Computational Analysis of Inverter Harmonics on the Performance of Three Phase Induction Motor .

[*1] Mr.Umesh E. Hiwase [2]Dr.Shubhada P. Muley, [3] Dr. Kishor B.Porate
[1, 2,3] *Priyadarshini College of Engineering,Nagpur.*

Abstract

For variable speed drive using fast switching power modulator has been widely used in industry for various applications. But degrading power factor and incursion current harmonics are the major problems. Thus computational analysis of motor performance is required to select the proper harmonics reduction techniques for smooth operation . In this research paper a throw analysis is done on the performance of induction motor on every aspect. For smooth operation of AC motor drive, multilevel inverters are preferred over a conventional two level inverter, with increasing the level of inverter output is nearly sinusoidal and, desired output voltage with reduces harmonic distortions is obtain . The main objective of this paper is to analysis and compare the effect of harmonics on Induction Motor by feeding conventional two level and multilevel inverter with respect to different mechanical parameters.

Keywords: *Computational analysis; multilevel inverter , Harmonic analysis, Total Harmonic Distortion ,mechnical parameter.*

Introduction

For voltage source inverter (VSI) fed ac drives system, self commutated fast switching devices like insulated gate bipolar transistor (IGBT) are preferred over a other devices ,which offer compact design, negligible gate power, low on state voltage drop, switching losses are less and control is easy. The maximum rating of low voltage (LV), pulse width modulation (PWM) VSI drives is limited by practical current rating.

The diode clamped multilevel structure is more suitable than other topology, for high and medium voltage ac drives which are directly connected to utility power system (direct to drive topology) [02], [04]. This topology requires only one power supply (with front end active converter and inverter at drive end) therefore; it is very sutable for industrial adjustable speed drive (ASD). In this research paper , diode clamped multilevel inverter (DCMLI) is to be explore to reduce /eliminate lower order harmonics of stator current by selecting appropriate switching states based on the level of inverter. The variation of speed , torque etc is also reduced by varying switching frequency of gate pulse in different phases. A same SPWM technique is developed and implemented for two level, three-level and five level inverter. Multilevel DCMLI is designed for three-phase, 3.7 kW, 415 V,50 Hz induction motor. The simulation results for different topologies was compared to validate theoretical and simulated values for different parameters of induction motor

Causes of Harmonics in Inverter output:

Any industry has various loads which inject current harmonics of different order in the power supply such as static converters (such as electric furnace, induction heating devices and switching power supply). Mainly power modulator such as switching sources and converters are most important sources of harmonic generation. Converters usually generate harmonics from n^{th} level in AC side.

$$n = k\text{np} \pm 1$$

Where: k - is a constant and
n_p is the number of gate pulses.

In industry prime mover / motor (Specially Induction motor) have been designed to work on pure sinusoidal supply , but in real the power is non-sinusoidal that reduces the efficiency and life time of the drive . Temperature rise in the motor is most common parameter that decreases the life time . Induction motor under perfect sinusoidal supply condition generate little amount of current harmonics which can be eliminated easily by filter , because of its coils structure and non linear behaviour of iron core. Most important consequent of this phenomenon is efficiency decrease.

Effect of Inverter Low Order Harmonics on Induction Motor:

1. Third Harmonics : Third harmonic and it multiples does not affect the performance as flux waves produced by each of the three phases neutralize each other as it differs in time phase by 120^o. The fundamental mmf wave produces flux which rotates at synchronous speed which given as ns = 120 f_1/P rpm where f_1 is supply frequency and P is number of poles of motor.

2. Fifth Harmonics : Fifth harmonic mmf wave produces flux which rotates at 120 f_1/5P = ns/5 rpm and in direction opposite to the fundamental mmf wave.
3. Seventh Harmonics : Similarly , seven harmonic mmf produces flux which rotates at ns/7 rpm and in the direction of fundamental m.m.f. wave.

Thus it is concluded that harmonic m.m.f. wave produces flux which rotates at 1/K times the fundamental speed and in the direction of fundamental wave if K = 6m + 1 and in the reversed direction if K = 6m - 1 where, m is any integer. The most important and predominant lower order harmonics whose effects must be minimized are 5^{th} and 7^{th} harmonics.

