Performance of Sinusoidal Pulse Width Modulation based Three Phase Inverter

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ABSTRACT
In this paper a new sinusoidal PWM inverter suitable for use with power MOSFETs is described. . The output waveforms in the proposed PWM inverter are investigated both theoretically and experimentally. The fundamental component of the three-phase line-to-line voltage is increased by about 15 percent above than that of the conventional sine-wave inverter. The sinusoidal PWM switching scheme allows control of the magnitude and the frequency of the output voltage. Therefore, the input to the PWM inverters is an uncontrolled, essentially constant dc voltage source. This switching scheme results in harmonic voltage in the range of the switching frequency and higher, which can be easily filtered out. This Paper proposes several carrier based modulation techniques for full bridge inverter. In this paper, various pulse width modulation techniques are implemented, which can minimize the total harmonic distortion and enhances the output voltages. The methodologies adopting the constant switching frequency, variable switching frequency multicarrier, phase shifted carrier pulse width modulation concepts are implemented in this paper. The above methodologies divided in to two techniques, triangular carrier and sawtooth carrier for gate signal generation. In this paper, simulation of three phase inverter using sawtooth waveform as carrier signal has been done. Another method using asymmetrical modulation technique with triangular waveform as a carrier signal has been done.

Keywords
PWM Inverter, Sawtooth waveform, Triangular waveorm, Matlab

1. INTRODUCTION
Nowadays in so many applications desire controlled A.C. for controlling speed of machines like Induction Motor, Brushless D.C. Motor etc. For getting controlled A.C. nowadays inverter is used. Inverter is converting uncontrolled D.C. into controlled A.C. There are so many types of inverter like two level, three level and five level etc. The multilevel inverter [MLI] is a promising inverter topology for high voltage and high power applications [3]. This inverter synthesizes several different levels of DC voltages to produce a staircase (stepped) that approaches the pure sine waveform [4-12]. This have high power quality waveforms, lower voltage ratings of devices, lower harmonic distortion, lower switching frequency and losses, higher efficiency, reduction of dv/dt stresses and gives the possibility of working with low speed semiconductors if its comparison with the two-levels inverters. Numerous of MLI topologies and modulation techniques have been introduced and studied extensively, but most popular MLI topology is Diode Clamp, Flying Capacitor and Cascaded Multilevel Inverter (CMLI). In this paper we use a CMLI that consist of some H-Bridge inverters and with un-equal DC. It is also namely Asymmetric Cascaded Multilevel Inverter (ACMLI). Its most implemented because this inverter more modular and simple construction and have other advantages than Diode clamp and flying capacitor [10].

There are many modulation techniques to control this inverter, such as Selected Harmonics Elimination or Optimized Harmonic Stepped-Waveform (OHSW), Space Vector PWM (SVPWM) and Carrier-Based PWM (CBPWM). Among these modulations CBPWM is the most used for multilevel inverter, because it have simple logical and easy to be implemented. The sinusoidal PWM switching scheme allows control of the magnitude and the frequency of the output voltage. Therefore, the input to the PWM inverters is an uncontrolled, essentially constant dc voltage source.

2. REALIZATION OF SPWM

2.1 Concept of sine-modulated PWM inverter
In Sine-PWM inverter the widths of the pole-voltage pulses, over the output cycle, vary in a sinusoidal manner. The scheme, in its simplified form, involves comparison of a high frequency triangular carrier voltage with a sinusoidal modulating signal that represents the desired fundamental component of the voltage waveform. The peak magnitude of the modulating signal should remain limited to the peak magnitude of the carrier signal. The comparator output is then used to control the high side and low side switches. Figure 1 shows an op-amp based comparator output along with representative sinusoidal and triangular signals as inputs. In the comparator shown in Figure 1, the triangular and sinusoidal signals are fed to the inverting and the non-inverting input terminals respectively and the comparator output magnitudes for high and low levels are assumed to be $+V_{CC}$ and -

V_{CC}.

