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A Review Paper on Multilevel Grid Converter Topologies

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Abstract:
Multilevel inverters are a source of high power, usually utilized in a medium-voltage application. Multilevel converters have acknowledged huge interest currently due to highly improved output waveform and reduce the harmonic distortion in the output waveform while not decreasing the electrical power converter output. A multilevel inverter employed a series of semiconductor power converters, thus generating higher voltage. Reverse biased semiconductor device produces a reverse leakage current from that semiconductor device. In earlier technique transformer is employed for generating multilevel output and grid synchronization. Transformer enhances the leakage current. Now transformerless technique and sine modulation techniques are presented to overcome the leakage current. This paper presents a review on most essential topologies, control techniques of multilevel inverters and reduction of leakage current.

Keywords: High-power applications; multilevel converters; power electronics; power quality

I. INTRODUCTION

Multilevel converters are gaining a lot of attraction in industrial and academic world, because of their many advantages with respect to conventional converters. They are becoming one of the preferred choices of electronic power conversion for high-power applications. They have effectively paved into the industry and therefore can be considered a mature and verified technology. Presently, they are commercially incorporated in standard and customized products that power a broad range of applications, such as compressors, extruders, pumps, fans, grinding mills, rolling mills, conveyors, crushers, blast furnace blowers, gas turbine starters, mixers, mine hoists, reactive power compensation, marine propulsion, high-voltage direct-current (HVDC) transmission, hydro pumped storage, wind energy conversion, and railway traction, to name a few. Converters for these applications are commercially offered by a growing group of companies in the field. Although it is an grown up and already proven technology, multilevel converters depicts a great deal of challenges, and even more importantly, they offer such a ample range of possibilities that their research and development is silent growing in depth and width. Researchers all over the globe are contributing to further enhance energy efficiency, reliability, power density, simplicity, and outlay of multilevel converters, and broaden their application field as they more become attractive and competitive than classic topologies [1].Different configuration of multilevel converters are shown in fig.1. and there classification in fig.2.

The main purpose of using multilevel converters is to generate a sinusoidal voltage from dissimilar DC voltage levels. The total harmonic distortion (THD) and dv/dt of the voltage or current waveform reduces more, as voltage levels increases control algorithm complexity increases, especially for a back-to-back multilevel structure, where the intermediate DC links have to be equally balanced. Multilevel converter systems are generally classified as diode-clamping inverters, cascade inverters, and flying-capacitor inverters.

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Three different topologies have been proposed for multilevel inverters: diode-clamped (neutral-clamped) [3]; capacitor-clamped (flying capacitors) [2], [4], [5]; and cascaded multicell with separate dc sources [1], [6]–[7]. In addition, several modulation and control strategies have been developed or adopted for multilevel inverters including the following: multilevel sinusoidal pulse width modulation (PWM), multilevel selective harmonic elimination, and space-vector modulation (SVM). The most attractive features of multilevel inverters are as follows.

1) They can generate output voltages with low distortion.

2) They draw input current with very low distortion.

3) They generate smaller common-mode (CM) voltage, thus reducing the stress in the motor bearings. In addition, using refined modulation methods, CM voltages can be eliminated [8].

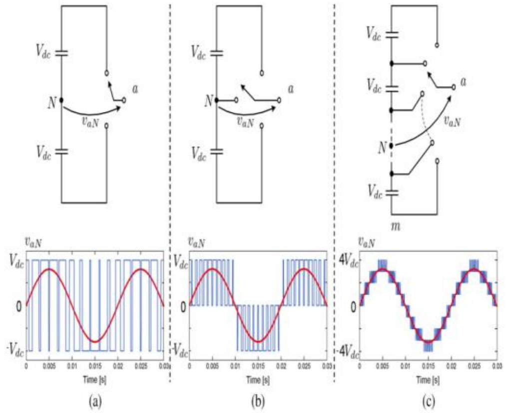

Fig.1 One phase leg of an converter with outputs (a) two levels, (b) three levels, and (c) 9 levels.

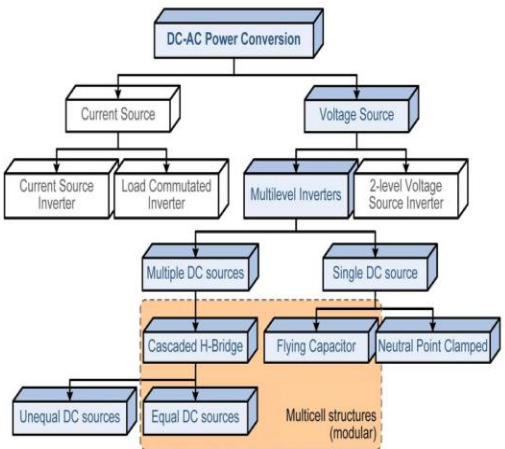

Fig. 2. Multilevel converter classification

II. CONVERTER TOPOLOGIES

A. Neutral Point Clamped Converters

A three-level diode-clamped converter is shown in Fig. 2(a). In this circuit, the dc-bus voltage is divided into three levels by two series-connected bulk capacitors,and the center point of the two capacitors *n* can be defined as the neutral point.[9] The output voltage has three states: $V_{dc}/2$, 0, and $-V_{dc}/2$.

