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SIMULATION AND ANALYSIS OF AN ADVANCED 150° CONDUCTION MODE FOR THREE PHASE VOLTAGE SOURCE INVERTER AND COMPARISON WITH 120° AND 180° CONDUCTION MODE

Deep N. Sangani,
Department Of Electrical Engineering
G.H.Patel College of Engineering and Technology
Ahmedabad, India

***Abstract*— This paper presents a novel 150°conduction mode of widely used three phase voltage source inverter (VSI). In 150° conduction mode of three phases VSI each switch conducts for 150° time period. So the output phase voltage of VSI becomes 7 level, 12 step waveform compared to only 4 level and 3 level in 180°and 120° conduction modes respectively. This result into 50% harmonic reduction compared to conventional 180° and 120°conduction mode .Presence of THD using FFT analysis is mentioned in this paper.**

***Index Terms*—150°Conduction Mode, Three phase VSI, Total Harmonic Distortion (THD), output phase voltage, MATLAB.**

I. INTRODUCTION

An inverter is a device which converts DC power into AC power at desired voltage and desired frequency. Inverters are widely used in industrial applications such as Uninterruptible Power Supplies (UPS), Flexible AC Transmission System (FACTS) devices, Variable Frequency Drives (VFD), Active Power Filters, High Voltage Direct Current transmission system etc.So, the improvement in the output voltage and reduction in harmonic distortion is very important factor to be considered. A variable output voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant.

The inverter gain may be defined as the ratio of the ac output voltage to dc input voltage. On the other hand, if the input dc voltage is kept constant, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse width modulation control within the inverter. The conventional 180° and 120°conduction mode of three phase VSI produces approximately 30% of THD in output phase voltage. To decrease the THD level of output phase voltage multilevel inverter (MLI) topologies of VSI can be used but they also have drawbacks like greater number of requirement semiconductor devices, complex control etc.

II. CONSTRUCTION OF THREE PHASE VSI

Basic Construction of three phase VSI is shown in Figure 1.They are normally used for high power applications. In order to get a three phase output, three single phase inverters can be connected in parallel.

The gating signals of the three single phase inverters should be advanced or delayed 120° with respect to each other in order to obtain three phase balanced voltages. Three phase VSI contains six switches, switch may be IGBT, MOSFET, GTO etc. depending upon application. The diodes connected across the S1 to S6 switches are feedback diodes. These diodes will return back the stored energy from inductive load to the DC supply.

Three phase VSI takes DC power as input and converts DC power into AC power if the proper gate signals are given to the switches. A three phase star connected balanced load is considered and the simple square wave control technique is used in this paper instead of the pulse width-modulated (PWM) technique.

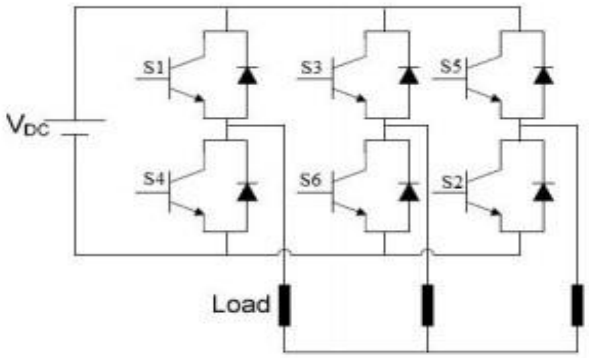

Fig.1. Diagram of three phase voltage source inverter

Figure 1.Three Phase Voltage Source Inverter Sometimes a large capacitor is connected at the input terminals of the inverter; to make the input dc voltage constant. This capacitor also suppresses the harmonics fed back to the dc source.