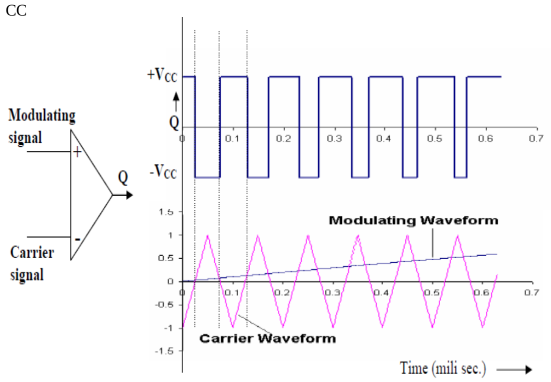

Figure 1. A schematic circuit for comparison of Modulating and Carrier signals

2.2 2-Level Inverter

The most common and popular technique of digital pure-sine wave generation is pulse-width-modulation (PWM). The PWM technique involves generation of a digital waveform, for which the duty-cycle is modulated such that the average voltage of the waveform corresponds to a pure sine wave. The simplest way of producing the PWM signal is through comparison of a low-power reference sine wave with a triangle wave. Using these two signals as input to a comparator, the output will be a 2-level PWM signal (Figure 2). This PWM signal can then be used to control switches connected to a high-voltage bus, which will replicate this signal at the appropriate voltage (Figure 3). Put through a Low Pass Filter, this PWM signal will clean up into a close approximation of a sine wave (Figure4). Though this technique produces a much cleaner source of AC power than either the square or modified sine waves, the frequency analysis shows that the primary harmonic is still truncated, and there is a relatively high amount of higher level harmonics in the signal. This can be removed using second order Low Pass Filter.

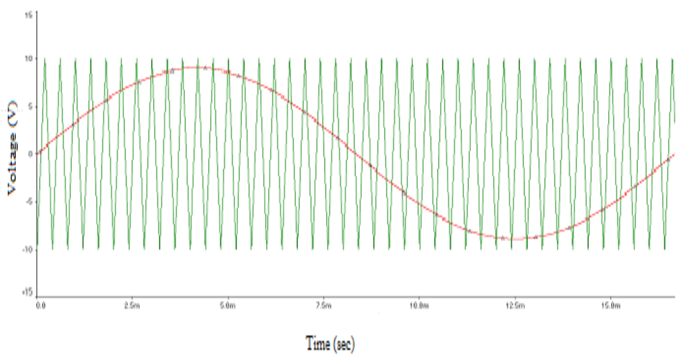

Figure 2. 2-Level PWM Comparison Signals

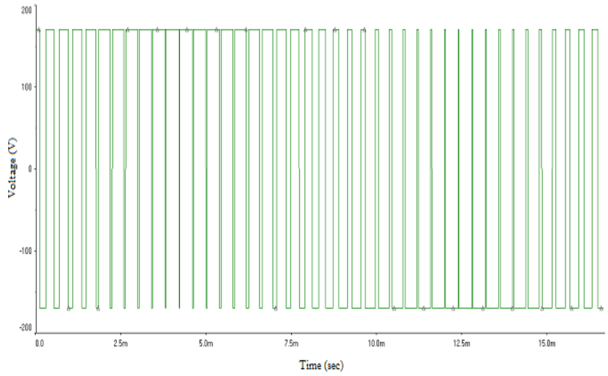

Figure 3. 2-Level PWM Output (Unfiltered)

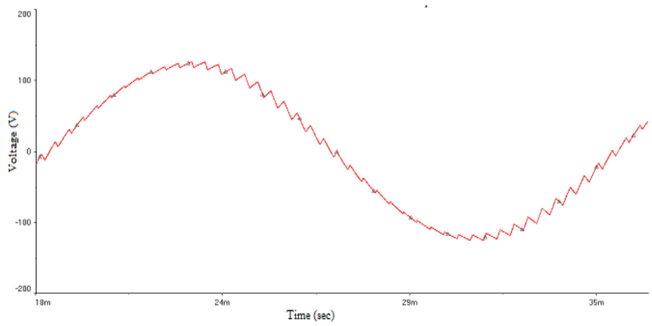

Figure 4. 2-Level PWM Output (Filtered)

