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Analysis and Control of Three Phase Multi level Inverters with Sinusoidal PWM Feeding Balanced Loads Using MATLAB

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Abstract— Multi level inverters are becoming very attractive for industries due to their high power rating, high voltage rating and high efficiency is achieved without transformer. These also improves the overall performance of the system as these produces fewer harmonics. As the number of levels increases the quality of voltage waveform is also increases. In this paper the analysis of Three Phase Diode Clamped Multi Level Inverter has been carried out in MATLAB/Simulink for different levels (3, 5 and 7) at varying loads. Diode-Clamped topology for Multi level inverter (DC-MLI) for different levels are analyzed in the terms of THD contents for output voltage and as well in output current. Sinusoidal PWM Technique is used to generate the gate pulses. The simulation of three phase three level, five level and seven level inverters is done in Matlab/Simulink.

I. INTRODUCTION

In multilevel inverters the main dc supply voltage is divided into several smaller sources which are further used to synthesize an ac voltage source into a staircase or stepped approximation of the desired sinusoidal waveform. The multilevel inverters combine the individual dc sources at particular times to make a sine wave. And by using more levels to synthesize the sine waveform, the waveform approaches the desired sine and the total THD is reduced to nearly zero.

Types of Multi level inverters

Mainly three types of Multi level inverters are there:

- Diode-Clamped inverter
- Flying Capacitor inverter
- Cascaded inverter

In this paper Diode-Clamped topology for Multi level inverter [10] is used. The simplest form of this topology is also known as the neutral point clamped converter. In this there are two pairs of switches (upper and lower).

For an 'M- level' Diode Clamped-Multi-Level Inverter:-

No. of Power Semi-Conductor Switches per phase = 2(m-1)

Clamping diodes per phase = (m-1) (m-2)

DC bus capacitors = (m-1)

Where m= No. of levels

The main role of capacitors is to divide the main dc voltage into smaller voltages i.e. for five level it is V_{dc}, ½ $V_{dc,}$ 0, -½ V_{dc} and -V_{dc}.

Diode-Clamped topology for Multi level inverter (DC-MLI) has a number of advantages some of them are as follows:

- The THD decreases with the increase in number of level.
- Common DC bus is used for all the phases.
- Flow of Reactive power can be controlled.

- Control scheme is quite simple.

II. MODULATION TECHNIQUE

The control of Multi level Inverter is much complicated as compared to two level Voltage source Inverter because extra need for the timing transitions between the voltage levels. Sinusoidal PWM, Space Vector Modulation and Harmonics Elimination PWM are some of the main modulation techniques for Multi level Inverter but Sinusoidal PWM is found the most popular method. The Space Vector Modulation and Harmonics Elimination PWM are used for some specific applications.

In Sinusoidal PWM, comparison of Reference (Sine) with Triangular waves (N-1) are done. The resulting intersection points are used as the switching instants of PWM pulses as shown in Figure 1.

