International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.11 No.04, pp 136-144, 2018

A Boosted Voltage Single Phase Five Level Inverter With Reduced Switches

P.Jeyalakshmi, C.R.Balamurugan*

Department of EEE/ Karpagam College of Engineering/Coimbatore, India

Abstract : Multilevel inverters are in big demand for high voltage applications. It is capable of producing voltages with very less harmonics. The proposed multilevel inverter is used to generate voltage of five levels. For producing five level voltage, it needs very less no of switches so that control signal generation is simple in this inverter. Inductance and capacitances are used to boost up the input voltage of inverter. The presented multilevel inverter is constructed and simulated using power electronics tool box of Matlab/Simulink. The output voltage waveform is obtained for various reference waveforms like Sinusoidal, Third Harmonic Injection (THI), Stepped wave reference and Trapezoidal reference. The peak Value of output voltage, RMS value and THD for different references are tabulated and compared.
Keywords : Multilevel Inverter, THD, THI, Trapezoidal reference, Stepped wave reference, PWM

1. Introduction

Multilevel inverters are used to get high voltages with low value of Total harmonic Distortion (THD).For high power applications these are very much used. High value of voltages can be obtained from a single DC source also. For the remaining sources capacitors can be used. Input voltage can be obtained from renewable sources like solar, wind and fuel cell. Multilevel inverters produce a step like waveform. When the number of levels is increased, the output waveform closely resembles sinusoidal waveform and automatically THD value is reduced. Increased THD value makes many unnecessary effects like heating, vibration, uneven changes in speed in the motors which are connected at the output of inverters. So it is mandatory to use a inverter which must be free from harmonics. So that nowadays multilevel inverters are in high demand for various applications. By implementing proper control techniques and without adding any external components the desired, harmonic free output waveform is derived from multilevel inverters. One switch in the presented topology is operated at low switching frequency which in turn reduces the switching stress and switching losses. The only drawback is the proposed topology uses more no of inductors and capacitors which may increase the size of the configuration. Balamurugan et al [1] discussed about different modulation methods including different references like sinusoidal, third harmonic injection (THI), 60 degree and stepped wave which are suitable for H bridge MLI. Hasan et al [2] proposed a new topology of a three-phase half-bridge multilevel inverter which includes two different structures. The experimental and simulation results were compared.

C.R.Balamurugan *et al* /International Journal of ChemTech Research, 2018,11(04): 136-144.

DOI : http://dx.doi.org/10.20902/IJCTR.2018.110416

Balamurugan et al [3] implemented a dspace Based Three Phase Five Level H-Bridge Inverter and analyzed the results for different Inverted Sine Carrier PWM Strategies. Prabaharan and Palanisamy [4] made a comparison of symmetric and asymmetric multilevel inverter which employs reduced no of switches.

Balamurugan et al [5] made an analysis of various Unipolar Inverted Sine Carrier Pulse Width Modulation techniques for the three phase Cascaded Multi Level Inverter and compared the results. Abraham and Benny [6] proposed a new topology of three phase seven level hybrid inverter which consists of three level cascaded H- Bridge and neutral point clamped multilevel inverter. Vinod Kumar et al [7] implemented a single phase five level inverter and compared the results of multicarrier PWM technique with low switching frequency PWM. Sambath et al [8] evaluated the performance of different Multi Carrier PWM Techniques for a Single Phase Five Level H-Bridge Type flying capacitor MLI. A. Shanmuga priyaa et al analyzed the performance of Cascaded Z-Source Multilevel Inverter which employs Third Harmonic Injection PWM technique. Wells et al [10] proposed a new modulation technique which eliminates harmonics without solving any transcendental equations.

2. Power Circuit Diagram For The Proposed Inverter

The proposed inverter uses minimum number of switches and less number of voltage sources. The inverter circuit is shown in fig 1.The suggested multilevel inverter topology has a single DC source and a single switch for producing five level output voltage. Remaining four switches are acting as polarity changing unit. Since the proposed circuit uses less no of sources and switches, the overall cost and weight of the system is reduced. It is easy to generate required no of gate signals when the no of switches are reduced. The presented inverter topology uses the switches S_1, S_2, S_3, S_4 and S_5, S_1 is used for generating five levels and switches S_2 to S_5 is used as a polarity changing unit.

