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Analysis, Design and Control of Sinusoidal PWM Three Phase Voltage Source Inverter Feeding Balanced Loads at Different Carrier Frequencies Using MATLAB

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ABSTRACT— This paper focuses on design and development of SPWM three-phase voltage source inverter in MATLAB/SIMULINK. Pulse Width Modulation variable speed drives are mainly applied in many industrial applications that require better performance. Recently, new developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Variable voltage and frequency supply to A.C. drives is obtained from a Voltage Source Inverter which can be a 1-ϕ and 3-ϕ VSI. There are number of Pulse width modulation (PWM) schemes which are used to obtain variable voltage and frequency supply. The mainly used PWM schemes for 3-ϕ Voltage Source Inverters are Carrier-Based Sinusoidal PWM and Space Vector PWM (SVPWM). There is an increasing trend of using Sinusoidal PWM (SPWM) because it can be easily digital realized. In this paper detail analysis of SPWM three-phase voltage source inverter has been carried out at different carrier frequencies with different loads. The 3-ϕ VSI is fed from a AC-DC converter. Simulation results of output currents are obtained and their THD's are compared using MATLAB/Simulink environment.

KEYWORDS — Sinusoidal Pulse Width Modulation (SPWM), Voltage Source Inverter (VSI), Total Harmonic Distortion (THD)

I. INTRODUCTION

The carrier-based PWM methods were developed first and were widely used in most applications. One of the earliest modulation signals for carrier-based PWM is sinusoidal PWM (SPWM). The SPWM technique is based on the comparison of a carrier signal and a pure sinusoidal modulation signal. Pulse-width modulation (PWM) is a technique where the duty ratio of a pulsating waveform is controlled by another input waveform. The intersections between the reference waveform and the Carrier waveform give the opening and closing times of the switches. PWM is commonly used in applications like motor speed control, converters, audio amplifiers, etc. The SPWM technique is the easiest modulation scheme to understand and to implement in software or hardware but this technique is unable to fully utilize the DC bus supply voltage available to the voltage source inverter. We are using the internal control of VSI for controlling its output and the same is shown in figure 1.

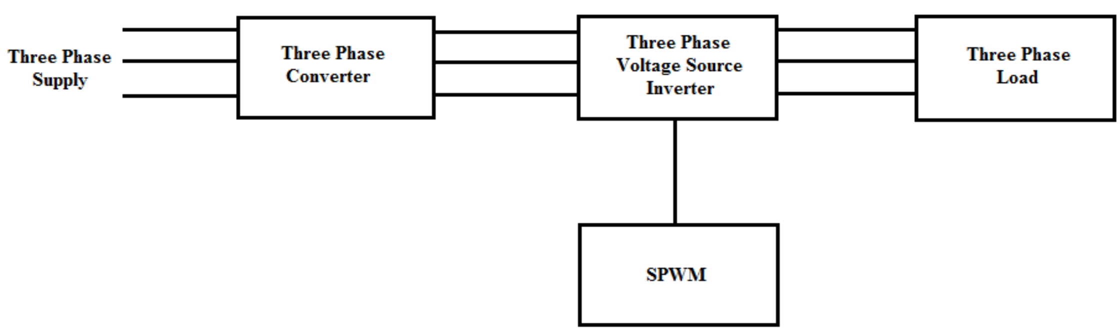

Figure 1. Block diagram of control of VSI using Sinusoidal PWM

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II. DEVELOPMENT OF SINUSOIDAL PWM

The sinusoidal pulse-width modulation (SPWM) technique produces a sinusoidal waveform by filtering an output pulse waveform with varying width. A high switching frequency leads to a better filtered sinusoidal output waveform. The desired output voltage is achieved by varying the frequency and amplitude of a reference or modulating voltage.
The variations in the amplitude and frequency of the reference voltage change the pulse-width patterns of the output voltage but keep the sinusoidal modulation. A low-frequency sinusoidal modulating signal is compared with a high-frequency triangular signal, which is called the carrier signal. The switching state is changed when the sine waveform intersects the triangular waveform. The crossing positions determine the variable switching times between states.

