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Comparison of Three Sinusoidal Pulse Width Modulation Techniques for Five-Level Cascaded Inverter using Simulink

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***Abstract*— Multi-level inverters are becoming very popular nowadays due to the usage of low rating devices for high rating applications, which overcome the limitation imposed by the rating of the semiconductor switches. In this paper, a comparative study of three different SPWM techniques for five-level cascaded inverter is presented. Simulink is used for simulation. Simulation results; waveforms and THD graphs are obtained. Harmonics of three SPWM techniques are tabulated for comparison.**

***Keywords*— *Multi-level Inverter, SPWM, THD, Simulink*.**

I. INTRODUCTION

Inverter application is increasing as most of the loads used are of alternating current loads and the renewable energy sources like wind, solar, etc., gives the direct current outputs. Many inverter topologies and different firing techniques were introduced in last few decades.

In paper [1], a simulation of Unipolar-SPWM strategy for single phase full bridge inverter is presented. Different three-level inverter topologies with SPWM technique that minimize the harmonic distortion in the output of the inverter has been simulated in paper [2].

In paper [3], the basic theory of a single-phase SPWM inverter, its Simulink modeling is presented. A new reliability evaluation technique on the basis of the state enumeration approach for multi-level inverters engages harmonic distortion levels produced by the inverter in the reliability index calculation is presented in [4]. Paper [5] proposes a new multi-level inverter topology based on H-bridge with DC-link switches. The output voltage is closer to sinusoidal wave. A new PWM method based on Phase Opposition Disposition modulation is which requires only one carrier signal is suggested.

Multi-level inverters play an important role in micro-grids which integrates several renewable energy sources. The reliability of multi-level inverters which interface different renewable unit, has critical impacts on providing electricity to the consumers connected to the grid.

The multi-level inverter system is used when high power with reduced harmonic content is required. But, as the output voltage level increases, the number of semiconductor switches in the circuit increases. In case of multi-level inverter system, the loss of semiconductor devices cannot be analyzed by conventional methods.

The elementary concept of a multilevel inverter is to achieve higher power by using a series of semiconductor switches with several low voltage dc sources for the power conversion by synthesizing staircase voltage waveforms.

In this paper, a basic Simulink models for generating conventional SPWM and waveforms are presented for better understanding of the further discussion. Then simulation of a cascaded five-level inverter for three different SPWM techniques is presented.

The objectives of this paper are as follows: Simulation of conventional method of generation of SPWM is presented in Section II. Simulation of three SPWM techniques has been presented in Section III. Simulation results for five-level cascaded inverter for three different SPWM techniques are given in Section IV and harmonics are tabulated for comparison.

II. SIMULATION OF GENARATING CONVENTIONAL SINUSOIDAL PULSE WIDTH MODULATION WAVEFORM

Sinusoidal Pulse Width Modulation techniques are characterized by pulses with different duty cycle but constant amplitude for each period. Pulse width is modulated in order to obtain controlled output voltage and reduced harmonics. SPWM is the most commonly used method for motor control and inverter applications. To generate the SPWM signal, conventionally, carrier triangle wave is compared with the sine wave of operating frequency.

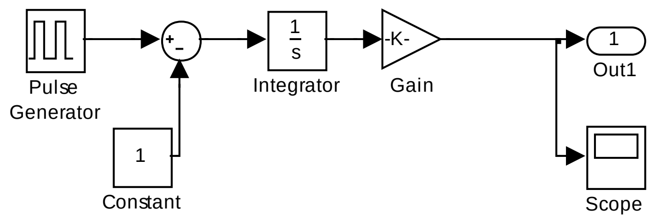

Fig. 1: Simulink model for generating triangular wave as in Fig. 2

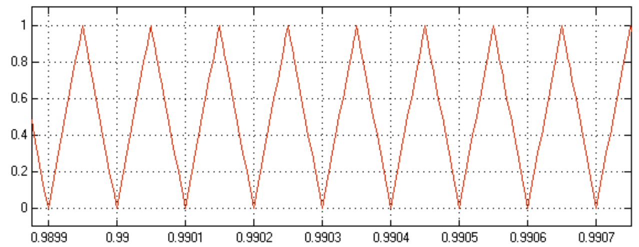

Fig. 2: Output waveform of model in Fig.1.

