A Novel Carrier for Sinusoidal Pulse Width Modulation Based Full Bridge Inverter

M.Kaliamoorthy[1] Dr.B.Ramireddy[2] D.V.Ashok Kumar[3]

Abstract: **A voltage source inverter is commonly used to supply a variable frequency, variable voltage to a three phase induction motor in a variable speed application. A suitable pulse width modulation (PWM) technique is employed to obtain the required output voltage in the line side of the inverter. Real-time methods for PWM generation can be broadly classified into triangle comparison based PWM (TCPWM) and space vector based PWM (SVPWM). In TCPWM methods such as sine-triangle PWM, three phase reference modulating signals are compared with a common triangular carrier to generate the PWM signals for the three phases. In SVPWM methods, a revolving reference voltage vector is provided as voltage reference instead of three phase modulating waves. The magnitude and frequency of the fundamental component in the line side are controlled by the magnitude and frequency, respectively, of the reference vector. In SVPWM based inverter determination of sector at each instant of the output voltage is the key algorithm which is very complex, where as TCPWM produces larger magnitude of harmonics in the output voltage so we proposes a novel carrier in lieu of conventional triangular carrier. The proposed carrier gives good fundamental component and less total harmonic distortion when compared with the conventional triangular carrier. The proposed carrier was implemented in the real time using an arbitrary signal generator AFG3102.**

Key words: **Triangular carrier, Space Vector PWM, Fundamental Component, Total Harmonic distortion.**

I. Introduction

Switching-mode single-phase DC-AC converters have been widely used in critical applications such as uninterrupted power supply systems and AC motor drivers. Among various control techniques, Pulse Width Modulation (PWM) technique is the most effective one that is commonly used to regulate the magnitude and frequency of the converter's output voltage. Pulse width modulation (PWM) techniques are effective means to control the output voltage frequency and magnitude. It has been the subject of intensive research during the last few decades. Various PWM control schemes have been discussed in literature. Basically they can be classified into two main categories, one is carrier based PWM and the other is space-vector PWM [1, 2]. Especially, the space-vector PWM is used for three-phase converter applications. Here we mainly consider the carrier based PWM approaches that are often applied to the single-phase applications. The dc-ac inverter is used to produce VVVF, has many applications like induction heating, stand-by aircraft power suppliers, uninterruptible power supplies (UPS) for computers, HVDC transmission lines etc. Among all the modern power electronic inverters, the voltage source inverter (VSI) is perhaps the most hunted power conversion system. The single phase VSI consists of four power semiconductor switches with anti-parallel feedback diodes as shown Fig.1. It converts a fixed dc voltage to single phase ac voltage with controllable frequency and magnitude. Since the VSI has discrete circuit modes for each set of switching states, generating an output voltage with correct frequency and magnitude requires an averaging approach. Although the basic for an inverter may seem simple, accurately switching these devices provides a number of challenges for the power electronic engineers.

II. Evaluation of PWM

One of the problems in facing the power electronic design engineers is about the reduction of harmonic content in inverter circuits. The classical square wave inverter used in low or medium power applications suffers from a serious disadvantage such as lower order harmonics in the output voltage. Hence to eliminate these low order harmonics, the size of the filter component required is substantially increased. Classical square wave inverters have been ruled out in high power applications where low distorted sinusoidal waveform is required.

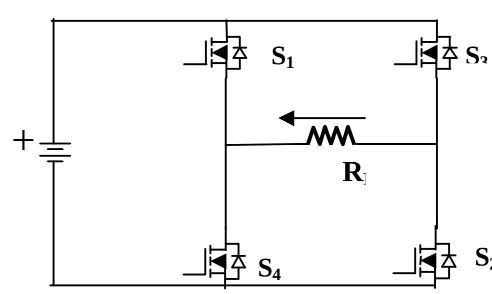

Fig 1. Power Circuit structure of a 1φ VSI

One of the solutions to enhance the harmonic free environment in high power converters is to use PWM control techniques. Instead of having a continuous pulse as in classical square wave inverter, having multiple pulses in the output can have control over harmonic content and the rms value of the voltage across the load without changing the input dc.

The process of varying the width of these pulses is known as Pulse Width Modulation. If the angular width of the pulses varies in sinusoidal fashion, such a scheme is known as Sinusoidal Pulse Width Modulation (SPWM). SPWM techniques enjoy an assortment of advantages such as high output quality, less Total Harmonic Distortion(THD), low distortion, low rating filter component etc. In case of SPWM techniques, as the harmonics are pushed into a high frequency range decided by the switching frequency, the size of filtering component gets dramatically reduced at cost of higher switching losses. Also the SPWM technique offers flexible control of output voltage and frequency with the line current being nearly sinusoidal in nature and thus improving the overall power factor of the system, which are indeed the requirements in ac drives.

