Analysis & Comparison of Harmonics Reduction Topologies for Three Phase Bridge Inverter

Dhirendrakumar R Rana
Department of Electrical Engineering
Vadodara Institute of Engineering, Kotambi, India

Abstract— This paper describes analysis and comparison of three different topologies for reduction of harmonic contents in three phase bridge inverter with 180 degree mode of conduction. IEEE standard 519-1992 is a useful document for understanding harmonics and applying harmonic limits in power systems. Three different topologies are basic inverter operation with no harmonics reduction, second is passive filter by using combination of inductor- capacitor elements (LC circuit) and third is pulse width modulation technique. Here in this paper sinusoidal pulse width modulation technique is explained. Three circuits are simulated in MATLAB simulink for harmonics analysis in fast Fourier transform (FFT). Out of Three topologies sinusoidal pulse width is best method for reduction of harmonics. Level of harmonics is analysed using Total harmonic Distortion (THD).In addition to this work Active Filter circuit can also be used to minimize the THD level by implementing series active filter for current waveform and shunt active filter for voltage waveform for three phase circuit.

Key words: Harmonics, Filter, Inverter, Fast Fourier Transform, Total Harmonic Distortion, Pulse Width Modulation, LC Circuit, Simulation, IGBT

I. INTRODUCTION

Harmonics are a concern because they can cause excessive heating and pulsating and reduced torque in motors and generators; increased heating and voltage stress in capacitors; and mal operation in electronics, switchgear and relaying. In short, harmonics can lead to reduced equipment life if a system is designed without consideration for harmonics and if equipment is not properly rated and applied. and applied. It is therefore useful to measure and limit harmonics in electric power systems. IEEE Std 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems. [1]

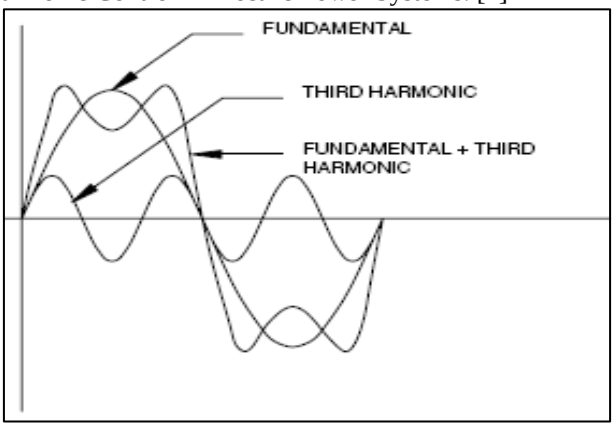


Fig. 1: Harmonic frequency waveforms

$$V_H = \sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + V_6^2 + V_7^2 \ldots)}$$

$$\text{THD} = \frac{V_H}{V_1} \times 100\%$$

A. Inverter

Three phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals.

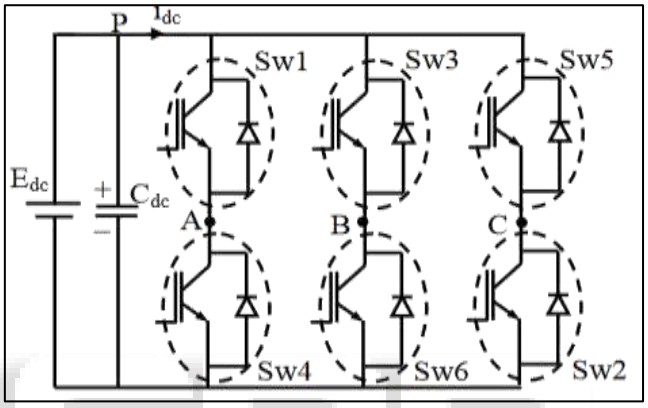


Fig. 2: Three phase voltage source inverter

For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated. Each switch conduct for 180 degree and turning on of the adjacent switch is staggered by 60degrees. The upper and lower switches of each pole conduct in complementary manner.

II. HARMONIC REDUCTION TOPOLOGIES

There are different techniques by which harmonics can be eliminated in the inverter circuit like passive filter, active filter, space vector modulation, pulse width modulation, third harmonic elimination, selective harmonic elimination. Out of these, two methods are described here.

A. LC filtering circuit

LC filter is designed for the second-order passive filter, which contains two reactive components that are inductor and capacitor. When a capacitor and an inductor are pla2ed in the same filter, there are two reactive devices responding in opposite ways to the changes of frequency. The inductor blocks high frequencies and passes low frequencies, while the capacitor passes high frequencies but blocks low frequencies. The filtering action of resistor/capacitor filters are also dependent on the impedance that will vary the frequency.

