MEASUREMENT AND ANALYSIS OF COMMON MODE VOLTAGE IN CASE OF MULTI LEVEL INVERTER FED INDUCTION MOTOR DRIVE

Prafulla J. Kale
Department of Electrical Engineering, Govt. College of Engineering, Aurangabad (M.S), India

Dr. V. A. Kulkarni
Department of Electrical Engineering, Govt. College of Engineering, Aurangabad (M.S), India

ABSTRACT

In this paper, a method, to reduce the common mode voltage (CMV) using diode clamped multilevel inverter (DCMLI) with Pulse Width Modulation Technique for three phase induction motor drive is presented. Simulation model of Conventional Two Level Inverter fed Induction Motor (IM); Three Level Diode Clamped Inverter fed IM, Five Level Diode Clamped Inverter (FLDCI) fed IM with POD SPWM Technique are developed under MATLAB-SIMULINK. A Miniature Model of Three Level Diode Clamped Inverter fed Induction Motor Drive is developed. Simulation Results versus Hardware Results are compared to examine Common Mode Voltage.

Key words: CMV, DCMLI, FLDCI, MV, POD SPWM, THD


1. INTRODUCTION

Inverters are widely used in variable speed drives because of their ability to control the magnitude & frequency of the output voltage. Common mode voltage is main disadvantage of 2-level inverter. The Shaft voltage and the premature failure of the bearings is mainly effect of CMV [1]. The simultaneous switching of the series connected devices generates voltage with a high dv/dt at the output terminal of the inverter [2]. Hence, in the applications of AC motor drives, the analysis of the common mode voltage is important. A MLI can reduce as well as eliminate the CMV & reduces harmonic distortion at low switching frequency. Among the configurations of multilevel inverter, 5-level diode clamped multilevel inverters have some advanced features hence simulation is performed using FLDCI & simulation results show that it reduces CMV as well as THD [3]. A passive electromagnetic interference (EMI) filter can keep the shaft voltage in check and eliminate both bearing current and ground current from an inverter-driven motor rated at 400 V, 3.7 kW [4-11].
2. MULTILEVEL INVERTER
The basic structure of the multilevel inverter is to synthesize a sinusoidal voltage from several levels of voltages typically gain from capacitor voltage sources. “Multilevel” starts from three levels. The concept of multilevel inverter control is an alternative solution for induction motor which is operated to achieve performance equally that of dc motors [5]. The main multilevel configuration is classified into three types: diode clamped inverters, flying capacitor inverters and cascaded inverters.

3. DIODE CLAMPED MULTILEVEL INVERTER
The number of main switches in each topology is equal. Comparison with other types, diode clamped inverters require less number of capacitors but require additional clamping diodes. Hence the diode clamped multilevel structure is better for high and medium voltage drives which are easily connected to the utility drive. The Diode Clamped Multilevel Inverter typically consists of (m-1) capacitors on the DC bus in which m is the total number of positive, negative and zero levels in the output voltage. Figure 1 shows a three phase half-bridge five level diode clamped inverter. The order of numbering of the switches for phase x is Sa1, Sa2, Sa3, Sa4, Sa1”, Sa2”, Sa3” and Sa4” and likewise for other two phases. The DC bus consists of four capacitors C1, C2, C3 and C4 act as voltage divider. For a DC bus voltage Vdc, the voltage across each capacitor is Vdc/4 and voltage stress on each (Switch) device is limited to Vdc/4 through clamping diode. The midpoint of the four capacitors “n” can be defined as the neutral point. Table 1 shows the output voltage levels and the corresponding switch states for one phase of the chosen five levels DCMLI. The switches are arranged into 4 pairs (Sa1, Sa1”), (Sa2, Sa2”), (Sa3, Sa3”), (Sa4, Sa4”). If one switch of the pair is turned on, the complementary switch of the same pair must be off. Four switches are triggered at any point of time to select the required level in the five levels DCMLI [5].

