ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 4, Issue 3, pp: (16-20), Month: July - September 2017, Available at: www.paperpublications.org

EFFECT OF CONDUCTION ANGLE ON THE PERFORMANCE OF A MULTILEVEL INVERTER

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Abstract: **Multilevel inverter topology has emerged in recent times as a very important in different are of high power medium voltage energy control. In this paper, cascaded multilevel inverter is used to reduce the total harmonic distortion. A cascaded multilevel inverter consists of series H-bridge (single phase, full-bridge) inverter units. Cascaded multilevel inverters are very popular and has many applications in electric utilities and for industrial drives. When these inverters are used for industrial drives directly, the THD of the output voltage of inverters is very significant, as the performance of drive depends very much on the quality of voltage applied to drive. A multilevel inverter in high power rating improves the performance of the system by reducing harmonics. In this paper the operation of 5-level cascaded H-bridge inverter is simulated for resistive load. By changing the conduction angle of inverter units, change in THD of output voltage is analysed. The simulation is done by MATLAB software.**

Keywords: **Harmonic distortion, Multilevel inverter, conduction angle, Harmonic factor, Cascaded H-bridge inverter.**

I. INTRODUCTION

Multilevel inverters have an arrangement of power switching devices and capacitor voltage sources. Multilevel inverters are suitable for high-voltage applications because of their ability to synthesize output voltage waveforms with a better harmonic spectrum and attain higher voltages with a limited maximum device ratings. Multilevel inverter does not use transformers; series connected synchronized switching devices. The harmonic content of output voltage waveform decreases significantly if the number of voltage levels increases. The topology structure of multilevel inverter must have less switching devices as far as possible; have lower switching frequency for each switching device.

There are three main types of multilevel inverters:

- Diode-clamped (neutral-clamped)
- Capacitor-clamped (flying capacitors)
- Cascaded H-bridge inverter

The term multilevel starts with the three-level inverter. By increasing the number of levels in inverter, the output voltages have more steps generating a staircase waveform, it results to reduction in harmonic distortion.

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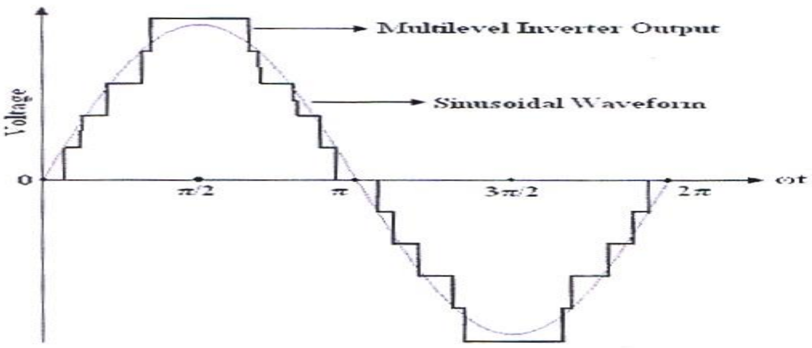

Fig. 1 Staircase Output Voltage of Multi level Inverter

The Fourier series expansion for the stair case waveform is:

$$V_{an}(\omega t) = \sum_{n=1,3,5,7}^{\infty} \frac{4V_{dc}}{n\,\pi} \{\cos(\alpha_1) + \cos(\alpha_2) + \cos(\alpha_3) + \ldots\} [\sin(n\omega t)]$$

The fundamental voltage is obtained from the calculated switching angles α_1 , α_2, α_3...... α_n. 'n' represents the order of the harmonics and the switching angles are equal to the number of DC sources. It is required to find the switching angles in the range of 0 to π/2 considering 5^{th} and 7^{th} order phase voltage to zero. For seven level cascaded inverter, the fundamental voltage in terms of switching angles is:

$$V_1 = \frac{4V_{dc}}{\pi} \{\cos(\alpha_1) + \cos(\alpha_2) + \cos(\alpha_3) + \ldots\}$$