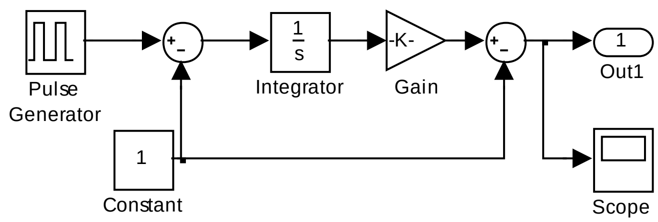

Fig. 3: Simulink model for generating triangular wave as in Fig.4.

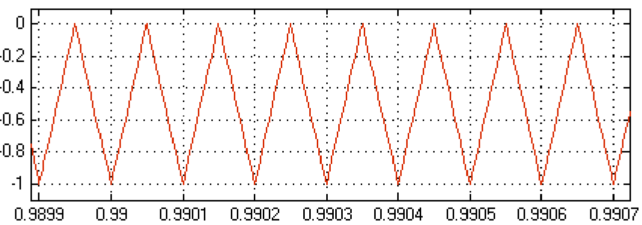

Fig. 4: Output waveform of model in Fig.3.

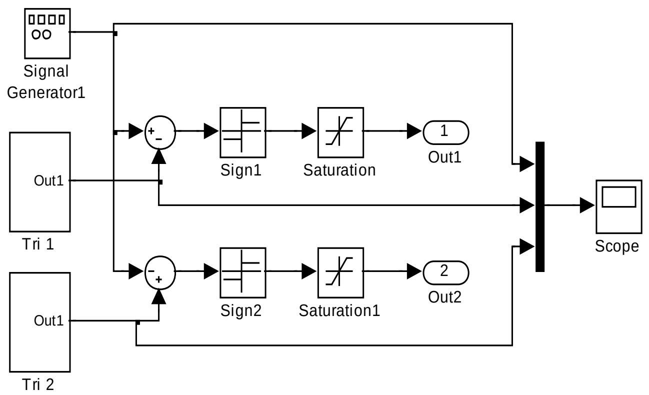

Fig. 5: Simulink model for generating SPWM as in Fig. 7.

Fig.1 shows the Simulink model for generating triangular wave as shown in Fig.2. Triangular wave generated has magnitude from 0 to 1 volt.

Fig.3 shows the Simulink model for generating triangular wave as shown in Fig.4. Triangular wave generated has magnitude from -1 to 0 volt.

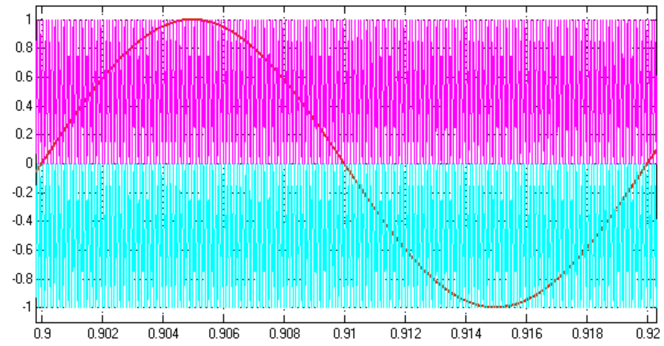

Fig. 6: Sine output of Signal Generator1 (red) and Triangular output of Tri 1 (pink) and Tri 2 (aqua blue).

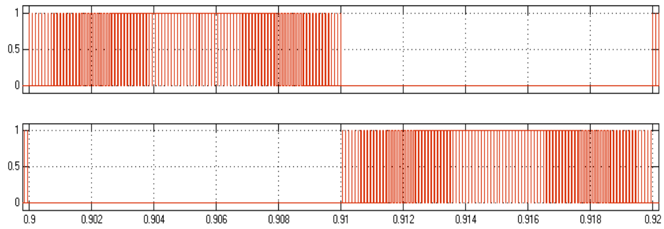

Fig. 7: SPWM output of model shown in Fig. 5 (Out 1 & Out 2).

Fig.5 shows the conventional method of generating SPWM waveform. In this figure, Tri 1 and Tri 2 are the triangular wave generators whose Simulink modeling is shown in Fig. 1 and Fig.3 respectively which gives carrier signal at 10 kHz. Signal Generator1 gives the sinusoidal wave of operating frequency (50 Hz) with magnitude of -1 to +1, as shown in Fig. 6. The two triangular waves and sine wave is compared as shown in Fig. 5 and the output is the SPWM waveform as shown in Fig.7.

