International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-6, Issue-4, December 2016

Performance Analysis of Nine-level DCMLI run Induction Machine using SVM Techniques

Urmila Bandaru, Subba Rayudu Duggupati

***Abstract*— Transformer-less voltage source multilevel converter topologies has the advantage of usage in medium voltage high current applications with reduced harmonic distortion. In this paper a comparative study of constant flux control run induction machine with space vector pulse width modulation controlled nine level diode clamped inverter is presented and analysed.**

***Index Terms*— Constant flux control, Diode clamped inverter, Pulse Width Modulation, Total harmonic distortion.**

I. INTRODUCTION

Multilevel Pulse Width Modulation (PWM) inverters have gained importance in high performance power applications with reduced ratings on individual devices. The output of an MLI exhibits more than two discrete levels. The input dc comprises fuel cells or photovoltaic cells of same energy level or different energy levels. Linearity of output waveform gets improved with amplitude modulation and pulse width modulation. Advantages of multilevel inverters are high voltage capability, reduced switching losses, reduced output dv/dt and good power quality. Three main topologies of multilevel inverters are: diode clamped inverter, flying capacitor inverter, and cascaded inverter [1]-[3]. PWM schemes of multilevel inverters are classified in to two types: multicarrier sub-harmonic PWM and Multicarrier switching frequency optimal pulse width modulation [2], [4], [8]. In this paper a nine-level diode clamped multilevel inverter (DCMLI) fed synchronously rotating reference frame induction machine is simulated. The control techniques open loop constant flux control for induction machine and SVPWM conventional (CS) and optimized switching sequence (OS) for nine-level DCMLI are implemented. Single carrier multi-modulation (SCMM) and multicarrier multi-modulation (MCMM) are devised in SVPWM for better performance [10]. The characteristic- total harmonic distortion (THD) is evaluated for performance of induction machine and is compared with existing model developed by V K Tripathi- May 2016. MATLAB/ SIMULINK environment is used for simulation.

II. PWM METHODS FOR MULTILEVEL INVERTER

The two basic approaches used to generate the PWM signals for multilevel inverters are:

a. Sub-Oscillation carrier based PWM- modulating waveform comparison with offset triangular carriers

b. SVPWM- space vector modulation based on a rotating vector in multilevel space

The maximum fundamental voltage that the SPWM inverter can output (without resorting to over-modulation) is only 78.5% of voltage output by a square-wave inverter. The zero sequence modification made by SFOPWM technique restricts its use to three phase three wire system; however it enables modulation index to be increased by 15.47% before over modulation or pulse dropping occurs compared to SPWM [7]. The SVPWM technique use required output voltage wave as reference vector rotating in a plane of 360 degrees approximating with near voltage vectors [5], [6].

Amplitude modulation index and frequency modulation index of multilevel inverter are given in (1) and (2) respectively.

$$m_a = A_m / (m-1)A_c \qquad (1)$$

$$m_f = f_c / f_m \qquad (2)$$

Where

m - Number of carrier waves also level of inverter, required for pulse generation.

A_m and f_m are amplitude and frequency of reference wave, a sinusoidal wave respectively

A_c and f_c amplitude of carrier wave, a triangular wave respectively

III. DIODE CLAMPED MULTILEVEL INVERTER

For an N level diode clamped inverter:

Number of levels in line-to-line voltage waveform

$$k=2N-1 \qquad (3)$$

Number of levels in line to load neutral of a star or wye load will be p=2k-1

Number of capacitors required, independent of number of phase, is $N_{cap}=N-1$

Number of clamping diodes per phase is $D_{clamp}=2(N-1)$

The number of possible switch states is $n_{states}=N^{phases}$

and the number of switches in each leg is $S_n=2(N-1)$

A. *Analysis of nine level DCMLI*

A three-phase nine-level diode-clamped inverter is shown in Figure1. Each phase is constituted by 16 switches. Switches S_{a1} through S_{a8} of upper leg form complementary pair with the switches S_{a1}' to S_{a8}' lower leg of the same phase.

Table I shows line to line voltage (V_{AB}) for various switchings'.