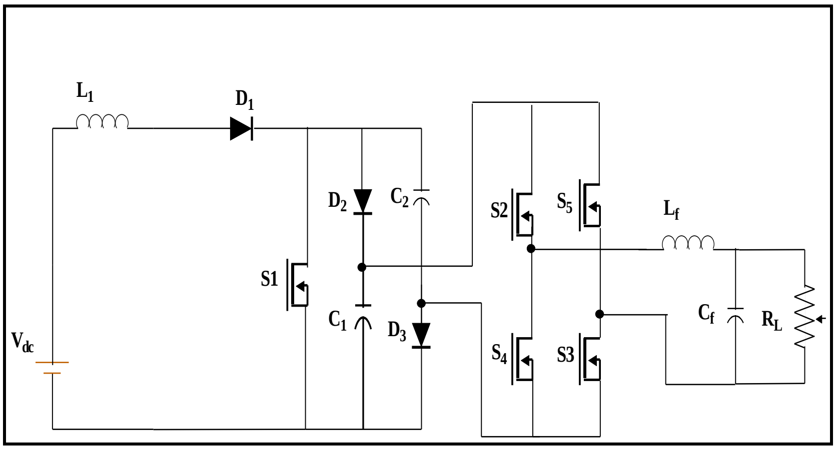

Fig.1. Power circuit diagram of proposed inverter

L_1 is the boosting inductor which is used to boost the input voltage .The boosted input voltage is given as input to the rest of the unit of inverter. Two diode capacitor legs are used in the power circuit diagram. The proposed circuit uses a single source of less value and the rest of the sources are replaced by capacitors. L_f and C_f are the filter components.

Parameters chosen for the proposed inverter are given below.

Switches S_1 to S_5	-	Ideal Switches
Diodes D_1, D_2, D_3	-	Power Diodes
Capacitors C_1=C_2	=	330µf
Filter capacitor C_f	=	38µf
Filter inductance L_f	=	0.8H
Input Inductance L_1	=	2mH
Load resistance R_L	=	200Ω
Input voltage V_{dc}	=	50V
Switching frequency	=	1 KHz

3. Control Strategies of Multilevel Inverter

The proposed multilevel inverter employs different references based pulse width modulation techniques like sinusoidal PWM, Third Harmonic Injection (THI) PWM, Stepped wave PWM and Trapezoidal PWM. In PWM the low frequency reference signal is compared with high switching frequency carrier signal and thereby generates pulses. Depending upon the reference waveform used it is classified as different types. The discussed inverter compares the results of inverter output voltage for various references used for pulse generation.

a) Sinusoidal Pulse width modulation (PWM)

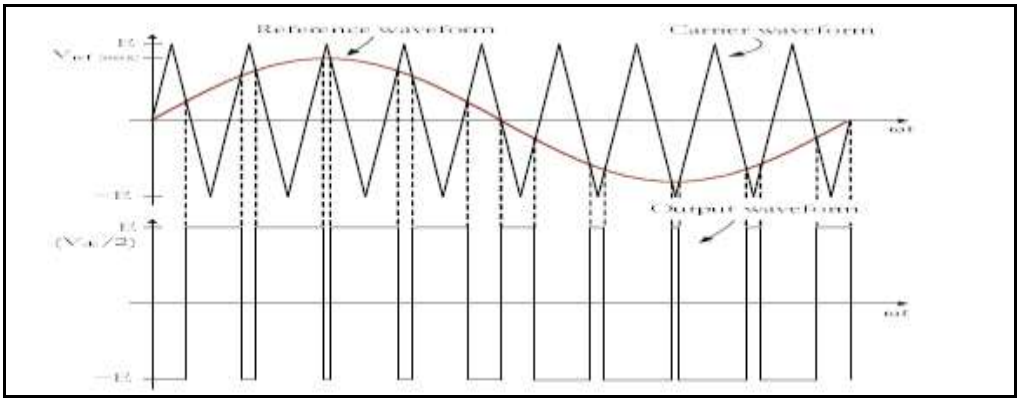

Fig.2 Pulse generation using Sinusoidal PWM

In sinusoidal PWM reference sine wave is compared with high frequency carrier to generate rectangular pulses. This is the most frequently used PWM technique. The comparison of sine and triangular waveform is shown in fig.2.