III. Simulation Models of Three SPWM Techniques

In this section, three different SPWM techniques used to control five-level cascaded inverter are presented. The three different techniques are as follows:

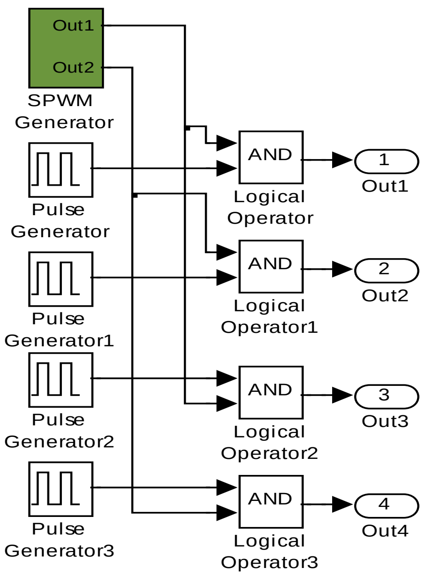

Fig. 8: Simulink Model of S-SPWM gate pulses generation for five-level cascaded inverter.

A. Technique-1: Selective-SPWM (S-SPWM)

In this technique, the SPWM generated by conventional method as show in Fig. 7 is logically AND with the PWM pulses of desired pulse width as shown in Fig. 12 to select the portion of SPWM as gate pulses by using model as shown in Fig. 8 is as shown in Fig. 13.

B. Technique-2: Phase-Shift SPWM (PS-SPWM)

In this technique, two triangular carrier waves and two sinusoidal waves are used as shown in Fig. 16. Here one sine wave lags the other by 90^0. Thus the output gate pulses of model in Fig. 9, will also have the phase shift of 90^0 between two sets of SPWM waveforms as shown in Fig. 17.

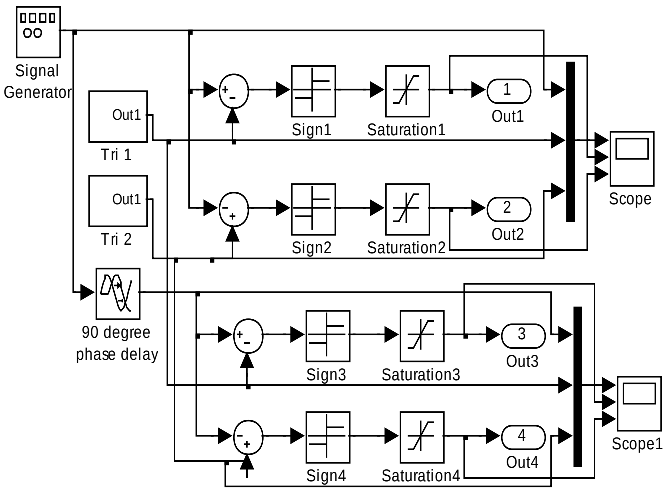

Fig. 9: Simulink Model of PS-SPWM gate pulses generation for five-level cascaded inverter.

C. Technique-3: Multi-carrier SPWM (MC-SPWM)

In this technique, four triangular carrier waves are compared with a sinusoidal wave of fundamental frequency (operating frequency=50Hz) as shown in Fig. 20 using the model as in Fig. 10 to get the gate pulses shown in Fig. 21

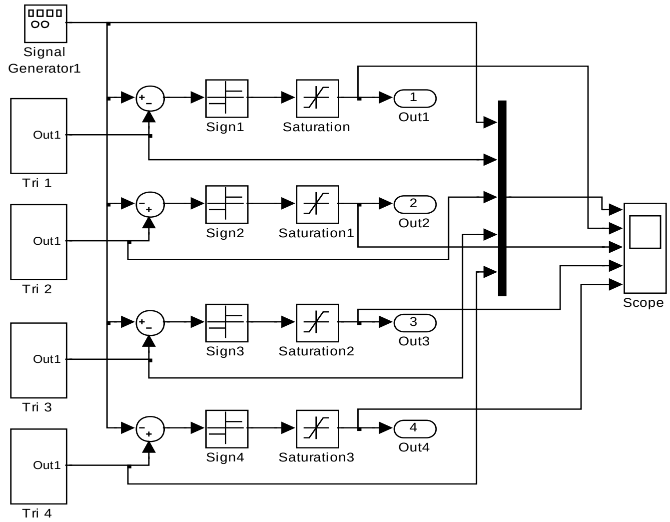

Fig. 10: Simulink Model of MC-SPWM gate pulses generation for five-level cascaded inverter.

