Modeling and Performance Analysis of Six Level Inverter for Medium Voltage Drives

T. Murali Krishna¹, C. Harish², N. Anusha³
¹,² Asst. Prof., ³ P. G. Scholar, Dept. of EEE, CBIT, Gandipet, Hyderabad, India

Abstract—The most apt power electronic converter for control of medium voltage ac drives is a Multi Level Inverter for its inherent advantages like less Total Harmonic Distortion [THD], ease of control, low dv/dt. As the number of voltage levels present in the output voltage of the inverter is more, then the output voltage of the inverter is kept near to a sinusoidal form, resulting in smooth torque and speed. In this paper, the modeling of a six level inverter is presented and its performance is compared with five level inverter using MATLAB Simulink.

Keywords—Multi level inverter, Neutral Point Clamped, Medium voltage drives, six levels.

I. INTRODUCTION

The main cause of bearings deterioration in ac drives is large change in voltages with respect to time is the main drawback of using conventional two level inverters[1]. In order to enhance the life time of bearings and to reduce the dv/dt problem one of the possible solution is to introduce more number of levels in the output voltage of inverters[2]. Various topologies have been suggested in order to introduce number of levels in the output voltage of the inverters, out of which neutral point clamped topology has given more importance in medium drives control[3]. Recently many hybrid topologies have been evolved by cascading different conventional topologies. But they require more complex driver circuits and require less number of switching elements[4-8]. As the ease of implementation and requirement of single source, neutral point clamped topology has been preferable for speed control of medium voltage drives[9].

II. NEUTRAL POINT CLAMPED TOPOLOGY

The basic topology to realize the multilevel inverter is neutral point or diode clamped topology in which the dc voltage is split into n levels using (n-1) series connected capacitors across the supply. This topology requires 2(n-1) uni-directional blocking, bi-directional conducting fully controlled switches per phase. The six-level NPC topology requires 5 series connected capacitors across the supply. The proposed topology of three phase six level inverter is represented in figure 1.

Figure 1 Neutral point clamped six level inverter.

III. SIX LEVEL INVERTER

Figure 2 Single phase circuit of six-level inverter.
The single phase circuit of six-level inverter is shown in figure 2, where IGBTs are used as switching devices. Each phase requires 10 switches to introduce six levels in the output voltage. The supply voltages V is divided into five equal levels, each of V/5 using five capacitors of same value connected in series and is connected as shown in figure 2. The six levels are 0, V/5, 2V/5, 3V/5, 4V/5 and V and are obtained by operating the switches in the desired sequence. It requires eight diodes in order to supply voltage at different levels to the load.

To obtain a voltage of V, the load will be connected across the supply as shown in figure 3, where all the top side switches need to conduct. The figure 4 represents the equivalent circuit for obtaining an output voltage of 4V/5. In order to get the output voltage 3V/5, the switches conducting is represented in figure 5.

The equivalent circuits for achieving an output voltage level of 2V/5, V/5 and 0 are given in figure 6, figure 7, and figure 8 respectively.

Figure 3 Single phase circuit for output voltage V.

Figure 4 Single phase circuit for output voltage 4V/5.

Figure 5 Single phase circuit for output voltage 3V/5.
Figure 6 Single phase circuit for output voltage 2V/5.

Figure 7 Single phase circuit for output voltage V/5.

Figure 8 Single phase circuit for output voltage 0.

Figure 9 Simulation diagram of six-level inverter.

The simulation diagram is shown in figure 9. The supply voltage is 200V. The triggering pulses for IGBTs are shown in the figure 10. The switching states of the circuit to get different output voltage levels are shown in the table below.
### TABLE I

<table>
<thead>
<tr>
<th></th>
<th>V(_{dc}/5)</th>
<th>V(_{dc}/4)</th>
<th>V(_{dc}/3)</th>
<th>V(_{dc}/2)</th>
<th>V(_{dc})</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>S(_c1)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>S(_c2)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S(_c3)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S(_c4)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S(_c5)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S(_c1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S(_c2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S(_c3)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>S(_c5)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The switches at the bottom are complementary signals to the top switches respectively. Hence the control signals designed for the top switches are given to the bottom switches using not logic.

**IV. RESULTS**

The simulation is carried out in MATLAB Simulink environment on a 4-pole squirrel cage induction motor. The line to line voltage of five level and six level inverters are shown in figures 11 and 12 respectively. The frequency spectrum of the line voltages is also shown in the figures 11 and 12. From the frequency spectrum it is observed that the harmonics present in the line voltage is reduced from 14.5% to 9.33% in six-level inverter.

The performance of the six-level inverter is checked on the same induction motor for the same load conditions. The figure 13 gives the information about the speed of the motor. It is observed that, there is no much increase in the speed of the machine. The figure 14 compares the torque information of the motor for five and six level inverters.
V. CONCLUSION

In this paper simulation of six-level inverter is presented and its performance is compared with the five-level inverter.

From the results it is observed that, the total harmonic distortion in the line voltage is decreased considerably in six-level inverter. There is no much change in the speed of the motor where as the ripple in the torque is considerably reduced.

REFERENCES