Advanced Research in Electrical and Electronic Engineering
p-ISSN: 2349-5804; e-ISSN: 2349-5812 Volume 4, Issue 4, July-September, 2017, pp. 223-230

http://www.krishisanskriti.org/Publication.html

A Review on Different Multilevel Inverters with Reduced Number of Switches to be used for AC Motor Drives

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Abstract—*Multilevel inverters are playing an important role on today's time .This gives us good quality voltage performance , reduction of total harmonic distortion ,reduces switching power loss and also give us high power ratings .The various types of topology that is made takes less power ,voltage switching and voltage sources than the conventional topology. In this paper, we will discuss several types of topologies, modulation techniques and how to reduce total harmonic distortion ,switching losses and voltage stress. At the last we will conclude topology review and their merits and demerits.*

Keywords: *Cascaded H-bridge (CHB), multilevel inverters (MLI),Total harmonic distortion (THD).*

1. INTRODUCTION

The multilevel inverters are a device which can be used for converts the DC power into AC power at variable frequency and variable voltage .Multilevel inverters come up rapidly because of its high reliability and large capacity with high power and medium voltage applications. The multilevel inverters are the combination of the semiconductor switches , capacitors ,diodes and voltages sources . That is reduces the THD , switching voltages and improved the output waveform it is seems like a sinusoidal waveform.

The main advantages of the multilevel inverters over conventional inverters faces low switching losses at high frequency and it is less affected with the THD , electromagnetic interference and low dv/dt stress . Table- I are shows that the comparision between the conventional inverter and MLI.To solve the high voltage and current stress ,THD ,interference. [1-10]

A multilevel inverter is dc input voltage source it is trying to gives a pure sinusoidal output waveform due to multiple voltage levels. It is used to smooth running of the AC drives motors.

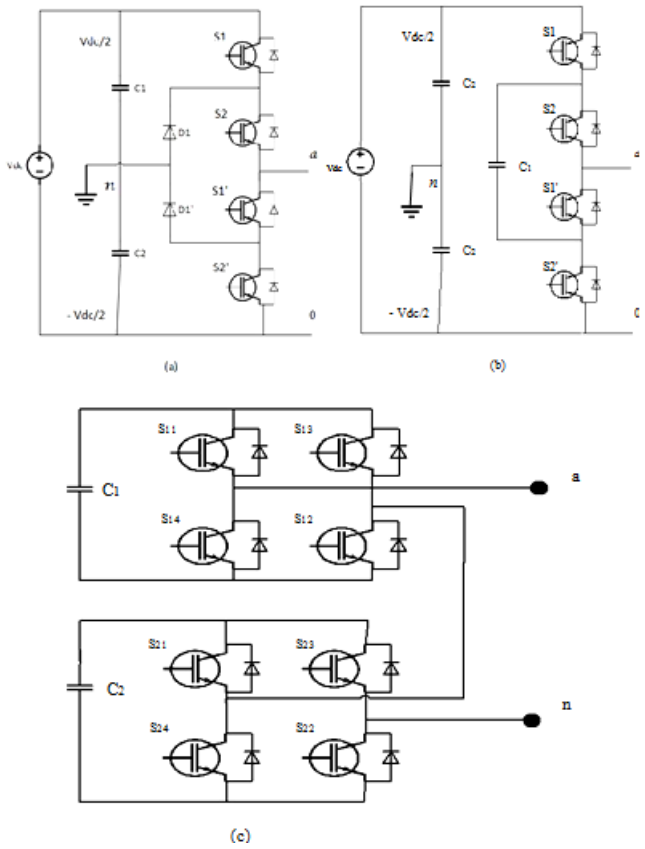


Fig. 1 Multilevel inverter topologies, (a) Diode Clamped MLI, (b) Flying Capacitor MLI, (c) Cascaded H-Bridge MLI

There are three types of main MLI topologies introduced as follows:

- Neutral Point Clamped / Diode Clamped MLI
- Capacitor Clamped / Flying Capacitor MLI
- Cascaded H-Bridge Multilevel Inverter

The topology proposed a diode clamped, capacitor clamped and cascaded inverter which is H bridge .The connection of H-bridge inverter in series this is called a cascaded H-bridge inverter. In the above these topology the first invented topology is diode clamped .The diode clamped topology is consists of input voltage source, diode and semiconductor switches. The diode clamped topology is reduced the voltage stress at the switches.[9,36,40]