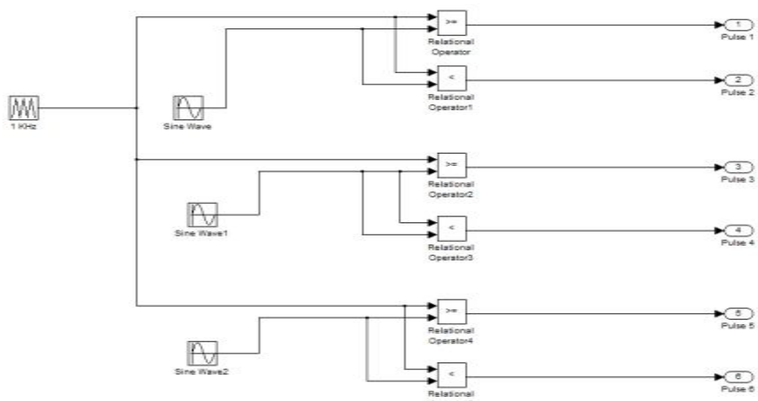

Figure 2. Control Signal Generation for SPWM

In three-phase SPWM, a triangular voltage waveform (V_T) is compared with three sinusoidal control voltages (Va, Vb, and Vc), which are 120° out of phase with each other and the relative levels of the waveforms are used to control the switching of the devices in each phase leg of the inverter.
SPWM is commonly used in applications like motor speed control, converters, audio amplifiers, etc.

III. SIMULATION RESULTS AND DISCUSSION

The performance of proposed VSI is simulated on MATLAB and the simulink model is shown in Fig 3.The main objective of this project is to generate the gate pulses for the thyristors used in the VSI. The gate pulses are generated by the SPWM method. In this method a triangular wave is compared with the three phase sinusoidal wave. When we compare the two waves, three/six outputs are generated which are further used to control the VSI as depicted in Fig 4. The simulated wave form of output voltage and current is shown in Fig.5 and Fig. 6.

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A. MATLAB Simulation of SPWM

