

Comparative Study of Different Types of Multilevel Inverter: With Respect to Output Voltage Waveform

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Abstract—Multilevel inverters are widely used in high power industrial application. This paper presents the generalized structure, operation and comparison between the different cascaded H-bridge multilevel inverter used for dc to ac power conversion. The main merit of the paper is to compare and minimize the total harmonic distortion which will help the design engineer for selection of appropriate multilevel inverter. The various switching topologies of different multilevel inverter have been analyzed in this paper. The simulation of multilevel inverter is done in simulation software.

Keywords: Multilevel inverters; PWM technique; Total harmonic distortion

1. INTRODUCTION

In multilevel power electronic converters, the desired output can be synthesized by combining several DC sources. solar panels, fuel cells, batteries, and ultra capacitors are the most common independent sources used. These converters are having single phase and three phase applications. The first topology introduced was the series H-Bridge converter which utilized a bank of series capacitors. Later flying capacitor design. In general multilevel converters are categorized into diode-clamped, flying capacitor, and cascaded H-bridge. The diode-clamped inverter provides multiple voltage levels through connection of the phases to a series bank of capacitors. Applications of diode clamped multilevel converters include high-power ac motor drives in conveyors, pump, fans, and mills. But due to capacitor voltage balancing issue diode-clamped inverter has been mostly limited to 3-level. Flying capacitor involves series connection of capacitor clamped switching cells. This can be used in high-bandwidth, high-switching frequency applications such as medium voltage traction drives. Drawback of this topology is large number of capacitors are more expensive and bulky. Finally cascaded H-bridge inverter consists of series power conversion cells. Voltage and power levels may be easily scaled. Cascaded H-bridge multilevel converter has been applied to high-power and high-quality applications such as static volt-ampere reactive generation, active filters, reactive

power compensators, photovoltaic power conversion, uninterruptible power supplies, and magnetic resonance imaging. Furthermore one of the growing applications for multilevel power electronic converters is electric drive vehicles in which the traction motor is driven by batteries.

2. CASCADED H-BRIDGE MULTILEVEL INVERTER

The cascaded H-Bridge multilevel inverter 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 obtained 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.[2][4]

3. SINGLE PHASE 2-LEVEL MULTILEVEL INVERTER

Fig. 1 shows Single phase Two level Cascaded H-Bridge inverter consisting of one isolated DC source, two IGBT switches & R-L load. The result of output voltage waveform of two level multilevel inverter is shown in Fig. 4. consists of three levels +V_{dc} and -V_{dc}.

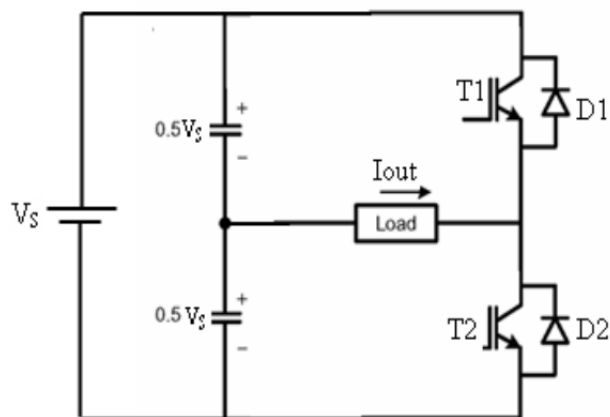


Fig. 1: Single phase Two level inverter[7]

Modes of Operation

Two modes of operation of two level multilevel inverter are explained below:

Mode 1:- In this mode of operation of two level inverter switch s1 is turned on. Output voltage obtained across the load is $+V_{dc}$.

Mode 2:- In this mode of operation of two level inverter switch s2 is turned on. Output voltage obtained across the load is $-V_{dc}$.

The same operation is shown in tabular form below in table I.

