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SINGLE PHASE CASCADED MULTILEVEL INVERTER USING MULTICARRIER PWM TECHNIQUE

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ABSTRACT

This paper deals with Single Phase Five level Inverter using Multi Carrier Based Pulse width modulation Technique. The voltage quality of conventional two level inverter is poor due the presence of harmonics and hence produces power loss which reduces the efficiency of the system. The multilevel inverter is used to improve the voltage quality by reducing the harmonics, as the number of voltage levels of multilevel inverter is increased the harmonics are reduced and hence losses are minimized significantly. The simulation of single phase cascaded five level multilevel is done using Multicarrier PWM technique and compared with stepped wave. Hardware module is designed for stepped wave and multicarrier PWM. The outputs of both simulation and hardware are analyzed.

Keywords: multicarrier PWM, stepped wave inverter, multilevel inverter, total harmonic distortion.

1. INTRODUCTION

The main function of the inverter is to generate an ac voltage from a dc source voltage. Inverters are commonly used in consumer and industrial applications. The output voltage of an inverter can be controlled in different ways. The most common method consists of controlling the pulse width modulation applied to MOSFETs IGBTs etc. In general with two level inverter more harmonics are produced which increases losses [1, 2] and cause heat problems in the machine [3], resulting in wear of the insulation covering the conductors and reducing the motor performance. To reduce these harmonics multilevel inverter is designed. Multilevel inverters include an arrangement of semiconductors and dc voltage sources required to generate a stepped output voltage waveform. The number of input DC voltages depends on the number of inverter output voltage levels and as the levels are increased the harmonics are reduced. Pulse width modulation is the main control strategy implemented in the power electronics. This is the best way of driving modern power electronic devices. Most of the power electronic circuits are controlled by PWM signals of various forms such as multi carrier PWM. Multilevel inverter structures are becoming increasingly popular for high power applications, their switched output voltage harmonics can be reduced since semiconductors are connected in series for multilevel inverter structures.

2. MULTILEVEL INVERTER

Multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations; it decreases the harmonic distortion in the output waveform. A multilevel converter not only achieves high power ratings, but also improves the performance of the whole system in terms of harmonics, dv/dt stresses, and stresses in the bearings of a motor. Several multilevel converter topologies have been developed; i) diode clamped, ii) flying capacitors, and iii) cascaded or H-bridge. This paper deals simulation and hardware design of single phase cascaded five level inverter with separate two dc sources using conventional method and multicarrier pulse width modulation technique and the output results of both methods are compared.

3. CASCADED MULTILEVEL INVERTER

A cascaded multilevel inverter consists of a series of H-bridge also called single-phase full bridge inverter. Each of H-bridge unit has its own dc source and each H-bridge can produce three different voltage levels: +V, 0, and -V by connecting the dc source to ac output side by different combinations of the four switches S1, S2, S 3, and S 4 of one H-bridge and S5, S6, S7 and S8 of other H-bridge. The ac output of each H-bridge is connected in series such that the synthesized output voltage waveform is the sum of all of the individual H-bridge's outputs [4]. By connecting the sufficient number of H-bridges in cascade and using proper modulation scheme, a nearly sinusoidal output voltage waveform can be synthesized. The Figure-1 shows the connecting diagram of single phase cascaded inverter.

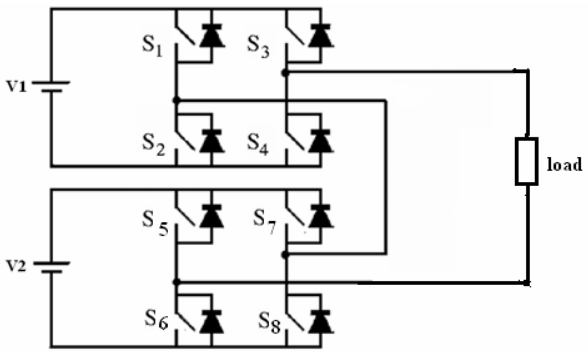

Figure-1. Single phase cascaded multilevel inverter.

Table-1. Switching states of cascaded multilevel inverter.