Further exploration reveals that SPWM has some constraints. The major one is the limitation of fundamental magnitude. In this case, however, the ratio of the fundamental component of the maximum line voltage to dc supply voltage is 0.87 %. This value indicates a poor utilization of dc power supply. There is a way called Over Modulation in which the fundamental component can be improved but lower order harmonics are introduced. Thus lot of modifications has been done in the literature to reduce the harmonic content in the PWM inverters but the method proposed by the researchers has limitations and drawbacks as pointed out[1-6]. This paper proposes a novel method in reducing the harmonic levels of PWM inverters. The main objective of this paper is to reduce the harmonic distortion of PWM inverters by modifying the carrier signal into different shapes and to find the better solution for harmonic levels in PWM inverters.

III. Triangular Carrier Based SPWM Inverters

The most popular and widely used PWM technique involves the simple direct comparison of a sinusoidal modulating signal with a triangular carrier signal to produce the PWM switching edges. The instantaneous real time intersection of these two signals determines the PWM switching instants by a process of natural selection or sampling called Natural sampled PWM. This is illustrated in Fig 2.

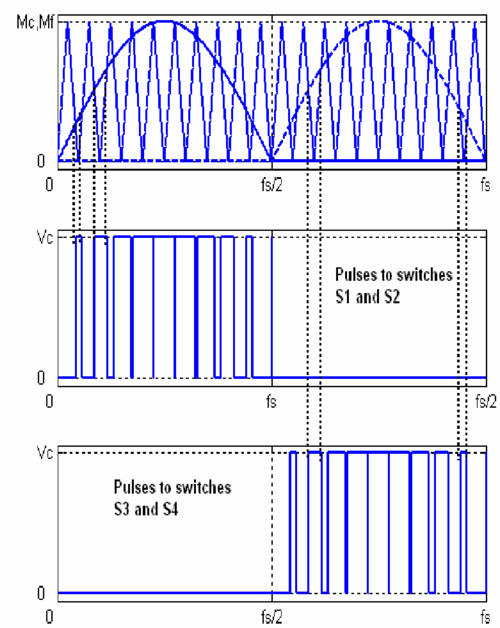

Fig 2 (a) Comparison between triangular and reference sine waveforms (b) pulses to switches

The PWM pulses shown in the figure 2 is given to the switches S_1, S_2, S_3 and S_4 of figure 1 to get the AC output waveform such a waveform and its harmonic spectrum is shown in the figure 3. The input DC voltage given to the inverter is 80 volts. It is observed from the harmonic spectrum that the total harmonic distortion of the output voltage waveform is 110.56% of the fundamental output voltage waveform. The value of amplitude modulation index taken in this case is 0.5 and the switching frequency of the MOSFET switches used here is 1 KHz. The THD% becomes still worst when we reduce the amplitude modulation index which is mostly used when we operate the AC motor drive in low speed region. Another way of reducing the THD% of the fundamental is to increase the switching frequency but it restricts the power electronic switches used in the hardware setup. It is palpable from the figure 3 that the harmonics are dominant around the even multiples of switching frequency of the MOSFET switches. Since dominant harmonics are of higher order and can be eliminated easily by any of the method proposed in [1] and the total THD% can be brought below acceptable IEEE limits.

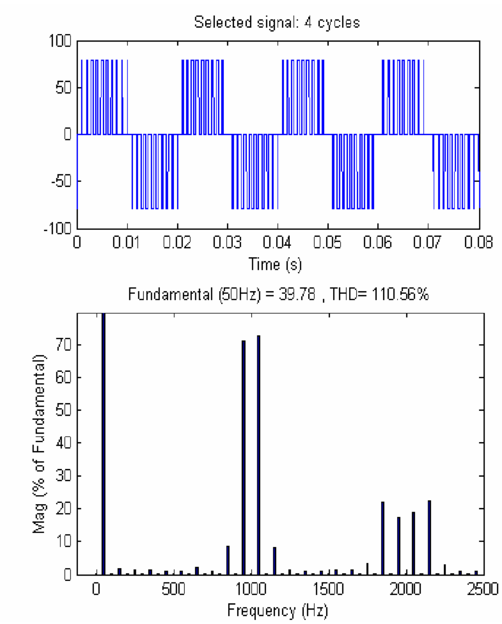

Fig.3 Output Voltage Waveform and Harmonic Spectrum of Triangular Carrier SPWM

IV. Proposed Carrier for SPWM Inverters

The authors have investigated all possible carriers instead of triangular carriers and compared it with the performance of conventional triangular carrier. The performance comparison is based on the fundamental component and the total harmonic distortion. Some of the carrier which has been taken for the investigation is W-type carrier-type carrier, w-type carrier, m-type carrier, N-type carrier, Y-type carrier, and u-type carrier. Among the examined carriers the small w type carrier signal found to have the superior performance. The w-type carrier which has the best performance is shown in the figure 4.

