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Comparative Performance Analysis of Bipolar and Unipolar Single Phase Full Bridge Inverter

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Abstract: **In this paper a comparative performance is analysed of Bipolar and Unipolar inverters using Matlab/ Simulink model for a lagging power factor load. The performance analysis is based upon the harmonic distortion in the output voltage of both the inverters for the same load at different carrier frequencies of the carrier signal and at different modulation index (MI) . SPWM technique is used to reduce the harmonic distortion in the output voltage. By changing the carrier signal frequency, selective order of harmonics can be eliminated and by increasing the modulation index, the % of harmonic component in the output voltage profile can be reduced. There are many inverter topologies but output voltage distortion and efficiency are the two main parameters for the selection of an inverter. In spwm technique two such topologies are Bipolar and Unipolar inverters are presented here. These bridge inverter topologies are fed with constant amplitude pulses with varying duty cycle for each period. The pulses are generated by comparison of two waves – a carrier wave, which is a triangular and a reference or modulating wave which is a sinusoidal wave. The frequency of the output wave is same as the frequency of the reference wave.**

Keywords: **Bipolar, Unipolar, PWM, Harmonic distortion, Even and Odd harmonics, Carrier and Reference signals.**

I. INTRODUCTION

The power circuit diagram for single phase voltage source inverter is shown in Fig 1. In which four switches are used to generate an AC output voltage with a DC power supply. Any semiconductor device like IGBT, MOSFET or BJT can be used as switches. In case of resistive load four switches are sufficient because the load current and the output voltage are in phase but in case of lagging power factor loads, diodes are connected in anti-parallel with switches allow the flow of current when the main device is turned off. These diodes are termed as the feedback diodes since the energy is fed back to the DC source.

Four semiconductor switches T1,T2,T3 and T4 are arranged with the load connected at the midpoints of the two legs . Feedback diodes are provided for all the switches. The switches T1,T2,T3 and T4 can be switched in three different ways:

When T1 and T2 are turned on the output voltage is + polarity.

When T3 and T4 are turned on the output voltage is – polarity.

When T1 and T4 or T2 and T3 are turned on together output voltage is zero.

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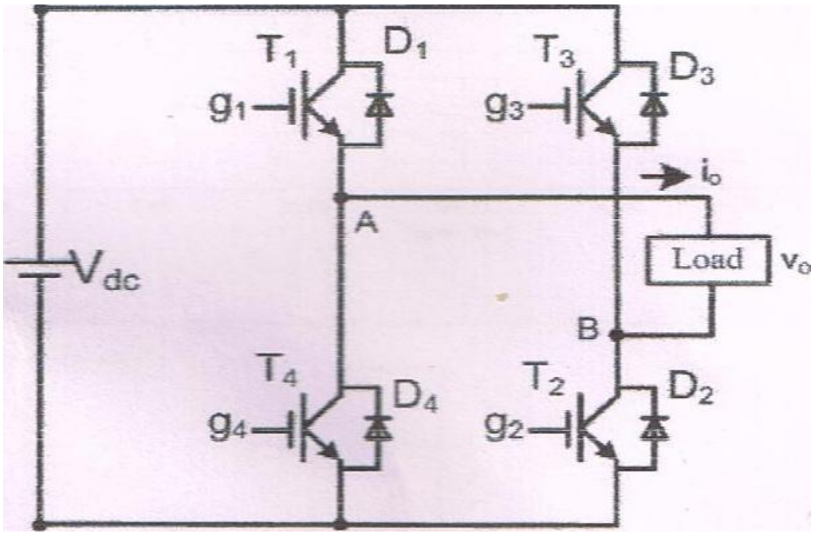

Fig 1. IGBT based single phase voltage source bridge inverter circuit diagram

II. BIPOLAR AND UNIPOLAR INVERTERS

Variation of duty cycle of the PWM signal provides a voltage across the load in a specific pattern will appear to the load as AC voltage. A pure sine wave can be obtained after passing this output voltage through a low pass filter. In SPWM two signals are compared. The modulating reference signal is sinusoidal and the carrier signal is a triangular wave. Gating pulses are produced by comparing the two signals and the width of each pulse is varied in proportion to the amplitude of the sine wave. The frequency of the reference signal determines the inverter output frequency and the reference peak amplitude controls the modulation index (MI) and the RMS value of the output voltage.