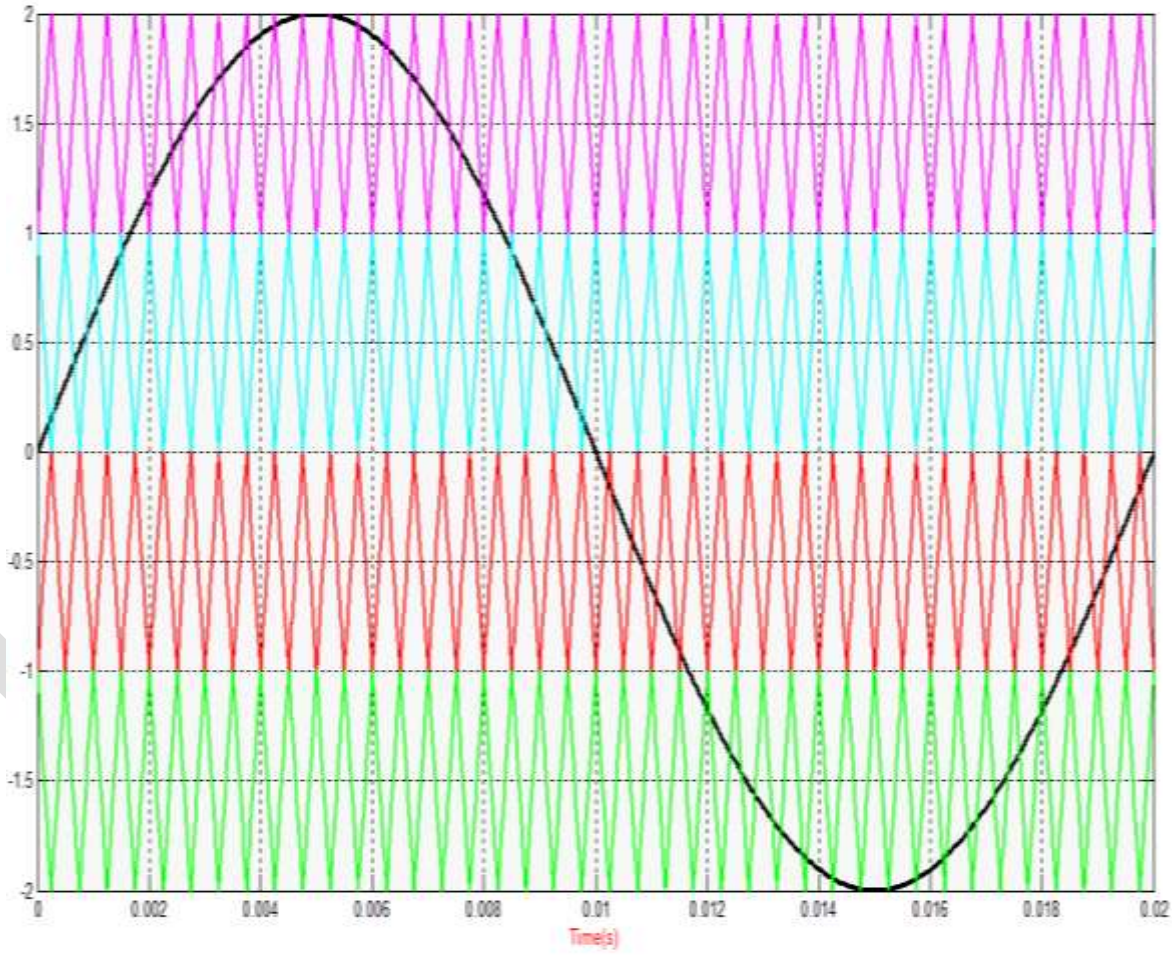

Figure 1 Comparison of Triangular Waves with Sine Wave

III. MATLAB SIMULATION

The main objective of this paper is to generate the gate pulses for the thyristors used in the Diode-Clamped Inverter. The gate pulses are generated by the SPWM method. When we compare the two waves i.e. Sine and Triangular, the pulses are generated which are further used to control the VSI. Matlab Simulation of 5- Level Diode-Clamped Inverter is shown in figure 2