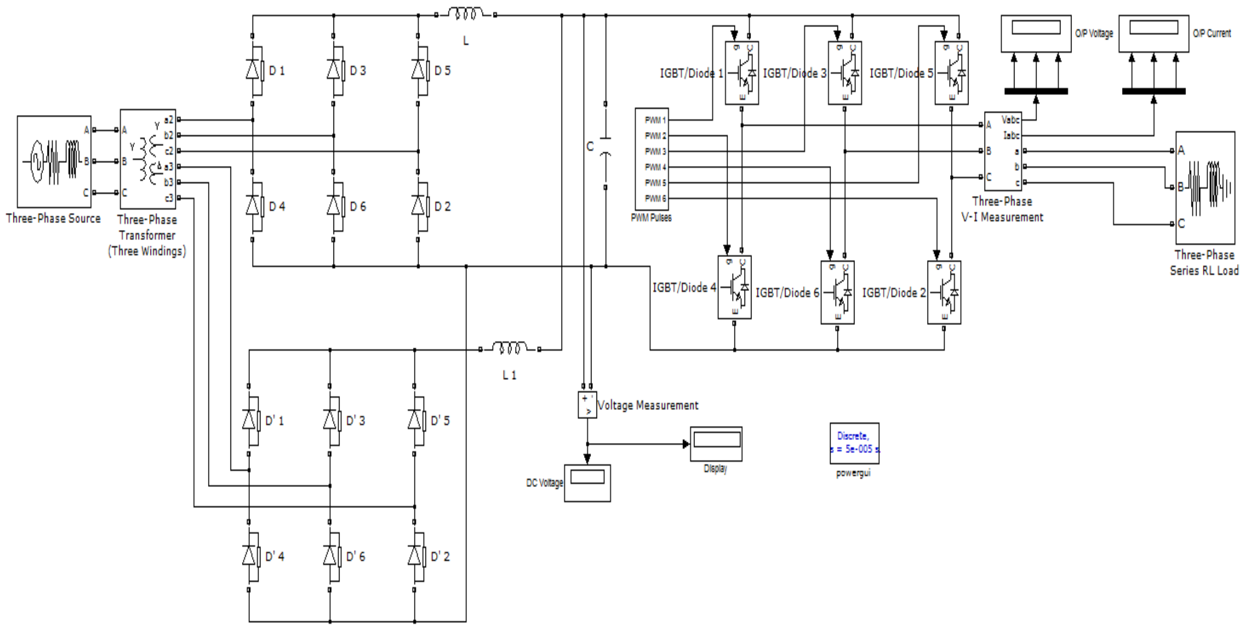

Figure 3. **Simulink Model of Three- Phase VSI**

Output Voltage, Output Current and Total Harmonic Distortion have taken at 0.85 Power Factor for different load values.

B. Output of the Three Phase Sinusoidal PWM

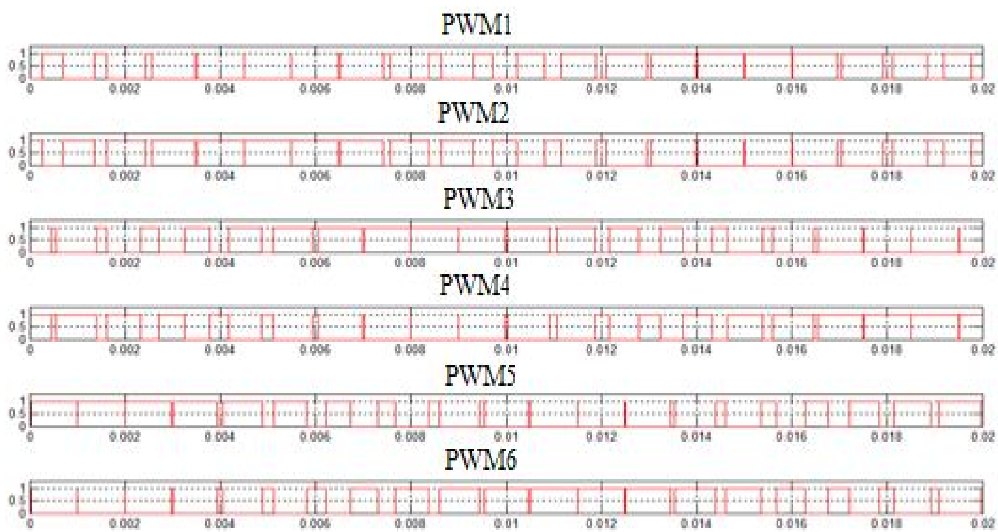

Figure 4. **Gate Signals**

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C. Output Voltage (Three Phase)

