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Harmonic Distortion Analysis of the Output Voltage in SPWM (Unipolar) Single Phase Full Bridge Inverter

[1]Nidhi Gupta, [2]Ashish Choubey

[1]M.E. Student (HVPS Engg), [2]Assistant Professor, Deptt. of Electrical Engineering, JEC Jabalpur, M.P., India

Abstract: **In this paper, a simulation of SPWM (Unipolar) strategy is presented for Single phase full bridge inverter. The model is simulated in Matlab/Simulink. For different power factor loads the % THD of the output voltage are observed. The change in modulation index (MI) and the frequency of the carrier signal (f_c) changes the % THD of the output voltage. The width of gate pulses are modulated in order to obtain controlled inverter out voltage and to reduce the harmonic content as well. A comparative study of the % THD of the output voltage for the same load when connected across a conventional inverter and across SPWM fed inverter helps to understand the performance of the inverter. In SPWM inverter, to generate the gate signals, triangle wave is the carrier wave which is compared with the reference sinusoidal wave. The frequency of the output voltage depends on the frequency of the reference wave.**

Keywords: **Sinusoidal pulse width modulation (SPWM), Unipolar, Total Harmonic distortion (THD), Order of Harmonics, lagging and leading pf loads.**

I. INTRODUCTION

Inversion is the process of conversion dc power to ac power at a required output voltage, current and frequency. A static semiconductor performs this electrical energy inverting transformation process. The inverter receives the DC power from a battery and then converts it to AC with the desirable frequency. The inverter is therefore adjustable frequency voltage source.

Inverters can be classified in two types:

- voltage sorce inverter (VSI)
- Current source inverter (CSI).

A voltage source inverter (VSI) is the one in which the DC input voltage is constant and is independent of the current drawn by the load. In VSI the dc source has small or negligible impedance. The voltage at the input terminals of inverter is always constant. A current source inverter (CSI) is fed with adjustable current from the dc source of high impedance that is from a constant dc source.

According to the connections of semiconductor devices, inverters are:

- Bridge Inverters
- Series Inverters
- Parallel Inverters

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A voltage source inverter (VSI) using thyristor as a switch requires forced commutation, while the VSI in which MOSFET, GTO, IGBT, power transistors are the switching devices, self commutation with gate pulse is required for their controlled turn on and off process.

II. SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

Pulse width modulation (PWM) is a powerful technique to controlling the switching devices in inverter circuits. PWM provides a way to decrease the Total Harmonic Distortion (THD) of load current and output voltage. The THD requirement can be met more easily when the output of PWM inverter is filtered. The unfiltered output will have relatively high THD, but the harmonic will be at the much higher frequencies which can be filtered out easily.

Sinusoidal pulse width modulation (SPWM) is a very simple technique used for harmonic reduction. In this technique a carrier wave (Triangular) is compared with a reference wave (Sinusoidal) to generate the gate pulses for the inverter.

A sinusoidal reference wave A_C, reference wave with 180^0 phase shift $-A_C$ and a triangular carrier wave A_r of higher frequency are compared for gate pulses. There are two important parameters in this modulation technique:

- Amplitude Modulation Ratio or Modulation Index (MI)
- Frequency Modulation Ratio

Amplitude Modulation ratio = $\frac{A_r}{A_c}$

Frequency Modulation ratio = $\frac{f_c}{f_r}$

The rms output voltage can be varied by varying the modulation index MI. Frequency modulation ratio changes the number of gating pulses per half cycle of the reference wave. It can be controlled by varying the frequency of carrier signal f_c. This type of modulation eliminates all harmonics less than or equal to 2P – 1. Where P is the number of pulses per half cycle = $\frac{f_c}{2f_r}$.

THD is a measure of closeness in shape between a waveform and its fundamental component. THD gives the information about total harmonic content, but it dose not indicate the level of each harmonic component. Lowest order harmonic (LOH) is that harmonic component whose frequency is closest to the fundamental one, and its amplitude is greater than or equal to 3% of the fundamental component.