Urmila Bandaru, EEE Department, Research Scholar, Rayalaseema University, Kurnool, Andhra Pradesh, India, +919985744913

Duggupati Subba Rayudu, EEE Department, Former Head, G Pulla Reddy Engineering College, JNTUA, Kurnool, Andhra Pradesh, India, +919618151410

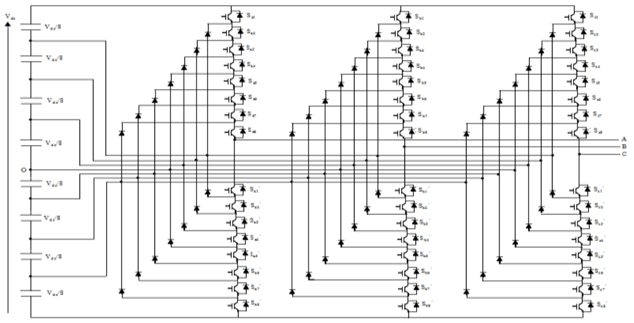

Figure1 Circuit Model of 3 Phase Nine-Level Diode Clamped Inverter

Table I Line Voltage of a Nine-Level Diode Clamped Inverter

S_{a1}	S_{a2}	S_{a3}	S_{a4}	S_{a5}	S_{a6}	S_{a7}	S_{a8}	V_{AB}
1	1	1	1	1	1	1	1	V_{dc}
0	1	1	1	1	1	1	1	$V_{dc}/8$
0	0	1	1	1	1	1	1	$2V_{dc}/8$
0	0	0	1	1	1	1	1	$3V_{dc}/8$
0	0	0	0	1	1	1	1	$4V_{dc}/8$
0	0	0	0	0	1	1	1	$5V_{dc}/8$
0	0	0	0	0	0	1	1	$6V_{dc}/8$
0	0	0	0	0	0	0	1	$7V_{dc}/8$
0	0	0	0	0	0	0	0	0

B. Analysis of induction machine

A three phase induction machine takes 160% of full load current during starting, which cause a severe disturbance to other equipment present in the plant. To reduce this effect in constant V/f control an induction machine is started at low frequencies with increased load torque normally 2.6 to 3.6 times to that of full load torque in industrial applications. At normal modulation index the induction machine runs at rated speed and feeds full load torque to loads. However the machine exhibits high current requirement at all modulation indices to maintain constant speed regulation in constant flux control technique [9].

IV. Simulation Results

Simulation parameter values present in Table II results figures from Figure2 to Figure17 for low and normal modulation indices.

Table II Constant Voltage per Frequency Control Parameter Values

Parameter	Values
Machine Ratings	30 kW, 400 V, 1470 rpm
Dc link voltage, Switching Frequency	400 V, 1.5 kHz
Simulation Time	[0 .4 .8 1.2 1.6 2 2.4 2.8 3.2]
Modulation Index	[0.275 0.5325 0.866 0.866 0.866 0.778 0.618 0.45 0]
Modulating Wave Frequency	[10 30 50 70 90 -45 -35 25 0]
Torque	[100 100 190 100 50 150 -120 -150 0]

Figure2 through Figure5 is the simulated results of CS-SVPWM and Figure6 to Figure9 are for OS-SVPWM at different loads. Figure2 and Figure4 are pole, phase and line voltages at various instants for required torque and speed for conventional switching sequence of MCMM and SCMM. Figure3 and Figure5 is the stator current, electromagnetic torque and rotor speed response of MCMM and SCMM based on industrial mode of operation on induction machine at different instants for torque rise, reversal, speed rise, reversal from low to normal range of mi. For same operating conditions of CS-SVPWM, Figure6 through Figure9 are the simulated results for OS-SVPWM.

Figure10 to Figure17 is the THD of line voltage, stator current for MCMM-CS and OS, SCMM-CS and OS for V/f control at highest normal modulation index of 0.866 and switching frequency of 1.5 kHz.