![Figure 1 A three phase five level DCMLI](image)

<table>
<thead>
<tr>
<th>Sa1</th>
<th>Sa2</th>
<th>Sa3</th>
<th>Sa4</th>
<th>Sa1’</th>
<th>Sa2’</th>
<th>Sa3’</th>
<th>Sa4’</th>
<th>V_{mb}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>V_{be}/2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>V_{be}/4</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>V_{be}/4</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>V_{be}/2</td>
</tr>
</tbody>
</table>

Table I Switching State and Magnitude of Output voltage [5]

4. COMMON MODE VOLTAGE
In the applications of AC motor drives, the analysis of the common mode voltage is important. It occurs between the neutral point of the star connected motor (node n) to the earth ground (node e), it leads to common mode current [2]. The Shaft voltage and the premature failure of the bearings is mainly effect of CMV. The simultaneous switching of the series connected devices produces voltage with a high dv/dt at the output terminal of the inverter. The sudden rise in inverter voltage is hazardous to the motor drive application. It is very important to reduce the CMV and limit this voltage within certain bounds. A MLI can reduce as well as eliminate the CMV [3]. Some approaches to reduce CMV include four leg inverters, passive filters and dual bridge inverters but five level diode clamped inverter is the best option to reduce CMV [5]. Causes of CMV are leakage current, bearing current & Bearing Failure.
5. MODELING & SIMULATION OF DIODE CLAMPED MULTILEVEL INVERTER

An Inverter fed three phase squirrel cage Induction Motor is used for simulation. Reduction of common mode voltage and Total Harmonic Distortion in Line Voltage is obtained by using Multilevel Inverter as explained in this paper. Analysis of CMV of the Three phase Induction Motor by using different Level Inverter i.e. Two Level Inverter, Three Level Inverter and Five Level Inverter. Here, Two Level Inverter and Three Level Inverter is control by using PWM technique. In Five Level Diode Clamped Inverter, SPWM technique is used to reduce CMV as well as THD.

MODULE 1: TWO LEVEL INVERTER FED INDUCTION MOTOR

Induction Motor is fed by Conventional Two Level Inverter. Simulation in MATLAB environment has been made for full load torque condition. In these Two Level Inverter, two levels i.e. +300 and -300 of output voltage is obtained. CMV from simulation result of Conventional method is found to be 300V to -300V. From FFF analysis THD is obtained 80.63% in Line Voltage of Two Level Inverter. Here, CMV is high and THD is also more.

Output Voltage of Two Level Inverter

![Figure 2 Output Voltage waveform of Two level Inverter](image)

![Fig.3 Common Mode Voltage waveform of Motor](image)

![Fig.4 Total Harmonic Distortion Two level Inverter Fed Induction Two Level Inverter](image)

MODULE 2: THREE LEVEL INVERTER FED INDUCTION MOTOR

Induction Motor is fed by Three Level Inverter. Simulation in MATLAB environment has been made for three fourth load torque condition. In this Module of Three Level Inverter should get three levels of output voltage and ±Vdc/3 CMV.
Output Voltage of Three Level Inverter

![Three Level Inverter Output Voltage](image)

**Figure 5** Output Voltage waveform of Three Level Inverter

CMV of Three Level Inverter

![Three Level Inverter CMV](image)

**Fig.6** Common Mode Voltage waveform

THD of Three Level Inverter

![Three Level Inverter THD](image)

**Fig.7** Total Harmonic Distortion of Three Level Inverter Fed Induction Motor

From Three Level Inverter output waveform three levels i.e. -300V, 0V and +300V of output voltage is obtained. Three Level Inverter is operates in 27 switching states. The CMV varies from -200V to +200V can be observed from waveform of CMV of Three Level Inverter. From FFT analysis THD is obtained 42.22% in Line Voltage of Two Level Inverter. Here, comparison with Two Level Inverter CMV & THD decreases.