b) Third Harmonic Injection (THI) PWM

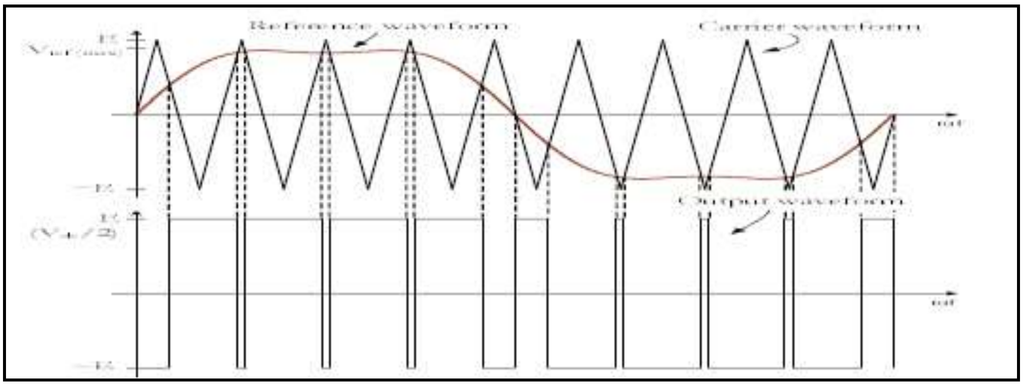

Fig.3 Pulse generation using Third Harmonic Injection PWM

In Third Harmonic Injection PWM the reference waveform is not a pure sinusoidal waveform. The reference waveform is generated by superimposing the fundamental frequency sinusoidal with third harmonic component of sinusoidal waveform. By comparing the high frequency carrier with this superimposed reference signal control signals are generated. Generation of pulses using Third Harmonic Injection PWM method is shown in fig.3.

c) Stepped wave PWM

In Stepped wave PWM, the reference signal is a stepped wave. When this stepped reference is compared with high frequency carrier control signals are generated. This type of control signal generation gives low distortion but higher fundamental amplitude of output. Gate pulse generation using Stepped reference PWM is shown in fig.4.

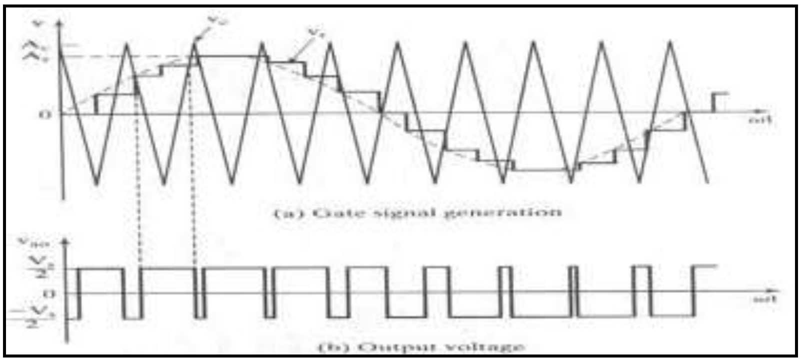

Fig. 4 Pulse generation using Stepped reference PWM

d) Trapezoidal PWM

In Trapezoidal PWM the reference signal is a trapezoidal waveform. By removing the vertex portion of fundamental frequency triangular waveform, trapezoidal waveform is derived. The high frequency triangular carrier signal is now compared with trapezoidal waveform, the control signals are generated. Gate pulses generation for switching devices is shown in fig.5.

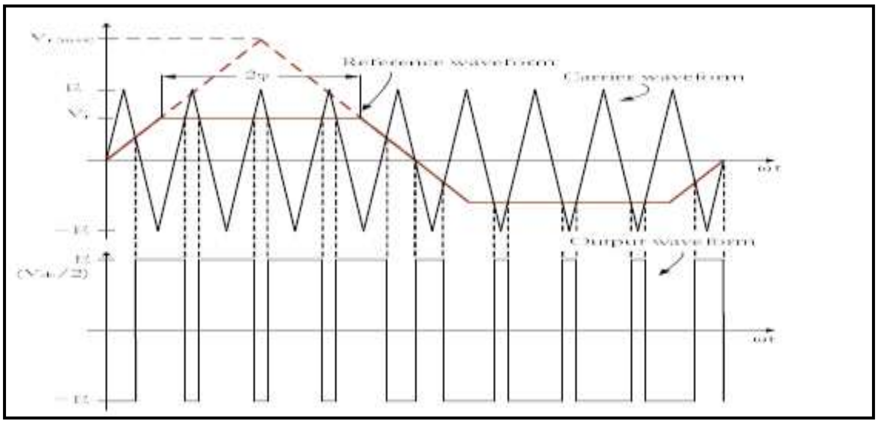

Fig.5 Pulse generation using Trapezoidal PWM

4. Simulation Results

The proposed 5 level MLI is constructed and simulated using MATLAB/SIMULINK. The output voltage waveforms for different modulation indices are analyzed. THD, Peak value of voltage (V_{peak}),RMS output voltage (V_{rms}) are noted for various modulation indices for different references like Sinusoidal, Third Harmonic Injection, Stepped wave and Trapezoidal wave are tabulated below.