III. SIMULATION AND ITS RESULTS

A. 150° Conduction Mode

For 150° mode VSI, each thyristor conducts for 150°of a cycle. Unlike 180° mode, 120° mode inverter, 150° has twelve steps, each of 30° duration, for completing one cycle of the output ac voltage. The twelve switching patterns are presented per cycle with each pattern duration is 30°. These transistors conduct in one interval, while only two transistors conduct in the next one, as in 180° and 120° conduction modes respectively.

$$V_{AN} = \sum_{n=1,3,5...}^{\infty} \frac{V_{DC}}{6n\pi} \left[\begin{array}{l} 4+\cos\left(\frac{n\pi}{6}\right)+\cos\left(\frac{n\pi}{3}\right)-\cos\left(\frac{2n\pi}{3}\right) \\ -2\cos\left(\frac{5n\pi}{6}\right)-\cos\left(\frac{4n\pi}{3}\right)+\cos\left(\frac{5n\pi}{3}\right) \\ +2\cos\left(\frac{11n\pi}{6}\right) \end{array} \right] \sin\left(\omega t+\frac{\pi}{6}\right)$$

Interval	Duration	Conducting Switches							
1	π/6	S1	S2	S3					
2	π/6		S2	S3					
3	π/6		S2	S3	S4				
4	π/6			S3	S4				
5	π/6			S3	S4	S5			
6	π/6				S4	S5			
7	π/6				S4	S5	S6		
8	π/6					S5	S5		
9	π/6					S5	S6	S1	
10	π/6						S6	S1	
11	π/6						S6	S1	S2
12	π/6							S1	S2

Table 1. Conduction Switch Mode of 150°Conduction Mode

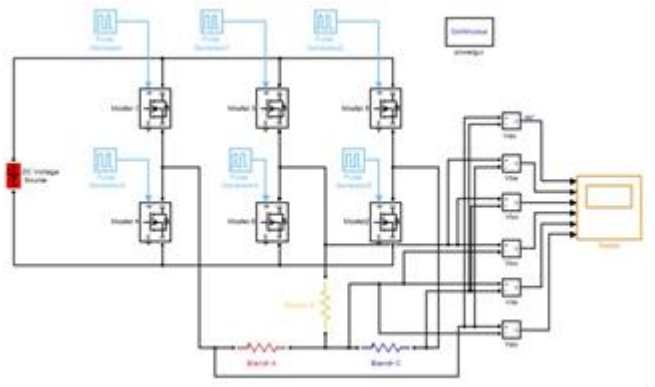

Fig.2. MATLAB/Simulation Model of three phase VSI

Fig. 2 shows simulation model of three phase VSI in MATLAB/SIMULINK environment. In simulation input DC voltage is taken as VDC= 100 V. MOSFET is taken as switch and R load is connected to the inverter. The value of load is taken as R = 10 Ω. Fig. 4 Shows Output phase and line Voltage for 150° Conduction Mode.

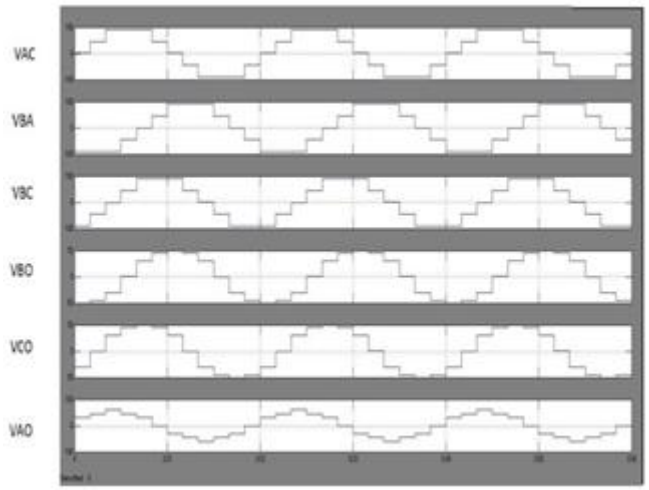

Fig.3.Output Voltages for 150°Conduction Mode

In the 150°conduction mode phase voltage becomes 7 level and 12 step waveform. So Total Harmonic Distortion (THD) in this mode reduces to 14.14 % compared to 27.56 % and 38.29 % in 180° and 120° conduction modes respectively.

