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Harmonic Analysis of Sine PWM and hysteresis current controller

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ABSTRACT: There are several pulse width modulation techniques used for various application. Some of them are sine PWM, hysteresis current controller, space vector pulse width modulation, third harmonic injection method. In this paper sine PWM and hysteresis current controller technique is explained in detail and harmonic analysis of these two techniques is performed using FFT tool of simulink in MATLAB.

Keywords: PWM techniques, Sine PWM(SPWM), Hysteresis current controller, Harmonics Analysis

I. INTRODUCTION

Various PWM techniques have been developed in past two decades. The main aim of PWM technique is to obtain various outputs with maximum fundamental component and minimum harmonics. The carrier based PWM methods were developed first and widely used in most applications. One of earliest and simplest carrier based PWM technique is sine PWM (SPWM) technique. The utilization rate of traditional sine PWM technique is only 78.5 % of DC bus voltage.

Another technique which is widely used is hysteresis band current controller because of its simplicity. This method has uses fast response of current loop. Another advantage is that it does not need any knowledge of load parameters. But it has disadvantage that switching frequency is irregular. In this paper sinusoidal band hysteresis current controller with low pass filter is used. A low pass filter is used to minimize ripple and therefore reducing higher order harmonics. The simulation study has been carried out in MATLAB environment.

II. SINUSOIDAL PWM

A. Single phase bipolar sinusoidal PWM

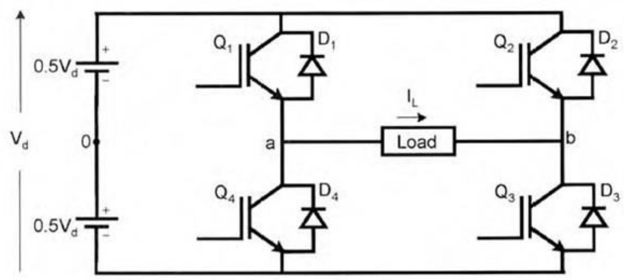

Fig. 1. Single Phase H bridge inverter

To understand single phase sinusoidal PWM (bipolar) consider the above fig. 1 single phase H bridge inverter. First a triangle wave at desire frequency is generated and compared with sinusoidal command or modulating voltage wave as indicated in below figure 2.

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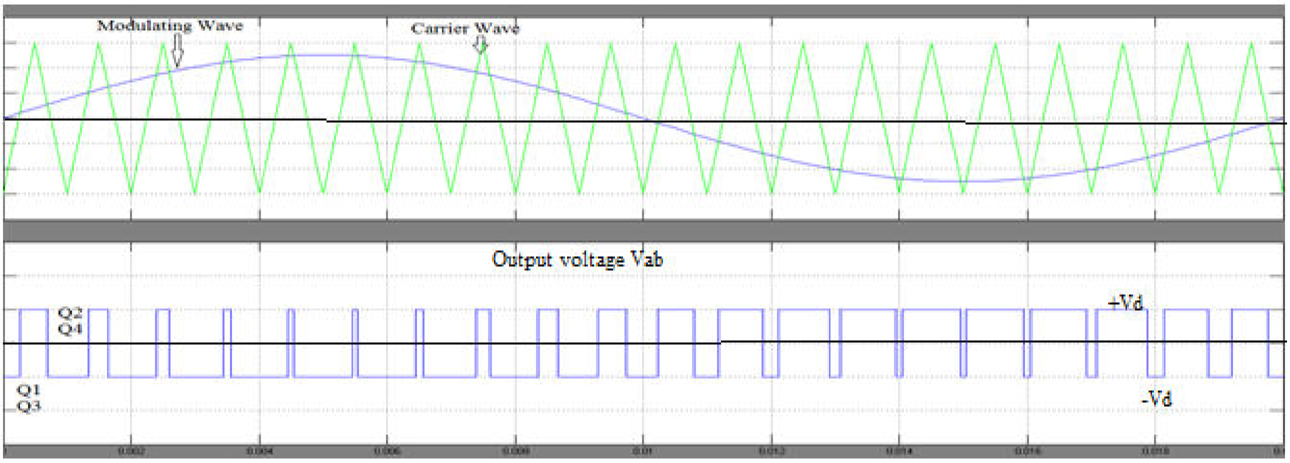