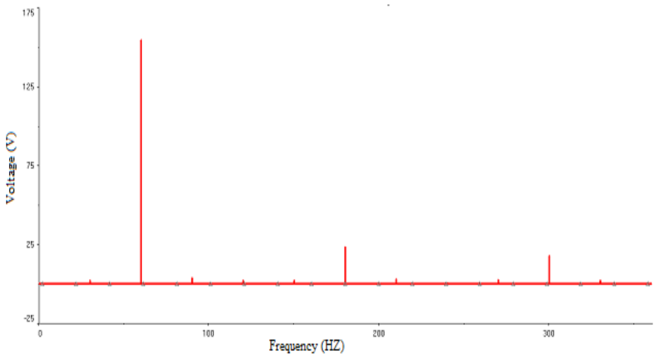

Figure 5. 2-Level PWM Harmonic Analysis

3. MODULATION INDEX

Modulation index is the ratio of peak magnitudes of the modulating waveform and the carrier waveform. It relates the inverter's dc-link voltage and the magnitude of pole voltage (fundamental component) output by the inverter. Now let $\widehat{V_m} \sin(\omega t)$ be the modulating signal and let the magnitude of triangular carrier signal vary between the peak magnitudes of $+\widehat{V_c}$ and $-\widehat{V_c}$. The ratio of the peak magnitudes of modulating wave $\widehat{V_m}$ and the carrier wave $\widehat{V_c}$ is defined as modulation-index *m*.

$$m = \frac{\widehat{V_m}}{\widehat{V_c}} \quad \text{.............(1)}$$

Normally the magnitude of modulation index is limited below one (i.e., 0<*m*<1). From the discussion in the previous section it can be concluded that for 0<*m*<1, the instantaneous magnitude of fundamental pole voltage

$V_{A0,1}$ will be given by:

$$V_{A0,1} = 0.5\, E_{dc}\ (m \sin \omega t) \quad .....(2)$$

where 'ω' is the angular frequency of the modulating waveform. For *m* = 1 the pole output voltage (fundamental component) will have a rms magnitude of

$$0.35 E_{dc}\ \left(= \frac{1}{2\sqrt{2}} E_{dc}\right) \quad ....(3)$$

4. SIMULATION AND ANALYSIS

Simulation and analysis for Sinusoidal Pulse width modulation on Voltage source inverter (VSI) has been done on MATLAB 7.10 (R2010a) using Simulation modeling and MATLAB (M-File) coding.The Simulink model for VSI is given by figure 6.

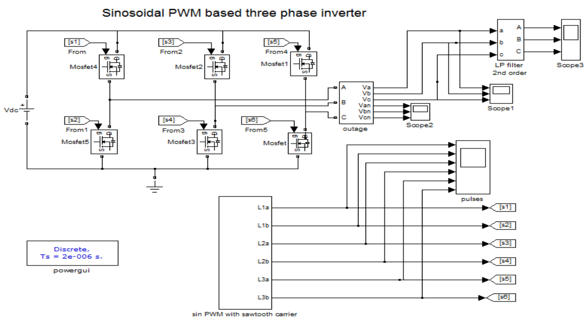

Figure 6. Simulink Model For SPWM based Three Phase Voltage Source Inverter(VSI)

4.1 Analysis of Voltage Source Inverter (VSI) with sinusoidal pulse width modulated output

In this part, we considered four values for analysis of VSI i.e., the frequency of output voltage, modulation index, Phase angle of the load in degrees and frequency of carrier signal. This is done by using MATLAB Coding (M-File).

The result were found for RMS value of output voltage, RMS value of output voltage, Fundamental Component, RMS value of load current, RMS value of supply current, Average value of supply current and performance parameters i.e., THD for output voltages and THD for output current.

4.2 SPWM based Three Phase Inverter using Sawtooth wave carrier signal

The block diagram of SPWM based three phase inverter using triggering circuit and low pass filter is shown in figure 7.