**MODULE 3: FIVE LEVEL DIODE CLAMPED MULTILEVEL INVERTER FED INDUCTION MOTOR**

Induction Motor is fed by Five Level Diode Clamped Inverter. Simulation in MATLAB environment has been made for full load torque condition. In this Module of Five Level Diode Clamped Inverter should get five levels of output voltage and ±Vdc/12 CMV.
Output voltage of five level Diode Clamped inverter

From Five Level Diode Clamped Inverter output waveform, five levels i.e. -300V, -150, 0V, +150 and +300V of output voltage is obtained. Five Level Inverter is operates in 125 switching states. The CMV varies from -50V to +50V can be observed from waveform of CMV of Five Level Diode Clamped Inverter. From FFT analysis THD is obtained 34.21% in Line Voltage of Five Level Diode Clamped Inverter.

| Table II Comparision of Total Harmonic Distortion In Line Voltage And Common Mode Voltage |
|-------------------------------------------------------|-----|-----------------|
| Two Level Inverter                                    | 80.51% | ±Vdc/2          |
| Three Level Inverter                                  | 42.14% | ±Vdc/3          |
| FLDC Inverter with POD SPWM                           | 34.21% | ±Vdc/12         |
Here, CMV is decreases as compare to CMV of Two Level and Three Level Inverter. THD is also decreases as compare to Two Level and Three Level Inverter.

**MODULE 4: HARDWARE PROTOTYPE OF 3-LEVEL DIODE CLAMPED INVERTER FED INDUCTION MOTOR DRIVE**

Hardware Prototype of 3-Level Diode Clamped inverter fed 3-Phase Induction Motor is developed and analyzed for CMV of the system. This system consists of five main modules Power supply model, Control Circuit Model, Gate Drive Circuit Model, Inverter Model, 3-Phase Squirrel Cage Induction Motor shown in figure11.

1) Power supply model - Two regulated power supply of +12v and +5v requires for different card of our circuit hence multi tapping step down Transformer whose rating 230/12Volt is used.
2) Control Circuit Model - In this system, In order to control IGBT, AT 89C52 Microcontroller was chosen to generate a three level Pulse Width Modulation (PWM) Technique for greater efficiency.

3) Gate Drive Circuit Model – In this system Insulated Gate Bipolar Transistor (IGBT) is used as switching device and TLP250 IC is a gate drive circuit. Microcontroller gives pulses to TLP250 IC. Output of TLP250 IC is given to IGBT Switches.
4) Inverter Circuit Model - A variable voltage, variable frequency three phase supply for three phase induction motor can be generated by a use of a Pulse Width Modulated (PWM) inverter. The implemented system is proposed to drive 3-Phase Induction Motor with 12 Switches is connected in the form a Diode Clamped Multilevel Inverter. The three phases are maintained at 120° relative to each other. Both the frequency and amplitude of the fundamental component of output voltage waveform can be varied by controlling the timing of the switching signals to the inverter devices.
5) Three-Phase Induction Motor – The experimental setup has been tested on Squirrel Cage Induction Motor of 0.37kW, Star Connected, 400Volt, 1.2A, 50Hz, 4-Pole, 1440 RPM as load.

**Hardware Results**

Hardware Prototype of 3-Level Diode Clamped inverter fed 3-Phase Induction Motor is developed and CMV of system has been examined. It has been found to be $\pm \frac{V_{dc}}{3}$
CONCLUSION

In this paper the simulation results of Conventional Two Level Inverter fed Induction Motor (IM), Three Level Diode Clamped Inverter fed IM, Five Level Diode Clamped Inverter fed IM with POD SPWM Technique are analyzed under MATLAB-SIMULINK. A Miniature Model of Three Level Diode Clamped Inverter fed Induction Motor Drive is developed and analyzed. The Common Mode Voltage of each system has been examined. Simulation Results versus Hardware Results are compared. As the level of Inverter goes on increasing it has been observed that the CMV and Total Harmonic Distortion decreases.

REFERENCES