In a Bipolar inverter the upper and lower switches in the same leg works in a complementary manner with one switch turned on and other turned off. So we need to consider only two independent gate signals which are generated by comparing a sine wave and a triangular wave. In this case the output voltage switches between positive and negative values and it is termed as Bipolar.

In a Unipolar inverter two reference sinusoidal waves are required, which are same in magnitude but 180^0 phase shift. These two signals are compared with a common triangular carrier signal and generating the two gate pulses for two two upper switches of two different legs T1 and T3. In Unipolar Invereter, the ouput voltage switches between 0 and +ve polarity in one half cycle and between 0 and –ve polarity in other half cycle. So this scheme is called Unipolar .

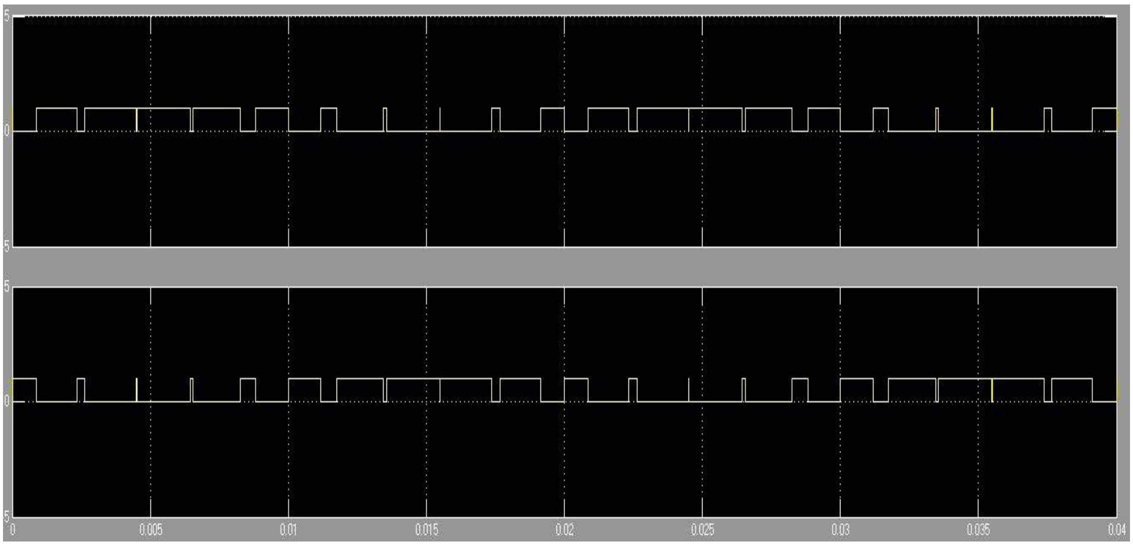

Fig 2. Gate pulses in a Bipolar Inverter

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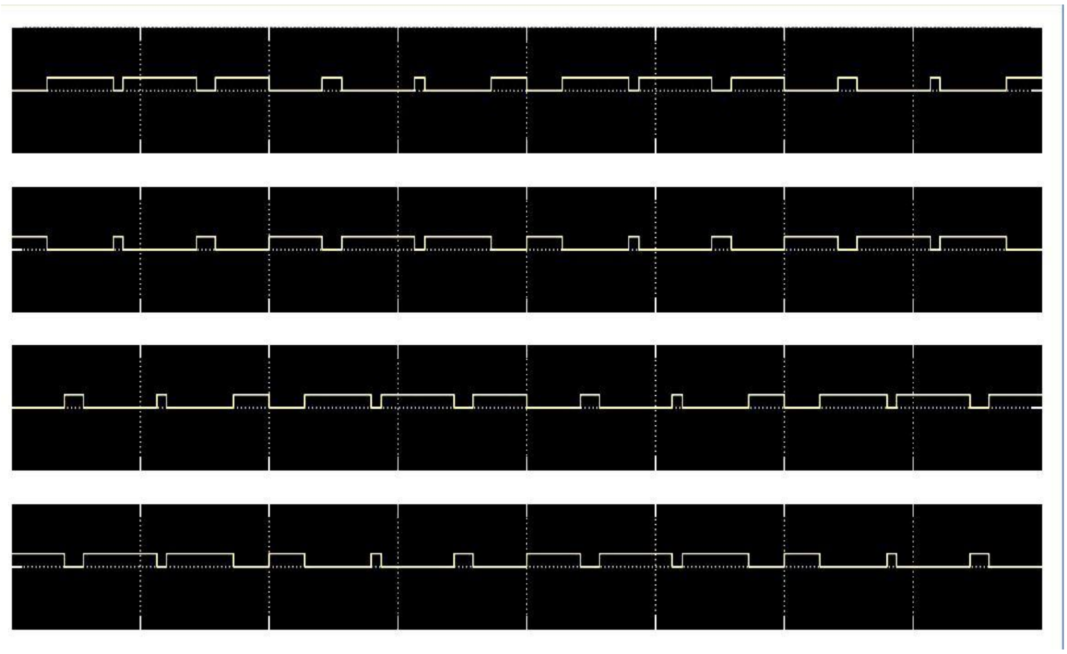