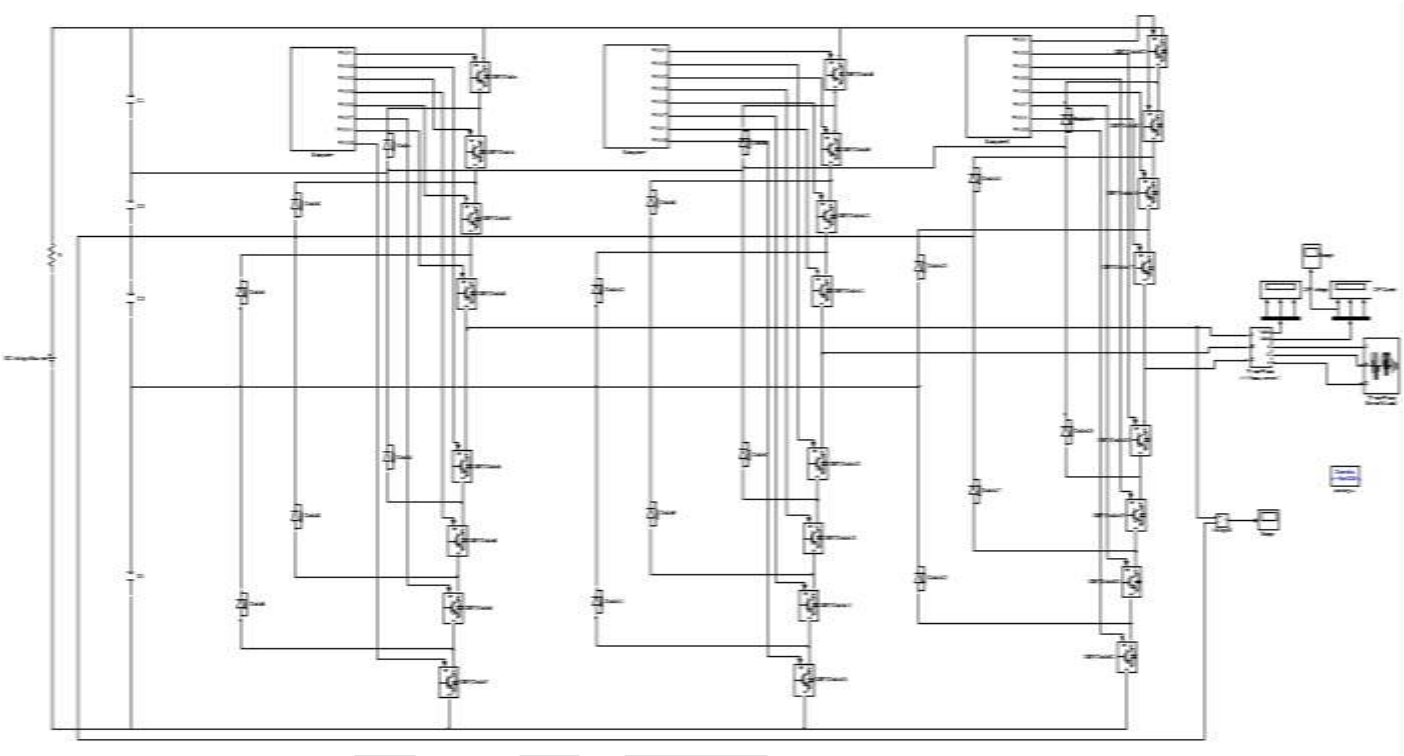

Figure 2 Matlab Simulation of 5- Level Diode-Clamped Inverter

IV. SIMULATION RESULTS

Different Level Inverters are analyzed for different values of loads. R-L load is taken for all the outputs and the power factor is taken as 0.8.