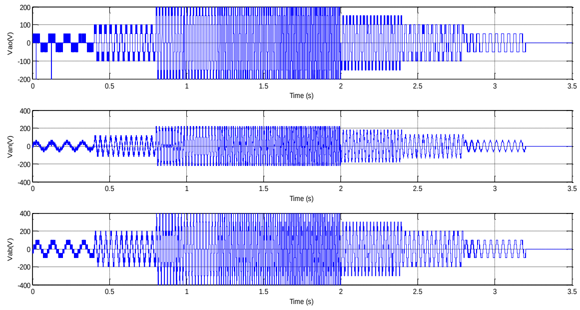

Figure2 CS MCMM Pole, Phase and Line Voltages

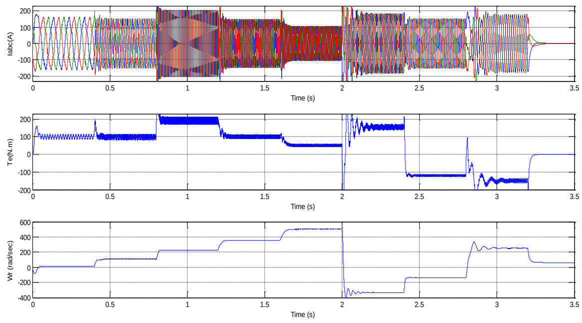

Figure3 CS MCMM Stator Currents, Torque and Speed

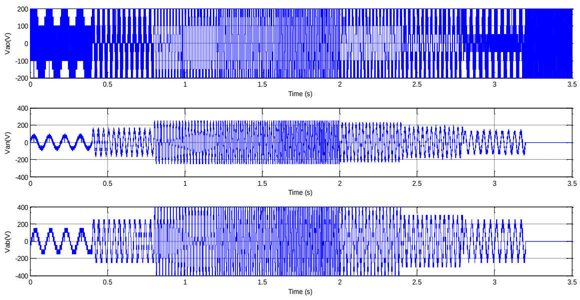

Figure4 CS SCMM Pole, Phase and Line Voltages

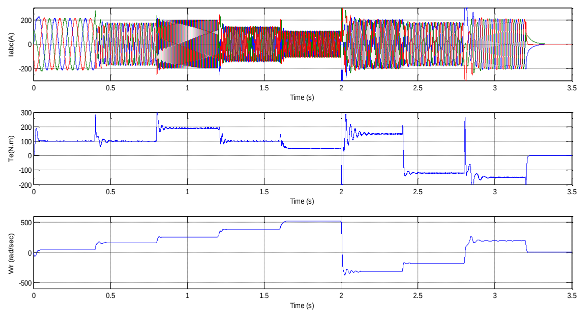

Figure5 CS SCMM Stator Currents, Torque and Speed

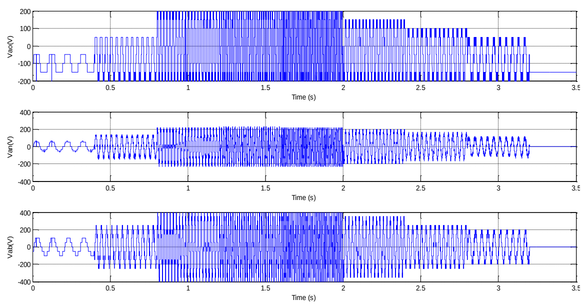

Figure6 OS MCMM Pole, Phase and Line Voltages

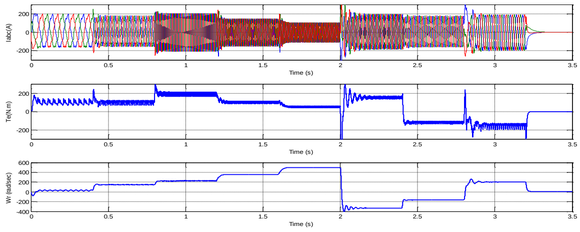

Figure7 OS MCMM Stator Currents, Torque and Speed

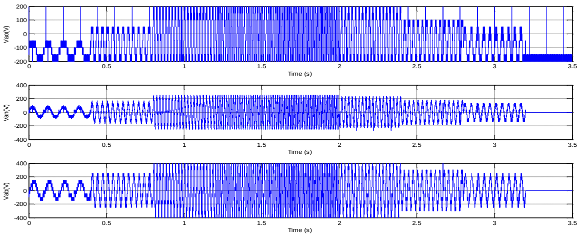

Figure8 OS SCMM Pole, Phase and Line Voltages

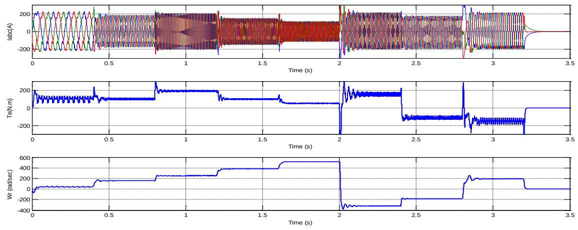

Figure9 OS SCMM Stator Currents, Torque and Speed

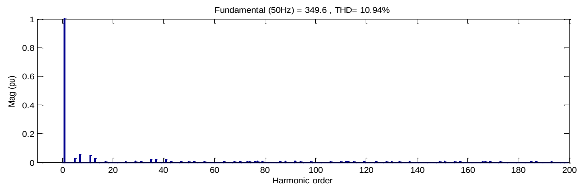

Figure10 CS MCMM Line Voltage THD

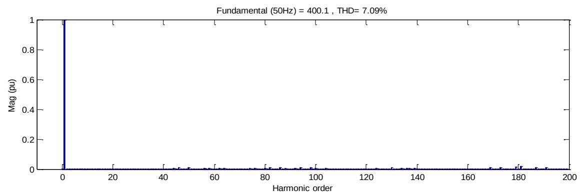

Figure11 CS SCMM Line Voltage THD

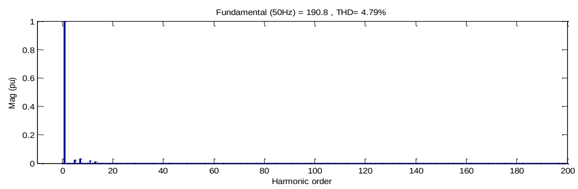

Figure12 CS MCMM Stator Current THD

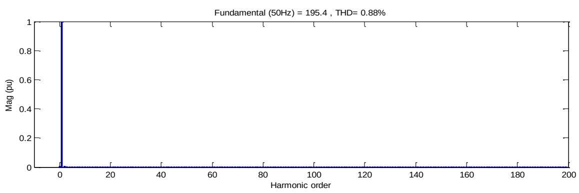

Figure13 CS SCMM Stator Current THD

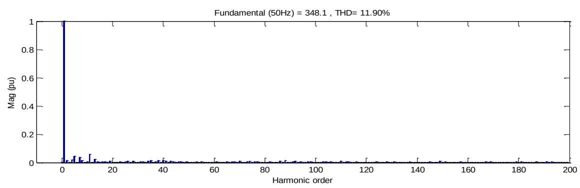

Figure14 OS MCMM Line Voltage THD

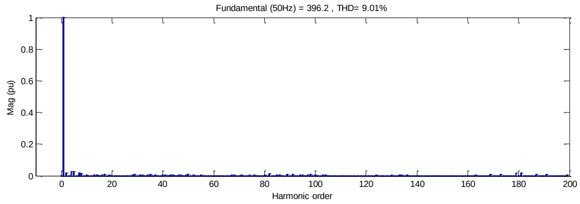

Figure15 OS SCMM Line Voltage THD

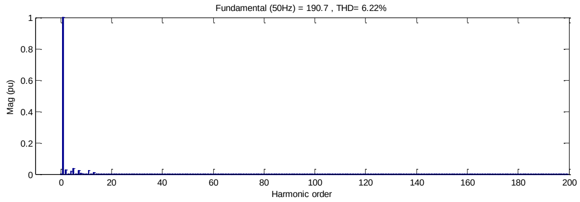

Figure16 OS MCMM Stator Current THD

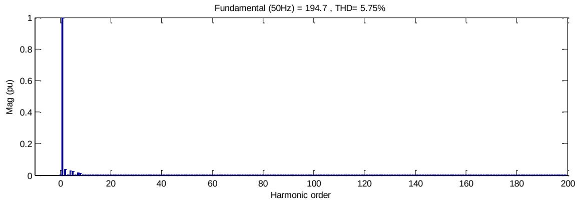

Figure17 OS SCMM Stator Current THD

V. COMPARISON WITH THE EXISTING RESULTS OF OTHER RESEARCHER'S MODEL