Table I: Modes of operation of single phase two level Inverter

MODE	SWITCH 1	SWITCH 2
1	1	0
2	0	1

4. SINGLE PHASE 3-LEVEL CASCADED H-BRIDGE MULTILEVEL INVERTER

Fig. 2 shows Single phase Three level Cascaded H-Bridge inverter consisting of single isolated DC source, four IGBT switches & R-L load. The result of output voltage waveform of three level multilevel inverter is shown in Fig. 5. consists of three levels 0, $+V_{dc}$, $-V_{dc}$. [10][4]

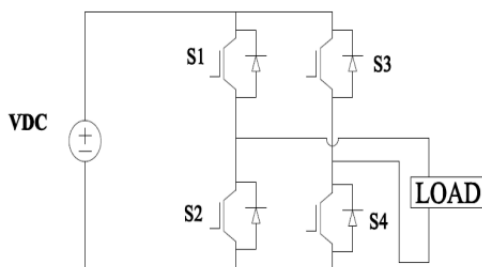


Fig. 2: Single phase Three level cascaded H-Bridge inverter [10]

Modes of Operation

Different modes of operation of three level cascaded H-Bridge multilevel inverter are explained below:

Mode 1:- In this mode of operation of three level cascaded H-Bridge inverter switches s1 & s2 are turned on & no source is connected to the load. Zero output voltage across the load is obtained.

Mode 2:- In this mode of operation of three level cascaded H-Bridge inverter switches s1 & s4 are turned on. Output voltage obtained across the load is $+V_{dc}$.

Mode 3:- In this mode of operation of three level cascaded H-Bridge inverter switches s2 & s3 are turned on. Output voltage obtained across the load is $-V_{dc}$.

Mode 4:- In this mode of operation of three level cascaded H-Bridge inverter switches s3 & s4 are turned on. Output voltage obtained across the load is zero.

The same operation is shown in tabular form below in table II.

Table II: Modes of operation of single phase three level cascaded H-Bridge Inverter

MODE	SWITCH 1	SWITCH 2	SWITCH 3	SWITCH 4
1	1	1	0	0
2	1	0	0	1
3	0	1	1	0
4	0	0	1	1

5. SINGLE PHASE 5-LEVEL CASCADED H-BRIDGE MULTILEVEL INVERTER

Fig. 3 shows single phase cascaded H-Bridge multilevel inverter consisting of two H-Bridges with 8 IGBT switches, two DC sources and R-L load. In this eight IGBT switches are (switch1, switch2, switch3, switch4, switch5, switch6, switch7, switch8) are used. Two H-Bridges are connected in series to generate five level output voltage. The output voltage of H-Bridge inverter 1 is V_1 and H-Bridge 2 is V_2 & total output voltage of 5 level inverter is V is, $V = V_1 + V_2$. The result of output voltage waveform of five level multilevel inverter is shown in Fig. 6. consists of five levels.

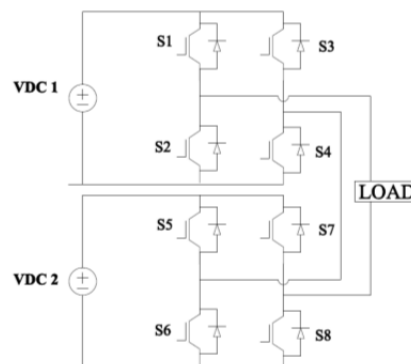


Fig. 3: Single phase Five level cascaded H-Bridge inverter [9]

Modes of Operation

The working operation of cascaded H bridge five levels multilevel is explained below:

Mode1:- In this mode of operation single phase five level cascaded H-Bridge multilevel inverter switch1; switch3, switch5 and switch7 are turned on without connecting source to the load. The output voltage across the load obtained is zero.

Mode2:- In this mode of operation single phase five level cascaded H-Bridge multilevel inverter switch1, switch3, switch5 and switch8 are turned on. The output voltage across the load obtained is $+V_{dc2}$.

Mode3:- In this mode of operation single phase five level cascaded H-Bridge multilevel inverter switch1, switch4, switch5 and switch8 are turned on. The output voltage across the load obtained is $V_{dc1} + V_{dc2}$.