II. SIMULINK MODEL

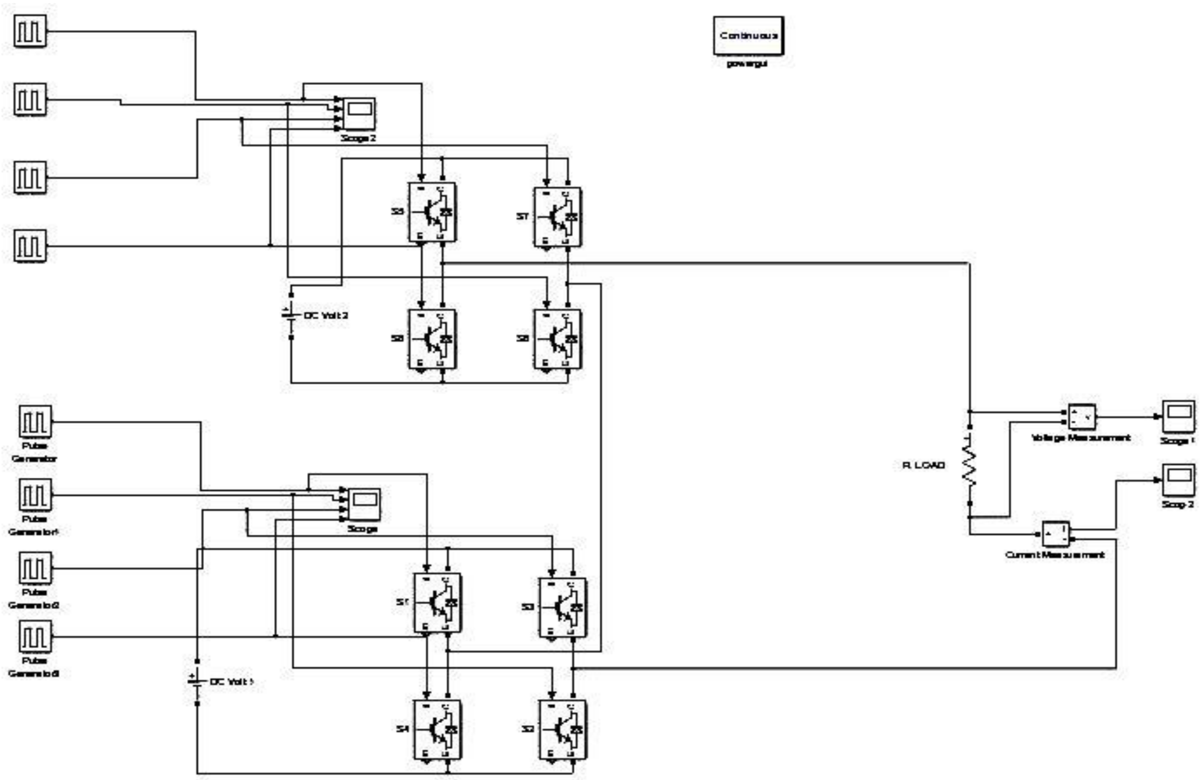

Fig 2. Simulink model of 5-level inverter

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III. RESULTS

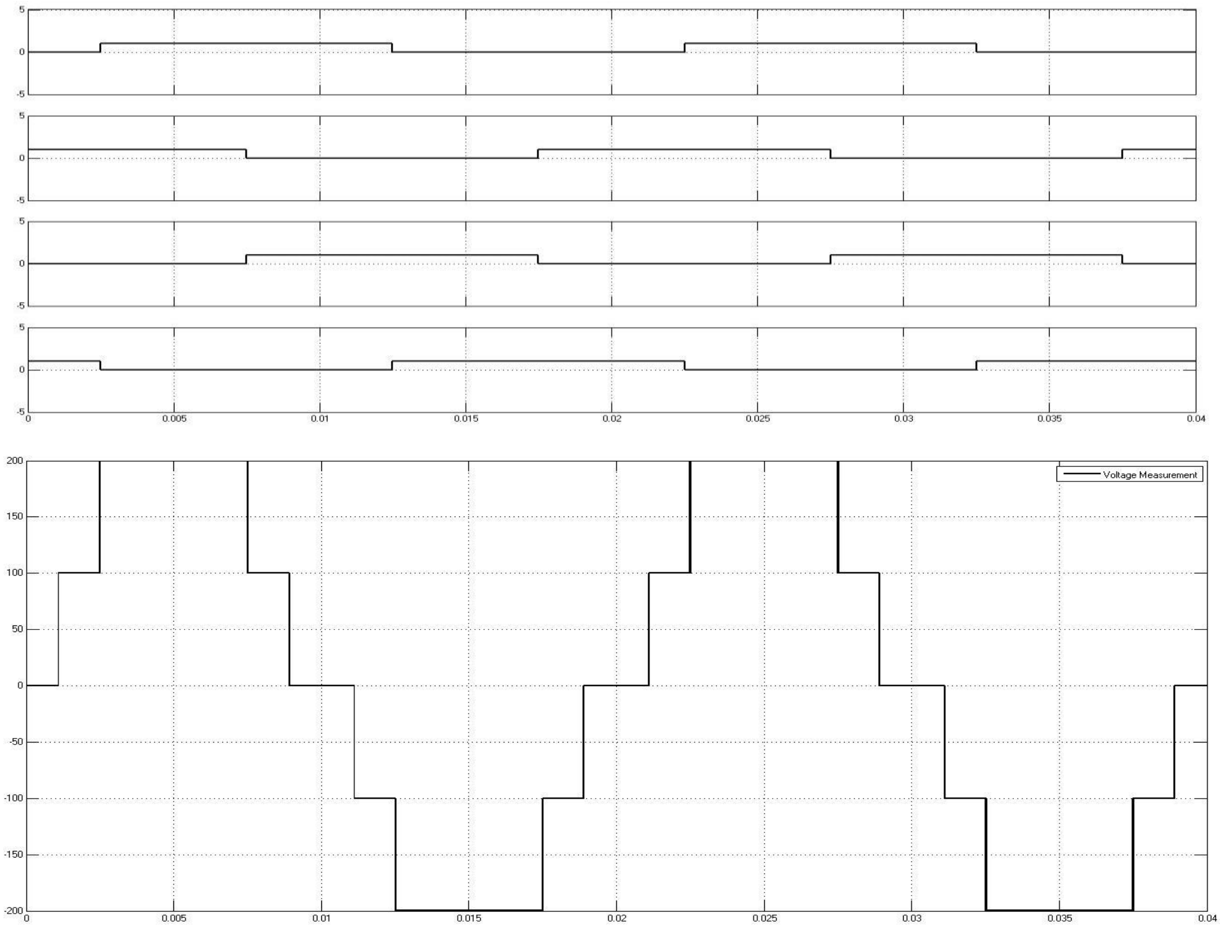

Fig.3 Switching pulses and output voltage of 5 level inverter

Table1. THD of output voltage and current under different combinations of conduction angles in 5-level inverter for resistive load R = 10 Ω

α_2	$\alpha_1 = 5^0$		$\alpha_1 = 10^0$		$\alpha_1 = 15^0$	
	$\%V_{THD}$	$\%I_{THD}$	$\%V_{THD}$	$\%V_{THD}$	$\%V_{THD}$	$\%I_{THD}$
55^0	22.13	22.13	19.44	19.44	19.84	19.84
50^0	19.99	19.99	18.4	18.4	17.97	17.97
45^0	18.17	18.17	16.48	16.48	17.15	17.15
40^0	18.36	18.36	16.49	16.49	17.26	17.26
35^0	18.64	18.64	17.04	17.04	17.75	17.75
30^0	20.52	20.52	19.83	19.83	20.27	20.27
25^0	23.92	23.92	23.7	23.7	24.07	24.07
20^0	27.44	27.44	25.43	25.43	27.73	27.73
15^0	30.39	30.39	30.29	30.29	-	-
10^0	35.39	35.39	-	-	-	-

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α_2	$\alpha_1 = 20^0$		$\alpha_1 = 25^0$		$\alpha_1 = 30^0$	
	$\%V_{THD}$	$\%I_{THD}$	$\%V_{THD}$	$\%V_{THD}$	$\%V_{THD}$	$\%I_{THD}$
55^0	22.28	22.28	24.9	24.9	31.15	31.15
50^0	19.90	19.90	25.63	25.63	30.22	30.22
45^0	20.23	20.23	23.25	23.25	28.16	28.16
40^0	19.7	19.7	23.54	23.54	29.27	29.27
35^0	20.02	20.02	25.43	25.43	30.68	30.68
30^0	23.06	23.06	26.52	26.52	-	-
25^0	26.04	26.04	-	-	-	-

