Technical Review of Multilevel Inverter

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Abstract – In this era Multi-level voltage source inverter technology has emerged as an important alternative in the control of high power medium voltage energy. More over it can also be used for charged balance controlled amongst the multiple input Dc sources in a given topology. Multilevel voltage source inverters have various advantages: Reduction in the electro-magnetic interference, reduction in the voltage ratings of the power semiconductor switching devices, better output voltage having reduced total harmonic distortion. This paper reviews the different firing sccheme for three, five, seven level diode clamp inverter, flying capacitor invertor, cascading H-Bridge multilevel inverter. The comparison can easily be made between harmonic distortion values a voltage and current waveforms .

Keywords – THD, SPVM, CPWM, PD, POD, AOPD, Multi level inverter

I. INTRODUCTION

In recent year many industrial drive use ac induction motor because induction motor is less expensive and reliable generally induction motor is used for constant speed but now a day's induction motor is also used for variable speed with the help of power electronics devices. These electronics devices not only improve the speed of motor but it can also improve the steady and dynamic characteristics of motor. There are various schemes such as PWM, SPWM, SVPWM, CPWM. etc for controlling multilevel inverter like diode clamp inverter, capacitor clamp inverter, cascading H-bridge multilevel inverter for achieving dynamics performance of induction motor. We use diode clamp inverter for high level converter. The most attractive feature of multilevel given below.

1) It produce output voltage with low distortion and lower dv/dt .

2) They draw input current with very low distortion.

3) It generates smaller common mode voltage for reducing the stress of the motor load.

4) It can operate with a lower switching frequency.

Inverter topologies

In recent year industry require higher power which is reached in megawatt. For working with higher voltage we introduce multi-level inverter to control ac drives. The diode clamp inverter is also known as neutral point clamp multi level inverter (NPCML).

A three level diode clamp inverter is shown in above fig (1). which consist of four switches connected in series namely S1,S2,S'1, and S'2 and two diode namely D1, D2 whereas two capacitor are C1,C2 and source voltage is E. the output voltage Vout has three voltage level E/2, 0, -E/2.

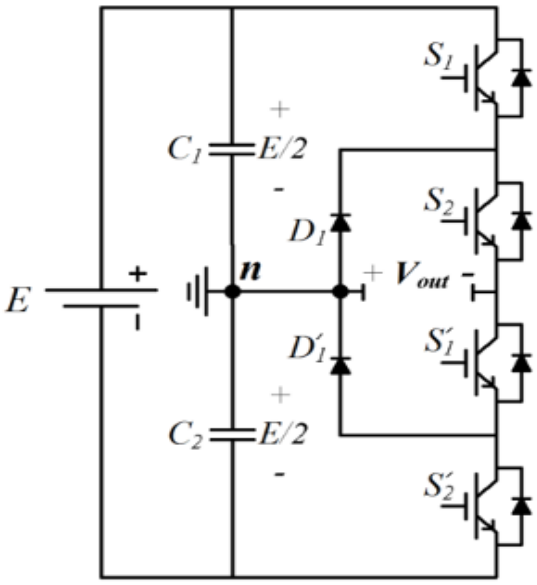

Fig.1: Three level diode clamp MLI

When switches S1 and S2 are ON the voltage will be E/2, when switches S2 and S'1 are ON then the voltage will be 0, when the switches S'1 and S'2 are ON then the voltage will be –E/2. notice that output voltage Vout is ac and Vao is DC. The switch state of three level diode clamp inverter is shown below .

Table no. 1 Switching table for three level DCMLI

V_o = Van	S1	S2	S'1	S'2
E/2	1	1	0	0
0	0	1	1	0
-E/2	0	0	1	1

If N is the number of level then

The number of capacitor require = (N-1)

The number of require power electronics switch = 2(N-1)

Number of Require diode are = (N-1)(N-2)

So from these formula for five level diode clamp inverter require 2(5-1) = 8 switches, (5-1) = 4 capacitor and (5-1)(5-2) = 12 diode. The five level diode clamp inverter is most extensively used multilevel inverter at present. It can reduce harmonics in both of the output voltage and current.