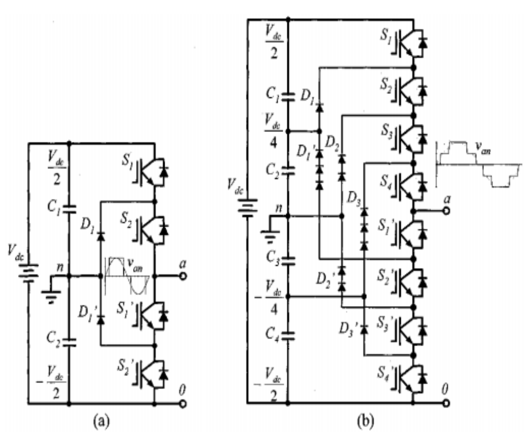

Fig.2. Neutral Point Clamped Converters circuit topologies. (a) Three-level. (b) Five-level.

For voltage level $V_{dc}/2$, switches S_1 and S_2 need to be turned on; for $-V_{dc}/2$, switches S'_1 and S'_2 need to be turned on; and for the 0 level, S_2 and S'_1 need to be turned on. Figure.2(b) shows a five-level diode-clamped converter in which the dc bus consists of four capacitors, C1, C2, C3, and C4. [10]

TABLE 1:

Switching States In One Leg Of The Five-Level Diode Clamped Converter –Level

O/P Voltage	Switching Sequence							
	s1	s2	s3	s4	s1'	s2'	s3'	s4'
Vdc	1	1	1	1	1	1	1	1
Vdc/2	1	1	1	0	1	1	1	0
0	1	1	0	0	1	1	0	0
-Vdc/2	1	0	0	0	1	0	0	0
-Vdc	0	0	0	0	0	0	0	0

Advantages

1. All of the phases share a common dc bus, which minimizes the capacitance requirements of the converter. For this reason, a back-to-back topology is not only possible but also practical for uses such as a high-voltage back-to-back inter-connection or an adjustable speed drive.[11]
2. The capacitors can be pre-charged as a group.
3. Efficiency is high for fundamental frequency switching.[12]

Disadvantages

1. Real power flow is difficult for a single inverter because the intermediate dc levels will tend to overcharge or discharge without precise monitoring and control.
2. The number of clamping diodes required is quadratically related to the number of levels, which can be cumbersome for units with a high number of levels.[13]

B. Flying Capacitor Converters

The FC topology is in some way similar to the NPC with the main difference being that the clamping diodes are replaced by flying capacitors.The circuit has been called the flying capacitor converter with independent capacitors clamping the device voltage to one capacitor voltage level.[14] The composition of this converter is similar to that of the diode-clamped inverter except that instead of using clamping diodes, the converter uses capacitors in their place. The flying capacitor involves series connection of capacitor clamped switching cells. This topology has a ladder structure of dc side capacitors, where the voltage on each capacitor differs from that of the next capacitor. The voltage increment between two adjacent capacitor legs gives the size of the voltage steps in the output waveform.fig shows single phase n-level configuration of capacitor clamped converter. An *n*level inverter will require a total of (*n*-1)×(*n*-2)/2 clamping capacitors per phase leg in addition to (*n*-1) main dc bus capacitors**.** [15]

Advantages

1. All of the phases share a common dc bus, which minimizes the capacitance requirements of the converter.
2. The capacitors can be pre-charged as a group.
3. Efficiency is high for fundamental frequency switching.

Disadvantages

1. Real power flow is difficult for a single inverter because the intermediate dc levels will tend to overcharge or discharge without precise monitoring and control.
2. The number of clamping diodes required is quadratically related to the number of levels, which can be cumbersome for units with a high number of levels.

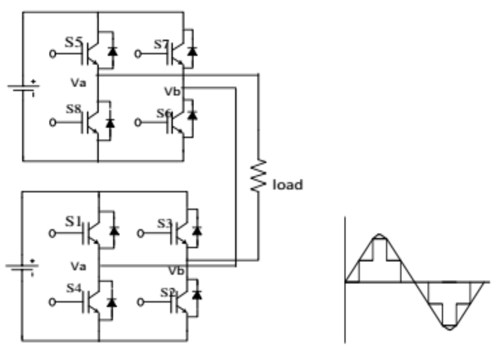

Fig.3.Capacitor-clamped multilevel converter circuit topologies. (a)Three-level.(b)Five-level.