Table 1: Parameter of Induction Motor

Sr No.	Parameter	Values in unit.
1	Stator Voltage	415 Volt.
2	Stator steady state Current	7.9 Amp
3	Rated Speed	1460 rpm
4	Load Torque	25 N-m

Other parameter calculated for simulation

Sr No.	Parameter	Values in unit.
1	Rotor Current	4.0 A
2	Stator Resistance	1.405 Ohms
3	Rotor Resistance	1.395 Ohms
4	Stator core loss current	6.356 A
5	Magnetizing Current	1.2 A
6	Excitation Current	2.72 A
7	Stator core loss Resistance	37.72 Ohms
8	Stator Magnetizing Inductor	0.1542 H
9	Magnetizing Reactance	23.26 Ohms
10	Slip	5.30 %
11	Rotor Frequency	2.65 Hz

Simulation *:*

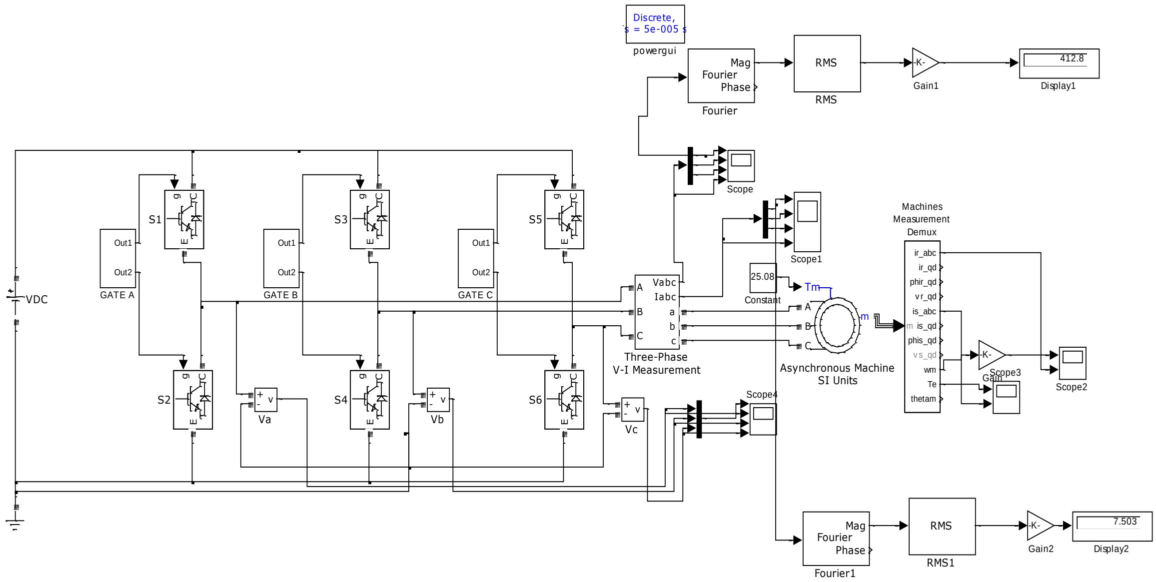

Fig : 1 MATLAB simulation for two level Inverter

Two Level Inverter

Above nameplate parameters (other required parameters are calculated by mathematical analysis) of Induction motor are consider for MATLAB simulation, and is done for two level inverter with DC input source voltage of 770 V, Modulation Index is consider as 0.9 and switching frequency of 5kHz. The results obtained for line current and voltage are shown in Fig.2and 3 respectively and their corresponding FFT analysis in Fig. 2 and 4 respectively.

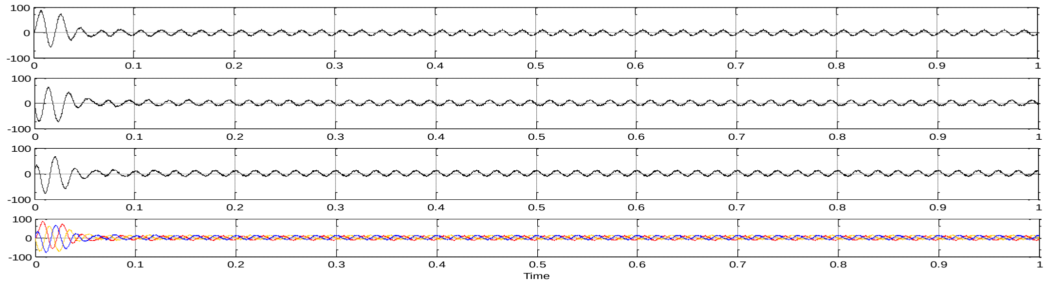

Fig.2 Current (Conventional Inverter)