TABLE I: Comparison of conventional Inverter and Multilevel Inverter

Sl. No.	Conventional inverter	Multilevel inverter
1.	High rate of change of voltage	Low rate of change voltage
2.	Switching stress are high	Switching stress are low
3.	Used for low voltage application	Used for high voltage application
4.	EMI are more	EMI are less
5.	High switching frequency	Low switching frequency
6.	Low power application	High power application

The comparison of these three topologies the cascaded H-bridge inverter[18] is mostly used because it reduces the voltage stress ,distortion in the input current and low total harmonic distortion .The everything has a limitation beyond its limitation its complexity will be increased and it gives a disadvantages instead of advantages. There is too many topologies are present at this time we want to reduce the total harmonic distortion and increasing the smoothness of the waveform [11-37]. We are observed these topologies .In this paper we are discuss about the topologies merits and demerits. The topological review the paper accentuation on the different types of modulation and optimization techniques [39-49] and reduces the total harmonic distortion.

2. RECENT MULTILEVEL INVERTER TOPOLOGIES

A. Active Neutral Point Clamped (ANPC)MLI

A five level ANPC topology[1] shown in fig 2 it is overcome the unbalance power loss distribution .The switching states table are shown the five level of voltages .Auther Eduardo Burguete are used the four auxillary capacitors and one larger capacitor C1 is used in the 5 level ANPC MLI. The working of the capacitor which is used in the ANPC are as:

(i) It avoids the semiconductor devices in series and reduces the hardware requirements and unbalanced of the voltage.
(ii) It reduces the overvoltage during the commutation and provides the low inductance path for current.

Advantages of auxillary capacitors:

(i) Voltage blocking are equal and no extra hardware are required and semiconductor which is connected in series are avoided.
(ii) Reduces the overvoltage during the commutation which provides the low inductance path for current.

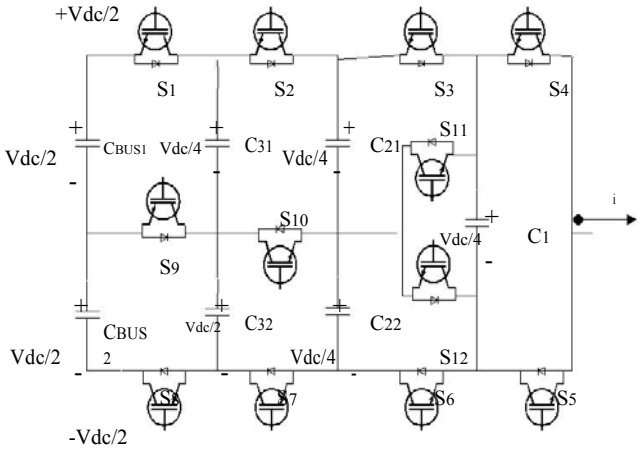


Fig. 2 Five level ANPC Topology

TABLE II: SWITCHING STATES OF THE NEW 5L-ANPC

Switching Vectors	Switch State												Output Voltage
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	Vo
*V*1	1	1	1	1	0	0	0	0	0	1	0	1	$+V\,dc/2$
*V*2	1	1	1	0	1	0	0	0	0	1	0	1	$+V\,dc/4$
*V*3	0	1	1	1	0	0	0	1	1	1	0	1	$+V\,dc/4$
*V*4	0	1	1	0	1	0	0	1	1	1	0	1	0(+)
*V*5	0	1	0	1	0	1	0	1	1	1	1	0	0(−)
*V*6	0	1	0	0	1	1	0	1	1	1	1	0	$-V\,dc/4$
*V*7	0	0	0	1	0	1	1	1	1	0	1	0	$-V\,dc/4$
*V*8	0	0	0	0	1	1	1	1	1	0	1	0	$-V\,dc/2$

B. Auxiliary Switch 5L-CHB MLI

The comparision between the conventional H-bridge[2] topology and modern H-bridge topology are as: The conventional H-bridge topology have auxiliary bi-directional switch to minimize the circuit complexity. The modern H-

bridge topology consists of the modulator , firing control circuit using FPGA. This topology have no requirement of the diodes and capacitors which can be reduces the main power switches .The voltage swing will be observed across the capacitor .The two capacitors are connected in parallel to maintain the operating range limitation.

Fig.3 Diagram of five level H-bridge inverter its output is shown in TABLE III.

