THD Analysis of Multilevel Inverter with Different Loads

Siji Chacko[1], Dr.Jaimol Thomas[2]

M.Tech Student, Dept. of EEE, SAINTGITS College of Engineering, Pathamuttom, India[1]

Professor, Dept. of EEE, SAINTGITS College of Engineering, Pathamuttom, India[2]

ABSTRACT: Multilevel inverters got a lot of attention in recent years because its ability to generate staircase waveform which is more close to pure sinusoidal waveform. It has lot of applications in industries, FACTS devices, vehicle propulsion etc where power quality is more important. Instead of using higher rating semiconductor devices it uses some combinations of small rating semiconductor devices. It has several advantages such as less THD (Total Harmonic Distortion), reduced Electro Magnetic Interference (EMI), lower switching stresses and increased voltage capability. In this paper reversing voltage type multilevel inverter is modelled and THD analyses with different loads are done. The multilevel inverter used in this paper has two parts; one operated at high frequency (Level generation part) and other operated at line frequency (polarity generation part). The switching loss can be reduced to some extend by the use of polarity generation part. These types of inverters are appropriate choice for all type of loads and resultant THD with each type of loads are analysed. Simulations has been carried out in MATLAB/SIMULINK

KEYWORDS: Electro Magnetic Interference, FACTS, Total Harmonic Distortion, MATLAB

Conventional transformer with multilevel inverter, H-bridge modules are connected to single dc source in parallel and secondary of single phase transformers are connected in series. But in [4] primary of three phase transformers connected to H bridge secondary is connected in series. But it is not suitable for variable frequency application. In [5] and [6], the multilevel output is generated with a multi winding transformer. But, the design and manufacturing of a multi winding transformer are difficult and costly for high power applications

This paper introduces an RV topology which uses less number of components that is mainly switches and its associated gate drives. One part works at fundamental frequency so the losses also reduced. It requires lesser number of carrier signals which reduces the complexity of control circuitary.

I. MULTILEVEL INVERTER

Multilevel inverters have different topologies. Main topologies are diode clamped type, flying capacitor type and cascaded H bridge type [7].

A. Proposed Multilevel Inverter

In conventional multilevel topologies, the power semiconductor switches are combined to produce an output in positive and negative polarities. In this topology there is no need to utilize all the switches for generating bipolar levels.

This topology separates the output voltage into two parts. One part is called level generation part and is responsible for level generating in positive polarity. Level generation part requires high frequency switches to generate the required levels. The other part is named polarity generation part and is responsible for generating the polarity of the output voltage. This part is the low-frequency part operating at line frequency.

Fig.1 shows Schematic diagram of a single phase eleven levels reverse voltage topology. This topology easily extends to higher voltage levels by adding the middle stage. To the H-Bridge we add each stage according to the number of

levels. So it's called advanced H-bridge type. This topology is modular and can be easily increased to higher voltage levels by duplicating the middle stage.
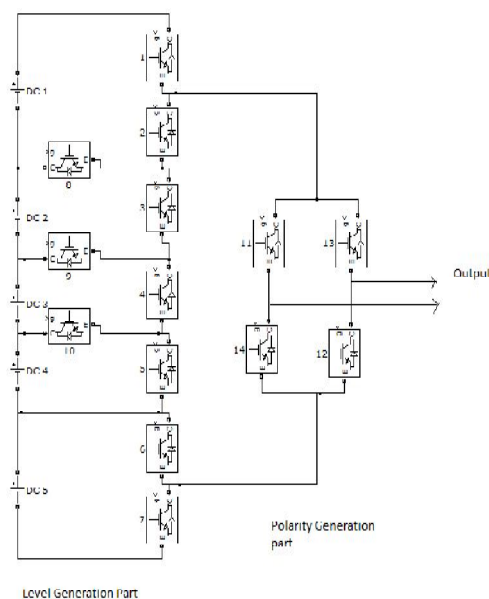

Figure 1: Single Phase Eleven Level Proposed Topology

This requires fewer switches in comparison to conventional inverters. It is also applied to three phase application. Isolated DC source are needed. It just requires half of the conventional carriers for SPWM controller. SPWM for Eleven-level conventional converters consists of ten carriers, but here, five carriers are needed. The reason is that the multilevel converter works only in positive polarity. To generate polarity, the positive voltage is fed to the full bridge.

Multilevel inverter control is implemented using reduced number of carriers, which is a great improvement. Proposed topology does not need fast switches for the polarity generation part.

