



Harmonics Analysis and THD Calculation of Modified Sinusoidal PWM Technique by FFT Tools

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ABSTRACT: Among the various other methods to vary the inverter gain, the most efficient one is to incorporate PWM control within inverters. It is advantageous by being easy to implement, has lower power dissipation, provides linear amplitude control and economical. PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion. Further research works are being carried out in order to expand the horizon of applications of the techniques.

KEYWORDS: pwm, spwm, duty cycle, thd, fft.

I. INTRODUCTION

PWM TECHNIQUE:

Pulse Width Modulation is a powerful technique for controlling analogue circuits with a power sent to a load. PWM is a way of digitally encoding analog signal levels. Duty cycle is defined as the ratio of (t_{on}/T), where T is the period in seconds. There are several PWM techniques which are being employed for diverse applications, a few of them being sinusoidal, square wave, trapezoidal, stair-case, delta, delta-sigma, space vector, harmonic injection, third harmonic PWM techniques. PWM techniques aim at providing better controllable output voltage along with reduction of harmonics.

II. SINUSOIDAL PWM TECHNIQUE

The sinusoidal PWM technique is very popular for industrial converters. In the SPWM technique, as shown in the figure below, where an isosceles triangular carrier wave of frequency f_c is compared with the fundamental frequency f sinusoidal modulating wave and the points of intersection determine the switching points of power devices. The notch and pulse widths of voltage waveforms vary in a sinusoidal manner so that the average or fundamental component frequency is the same as f and its amplitude is proportional to the command modulating voltage. The same carrier wave can be used for all three phases.

The Fourier analysis of the output voltage wave is involved and can be shown to be in the following form:

$$V = 0.5mV_d \sin(\omega t + \phi) + \text{high-frequency } (M\omega_c \pm N\omega) \text{ terms}$$

Where m = modulation index,

ω = fundamental frequency

ϕ = phase shift of output, depending on the position of the modulating wave.

The modulation index m is defined as:

$$m = V_p / V_T$$

Where V_p = peak value of the modulating wave

V_T = peak value of the carrier wave

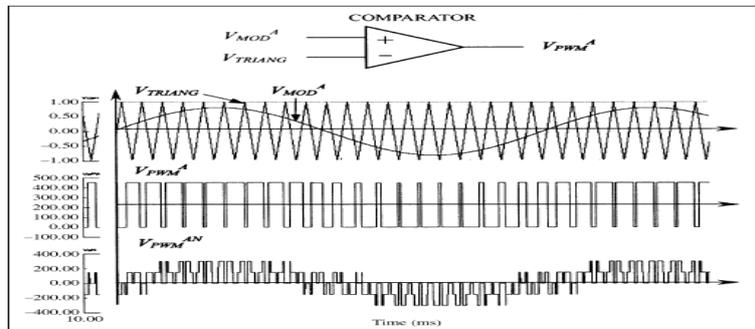
It can be varied between 0 and 1 to give a linear relation between the modulating an output wave.

The inverter basically acts as a linear amplifier.

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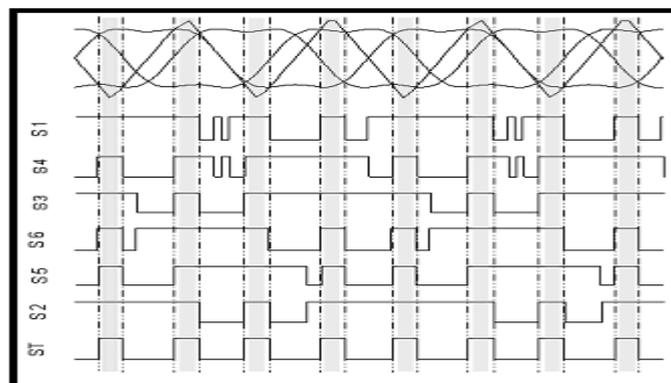
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Fig(1) SINUSOIDAL PWM

MODIFIED SPWM TECHNIQUE:

The widths of the pulses nearer to the peak of the sine wave do not change significantly with the variation of the modulation index. This is due to the characteristics of a sine wave, and the SPWM technique can be modified so that the carrier wave is applied during the first and the last 60° intervals per half-cycle. This is referred to as the modified SPWM technique. It helps in the reduction of harmonics thus improving the quality of power. The algorithm for generating the gating signals is same as that of the sinusoidal PWM technique.