4.3 SPWM based Three Phase Inverter using Triangular wave Carrier signal

The block diagram of SPWM based three phase inverter using triggering circuit and low pass filter is shown in figure 8.In this, Triangular wave Carrier signal is used in triggering circuit.

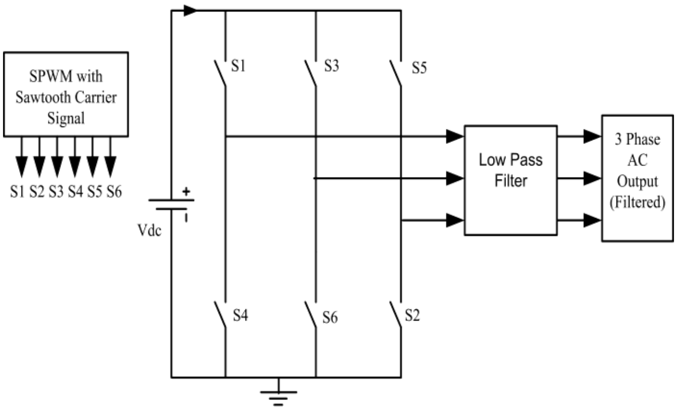

Figure 7. Block Diagram of Three Phase Inverter

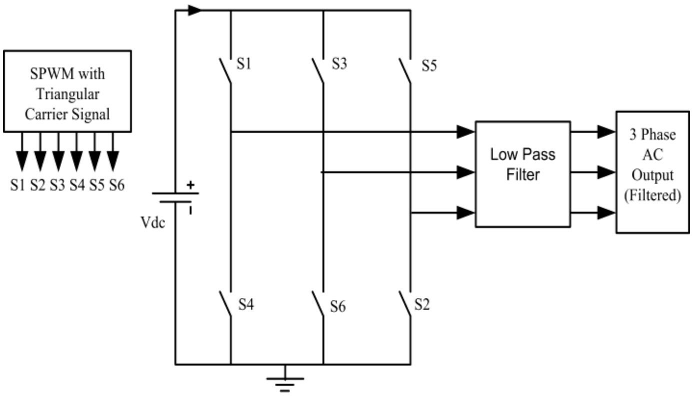

Figure 8. Block Diagram of Three Phase Inverter with Triangular wave carrier signal

5. RESULTS

The output waveform from Simulation modeling are shown below.

5.1 SPWM based Three Phase Inverter using Sawtooth wave carrier signal

The MATLAB Simulation modeling using block diagram (Figure 7) has been done and results were found for output Three phase Voltages, shown by figure 9 and 10.

5.2 SPWM based Three Phase Inverter using Triangular wave Carrier signal

The MATLAB Simulation modeling using block diagram (Figure 8) has been done and results were found for output Three phase Voltages, shown by figure 11 and 12.

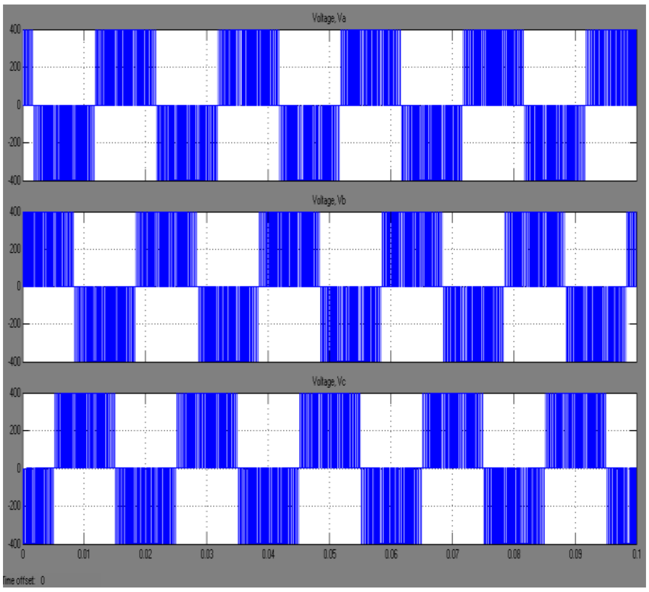

Figure 9. Three Phase Output Voltage waveform (without filter)