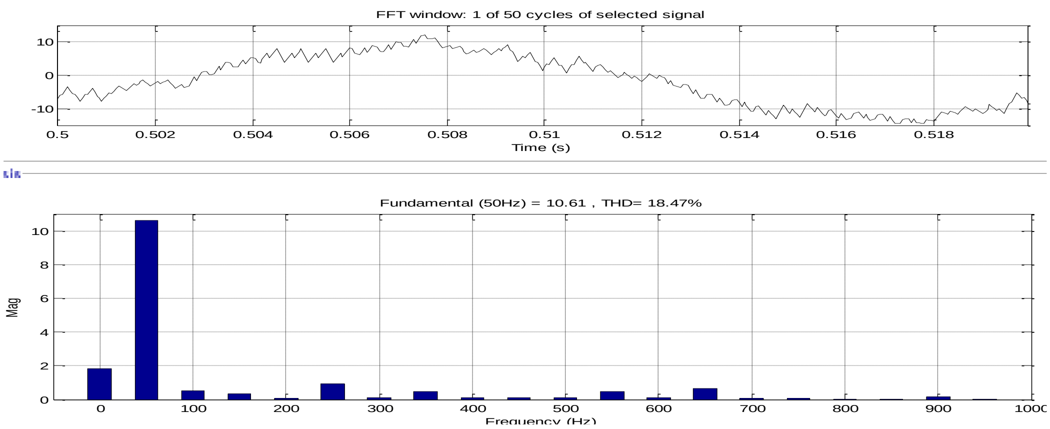

Fig.3 FFT analysis of Line Current (Conventional Inverter)

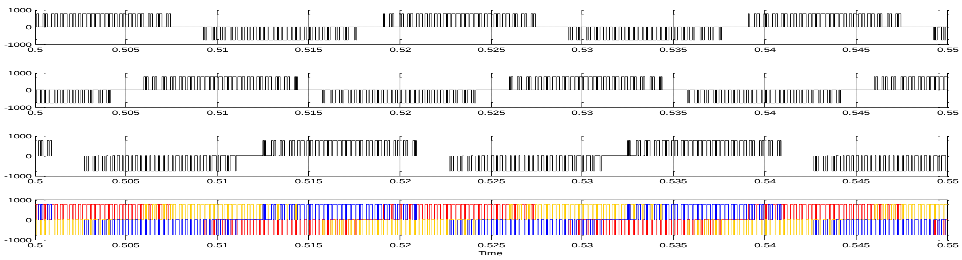

Fig.4 Voltage (Conventional Inverter)

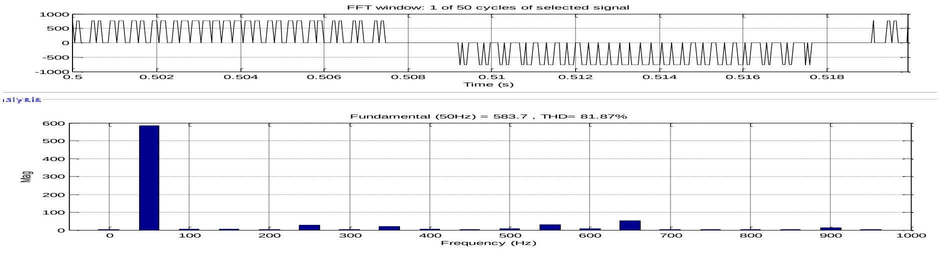

Fig.5 FFT analysis of Line Voltage (Conventional Inverter)

The motor speed and torque is measured and the deviations are shown in Fig.6 and Fig.7 respectively.

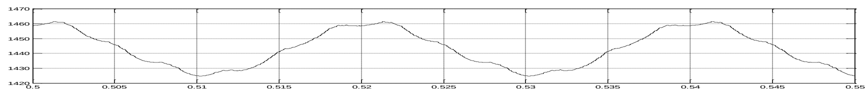

Fig.6 Speed Variation (Conventional Inverter)

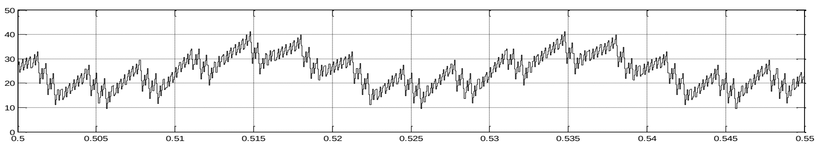

Fig 7 Torque Variation (Conventional Inverter)

Similarly, MATLAB simulation was done for same motor with three level and five level inverter and following results with refer to different parameter are obtain (Given in Table 2) and comparison of simulated with calculated results are given in Table :3