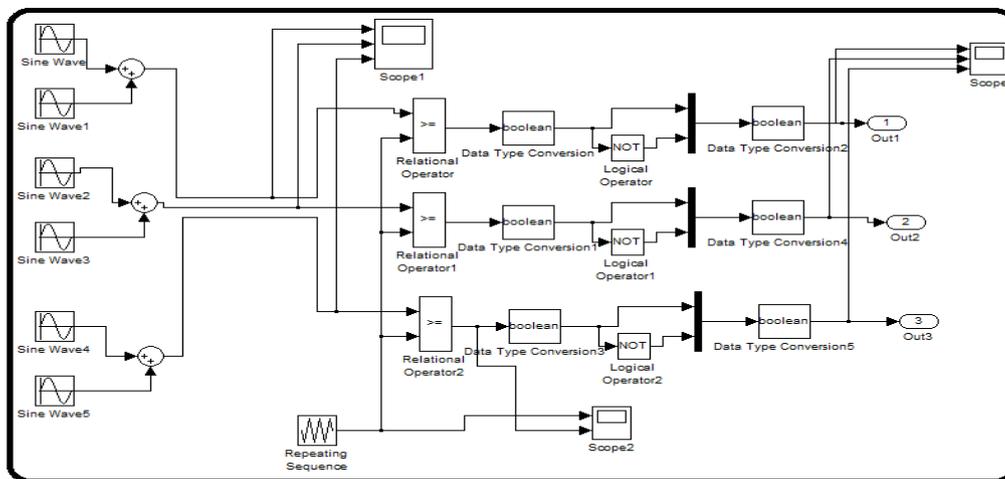
Fig(2) MODIFIED SINUSOIDAL PWM

IV. HARMONIC ANALYSIS USING FFT TOOL

Voltage and Current Harmonic Limits according to IEEE 519, harmonic voltage distortion on power systems 69 kV and below is limited to 5.0% total harmonic distortion (THD) with each individual harmonic limited to 3%. The current harmonic limits vary based on the short circuit strength of the system they are being injected into. Essentially, the more the system is able to handle harmonic currents, the more the customer is allowed to inject. The harmonic current limits specify the maximum amount of harmonic current that the customer can inject into the utility system. The utility is responsible for providing a clean (low distortion) voltage to the customer. The utility can only be fairly judged, however, when the customer meets the harmonic current limits. Otherwise, the customer may be guilty of causing the voltage distortion himself. The intent of IEEE 519 is that this recommended practice recognizes the responsibility that users have not to degrade the voltage of the utility serving other users by requiring nonlinear currents from the utility. It also recognizes the responsibility of the utilities to provide users with close to a sine wave of voltage. Using PWM control per cycle reduces the load current distortion induced in phase controlled circuits. Synchronization with the supply mains is not required. The THD can be reduced employing specified controlled PWM pattern. At high switching frequency, the largest harmonic can be reduced using simple capacitive filtering.

V. SIMULINK MODEL

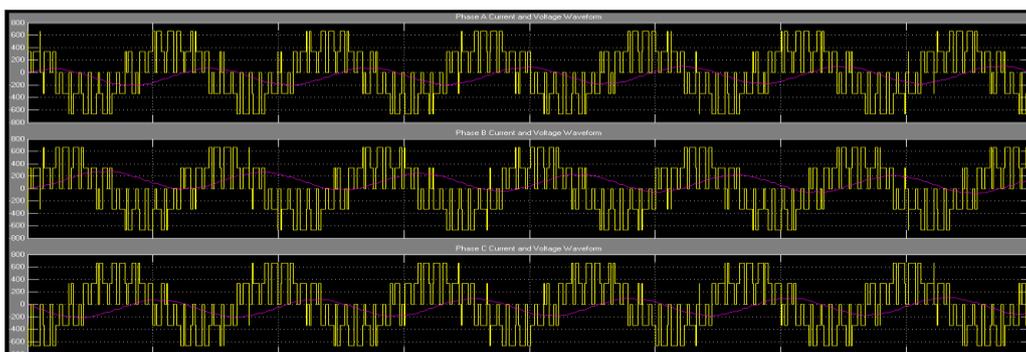
When considering sinusoidal PWM waveform, the pulse width does not change significantly with the variation of modulation index. The reason is due to the characteristics of the sine wave. Hence this sinusoidal PWM technique is modified so that the carrier signal is applied during the first and last 600 intervals per half cycle. The fundamental component is increased and its harmonic characteristics are improved. The main advantages of this technique is increased fundamental component, 79 improved harmonic characteristics, reduced number of switching power devices and decreased switching losses. Modified SPWM technique helps in the reduction of harmonics, thus improving the quality of power.



Fig(3) SUBSYSTEM OF MODIFIED SINUSOIDAL PWM.

