SPWM Based Two Level VSI for Microgrid Applications

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Abstract: **The advanced solid-state power electronic devices and microprocessors, various pulse-width-modulation (PWM) techniques developed are many available today for industrial applications. This paper presents the implementation of the sinusoidal PWM (SPWM) technique to two level VSI in MATLAB/ Simulink environment. It discusses the ease of implementation and analyzing the output harmonic spectra of various output voltages (line-to-neutral voltages, and line-to-line voltages) and their total harmonic distortion (THD). The SPWM technique can increase the fundamental output voltage and the results are presented.**

***Keywords*: SPWM, Voltage Source Inverter (VSI), Modulation Index, THD.**

I. INTRODUCTION

Duty ratio of a pulsating waveform is controlled by another input waveform using Pulse Width Modulation (PWM) technique. The intersection of the reference voltage waveform and the carrier waveform give the opening and closing times of the switches. The main aim of any modulation technique is to obtain a variable output with a maximum fundamental component and minimum harmonics [1]. PWM is commonly used in applications like motor speed control, converters, audio amplifiers, etc. For example, it is used to reduce the total power delivered to a load without losses, which normally occurs when a power source is limited by a resistive element.PWM is used to adjust the voltage applied to the motor. By changing the duty ratio of the switches it changes the speed of the motor. The longer the pulse is closed compared to the opened periods, the higher the power supplied to the load is. The change of state between closing (ON) and opening (OFF) is rapid, so that the average power dissipation is very low compared to the power being delivered. PWM amplifiers are more efficient and less bulky than linear power amplifiers.

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In addition, linear amplifiers that deliver energy continuously rather than through pulses have lower maximum power ratings than PWM amplifiers. There is no single PWM method that is the best suited for all applications and with advances in solid-state power electronic devices and microprocessors, various pulse-width modulation (PWM) techniques have been developed for industrial applications [2].

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 [3]. This drawback led to the development of SVPWM. The implementation of the conventional SVPWM is especially difficult because it requires complicated mathematical operations. In the under-modulation region, this algorithm provides 15.5% higher output voltages compared to the SPWM technique [5]. Moreover, the utilization of the DC bus voltage can be further increased when extending into the over-modulation region of SVPWM.

This paper synthesizes the main theories behind three-phase generation of SPWM. This technique is used to generate respective output PWM signal. Also analyzed harmonic content and distortion of voltages and currents with the help of total harmonic distortion (THD) measurement. This paper discusses the principles, theories, mathematical equations, and procedures involved and MATLAB/Simulink package for implementation of this model [6].

II. 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.

In fig.1, a low-frequency sinusoidal modulating waveform is compared with a high-frequency triangular waveform, which is called the carrier waveform. In three-phase SPWM, a triangular voltage waveform (VT) is compared with three sinusoidal control voltages (V_a, V_b, and V_c), which are 120^O 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.

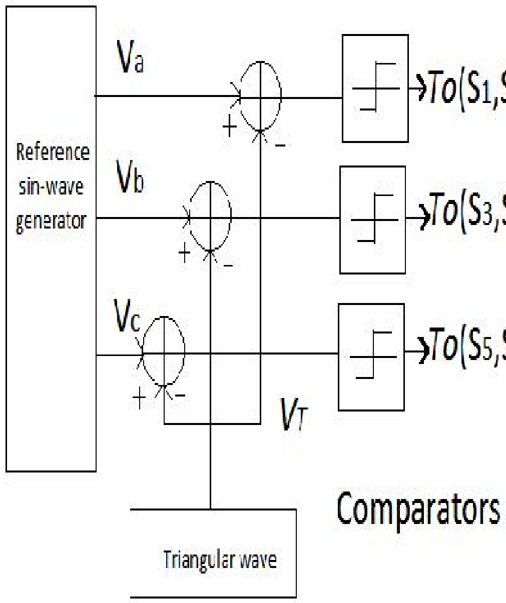

Fig.1. Control Signal Generator for SPWM

A six-step inverter is composed of six switches S_1 through S_6 with each phase output connected to the middle of each inverter leg as shown in fig.2. The output of the comparators forms the control signals for the three legs of the inverter.