Mode4:- In this mode of operation single phase five level H-Bridge cascaded multilevel inverter switch2, switch4, switch6 and switch7 are turned on. The output voltage across the load obtained is $-V_{dc2}$.

Mode5:- In this mode of operation single phase five level H-Bridge cascaded multilevel inverter switch2, switch4, switch6 and switch8 are turned on. The output voltage across the load obtained is zero.

Mode6:- In this mode of operation single phase five level H-Bridge cascaded multilevel inverter switch3, switch2, switch7 and switch6 are turned on. The output voltage across the load obtained is $-V_{dc1} - V_{dc2}$.

The same operation is shown in tabular form below in table III.

Table III: Modes of operation of single phase five level cascaded H-Bridge Inverter

MO DE	SWIT CH1	SWIT CH2	SWIT CH3	SWIT CH4	SWIT CH5	SWIT CH6	SWIT CH7	SW ITC H8
1	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	0	1
3	1	0	0	1	1	0	0	1
4	0	1	0	1	0	1	1	0
5	0	1	0	1	0	1	0	1
6	0	1	1	0	0	1	1	0

6. MATLAB/SIMULINK MODEL AND SIMULATION RESULT DISCUSSION

The simulation case study has been carried out to validate the result. Fig. 4, Fig. 6 and Fig. 8 shows the simulation model of the different types of multilevel inverter topology where the total harmonic distortion is analyzed. And the result of output voltage waveform of different types of multilevel inverter is shown in Fig. 5, Fig. 7 and Fig. 9 respectively.

