CHAPTER 3

CASCADED H-BRIDGE MULTILEVEL INVERTER

3.1 Introduction

Multilevel inverters have been widely used in many applications since the technology is advantageous to increase the converter capability as well as to improve the output voltage quality. Multilevel inverters are able to produce a staircase output waveform, that is more approaching sinusoidal and produce a smaller number of harmonics compare to the conventional inverter output voltage. There are mainly three types of multi-level inverters, Diode clamped, Flying capacitor inverter and cascaded h- bridge multi-level inverter

Cascaded h-bridge multilevel inverters have been developed for utility applications including utility interface of renewable energy, voltage regulation, VAR compensation, and harmonic filtering in power systems. A modified cascaded H-bridge multilevel inverter (MLI) is implemented for solar applications. A new design of asymmetric cascaded H-bridge multilevel inverter is implemented in the grid side of the wind energy conversion system. A Five level cascaded H-bridge multilevel Inverter is also designed for induction motor drive.

The structure of the cascaded H-bridge (CHB) may consist of two or more H-bridge inverters. The CHB inverter can be supplied by separated DC sources or a single DC source. This type of inverter consists of two cells H-bridge inverter hence employs 8 power electronic switches. The modulation technique that applies to each cell of inverter may be the same or different. It varies from fundamental switching frequency PWM, carrier based PWM or combination of the two different PWM methods (known as mixed / hybrid PWM method)

3.2 5 Level cascaded H-Bridge

The modes of operation of 5 Level Cascaded H-Bridge is discussed in chapter 2 for each mode turned on switching devices and the current flow is discussed below. In mode-1 the output voltage across the load will be $+V_{dc}$ and the switches S_1, S_2, and S_6 are turned on, the

current will flow from source-1 to load in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_6, S_2, $-V_{dc1}$, the current flow is shown in fig.3.1

