

## Implementation of Different modulation techniques for Eleven Level Cascaded H-Bridge Inverter with Reduced Switch Count

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**Abstract:** In this paper a topology of Cascaded H-Bridge multi level inverter is proposed with reduced number of switches. The proposed topology has been implemented using four different modulation techniques. Also the performance analysis is done to evaluate THD of the system under various load condition. The proposed topology is economical since to generate eleven level it requires only eight switches and three isolated DC sources. More over the THD of the output voltage is also very low.

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### I. INTRODUCTION

Power Electronics Devices (PED), especially DC to AC inverter are now-a-days widely used in industries because of numerous advantages they provide such as less energy consumption, better efficiency, good quality, less maintenance requirement etc.

In case of medium voltage grid, it is tough to directly connect one power semiconductor switch. And therefore a Multilevel Inverter (MLI) structure has been invented for high power and medium voltage applications for example, mills, pumps, laminators, blower, conveyers, fans, compressors etc. MLI also allow using low power application in renewable sources like wind photovoltaic and fuel cell, they also help in attaining high power rating that is too in a very cost effective way.

Initially and most commonly MLI application has been in traction, both locomotive and track side static converter. And recently they are used in VAR compensation and stability enhance emend, high voltage dc transmission, high voltage motor drive and also in medium voltage induction motor variable speed drive. In modern industrial application of multilevel inverter focuses on medium voltage motor drive, utility interface for renewable energy system, Flexible AC transmission system, and traction drive systems.

Since MLIs are used in such a wide areas and therefore they should be able to manage high voltage and large power. And that is why, two level high voltage and large power inverters are designed with series connection of switching power devices like gate turn off thyristors (GTO's), integrated gate commutated transistors (IGCTs), and integrated bipolar transistor (IGBTs) because when they are connected in series high voltage can be achieved. On the other hand series combination has its own problems like non equal distribution of applied voltage across the devices that can cause the applied voltage of each device higher than blocking voltage of individual device at the time of transient and steady state switching operation. In order to effectively solve the above described problem, many different topologies of MLI have been invented and utilized. As the name suggest there are multiple level of output voltage retrieved by many DC voltage sources. Also the quality of the output voltage is enhanced because of the increased voltage levels, so the cost and quality of the filter can be reduced.

The concept of MLI was given in 1975. Separate DC full bridge cells are connected in series to obtain a staircase AC output voltage. The term multilevel started with three level converters. And after that many level inverters have been invented. Diode clamped multilevel inverter (DC-MLI) which is also called Neutral point clamped inverter (NPC) scheme was invented in 1981. Capacitor clamped inverter also Called flying capacitor (FC) type was invented in 1992. And in 1996 cascaded H bridge multilevel inverter (CHB-MLI) was invented. CHB is the combination of DC and FC type inverter. Although the CHB-MLI was invented sometime earlier but its application became noticeable in mid-90's. CHB-MLI is very advantageous in motor drives and utility. It can be also used in regenerative type motor drive. The most recent MLI topologies are mixed MLI, hybrid MLI, and soft switched MLI. These inverters are helpful in enhancing rated inverter voltage and power if the voltage level is increase. The ripple component of inverter voltage and Electromagnetic Interference (EMI) effects can be reduced because these can increase the equivalent switching frequency without increasing switching frequency. MLI can be used in many ways. The simplest way is parallel or series connection of traditional converter to

make a MLI. The voltage or current rating of the MLI becomes a multiple of all the individual switches, and therefore the power rating of the converter can cross the limit imposed by the individual switching devices.

To obtain higher power, the basic concept of a MLI is to use semiconductor switches in series with many lower level voltage dc sources to do power conversion by synthesizing a stair like voltage waveform. Batteries, capacitors and renewable voltage sources can be used for multiple dc voltage sources. To achieve high voltage at the output the commutation of the power switches plays an important role. Power semiconductor's devices rated voltage depends upon the rating of dc voltage sources they are connected to.

