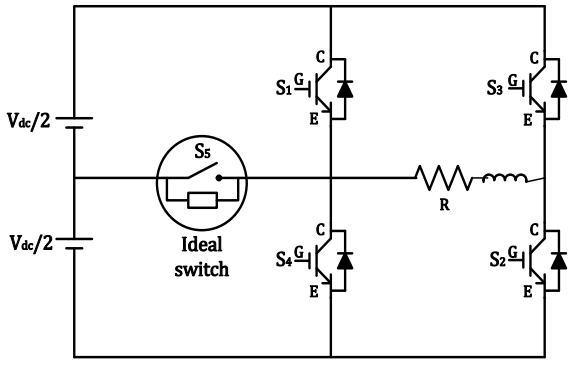


Fig. 3: Five Level MLI with Five Switches.

Figure 3 shows the five level multilevel inverter with five switches.

Table 3: Switching Sequence

Voltage levels	Switching Sequence				
	S_1	S_2	S_3	S_4	S_5
0	off	on	off	on	off
Vdc/2	off	on	off	off	on
Vdc	on	on	off	off	off
-Vdc/2	off	off	on	off	on
-Vdc	off	off	on	on	off

Table 3 shows the switching sequence for five level MLI with five switches.

5. Simulation results

5.1. Five level mli with 8 switches

Case 1: R Load

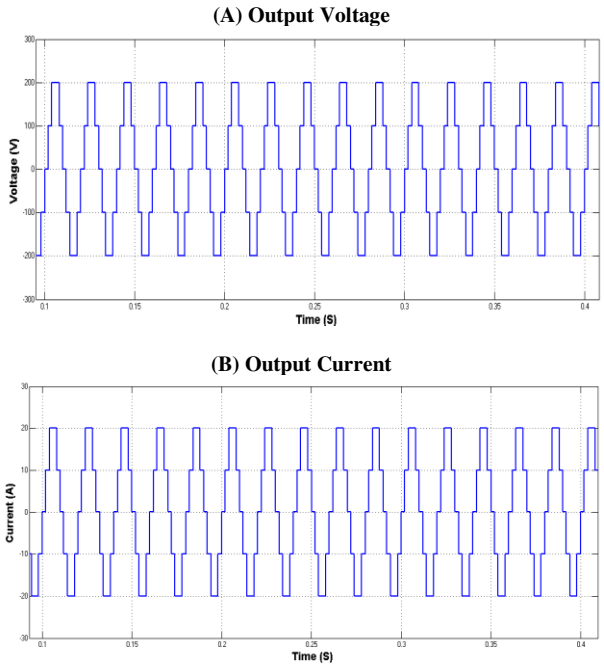


Fig. 4: (A) Output Voltage (B) Output Current.

Figure 4 shows the output voltage and current for resistive load. The output voltage magnitude is 200 volts and current magnitude is 20 amps.

Case 2: Rl Load

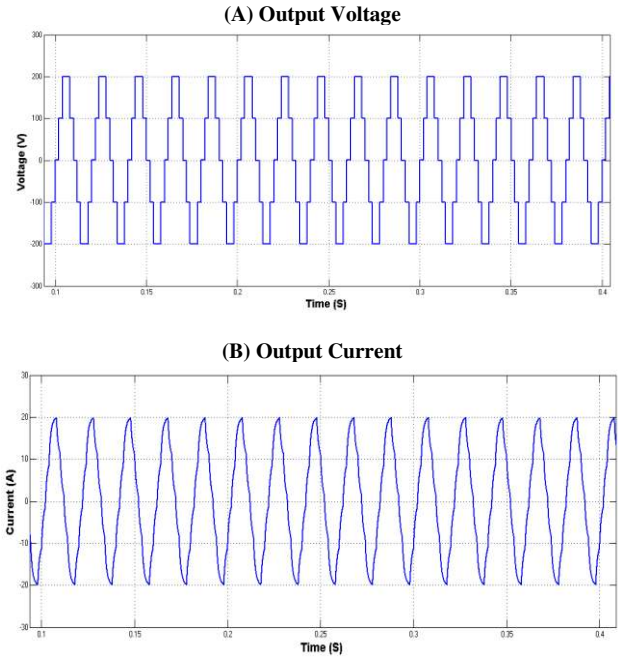


Fig. 5: (A) Output Voltage (B) Output Current.

Figure 5 shows the output voltage and current for inductive load.

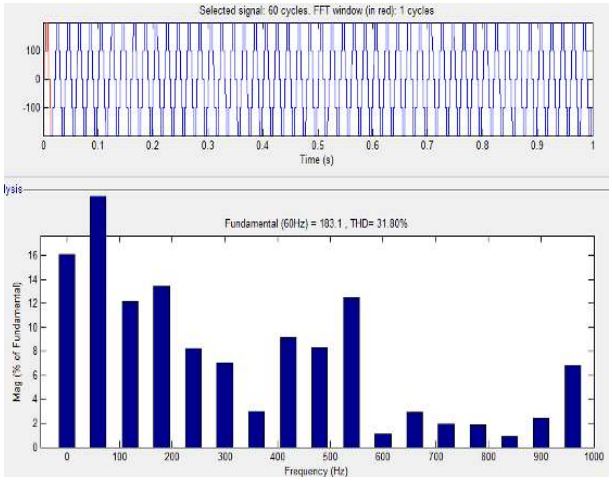


Fig. 6: Output Voltage THD.

