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An Overview of Different PWM Techniques to Reduce Total Harmonic Distortion of Output in H-Bridge Inverter

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Abstract: **There are three types of DC/AC inverters available on the market, which are classified by their output types: (1) in practice, DC/AC conversion is done with topologies of varying precision. It can be as simple as applying voltages of equal magnitude in opposite directions across a load to generate a square wave. It is a square wave inverter. (2) A more precise method of DC/AC conversion is the modified sine wave, which introduces a dead time in a normal square wave output so that higher peak voltage can be used to produce the same average voltage as a sinusoidal wall-outlet output. This method produces fewer harmonics than square wave generation, but it still is not quite the same as the AC power that comes from AC outlet. The harmonics that are still present in a modified sine wave makes this type of inverter unsuitable for use while electrical noise is a concern, such as in medical devices which monitor the vital signs of a human.(3)Pure sine wave DC/AC conversion will introduce the least amount of harmonics into an electrical device, but are also most expensive method. Since the AC sine wave must come from a DC source, switching must still take place. However, switching takes place with logic so that the energy delivered to a load approaches that of a pure sine wave. This means that extra components and design considerations are involved in the control circuitry of a pure sine wave inverter, driving up cost.**

In this paper an overview is presented of different PWM techniques to control the output voltage as well as to reduce the total harmonic distortion of output voltage in an H-bridge inverter.

Keywords: **Pulse width modulation, H-bridge inverter, Carrier signal, Reference signal, MPWM, SPWM.**

I. INTRODUCTION

Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of doing this is by pulse-width modulation control used within the inverter.In this method, a fixed DC input voltage is given to the inverter and a controlled AC output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as Pulse-Width-Modulation (PWM) Control.

The advantages possessed by PWM techniques are as under:

(i) The output voltage control with this method can be obtained without any additional components.

(ii) With the method, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimised.

The different PWM techniques are as under:

(i) Single-pulse width modulation (Single PWM)

(ii) Multiple pulse width modulation (MPWM)

(iii) Sinusoidal pulse width modulation (SPWM)

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The PWM techniques listed above differ from each other in the harmonic content in their respective output voltages. Thus, choice of a particular PWM technique depends upon the permissible harmonic content in the inverter output voltage. In PWM technique, the devices are switched on and off several times within each half cycle to control the output voltage which has low harmonic content.

II. SINGLE PULSE WIDTH MODULATION (SPWM)

The working of Single PWM technique is as under:

(i) In single pulse width modulation control technique only one pulse will be there for every half cycle. The width of the single pulse can be adjusted in order to control the output voltage of the inverter.

(ii) By comparing rectangular reference signal of amplitude (Ar) and a triangular carrier wave (Ac), the gating signals can be generated as shown in fig. 1. This generated gating signal is used to control the output of single phase full bridge inverter.

(iii) The fundamental frequency of the output voltage is determined by the frequency of the reference signal. For this technique the amplitude modulation index (M) can be defined as:

$$M = \frac{A_c}{A_r}$$

The instantaneous output voltage of the inverter can be given as:

$$V_O = V_S \ (S_1 \ - S_4 \ )$$

(iv) In single pulse modulation a pulse of width δ located symmetrically about π/2 and another pulse located symmetrically about 3π/2. The range of pulse width δ varies from 0 to π; i.e. 0 < δ < π. The output voltage is controlled by varying the pulse width δ. The shape of the output voltage wave is called quasi-square wave.Positive and negative half cycles of the output voltage Vo are symmetrical about π/2 and 3π/2 respectively. In addition, these half cycles are also identical. As a result, the output voltage can be described by Fourier series as

$$V_o = \sum_{n=1,3,5...}^{\infty} \frac{4\,V_S}{n\pi} \sin\frac{n\pi}{2} \sin nd \sin \omega t$$

(v) If pulse width is made equal to $\delta = \frac{2\,\pi}{n}$, then to eliminate nth harmonic from the inverter output voltage width of the pulse in each half cycle can be decided.