## **II. CASCADED H BRIDGE MLI**

H Bridge is now a day used in high power AC supplies and adjustable speed drive application. A CHB-MLI is made by the series combination of H bridge (single phase full bridge) inverter unit in each of its three phases. Every H Bridge unit consists of its own dc sources, which will be a battery unit for an induction motor and fuel cell or solar cell. Every SDC (separate D.C. source) is concerned with the single phase full bridge inverter. The AC terminal voltages are connected in series. With the help of different combination of the four switches it is  $V_{dc}$ ,  $-V_{dc}$  and zero. The AC output of the full bridge converters which are in same phase are connected in series and are able to obtain the voltage waveform which is the sum of the converters output. Also the number of output voltages is in a total different way from those of the DC and FC type. Here in the proposed topology the number of output voltage levels is obtained by  $m = 2N + 1$ , where N is the number of DC sources. For example, in case of a seven level CHB-MLI the total number of DC sources are three and the total number of full bridge converter is also three. If the conducting angle at different converter level is controlled then minimum harmonic distortion can be obtained. A quasi square waveform is produced by each H bridge unit by phase shifting the positive and negative phase legs switching timings. Each of the switching device conducts for  $180^\circ$ , independent of the pulse width of the quasi square wave. The entire switching devices current stress equal by this switching method. The power will flow from the batteries through the cascaded inverters to the motor in the motoring mode. The cascaded converter acts as rectifiers and power will flow from charger to the batteries in the case of charging mode. If regenerative braking is used then the cascaded converter is can also use as a rectifier the help in recovering the kinetic energy. The cascaded inverters are also used in parallel HEV configuration. With the help of this new converter the problem of extra clamping diodes or voltage balancing capacitors can be overcome. The combination pair of the  $180^\circ$  conducting method and pattern -swapping scheme make the voltage and current stresses of the cascade inverter's the equal and battery voltage balanced. Identical H -bridge inverter units can be used, therefore improving modularity and Manufacturability and to a high extent reducing production costs. Battery -fed cascade inverter prototype driving an induction motor at speed of 50% and 80% that is rated speed both the voltage and current are almost sinusoidal. EMI and the common mode voltage are very less than what would be obtained from a PWM inverter because of the excessively low  $dv/dt$  and sinusoidal voltage output.

The main advantages of utilizing the cascade inverter in an induction motor are:

- 1) This makes an induction motor more accessible/safer and also open wiring is possible for most of an induction motor power system.
- 2) Earlier 230 V or 460 V motors can be utilized, thus higher efficiency is expected as compared to low voltage motors.
- 3) There is no EMI problem or common -mode voltage/current problem occurs.
- 4) Low voltage switching devices can also be used.

No charge unbalance problem appears in both charge mode and drive mode. CHB-MLI are very useful in case of an induction motor (IM) that has many number of separate dc sources (batteries) each for the individual H bridges, these inverters are not an option in case of series hybrid IMs because we know that CHB-MLI are not easy to be connected back -to-back. In case of series-configured IMs where an on-board combustion engine produces ac power with the help of an alternator or generator, a multilevel back -to-back diode clamped inverter drive can best interface with the source of ac power and yet still it is easily meet the high power and/or high voltage requirements of the IM.

IMs usually have an ac voltage source produced from an alternator or combustion engine generator. A rectifier will convert this AC voltage into DC voltage for theelectric energy storagedevices onboard – batteries or capacitors. An inverter will help in converting the DC voltage into a variable voltage and variable frequency ac in order to drive the main IM.

## **III. PROPOSED CHB-MLI TOPOLOGY**

Here the proposed topology is a MLI using total eight number of switches and three DC voltage sources to generate a 11 level multilevel inverter for both single and three phase. The three DC voltages are connected in series with each other. The value of the DC voltage sources is  $V_{dc}$ ,  $2V_{dc}$  and  $2V_{dc}$ . That means if  $V_{dc}$  is 100volts then the other two voltages will be 200volts. Four PWM techniques are used to obtain the result.