IV. SIMULATION RESULTS

Fig.11 shows a Simulink model of five-level cascaded inverter. It consists of two H-bridge with four semiconductor switch each, with separate DC voltage sources of 115V. Two H-bridges are operated with either of three SPWM techniques mentioned earlier.

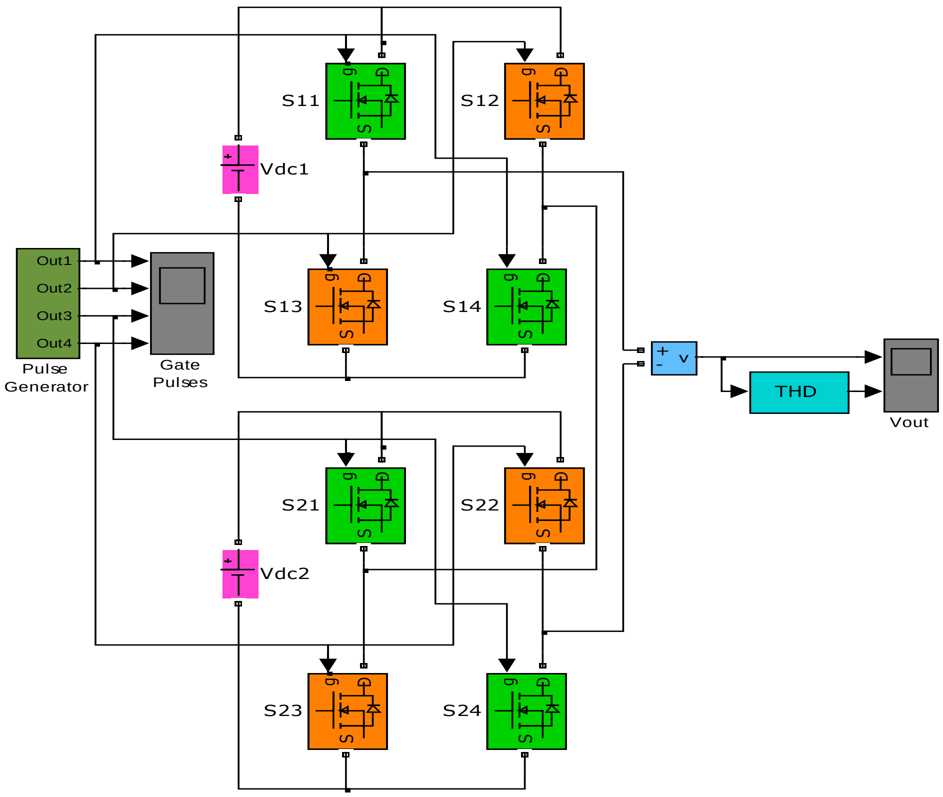

Fig. 11: Simulink model of five-level cascaded inverter.

Fig. 12, 16 & 20 shows the basic waveforms used to generates gating signals as shown in Fig. 13, 17 & 21 using models shown in Fig. 8 (S-SPWM), 9 (PS-SPWM) &10 (MC-SPWM) respectively. When these gating pulses are used in the model shown in Fig. 11, it gives the output voltage waveforms as shown in Fig. 14, 18 & 22 respectively.

Harmonics graphs for these three SPWM gate pulse techniques are shown in Fig. 15, 19 and 23 respectively. The fundamental components and harmonics are tabulated in Table-I for comparison.