A. Output Phase Voltage of 3-Level Inverter

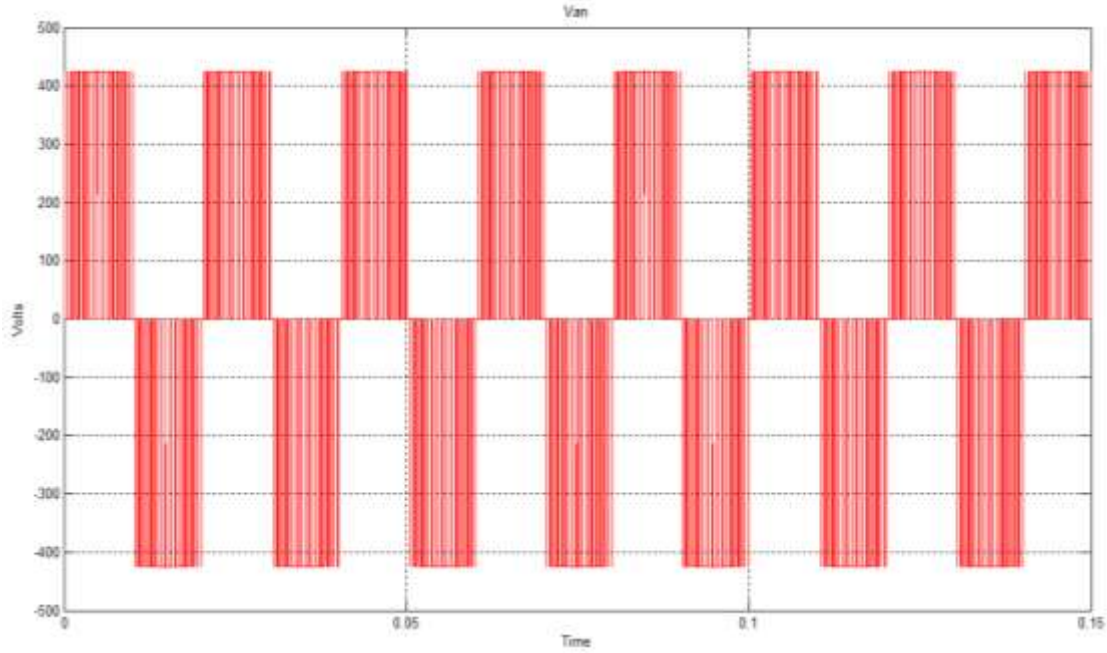

Figure 3. Output Phase Voltage of 3-Level Inverter

B. Output Current of 3-Level Inverter at 1 KW

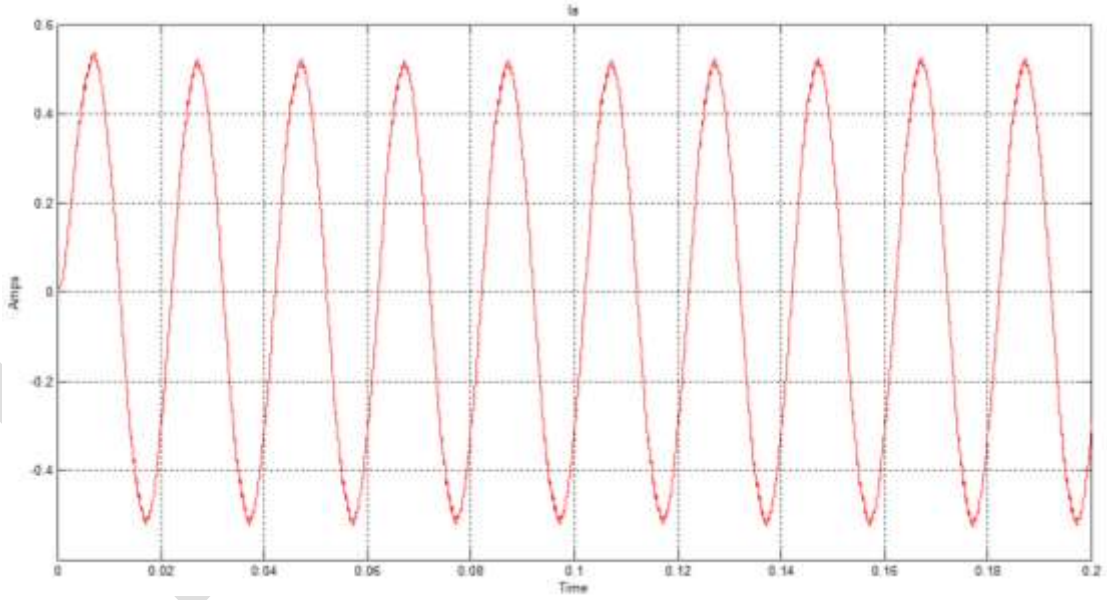

Figure 4. Output Current of 3-Level Inverter at 1 KW