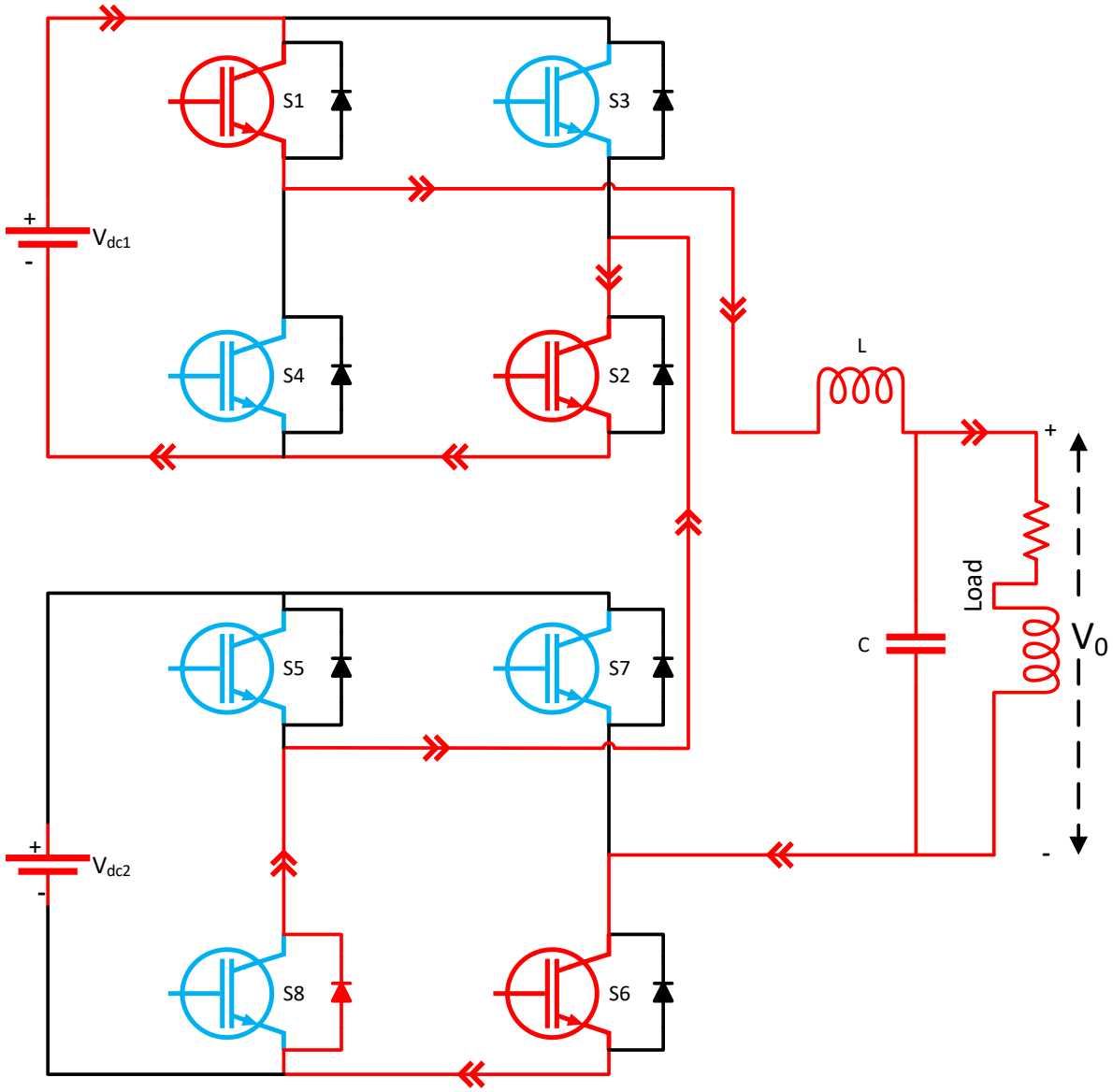

Fig. 3.1 5 Level CHB in Mode-1 ($+V_{dc}$)

In mode-2 the output voltage across the load will be $+2V_{dc}$ and the switches S_1, S_2, S_5, S_6 are turned on, the current will flow in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_6, $-V_{dc2}$, $+V_{dc2}$, S_5, S_2, $-V_{dc1}$, the current flow is shown in fig.3.2

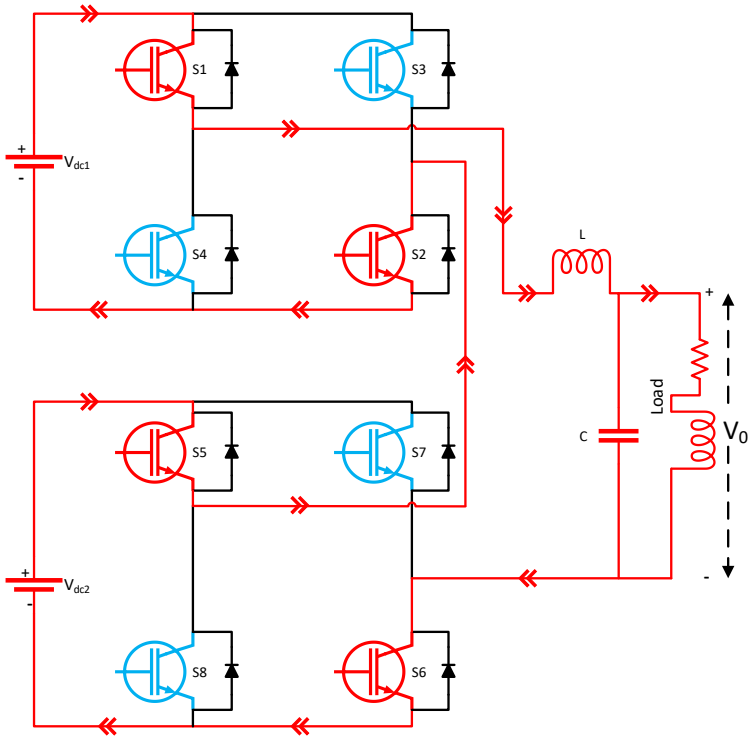

Fig. 3.2 5 Level CHB in Mode-2 (+2V_{dc})

In mode-3 all the switches are in off position and the output voltage across the load will be zero. As shown in fig.3.3.

