Comparative Study of Five Level Diode Clamp and Cascaded H-Bridge Inverter

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Abstract:
A multilevel inverter is very trendy in now days. The purpose of multilevel inverter is to generate stair case sinusoidal pulse using DC Source. The Multilevel inverter suitable for high voltage and high power applications. Multilevel inverters are used for industrial drive directly, the THD contents in output voltage of inverters is very significant index as the performance of drive depends very much on the quality of voltage applied to drive. This paper Presents comparison on cascade H-bridge and diode clamp five level inverter at different modulation index. THD analysis is carried out using MATLAB simulation.

Keywords: Cascaded H-bridge, Diode Clamp inverter

I. Introduction
In conversion of DC to AC Multilevel inverter is replacing conventional Inverter because of it high power applications with good potential for further development. The most attractive feature of this inverter is in the medium-to-high voltage range, motor drives, power distribution, and power conditioning applications. In present power sector is growing very fast, industry are demanding power in the megawatt level. It is not possible for convention inverter as the semiconductor devices must be connected in series to obtain the required high-voltage operation. This can be only possible when outputs of several conventional inverters are added with transformers or inductors, or direct series connection, or by more complex topologies [2]. For these reasons, a new family of multilevel inverters has emerged as the solution for working with higher voltage levels.

Multilevel inverter is replacing conventional inverter and step-up transformer because of its upgrading features like increment in output voltage and power does not require an increase in rating of individual device. The concept of multilevel inverter has been proposed on 1975. The purpose of multilevel inverter to generate desired multi-staircase single or three phase voltage by combining several DC voltage sources. Solar cells, fuel cells, batteries and ultracapacitors are the most common independent sources used. One important application of multilevel converters is focused on medium and high-power [3].

In multilevel inverter the term level is referred to as the number of node to which the inverter can be accessible [1]. In this output voltage can be defined as voltage Across output terminal of the inverter and the ground point and input node voltage and Current is referred to input terminal of the inverter with reference to ground. The structural switches, be capable of withstanding very high input voltage for high power application and lower switching frequency for each switching device.

The multilevel inverter are widely used in power sector because of its high quality output voltage. The multilevel inverter enhance the output voltage level and it generated a close to ac sinusoidal steeped wave which consequence is high output wave and less harmonic distortion. Mostly power electronic switch like IGBT, MOSFET, GTO, MCT \(^*\), AND POWER BJT used for inverter because of switching frequency of semiconductor device is high, inverter output voltage can also be attuned by exercising a control within the inverter by itself [2].

In general multilevel inverter can be viewed as voltage synthesizers, in which the high output voltage is synthesized from many discrete smaller voltage levels. The main advantages of this approach are summarized as follows:
1. They can generate output voltages with extremely low distortion and lower \(\frac{dv}{dt}\).
2. They draw input current with very low distortion.
3. They can operate with a lower switching frequency.

II. Type of multilevel Inverter

Multilevel inverter are three type
1. Cascaded H-bridge
2. Diode clamp
3. Flying capacitor

III. Cascaded H-Bridges

A single-phase structure of an m-level cascaded inverter is seen in Figure.1 Each Separate DC source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each Inverter level can generate three different voltage outputs, \(+V_{dc}\), 0, and \(-V_{dc}\) by connecting the dc source to the ac output by different combinations of the four switches, S1, S2, S3, and S4. To obtain \(+V_{dc}\), switches S1 and S4 are turned on, whereas \(-V_{dc}\) can be obtained by turning on switches S2 and S3. By turning on S1, S2, S3, and S4, the
output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels M in a cascade inverter is defined by \( m = 2s + 1 \), where \( s \) is the number of separate dc sources.

The phase voltage \( v_n = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5} \). For a stepped waveform such as the one depicted in Figure 3.5 with \( s \) steps, the Fourier Transform for this waveform follows:

\[
H(n) = \frac{4}{\pi n} \left[ \cos(n \theta_1) + \cos(n \theta_2) + \ldots + \cos(n \theta_n) \right],
\]

Where \( n = 1, 3, 5, 7 \)

![Figure 1: N-Level Inverter](image1)

**FIGURE NO 1 N-LEVEL INVERTER**

The conducting angles 1, 2, 3, ..., \( s \) can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5th, 7th, 11th, and 13th, harmonics are eliminated. More detail on harmonic elimination techniques will be presented in the next section. Multilevel cascaded inverters have been proposed for such applications as static var generation, an interface with renewable energy sources, and for battery-based applications.

**Advantages:**
1. The number of possible output voltage levels is more than twice the number of dc sources \( (m = 2s + 1) \).
2. The series of H-bridges makes for modularized layout and packaging. This will enable
3. The manufacturing process to be done more quickly and cheaply.

**Disadvantages:**
1. Separate dc sources are required for each of the H-bridges. This will limit its application to products that already have multiple SDCSs readily available.