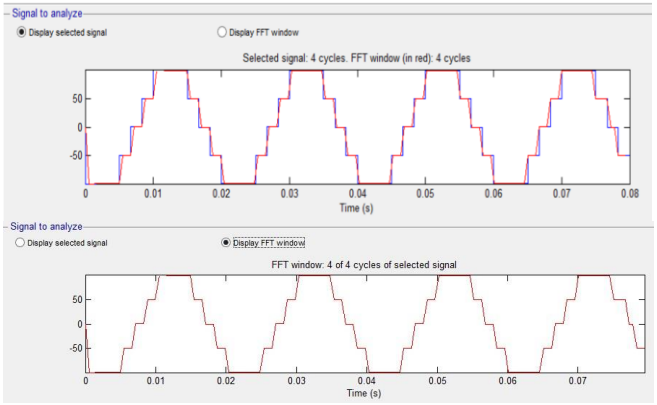

Fig.4.Signal analysis of Vab for 150°Conduction Mode

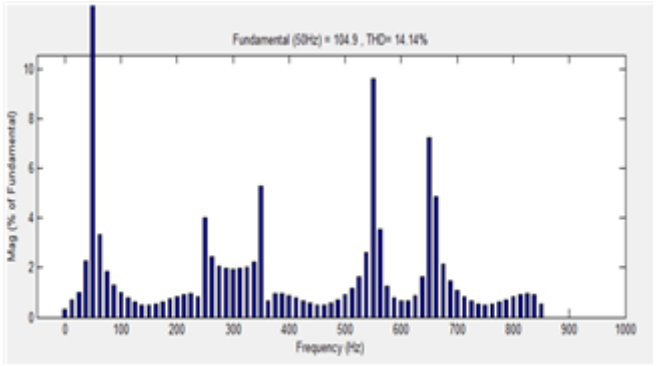

Fig.5.FFT analysis of Vab for 150°Conduction Mode

B. 120° Conduction Mode

In this conduction mode each switch conducts for 120°time period or 2π/3 radians. At any instant of time, two switches will conduct simultaneously. After every 60°or π/3 radians, one of the conducting switch is turned off and some other switch will start conducting.

$$V_{AN} = \sum_{n=1,3,5...}^{\infty} \frac{2V_{DC}}{n\pi} \sin\left(\frac{n\pi}{3}\right) \sin n\left(\omega t + \frac{\pi}{6}\right)$$

In this conduction mode there is a delay of π/6 between turning on and turning off of switches of same leg. So there is no possibility of short circuit. Operation of switches in 120° conduction modes is shown in Table 2.

Interval	Duration	Conducting Switches						
1	π/3	S1	S2					
2	π/3		S2	S3				
3	π/3			S3	S4			
4	π/3				S4	S5		
5	π/3					S5	S6	
6	π/3						S6	S1