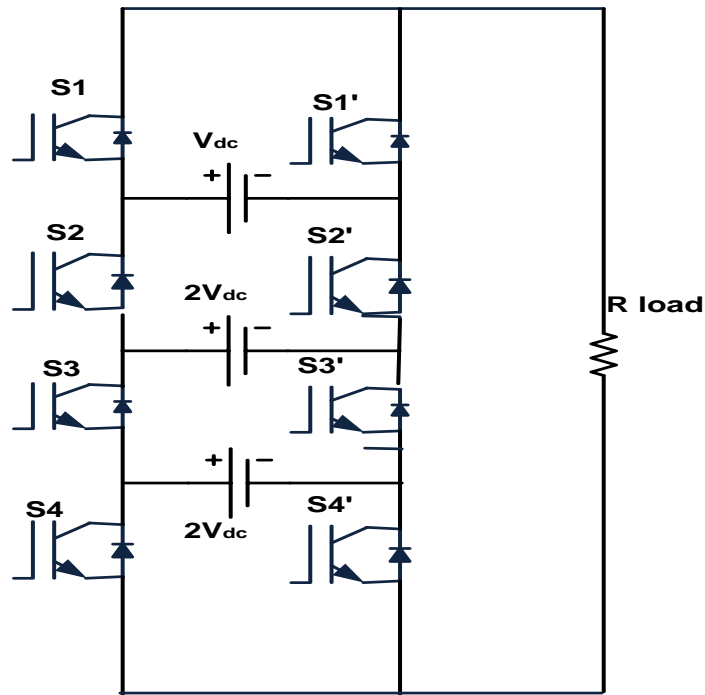


Figure-1 Proposed configuration of CHB-MLI

#### IV. SIMULATION AND RESULT DISCUSSION

Four different PWM techniques are used and they are In-phase disposition, Alternate phase Opposition disposition, Carrier wave and variable frequency. Triangular wave generators are used to produce these methods. Simulation results of a three phase 11level inverter are shown using four different PWM techniques and also their Total Harmonic reduction is shown. A comparison between these methods is also discussed. The simulation is performed using MATLAB. The proposed topology is test for R and RL load and THD of the output voltage waveforms is analyzed.

Table-1 Component and rating used in the proposed topology.

Components	Ratings
R load	124 ohms
RL load	115 ohms and 182mH
switching frequency	10khz
LC filter	1e-3 H and 1e-6 F
frequency=50 Hz	0.96mH
input voltage	450 V