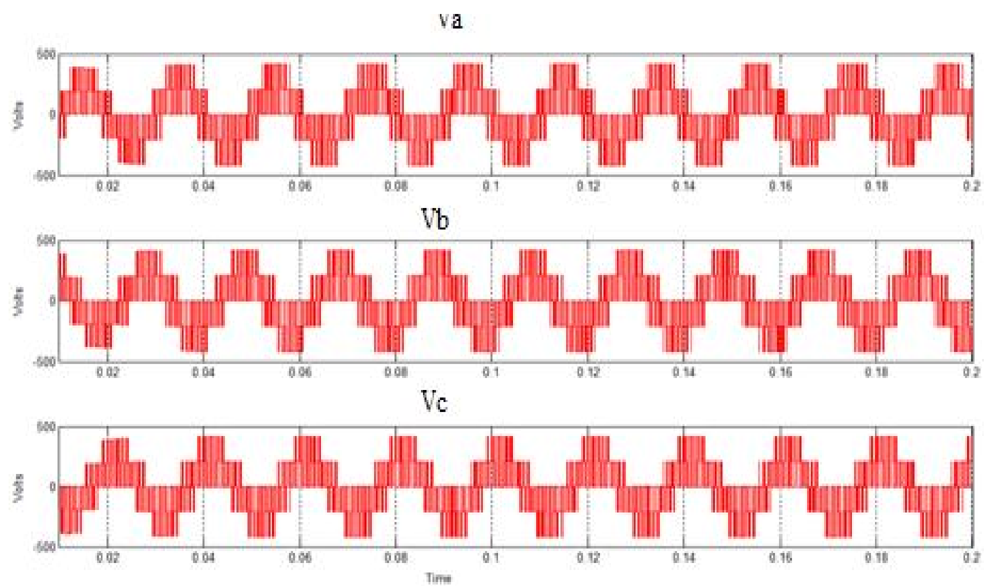

Figure 5. Three Phase Output Voltages

D. Output Current (Three Phase)

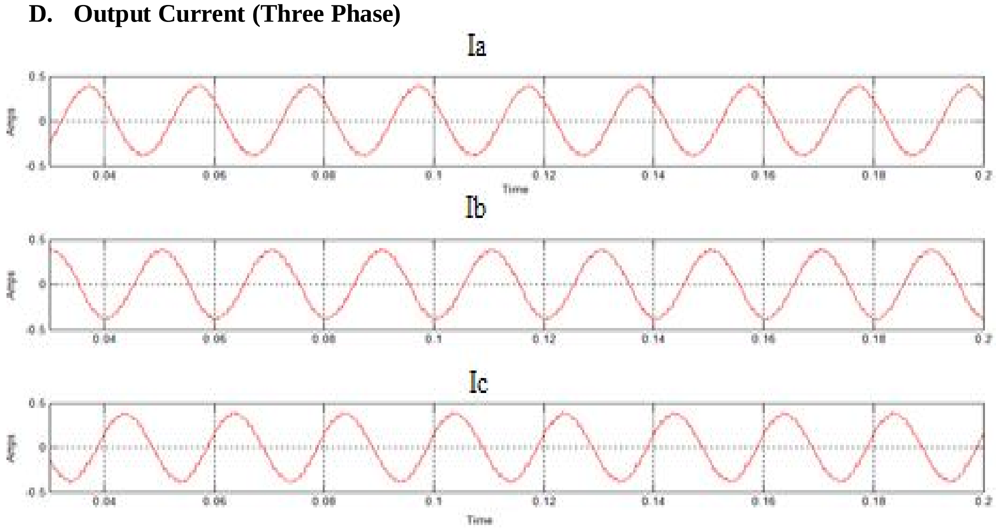

Figure 6. Three Phase Output Current

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Total Harmonics Distortion for output current 'Ia' at different Loads and at different career frequencies is shown in the Fig 7-11.