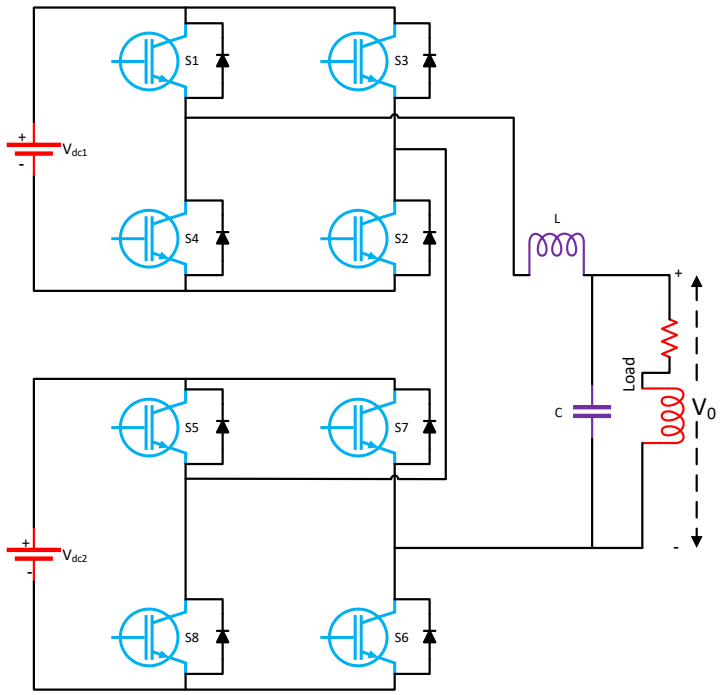

Fig.3.3 5 Level CHB in Mode-3 (0 Volts)

In mode-4 the output voltage across the load will be $-V_{dc}$ and the switches S_4, S_7, and S_8 are turned on, the current will flow from source to load in $+V_{dc2}$, S_7, $-V_0$, $+V_0$, S_4, S_8, $-V_{dc2}$, the current flow is shown in fig.3.1

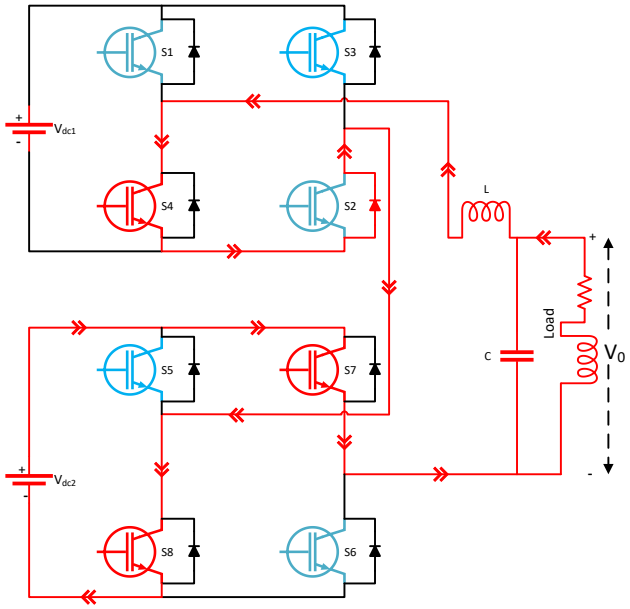

Fig.3.4 5 Level CHB in Mode-4 ($-V_{dc}$)

In mode-5 the output voltage across the load will be $-2V_{dc}$ and the switches S_3, S_4, S_7, S_8 are turned on, the current will flow from source to load in $+V_{dc2}$, S_7, $-V_0$, $+V_0$, S_4, $-V_{dc1}$, $+V_{dc1}$, S_3, S_8, $-V_{dc2}$, the current flow is shown in fig.3.5

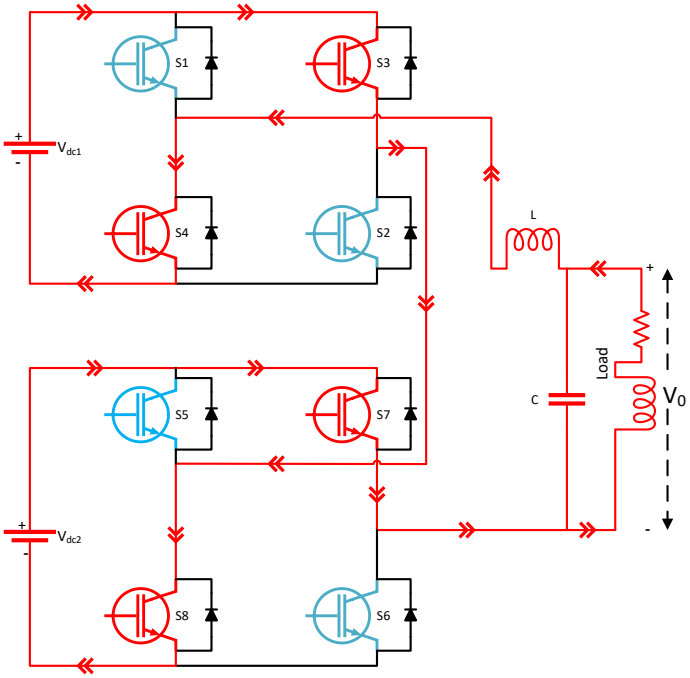

Fig.3.5 5 Level CHB in Mode-5 ($-2V_{dc}$)