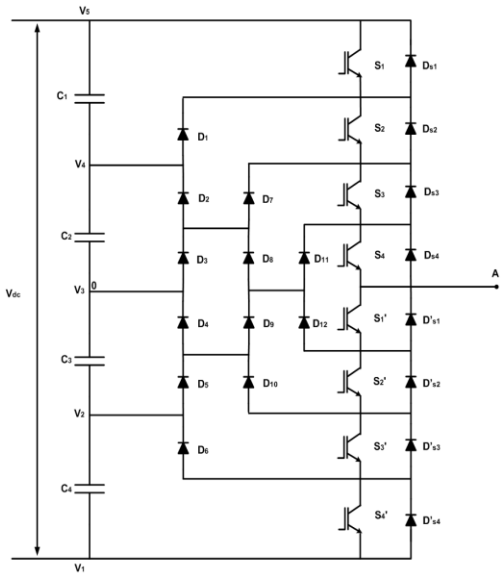

Fig.2: Five level diode clamp MLI.

In the above fig(2). show the five level diode clamp inverter in which consist 8 switches namely S1, S2, S3, S4 and S'1, S'2, S'3, S'4 and four capacitor C1, C2,C3 and C4 and 12 diode D1 to D12 . for voltage Vdc the voltage across each capacitor will be Vdc/4.

There are following 5- level of voltages

1) when upper switches S1 to S4 ON then the voltage will be Van = Vdc/2.
2) When upper switch S2 to S4 ON and one lower switch S'1 ON then the output voltage will be Vdc/4
3) For voltage level Van = 0, two upper switch S3 and S4 and two lower switch S'1 and S'2 ON.
4) The voltage level Van = -Vdc/4 then one upper switch S4 and three lower switch S'1 to S'3 will be ON.
5) When the lower switches S'1 to S'4 ON then the voltage level will be Van = -Vdc/2

The Switch state of five level diode clamp inverter Shown below in Table-2.

Table no.2 Switching table for five DCMLI

Vout	S	S	S	S	S	S	S	S
Vdc/2	1	1	1	1	0	0	0	0
Vdc/4	0	1	1	1	1	0	0	0
0	0	0	1	1	1	1	0	0
-Vdc/4	0	0	0	1	1	1	1	0
-Vdc/2	0	0	0	0	1	1	1	1

Advantages of diode clamp inverter.

1) The control technique is simple

2) when no. level increases the distortion contain reduced.

Disadvantages of DCMLI.

1)When no of level is high more clamping diodes are required.

Capacitor clamp multilevel inverter

The three level capacitor clamp inverter is also called flying capacitor inverter. Which consists of four switches namely S1, S2, S'1, S'2 and voltage source is Vdc and capacitor C1, C2, C'2 . Three level flying capacitor provides three level of voltage i.e, Van =Vdc/2, 0 and –Vdc/2.

1) For voltage Vdc/2 the switches S1 and S2 will be ON.

2) For voltages 0 switches S2 and S'1 will be ON

3) For voltage –Vdc/2 switches S'1 and S'2 will be ON

Five level Capacitor clamp inverter – Five level capacitor clamp inverter is more flexible than diode clamp inverter. In this inverter capacitor is more require than diode clamp inverter.

The capacitor required for m-level

No of capacitor per phase = (m-1)(m-2)/2

No of capacitor for main dc-bus = (m-1)

So for five level capacitor clamp inverter required six capacitor per phase and four capacitor for main dc-bus . fig.(3) below show the five level capacitor clamp inverter.

