Harmonics analysis of Sinusoidal PWM and Third harmonic injection PWM controlled Voltage source inverter

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Abstract- **The sinusoidal Pulse Width Modulation (SPWM) technique is one of the most popular PWM technique for controlling output and harmonic reduction of inverter. Recent developments in power electronics and semiconductor technology have lead use of higher carrier frequency in PWM modulation techniques. In the presented work voltage source inverter is connected to the RL load with LC filter. Two PWM techniques have been used to operate voltage source inverter are sinusoidal(SPWM) PWM and third harmonic injection(THIPWM) PWM. The simulation result shows THIPWM has better performance when compared to SPWM Both techniques are shown with MATLAB simulink and compared in terms of THD.**

Index Terms- SPWM, THD, Voltage source inverter, carrier frequency, third harmonic injection PWM.

1. INTRODUCTION

Inverter converts input DC voltage into a.c. output voltage. Three phase inverters are normally used for high power applications. The applications of inverters include uninterrupted power supply (UPS), adjustable speed drives, a.c. motor speed controllers etc.

Voltage source inverter is
These considered parameters are varied to get desired low harmonics output. In this paper generated by comparing reference sine wave and triangular wave. Sinusoidal PWM and third harmonic injection PWM techniques are considered to operate VSI. They are compared in terms of THD.

2. CONTROL TECHNIQUES

Various PWM control strategies have been developed in the past two decades [2] To obtain variation of output voltage and PWM control strategies such as Sinusoidal pulse width modulation (SPWM),Third harmonic pulse width modulation (THPWM), Space vector pulse width modulation(SVPWM) and 60° PWM are most commonly used for three phase inverters. SPWM is simplest of all the above PWM techniques.]. The required signals for gates of inverter are generated by comparing reference sine wave and triangular carrier signal in SPWM technique. In 1975 Buja developed THPWM technique. THPWM is implemented in same manner as SPWM the difference is that reference a.c. waveform is not sinusoidal but consists of both fundamental component and third harmonic component[1],[4]. The advantages of PWM techniques are that they are easy to implement and control, reduces lower order harmonics [5]. SPWM and THPWM techniques are analyzed and compared in terms of harmonics.
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2.1 Sinusoidal PWM

Three sinusoidal modulating signals (V_m) at low frequency but displaced from each other by 120° are compared with a high frequency triangular carrier signal (V_r). The resulting switching signals from each comparator are used to drive the inverter respective switches. The harmonic content in the converter output waveform is chosen as the performance criterion and it is desired to minimize for proper operation. The frequency of reference signal determines the inverter output frequency & amplitude of reference signal controls the modulation index. The harmonic distortion of SPWM is higher than other switching schemes especially at high modulating index. Switching losses are also high in SPWM.

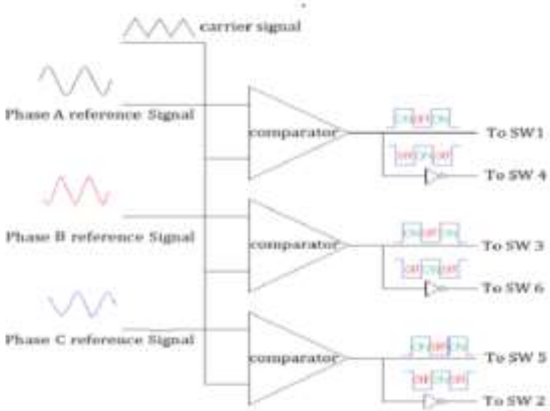

Fig-2.2 Sinusoidal pulse width modulation

2.2 Third harmonic injection PWM

In order to improve the inverters performance third harmonic injection PWM (THIPWM) technique was developed. THIPWM is improved sinusoidal PWM technique which adds a third order harmonic content into sinusoidal reference signal (V_r) of fundamental frequency. The resultant waveform is compared with the high frequency triangular carrier waveform. The comparator output generates signal pulses to trigger switches of the inverter exactly as in SPWM inverter. Amplitude of third harmonic signal is 1/6 of sinusoidal reference signal. Addition of third harmonic to sinusoidal reference leads to 15.5% increase in the utilization rate of the DC voltage. The comparator output is used for controlling the inverter switches exactly as in SPWM inverter. The reference signal is composed of fundamental and third harmonic frequency components as following equations.