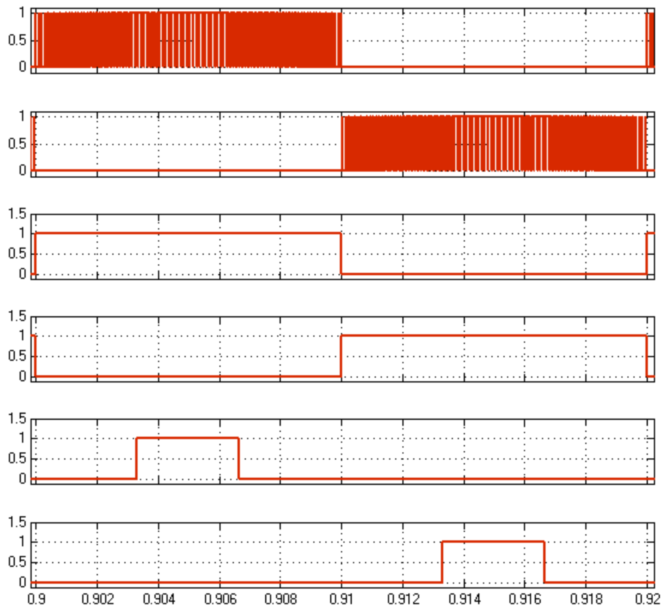

Fig. 12: Output of SPWM generator and Pulse generators shown in Fig. 8.

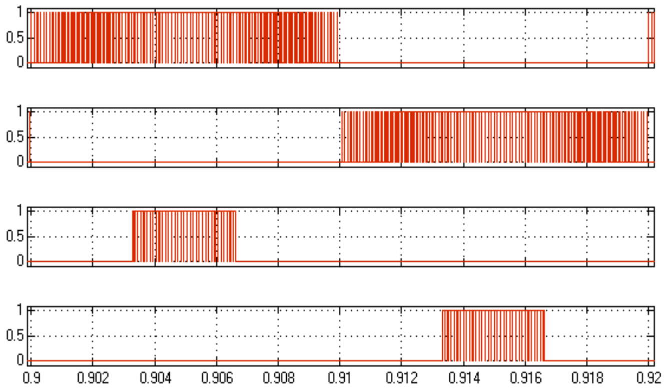

Fig. 13: Gating pulses generated by the model shown in Fig. 8, (S-SPWM).

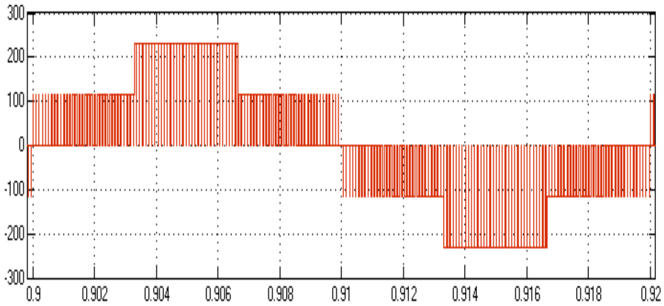

Fig. 14: Output Voltage of inverter shown in Fig. 11 for the gating pulses as shown in Fig. 13, (S-SPWM).

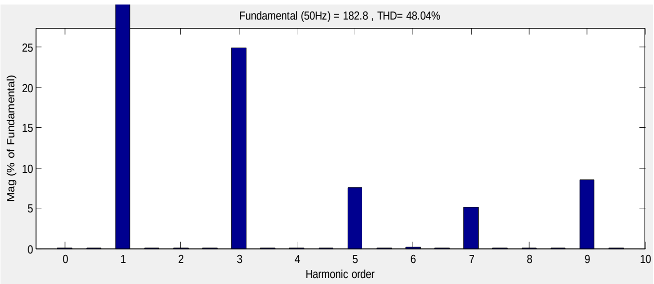

Fig. 15: FFT analysis of output voltage waveform as in Fig. 14.

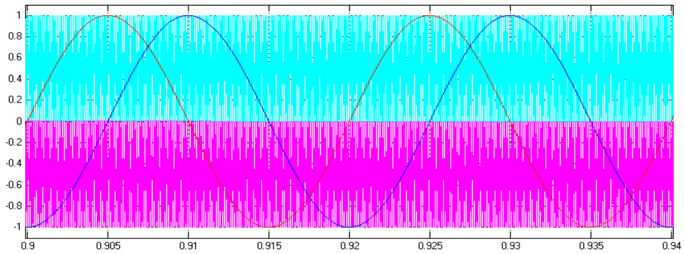

Fig. 16: Sine output of Signal Generator (red), with phase delay of 90^0 (blue), Triangular output of Tri 1 (pink) and Tri 2 (aqua blue).