Fig 3. Gate pulses for Unipolar Inverter

III. SIMULATION RESULTS

Load	Bi-Polar Inverter Current THD	Uni-Polar Inverter Current THD	Out Put Voltage THD
5 KW 0 pf lag	12.1 %	12.1%	48.35%
5 KW 0.6 pf lag	14.77%	14.74%	
5 KW 0.8 pf lag	18.65%	18.66%	
5 KW Unity pf	48.35%	48.35%	
5KW 0.8 pf lead	59.44%	59.43%	
5 KW 0.6 pf lead	76.22%	76.6%	
5 KW 0 pf lead	84.91%	84.59%	

It is clear from the above results that Bipolar and Uni- polar Inverters perform similarly for the different load conditions. Output current THD are almost same for the same load. The %THD of the output voltage is constant.

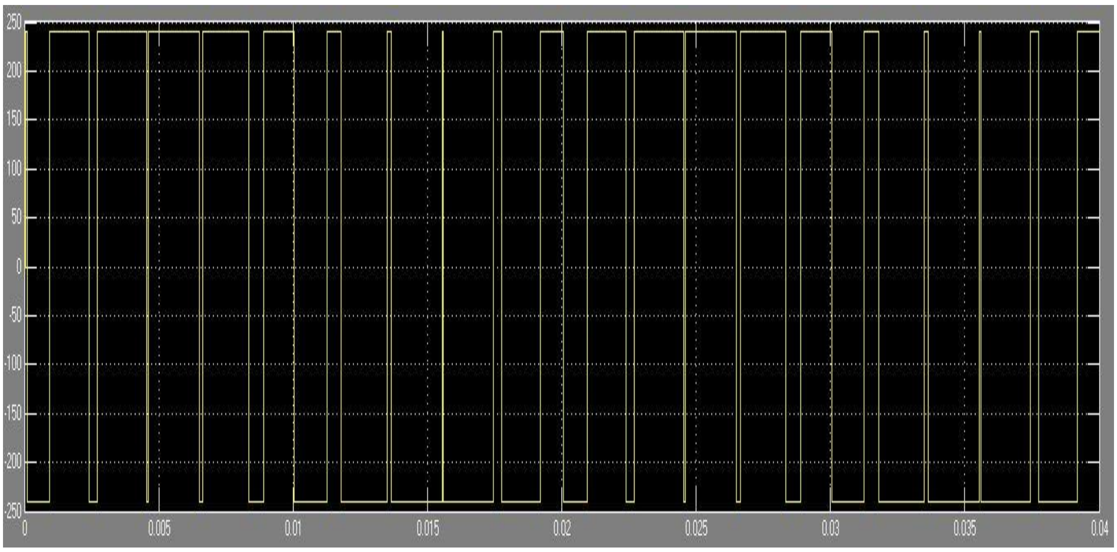

Fig 4. Output Voltage of Bipolar Inverter at f_c = 500 Hz and MI = 1

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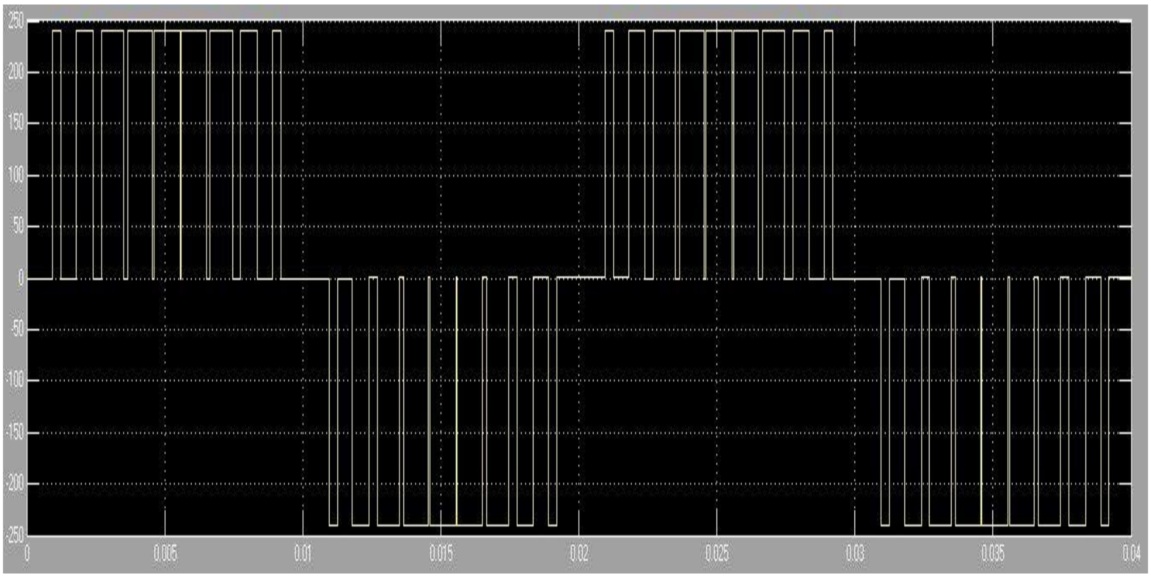