$$
\begin{aligned}
V_{mA} &= m.\{\sin(\omega_0 t)+k.\sin(3.\omega_0 t)\} \\
V_{mB} &= m.\{\sin(\omega_0 +120^{\circ})+k.\sin(3.\omega_0 t)\} \\
V_{mC} &= m.\{\sin(\omega_0 +240^{\circ})+k.\sin(3.\omega_0 t)\} \\
V_{mK} &= k.\sin(3.\omega_0 t)
\end{aligned}
$$

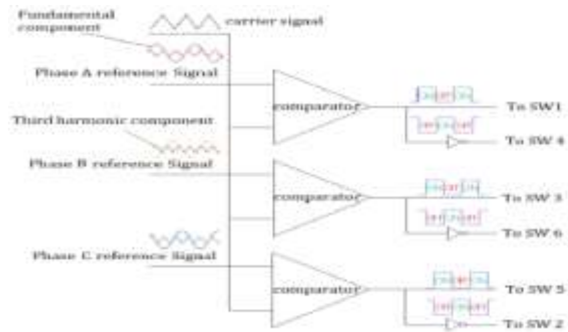

Fig-3.1 Third harmonic injection PWM

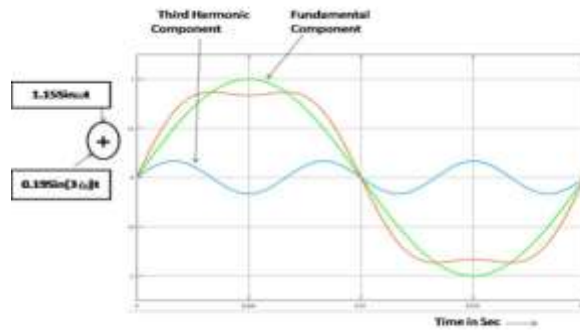

Fig-3.3 Third harmonic injection PWM modulating signal

3. AMPLITUDE MODULATION INDEX

It is ratio of amplitude of reference signal to the carrier signal.

$M_a = \frac{A_m}{A_c}$

4. RESULTS

Presented THD ANALYSIS OF VSI with sinusoidal PWM and third harmonic injection PWM.

MATLAB simulation parameters

1. Switching frequency(fc) = 2 KHz to 18 KHz
2. Fundamental frequency(f)= 50 Hz
3. Modulation index(Ma)= 0.5
4. RL load= 2 KW
5. DC input voltage = 700 V

AS presented below simulation results of VSI at different carrier frequency (fc) and Modulation index is 0.5 at both PWM techniques.

(a) VSI outputs at fc= 2 KHz

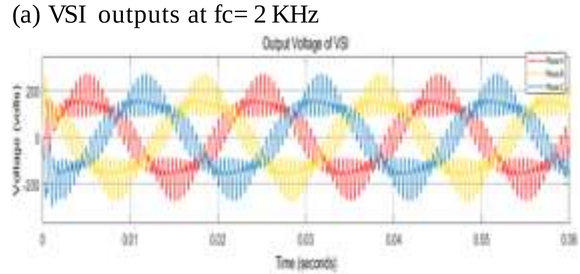

Fig.4.1 Output voltage of VSI using sinusoidal PWM at carrier frequency (f_c) = 2 KHz