VI. OUTPUT WAVEFORMS OF INVERTER

The word ‘inverter’ in the context of power-electronics denotes a class of power conversion (or power conditioning) circuits that operates from a DC voltage source or a DC current source and converts it into AC voltage or current. Even though input to an inverter circuit is a DC source, it is not uncommon to have this DC derived from an AC source such as utility AC supply. Thus, for example, the primary source of input power may be utility AC voltage supply that is ‘converted’ to DC by an AC to DC converter and then ‘inverted’ back to AC using an inverter. Here, the final AC output may be of a different frequency and magnitude than the input AC of the utility supply.



Fig(3) VOLTAGE AND CURRENT WAVEFORMS USING R LOAD.

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VII.GENERATION OF PWM SIGNAL

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency. The duty cycle describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle. The frequency determines how fast the PWM completes a cycle (i.e. 1000 Hz would be 1000 cycles per second), and therefore how fast it switches between high and low states. By cycling a digital signal off and on at a fast enough rate, and with a certain duty cycle, the output will appear to behave like a constant voltage analog signal when providing power to devices.

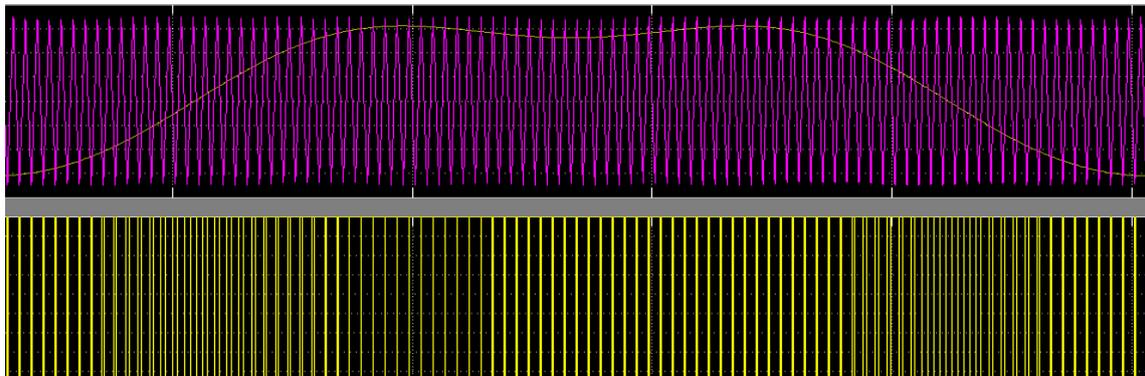
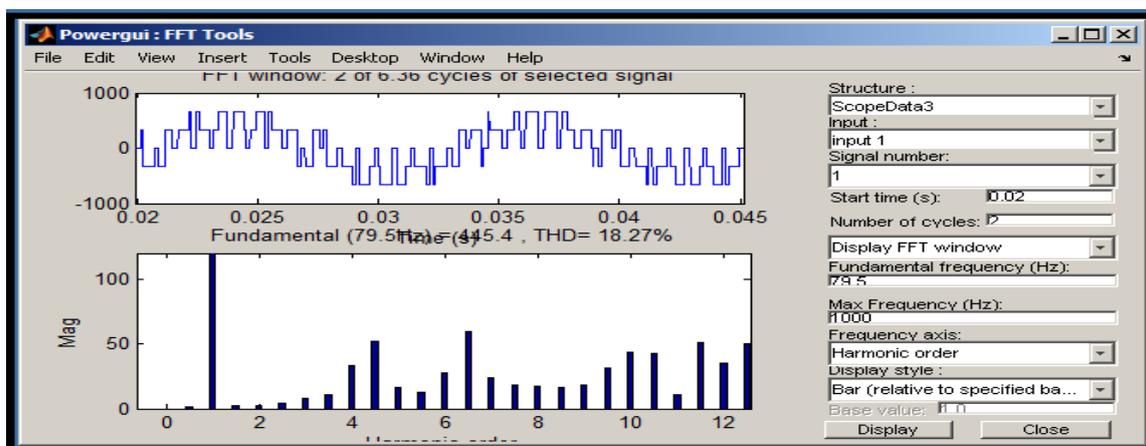


Fig.(7)

VIII. FFT ANALYSIS

FFT ANALYSIS TOOL

The Fast Fourier Transform (FFT) tool in MATLAB-Simulink allows the computation of the fundamental component of voltage and current while simulation is running. This FFT tool of Powergui is used to display the frequency spectrum of voltage and current waveforms. The fundamental component and total harmonic distortion (THD) of the Vab voltage are displayed above the spectrum window. Harmonics are displayed in percent of the fundamental component.



IX.CONCLUSION

PWM technique is very useful in improving the power quality. The modified sinusoidal PWM techniques can be applied to generate the notches that would eliminate certain harmonics effectively in the output voltage. Such



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techniques reduce the harmonics and cause improvement in the fundamental peak voltage, thereby enhancing the quality of power.

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