The total harmonic distortion for output voltage is shown in figure 6. The measured value of THD is 31.80%.

5.2. Five level mli with 6 switches

Case 1: R Load

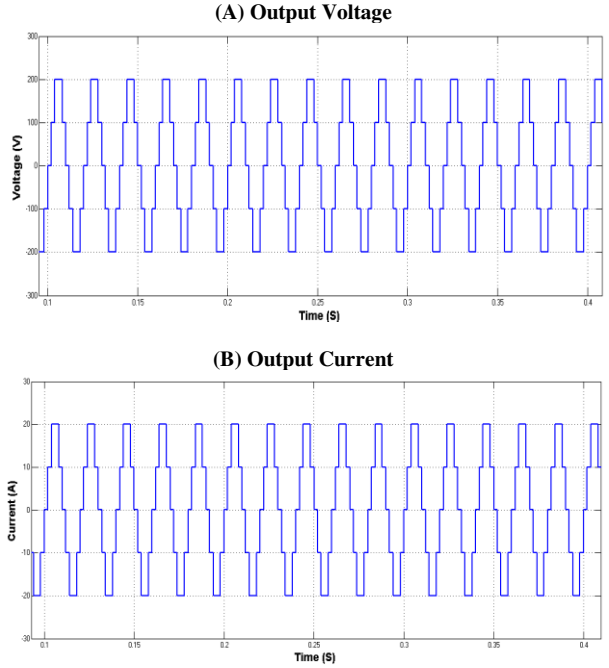
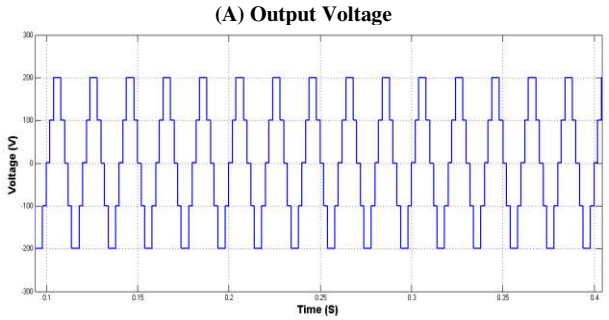


Fig. 7: (A) Output Voltage (B) Output Current.

Figure 7 shows the output voltage and current waveforms for resistive load.

Case 2: Rl Load



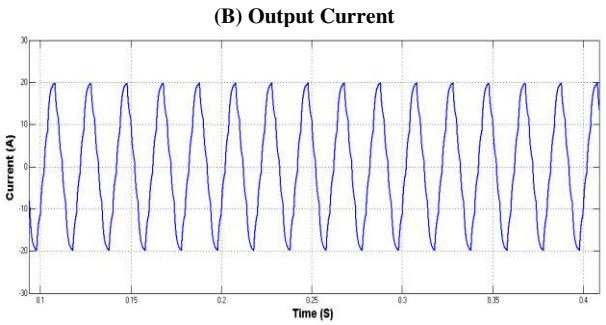


Fig. 8: (A) Output Voltage (B) Output Current.

Figure 8 shows the output voltage and current waveforms for inductive load.

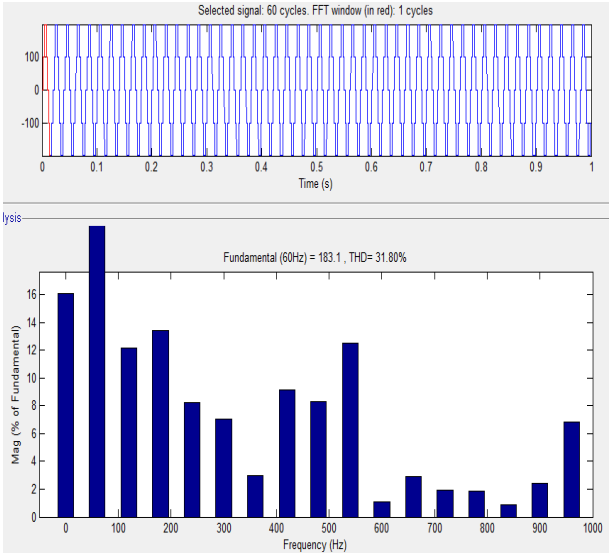


Fig. 9: Output Voltage THD.

The THD of output voltage is shown in figure 9 and value of THD is 31.08%.