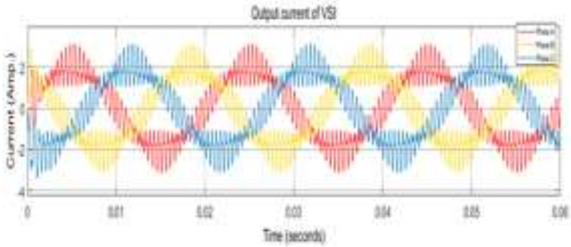

Fig.4.2 Output current of VSI using sinusoidal PWM at carrier frequency (f_c) = 2 KHz

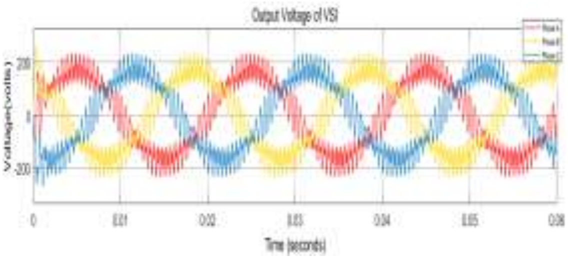

Fig.4.3 Output voltage of VSI using third harmonic injection PWM at carrier frequency (f_c) = 2 KHz

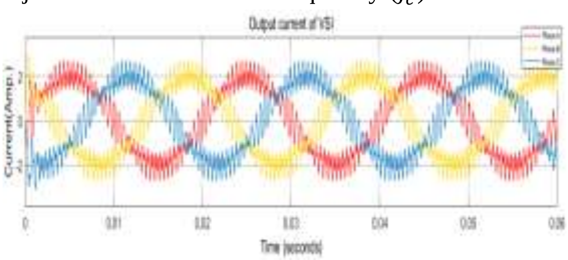

Fig.4.4 Output current of VSI using third harmonic injection PWM at carrier frequenc (f_c) = 2 KHz

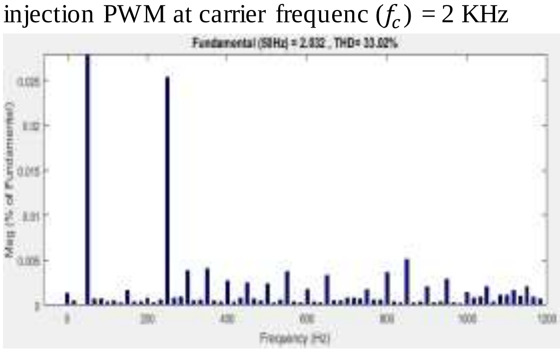

Fig.4.5 FFT analysis of output current of VSI using sinusoidal PWM

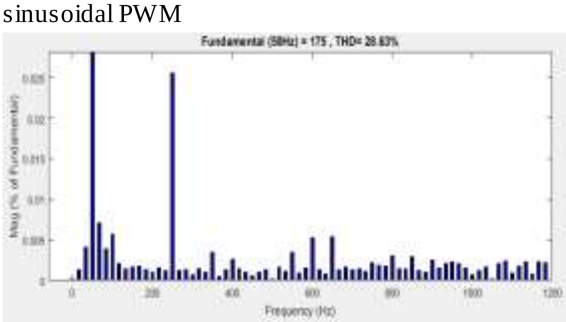

Fig.4.6 FFT analysis of output current of VSI using third harmonic injection PWM

(b) VSI outputs at fc= 8 KHz

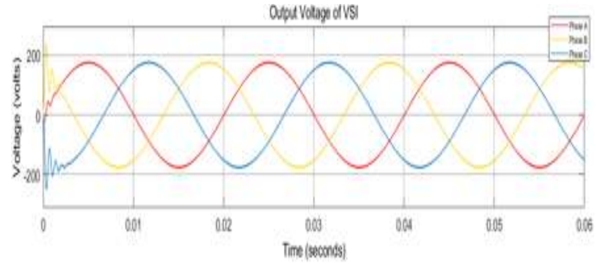

Fig.4.7 Output voltage of VSI using sinusoidal PWM at carrier frequency (f_c) = 8 KHz