THD, Peak values of voltage (Vpeak), RMS output voltage (Vrms) are noted down for various modulation indices for Sinusoidal reference wave is shown in table 1.

Table 1. THD, Vpeak, Vrms values for Sinusoidal PWM

S.No	MI	THD(%)	V_{peak}(v)	V_{rms}(v)
1.	1.1	24.53	674.4	476.9
2.	1	27.27	512.6	362.4
3.	0.9	31.77	293.6	207.6
4.	0.8	36.83	193.2	136.6
5.	0.7	41.51	131.5	92.98

THD, Peak value of voltage (Vpeak), RMS output voltage (Vrms) is observed for various modulation indices for Third Harmonic Injection reference wave is shown in table 2.

Table 2. THD, Vpeak, Vrms values for Third Harmonic Injection (THI) PWM

S.No	MI	THD(%)	V_{peak}(v)	V_{rms}(v)
1.	1.1	30.68	1126	796
2.	1	32.93	803	568
3.	0.9	32.63	372.8	263.6
4.	0.8	38.96	254.9	180.3
5.	0.7	42.85	174.6	123.4

THD, Peak value of voltage (Vpeak),RMS output voltage (Vrms) are noted down for various modulation indices for Stepped wave reference wave is shown in table 3.

Table 3. THD, Vpeak, Vrms values for Stepped wave PWM

S.No	MI	THD(%)	V_{peak}(v)	V_{rms}(v)
1.	1.1	26.27	648.6	458.6
2.	1	25.3	605	427.8
3.	0.9	32.99	334	236.2
4.	0.8	38.04	204.4	144.5
5.	0.7	40.51	138.3	97.78

THD, Peak value of voltage (Vpeak), RMS output voltage (Vrms) are noted down for various modulation indices for Trapezoidal reference wave is shown in table 4.

Table 4. THD, Vpeak, Vrms values for Trapezoidal PWM

S.No	MI	THD(%)	V_{peak}(v)	V_{rms}(v)
1.	1.1	25.74	938.8	663.8
2.	1	20.36	936.4	662.1
3.	0.9	32.56	352.2	249
4.	0.8	37.83	257.3	181.9
5.	0.7	41.86	174.6	123.4