Table 2. Conduction Switch Mode of 120°Conduction Mode

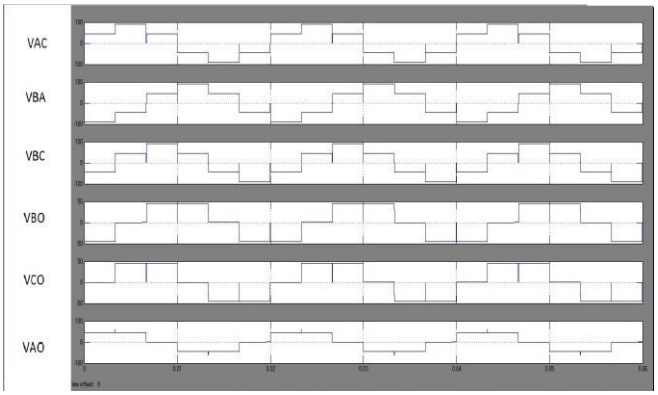

Fig.6.Output Voltages for 120°Conduction Mode

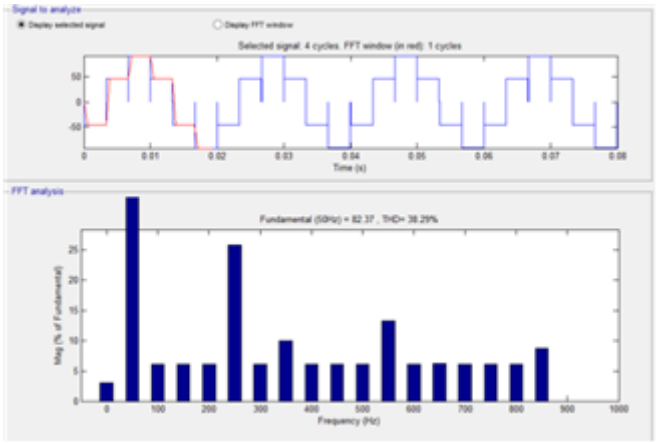

Fig.7. FFT analysis of Vab for 120°Conduction Mode

C.180° Conduction Mode

In this conduction mode each switch conducts for 180°time period or π radians. At any instant of time, three switches will conduct simultaneously, two of which are from one group (upper three or lower three) and remaining one from the other group. After every 60°or π/3 radians, one of the conducting switches is turned off and some other switch will start conducting.

$$V_{AN} = \sum_{n=1,3,5...}^{\infty} \frac{4V_{DC}}{\sqrt{3}n\pi} \sin\left(\frac{n\pi}{3}\right) \sin(n\omega t)$$

In this conduction mode upper switch of the leg turns off and at the same time lower switch of the same leg will be turned on. So there is no time delay between the turnings off and turning on of upper and lower switches of same leg, so there may be possibility of short circuiting of DC supply through upper and lower switches of same leg. Operation of switches in 180°conduction modes is shown in Table 3:

Interval	Duration	Conducting Switches							
1	π/3	S1	S2	S3					
2	π/3		S2	S3	S4				
3	π/3			S3	S4	S5			
4	π/3				S4	S5	S6		
5	π/3					S5	S6	S1	
6	π/3						S6	S1	S2

Table 3. Conduction Switch Mode of 180°Conduction Mode

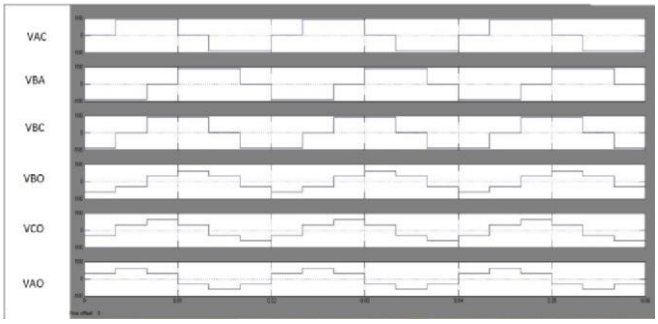

Fig.8.Output Voltages for 180°Conduction Mode

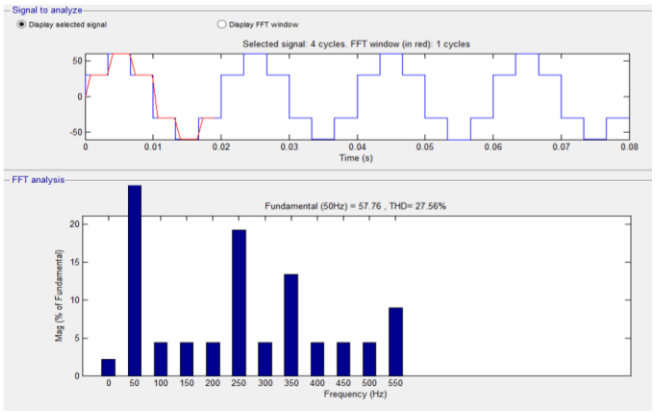

Fig.9. FFT analysis of Vab for 180°Conduction Mode

IV. COMPARISION BETWEEN 150°, 120°AND 180°

Phase voltages in case of 180° and 120° conduction modes are only 4 level and 3 level respectively. On the other hand 150° conduction mode gives seven level phase voltages which more closer to ideal sinusoidal wave. Waveforms of phase voltage for all the conduction modes are given the Fig. 13, Fig. 14 and Fig. 15.