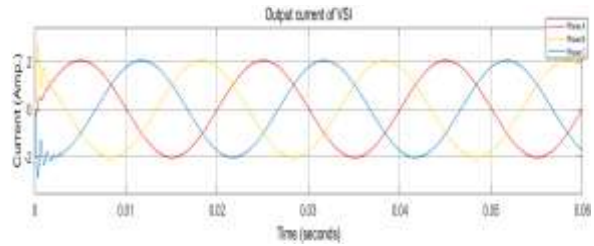

Fig.4.8 Output current of VSI using sinusoidal PWM at carrier frequency (f_c) = 8 KHz

Fig.4.9 Output voltage of VSI using third harmonic injection PWM at carrier frequency (f_c) = 8 KHz

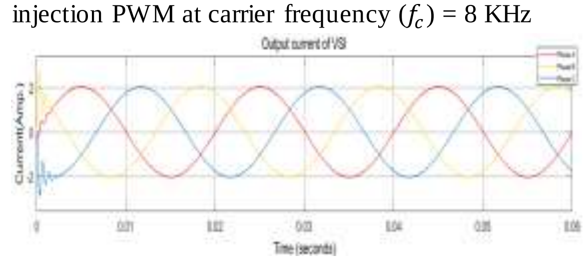

Fig.4.10 Output current of VSI using third harmonic injection PWM at carrier frequency (f_c) = 8 KHz

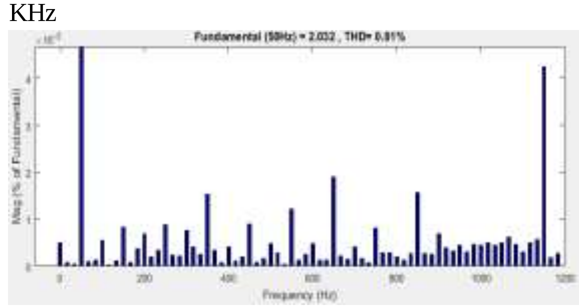

Fig.4.11 FFT analysis of output current of VSI using sinusoidal PWM

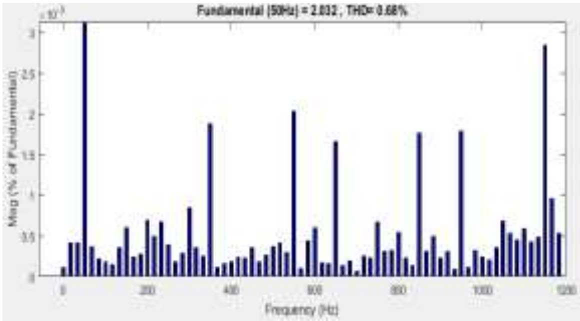

Fig.4.12 FFT analysis of output current of VSI using third harmonic injection PWM

(c) VSI outputs at fc= 12 KHz

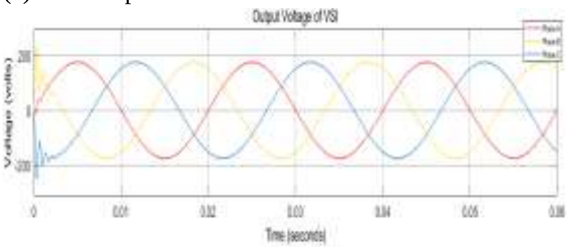

Fig.4.13 Output voltage of VSI using sinusoidal PWM at carrier frequency (f_c) = 12 KHz

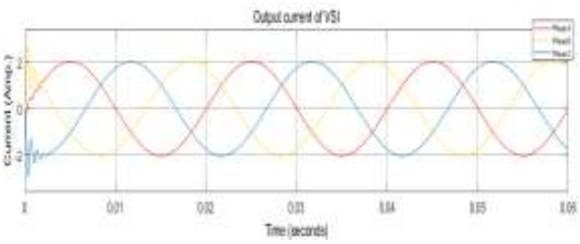

Fig.4.14 Output current of VSI using sinusoidal PWM at carrier frequency (f_c) = 12 KHz