E. THD Output Current at 1 KHz Carrier Frequency (Load=1KW at 0.85 pf)

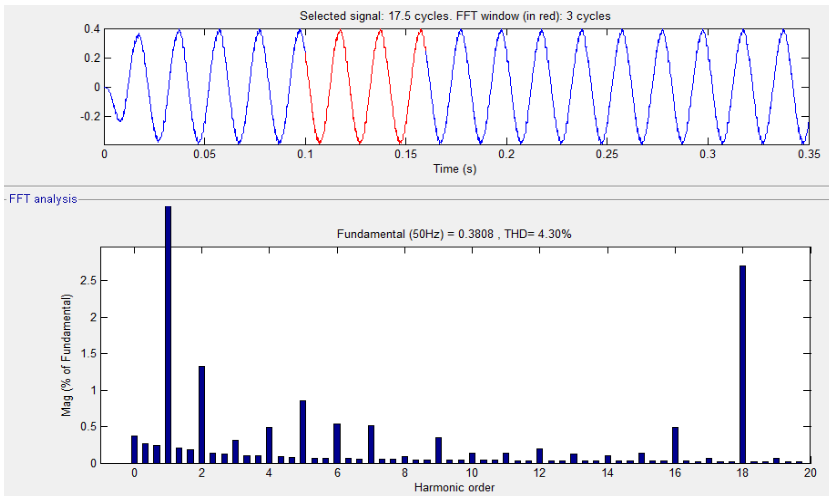

Figure 7. FFT Analysis of Output Current at 1 KHZ Carrier Frequency for 3 Cycles

F. THD of Output Current at 3 KHz Carrier Frequency (Load=1KW at 0.85 pf)

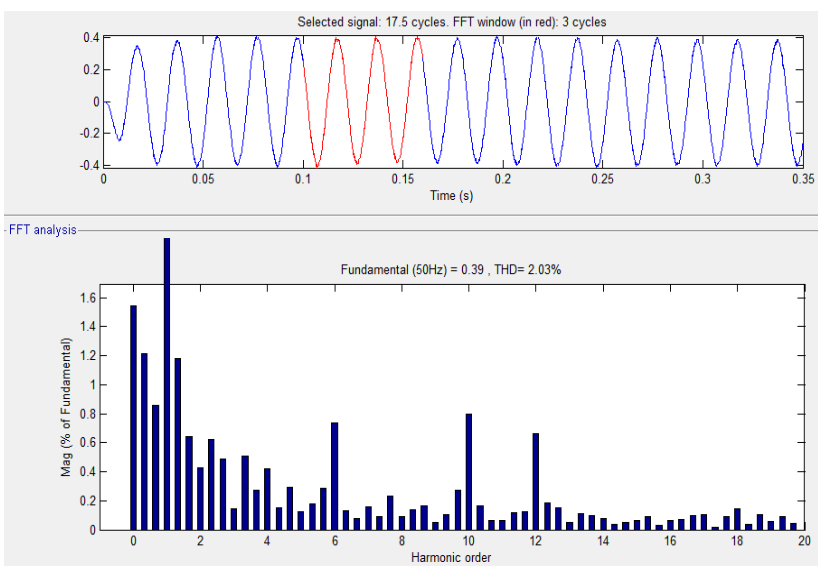

Figure 8. FFT Analysis of Output Current at 3 KHZ Carrier Frequency for 3 Cycles

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G. THD of Output Current at 7 KHz Carrier Frequency (Load=1KW at 0.85 pf):