Parameter	**2 Level**	**3 Level**	**5 Level**
Current THD	18.47 %	6.66 %	4.25 %
Voltage THD	81.87 %	39.11 %	17.87 %
Speed Variation	1425- 1460 rpm	1435-1460 rpm	1433-1453 rpm
Torque Variation	10-40 NM	15-35 NM	20-30 NM

Table 2 : THD comparison of 2 level, 3 level and 5 level inverter

Parameter	**Simulated**			**Calculated**		
	2 Level	3 Level	5 Level	2 Level	3 Level	5 Level
Magnitude of Reference Signal (A_r)	0.9	0.9	1.8	0.9	0.9	1.8

Magnitude of Carrier Signal (A_c)	1	1	1	1	1	1
Modulation index	0.9	0.9	0.9	0.9 (A_r/A_c)	0.9 ($2A_r/(n-1)A_c$)	0.9 ($2A_r/(n-1)A_c$)
Vdc	770V	(370*2=)740V	(190*4)=760V	753.5	753.5	753.5
Vrms (Line voltage)	412.8V	412.2V	413.4	415	415	415
Irms	7.508A	7.466A	7.661	7.47A P/√3VL*p.f (p.f=0.689)	7.42A P/√3VL*p.f (p.f=0.694)	7.64A P/√3VL*p.f (p.f=0.674)
Speed Variation	1425-1460rpm	1435-1460rpm	1433-1453rpm			
Average Speed	1442 rpm 98.7% of N rated	1448 rpm 99.2% of N rated	1443 rpm 98.8 % of N rated			
% Speed Variation	2.39%	1.71%	1.00 %			
Torque Variation	10-40 Nm	15-35 Nm	20-30 Nm			
Average Torque	25N-m	25N-m	25 Nm			

Table 3 :Comparison of simulated and calculated result

MATLAB simulation for conventional 2 level; 3 level and 5 level diode clamped inverter to study the effect of harmonics is carried out. The % variation in THD was presented in table 2 and table 3and magnitude of voltage and current magnitude for different harmonic order is indicated in Table 4.

Harmonics Order	**Voltage** (Fundamental -583)			**Current** (Fundamental -10.1)		
	2 Level	**3 Level**	**5 Level**	**2 Level**	**3 Level**	**5 Level**
3rd	5.43	1.85	1.17	0.34	0.03	0.05
5th	28.89	3.59	6.35	0.93	0.06	0.21
7th	20.46	4.44	6.21	0.48	0.08	0.13
9th	4.85	1.23	0.85	0.1	0.02	0.02
11th	31.39	11.18	3.98	0.47	0.22	0.03
13th	53.23	8.00	3.87	0.68	0.09	0.05

Table 4 : Magnitude of voltage and current e for different harmonic order

Conclusion :

For variable speed drive , based on the selection of drive for particular application and grade of winding of the motor to be used power supply must be analyzed . It has concluded that deviation in parameter such as Speed , Torque was more in two level , three level multilevel inverter fed drive as compare to five level multilevel inverter drive. So by increasing the level of inverter deviation in can reduce.

References:

1] Mohan M.Renge and HiralalM.Suryawanshi , “Five –Level Diode Clamped Inverter to Eliminate Common Mode Voltage and Reduce dv/dt in Medium Voltage Rating Induction Motor”,IEEE Transactions on Power Eletronics , Vol. 23, No. 4 July 2008, pp 1598-1606.

2] Prasad, H.; Sudhakar, T.D.; Chilambarasan, M., "Mitigation of current harmonics in a solar hybrid system by installation of passive harmonic filters," in International conference on Computation of Power, Energy Information and Commuincation (ICCPEIC), pp.0345-0349, 22-23 April 2015

3] ShashikantR.Vaishnani, HardikH.Raval ,BhavansN.Shah, “Mitigation of Harmonics in A.C.Drive by using multi-pulse Transformer Solution.” International Journal of Engineering Science and Innovative Technology (IJESIT) , Vol., 2 , Issue 2 , March 2013, pp – 653-662.

4] Davari, P.; Yongheng Yang; Zare, F.; Blaabjerg, F., "A novel harmonic elimination approach in three-phase multi-motor drives," in IEEE conference on Energy Conversion Congress and Exposition , pp.7001-7008, 20-24 Sept. 2015.