Fig 5. Output Voltage of Unipolar Inverter at f_c = 500 Hz and MI = 1

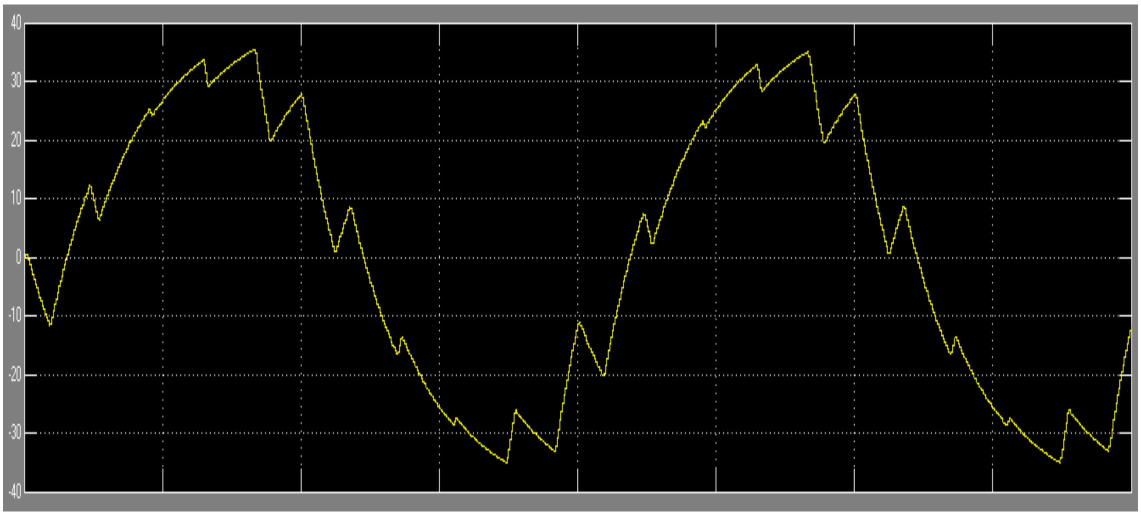

Fig 6. Load current in Bipolar Inverter at f_c = 500 Hz and MI = 1

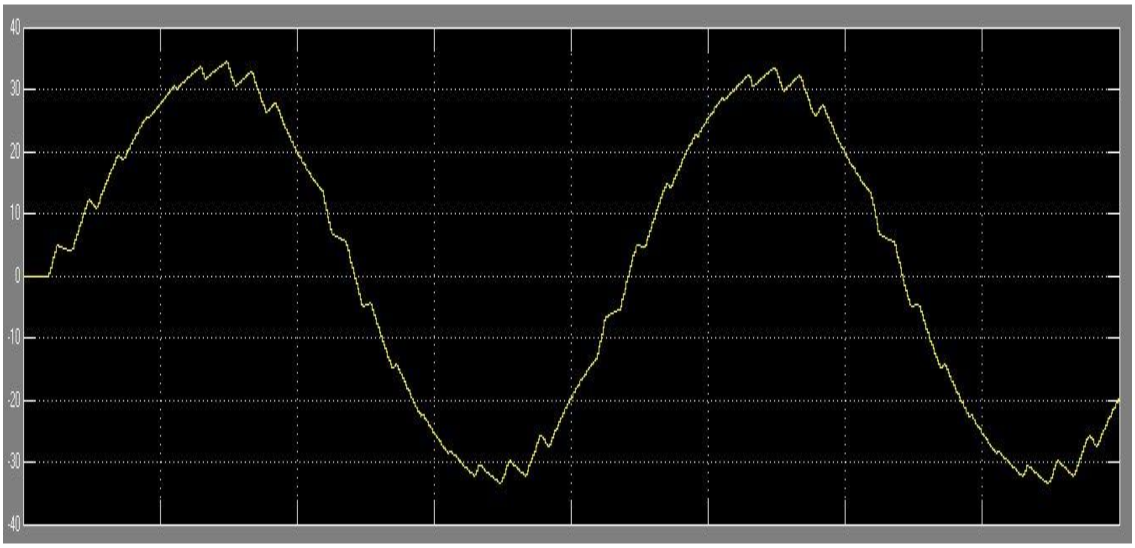

Fig 7. Load current in Unipolar Inverter at f_c = 500 Hz and MI = 1

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Table 1. Comparative output voltage profile for Bipolar and Uni-polar Inverter for f_c = 50 Hz and MI = 1

Harmonic Order	MI = 1	
	Bi-Polar $(THD)_V = 50.03\%$ **% of fundamental**	Unipolar $(THD)_V = 48.41\ \%$ **% of fundamental**
DC	0.99	0.59
2	0.39	0.39
3	34.37	33.84
4	1.98	1.18
5	19.33	19.65
6	0.4	0.39
7	15.14	14.68
8	1.98	1.18
9	10.34	10.69
10	0.4	0.39
11	9.87	9.43
12	1.97	1.18
13	6.87	7.22

Table 2. Comparative output voltage profile for Bipolar and Uni-polar Inverter for f_c = 300 Hz and MI = 0.6 and 1

Comparative Output Voltage Profile for f_c = 300 Hz				
Harmonic Order	MI = 0.6		MI = 1	
	Bi-Polar $(THD)_V = 214.95\%$ **% of fundamental**	Unipolar $(THD)_V = 105.58\%$ **% of fundamental**	Bi-Polar $(THD)_V = 101.27\%$ **% of fundamental**	Unipolar $(THD)_V = 49.92\%$ **% of fundamental**