Table2. Output voltage profile (% harmonics) for different value of α_1 when $\alpha_2 = 45^0$ in 5-level inverter for resistive load R = 10 Ω

Harmonic Order	$\alpha_2 = 45^0$			
	$\alpha_1 = 5^0$	$\alpha_1 = 10^0$	$\alpha_1 = 15^0$	$\alpha_1 = 20^0$
	$\%V_{THD} = 18.17$	$\%V_{THD} = 16.48$	$\%V_{THD} = 17.15$	$\%V_{THD} = 20.23$
DC	2.43	0	0	0
3	4.40	3.14	0	5.43
5	1.24	2.84	5.35	11.98
7	11.06	6.48	3.87	1.58
9	7.31	3.9	0	1.97
11	3.20	6.27	8.59	6.91
13	3.09	8.2	7.1	2.51
15	1.50	2.2	0	5.20
17	3.28	0.21	3.08	5.28

Harmonic Order	$\alpha_2 = 45^0$		
	$\alpha_1 = 25^0$	$\alpha_1 = 30^0$	$\alpha_1 = 35^0$
	$\%V_{THD} = 23.25$	$\%V_{THD} = 28.16$	$\%V_{THD} = 35.01$
DC	0	1.19	2.72
3	8.71	14.92	21.66
5	17.04	20.04	22.13
7	3.55	2.38	3.41
9	1.12	4.48	10.25
11	2.16	1.99	1.83
13	0	3.44	4.19
15	6.11	2.88	1.57
17	4.78	3.98	0.97

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Table3. Output voltage harmonic profile (% harmonics) for different value of α_2 when $\alpha_1 = 15^0$ in 5-level inverter for resistive load R = 10

Harmonic Order	$\alpha_1 = 15^0$			
	$\alpha_2 = 55^0$	$\alpha_2 = 50^0$	$\alpha_2 = 45^0$	$\alpha_2 = 40^0$
	$\%V_{THD} = 19.84$	$\%V_{THD} = 17.97$	$\%V_{THD} = 17.15$	$\%V_{THD} = 17.26$
DC	0	0	0	0
3	5.43	4.15	0.67	2.59
5	3.09	0	5.64	9.28
7	6.15	6.44	2.81	2.32
9	9.52	6.51	0.64	0.97
11	9.27	10.94	8.55	4.47
13	0	1.79	8.28	7.25
15	2.91	0	0.71	2.7
17	4.45	4.05	1.83	3

Harmonic Order	$\alpha_1 = 15^0$			
	$\alpha_2 = 35^0$	$\alpha_2 = 30^0$	$\alpha_2 = 25^0$	$\alpha_2 = 20^0$
	$\%V_{THD} = 17.75$	$\%V_{THD} = 20.27$	$\%V_{THD} = 24.07$	$\%V_{THD} = 27.73$
DC	0	0	0	0
3	8.57	12.22	16.91	20.42
5	8.45	6.86	3.57	0
7	6.03	8.17	9.46	8.38
9	0.43	3.32	7.96	10.17
11	0.21	0.08	3.77	7.94
13	4.16	0.99	0.4	3.91
15	6.09	3.65	0.63	0
17	2.89	4.27	0.14	2.55

IV. CONCLUSIONS

1. From figure 2 it is clear that output voltage and current of 5-level inverter is staircase wave shape for resistive load R= 10 Ω.
2. THD of output voltage and current for resistive load is given in table 1 at different combinations of conduction angles. It is clear that $\%v_{THD}$ is 16.48% (minimum) when $\alpha_1 = 10^0$ and $\alpha_2 = 45^0$. For other combinations of conduction angles it is higher than 16.48%.
3. From table 2 it is clear that for $\alpha_2 = 45^0$, at different values of α_1, the THD is changing and for particular values of α_1 some particular harmonics can be eliminated. For $\alpha_1 = 15^0$, 3rd , 9th and 15th harmonics are absent in voltage profile.
4. It can be concluded that by selecting proper combination of conduction angles harmonic distortion can be improved.

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