In Table III the proposed 9-level DCMLI fed industrial application induction motor simulated results for THD is presented comparing with existing 9-level model simulated by Tripathi [12]. The proposed model has shown better performance over the existing model.

Table III Comparison of the Proposed 9-Level DCMLI with other Researcher's 9-Level DCMLI Model

Performance Parameter THD Value in %	Proposed 9-Level for Industrial Applications				SVPWM 9-level DCMLI [Tripathi et al, May 2016]
	MCMM		SCMM		MCMM
	CS	OS	CS	OS	CS
Voltage THD	*10.94*	11.90	7.09	9.01	*12.87*
Current THD	4.79	6.22	0.88	5.75	Not Available

VI. CONCLUSIONS

1. The conventional switching sequence SCMM show output voltage response at low modulation indices even up to 0.1125 however MCMM do not. This represents SCMM works for low modulation indices.
2. The conventional switching sequence SCMM show more linear output wave with drastic increase in voltage compared to MCMM.
3. The optimized switching sequence improved output voltage response for MCMM compared to conventional switching sequence MCMM at low modulation index of 0.1.
4. In both MCMM and SCMM the THD decreases as modulation index increases from low to normal value. The THD decreases with SCMM compared to MCMM in both CS and OS.
5. In optimized sequence switching losses are decreased instead of THD decrement. For same region number of

switching states reduce to 8 or 10 with optimized sequence compared to conventional sequence with Table2 of Reference [11].