III. SIMULATION RESULTS

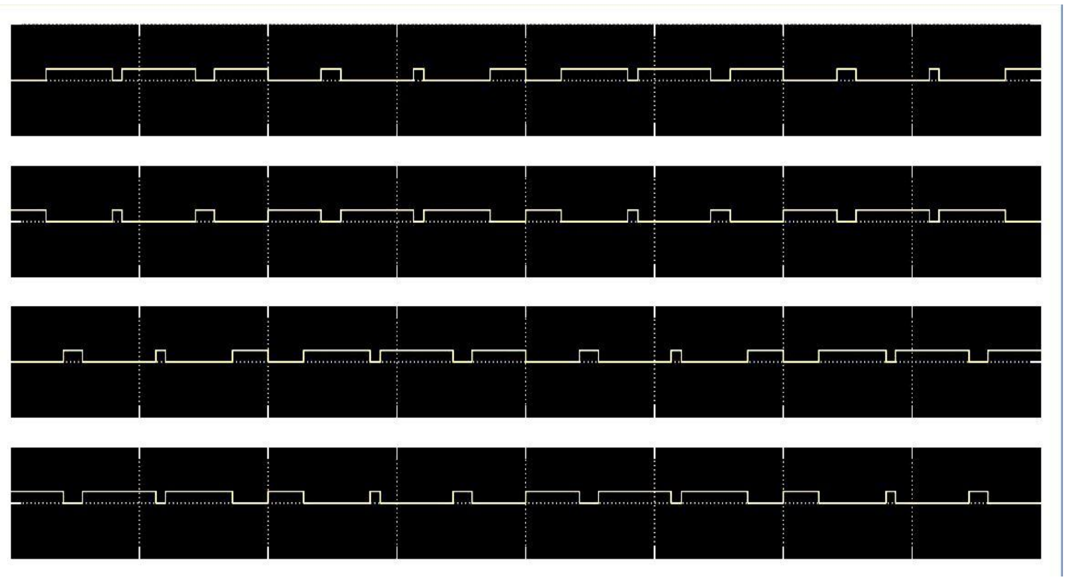

Fig.1: Triggering pulses for SPWM Unipolar Full Bridge Inverter

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THD analysis of output voltage and current in a conventional full wave bridge inverter supplied by 240V DC source at constant load variable power factor:

Load	THD load current	THD output voltage
5kw 0 pf lag	12.1 %	48.35%
5kw 0.6 pf lag	14.74 %	
5kw 0.8pf lag	18.66 %	
5kw unity pf	48.35 %	
5kw 0.8pf lead	59.43 %	
5kw 0.6pf lead	76.6 %	
5kw 0 pf lead	84.59 %	

It is clear from the above results that THD of the current depends upon the load pf. Harmonic distortion of current is high for a purely capacitive load and it is minimum for a purely inductive load. The THD of the output voltage is independent from the load power factor.

A 5 kw 0.8 lag pf load is connected to a 240V DC sources supplied single phase spwm fed unipolar full bridge inverter. For different values of carrier frequency f_c THD analysis of the output voltage is shown by the tables below:

Table 1

For MI = 1 and f_c = 50 Hz V_{OUT} = 240 volts , $(THD)_V$ = 48.35 % Voltage profile of the out put voltage								
Harmonic Order	DC component	3	5	7	9	11	13	All even order harmonics are 0.39 % of fundamental component
% of fundamental	0.19	33.33	20	14.28	11.1	9.08	7.68	

Table 2

For f_c = 300 Hz and MI = 0.6 V_{OUT} = 105.57 volts , $(THD)_V$ = 105.57 % Voltage profile of the out put voltage							
Harmonic Order	DC component	3	5	7	9	11	13
% of fundamental	0	4.79	0.14	2.51	12.14	64.35	62.76