C. Output Phase Voltage of 5-Level Inverter

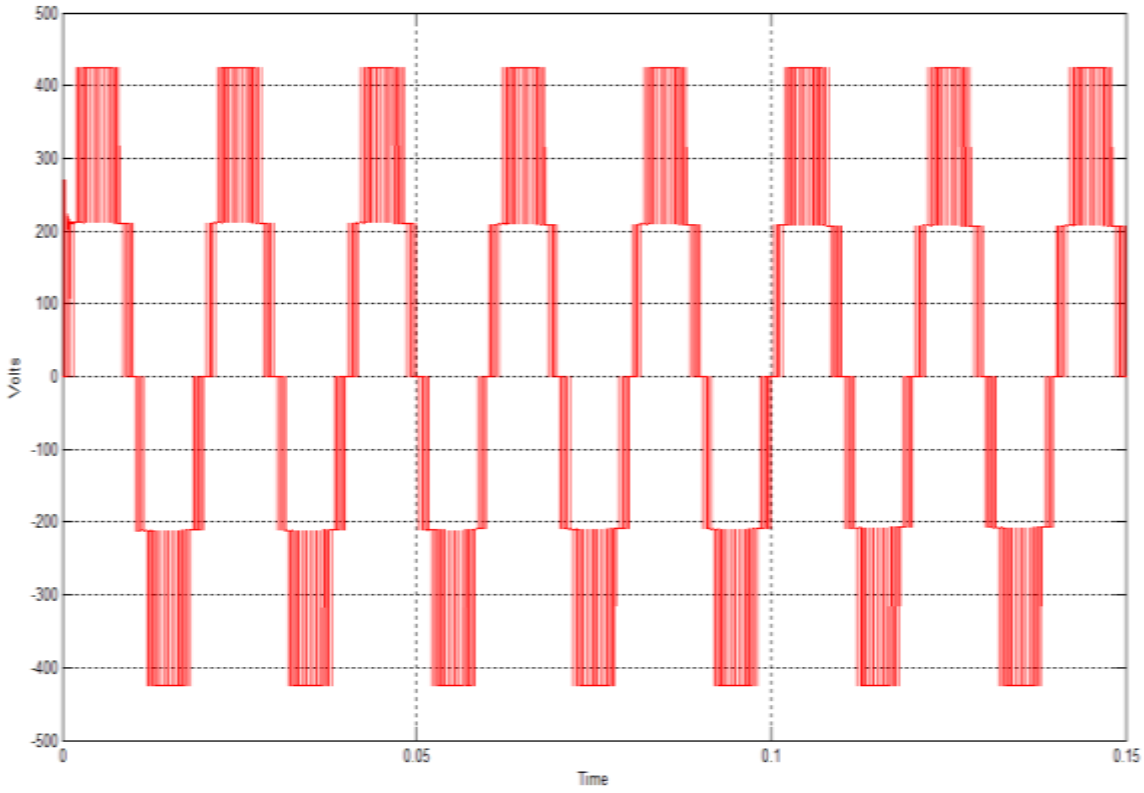

Figure 5. Output Phase Voltage of 5-Level Inverter

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D. Output Current of 5-Level Inverter at 1 KW