A. Modes of Operation
There are ten possible switching patterns to control the multilevel inverter, shown in Table 1. In order to avoid unwanted voltage levels, the switching modes should be selected so that the switching transitions become minimal during each mode transfer. This will minimize switching power dissipation

TABLE I: Modes of Operation

LEVEL MODE	0	V_{dc}	$2V_{dc}$	$3V_{dc}$	$4V_{dc}$	$5V_{dc}$
1	2,3,4,5,6	1,3,4,5,6,8	1,4,5,6,9	1,10,5,6	1,6	1,7
2		2,3,4,5,7	2,3,4,10,7	2,3,9,7	2,7	

II. CONTROL STRATEGY

The carrier based PWM technique fulfils the on and off states of the switches by comparing a modulating signal Vm (sinusoidal) and a triangular waveform V_c (carrier signal). The modulating signal is a sinusoidal at frequency Fm and amplitude Vm and the carrier signal is at frequency F_c and amplitude V_c. This is the sinusoidal PWM (SPWM) method.

The modulation index is defined as,

$$m_a = \frac{V_c}{V_m} \qquad (1)$$

and the normalized carrier frequency is ,

$$m_f = \frac{F_c}{F_m} \qquad (2)$$

In this topology phase deposition-SPWM is adopted for its simplicity and the carriers are in phase with each other. Here phase deposition SPWM is used for driving the high frequency switches and low frequency polarity generation part drive signals are generated with the line frequency (50Hz), and they only changes at zero-voltage crossings. Conventional cascaded multilevel inverter uses (n-1) carriers and in the proposed topology carriers for an n level inverter is (n-1) / 2

III. NUMBER OF COMPONENTS

One of the main advantages of this topology is that it requires less high-switching frequency components. The reliability of a system is indirectly proportional to the number of its components. As the number of high-frequency switches is decreased, the reliability of the converter is increased. 2(*N*-1) switching devices are required for an *N* level conventional cascaded H bridge multilevel inverter where *N* is the number of the output voltage level. In this topology only ((N-1) +4) switches are needed for an N level inverter. It can clearly be mentioned that the number of components of this topology is lower than that of other topologies and it will decrease tremendously with higher voltage levels. Switches in the full bridge converter are switched at line frequency.

IV. METHODOLOGY

The eleven-level inverter whose output voltage has eleven values: zero,V_{dc}, $2V_{dc}$, $3V_{dc}$, $4V_{dc}$, $5V_{dc}$,- V_{dc}, $-2V_{dc}$, -3 V_{dc}, $-4V_{dc}$, $-5V_{dc}$ so called an eleven level PWM inverter. This inverter can reduce the harmonic components and the switching stress. Operational principles and switching functions are analyzed. The proposed inverter improves the dynamic performances. PWM signals are generated using PD-SPWM technique. Output voltage obtained was 500 V_{p-p} and 4 KHz is the switching frequency. DC power supplies are adjusted to 50 V

V. SIMULATION RESULTS

Simulation of proposed multilevel inverter (eleven level) is performed using MATLAB. The output waveforms of these are given. All input dc sources are equal. The waveform of proposed multilevel inverter with resistive load is shown in Fig 2. The resulting THD was 10.79 % .

The harmonic spectrum is shown in Fig .3, With a small size filter the THD of output brings to IEEE519 std, for this an inductance of 5 mH an capacitance of 2 µF are used. Current waveforms after using filter is shown in Fig.4 Table.2 shows the number of switches and carrier signals used in cascaded H-bridge and the proposed topology. It should be noted that proposed topology uses less number of switches and carrier signals.
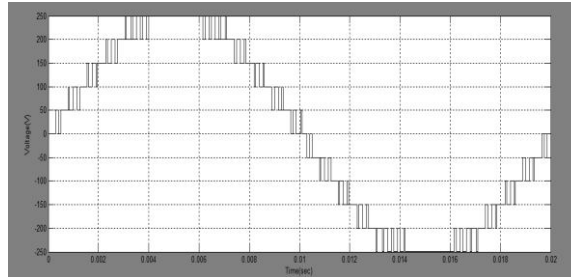
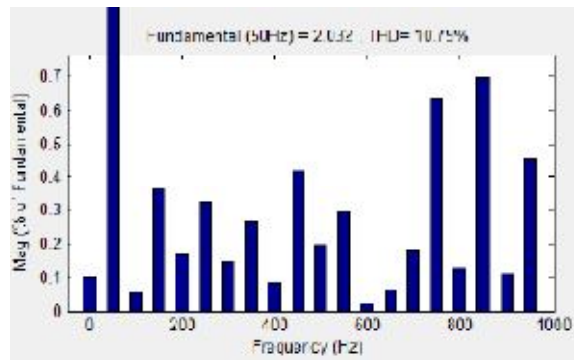Fig.2 Output Voltage Waveform of Eleven Level Inverter