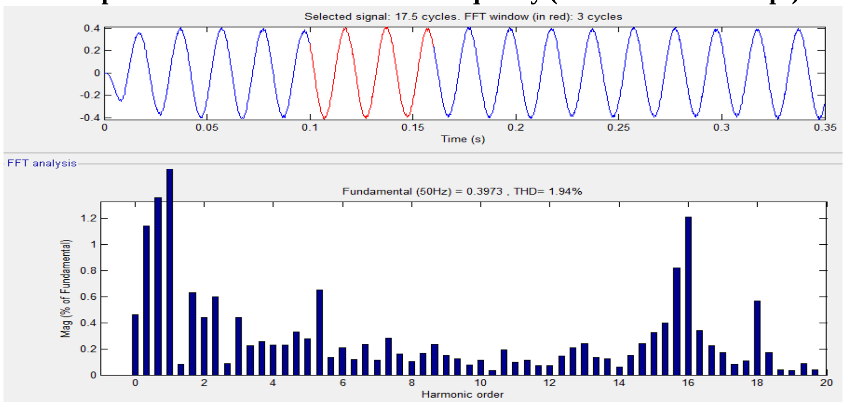

Figure 9. FFT Analysis of Output Current at 7 KHZ Carrier Frequency for 3 Cycles

H. THD of Output Current at 11 KHz Carrier Frequency (Load=1KW at 0.85 pf)

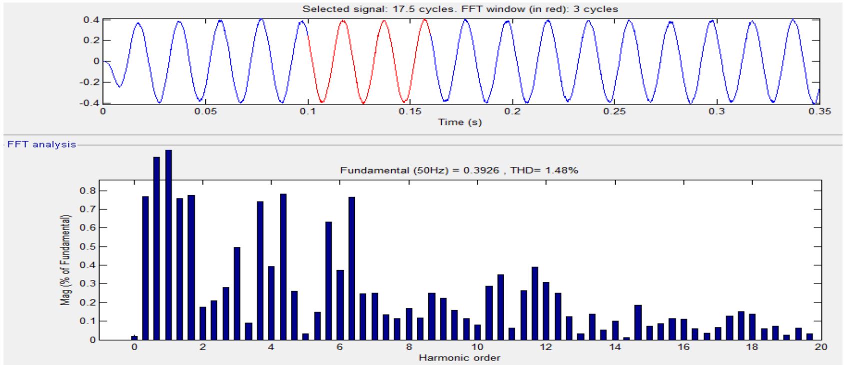

Figure 10. FFT Analysis of Output Current at 11 KHZ Carrier Frequency for 3 Cycles

H. THD of Output Current at 13 KHz Carrier Frequency (Load=1KW at 0.85 pf)

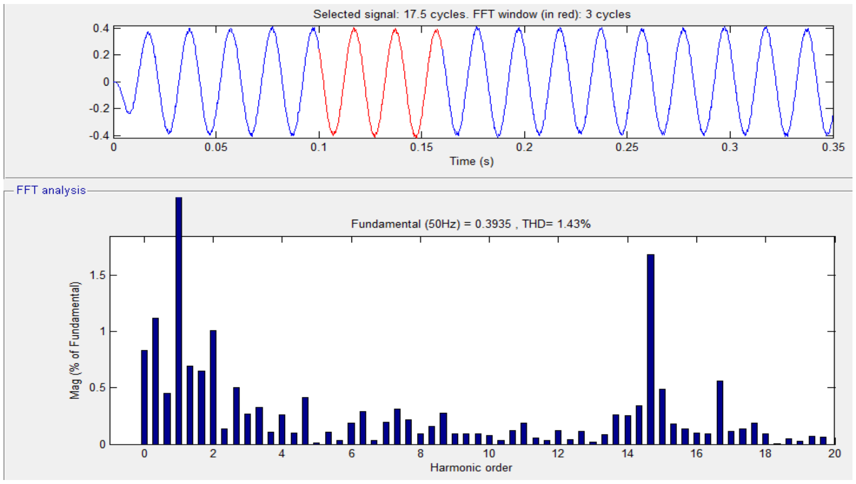

Figure 11. FFT Analysis of Output Current at 13 KHZ Carrier Frequency for 3 Cycles

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Table No. 1

Load	Carrier frequency	1 KHz	3 KHz	7 KHz	11 KHz	13 KHz
R-L Load (1 KW at 0.85 P.F.)	THD	4.30 %	2.03	1.94 %	1.48 %	1.43 %
	Current	0.3808	0.39	0.3973	0.3926	0.3935
R-L Load (3 KW at 0.85 P.F.)	THD	4.29 %	2.04 %	1.95 %	1.48 %	1.41 %
	Current	1.028	1.048	1.068	1.055	1.068
R-L Load (5 KW at 0.85 P.F.)	THD	4.29 %	2.05 %	1.96 %	1.48 %	1.39 %
	Current	1.586	1.607	1.638	1.618	1.622
R-L Load (7 KW at 0.85 P.F.)	THD	4.28 %	2.06 %	1.97 %	1.48 %	1.37 %
	Current	2.063	2.073	2.0118	2.092	2.098

IV. CONCLUSION AND FUTURE WORK

A. Conclusion

In this paper, Simulink model for Sinusoidal PWM three-phase VSI has been developed and tested in the MATLAB/Simulink environment for different Loads at different career frequencies. The simulation results are compared and analyzed by plotting the output harmonic spectra of various output Currents, and computing their Total Harmonic Distortion (THD) whosel comparison is shown in Table No. 1.Tthe THD for the output current decreases with increase in the carrier frequency up-to 13 KHz. So it is concluded that this design is well efficient for the carrier frequency in the range of 11-13 KHz.

B. recommendations for future work

There is couple of interesting topics suggested for future research:

- The Twelve Pulse VSI would be implemented in the Matlab/Simulink.
- Further simulation studies should be performed using Space Vector PWM techniques.

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