V0	S1	S2	S3	S4	S5	S6	S7	S8
V1	0	0	0	0	0	0	0	0
V2	0	1	0	0	0	1	1	0
V3	0	1	1	0	0	1	1	0
-V2	1	0	0	0	0	0	0	1
-V3	1	0	0	0	1	0	0	1

4. MULTI CARRIER PWM TECHNIQUE

The most common and popular technique of digital pure-sine wave generation is pulse width modulation [5, 6]. The PWM technique involves generation of a digital waveform, for which the dutycycle is modulated such that the average voltage of the waveform corresponds to a pure sine wave. The simplest way of producing the PWM signal is through comparison of a low-power reference sine wave with a triangle wave. Multicarrier PWM methods uses high switching frequency carrier waves in comparison to the reference waves to generate a sinusoidal output wave. The Figure-2 shows multicarrier PWM waveform for cascaded multilevel inverter.

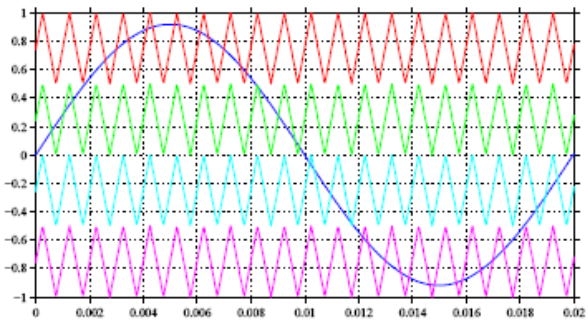

Figure-2. Reference and carrier waves.

5. SIMULATION RESULTS

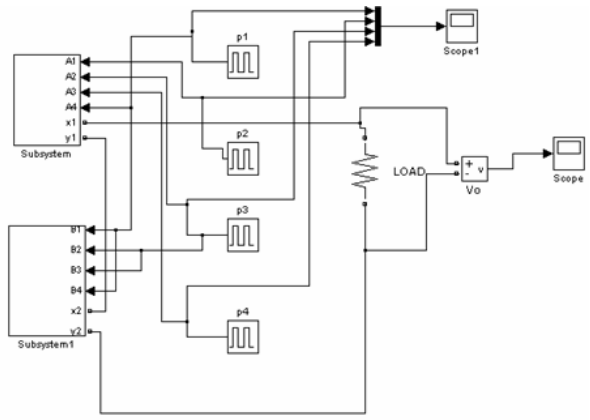

Figure-3. Simulation circuit for cascaded five level inverter

Simulation of Single Phase Cascaded Five Level Inverter is shown in Figure-3. The output of the bridge inverter is connected to the resistive load. The cascaded inverter converts the DC voltage into AC voltage and the output voltage waveform is shown in Figure-7.

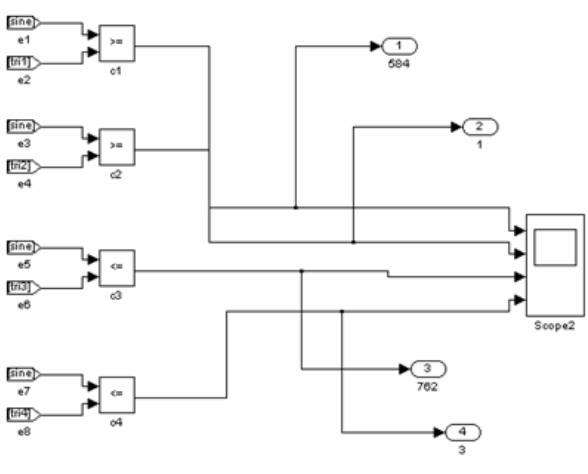

Figure-4. Simulation circuit for multicarrier pulse width modulation technique.

Multicarrier PWM technique is simulated as per the circuit shown in the Figure-4. In general inverter with m-level, m-1 carrier with same frequency f_c and same peak to peak amplitude Ac are disposed [7]. The reference or modulation waveform has peak to peak amplitude Ar and frequency fr. The reference waveform is compared with carrier signals and if it is greater than a carrier signal then switch/device correspond to that carrier is switched on and if the reference is less than carrier signals then device correspond to carrier is switched off. The Sinusoidal pulse width modulation is commonly used in Industrial application. The frequency of reference signal fr determines the inverter output frequency fo and its peak amplitude Ar controls the modulated index M and then in turn the rms output voltage Vo. Here the modulation index is defined as the ratio of amplitude of reference signal to the amplitude of carrier signal [8]. The rms output voltage can varied by varying the modulation index M. If δ is the width of each pulse then rms output voltage can be found from $Vo = Vs\sqrt{((p\delta)/(\pi))}$.