5.3. Five level mli with 5 switches

Case 1: R Load

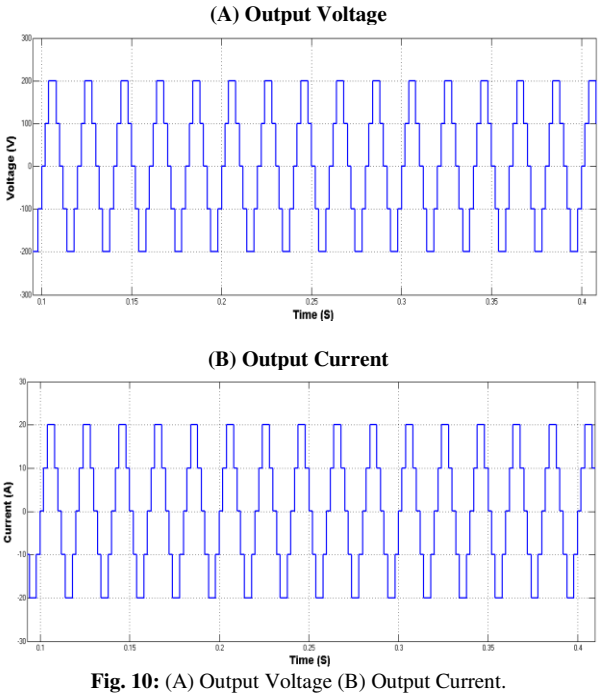


Fig. 10: (A) Output Voltage (B) Output Current.

Figure 10 shows the output voltage and current waveforms for resistive load.
Case 2: Rl Load

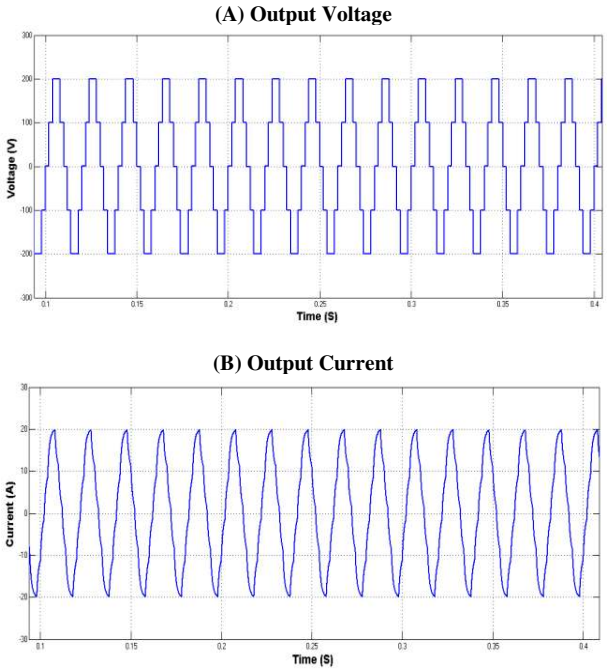


Fig. 11: (A) Output Voltage (B) Output Current.

Figure 11 shows the output voltage and current waveforms for inductive load.

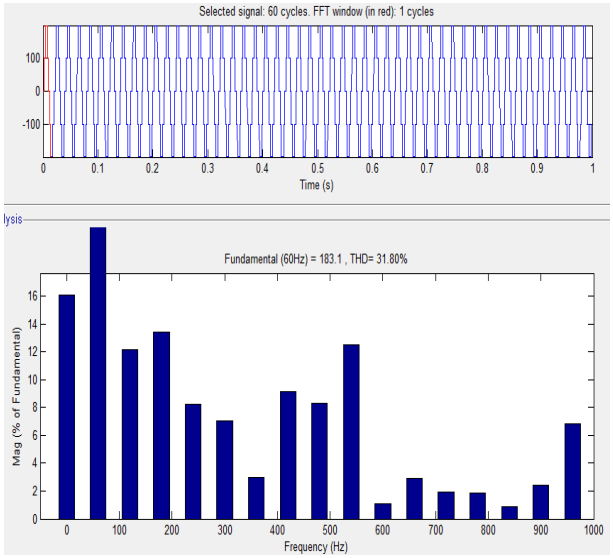


Fig. 12: Output Voltage THD.

The total harmonic distortion for output voltage is shown in figure 12 and the value of THD is 31.08%.

Table 4: Comparison between Three Topologies

Topology	No of Switches	No of Gate Driving Circuits	No of Extra Diodes	No of Voltage Sources
5-level with 8 switches(symmetrical CHB)	8	8	Nil	2
5 level with 6 switches	6	6	Nil	2
5 level with 5 switches	5	5	Nil	2

The comparison between three topologies is given in Table 4.

6. Conclusion

This paper explains the multilevel inverter need and comparison of 3 various topologies for five level output voltage. For five level inverter cascaded H-bridge inverter (symmetrical), symmetrical six switch inverter and symmetrical five switch inverter topologies have been explained with switching table. The cascaded H-bridge requires 8 switches, six switch inverter requires six switches and five switch inverter requires five switches. The analysis is done for both resistive and inductive loads. The simulation is done using Matlab/simulink software and results are presented. The parameters comparison is given in the comparison table. The total harmonic distortion is measured as 31.08%.

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