A COMPARATIVE STUDY OF CASCADED H BRIDGE AND REVERSING VOLTAGE MULTILEVEL INVERTER TOPOLOGIES

ROSHNY MARY B ¹, NEETHU S ²

¹P G Scholar, Department of EEE Sree Narayana Gurukulam College of Engineering Kolenchery, India
²Assistant Professor, Department of EEE Sree Narayana Gurukulam College of Engineering, Kolenchery, India

ABSTRACT

Multilevel inverters are mainly using for high power high voltage applications. It can overcome the limitations of a conventional two level inverter such as higher total harmonic distortion and higher electromagnetic interference. The main peculiarity of multilevel inverter is that it can generate nearly sinusoidal output voltage. Conventional multilevel inverter topologies include diode clamped multilevel inverter, flying capacitor multilevel inverter and cascaded H bridge multilevel inverter. The main limitations of the conventional topologies are large number of components, complex PWM control methods and voltage balancing problem. As the number of level increases, these limitations will become more pronounced. So in this paper a new multilevel inverter topology called reversing voltage is proposed. The proposed topology needs less number of components and carrier signals and THD of the proposed topology is less compared to conventional topologies. In this paper proposed seven level topology is compared with the conventional cascaded H bridge seven level inverter in terms of THD and number of components required. Finally an experimental set up of the proposed seven level topology is built and evaluated.

Keywords: Phase Disposition (PD) SPWM, Reversing Voltage (RV) Topology, Total Harmonic Distortion.

1. INTRODUCTION

Advanced power electronic converters are required to meet high power demand. As a result, different multilevel converter topologies are developed. Multilevel converter topology was first introduced by Nabe in 1981. A conventional voltage source inverter (VSI) can produce an output voltage with two levels ±Vdc/2, commonly known as two level inverter. The main problem associated with the conventional two level inverter is the high ripple content present in the output voltage or current [1]. So to improve the performance of the inverter, different PWM control methods have to be adopted along with high switching frequency. But switching frequency cannot be increased beyond a particular limit due to switching losses [2].

Multilevel inverter consists of series of semiconductors and capacitors, whose output will be a stepped waveform. Figure 1 shows one leg of a multilevel inverter with different number of levels. Renewable energy sources such as wind, fuel cell and solar panels can be directly interfaced with the multilevel inverter for high power applications [3].
The various multilevel inverter topologies include diode clamped multilevel inverter, capacitor clamped multilevel inverter and cascaded H bridge multilevel inverter. In diode clamped multilevel inverter a bank of series connected capacitors will divide the dc link voltage into small steps. Inverter poles can be connected to any one of these voltage steps to generate the complete multilevel output. Flying capacitor multilevel inverter consists of pre charged capacitors and this capacitor voltage is added or subtracted from the dc voltage to obtain the required levels. Cascaded H bridge multilevel inverter includes a number of single phase H bridges connected in series, the output of which is equal to the sum of voltage produced by each bridge. Table 1 shows the total number of components required for different conventional multilevel inverter topologies [4].

The reliability of a multilevel inverter is inversely proportional to the number of components used in the inverter. So as the number of components decreases the reliability of the inverter increases. Referring to Table.1, cascaded H bridge multilevel topology is found to be the best in terms of reliability and modularization. The objective of this paper is to introduce a new multilevel inverter topology called Reversing Voltage (RV). The proposed topology requires less number of components compared to conventional inverters and has lower control complexity.

### Table.1- Number of Components for Three Phase Inverters.

<table>
<thead>
<tr>
<th>Inverter Type</th>
<th>NPC</th>
<th>Flying Capacitor</th>
<th>Cascade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Switches</td>
<td>6(N-1)</td>
<td>6(N-1)</td>
<td>6(N-1)</td>
</tr>
<tr>
<td>Main diodes</td>
<td>6(N-1)</td>
<td>6(N-1)</td>
<td>6(N-1)</td>
</tr>
<tr>
<td>DC Bus Clamping Diodes</td>
<td>(N-1)(N-2)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Clamping Capacitors</td>
<td>3(N-1)</td>
<td>3(N-1)(N-2)</td>
<td>0</td>
</tr>
<tr>
<td>Flying Capacitors</td>
<td>0</td>
<td>3(N-1)(N-2)</td>
<td>0</td>
</tr>
<tr>
<td>Total Numbers</td>
<td>(N-1)(3N-7)</td>
<td>(N-1)(3N-2)</td>
<td>27(N-1)</td>
</tr>
</tbody>
</table>

The cascaded multilevel inverter consists of a number of single phase H bridges connected in series. The output voltage of the multilevel inverter is the sum of voltage produced by each bridge. Figure 2 shows a conventional cascaded seven level inverter. It consists of three single phase bridges connected in series. Each bridge can generate three different levels, i.e. +V, 0 or −V. For N level output it requires 2(N-1) high frequency switches, and N-1 carrier signals. When the number of level increases, the control of the inverter become more complex [5].
In conventional topologies, all switches are combined to produce a complete multilevel output. But there is no need to use all these switches for generating multilevel output. This idea is implemented in the new topology. This is a hybrid multilevel inverter topology. It actually separates the output voltage into two sections. First section is called level generation part and is responsible for generating the required positive level voltage. The peculiarity of level generation part is that it will generate only positive level voltage. The switches used in this section should have high switching frequency capability. The other section is called polarity generation part which decides about the polarity of the output voltage. This section requires low frequency switches. So there is no need for all switches to be of high frequency type. The block diagram representation of the inverter is shown in figure 3.