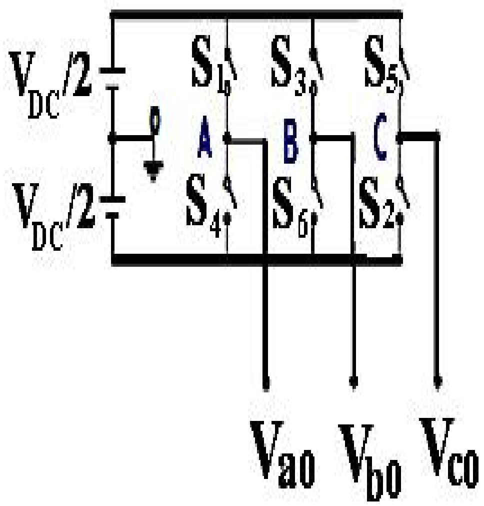

Fig.2. Three-Phase Sinusoidal PWM Inverter

A. Modulation Index of Sinusoidal PWM

The Fourier series expansion of a symmetrical square wave voltage with a peak magnitude of $V_{dc}/2$ has a fundamental of magnitude $2V_{dc}/\pi$. The maximum of the output voltage generated by the SPWM method is $V_{dc}/2$. The modulation index is defined as the ratio of the magnitude of output voltage generated by SPWM to the fundamental peak value of the maximum square wave. Thus, the maximum modulation index of the SPWM technique is as follows.

$$MI = \frac{V_{PWM}}{V_{MAX-SIXSTEP}} = \frac{\frac{V_{dc}}{2}}{\frac{2V_{dc}}{\pi}} = \frac{\pi}{4} \approx 0.7855 - \qquad (1)$$

The method for increasing the output voltage about is SPWM technique i.e. the Sinusoidal Pulse Width Modulation technique. In the SPWM technique, the duty cycles are derived through comparison. The SPWM technique can increase the fundamental component. The fundamental voltage can be improved up to an equivalent square wave where a modulation index of near to unity is reached.

A typical two-level inverter has 6 power switches (labeled S_1 to S_6) that generate three phase voltage outputs. A detailed model of a three-phase bridge inverter is shown in fig.3.

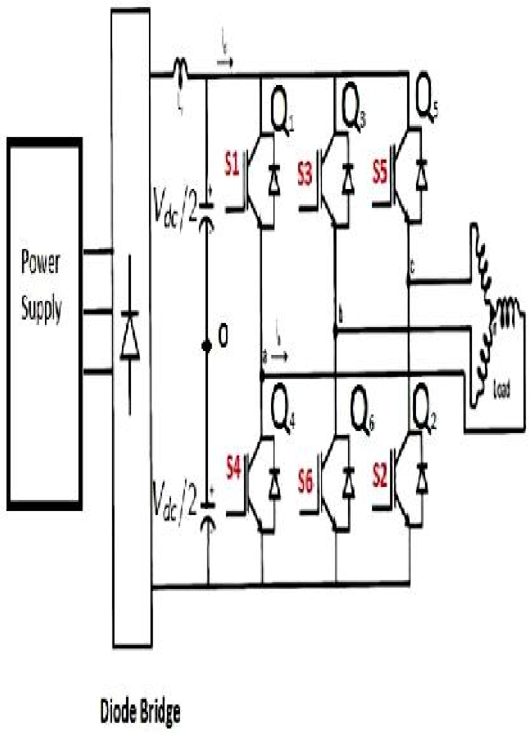

Fig.3. Three-Phase Bridge Inverter

III. Simulation And Results

The simulink model of Three-Phase Bridge Inverter using SPWM ia shown in fig.4. The SPWM technique treats each modulating voltage as a separate entity that is compared to the common carrier triangular waveform. A three-phase voltage set (Va, Vb,and Vc) of variable amplitude is compared in three separate comparators with a common triangular carrier waveform of fixed amplitude as shown in the same figure. The output (Vao, Vbo, and Vco) of the comparators form the control signals for the three legs of the inverter composed of the switch pairs (S_1;S_4), (S_3;S_6), and (S_5;S_2), respectively.

The simulation in MATLAB/ Simulink is performed under the following conditions:Vdc = 400 V, Switching frequency = 1800 Hz, Inverter frequency = 50 Hz, Vref = 200V. The phase and line voltages of SPWM after filtering are shown in figures 5 & 6 respectively. Total harmonic distorsion is shown in the fig.7.