Fig. 2. Waveform of carrier wave and modulating wave

Device pair Q_1 and Q_3 is turned on when amplitude of modulating wave is higher than amplitude of carrier wave. Similarly Device pair Q_2 and Q_4 is turn on when amplitude of modulating wave is less than amplitude of carrier wave. The resulting PWM output is shown in below part of fig. The technique is called bipolar because a pair of devices, one from each pole, switches togher to generate bipolar voltage wave. We can see that output of fundamental frequency is same as modulating frequency and amplitude of output PWM voltage is varies linearly with amplitude of modulating wave until peak of modulating wave and carrier wave are equal.

B. Single phase unipolar sine PWM

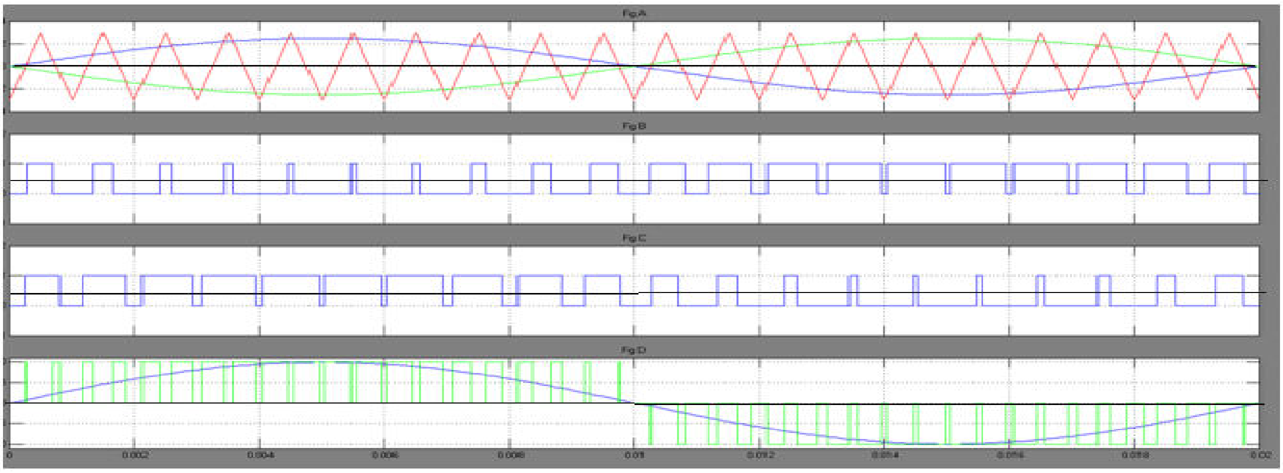

Fig. 3. Waveform of carrier wave and modulating wave and output voltage

In single phase unipolar sine PWM single phase H bridge inverter is similar which is used in single phase bipolar sinusoidal PWM technique. Here difference is that two legs of H bridge inverter are switch separately.The modulating signal v^*_{ao} for the left leg is compared with the triangular carrier wave to generate the actual V_{ao} wave shown in part (b). This wave has the same shape as V_{ab} in Figure 2.1, except it has an amplitude variation of +/-0.5Vd with respect to the dc center point. The modulating signal V^*_{bo} for the right leg is at 180° phase angle with V^*_{ao}, and the actual V_{bo} wave is shown in part (c). The output voltage is given by $V_{ab} = V_{ao} – V_{bo}$ as indicated in part (d).

The scheme is called unipolar because output voltage of PWM varies between o to + V_d for positive half cylcle and o to – V_d during negative half cycle.