Table 2.

Switching Sequence for Diode Clamped Five-level converter.

O/P Voltage	Switching Sequence							
	s1	s2	s3	s4	s1'	s2'	s3'	s4'
0	0	0	1	1	1	1	0	0
Vdc/4	0	1	1	1	1	0	0	0
Vdc/2	1	1	1	1	0	0	0	0
-Vdc/4	0	0	0	1	1	1	1	0
-Vdc/2	0	0	0	0	1	1	1	1

Advantages

1. All of the phases share a common dc bus, which minimizes the capacitance requirements of the converter.
2. The capacitors can be pre-charged as a group.
3. Efficiency is high for fundamental frequency switching.

Disadvantages

1. Real power flow is difficult for a single inverter because the intermediate dc levels will tend to overcharge or discharge without precise monitoring and control.
2. The number of clamping diodes required is quadratically related to the number of levels.

C. Cascaded Multilevel Converter

The concept of this inverter is based on connecting H-bridge inverters in series to get a sinusoidal voltage output. The output voltage is the sum of the voltage that is generated by each cell [16], [17], [18]. The number of output voltage levels are 2*n*+1, where *n* is the number of cells. The switching angles can be chosen in such a way that the total harmonic distortion is minimized. One of the advantages of this type of multilevel inverter is that it needs less number of components comparative to the Diode clamped or the flying capacitor, so the price and the weight of the inverter is less than that of the two types.Figure.4 shows the power circuit for one phase leg of a three-level and five-level cascaded inverter. negative dc voltage). The resulting output ac voltage swings from -Vdc to +Vdc with three levels, -2Vdc to +2Vdc.

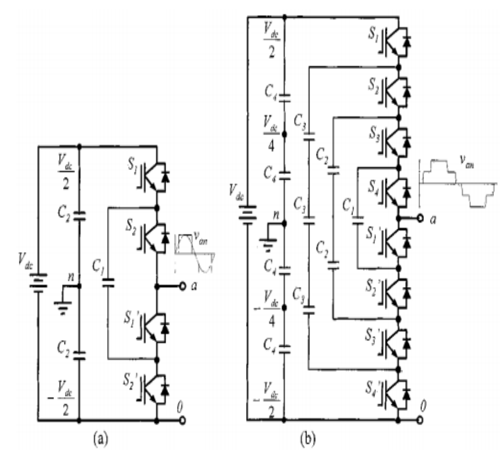

Fig4. Five level cascaded H-bridge inverter.

Table 3

Operating Switches with Different Voltage Level

S.No	Voltage Level	Operating Switches
1	0	S1,S3,S5,S7
2	Vdc	S2,S6,S8,S2
3	2Vdc	S1,S6,S5,S2
4	-2Vdc	S3,S8,S7,S4
5	-Vdc	S3,S7,S5,S4

Advantages

1. Easy packaging and storage.
2. Produce common mode voltage, stress is reduced.
3. Low distortions in the input current.
4. Operates at both fundamental switching frequencies.
5. Total harmonic distortion is very low in the output waveform without any filter circuit.[17]

Disadvantages

1. Separate DC sources or capacitor are required for each module.
2. A more complex controller is required due to the amount of capacitors.

Comparison of Different Multilevel Inverters [18]

1. Number of semiconductor devices in each phase leg.
2. Number of Dc bus capacitors present.
3. Amplitude of harmonic components.
4. Number of balancing capacitors in each phase leg.
5. Total Harmonic Distortion in the output voltage.
6. Control complexity based on power switches and voltage unbalances.
7. Cost estimation associated with power circuit.

Table 4
The basic comparison based on the number of components used.[19]

s.no	Topology	Diode- Clamped	Flying Capacitor	Cascaded
1	Power semi conductor switches	2(m-1)	2(m-1)	2(m-1)
2	Clamping Diode per Phase	(m-1)(m-2)	0	0
3	DC Bus capacitor	(m-1)	(m-1)	(m-1)/2
4	Balancing Capacitor per Phase	0	(m-1)(m-2)/2	0
5	Voltage unbalancing	Average	High	very small
6	Applications	Motor drive system STATCOM	Motor drive system STATCOM	Motor drive system, PV, fuel cells, battery system

CONCLUSION

The paper presents a brief discussion on basic multi-level converter topologies. Fundamental multilevel converter structures including the advantages and disadvantages of each technique have been discussed. The main advantage of MLI family is that it finds a solution to the problems of total harmonics distortion, EMI, and dv/dt stress on switch. In industrial and commercial market areas, more and more product are available that depends on the multi-level inverter topologies. Research works are in progress considering the structure complexity and control circuits. This helps to reduce the power electronics components and improve total harmonics profile and total cost of the system.

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