DC	0.42	0	0.25	0
2	2.72	0	0.51	0
3	5.44	4.79	1.96	1.28
4	18.74	0	31.93	0
5	2.52	0.14	1.8	0.95
6	169.15	0	61.55	0
7	3.49	2.51	2.61	2.18
8	20.49	0	32.59	0
9	12.27	12.14	22.25	22.27
10	2.17	0	1.17	0
11	64.23	64.39	19.05	19.08
12	2.5	0	4.28	0
13	62.95	62.76	18.22	18.06

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Table 3. Comparative output voltage profile for Bipolar and Uni-polar Inverter for f_c = 500 Hz and MI = 0.6 and 1

Comparative Output Voltage Profile for f_c = 500 Hz				
Harmonic Order	MI = 0.6		MI = 1	
	Bi-Polar $(THD)_V = 217.98\%$ **% of fundamental**	Unipolar $(THD)_V = 107.83\%$ **% of fundamental**	Bi-Polar $(THD)_V = 105.56\%$ **% of fundamental**	Unipolar $(THD)_V = 55.1\%$ **% of fundamental**
DC	0.42	0	0.26	0
2	5.34	0	0.55	0
3	3.27	3.12	1.72	1.62
4	0.99	0	1.48	0
5	1.62	1.45	0.61	0.37
6	2.68	0	2.53	0
7	3.33	3.12	1.61	1.58
8	20.82	0	29.68	0
9	1.62	1.5	0.52	0.11
10	172	0	64.9	0
11	3.4	3.24	0.56	0.11
12	19.33	0	30.89	0
13	1.24	0.71	0.65	0.48