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C. Three phase sinusoidal PWM

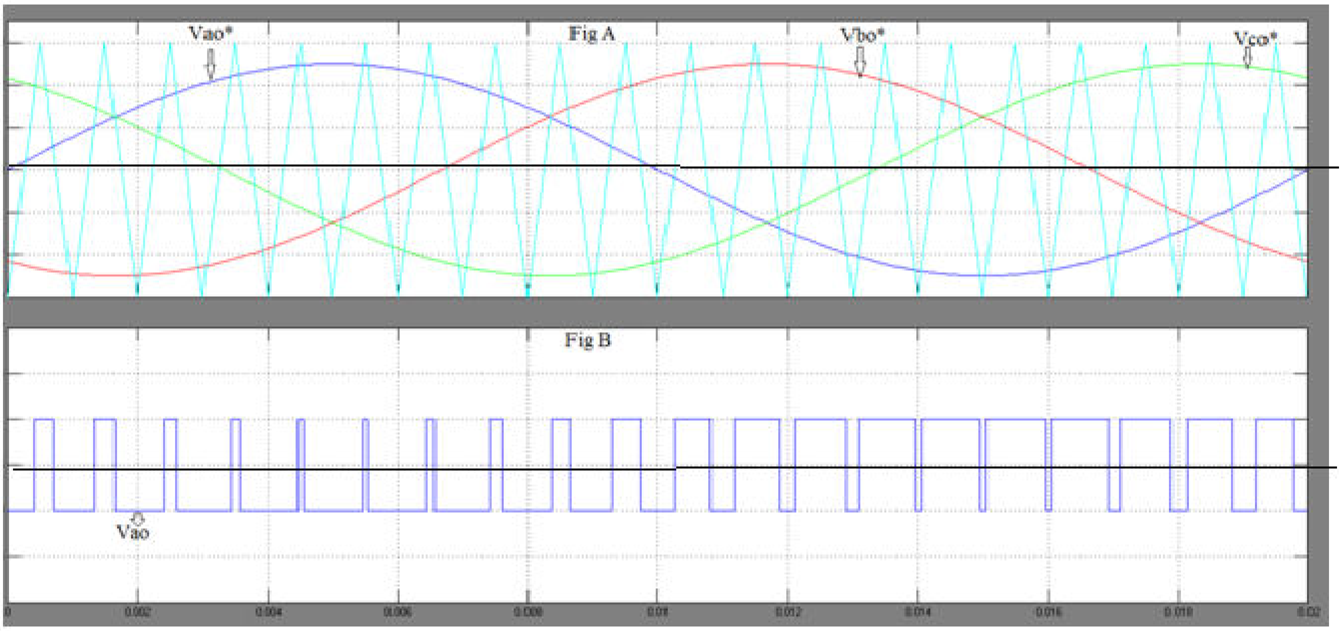

Fig. 4. Waveform of carrier wave and modulating wave and output voltage

The principle of single phase unipolar sinusoidal PWM can be utilized to three phase sinusoidal PWM technique. Here modulating wavefrom is displaced by 180 degree each other and concept is similar which has been used in single phase unipolar PWM technique. From fig 4 we can see that modulating wave V^*_{ao}, V^*_{bo}, V^*_{co} is displaced by 180 degree. Each leg of three phase inverter is switch separately. For first leg if magnitude of modulating wave V^*_{ao} is higher than carrier wave than upper switch is turn on otherwise and if it is less than lower switch is turn on. Similar concept is used for other legs of three phase inverter for V^*_{bo} and $V^*_{co.}$ Terms associate with three phase inverter are explained below:

a. Frequency modulation ratio (M_f) : It can be defined as ratio of PWM frequency(Carrier wave frequency) to fundamental frequency(Modulating wave frequency).

If frequency modulation is not integer then there may be exist subharmonics at output voltage.
If frequency modulation is not odd then DC componenets may be exist and even harmonics may be present at output.
To suppress odd multiple of 3 and even harmonics, Frequency moduaion should be kept multiple of 3.

b. Modulation Index (M): It can be defined as ratio of amplitude of modulating waveform to amplitude of carrier waveform.

If M<1 it means that PWM inverter operates at under modulation and if M>1 it means that PWM inver operates at over modulation. Generally PWM inver operates at under modulation. If it is operated at over modulation then linear relation between modulating wave and output voltage will not be continue.