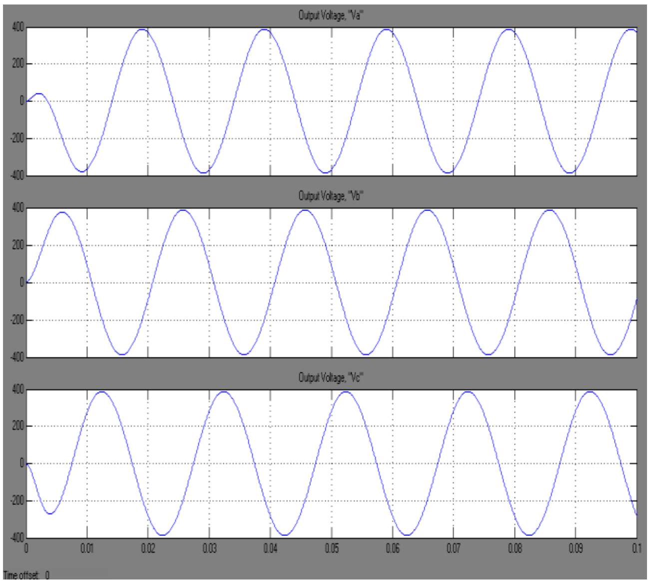

Figure 10. Three Phase Output Voltage waveform (with filter).

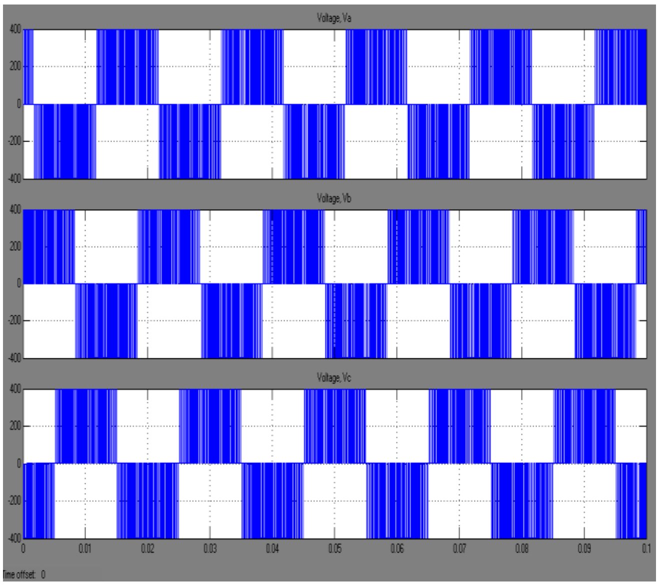

Figure 11. Three Phase Output Voltage waveform with Triangular wave carrier signal (without filter).

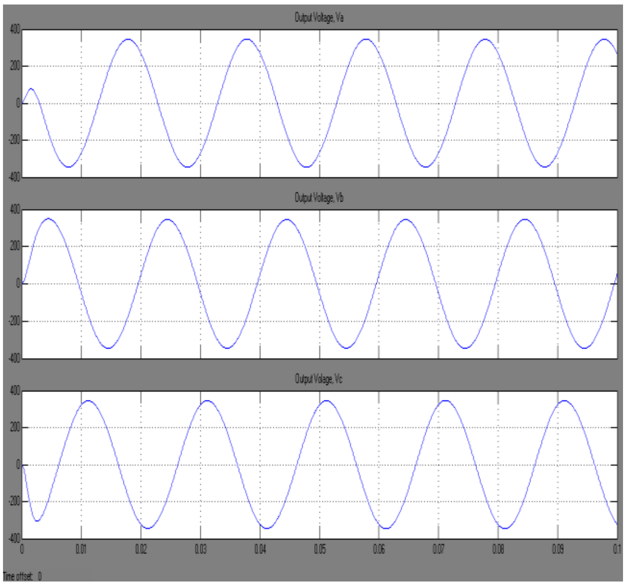

Figure 12. Three Phase Output Voltage waveform with Triangular wave carrier signal (with filter).