**III. Diode-clamped multilevel inverter**

Diode Clamped Multilevel Inverter

The first practical multilevel topology is the neutral point clamped PWM technology first introduced by Nabe.etal in 1980. For \( m \)-level inverter, dc bus voltage is splits into \( m \) levels by \( (m-1) \) series connected bulk capacitors[4]. According to the original invention, the concept can be extended to any number of levels by increasing the number of capacitors. Early descriptions of this topology were limited to three-levels where two capacitors are connected across the dc bus resulting in one additional level. The additional level was the neutral point of the dc bus, so the terminology neutral point clamped (NPC) inverter was introduced. However, with an even number of voltage levels, the neutral point is not accessible, and the term multiple point clamped (MPC) is sometimes applied. Due to capacitor voltage balancing issues, the diode-clamped inverter implementation has been mostly limited to the three-level. Because of industrial developments over the past several years, the three-level inverter is now used extensively in industry applications. Although the structure is more complicated than the two-level inverter, the operation is straightforward and well known.

In this structure the DC bus voltage divided into three level by connecting series capacitor \( c_1 \) and \( c_2 \). The midpoint of \( c_1 \) and \( c_2 \) is neutral point denoted by “n”. The output Voltage of phase a has three state \( \frac{V_{dc}}{2} \) and \( 0, \frac{V_{dc}}{2} \). For \( \frac{V_{dc}}{2} \) switch \( s_1 \) and \( s_2 \) is turn on and for \( \frac{V_{dc}}{2} \) [5].

The diode D1 and D2 play very important role to distinguish the circuit from a conventional two-level inverter. These two diodes clamp the switch voltage to half the level of the dc-bus voltage. At the instant when \( s_1 \) and \( s_2 \) turn on then voltage across a and 0 is \( V_{dc} \). In this case diode \( D_1 \) balance out the voltage sharing between \( S_1 \) and \( S_2 \) with \( S_1 \) blocking voltage across \( C_1 \) and \( S_2 \) blocking voltage across \( C_2 \). The output voltage across \( V_{an} \) is AC and \( V_{ao} \) is DC, the voltage across \( C_1 \) is \( \frac{V_{dc}}{2} \) i.e difference between \( V_{an} \) and \( V_{ao} \).
Fig. 3 shows a five-level diode-clamped converter in which the dc bus consists of four capacitors $C_1, C_2, C_3, C_4$, and $C_5$. For dc-bus voltage $V_{dc}$, the voltage across each capacitor is $\frac{V_{dc}}{5}$, and each device voltage stress will be limited to one capacitor voltage level through clamping diodes.

**ADVANTAGE**
1. More number of levels leads to less harmonic distortion.
2. Reactive power flow is controlled.
3. High efficiency for fundamental switching frequency.
4. Control method is easy.

**DISADVANTAGE**
1. More number of clamping diodes.
2. Real power flow is difficult because of imbalance capacitances.
3. Different current ratings required for switches.

**IV. Flying capacitor structure**
Another fundamental multilevel topology, the flying capacitor, involves series connection of capacitor clamped switching cells [6]. This topology has several unique and attractive features when compared to the diode-clamped inverter.

One feature is that added clamping diodes are not needed. This topology has a ladder structure of DC side capacitors. The voltage on each capacitor differs from that of the next capacitor [7].

The voltage increment between two adjacent capacitor legs gives the size of the voltage steps in the output waveform. One advantage of the flying capacitor based inverter is that it has redundancies for inner voltage levels. Unlike the diode clamped inverter, the flying capacitor inverter does not require all of the switches that are ON (conducting) in a consecutive series (Chunmei Feng et al 2007). Moreover, the flying capacitor inverter has phase redundancies, whereas the diode clamped inverter has only line-line redundancies.

**ADVANTAGE**
1. Flexible switch redundancy for balancing the voltage.
2. Lower harmonic distortion when levels are more.
3. Both real and reactive power is controlled.

**DISADVANTAGE**
1. Excess number of storage capacitors.
2. Inverter control is complicated.
3. Switching frequency and losses are more.

**V. FFT of five level Cascade H-bridge inverter**
THD Analysis is done with help of FFT using Matlab tool/version 2010. Performance of five level cascaded H-bridge inverter at no load. The FFT analysis is done for five cycle for maximum frequency of 5000 Hz and cycle started from 0.01 second.

**VI. FFT Analysis for Modulation at 0.25 modulation Index**

**FFT Analysis of Five Level Diode Clamp Inverter**
THD Analysis is done with help of FFT using Matlab tool/version 2010. Performance of Five level Diode clamp inverter at no load is analyzed on

**VII. FFT Analysis of Five Level Diode Clamp Inverter**

![FFT Analysis of Five Level Diode Clamp Inverter](image_url)
TABLE NO I
Comparative analysis between five level Diode Clamp and five level cascaded H-bridge at modulation index 0.25 and 0.2

<table>
<thead>
<tr>
<th>Modulation index</th>
<th>Cascade H-bridge</th>
<th>Diode Clamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>41.68</td>
<td>38.03</td>
</tr>
<tr>
<td>0.25</td>
<td>34.98</td>
<td>26.87</td>
</tr>
</tbody>
</table>

VII. Conclusion

This paper represents comparative study of cascaded H-bridge and Diode Clamp inverter on basis of total harmonic distortion using FFT Analysis. Cascaded H-bridge five level inverter have lower total harmonic distortion at modulation index 0.2 and 0.25 whereas in diode clamp five level inverter have high total harmonic distortion at modulation index 0.2 and 0.25 in comparison with Cascaded H-bridge five level inverter.

References

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