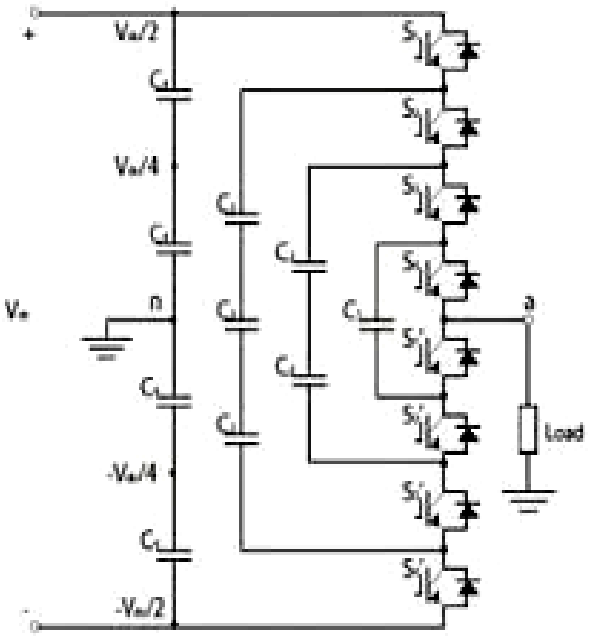

Fig. 3 five level capacitor clamp inverter

Voltage level of five level capacitor clamp inverter :

1) For voltage level Van = Vdc/2 all the upper switches will be ON
2) For voltage level Van =Vdc/4 There are level of voltage
   a. When switches S1, S2, S3, S'1 is ON then (Van =Vdc/2 for upper capacitor C4 and –Vdc/4 for capacitor C1)
   b. when switches S2, S3, S4, S'4 are ON then (Van = 3Vdc/4 for capacitor C3 and –Vdc/2 For lower switch C4).
   c. when switches S1, S3,S4 S´3 are ON then (Van = Vdc/2 of upper capacitor C4 and -3 Vdc/4 for capacitor C3 and +Vdc/2 for capacitor C2).
3) For output voltage Van =0
   i. When switches S1, S2, S1',S2' are ON then the voltage will be(Van = Vdc/2 for upper capacitor C4' and – Vdc/2 for C2')
   ii. When switches S3,S4,S3',S4', then the output voltage level (Van = Vdc/2 for capacitor C2 and –Vdc/2 for lower capacitor C4)
   iii. When switches S1, S3, S1',S3' are ON then the voltage level will be(Van = Vdc/2 for the upper capacitor C4', -3Vdc/4 for capacitor C3'and + Vdc/2 of C2' and –Vdc/4 for C1)
   iv. when switches S1, S4,S2',S3' then output voltage (Van = Vdc/2 of upper capacitor C4' and -3Vdc/4 for the capacitor C3' and +Vdc/4 for the capacitor C1)
   v. when switches S2,S4,S2',S4' are ON then the output voltage Van = 3Vdc/4 for C3' and –Vdc/2 for capacitor C2' and +Vdc/4 of capacitor C1 and –Vdc/2 of lower capacitor C4')
   vi. When switches S2,S3, S1',S4' are ON then the output voltage will be (Van = 3Vdc/4 of capacitor C3' and – Vdc/4 of capacitor C1 and –Vdc/2 of lower capacitor C4')
4) For output voltage level Van = -Vdc/4, the possible combinations are
   a. when switches S1, S1',S2',S3', are ON then the output voltage (Van = Vdc/2 of the upper capacitor C4' and -3Vdc/4 of the capacitor C3')
   b. when switches S4,S2',S3',S4' are ON then the output voltage level (Van = Vdc/4 of the capacitor C1 and –Vdc/2 of the lower capacitor C4')and when switches S3,S1',S3',S4' then the voltage will be (Van = Vdc/2 of capacitor C2' and –Vdc/4 of capacitor C1 and –Vdc/2 of lower capacitor C4')
   c. For output voltage level Van = -Vdc/2 all lower switches S1'-S4' are turned ON.

Advantages of flying capacitor are as follows:

(1)Flying capacitor has no need of filters similar to diode clamp capacitor.