If δ_m is the width of mth pulse then above equation can be extended to obtain the rms output voltage as follows:

$$Vo = Vs \left(\sum_{2p}^{m=1} \delta m/\pi \right)^{1/2}$$

The output waveform for the multicarrier pwm technique is shown in Figure-5. The simulation is carried out for modulation index M=0.9 [9].

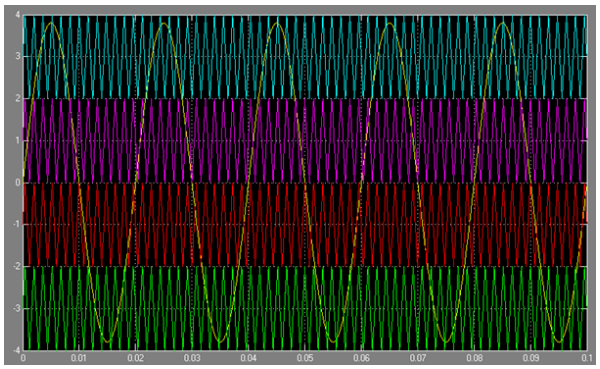

Figure-5. Output waveform of multicarrier PWM technique.

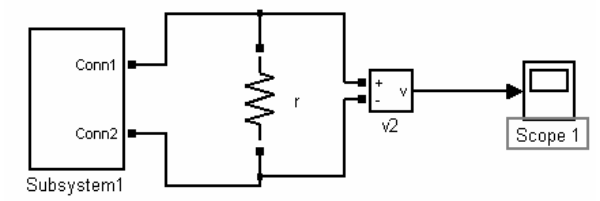

Figure-6. Simulation circuit for five level cascaded inverter using multicarrier pwm technique.

H-bridge five level inverter using multicarrier PWM simulink circuit is shown in Figure-6. The circuit is simulated in matlab and harmonics are obtained using FFT analysis. The output voltage waveform is shown in the Figure-8.

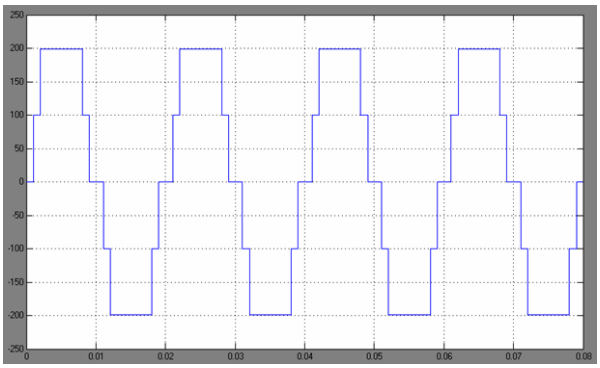

Figure-7. Single phase five level cascaded inverter output voltage.

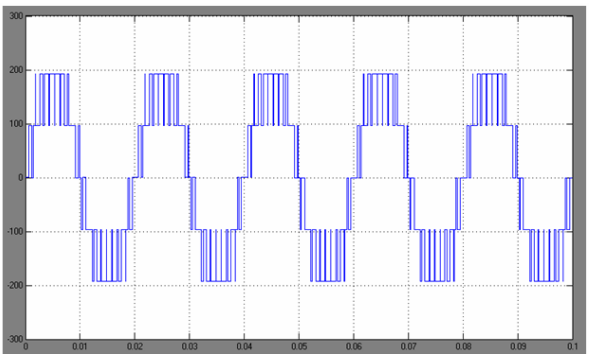

Figure-8. Single phase five level cascaded inverter output voltage using multicarrier PWM technique.

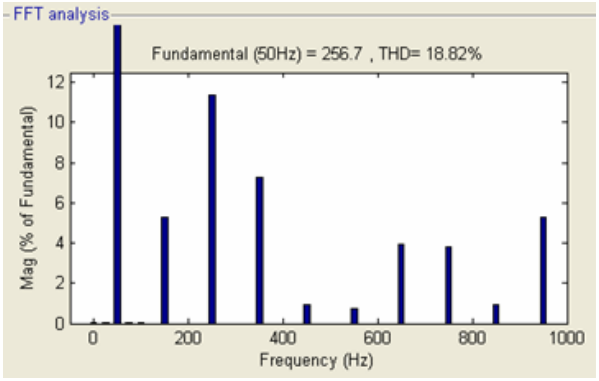

Figure-9. Five level inverter FFT analysis.