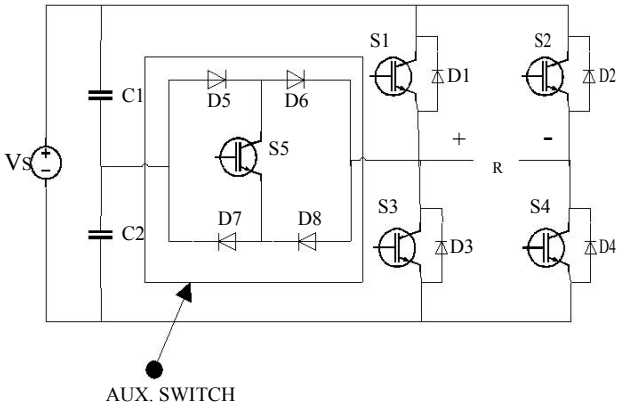


Fig.3 Auxiliary Switch Cascade H-Bridge Topology

TABLE III: Switching Combinations Required to Generate Five Level Output Voltage Waveform

S1	S2	S3	S4	S5	VR
ON	OFF	OFF	ON	OFF	Vs
OFF	OFF	OFF	ON	ON	Vs/2
OFF	OFF	ON	ON	OFF	0
OFF	ON	OFF	OFF	ON	-Vs/2
ON	OFF	OFF	ON	OFF	-Vs

C. Cross-Connected Source-Based Multilevel Inverter (CCS-MLI) Topology

A cross connected source multilevel inverter [4] are introduces the connection of the DC sources are in opposite polarity .The opposite polarity of the DC sources are minimizes the component count. In this topology the less active switch counts and the compressed switching losses are less. This topology are also used as level doubling network. It is doubling the level of the output voltage. The generalized circuit of the cross connected multilevel inverter are used for both symmetrical as well as asymmetrical .It is controlling the equal load sharing in a higher level topology.

CCS-MLI topology is used for different switching frequencies and the available literature are concluded the higher switching frequencies .The voltage stress are reduced .Fig 4 are shows the CCS-MLI topology with the DC sources are cross connected.

Table IV showing the possible switching combinations, output level and conducting switches.

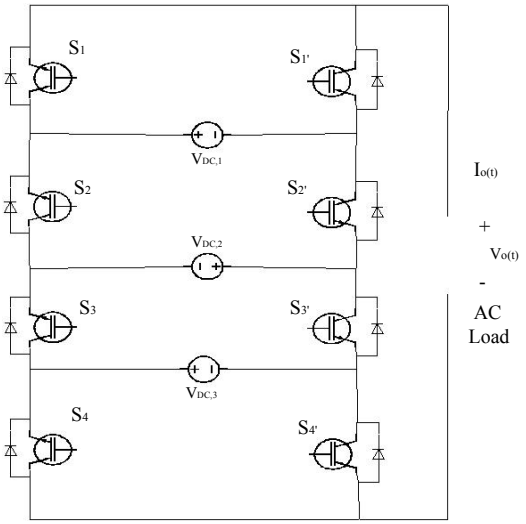


Fig. 4 CCS- MLI Topology

TABLE IV: Switching combinations for positive voltage levels in CCS-MLI

State	Output Level	Source combination	Conducting Switches
1	V_{DC}	$V_{DC,1}$	S_1, S_2', S_3', S_4'
2	V_{DC}	$V_{DC,2}$	S_1', S_2', S_3, S_4
3	V_{DC}	$V_{DC,3}$	S_1, S_2, S_3, S_4'
4	$2V_{DC}$	$V_{DC,1} + V_{DC,2}$	S_1, S_2', S_3, S_4
5	$2V_{DC}$	$V_{DC,2} + V_{DC,3}$	S_1, S_2, S_3, S_4
6	$3V_{DC}$	$V_{DC,1} + V_{DC,2} + V_{DC,3}$	S_1', S_2', S_3, S_4'
7	0	-	S_1, S_2, S_3, S_4
			S_1', S_2', S_3', S_4'

D. Seven Level Five Switch MLI Topology

D.Vijay kumar proposed a new seven level MLI [5]with the use of five IGBT switches .The Auther are compare the seven level nine switches topology to the seven level five level bidirectional switch .The seven level nine switches consists of the three DC voltages sources ,five complementary switches and one H-bridge having four switches. While the seven level five switches topology consists of 4 DC voltage sources and five bidirectional switches .Both are produces the same output voltage but seven level five switches are consists of less number of switches and switching losses are minimized.