6. In SVPWM at low modulation indices THD is more because of low order harmonics present with instantaneous inequalities in dc sources.
7.

In constant V/f control, required torque is available at the outlet of machine by accessing more stator currents in SVPWM.

APPENDIX

Parameter of 30 kW, 400 V, 4 Pole, 50 Hz Induction Machine

Rr= 0.39;	rotor resistance in ohms
Rs= 0.19;	stator resistance in ohms
Lls= 0.21e-3;	stator winding Leakage Inductance in henrys
Llr= 0.6e-3;	rotor winding Leakage Inductance in henrys
Lm=4e-3;	magnetizing inductance in henrys
p= 4;	number of poles
J= 0.0226;	moment of inertia in Kg-m^2

REFERENCES

[1] José Rodríguez, Jih-Sheng Lai, Fang Zheng Peng "Multilevel Inverters: A Survey of Topologies, Controls, and Applications", *IEEE Transactions*, Vol. 49, No. 4, August 2002.

[2] G.Carrara, S.Gardella, M.Marchesoni, R.Salutari And G.Sciutto, "A New Multilevel PWM Method: A Theoretical Analysis", *IEEE Transactions on Power Electronics*, Vol. 7, No. 3, July 1992, pp.497-505.

[3] A. Nabae, I. Takahashi, H. Akagi. "A Neutral-Point Clamped PWM Inverter", *IEEE Tranactions on Industrial Applications*, Vol.-17, No. 5, 1981, pp. 518-523.

[4] B.Urmila and D. Subba Rayudu, "Design of Multilevel Inverter driven Induction Machine" Innovative Systems Design and Engineering, ISSN 2222-2871, Volume 2, No.6, Oct-2011, pp. 86-97.

[5] J. S. Lai And F. Z. Peng, "Multilevel converters—a new breed of power converters," *IEEE Tranactions on Industrial Applications*, Vol. 32, pp. 509–517, May/June 1996.

[6] J. Holtz, "Pulsewidth modulation-A Survey," *IEEE Trans. Ind. Electron*, Vol. 39, pp. 410–420, Oct. 1992.

[7] J.K. Steinke, "Control strategy for a three phase ac traction drive with a 3-level GTO PWM inverter", *IEEE PESC*, 1988, pp. 431-438.

[8] Leon M. Tolbert, Fang Z. Peng, Thomas G. Habetler, "Novel Multilevel Inverter Carrier-Based PWM" *IEEE IAS 1998*, Missouri, Oct 10-15, 1998, pp. 1424-1431.

[9] Chookiat Nitayotan, Woravit Tearwattanarattikal, Surapong Suwankawin, Somboon Sangwongwanich, "Enhancement of the Performance of General-Purpose V/f Inverters with Automatic Torque Boost and Automatic Adjustment Method of Acceleration/Deceleration Times", *The 2005 International Power Electronics Conference*, pp. 390-397.

[10] Nguyen Van Nho, Myung Joong Youn "A Single Carrier Multi-Modulation Method In Multilevel Inverters", *JPE* 5-1-10, *Journal of Power Electronics*, Vol. 5, No. 1, January 2005, pp. 76-82.

[11] B.Urmila, D. Subba Rayudu , "Constant V/f Control on Induction Machine Fed by SVPWM Run Nine-Level Diode Clamped Inverter", *International Conference on Innovations in Electrical and Electronics Engineering (ICIEEE-2014,)* ISBN: 978-93-82163-55-8 September 5-6, 2014, pp.327-332.

[12] Abhay Kumar, Vinay Kumar Tripathi "Performance & Analysis of Grid Connected Renewable Energy System with Multilevel NPC Inverter", *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*, Vol. 4, Issue.6, pp.305-311, May 2016.

Urmila Bandaru received M.Tech. from S.K.University in 2008. Her research interests include power electronics, ac drives, nanotechnology, micro electronics and electrical science of human body. Her services include Editorial member of various journals, reviewer for various journals, conferences and membership in IEEE.

Subba Rayudu D received his M.Sc (Engg) degree from Madras University in 1962 and Ph.D degree from Indian Institute of Technology, Madras, India in1977. His research interests include Electrical machines, Power Electronics, Analog Electronics and Integrated circuit applications.