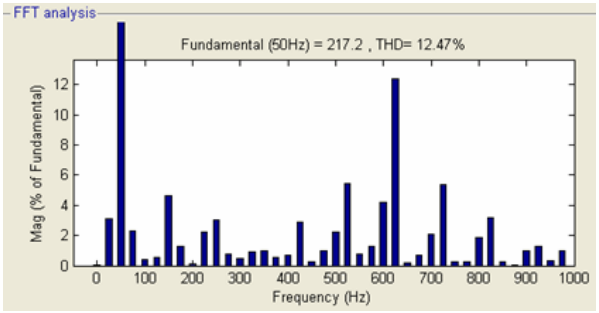

Figure-10. Five level inverter FFT analysis using multicarrier PWM technique.

6. EXPERIMENTAL RESULTS

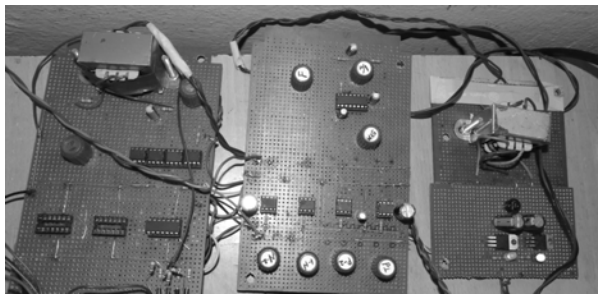

Figure-11. Hardware setup of multicarrier PWM technique.

In the circuit shown in figure, the 230/12v step down transformer is connected to the 230v supply and the output 12v is taken as reference through a 20K pot (to adjust amplitude).

ICXR2206 is used to generate triangular wave [10]. This IC can produce 1 MHz frequency signals. IC741 is used to clamp the triangular to the desired level.

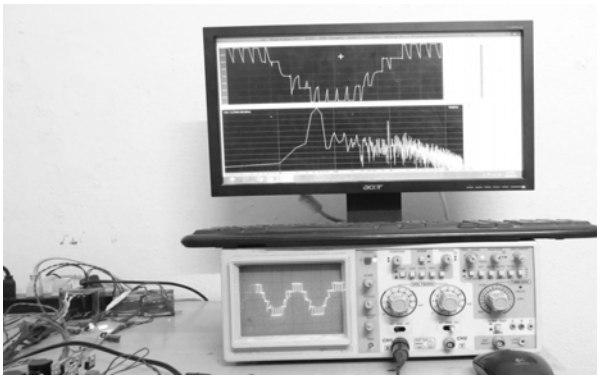

Figure-12. Prototype of five level single phase cascaded multilevel inverter using multicarrier PWM technique.

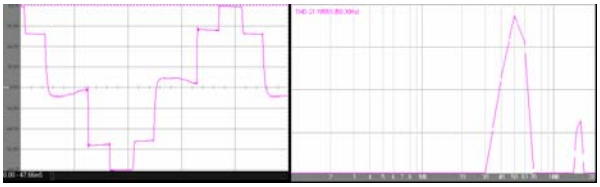

Figure-13. Output and THD waveforms of five level single phase cascaded multilevel inverter.

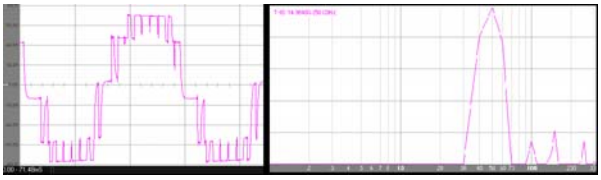

Figure-14. Output and THD waveforms of five level single phase cascaded multilevel inverter using multicarrier PWM.

7. CONCLUSIONS

The Single Phase Five level Cascaded inverter is simulated using conventional method and using multicarrier PWM technique. The results of both methods are compared and observed that the total harmonic distortion in the output voltage of multilevel inverter using multicarrier PWM is less compared to conventional method or stepped wave. This can be extended to higher levels so that harmonics are reduced further. The hardware implementation of the both methods is carried out and the experimental results are closer to the simulation results.

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