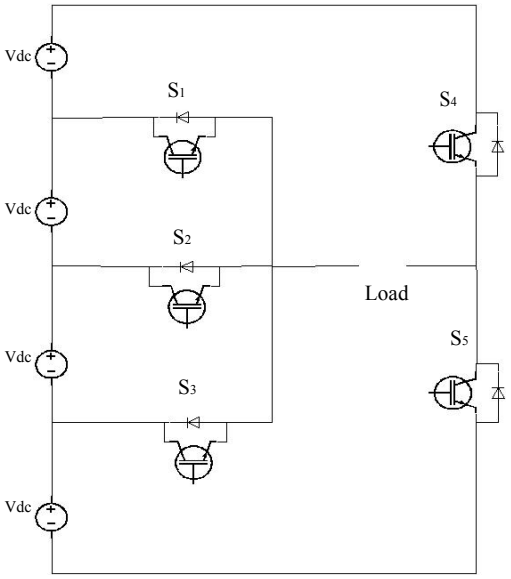


Fig. 5 A new Seven Level 5 Switch Topology

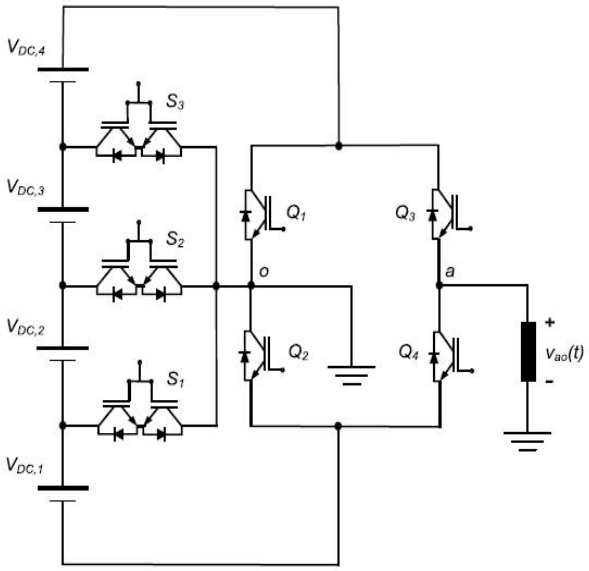


Fig. 6 T-Type Inverter Topology

In this topology the three positive voltage level and three negative voltage level and one is zero. which is shown in TABLE V.

TABLE V: Switching Scheme for Seven Level 5Switch Topology

Sl. No	S1	S2	S3	S4	S5	Output Voltage
1	OFF	OFF	ON	OFF	ON	+Vdc
2	OFF	ON	OFF	OFF	ON	+2 Vdc
3	ON	OFF	OFF	OFF	ON	+3 Vdc
4	OFF	OFF	OFF	OFF	OFF	0
5	ON	OFF	OFF	ON	OFF	- Vdc
6	OFF	ON	OFF	ON	OFF	-2 Vdc
7	OFF	OFF	ON	ON	OFF	-3 Vdc

The table VI shows the different level of voltage and it is not possible the equal load sharing.

TABLE VI: Valid Switching States for T-Type Inverter

State	Output Voltage	Switches in ON state
1	- Vdc,1	S1,Q4
2	Vdc,4	S3,Q3
3	-(Vdc,1+Vdc,2)	S2,Q4
4	Vdc,3+Vdc,4	S2,Q3
5	-(Vdc,1+Vdc,2+Vdc,3)	S3,Q4
6	Vdc,2+Vdc,3+Vdc,4	S1,Q3
7	-(Vdc,1+Vdc,2+Vdc,3+Vdc,4)	Q1,Q4
8	Vdc,1 +Vdc,2+Vdc,3+Vdc,4	Q2,Q3
9	0	Q1,Q3
10	0	Q2,Q4

E. T-Type MLI Topology

Victor guzman proposed a new MLI which is called as T-Type multilevel inverter topology[6].The T-Type topology is a five level inverter which is consist of the four input voltage sources three bidirectional switches $Sj\ \{j = 1, 2, 3\}$

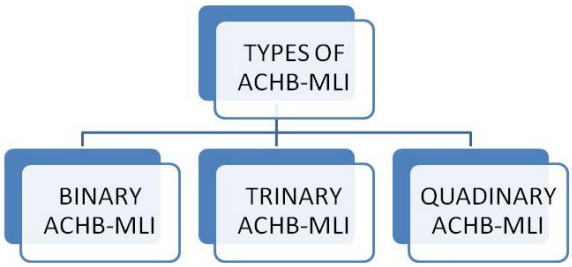
The bidirectional switches are conducting both the direction of the current .The four switches are unidirectional which is conducting one direction of the current.