6. CONCLUSION

The switch-mode, Voltage source dc-to-ac inverter are described above accept dc voltage source as input and produce three phase sinusoidal output voltages at a low frequency relative to the switching frequency. The relationship between the control input and full-bridge inverter output magnitude is summarized shown in result, assuming sinusoidal PWM in the linear range of m≤ 1.0. The second order low pass filter has been used to filter out the harmonic content of ac signal. Calculation for RMS value of output voltage, RMS value of output voltage, Fundamental Component, RMS value of load current, RMS value of supply current, Average value of supply current and performance parameters i.e., THD for output voltages and THD for output current has been done using M-file coding. Using MATLAB Simulation models, it was found that Sawtooth waveform model gives more appropriate three phase voltage waveform as compared to Triangular waveform carrier signal model.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] N.Mohan, T.M.Undeland, and W.P.Robbins, Power Electronics; Converters, Applications and Design, John Wiley and Sons**,** Singapore, 1995.

[2] E, Acha, V. G. Agelidis, O. Anaya-Lara and T. J. E. Miller, Power Electronics Control in Electrical System, Newnes Power Engineering Series, Oxford, 2002.

[3] D. Shingare, Industrial and Power Electronics, Electotech Publication Engineering series, 3rd ed., 2007.

[4] Kyu Min Cho. Won Seok OhYoung Tae Kim, and Hee Jun Kim "A new switching strategy for pulse width modulation (PWM) power converters", IEEE Transactions on Industrial Electronics. vo1.54. no.1. pp.330-337. February 2007.

[5] B. S. Suh, G. Sinha, M. D. Manjrekar, T. A. Lipo, "Multilevel Power Conversion – An Overview of Topologies and Modulation Strategies", IEEEOPTIM Conference Record, pp. 11-24, vol. 2, 1998.

[6] E. Babaei, S.H. Hosseini, G.B. Gharehpetian, M. Tarafdar Haquea, M. Sabahi, "Reduction of dc voltage sources and switches in asymmetrical multilevel converters using a novel topology", Electric Power Systems Research, 77, 2007, pp. 1073–1085.

[7] J.S. Lai and F.Z. Peng, "Multilevel converters—A new breed of power converters", IEEE Transactions on Industry Applications, vol.32, pp. 509–51, May/June, 1996.

[8] Kuhn, H. Ruger, N.E. Mertens, A., "Control Strategy for Multilevel Inverter with Non-ideal DC Sources", Power Electronics Specialists Conference (PESC), Hanover, 2007.

[9] L. M. Tolbert, John N. Chiasson, Zhong Du, and Keith J. McKenzie, "Elimination of Harmonics in a Multilevel Converter With Nonequal DC Sources", IEEE Transactions On Industry Applications, Vol. 41, No. 1, January/February 2005, pp. 75-82.

[10] M. G. Hosseini Aghdam, S. H. Fathi, G. B. Gharehpetian, "A Complete Solution of Harmonics Elimination Problem in a Multi-Level Inverter with Unequal DC Sources", Journal of Electrical Systems, 3-4, 2007, pp.259-271.

[11] S. J. Park, F. S. Kang, S. E. Cho, C.J. Moond, H. K. Nam, "A novel switching strategy for improving modularity and manu [facturability of cascaded transformer- based multilevel inverters", Electric Power Systems Research, 74. 2005, pp. 409–416.

[12] S. Krishna, "Harmonic Elimination by Selection of Switching Angles and DC Voltages in Cascaded Multilevel Inverters", Fifteenth National Power Systems Conference (NPSC), IIT Bombay, December 2008.

[13] K.Taniguchi and H.lrie. "A modulating signal for three-phase sinusoidal PWM inverter", Tran.sactions of Institution of Electrical Engineering (Japan),vol. 105-B. no. 10. pp.880-885. October 1985.