(vi) The RMS value of the output voltage: $V_O = V_S \left(\frac{\delta}{\pi}\right)^{1/2}$

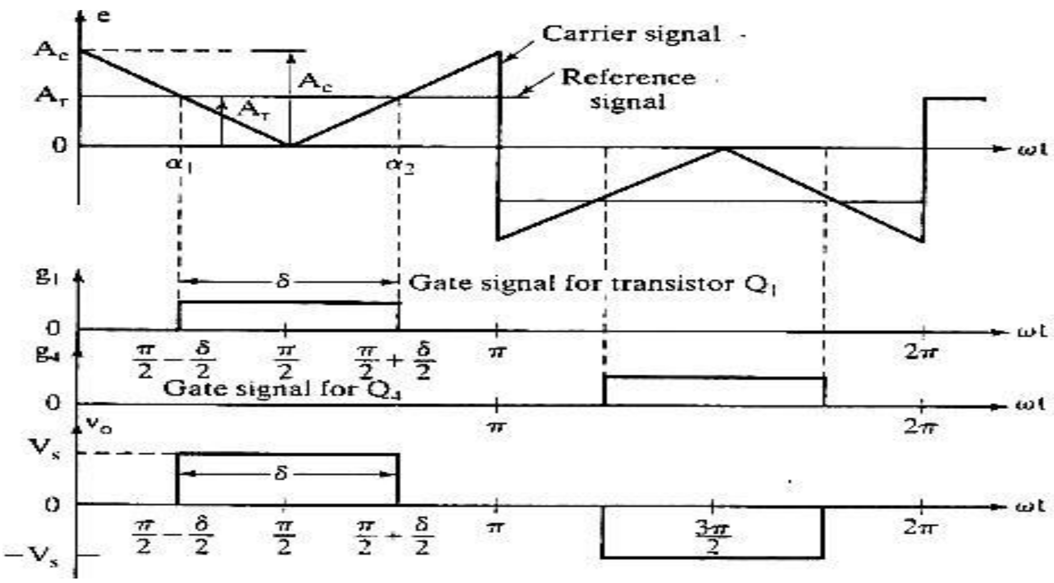

Fig.1: Single PWM Technique

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III. MULTIPLE PULSE WIDTH MODULATION (MPWM)

The main drawback of single PWM technique is high harmonic content. In order to reduce the harmonic content, the multiple PWM technique is used. The working of MPWM technique is as under:

(i) The generation of gating signal is achieved by comparing the reference signal of amplitude (Ar) with a triangular carrier signal (Ac .The output frequency (fo) is determine by the frequency of the reference signal. The output voltage can be controlled by modulation index M.

(ii) The number of pulses (P) per half cycle is calculated by the carrier frequency (fc). Number of pulses per half cycle is found by

$$P = \frac{f_c}{2\,f_r} = \frac{m_f}{2}$$

(iii) If δ is the width of each pulse, the RMS output voltage will be:

$$V_O = V_S \left(\frac{P\delta}{\pi}\right)^{1/2}$$

(iv) The variation of the modulation index M from 0 to 1 varies the pulse width d from 0 to T/2P (0 to п/P) and the RMS output voltage from 0 to V_S.