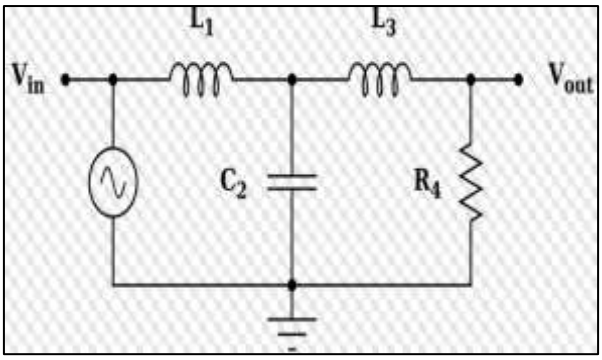


Fig. 3: LC Filter circuit

The impedance of a capacitor is inversely proportional to frequency or increasing frequency leads to reducing impedance. For an inductor, its impedance is directly proportional to the frequency. Increasing frequency leads to increasing impedance. The frequency for the LC filter can be calculated as

$$f = \frac{1}{2\pi\sqrt{LC}}$$

So, with these two reactive components, most of the frequency can block and reduce the number of harmonic frequency that goes through the system. Because of this, it can reduce the current harmonics for phase and neutral conductor.[2]

B. PWM technique

The switches in the voltage source inverter can be turned on and off as required. In the simplest approach, the top switch is turned on If turned on and off only once in each cycle, a square wave waveform results. However, if turned on several times in a cycle an improved harmonic profile may be achieved.

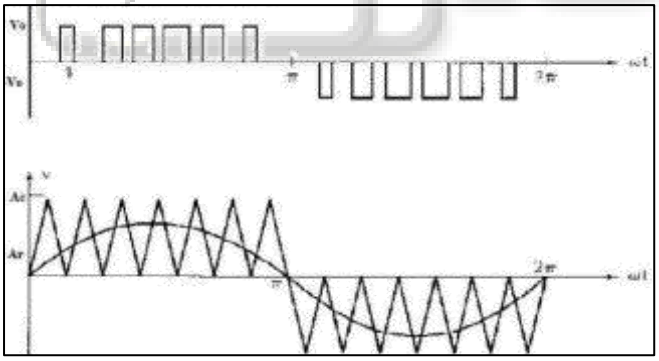


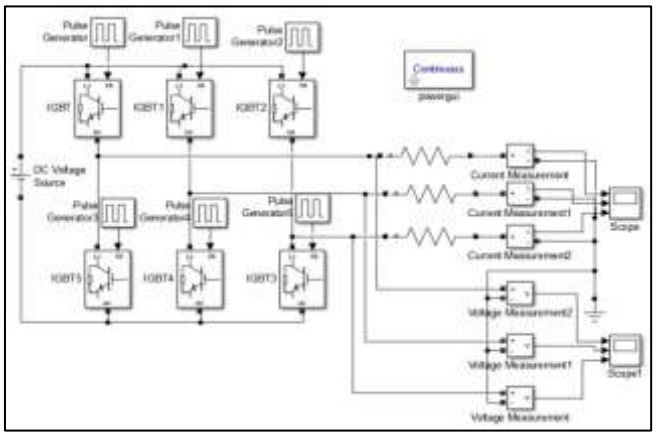
Fig. 4: Sinusoidal Pulse Width Modulation

Generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular

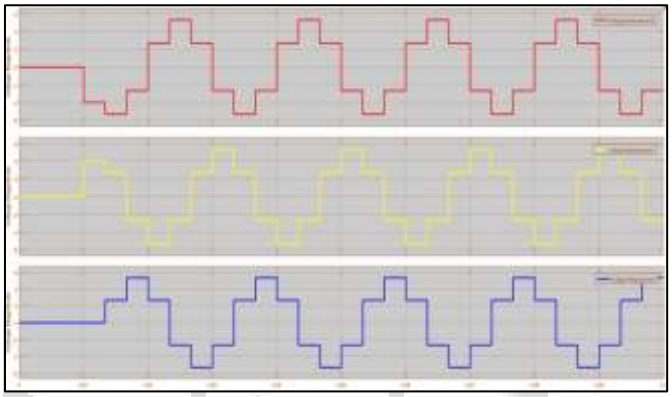
carrier is Ac, the ratio m=Am/Ac is known as the modulation index.[4]