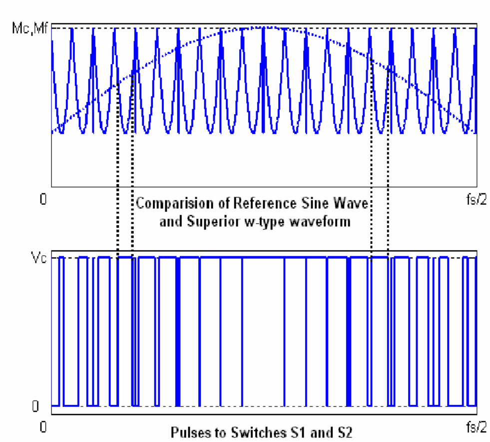

Fig 4 Comparison between superior w-type carrier and reference sine waveforms and pulses to switches

The output voltage waveform and the harmonic spectrum of SPWM inverter with w-type carrier of frequency 1KHz and amplitude modulation index of 0.5 is shown in the figure 5.The fundamental voltage and THD% for the same amplitude and frequency modulation indices is 44.15 Volts and 87.10% respectively.(M_a=0.5 and M_f=20 in both cases of triangular and w-type carrier).The difference in fundamental component is about 4.37 volts and the total harmonic distortion is also reduced when compared with the conventional triangular carrier waveform. Thus from the simulation results it is concluded that the w-type carrier is having superior performance in the form of fundamental component and THD.

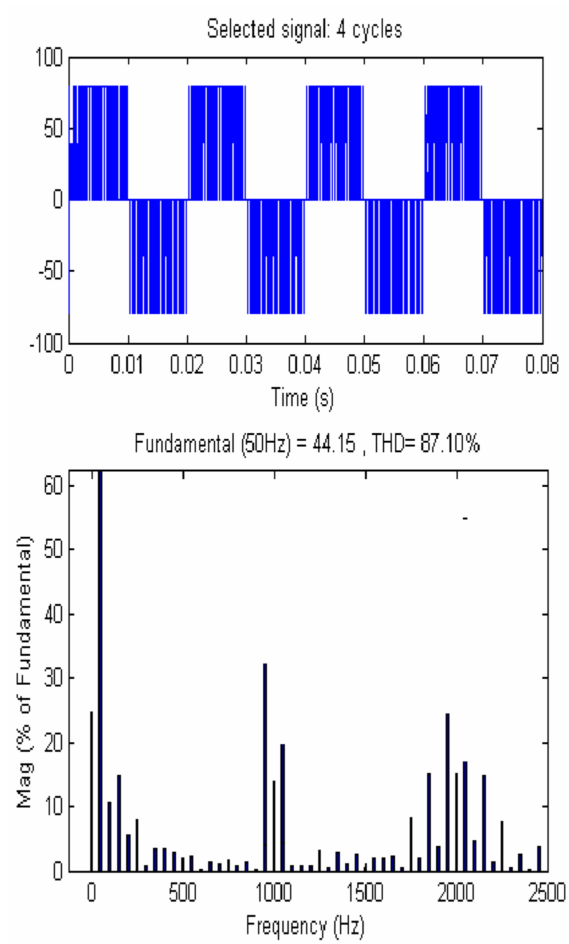

Fig.4 Output Voltage Waveform and Harmonic Spectrum of w-type Carrier SPWM

The graph shown below in figure 5 and figure 6 compares the analysis carried by the authors for different types of carrier signals. Figure 5 shows the performance of different types of carrier signals in terms of the fundamental component for various values of amplitude modulation index (M_a).