(2)A large amount of packing capacity .

Disadvantages of flying capacitor :

(1)Its circuit is more complicated than diode clamp inverter .

(2)In flying capacitor has high switching losses .

Cascade H-Bridge multilevel inverter :

Cascade H-Bridge multilevel is better than other multilevel inverter because its structure is simple. It requires less switching components. Cascade H-Bride multilevel inverter is the group of capacitor and switches, but the diode clamp inverter is much interested in motor drives because it need single DC source where as cascading H – Bridge multilevel inverter require individual DC sources.

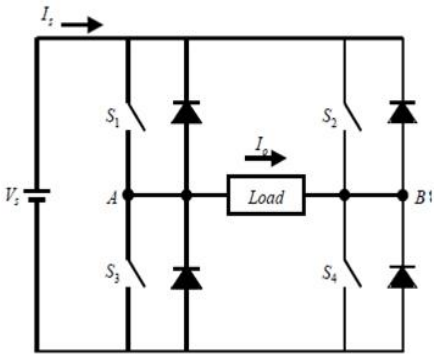

Fig. 4 Cascading H-Bridge MLI

In the above fig 4. show the circuit diagram of cascading H-Bridge multilevel inverter Fig. Cascading H-Bridge multi level inverter is most important topology in the multilevel inverter. It gives a desire AC voltage from several DC input voltage it require less number of component as compare to diode clamp inverter and flying capacitor inverter each H-Bridge multilevel inverter produce three level of voltage Vdc, 0, -Vdc by different combination of four switches S1, S2, S3 and S4 . then the magnitude of ac output voltage will be.

$$V0 = V01+V02+V03+Von \quad \text{----------(1)}$$

Switching pattern of cascade H-Bridge multilevel inverter

is shown below.

Table no. 3 Swatching table for cascade H-Bridge MLI

V0 = Van	S1	S2	S3	S4
Vdc	1	0	0	1
0	1	1	0	0
0	0	0	1	1
- Vdc	0	1	1	0

There are following advantage of cascading H-Bridge multilevel inverter :

(1)It reduce total harmonic distortion.

(2)It require less number of component for each level

(3)it is more flexible than other multilevel inverter.

(4)its circuit is simple and reliable.

Disadvantage:

The main disadvantage of cascading H-Bridge multi inverter is it require separate DC voltage sources. Cascading H-Bridge multilevel inverter is also used for reverse polarity of motor and breaking.

Table no. 4 Switching table for breaking motor

S1	S2	S3	S4	Result
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor coasts
0	1	0	1	Motor breaks
1	0	1	0	Motor breaks
1	1	0	0	Short circuit
0	0	1	1	Short circuit
1	1	1	1	Short circuit

Solar inverter: A solar inverter converts DC electrical energy of photovoltaic module in to AC electrical energy . It consist of three circuit : Hybrid controller circuit, charger circuit, A pulse driver and full bridge circuit. Solar power conversion is the most important term , so we use DC to DC converter for better output result of inverter. It is necessary to couple the solar cell to operating a low DC voltage.

Control topology of inverter : -

There are following method for controlling the multi level inverter discuss below.

(a)Pulse width modulation technique (PWM).

(b)Sinusoidal Pulse width modulation (SPWM).

(C)Third harmonics pulse width modulation (THI-PWM).

(d)Space vector pulse width modulation (SPPWM)

(e)Selective harmonic elimination method (SHE-PWM).

Pulse width modulation control:-

This method is most popular method of controlling the output voltage, in this method a fixed dc input voltage is given is given to the inverter and controlled ac output voltage is obtained by adjusting the off periods of the inverter components.

There are following advantage of pulse width modulation

(1)The output voltage control with this method can be obtained without any additional components.

(2)with this method lower order harmonics can be eliminated or minimised along with its output voltage control. As higher order harmonics can be filtered easly, the filtering requirements are minimsed.