Circuit diagram for the single phase seven level inverter based on reversing voltage is shown in figure 4. Left portion of the circuit represents level generation part and right portion represents polarity generation part. Six high frequency switches are used in the level generation part. The positive level generated by the level generation part is transferred to polarity generation part. Polarity generation part consists of a single phase H bridge inverter which can work in two modes forward and reverse mode. Switches 1 and 2 are operated in the forward mode, whereas switches 3 and 4 are operated in the reverse mode. In forward mode, positive level generated by the level generation part is transferred to the output in the same polarity. In reverse mode, positive level is transferred to the output in the reverse polarity, so that complete cycle can be obtained.
Fig. 4. Single phase seven level inverter based on reversing voltage

It can also be used for three phase applications. Three phase seven level model is shown in figure 5. Here output of each leg is given to a single phase full bridge inverter, output of which drives the primary of a transformer. The secondary of the transformer is delta connected which can be connected to the three phase system. Fig. 5 shows the corresponding three phase RV model.

Fig. 5. Three phase RV model
3. SWITCHING SEQUENCE

Switching sequence in this inverter is very easy. Table.2. shows the switching modes for the proposed seven level inverter. While selecting a particular switching pattern, make sure that switching transitions are minimum. Referring to table.2, there are six switching patterns to control the inverter. The sequence of switches (2-3-4), (2-3-5), (2-6-5), and (1-5) are used for levels 0 up to 3, respectively. The output voltage will be the sum of voltage sources which are included in the current path. Current path for each level is shown in figure.6 according to the above switching pattern.

Table.2. Switching modes for seven level RV model

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>MODE</th>
<th>V_{dc}</th>
<th>2V_{dc}</th>
<th>3V_{dc}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,3,4</td>
<td>2,3,5</td>
<td>1,4</td>
<td>1,5</td>
</tr>
<tr>
<td>2</td>
<td>2,4,6</td>
<td>2,6,5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Fig.6.Switching sequence](image)
4. CONTROL STRATEGY

PD (Phase Disposition) SPWM is adopted to control the inverter. Here all carriers are in phase but have definite offset from each other. Conventional multilevel inverter requires N-1 carriers for N level output. Since only positive levels are generated in the proposed topology, we can reduce the number of carriers required to \((N-1)/2\) [6, 7]. All high frequency switches are operated under PDS PWM control and the low frequency switches are operated at line frequency. The three carriers and sinusoidal modulating signal for inverter control are shown in figure 7. [8, 9]

![Carrier and modulating signal](image1.png)

5. COMPARISON

In order to validate the superiority of RV topology over cascaded inverter, first of all the number of components required are compared. Referring to table 3, the number of components required for the RV topology is smaller.

![Number of components required](image2.png)

<table>
<thead>
<tr>
<th>Inverter Type</th>
<th>RV</th>
<th>Cascade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Switches</td>
<td>(3(N-1)+4)</td>
<td>(6(N-1))</td>
</tr>
<tr>
<td>Main diodes</td>
<td>(3(N-1)+4)</td>
<td>(6(N-1))</td>
</tr>
<tr>
<td>DC Bus Capacitors/</td>
<td>((N - 1))</td>
<td>(3(N - 1))</td>
</tr>
<tr>
<td>Isolated Supplies</td>
<td>(2)</td>
<td>(2)</td>
</tr>
<tr>
<td>Total Numbers</td>
<td>((13N + 35))</td>
<td>(27(N - 1))</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
<td>(2)</td>
</tr>
</tbody>
</table>
6. SIMULATION RESULTS

Simulation results for both the inverters are shown below. Here each DC power supply is adjusted to 50V and the load used is RL load. Output voltage is 300V\(_{p-p}\).

![Fig.9. output of cascaded inverter](image)

![Fig.10. THD of cascaded inverter](image)

![Fig.11. Output of RV topology](image)
THD of the cascaded inverter is 17.72% and THD of RV topology is 1.25%. So the THD of the RV topology is very small in comparison with the THD of cascaded inverter. Therefore the proposed topology is very advantageous since it requires less number of components and carrier signals for the same output.

7. EXPERIMENTAL RESULTS

A prototype of seven level inverter using RV topology is built. Each DC voltage source is set to 5V. Control signals are generated by PIC16F876. Output voltage is 30V_p-p.
8. CONCLUSION

This paper has provided a brief summary of different conventional multilevel inverters. The cascaded multilevel inverter is compared with RV topology to show the superiority of the proposed inverter. In the proposed topology, switching operations are divided into high and low frequency parts. Proposed topology is better for all applications because it has less control complexities; cost is also less and gives less % THD. Hence proposed topology is preferred than conventional cascaded inverter. The carrier based PWM scheme using the PD strategy is used here. PD-SPWM control method for this topology has fewer complexities since it use only positive carriers. The results show that this proposed topology can work as a multilevel inverter with reduced number of carriers for SPWM. The hardware implementation of power and control circuit has been implemented.

REFERENCES