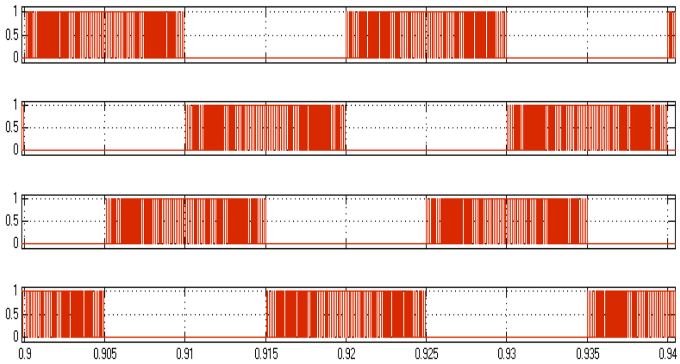

Fig. 17: Gating pulses generated by the model shown in Fig. 9, (PS-SPWM).

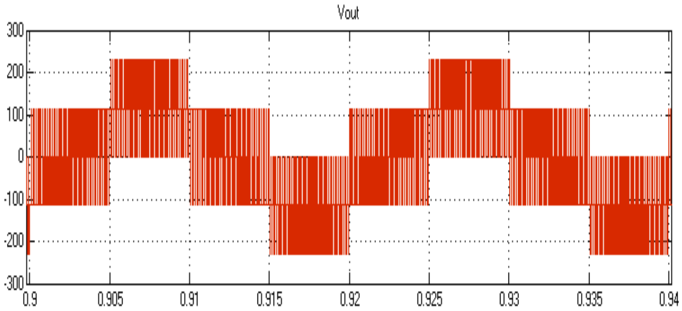

Fig. 18: Output Voltage of inverter shown in Fig. 11 for the gating pulses as shown in Fig. 17, (PS-SPWM).

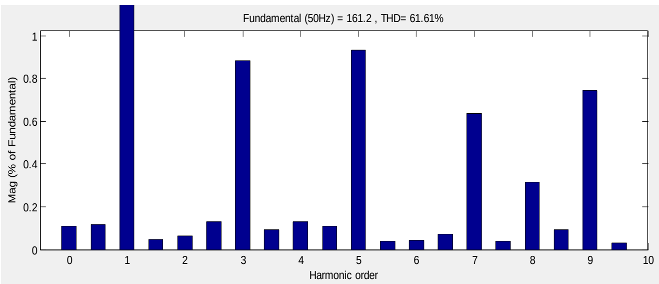

Fig. 19: FFT analysis of output voltage waveform as in Fig. 18.

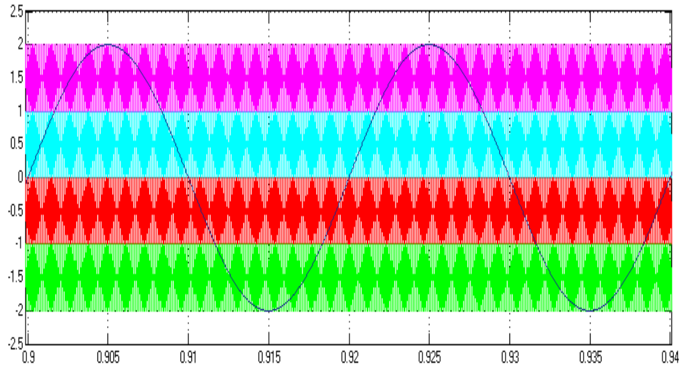

Fig. 20: Sine output of Signal Generator1 (blue) and Triangular outputs of Tri 1 (pink), Tri 2 (aqua blue), Tri 3 (red) and Tri 4 (green).

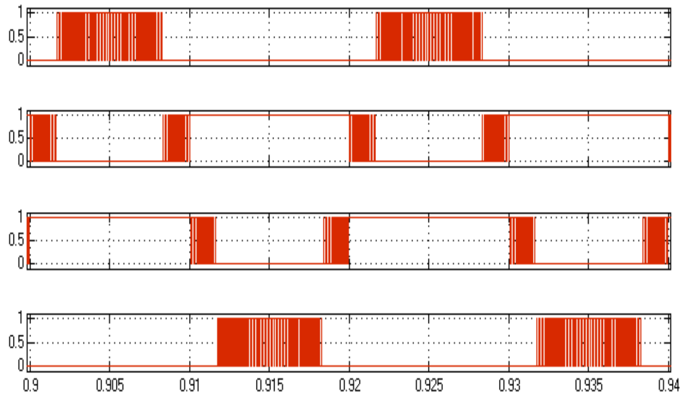

Fig. 21: Gating pulses generated by the model shown in Fig. 10, (MC-SPWM).