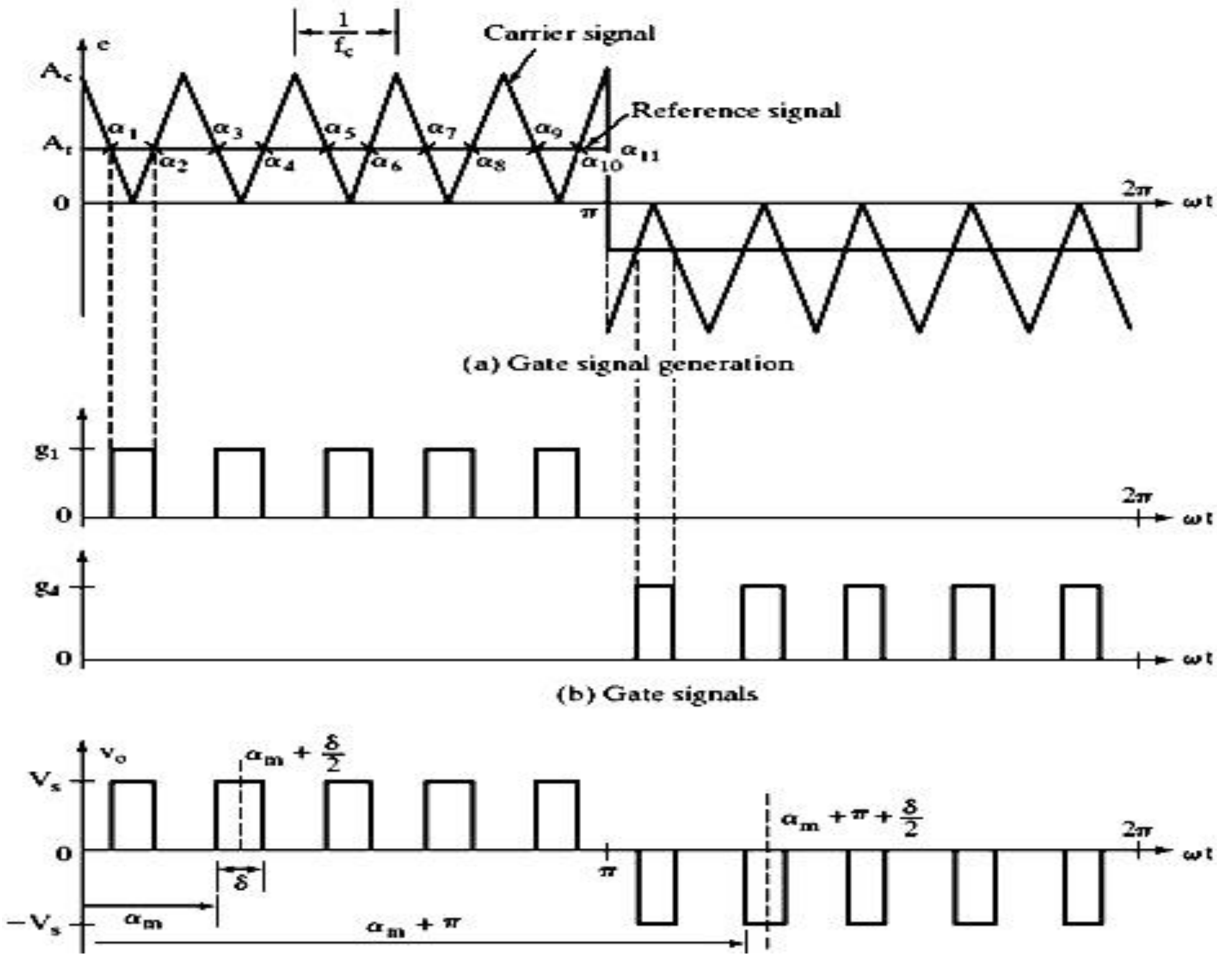

Fig.2: Multiple pulse width modulation (MPWM)

(v) In MPWM technique, the fundamental component of output voltage is lower than its value in single pulse modulation. For more number of pulses per half cycle, the amplitudes of lower order harmonics are reduced but those of some higher order harmonics are increased significantly. But this is no disadvantage, as higher order harmonics can be filtered out easily.

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IV. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

The working of SPWM technique is as under:

(I) In this method of modulation, several pulses per half cycle are used as in case of multiple pulse width modulation. In MPWM, the pulse width is equal for all the pulses, but in SPWM the pulse width is a sinusoidal function of the angular position of the pulse in a cycle.

(II) The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency fc. This SPWM is commonly used in industrial applications. The frequency of reference signal fr determines the inverter output voltage frequency; and its peak amplitude Ar controls the modulation index M, and then in turn the RMS output voltage Vo.