5] Lee, K.; Carnovale, D.; Young, D.; Ouellette, D.; Zhou, J., "System harmonic interaction between DC and AC adjustable speed drives and cost effective mitigation," in IEEE conference on Energy Conversion Congress and Exposition (ECCE), pp.4069-4076, 20-24 Sept. 2015

6] ConcettinaBucccella, Carlo Cecati, Maria Gabriella Cimoroni and KavehRazzi, “ Harmonic Mitigation Technique for Multilevel Inverter in Power Systems,” International Symposium on Power Electronics , Electrical Drives , Automation and Motion, pp – 73-77, 2014

7] EdirsPouresmaeil ,DanialMontesinos-Miracle and OrioiBellmunt, “ Control Scheme of Three –Level NPC Inverter for Integration of Renewable Energy Resources into AC Grid.” IEEE Transaction System Journal , Vol- 6 ,No. 2 , pp 242-253, June 2012.

8] SuleOzdemir, EnginOzdemir , Leon M.Tolbert and SurinKhomfoi , “ Elimination of Harmonics in a Five –Level Diode Clamped Multilevel Inverter Using Fundamental Modulation.” International Conference on Power Electronics and Drive Systems ,Bangkok, Thailand, Pp 850-854, 27-30Nov. 2007.

9] AmirhosseinMoeini, HosseinIman-Eini, MohanadkasemBakhshizadeh. “ Selective harmonic mitigation –pulse-width modulation technique with variable DC-link voltages in single and three –phase cascaded H-bridge inverters.” IET Transaction on Power Electronics, Vol- 7 , Issue- 4 , pp – 924-932,2014

10] AnkitaPapriwal, Dr. AmitaMahar, “ Mitigation of Harmonics in Inverter.” IOSR Journal of Engineering (IOSRJEN) , Vol – 2 , Issue – 9 , pp- 98-105, Sept – 2012 .

11] Sharana Reddy, B. Basavaraja , “ Simulation and Analysis of Common Mode Voltage in 2 Level and multilevel Inverter Fed Induction Motor Drive with Long Cable.” International Journal of Engineering and Advanced Technology (IJEAT), Vol- 2 , Issue- 2, PP- 406-410, Dec-2012 .

12] S.jaisiva,sSneelan,T.ilansezhian.” Harmonic analysis in non – linear loads of power system,International Research Journal of Engineering and Technology (IRJET),Volume: 03 Issue: 05 May-2016, PP1474-1478.

13] Dr. R.A.Keswani ,Prof.U.E.Hiwase , "MRA analysis for faults identification in multilevel inverter" International Research Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 06 June-2017, e-ISSN: 2395 -0056, p-ISSN: 2395-0072 , P.No 2168-2171.

14] S.C.Rangari , H.M.Suryawanshi ,Bhavika Shah , "Effect of inverter switching frequency on the stator current harmonics of five phase induction motor" IEEE 2017 International Conference on Energy Communication , Data Analytics and Soft Computing , 1-2 Aug 2017.

15] P. Farhadi, F. A. Baroogh and M. Gheydi, "Comparative study of conventional SVPWM algorithms in terms of producing harmonics and the effect of the harmonics on induction motor," IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), Milan, 2017, pp. 1-5.doi:10.1109/EEEIC.2017.7977716.

16] Adrian STOICESCU* , , Paul PĂDURE , Cristinel HĂRĂGUŢĂ , Mariana MANEA ," Methodologies of MeasuringMechanical Power Delivered at the Shaft of an Induction Motor Driven by VFD" INCAS BULLETIN, Volume 4, Issue 4/ 2012, pp. 161–170,ISSN 2066 – 8201.

17] Marzoughi, Alinaghi & Burgos, Rolando &Boroyevich, Dushan&Xue, Yaosuo. (2017). "Design and Comparison of Cascaded H-Bridge, Modular Multilevel Converter, and 5-L Active Neutral Point Clamped Topologies for Motor Drive Applications." IEEE Transactions on Industry Applications. PP. 1-1. 10.1109/TIA.2017.2767538

18] Monika Gairol, Mr.Sandeep Singh Negi ," Performance Analysis of Induction Motor Drive using Different Cascaded H-Bridge Multilevel Inverter Topology." International Research Journal of Engineering and Technology (IRJET) Volume: 06 Issue: 02 , Feb 2019, ISSN: 2395-0072, PP 603-605 , 2019

19] Abdul Khalique Junejo, 2 Abdul Sattar Saand, 3 Nauman Ali Larik, 4 Muhammad Usman Keerio, (IJCSIS) International Journal of Computer Science and Information Security, Vol. 14, No.8, ," Simulation and Computational Performance of Motor under the Influence of Unbalanced VoltageSupply"PP586-593,August2016