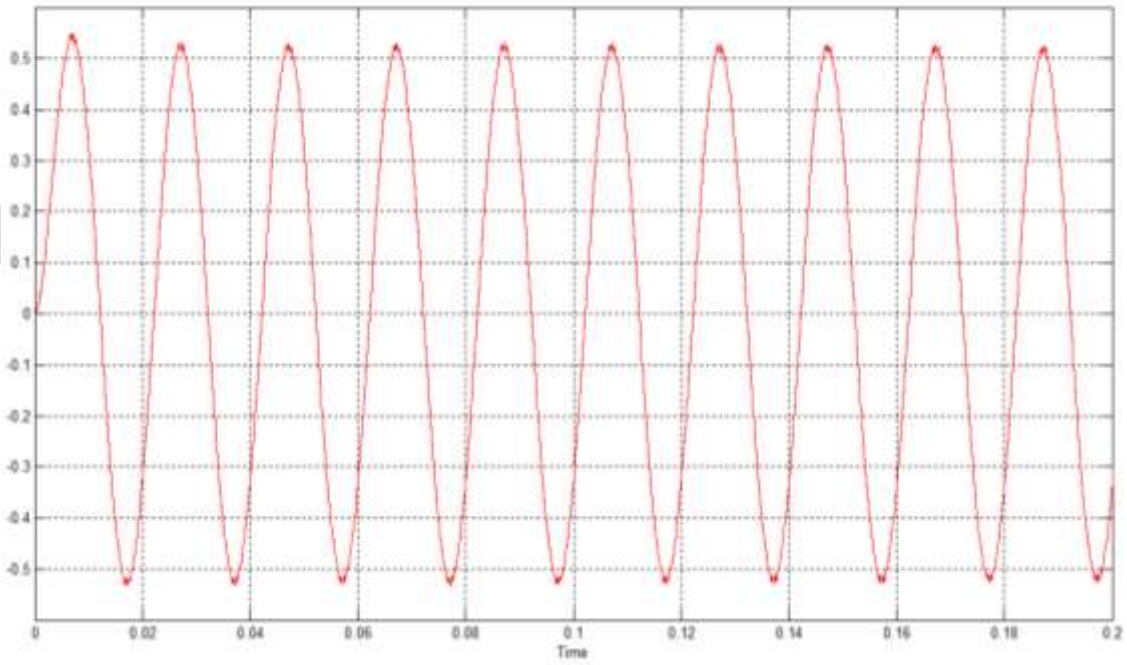

Figure 6. Output Current of 5-Level Inverter at 1 KW

E. Output Phase Voltage of 7-Level Inverter

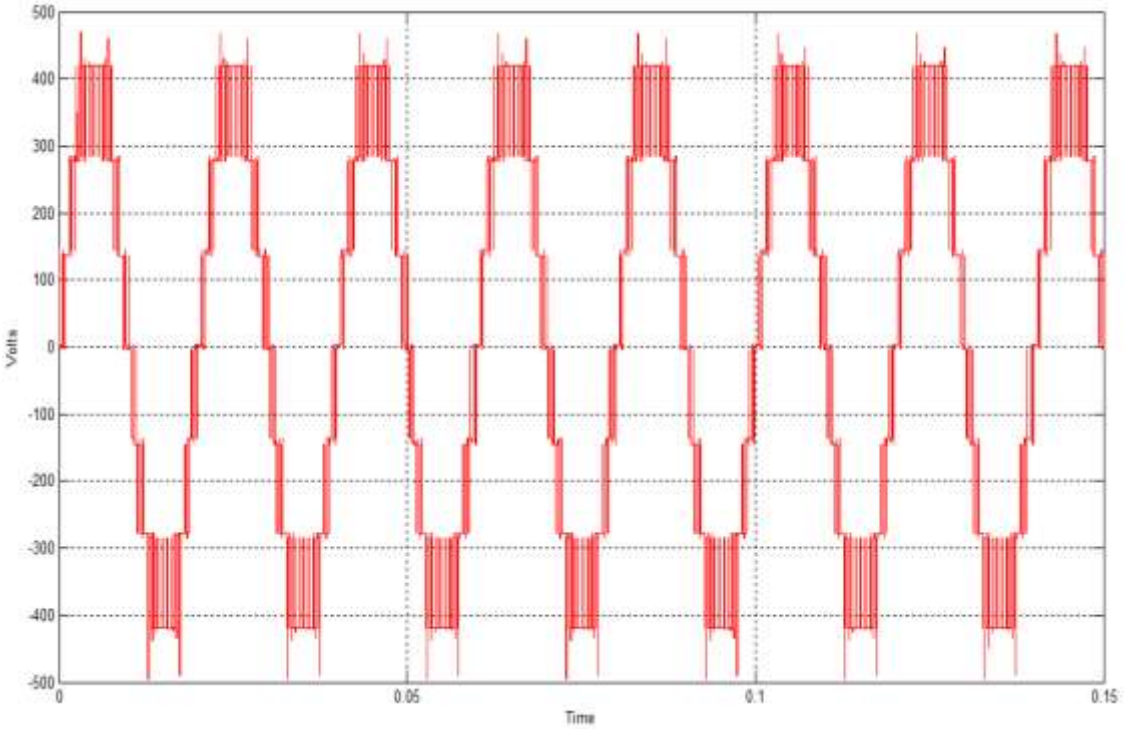

Figure 7. Output Phase Voltage of 7-Level Inverter

F. Output Current of 7-Level Inverter at 1 KW

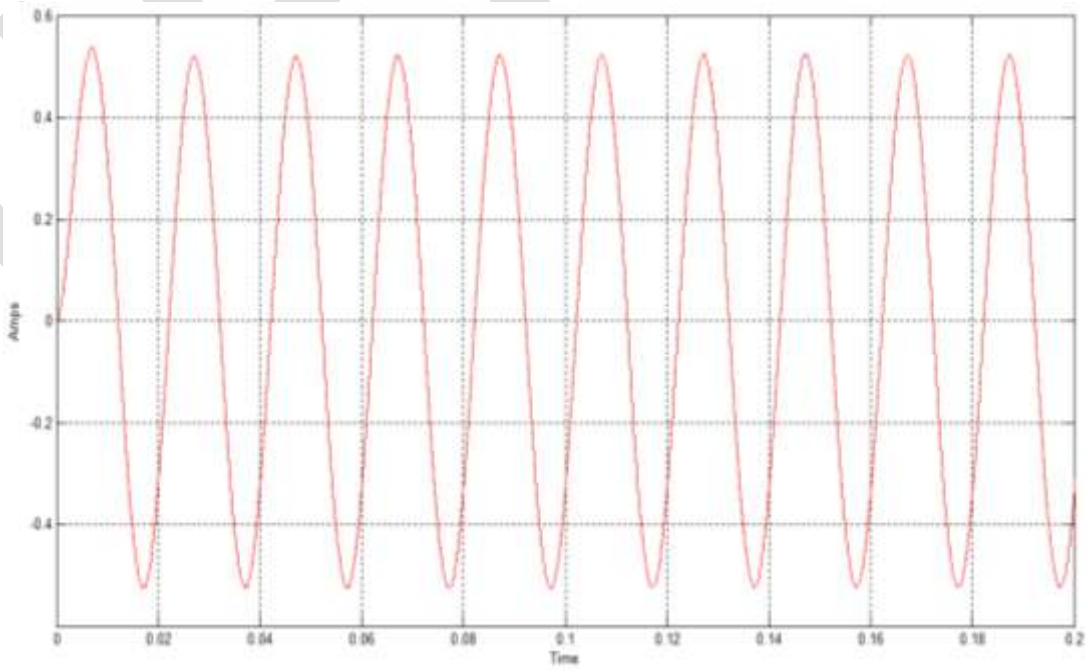

Figure 8. Output Current of 7-Level Inverter at 1 KW

V. RESULTS

The THD for output voltages and output currents is summarized in the tables. Table 1 shows the comparison of the THD of Output Currents of different Levels at different loads. And Table 2 shows the comparison of the THD of Output Voltages of different Levels at different loads.

Table No.1

Load / Level		1 KW	3 KW	5 KW	7 KW	9 KW
3-Level Inverter	Current	0.5115	1.534	2.556	3.578	4.6
	THD	1.99 %	1.99 %	1.99 %	1.99 %	1.99 %
5-Level Inverter	Current	0.5214	1.534	2.509	3.447	4.348
	THD	1.14 %	1.26 %	1.40 %	1.56 %	1.73 %
7-Level Inverter	Current	0.5227	1.563	2.602	3.641	4.678
	THD	0.55 %	0.55 %	0.54 %	0.53 %	0.53 %

Table No.2

Load / Level		1 KW	3 KW	5 KW	7 KW	9 KW
3-Level Inverter	Voltage	410.8	410.6	410.5	410.5	410.4
	THD	57.19 %	57.27 %	57.27 %	57.27 %	57.26 %
5-Level Inverter	Voltage	417.7	409.5	401.5	393.8	386.34
	THD	28.12 %	29.69 %	31.57 %	33.74 %	36.22 %
7-Level Inverter	Voltage	418.5	417.2	416.7	416.4	416.2
	THD	18.80 %	19.41 %	19.52 %	19.54 %	19.55 %

VI. CONCLUSION

This paper has evaluated the Sinusoidal PWM technique for Diode-Clamped Multi level. In this paper, Simulink model for same has been developed and tested in the MATLAB/Simulink environment for different values of Loads. The simulation results are compared and analyzed by plotting the output harmonic spectra of various output Currents and output Voltages and computing their Total Harmonic Distortion (THD) and their final comparison is shown in Tables. It is observed that with the increase of level the THD of output current and voltage decreases. THD of load currents at all levels is less than 5 % shows the durability of design of this multilevel inverter. It is clear from the comparison that the Harmonics are reduced as the number of Levels increases and hence the overall system efficiency increases.