Space vector pulse width modulation:

In a conventional two level multilevel inverter the harmonics reduction in the output current of inverter is compited by increasing the switching frequency however in high power applications the switching frequency of the power device is restricted below 1kHz because of increasing switching losses and level of dc voltage . while the very high dv/dt which is generated with high DC link voltage is the cause for electromagnetic interferance and motor winding stress. There for from the harmonic reduction and high DC – link voltage level point of view multilevel inverters are more suitable.

Much has been worked on the space vector modulation of multilevel inverter. In SVPWM method the output voltage is presented in three dimensional Euclidean space. The principle of this method is that increasein the number of level by one allowes forms and additional hexagonal rings of equilateral trangles which surrreounds the outermost hexagon. The hexagon which represent space vector diagram is flatten and reference voltage vector is normalize so that the computation of the algorithm is reduce.

A SVPWM has a predictive current control loop in this load the current is determined for all output voltage vectors of the inverters. The calculation of current error and selection of switching state is done when the value of error is less. A SVM causes reduction in the inverter output voltage distortion because of turn OFF , turn ON and dead times of power modules without increasing the harmonics content.

The reference vector can be written as

$$V = (T1\ Vn + T2\ Vn+1)/Ts \quad \text{----------(2)}$$

Where as T1, T2 are applied effective times corresponding to the active vectors V1 – V6.

The effective time can be calculated as follows

$$T1 = VTs \sin(\pi/3-\alpha) / Vdc2/3 \sin(\pi/3) \text{ ------- (3)}$$

$$T2 = VTs \sin(\alpha) / Vdc2/3 \sin(\pi/3) \text{ ----------(4)}$$

$$T_o = Ts - T1 - T2 \text{ ----------(5)}$$

Where T_o is the time corresponding to null vector Vdc is the DC linkage voltage and Ts is the sampling time.

Multicarrier Sine–PWM :-

Multilevel carrier based PWM method have triangular waves or sawtooth waves multiple carrier signals show freedom in following characteristics – frequency, amplitude, face of each carrier and offset between the carriers. The reference wave can be either sinusoidal or trapezoidal. A reference wave two shows freedom in parameters like frequency, amplitude, phase angle, and injection of zero sequence signal to it. Hence many multilevel carrier based PWM methods, using these combinations may be obtained.

The carrier based schemes can be classified as:

(a)level shift PWM (LSPWM)

(b)phase shifted PWM (PSPWM)

(C)Hydrid (H)

Level shift PWM

(1)Alternative phase opposition disposition (APOD) – In alternative phase opposition disposition the carrier signals are out of phase by 180^o.

(2)Phase disposition (PD) : - In phase disposition the carrier signals are in phase.

Fig . 5 Carrier signal wave of phase disposition

(3)phase opposition disposition (POD) - in POD the carrier signals are all in phase above and below the zero reference but phase difference of 180^o.

Phase shifted PWM –

In phase shifted PWM carrier signals have same amplitude and all are phase shifted .

Hybrid H-

The hydrid is the combination of phase shifted and level shifted technique.

Sinusoidal pulse width modulation (SPWM):- The SPWM technique provides the way for pushing the predominent harmonics to a high frequency . in SPWM technique the comparision between the carrier signal of high frequency and modulating signal of the desired frequency can be easly done. Increasing the switching frequency leads to deduction in lower order harmonics from the outputvoltage.

$$Vm = m \sin(\omega + j\, 2\pi/3) \text{ ----------(6)}$$

$$m = Am/Au1+Au2+Al1+Al2 \text{ ----------(7)}$$

$$mf = fc/fm \text{ ----------(8)}$$

where j = 0, -1, +1 x = a, b, c,

m = modulation index, mf = frequency ratio, fc = carrier wave frequency, fm = modulating wave frequency, Am = modulating wave to peak amplitude, Au1, Au2, Al1, Al2 = upper1, upper2, lower1 and lower2 carrier waves peak –to-peak amplitudes.

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