3.3 9 Level Cascaded H-Bridge

In 5 Level cascaded H-Bridge the stepped output waveform contains harmonics to reduce that harmonics to some extent the levels of the CHB has been increased to 9 Level. For 9 Level inverter modes are discussed in detail and as shown in fig.5.6. In mode-1 the output voltage across the load will be $+V_{dc}$ the switches S_1, S_2, S_6, S_{10}, S_{14} are turned on, the current will flow from source to load in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_{14}, S_{10}, S_6, S_2, $-V_{dc1}$.

In mode-2 the output voltage across the load will be $+2V_{dc}$ and the switches S_1, S_2, S_6, S_{10}, S_{13}, S_{14} are turned on. The current will flow from source to load in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_{14}, $-V_{dc4}$, $+V_{dc4}$, S_{10}, S_6, S_2, $-V_{dc1}$.

In mode-3 the output voltage across the load will be $+3V_{dc}$ and the switches S_1, S_2, S_6, S_9, S_{10}, S_{13}, S_{14} are turned on. The current will flow from source to load in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_{14}, $-V_{dc4}$, $+V_{dc4}$, S_{10}, $-V_{dc3}$, $+V_{dc3}$, S_9, S_6, S_2, $-V_{dc1}$.

In mode-4 the output voltage across the load will be $+4V_{dc}$ and the switches S_1, S_2, S_5, S_6, S_9, S_{10}, S_{13}, S_{14} are turned on. The current will flow from source to load in $+V_{dc1}$, S_1, $+V_0$, $-V_0$, S_{14}, $-V_{dc4}$, $+V_{dc4}$, S_{10}, $-V_{dc3}$, $+V_{dc3}$, S_9, S_6, $-V_{dc2}$, $+V_{dc2}$, S_5, S_2, $-V_{dc1}$.

In mode-5 the output voltage zero will appear across the load in this all the switching devices in off position.

In mode-6 the output voltage across the load will be $-V_{dc}$ and the switches S_4, S_8, S_{12}, S_{15}, S_{16} are turned on. The current will flow from source to load in $+V_{dc4}$, S_{15}, $-V_0$, $+V_0$, S_4, S_8, S_{12}, S_{16}, $-V_{dc4}$.

In mode-7 the output voltage across the load will be $-2V_{dc}$ and the switches S_3, S_4, S_8, S_{12}, S_{15}, S_{16} are turned on. The current will flow from source to load in $+V_{dc4}$, S_{15}, $-V_0$, $+V_0$, S_4, $-V_{dc1}$, $+V_{dc1}$, S_3, S_8, S_{12}, S_{16}, $-V_{dc4}$.

In mode-8 the output voltage across the load will be $-3V_{dc}$ and the switches S_3, S_4, S_7, S_8, S_{12}, S_{15}, S_{16} are turned on. The current will flow from source to load in $+V_{dc4}$, S_{15}, $-V_0$, $+V_0$, S_4, $-V_{dc1}$, $+V_{dc1}$, S_3, S_8, $-V_{dc2}$, $+V_{dc2}$, S_7, S_{12}, S_{16}, $-V_{dc4}$.