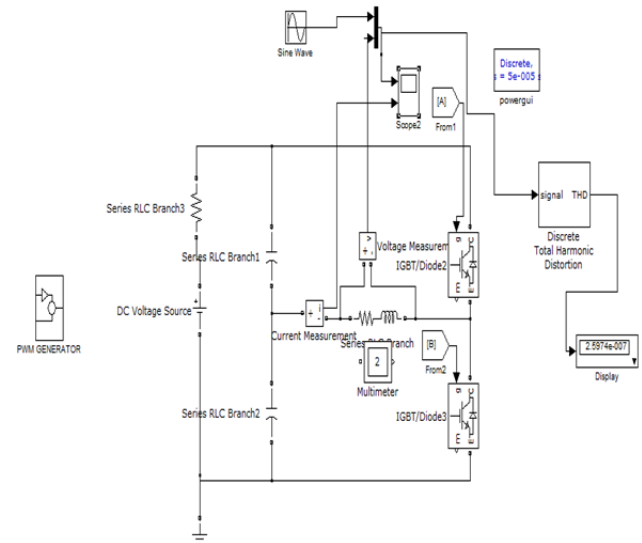


Fig. 4: Simulation model of two level inverter

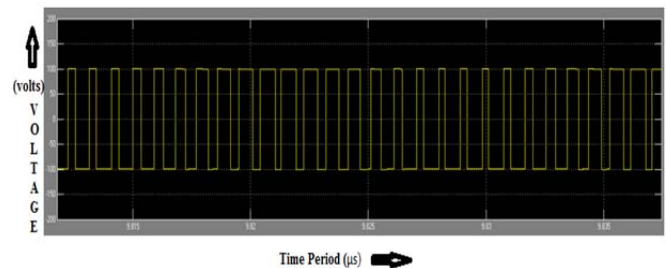


Fig. 5: Output voltage waveform of two level inverter

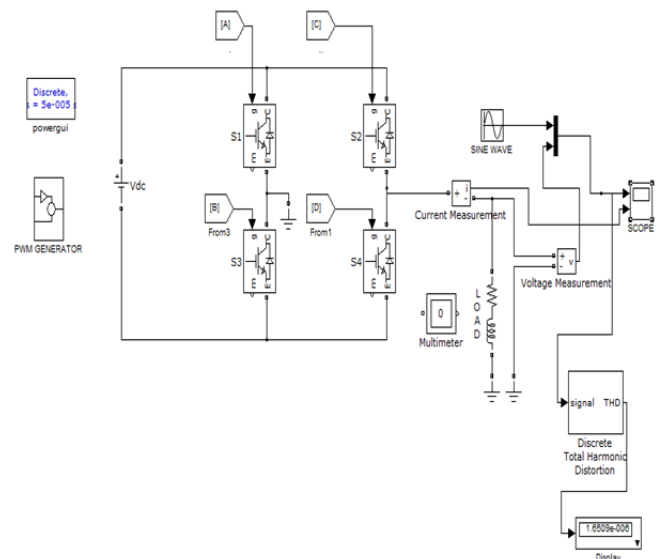


Fig. 6: Simulation model of three level inverter

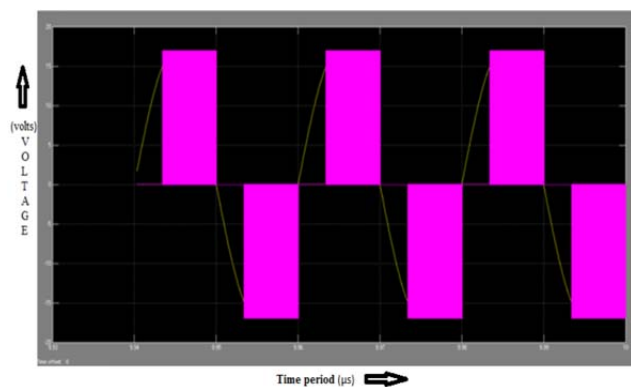


Fig. 7: Output voltage waveform of three level inverter

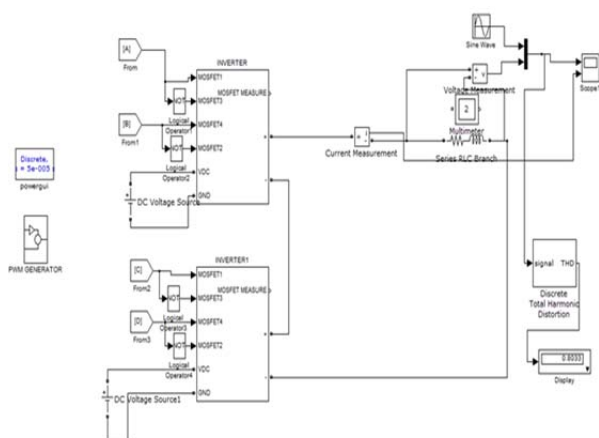


Fig. 8: Simulation model of five level inverter

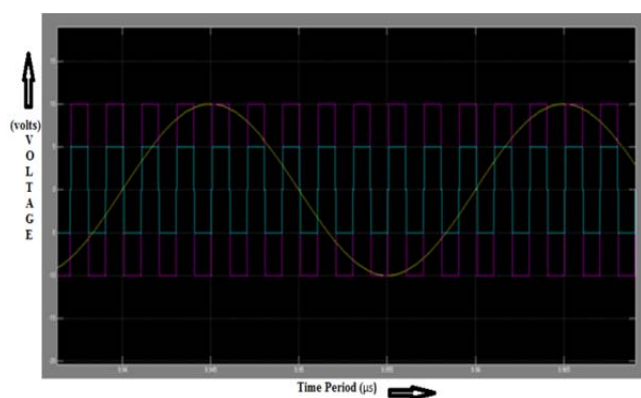


Fig. 9: Output voltage waveform of five level inverter

Table IV: Comparison Between Different Multilevel Inverters

Parameter	Two Level Inverter	Three Level Inverter	Five Level Inverter
Number Of Switches	2	4	8
THD Of Load Voltage	High	Low	Very Low

7. CONCLUSION

Thus the single phase two level inverter is compared with single phase three level and five level cascaded H-bridge inverter using software simulation on the basis of switches, THD analysis with RL load. The total harmonic distortion in two level inverter is more as compared to three and five level inverter and total harmonic distortion in three level inverter is more as compared to five level inverter. Thus, we can say as the number of level increases, THD decreases and hence active power increases. This study will help the design engineer for the selection of appropriate multilevel inverter for further applications.

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