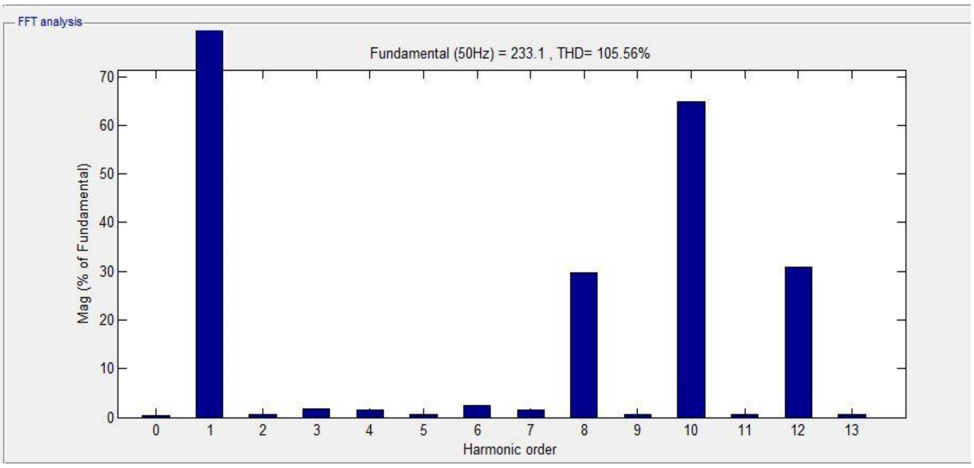

Fig 8. Harmonic spectra of ouput voltage of Bipolar Inverter at f_c = 500 Hz and MI = 1

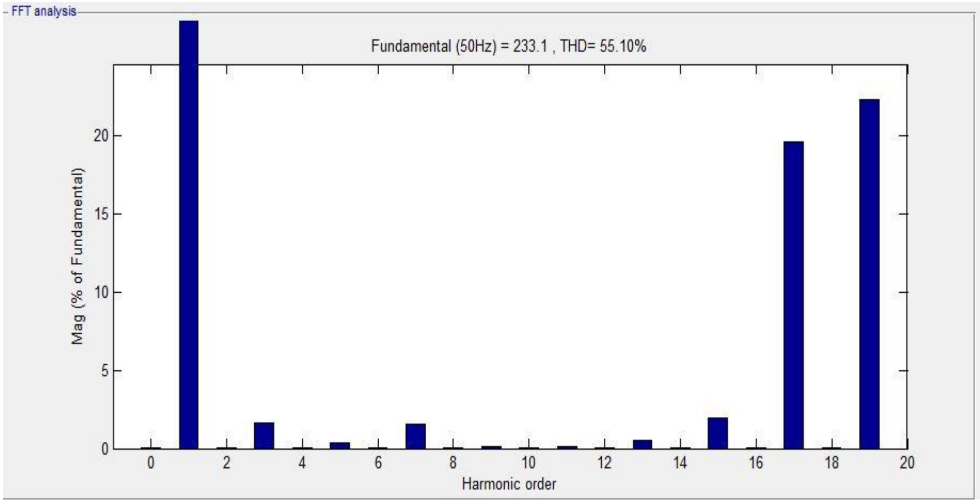

Fig 9. Harmonic spectra of ouput voltage of Unipolar Inverter at f_c = 500 Hz and MI = 1

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IV. CONCLUSION

1. It is clear from table 1 that at f_c = 50 Hz and MI = 1, both Bipolar and Unipolar inverters shows same output voltage profile. At f_c = 50 Hz spwm fed inverters acts like a conventional inverter. The percentage of lower order odd harmonics (3,5 & 7) is high and even order harmonics are also present with a very small or negligible % of fundamental component.

2. In table 2, on increasing the carrier frequency f_c = 300 Hz, the output voltage profile of unipolar inverter improves significantly. The odd harmonics are reduced by a significant % and even harmonics become 0. On the other hand in Bipolar Inverter also, the % of odd harmonics goes down but % of even harmonics get up. The % of harmonics gets reduced on changing the modulation index (MI) from 0.6 to 1.

3. The profile of the output voltage for f_c = 500 Hz shows the same trend.

4. It can be concluded that on increasing carrier frequency, lower order harmonics goes down and on increasing modulation index (MI) harmonics get reduced for the same carrier frequency. Existing higher order harmonics can be filtered out by using filters in the out.

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