The Simulink model of discussed boosted voltage MLI is shown below in fig.6

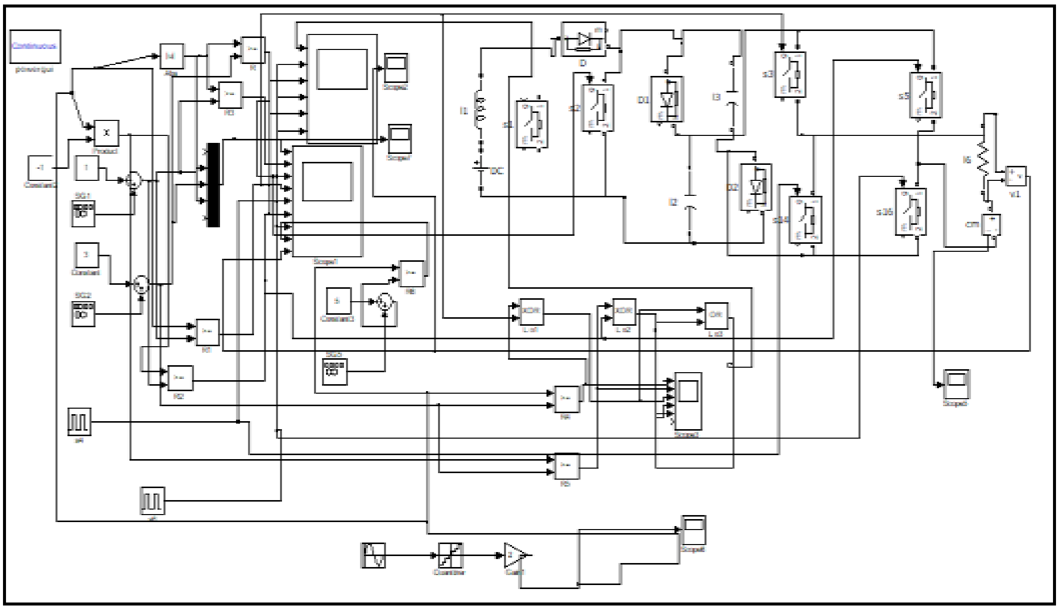

Fig. 6 Simulink model of Suggested 5 level inverter

Representation of high frequency Carrier and Unipolar Sinusoidal reference is shown in fig.7.

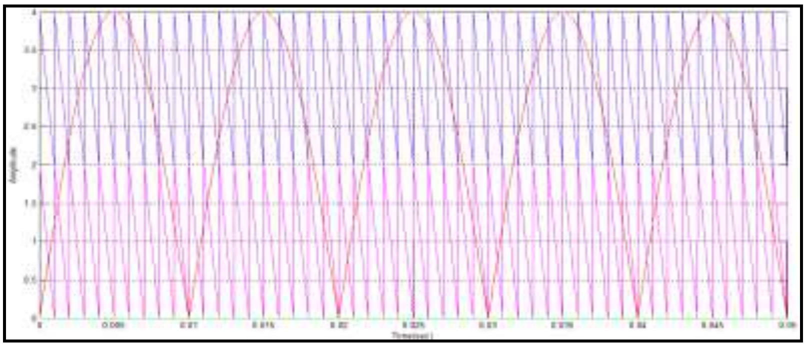

Fig.7 Placement of Carrier and Sinusoidal reference

Output voltage waveform of boosted voltage inverter for sinusoidal reference is shown in fig.8.

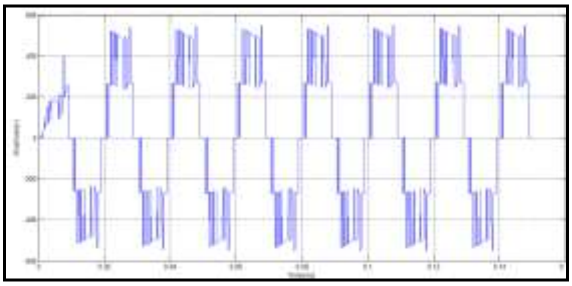

Fig.8 Output voltage waveform of boosted voltage inverter for sinusoidal reference

Total Harmonic Distortion of output voltage of proposed multilevel inverter is shown in fig.9.

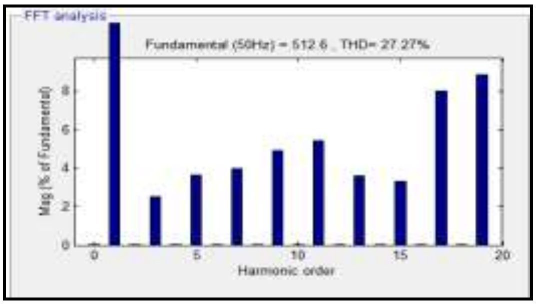

Fig.9 Total Harmonic Distortion of output voltage of proposed multilevel inverter

The arrangement of Unipolar THI reference and carrier waveforms are shown in fig.10.

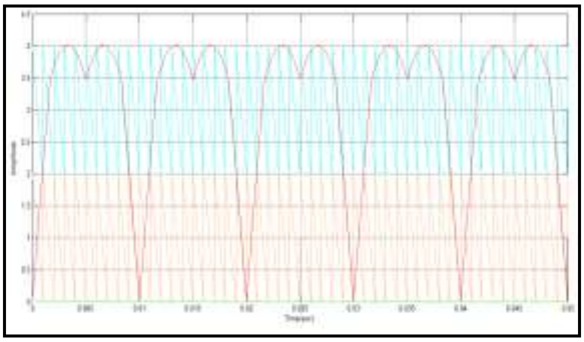

Fig.10 Arrangement of THI reference and carrier waveforms

The output voltage waveform across the load is shown in fig.11.