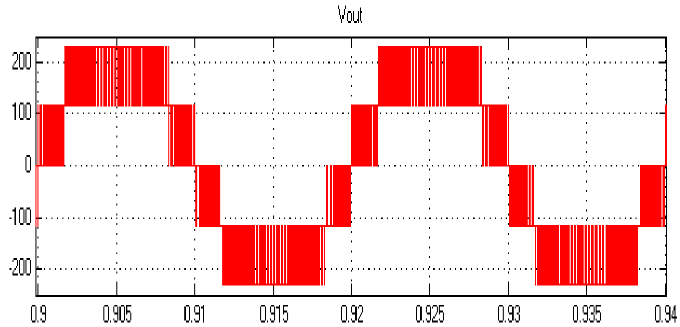

Fig. 22: Output Voltage of inverter shown in Fig. 11 for the gating pulses as shown in Fig. 21. (MC-SPWM).

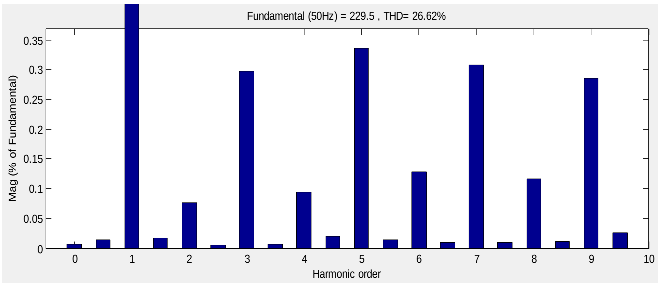

Fig. 23: FFT analysis of output voltage waveform as in Fig. 22.

In all three techniques THD is high due to the harmonic of order 200 i.e., 10 kHz, which is the frequency of carrier triangular signal.

TABLE I. PERCENTAGE HARMONICS IN OUTPUT VOLTAGE (V_{OUT})

SPWM Technique	Fundamental (50Hz)	Harmonic order				THD (%)
		3	5	7	9	
S-SPWM	182.8 V	24.90%	7.59%	5.13%	8.57%	48.04
PS-SPWM	161.2 V	0.88%	0.93%	0.63%	0.74%	61.61
MC-SPWM	229.5V	0.30%	0.34%	0.31%	0.29%	26.62

From Table I, it can be seen that the MC-SPWM has good fundamental component and less harmonics. The S-SPWM technique results in more harmonics. PS-SPWM has very less harmonics (less than 1%), almost nearer to MC-SPWM. THD can be reduced by a greater extent using proper filter design.

V. SUMMARY AND CONCLUSION

This paper has done a comparative analysis of three sinusoidal pulse width modulation techniques. The waveforms and harmonic analysis for the three techniques, using Simulink, are tabulated for comparison. From the harmonics table it can be observed that Multi-carrier sinusoidal pulse width modulation technique (MC-SPWM) results in fewer harmonic compared to other two techniques.

REFERENCES

(1) Sachin Maheshri and Prabodh Khampariya, “Simulation of single phase SPWM (Unipolar) inverter”, International Journal of Innovative Research in Advanced Engineering (IJIRAE), Volume 1, Issue 9, pp. 12-18, October 2014.

(2) Kapil Jain, Pradyumn Chaturvedi, “MATLAB-based Simulation & Analysis of Three-Level SPWM Inverter”, International Journal of Soft Computing and Engineering (IJSCE), Volume-2, Issue-1, pp. 56-59, March 2012.

(3) Sandeep Phogat, “Analysis of Single-Phase SPWM Inverter”, International Journal of Science and Research (IJSR), Volume 3, Issue 8, pp. 1793-1798, August 2014.

(4) S. M. Sadat Kiaee, A. Namadmalan, J. Shokrollahi Moghani, “A New Reliability Evaluation Technique for multilevel Inverters”, 4th Power Electronics, Drive Systems & Technologies Conference (PEDSTC2013), IEEE, pp. 361-366, Feb 13-14, 2013, Tehran, Iran.

(5) Ho-Dong Sun, Min-Young Park, Jong-Hyoung Park, Heung-Geun Kim, Tae-Won Chun, Eui-Cheol Nho, “Novel H-bridge Multi-level Inverter with DC-link Switches”, 8th International Conference on Power Electronics –ECCE Asia, IEEE, pp. 1734-1741, May 30-June 3, 2011, The Shilla Jeju, Korea.