III. SIMULATION RESULT

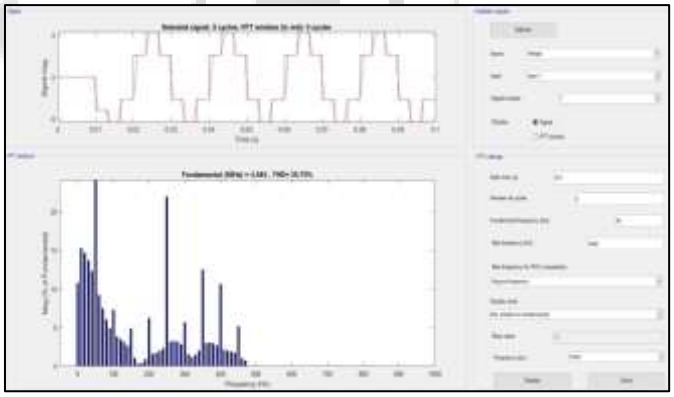
A. Simulation of Three phase inverter



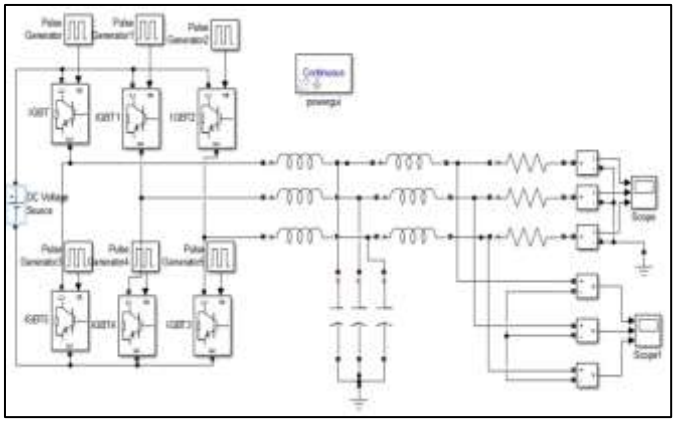
B. Phase Voltage Waveforms



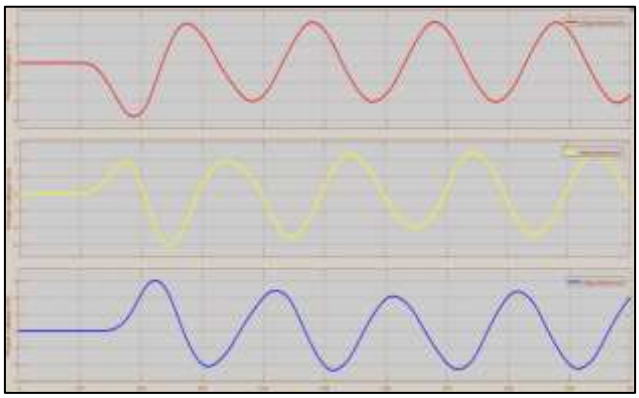
C. FFT analysis for phase voltage V_{N1}



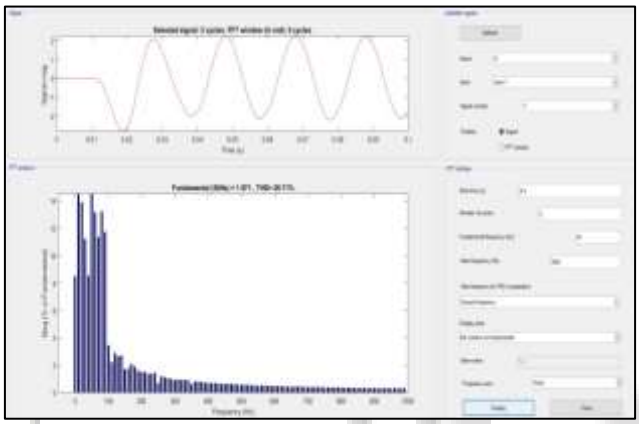
D. Simulation of Inverter using LC Filter



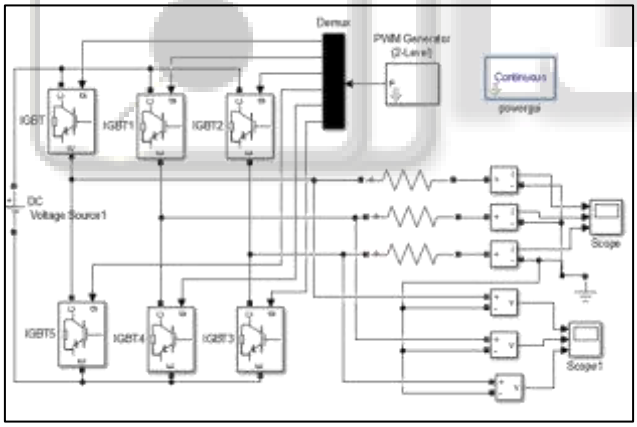
E. Phase Voltage Waveforms using LC circuit



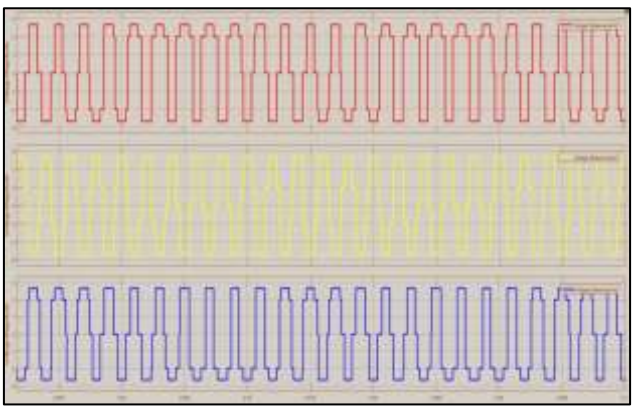
F. FFT analysis for phase voltage V_{N1}