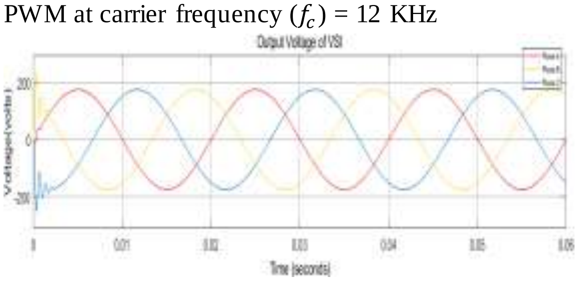

Fig.4.15 Output voltage of VSI using third harmonic injection PWM at carrier frequency (f_c) = 12 KHz

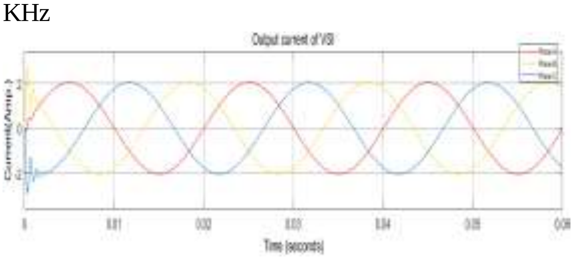

Fig.4.16 Output current of VSI using third harmonic injection PWM at carrier frequency (f_c= 12 KHz

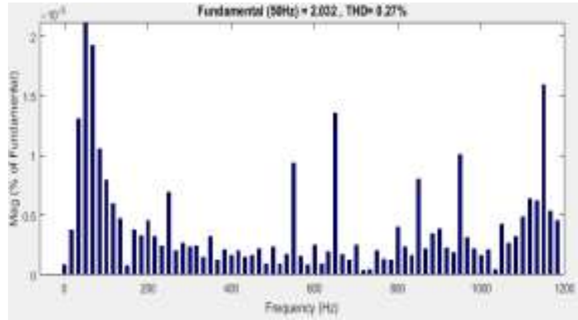

Fig.4.17 FFT analysis of output current of VSI using sinusoidal PWM

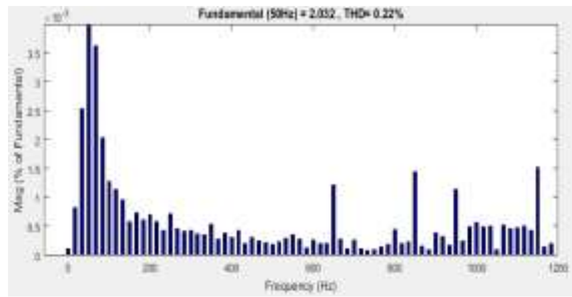

Fig.4.18 FFT analysis of output current of VSI using third harmonic injection PWM

(d) VSI outputs at fc= 18 KHz

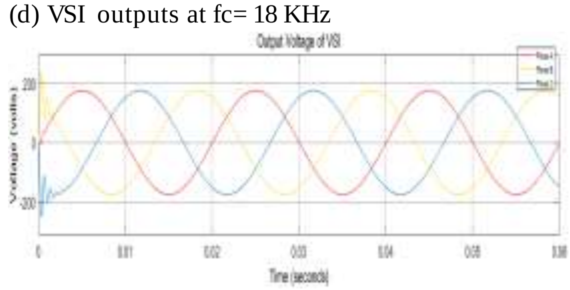

Fig.4.19 Output voltage of VSI using sinusoidal PWM at carrier frequency (f_c) = 18 KHz

