This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/JESTPE.2014.2313153, IEEE Journal of Emerging and Selected Topics in Power Electronics

Common Mode Voltage and Vibration Mitigation of a Five-Phase Three-level NPC Inverter fed Induction Motor Drive System

Saifullah Payami, *Student Member, IEEE,* Ranjan Kumar Behera, *Senior Member, IEEE,* Atif Iqbal, *Senior Member, IEEE,* and Rashid Al-ammari, *Member, IEEE*

***Abstract*—Common Mode (CM) voltage is one of the main reasons for the flow of bearing currents in induction motors (IM) that ultimately leads to the bearing failure and causes severe vibrations. For three-phase IM drives, many works have been reported either on the reduction or on the elimination of CM voltages that are generated due to pulse width modulation (PWM) action of the feeding power converters. However, for five-phase IM drives, very few studies are available with the perspective of the CM voltage elimination. Also, the effect of CM voltage on the mechanical vibrations of a five-phase IM has not been reported in the literature. Hence, in this paper, firstly, the modeling of CM current generated in the five-phase induction motor (IM) is done and its expression based on admittance transfer function is derived. Then the CM voltage is eliminated from a five-phase three-level neutral point clamped (NPC) voltage source inverter (VSI). The space vector pulse width modulation (SVPWM) technique is developed for the elimination of CM voltages. Only those switching states are selected which give zero CM voltage. The same selected switching states also give the balanced dc link capacitor voltages. Its effect is observed on the mechanical vibration of the motor and it is correlated with the CM current. The mechanical vibration is observed for both, with and without CM voltage elimination. Both the simulation and experimental results are given to validate the concept proposed.**

***Index Terms*—Five-phase induction motor, common mode voltage, bearing current, mechanical vibration, five-phase neutral point clamped inverter**

I. Introduction

THE technology for three-phase IM drives is well established and widely accepted in industries because of the readily available three-phase power supply. With the advancement in the power electronics, multiphase IM is also competing with its counterpart for high power applications because of their inherent advantages, as the power supply for these motors remains no more an issue. Detailed review regarding the development in multiphase drives is available in [1]–[3]. Some of the advantages of multiphase induction motor are lower torque pulsation [4]–[6], higher torque density [7], [8], fault tolerance [9], [10] and lower current ripple [11]. As multilevel inverters, especially NPC VSI, is suitable for medium voltage high power applications [12]–[14], multilevel-multiphase IM drives is constantly being explored [15]–[17] for industrial applications.

Various inverter topologies are used with different PWM techniques for the control of speed, torque and current of three-phase or multiphase IM drives. But one of the problems associated with these types of pulse width modulated inverter fed drives is the generation of CM voltage due to their switching actions. Because of the CM voltage, bearing current and shaft voltage is generated which are main reasons for the bearing failure [18]–[23]. The modeling and cause of bearing currents due to pulse width modulated inverters is given in [18]–[20]. The causes of the shaft voltage and bearing currents and how bearing currents depend on the various system parameters in an inverter driven IM are discussed in [21]–[23]. The CM model of a three-phase IM is represented by the admittance transfer function in [24]. From [25], one can relate the mechanical vibrations with the current measured waveform. All these studies are done with the perspective of three-phase IM drive. Based on the study of [24] CM model of five-phase IM is developed in this paper.

Since the CM voltage is the one of the main reasons for the bearing current, if not eliminated, can lead to the bearing failures. Many researchers have worked either for elimination or reduction of CM voltage. For the mitigation of CM voltage, one approach is to use CM filters [26], [27]. But, using filters increases the cost and size of the inverters. So, another approach is the modification in the modulation strategy of the inverters. Reduction of CM voltage for two-level three-phase inverter is dealt in [28]–[30]. In [29], [30] dual two-level inverter approach is adopted for CM voltage elimination. CM voltage elimination for three-level three-phase inverter topology is dealt in [31]–[35] and [36]–[38] deals with even higher number of levels. Recently, [39], [40] gives the modulation techniques for the reduction in CM voltage for five-phase two-level inverters. While the former gives the predictive control technique for reduction in CM voltage, the latter gives the SVPWM technique. In [41], Karugaba et al. have proposed the CM voltage quantification for multilevel multiphase diode clamped VSI systems by the number of possible levels and step sizes between different levels and their frequencies of occurrence.

Krug et al. [42] have compared the vibration of a three-phase IM when it is fed by a three-level and two-level

S. Payami is with the Department of Electrical Engineering, Indian Institute of Technology Patna, Patna-800013, India email:saif.payami@gmail.com

R. K. Behera is with the Department of Electrical Engineering, Indian Institute of Technology Patna, Patna-800013, India. email:rkb@iitp.ac.in

A. Iqbal is with the Dept. of Electrical Engineering, Qatar University, Doha, Qatar. He is on academic leave from the Dept, of Electrical Engineering, Aligarh Muslim University, Aligarh, India.

Rashid Al-ammari is with the Department of Electrical Engineering, Qatar University, Doha, Qatar email:ralammari@qu.edu.qa