Table 3

For f_c = 300 Hz and MI = 1 V_{OUT} = 188.2 volts , $(THD)_V$ = 49.92 % Voltage profile of the out put voltage							
Harmonic Order	DC component	3	5	7	9	11	13
% of fundamental	0	1.28	0.95	2.18	22.27	19.08	18.06

Table 4

For f_c = 500 Hz and MI = 0.6 V_{OUT} = 147 volts , $(THD)_V$ = 107.82 % Voltage profile of the out put voltage							
Harmonic Order	DC component	3	5	7	9	11	13
% of fundamental	0	3.12	1.45	3.12	1.5	3.24	0.71

Table 5

For f_c = 500 Hz and MI = 1 V_{OUT} = 188.2 volts , $(THD)_V$ = 55 % Voltage profile of the out put voltage							
Harmonic Order	DC component	3	5	7	9	11	13
% of fundamental	0	1.62	0.37	1.58	0.11	0.11	0.48

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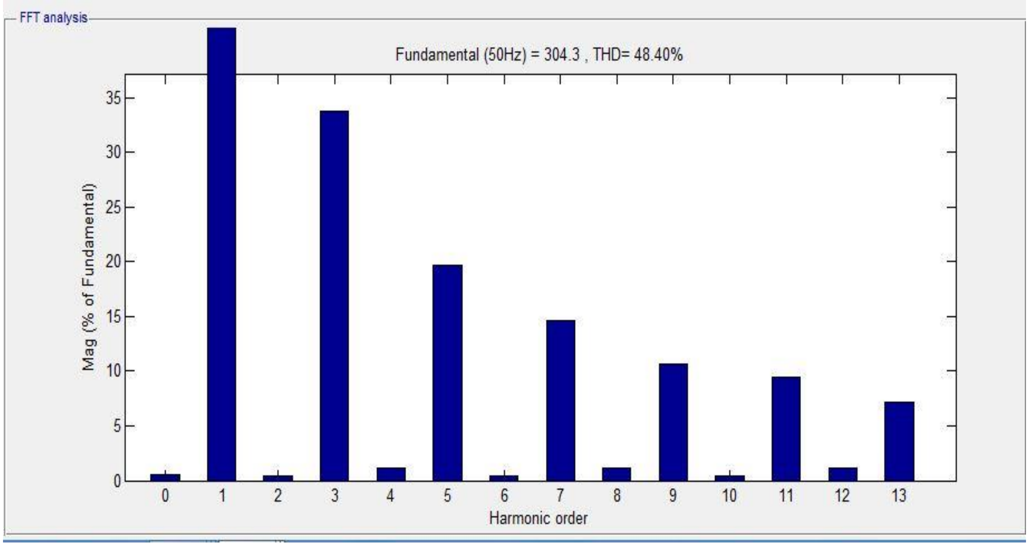