- **Simulation results for In-phase Disposition (IPD)**

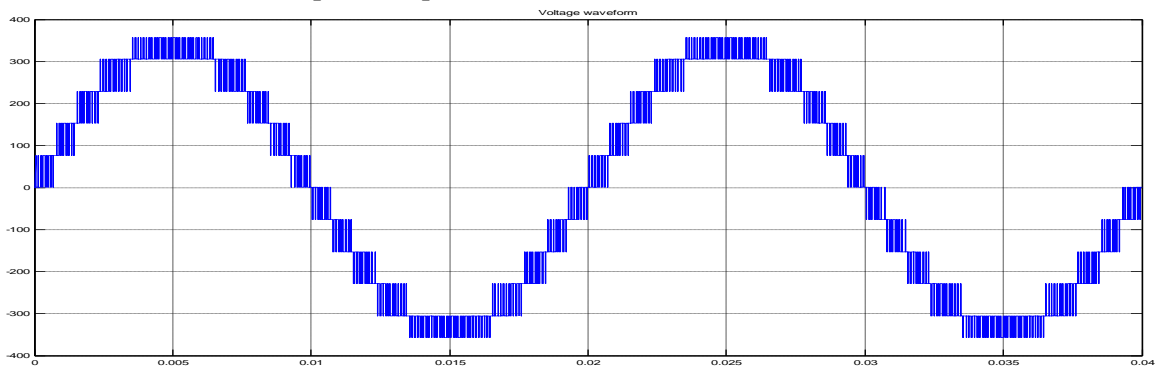


Figure 2 Output voltage of 11 level CHB-MLI for R load using IPD PWM

- **Simulation results for Alternate Phase Opposition Disposition (APOD)**

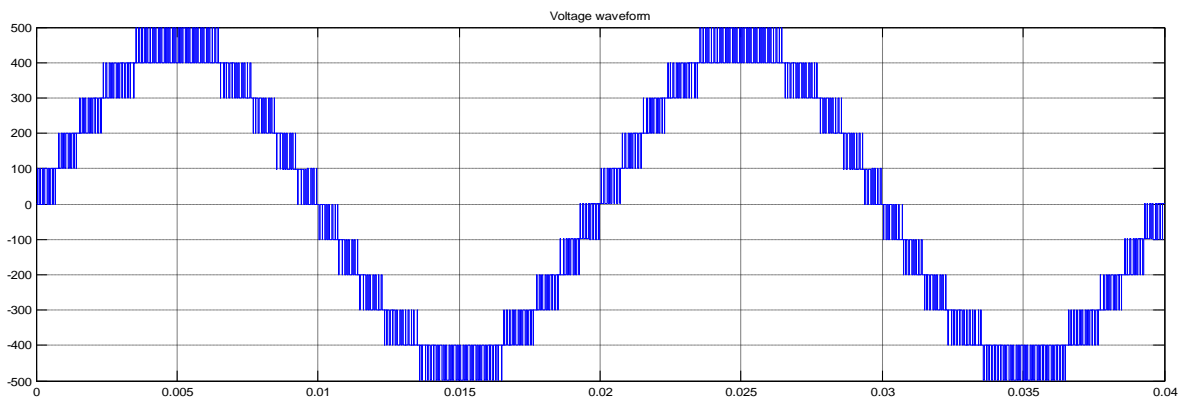


Figure 3 Output voltage of 11 level CHB-MLI for R load using APOD PWM

- **Simulation results for Carrier overlap (CO)**

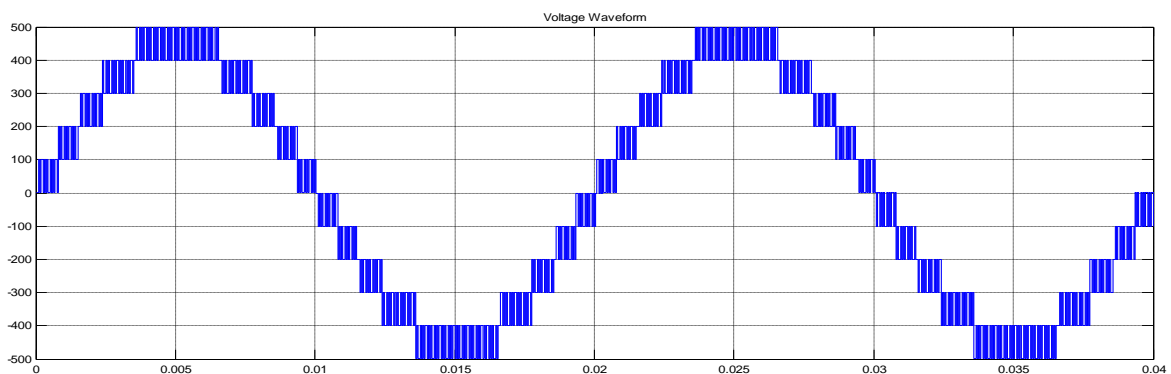
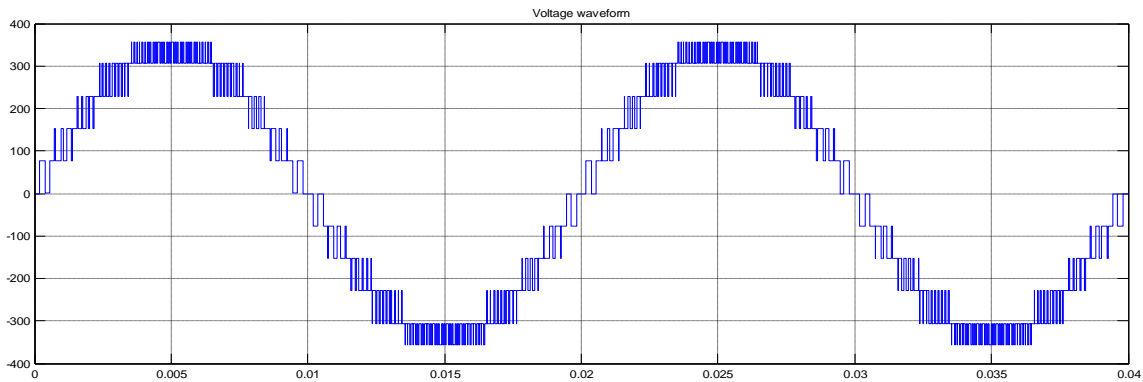


Figure 4 Output voltage of 11 level CHB-MLI for R load using CO PWM

• **Simulation results for Variable Frequency (VF)**



**Figure 5** Output voltage of 11 level CHB-MLI for R load using VFPWM

The THD analysis of the output voltage waveform is carried out for both R load and RL load whose comparative analysis is presented in Table-2. To reduce the THD a filter component is also added with the converter circuit whose results are presented in Table 2. The comparative analysis of the various topologies for component requirement is also done which is presented in Table 3.

**Table-2** comparison of THD for output voltage using different PWM techniques

Level Shifted PWM techniques	Without Filter		With Filter	
	R load	RL load	R load	RL load
IPD	0.22	0.27	0.27	0.27
APOD	0.38	0.37	0.25	0.37
CO	1.80	1.81	1.80	1.81
VF	0.47	0.47	0.38	0.47

**Table-3** comparison of the component requirement for various MLI topologies

Inverter type Parameter	Eleven level topology: m=11			
	FC	NPC	CHB	Proposed CHB
Switching devices	20	20	20	8
Diodes	20	20	20	0
Clamping Diode	0	90	0	0
Capacitor balance	45	0	0	0
DC bus	10	10	5	3

**V. CONCLUSION**

Three Phase 11 level inverter topology with less number of switches is proposed and simulated. Various PWM methods are analyzed and compared. From simulation results and THD analysis it is found that In-phase level shift PWM method provides minimum 0.2% of THD in the output voltage. Therefore this will be the best PWM technique for inverter switching. The comparative analysis of the proposed topology with the generalized MLI topologies is done for the component requirement and it is found that the proposed topology required least no. of component for the same level of voltage as compared to other MLIs.

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