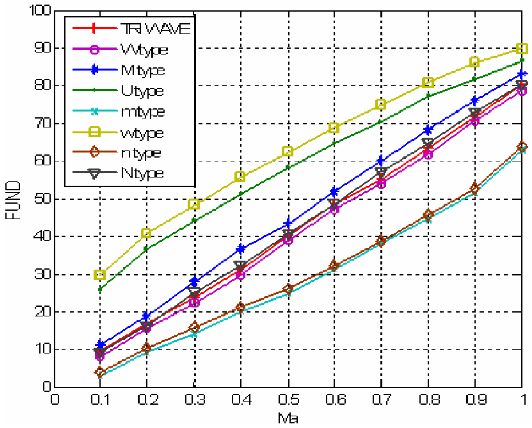

Fig 5 Comparison of Fundamental component of different carrier signals for various values of M_a.

It is obvious from the figure 5 that the w-type carrier which has the superior performance is staged on the top when compared with all other carriers. This means that the w-type carrier has high fundamental component when compared with other carrier signals. Note that the conventional triangular signal is in the fifth position from the top (marked with —+—).Figure 6 shows the performance of different types of carrier signals in terms of total harmonic distortion for various values of M_a.

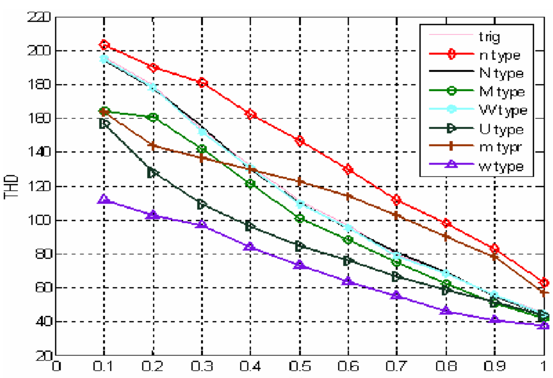

Fig 6 Comparison of THD% of different carrier signals for various values of M_a.

It is obvious from the figure 6 that the w-type carrier which has the superior performance is staged on the bottom when compared with all other carriers. This means that the w-type carrier has low total harmonic distortion when compared with other carrier signals. Note that the conventional triangular signal is in the fifth position from the bottom.

V. Hardware Implementation of W-type Carrier

To validate the performance of the best carrier with the simulation results the best carrier proposed was implemented in the real time using arbitrary signal generator AFG3102. The arbitrary signal generator AFG3102 is capable of generating any arbitrary waveform. This instrument is used to generate the w-type carrier (superior carrier). The AFG3102 generated w-type carrier is shown in the figure 7.

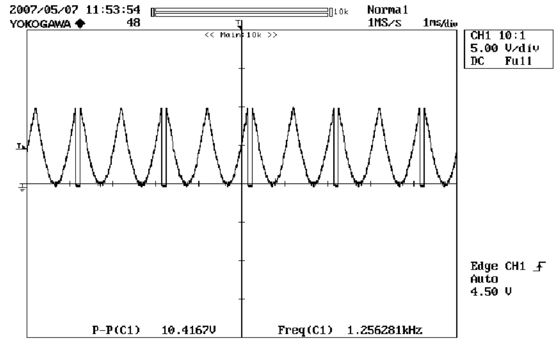

Fig 7 Implementation of Superior Carrier in AFG3102

Figure 8 shows the output voltage waveform of a full bridge inverter which uses best carrier for PWM modulation. The output frequency of the waveform is 50Hz and the inverter switches are made to operate at M_a=0.5.The entire hardware setup used in the power electronics laboratory is also shown in the figure 9.

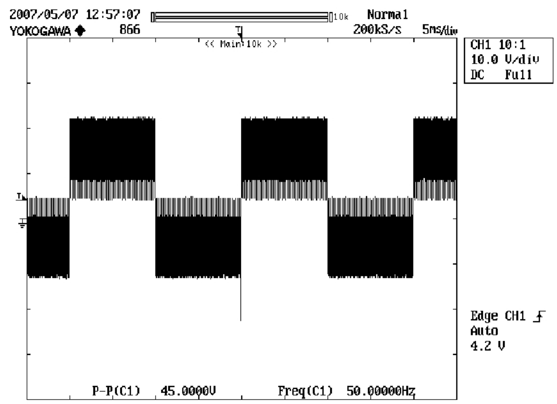

Fig 8 Output Voltage waveform of Inverter with best carrier based modulation

Figure 9 Entire Hardware setup in Power Electronics Laboratory

VI. Conclusions

The conventional triangular carrier signal used for generating PWM pulses have drawback of high harmonic content in the output voltage. This triangular carrier has been modified into w-type which has good performance when compared with TCPWM. The proposed carrier was simulated in the Matlab/Simulink environment and to validate the simulation results the proposed carrier was implemented using arbitrary signal generator AFG3102.

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