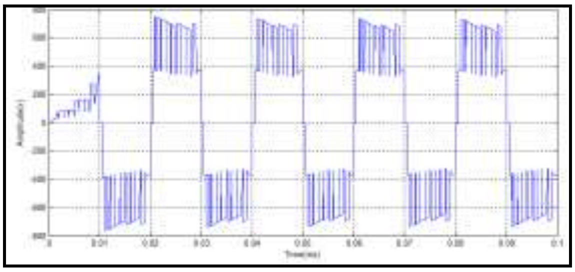

Fig.11 Output voltage waveform across the load

Total harmonic distortion of output voltage is shown in fig.12.

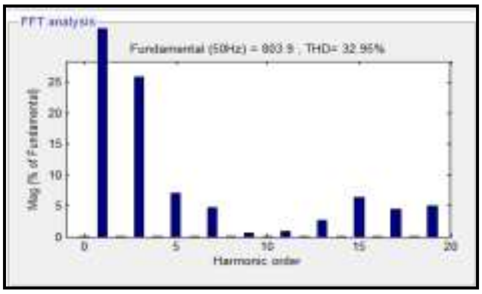

Fig.12 Total harmonic distortion (THD) of output voltage

The presentation of Unipolar stepped reference waveform with carrier signal is shown in fig.13.

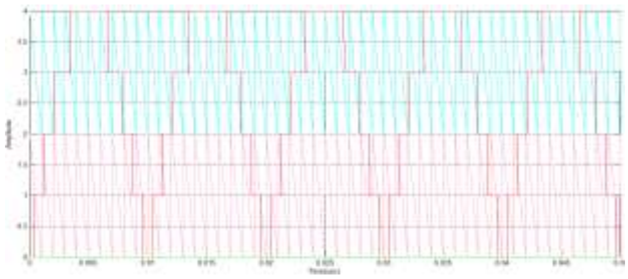

Fig.13 Presentation of stepped reference waveform with carrier signal

Output voltage waveform across the resistive load of the proposed inverter when stepped reference waveform is used is shown in fig.14.

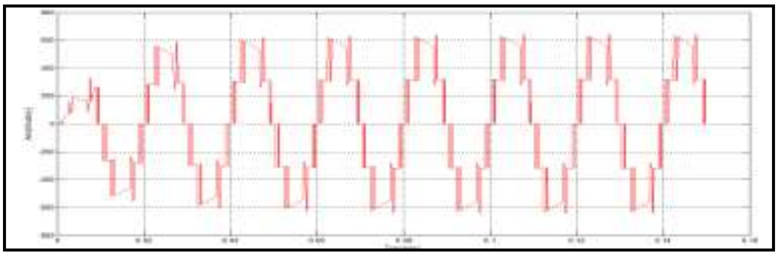

Fig.14 Output voltage waveform across the resistive load of the proposed Inverter

THD of the discussed inverter is shown in fig.15.

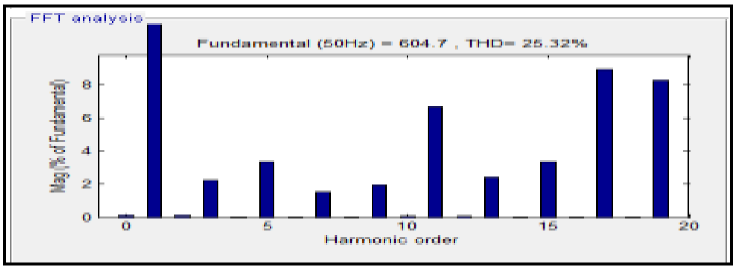

Fig.15 THD of the discussed five level inverter

Carrier arrangement with Trapezoidal reference waveform is shown in fig.16.

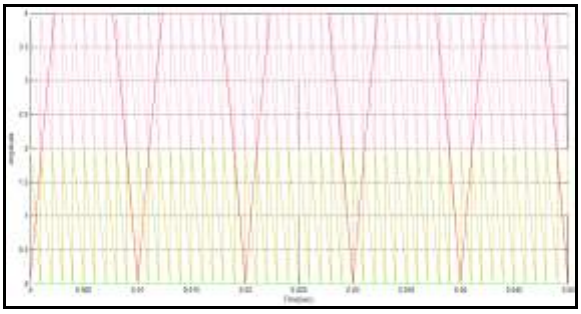

Fig.16 Carrier arrangement with Trapezoidal reference

Output voltage waveform across load in trapezoidal reference waveform in shown in fig.17.