Fig.2: Output voltage Harmonic spectra for f_c = 50 Hz and MI = 1

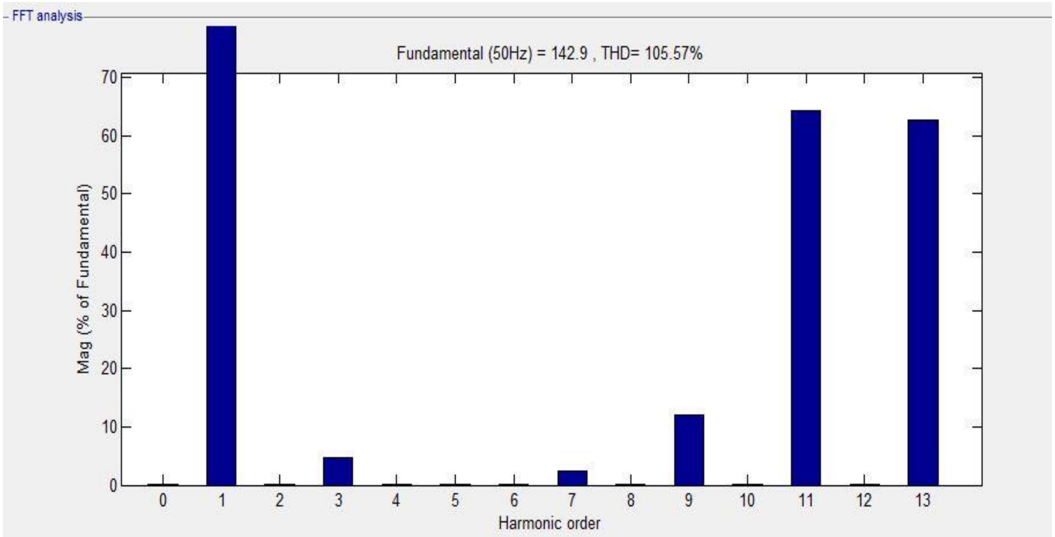

Fig.3: Output voltage Harmonic spectra for f_c = 300 Hz and MI = 0.6

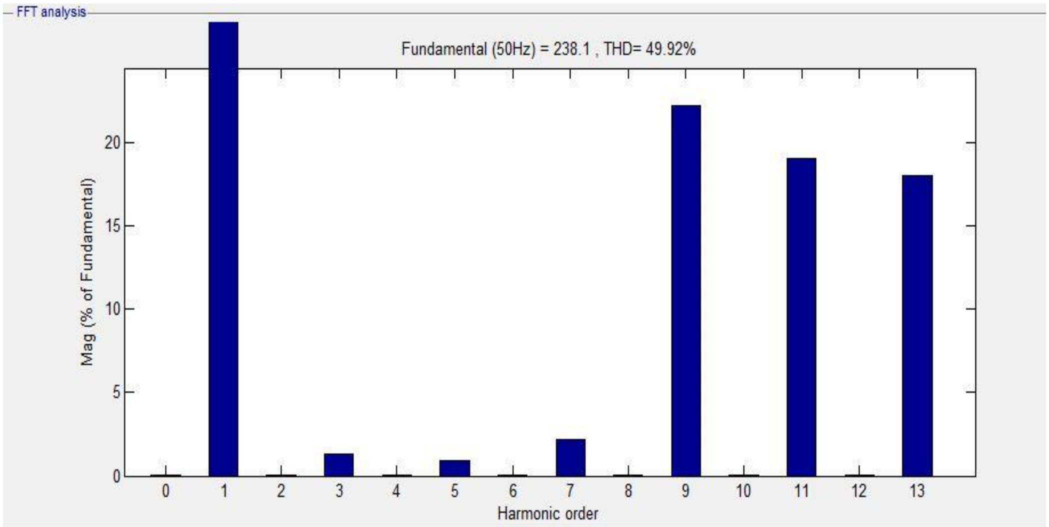

Fig.4: Output voltage Harmonic spectra for f_c = 300 Hz and MI = 1

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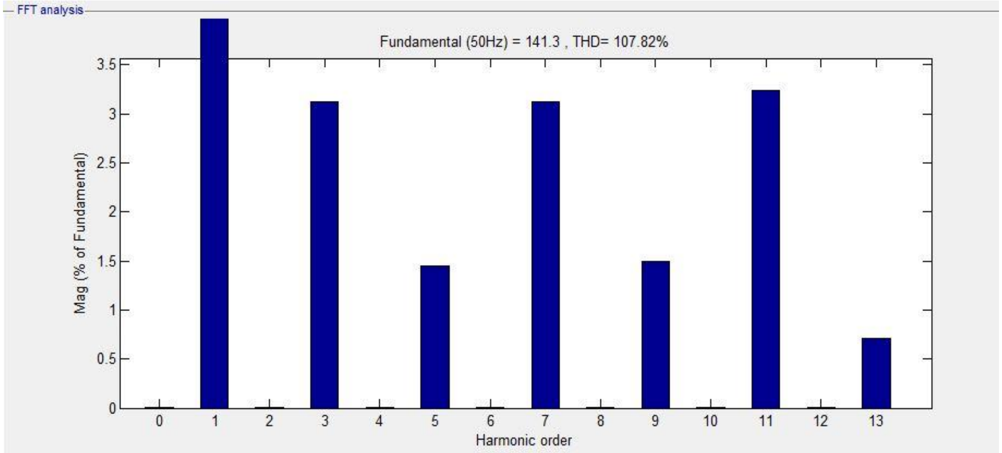