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III. HYSTERESIS BAND CURRENT CONTROLLER

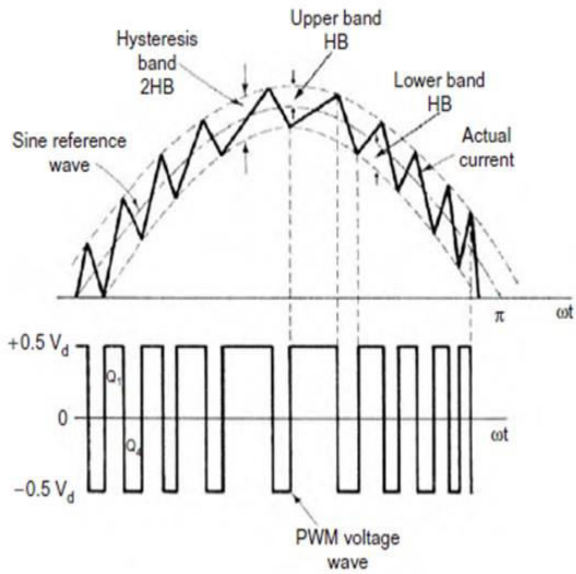

Fig. 5 Principle of hysresis band current controller

One of the simplest current control PWM techniques is the hysteresis band (HB) control shown in this figure 5. Basically, it is an instantaneous feedback current control method in which the actual current continuously tracks the command current within a pre assigned hysteresis band. As indicated in the figure 5, if the actual current exceeds the HB, the upper device of the half-bridge is turned off and the lower device is turned on. As the current decays and crosses the lower band, the lower device is turned off and the upper device is turned on. If the HB is reduced, the harmonic quality of the wave will improve, but the switching frequency will increase, which will in turn cause higher switching losses.

This same logic can applied to three phase waveform also. In three phase 3 reference signal 120 phase shifted is used and is compared with load current as a result we get desired output. Advantage and disadvantage of this method is shown below.

Advantages:
1. Excellent dynamic response.
2. Low cost and easily implementation.

Disadvantages:
I. Large current ripple in steady state.
II. Variation of switching frequency.
III. No intercommunication between each hysteresis controller of three phases and hence no strategy to generate zero voltage vector. Hence signal will leave hysteresis band whenever zero vector is turn on.
IV. The modulation process generates sub harmonic components.

V. SIMULATION RESULTS

MATLAB/Simulink software is used to implementation of SPWM, Hysteresis band PWM. Simulink models are built on the corresponding in previous methods. LC filters are required at the outputs in order to filter out the PWM

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waveforms and visualize the fundamental results. A Comparison of Harmonic Analyses Of The Various PWM Techniques Undertaken In this Project are shown below for different loads.

TABLE I

With Constant Load (R = 3 Ω)		
PWM Technique	**% Current THD**	**%voltage THD**
SPWM	0.78 %	0.78 %
Hysteresis PWM	4.5 %	4.5 %

TABLE II

With Constant Load (R = 3 Ω and L = 5mH)		
PWM Technique	**% Current THD**	**%voltage THD**
SPWM	0.92 %	0.61 %
Hysteresis PWM	3.56 %	4.72 %

TABLE III

With Constant Load (R = 3 Ω, L = 5 mH and C = 50μF)		
PWM Technique	**% Current THD**	**%voltage THD**
SPWM	4.03 %	1.14 %
Hysteresis PWM	4.22 %	2.26 %

TABLE IV

With Constant Load (5 HP Induction Motor)		
PWM Technique	**% Current THD**	**%voltage THD**
SPWM	1.24 %	2.86 %
Hysteresis PWM	1.22 %	2.79 %

IV. CONCLUSION

Some Major Concerns in Comparing Different PWM Techniques:

- Good utilization of DC power supply that is to deliver a higher
- Output voltage with the same DC supply.
- Low switching losses.
- Good linearity in voltage and or current control.
- Low harmonics contents in the output voltage and or currents, especially in the low frequency region.

The different voltage control techniques produce a range of harmonics on the output voltage. From my simulation results I observed that Sine PWM is more effective in reducing the Lower order harmonics as compared to hysteresis band PWM with low switching losses.

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BIOGRAPHY

Kedar Patil received the B.Eng in Electrical from VNSGU, Surat, India in 2011 and he is pursuing M.Tech. degree in Electrical Power System from CHARUSAT, Changa, India. His current research interests include renewable energy sources, Wind Farms, PMSG, Application of power electronics in power system, and PV System.