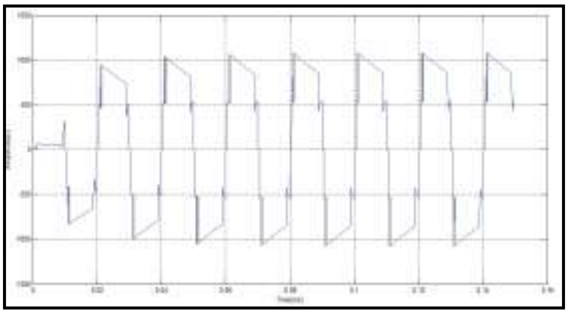

Fig.17 Output voltage across resistive load of boosted voltage inverter

Total harmonic distortion of output voltage when trapezoidal reference is used is shown in fig.18.

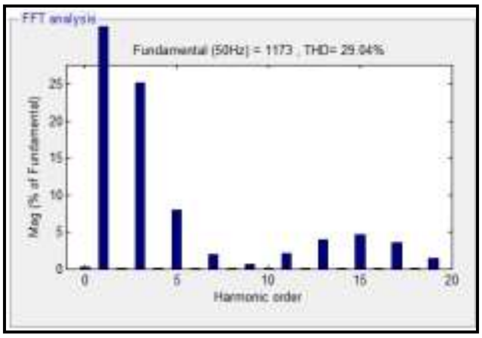

Fig.18 Total harmonic distortion of output voltage for Trapezoidal reference

5. Conclusions

A five level inverter with minimum number of switches is presented in this paper. The inverter is capable of boosting the input voltage due to the arrangement of inductor and switches. Output voltage is taken across resistive load for different references like sinusoidal, Third Harmonic Injection, Stepped wave reference and Trapezoidal reference waveforms. The RMS output voltage, Peak output voltage and THD for different modulation indices for different references are noted down and are compared. In future the same can be extended for higher levels.

References

1. Balamurugan, C.R, Natarajan, S.P, Bensraj, R, Anandhi, T.S, Hybrid Carrier PWM Strategies for Three Phase H-bridge Multilevel Inverter, WSEAS Transactions on Power System, ISSN No. 2224-350X., 2016, 11; 90-99.
2. Md Mubashwar Hasan, Abu-Siada, A, Rabiul Islam, Md, Design and Implementation of a Novel Three-Phase Cascaded Half-Bridge Inverter, IET Power Electronics, 2016, 9(8); 1741-1752.
3. Balamurugan, C.R, Natarajan, S.P, Bensraj, R, dspace Based Implementation of Various Inverted Sine Carrier PWM Strategies for Three Phase Five Level H-Bridge Inverter, International Journal of Advanced Engineering Technology, ISSN No. 0976-3945, 2016, 7(1); 103- 112.
4. Prabaharan, N, Palanisamy, K, Comparative Analysis of Symmetric and Asymmetric Reduced Switch MLI Topologies using Unipolor Pulse Width Modulation Strategies, 2016, 9(15); 2808-2823.
5. Balamurugan, C.R, Natarajan, S.P, Anandhi, T.S, Bensraj, R, Research on Unipolar Inverted Sine Carrier PWM Strategies for Three Phase Five Level CMLI, International Journal of Energy Science and Engineering, 2015, 1(1); 1-12.
6. Babitha T Abraham, Anish Benny, NPC-H Bridge Multilevel Inverter using Third Harmonic Injection, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2014, 3(5); 174-181.
7. Vinod Kumar, P, Santosh Kumar, Ch, Ramesh Reddy, K, Single phase Cascaded Multilevel inverter using Multicarrier pwm technique, ARPN Journal of Engineering and Applied Sciences, 2013, 8(10), 796-799.
8. Sambath, E, Natarajan, S.P, Balamurugan, C.R, Performance Evaluation of Multi Carrier Based PWM Techniques for Single Phase Five Level H-Bridge Type FCMLI, IOSR Journal of Engineering, 2012, 2(7), 82-90.
9. Shanmuga priyaa, A, Seyezhai, R, Mathur, B. L, Performance Analysis of Cascaded Z-Source Multilevel Inverter using Third Harmonic Injection PWM, International Journal of Computer Technology and Electronics Engineering , 2012, 2(1), 143-149.
10. Wells, R, Geng, X, Chapman, P. L, Krein, P. T, Nee, B.M, Modulation-based harmonic elimination, IEEE Trans. Power Electronics., 2007, 22(1); 336-340.

*****