Fig.5: Output voltage Harmonic spectra for f_c = 500 Hz and MI = 0.6

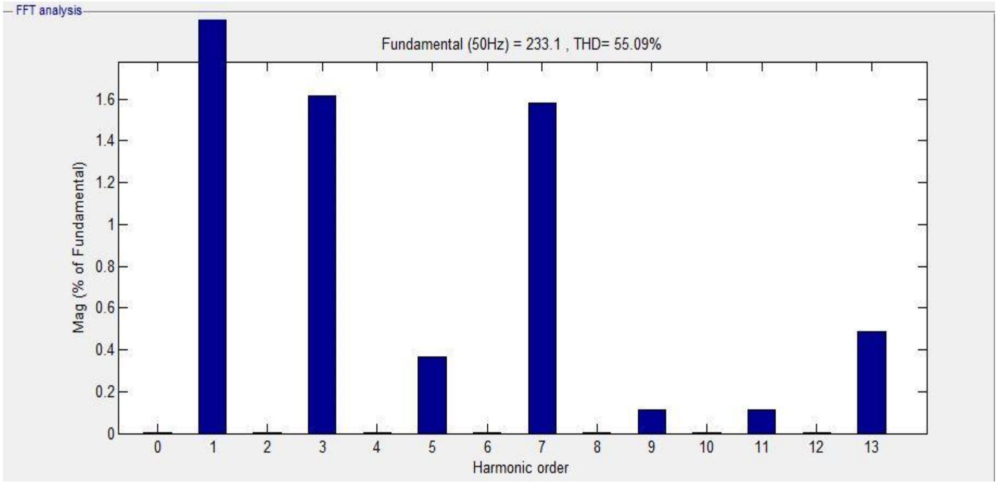

Fig.6: Output voltage Harmonic spectra for f_c = 500 Hz and MI = 1

IV. CONCLUSION

From the results shown in table 1 to table 5 and harmonic spectra of the output voltage shown in fig.2 to fig.6, following conclusions can be drawn:

1. For a lagging power factor load, the output voltage contains odd harmonics in significant % of the fundamental component. The even harmonics are not in a significant % of fundamental component.

2. To reduce the THD of the output voltage the frequency of carrier signal f_c and the modulation index MI plays the key role. On changing the (MI) from 0.6 to 1, output voltage THD reduces from 105% to 49% at a carrier frequency 300 Hz. To eliminate any particular order of harmonics carrier frequency f_c is the key factor. At carrier frequency f_c = 300 Hz , lower order harmonics are reduced as compare to their % for 50 Hz carrier frequency. On changing the modulation index (MI) from 0.6 to 1 on the same carrier frequency, the % of the odd harmonics goes down significantly.

3. The same trend of results can also be observed for f_c = 500 Hz and for MI = 0.6 & 1..

4. The magnitude of the output voltage varies with change in MI. It increases as MI approaches to the higher value i.e. 1.

REFERENCES

[1] Muhammad H.Rashid, Third edition, “Power electronics circuits,devices and applications”,Practice Hall of India.

[2] M D Singh, K.B.Khanchandani, Second edition, “Power electronics”,Tata McGraw Hill Education Private Limited.

[3] Bose K.B.(1997) , “Power electronics and Variable frequency Drives”, IEE Press ISBN 0-7803-1061-6, New York.