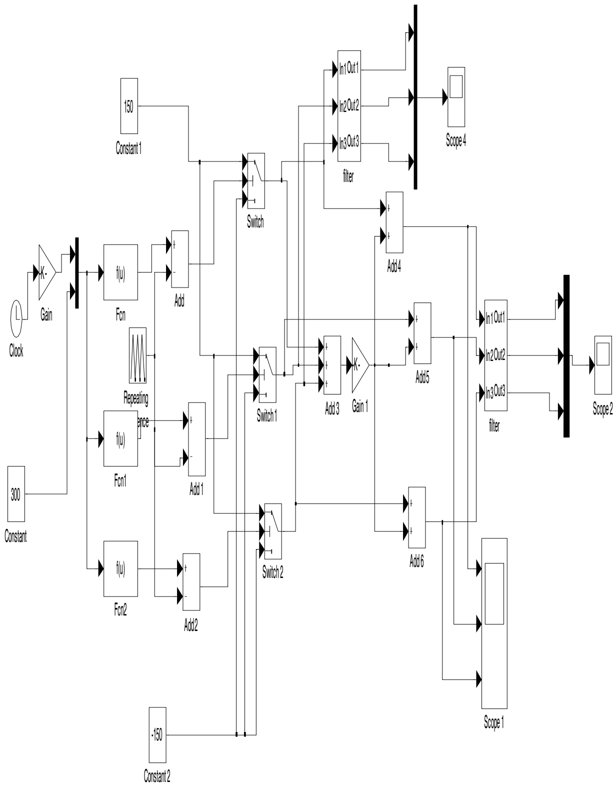

Fig.4. Simulink Model using SPWM

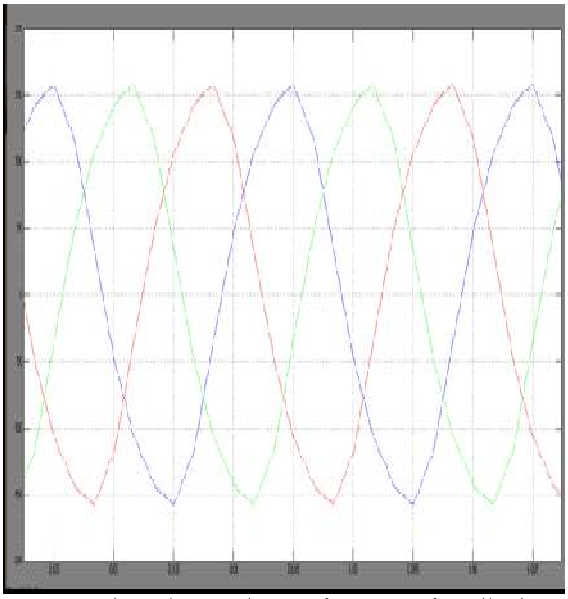

Fig.5 Phase Voltages of SPWM After Filtering

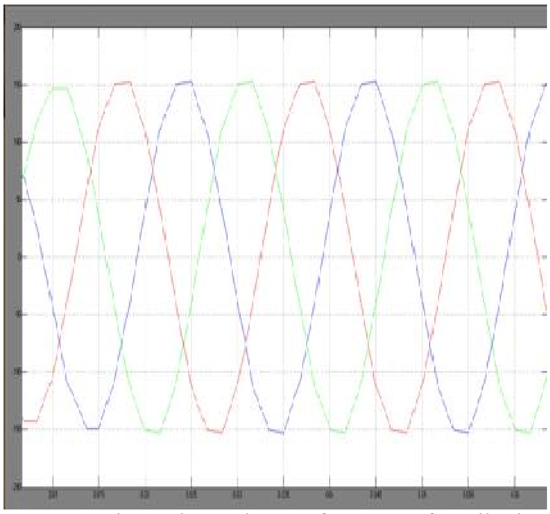

Fig.6. Line Voltages of SPWM After Filtering

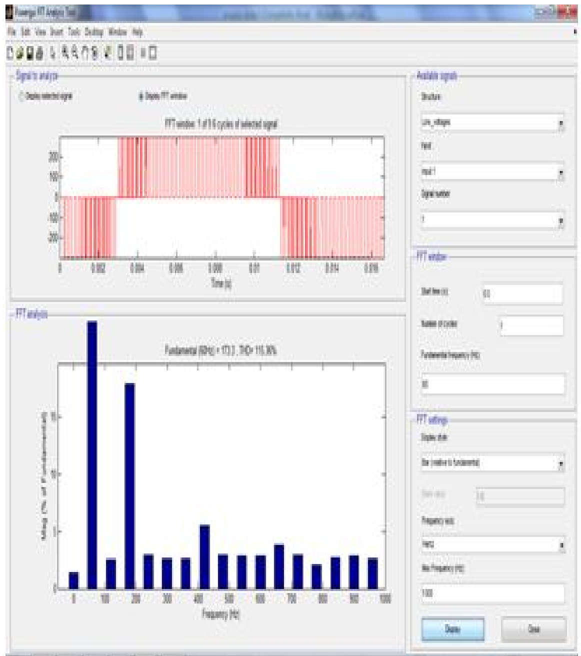

Figure 16. THD of the Two Level Inverter

IV. CONCLUSION

This paper has evaluated Sinusoidal Pulse Width Modulation based two level VSI. The SPWM technique can be applied to a three-phase inverter and it increases the overall system efficiency. It includes a higher modulation index, lower switching losses, and less harmonic distortion compared to ordinary PWM. SPWM research has been widespread in recent years making it one of the most popular methods for three-phase inverters because it has a higher fundamental voltage output than PWM for the same DC bus voltage. The SPWM is significantly better than PWM by approximately 10.3%.

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