The T-Type multilevel inverter topology are symmetric. It is not possible to synthesize the switching pattern combination of the input voltage levels at the output terminals. It takes time only a change in the polarity .The switching pattern are shown in table VI.

F. Asymmetric Cascaded H-Bridge MLI(ACHB-MLI)

E. Babaci proposed the asymmetrical cascaded H-bridge MLI[30] has a unequal magnitude of the DC voltage sources. In this topology the two modules are uses with the different magnitude of the DC voltage sources. This topology are divided into three types according to the magnitude of the DC voltage .

The ACHB-MLI are reduces the extra clamping diodes or capacitors are balancing the DC voltage in other topology in this topology we can reduces the capacitors.



1. Binary ACHB-MLI

   In the binary modules the two values of the DC voltage sources are V_{dc} and $2V_{dc}$.
   The output voltage levels are as:

   $$Vn = 2^n \quad , n = 1, 2,3,\ldots.$$

   n = the H-Bridge module count.

2. Trinary ACHB-MLI

   In Trinary modules the DC voltages are V_{dc} and $3V_{dc}$ are used.
   The output voltage levels are as:

   $$Vn = 3^n \quad , n = 1,2,3,\ldots.$$

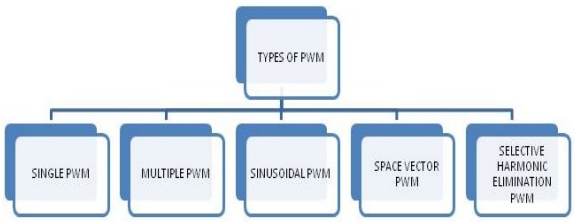
3. Quadinary ACHB-MLI

   In the Quadinary modules the DC voltages are V_{dc} and $4V_{dc}$ are used.
   The output voltage levels are as:

   $$Vn = 4^n \quad , n = 1,2,3,\ldots.$$

3. MODULATION AND OPTIMIZATION TECHNIQUES

There is different types of modulation are to control the output voltage[39-45].The average voltage are found at the output this is control by the devices. The best modulation technique is pulse width modulation. In the pulse width modulation the variation of width of pulse this is called as duty cycle .The different types of the PWM techniques are used to reduced the harmonics and increases the smoothness of the waveform. The different types of PWM are as follows:



A. Single Pulse Width Modulation

A single gate pulse per half cycle is controlled the output voltage.

B. Multiple Pulse Width Modulation

The ramp signal is compared with the DC voltage .In this technique the multiple gate pulses per half cycle.

C. Sinusoidal Pulse Width Modulation

In this technique the comparision between the two signal are is sinusoidal wave and another is triangular carrier signal. This technique is used to suppressed the higher level of harmonics .The output voltage waveform are in order of n and n+2.

$$n = fc/fm$$

f_c=carrier frequency
f_m=modulating signal frequency

In SPWM technique the controlling of the output waveform by the change in the modulation index.

Table VII : MLI Advantages and Disadvantages on Comparision Basis

Topology	Advantages	Disadvantages
Active Neutral Point Clamped	Control of over voltage and reduces the over voltage	The number of switches are increases
Auxiliary Switch 5L-CHB	Number of switches are less	Extra circuit is required
Cross –connected source based inverter	Voltage stress are reduced and having a equal load sharing	Number of switches are rises gradually for asymmetrical topology
Seven level five switch MLI	Harmonic distortion are less	Not used for higher level
T-Type MLI	Device count are less	Equal load sharing is not possible
Asymmetric cascaded H-bridge MLI	The waveform of the output voltage is look like sinusoidal	Unequal voltage stress

4. CONCLUSION

Table VII are shows that the advantages and disadvantages of the various types of topology. An ANPC-MLI topology is reduces the overvoltage .Auxiliary switch CHB-MLI is reduced the number of switch to required in the 5 level output voltage .The seven level 5 switches are reduces the switching losses .CCS-MLI topology are useful for equal load sharing.

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