REFERENCES:

[1] Tim Cunnyungham, "Cascaded Multilevel Inverter for Large Hybrid Electric Vehicle Applications with Variant DC Sources", A thesis presented for the Master of Science degree, The University of Tennessee, Knoxville, May 2001.

[2] T1hami Colak, Ersan Kabalci, and Seref Sagiroglu, "The Design and Analysis of a 5-Level Cascaded Voltage Source Inverter with Low THO," Lisbon, Portugal, pp.575-580, March 18-20, 2009.

[3] Calais, M.; Borle, L.J.; Agelidis, V.G., Analysis of multicarrier PWM methods for a single-phase five level inverter, Power Electronics Specialists Conference, PESC.2001 IEEE 32nd Annual, Volume 3, Issue , 2001. Pp: 1351 – 1356.

[4] Nabae A., Takahashi I., Agaki H., *A New Neutral-Point-Clamped PWM, Inverter*, IEEE Transactions on Industry Applications, Vol. IA-17, No. 5, Sep.-Oct., 1981.

[5] D.G. Holmes, T.A.Lipo," Modern Pulse Width Modulation Techniques for Power Converter", IEEE Press, 2003

[6] Rajesh Kr Ahuja, Lalit Aggarwal, Pankaj Kumar "Simulation of Single Phase Multilevel Inverters with Simple Control Strategy Using MATLAB", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 10, October 2013

[7] B.P.Mcgrath and D.G Holmes "reduced n PWM harmonic distortion for multi level inverters operating over a wide modulation range" IEEE Transactions on power electronics vol 21 no 4 pp941-949, july 2006.

[8] Zainal Salam and Junaidi Aziz "Derivation of Switching Angles of the Cascaded Multilevel Voltage Source Inverter Subjected to a New Pulse Width Modulation Scheme", *The Institution of Engineers, Malaysia, Vol. 72, No.3, September 2009.*

[9] Rajesh Kumar Ahuja, Amit kumar ""Analysis, Design and Control of Sinusoidal PWM Three Phase Voltage Source Inverter Feeding Balanced Loads at Different Carrier Frequencies Using MATLAB" in IJAREEIE, Volume 3, Issue 5, May 2014

[10] Tim Cunnyngham "Cascade Multilevel Inverters for Large Hybrid-Electric Vehicle Applications with Variant Dc Sources", M.S. thesis, The University of Tennessee, Knoxville, 2001.

[11] Maheswari, S. Mahendran, Dr. I. Gnanambal, "Implementation of Fundamental Frequency Switching Scheme on Multi –Level Cascaded H-Bridge Inverter Fed Three Phase Induction Motor Drive" Wulfenia journal, Klangfurt Austria, Vol 19, No. 8, pp10-24,2012.

[12] N. Celanovic and D. Boroyevich, "A comprehensive study of neutral-point voltage balancing problem in three level neutral-point-clamped voltage source PWM inverters ". *IEEE Transactions on Power Electronics*, Vol. 15, No. 2, pp. 242–249,2000.

[13] Y.R. Manjunatha, M.Y. Sanavullah, "Generation of equal step multilevel inverter output using two unequal batteries", International Journal of Electrical and Power Engineering, Vol.1, Issue 2, pp. 206-209,2007.

[14] M. Ayadi, L. El Mbeki, M. A. Fakhfakh, M. Ghariani, R. Nazi, "A Comparison of PWM Strategies for Multilevel Cascaded and Classical Inverters Applied to the Vectorial Control of Asynchronous Machine", International Review of Electrical Engineering , Vol. 5, No.5, pp.2106-2114 September-October 2010.

[15] R. Lund, M. D. Manjrekar, P. Steimer , T. A. Lipo, "Control strategies for a hybrid seven-level inverter", *in Proceedings of the European Power Electronic Conference*, Lausanne, Switzerland, Sep 2009.

[16] V.Kumar Chinnaiyan, Dr. Jovitha Jerome, J. Karpagam, and T. Suresh, "Control techniques for Multilevel Voltage Source Inverters," in *Proceedings of The 8th International Power Engineering Conference (IPEC 2007)*, Singapore, pp. 1023-1028,3-6 Dec 2007.

S. K. Pillai, A first course on electrical drives, 2nd ed., New Age International Publishers, 2004