Fig.3 Harmonic Spectrum of Eleven Level Inverter

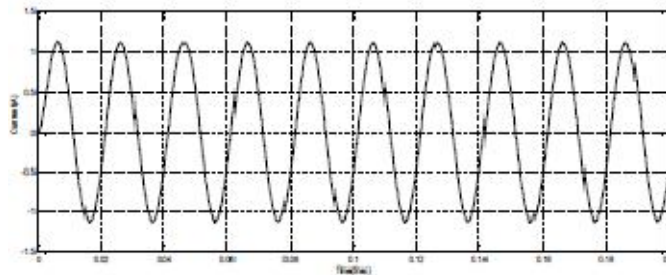Fig.4 Output Current Waveform with filter

TABLE .2 Number Of Components

Components	Cascaded H-Bridge	Proposed Topology
Switches	20	14
Carrier signals	10	5

The THD analysis of these three levels with various loads are conducted and obtained results are shown in Table .3. It shows with increase in number of levels current THD reduces. Inverters with RL(R = 124,L=182 mH) load shows a good improvement in THD than inverters with R load. It is pointed out that the load inductance plays an important role in shaping good quality current waveform. By using filter current THD further get reduced.

Table 7.3: FFT Analysis of current waveform with R load, RL load and R load with filter

Level	Various loads current TIID (%)		
	R load	RL load	R load with filter
seven	17.27	9.85	2.68
nine	13.68	9.32	2.11
eleven	10.79	9.29	1.68

VI. CONCLUSION

Multilevel inverters have been used in many industrial applications like HVDC, FACTS, PV systems, UPS and Industrial drive applications. In the proposed topology switching operations are separated into high and low frequency parts. Instead of using other inverter topology, proposed topology is better for all these applications because it has less control complexities and cost. It also reduces the THD of output to a great extend thus reduces the size of filter too. As the level increases THD of Output reduces. It can be used in applications where quality of output is primary need. The simulation results show the improvement of quality of voltage waveform as level increases. Simulation results with various loads were discussed. All types of loads are works well with this advanced H-Bridge topology.

REFERENCES

[1]   K. Jang-Hwan, S.-K. Sul, and P. N. Enjeti, "A carrier-based PWM method with optimal switching sequence for a multilevel four-leg voltage source inverter," *IEEE   Trans. Ind. Appl.*, vol. 44, no. 4, pp. 1239–1248,Jul./Aug. 2008.
[2]   F. Wang, "Multi-level PWM VSIs," *IEEE Ind. Appl. Mag.*, vol. 10, no. 4,pp. 51–58, Jul./Aug. 2004
[3]   K. Y. Lau, M. F. M. Yousof, S. N. M. Arshad, M. Anwari, andA. H. M. Yatim, "Performance analysis of hybrid photovoltaic/dieselenergy system under Malaysian conditions," *J. Energy*, vol. 35, no. 8,pp. 3245–3255, Aug.
[4]   Y.Suresh , A.K.Panda "Performance of Cascade Multilevel H-Bridge Inverter with Single DC Source by Employing Low Frequency Three-Phase Transformers"
[5]   8. R. Teodorescu, F. Blaabjerg, J. K. Pedersen, E. Cengelci, and P. N. Enjeti, "Multilevel inverter by cascading industrial VSI," *IEEE Trans. Ind. Electron.*, vol. 49, no. 4, pp. 832–838, Aug. 2002
[6]   D. A. B. Zambra, C. Rech, and J. R. Pinheiro, "A comparative analysis between the symmetric and the hybrid asymmetric nine-level series connected H-bridge cells inverter," in *Proc. Eur. Conf. Power Electron. Appl.*,2007, pp. 1–10
[7]   J.-S. Lai and F. Z. Peng, "Multilevel converters-a new breed of power converters," *IEEE Trans. Ind. Appl.*, vol. 32, no. 3, pp. 509–517, May/Jun. 1996