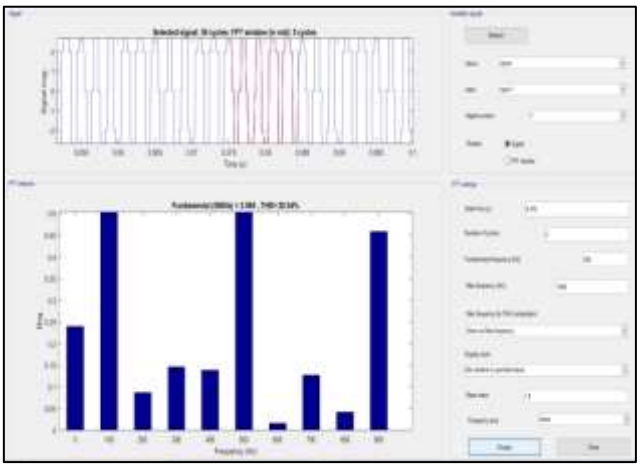
G. Simulation of Inverter using PWM



H. Phase Voltage Waveforms using LC circuit



I. FFT analysis for phase voltage V_{N1}



Harmonics in Output Phase Voltage	
Method Used	% THD
Basic Inverter	35.74
LC Filter	26.71
SPWM	20.54

Table 1: Comparison

IV. CONCLUSION

Simulation of three phase voltage source inverter for 180 degree mode of conduction is done in MATLAB Simulink for 0.1ms duration for three different topologies.

From the comparison table it is seen that without application of filter circuit, square waveforms are obtained which have higher values of THD of the order of 35.74%, while by using LC filter circuit it can be reduced to 26.71%, and by the use of different pulse width modulation technique , it can be again reduced to 20.54.

Although the percentage THD in current waveforms is higher than 5% which is the prescribed IEEE limit according to 591:1992 standard. [1] This THD level can be reduced by adjusting modulating index and frequency ratio of carrier and reference signal. By using Shunt or series inverter THD level can be reduced compare to these three topologies. [1]

REFERENCES

[1] IEEE Std 519-1992, "IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems," © Institute of Electrical and Electronics Engineers, Inc. 1993.
[2] [2] Application of LC Filter in Harmonics Reduction by Najwa Mahamad, C. M. Hadzer and Syafrudin Masri, National Power & Energy Conference (PECoo) 2004 Proceedings, Kuala Lumpur, Malaysia
[3] IEC Standard 61000-4-7, "Testing and Measurement Techniques – General Guide on Harmonics and Interharmonics Measurements and Instrumentation for Power Supply Systems and Equipment Connected Thereto," International Electrotechnical Commission, 2000.
[4] Pwm Methods For Two-Phase Inverters By Do-Hyun Jang, Ieee Industry Applications Magazine • MarApr 2007 •

[5] Hirofumi Akagi,―INSTANTANEOUS POWER THEORY AND APPLICATIONS TO POWER CONDITIONING‘-Tokyo Institute of Technology, Japan, Edson Hirokazu Watanabe, UFRJ-Federal University of Rio de Janeiro, Brazil, Mauricio Aredes, UFRJ-Federal University of Rio de Janeiro, Brazil
[6] POWER QUALITY‘‘ by C.SANKARAN, CRC Press
[7] K. H. Yiauw and M. S. Khanniche __A Novel Three-Phase Active Power Filter‘‘ University of Wales, Swansea, UK Rev. Energ. Ren. : Power Engineering (2001) 77-84
[8] Some Aspects on 3 Phase Bridge Inverter (180 Degree Mode) by Ananya Dutta, International Journal of Engineering Inventions e - ISSN: 2278-7461, p-ISSN: 2319-6491 Volume 3, Issue 4(November2013) PP:18-21
[9] Joao Afonso, Carlos Couto, Julio Martins ―ACTIVE FILTERS WITH CONTROL BASED ON THE P-Q THEORY‖Departamento De Electrónica Industrial Universidade, Do minho- 4800 Guimaraes – Portugal
[10] Luis A. Moran, Juan W. Dixon, ―USING ACTIVE POWER FILTERS TO IMPROVE POWER QUALITY‖ Departamento De Ing. Electrica Universidad De Concepcion, Concepcion – chile, lmoran@manet.die.udec.cl
[11] INSTANTANEOUS POWER THEORY AND APPLICATIONS TO POWER CONDITIONING” by Hirofumi Akagi