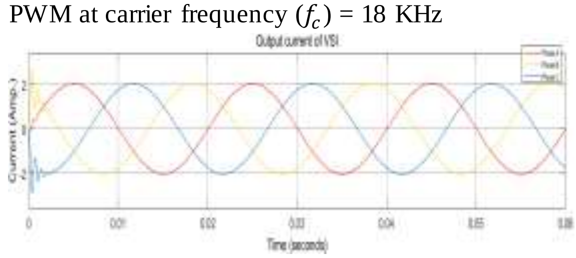

Fig.4.20 Output current of VSI using sinusoidal PWM at carrier frequency (f_c) = 18 KHz

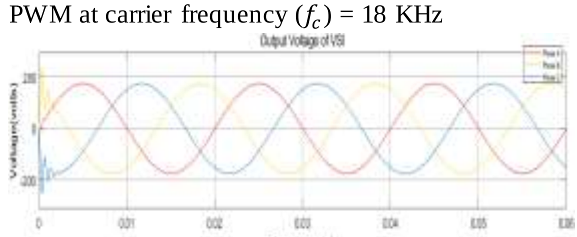

Fig.4.21 Output voltage of VSI using third harmonic injection PWM at carrier frequency (f_c) = 18 KHz

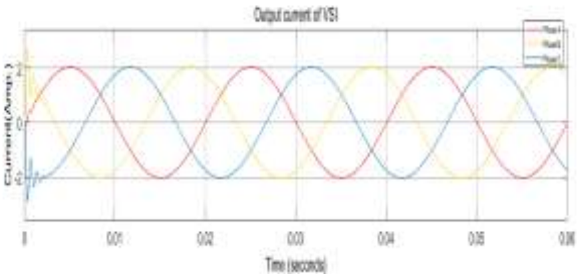

Fig.4.22 Output current of VSI using third harmonic injection PWM at carrier frequency (f_c) = 18 KHz

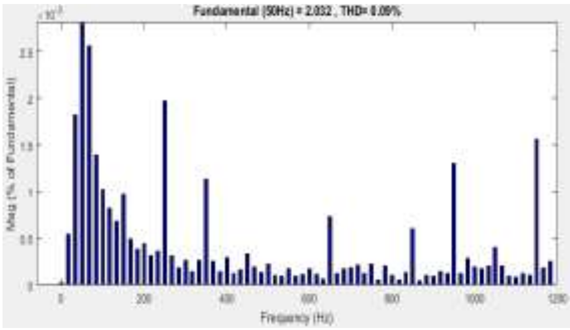

Fig.4.23 FFT analysis of output current of VSI using sinusoidal PWM

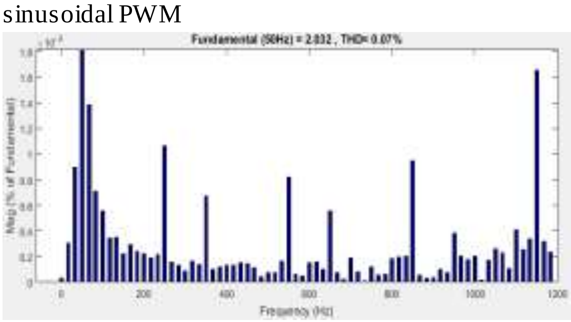

Fig.4.24 FFT analysis of output current of VSI using third harmonic injection PWM

5. CONCLUSION

A three phase VSI has been implemented with SPWM and THPWM control strategies. We have done MATLAB simulink model and FFT analysis at different carrier frequency values. FFT Analysis of VSI output current THD is done at carrier frequencies from 2KHz to 18KHz and modulation index is 0.5. From simulation results proved that with increasing carrier frequency THD is decreasing in both techniques for the output current. It is concluded that THIPWM technique is giving lesser THD of three phase inverter output current when compared to SPWM technique with increasing carrier frequency. THIPWM is providing better quality output than SPWM. It has clearly shown that by varying carrier frequency from low to high value we can minimize the THD of phase currents.

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