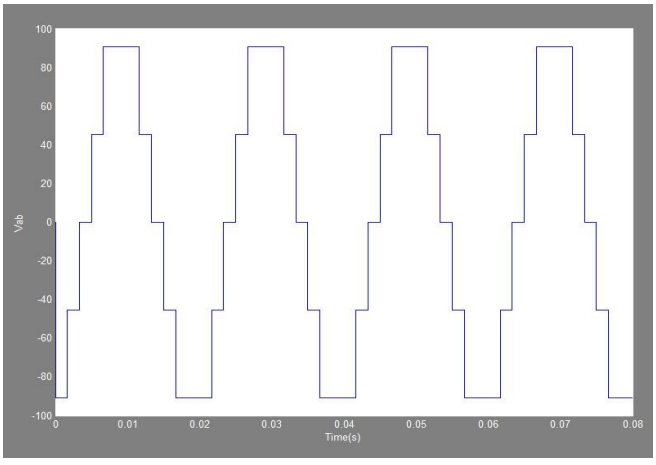

Fig.10.*Line Voltages for 150°Conduction Mode*

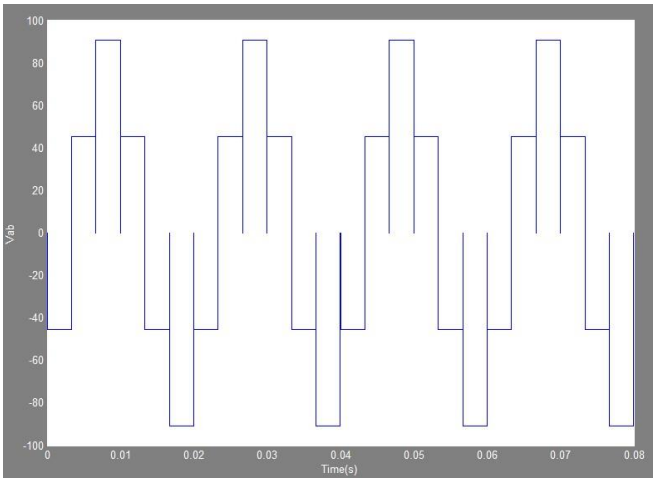

Fig.11.Line Voltages for 120°Conduction Mode

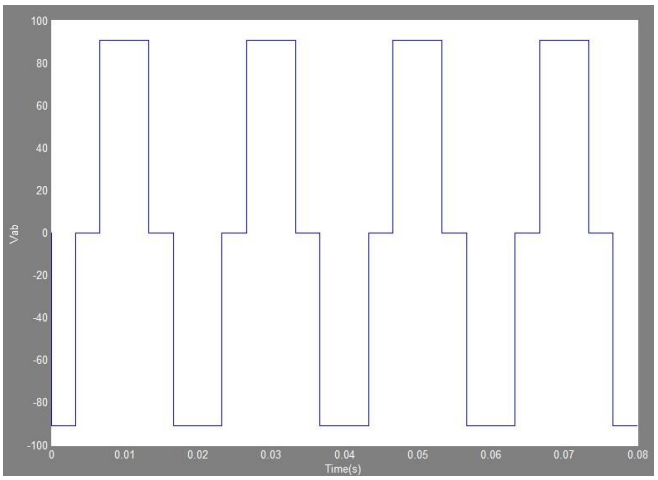

Fig.12.Line Voltages for 180°Conduction Mode

we can conclude that in 150° conduction mode gives more sinusoidal linevoltages compared to 180° and 120°conduction modes. Moreover from Table 3 we can see that rms output value of line voltage is in 150° conduction mode is almost near to 180°conduction mode, whereas in 120° mode it is less.