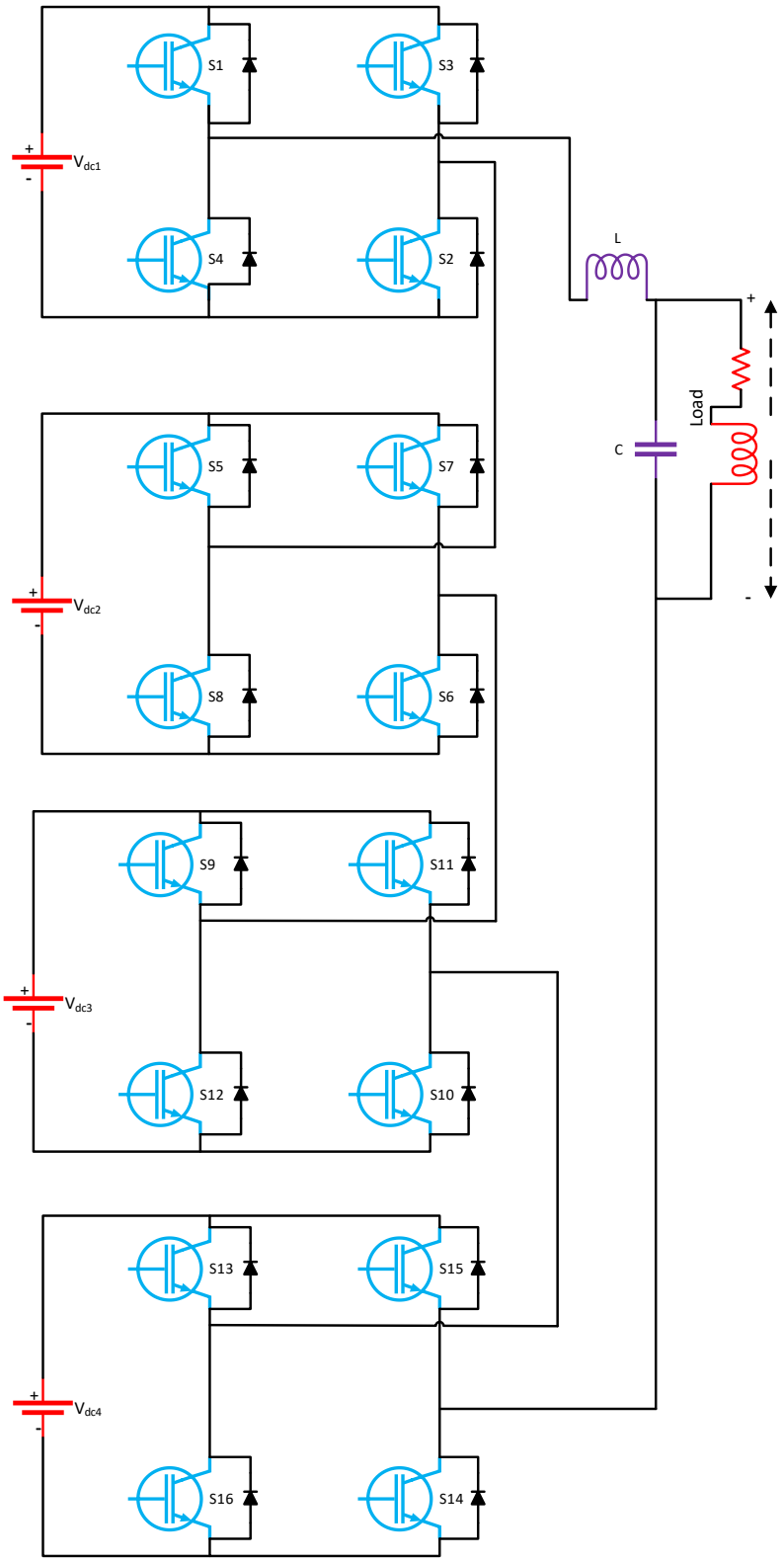

Fig.3.6 9 Level Cascaded H-Bridge

In mode-9 the output voltage across the load will be $-4V_{dc}$ and the switches S_3, S_4, $S_{+,}$ S_8, S_{11}, S_{12}, S_{15}, S_{16} are turned on. The current will flow from source to load in $+V_{dc4}$, S_{15}, $-V_0$, $+V_0$, S_4, $-V_{dc1}$, $+V_{dc1}$, S_3, S_8, $-V_{dc2}$, $+V_{dc2}$, S_7, S_{12}, $-V_{dc3}$, $+V_{dc3}$, S_{11}, S_{16}, $-V_{dc4}$.

The modes of operation of 9 Level cascaded H-Bridge is shown in table.3.1

Table.3.1 Mode of operation of 9 Level CHB

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
V_{dc}	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0
$2V_{dc}$	1	1	0	0	0	1	0	0	0	1	0	0	1	1	0	0
$3V_{dc}$	1	1	0	0	0	1	0	0	1	1	0	0	1	1	0	0
$4V_{dc}$	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$-V_{dc}$	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	1
$-2V_{dc}$	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	1
$-3V_{dc}$	0	0	1	1	0	0	1	1	0	0	0	1	0	0	1	1
$-4V_{dc}$	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1

For 5 Level CHB the output waveform contains 5 stages i.e. $+V_{dc}$, $+2V_{dc}$, 0, $-V_{dc}$, $-2V_{dc}$, the output waveform looks nearer to sinusoidal, but because of the less no of steps in the output the total harmonic distortion will be more the output and that is not preferable for integration. So to reduce that harmonics the number of steps in the output will increase to 9, the output waveform is similar to sinusoidal and also the total harmonics distortion will be reduced to more than half as compared to 5 Level.