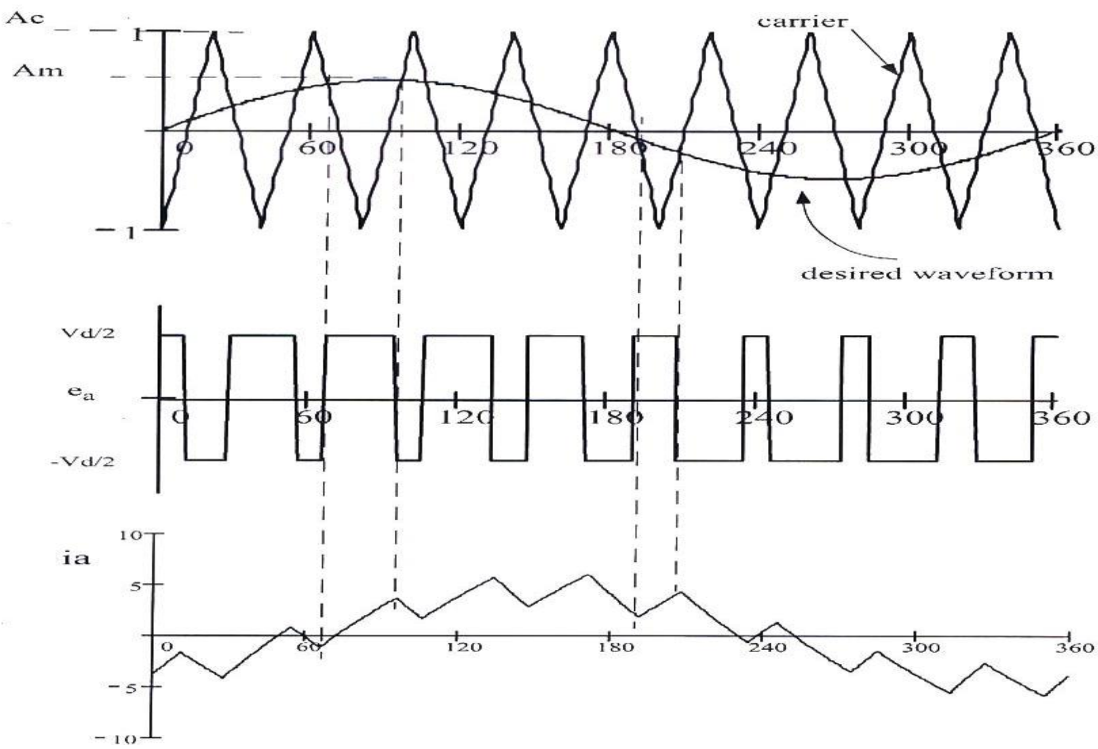

Fig.3: SPWM Technique Gate Pulses and Output Current

(III) Comparing the bidirectional carrier signal (triangular wave) with two sinusoidal reference signals (both 180^0 out of phase with each other), produces gating signals g1 and g4 respectively. However g1 and g4 cannot be released at the same time. Using these two signals as input to the comparator, the output will be a 2-level PWM signal.

(IV) When reference signal is greater than the modulating signal pulses are on and vice versa. This PWM signal is then sent to the diagonal switches of the inverter, i.e.; S1 & S2. For that time other switches are off as they do not get any gating pulse to their gate terminals.

(V) The number of pulses per half cycle depends on the carrier frequency. Within the constraint that two switches S1 and S4 cannot conduct at the same time, the instantaneous output voltage will be uni-polar.

(VI) The RMS output voltage can be varied by varying the modulation index M. It can be observed that the area of each pulse corresponds approximately to the area under the sine wave between the adjacent midpoints of off periods on the gating signal.

(VII) In SPWM modulation if δ_m is the width of mth pulse, then the rms output voltage

$$V_o = V_S \left(\sum_{\mathrm{m=1}}^{\mathrm{2p}} \frac{\delta_m}{\pi}\right)^{1/2}$$

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(VIII) This type of modulation eliminates all harmonics less than or equal to 2P±1. The distortion factor DF is significantly reduced compared with that of multiple-pulse modulation (MPWM).

The peak fundamental output voltage for SPWM control can be found approximately

$V_{m1} = \delta V_S$ for $0 \leq \delta \leq 1$

(IX) It is clear that for M = 1, the maximum peak fundamental output voltage is equal to source voltage Vs. To increase the fundamental output voltage, M must be increased beyond 1. The operation beyond M = 1, is called over-modulation. Over modulation basically leads to square wave operation and adds more harmonics as compare to the operation in under-modulation range ($0 \leq M \leq 1$). Over-modulation is normally avoided in applications requiring low distortion.

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 harmonics is still truncated, and there is a relatively high amount of higher level harmonics in the output signal. Although such PWM scheme has frequent switching which leads to high switching loss, these are used as these improve power quality.

IV. CONCLUSION

It can be concluded that sinusoidal pulse width modulation technique reduces the inverter output harmonics efficiently. The output voltage of inverter is nearer to the pure sine wave.

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