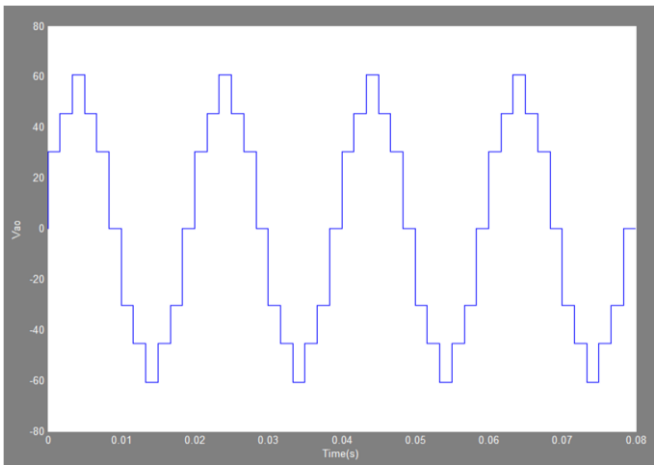

Fig.13.Phase Voltages for 150°Conduction Mode

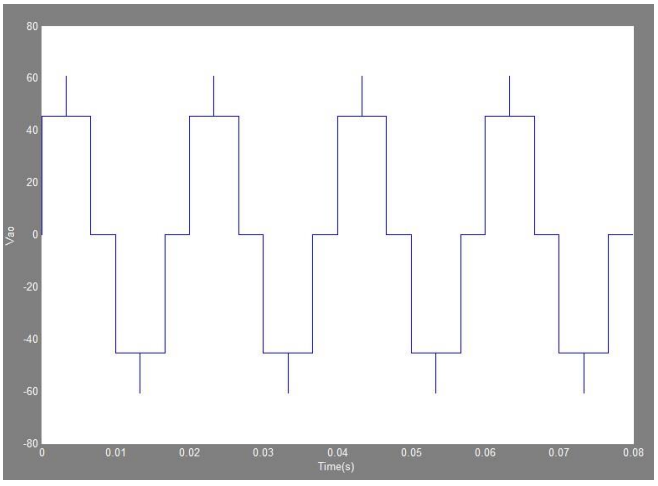

Fig.14.Phase Voltages for 120°Conduction Mode

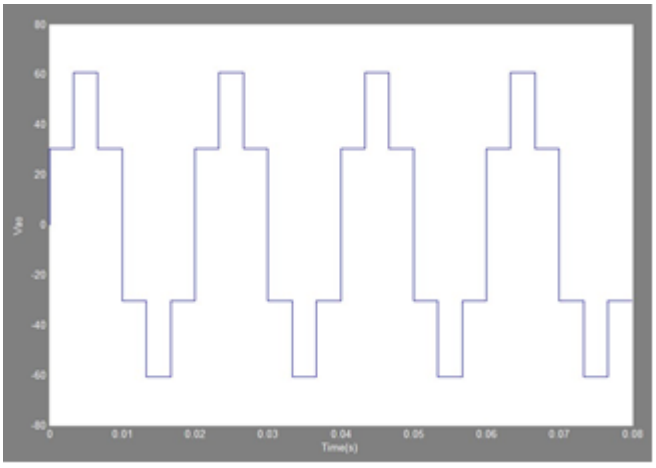

Fig.15.Phase Voltages for 180°Conduction Mode

Topic	120°	150°	180°
Vlines(rms)	35.49	**39.58**	39.25
Vph(rms)	58.25	**65.04**	64.78
Steps in phase output voltage	6	12	6
THD in phase voltage	38.29%	**14.14%**	27.56%
Levels in output phase voltage	3	7	3
Order of harmonics	6N±1	12N±1	6N±1
Lowest order of harmonics	5	11	5
Phase Delay	33.33	41.67	50

Table 4. Comparison between Conduction Mode of 120°, 150°, 180°

V. CONCLUSION

Three phase voltage source inverter in 150° conduction mode with a resistor connected load gives 7 levels, 12 steps output phase voltage waveform which is closer to sinusoidal waveform compared to 180° and 120° conduction modes. This result in a reduction of THD value of the output phase voltages. Detail study reveals that there is increase in the RMS value of output voltages, so total required VA ratings of the inverters reduced greatly over wide load conditions. Analysis of simulation result shows that same amount of levels in output phase voltage can be obtained by using less amount of switches and diodes with less control complexity.

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