

## Simulation and Analysis of 150° Conduction Mode For Three Phase Voltage Source Inverter

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**Abstract:-** In this paper a 150° conduction mode of three phase voltage source inverter (VSI) is presented. In this mode of three phase VSI each switch conducts for 150° time period. Here compared to only 4 level and 3 level in 180° and 120° conduction modes, the output phase voltage of VSI becomes 7 level, 12 step waveform respectively. This results into reasonable Total Harmonic Distortion (THD) level reduction compared to conventional 180° and 120° conduction modes VSI. All simulation results are obtained using MATLAB/SIMULINK toolbox.

**Keywords:-** Three phase VSI, 150° conduction mode, THD reduction, MATLAB Simulation

### I. INTRODUCTION

For desired voltage and desired frequency, an inverter is a device which converts DC power into AC power. In many applications like Variable Frequency Drives (VFD), Active Power Filters, Uninterruptible Power Supplies (UPS), Flexible AC Transmission System (FACTS) devices, High Voltage Direct Current transmission system etc. inverters are widely used. Because of this, the reduction in harmonic distortions and improvement in the output voltage is very important factor to be considered. By maintaining the gain of the inverter constant and varying the input dc voltage a variable output voltage can be obtained. By pulse width modulation (PWM) control technique within the inverter, if the input dc voltage is kept constant, a variable output voltage can be obtained by varying the gain of the inverter. The THD in output phase voltage by conventional 180° and 120° conduction mode of three phase VSI is approximately 30%. To decrease the THD level of output phase voltage, multilevel inverter (MLI) topologies of voltage source inverter (VSI) can be used but they also have drawbacks like greater number of requirement of semiconductor devices, complex control etc.

### II. CONSTRUCTION OF THREE PHASE VSI

Basic Construction of 3-phase voltage source inverter (VSI) is shown in Figure 1. Three single phase inverters can be connected in parallel in order to get a three phase output. They are used normally for high power applications. In order to obtain three phase balanced voltages, the gating signals of the three single phase inverters should be advanced or delayed 120° with respect to each other. Depending upon application 3-phase VSI contains six switches like IGBT, MOSFET, GTO etc. Here the feedback diodes, connected across the switches S1 to S6, 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. To make the input dc voltage constant sometimes a large capacitor is connected at the input terminals of the inverter which is also suppressing the harmonics fed back to the dc source.

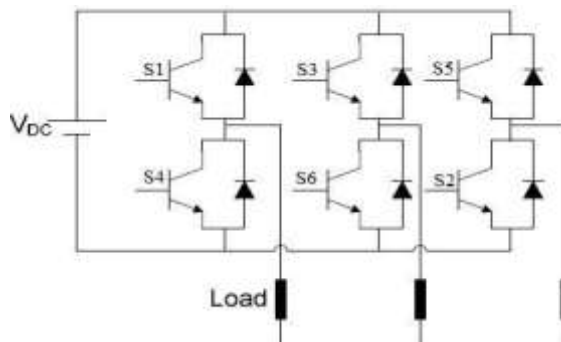


Figure 1. Three Phase Voltage Source Inverter

### III. DIFFERENT CONDUCTION MODES

There are three conduction modes of 3- phase voltage source inverter (VSI).

**A. 180° Degree Conduction Mode**

In this conduction mode each switch conducts for  $\pi$ - radians or 180° time period. Here three switches will conduct simultaneously, two of which are from one group (upper three or lower three) and remaining one from the other group at any instant of time. After every 60° or  $\pi/3$ - radians, one of the conducting switches is turned off and other switch will start conducting. 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. There for it may be possibility of short circuiting of DC supply through upper and lower switches of same leg.

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

Operation of switches in 180° conduction modes is shown in Table I.

**Table I.** Conduction Of Switches In 180° Conduction Mode

Interval	Duration	Conducting Switches					
1	60°	S1	S2	S3			
2	60°		S2	S3	S4		
3	60°			S3	S4	S5	
4	60°				S4	S5	S6
5	60°					S5	S6
6	60°					S6	S1

**B. 120° Degree Conduction Mode**

In this conduction mode each switch conducts for 120° time period or  $2\pi/3$  radians. Here two switches will conduct simultaneously at any instant of time. After every 60° or  $\pi/3$  radians, one of the conducting switch is turned off and other switch will start conducting. In this conduction mode there is a delay of  $\pi/6$  between turning on and turning off of switches of same leg. So there is no possibility of short circuit.

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

Operation of switches in 120° conduction modes is shown in Table II. Here switch utilization factor and rms output value of switches is less compared to 180° conduction mode.

**Table II.** Conduction Of Switches In 120° Conduction Mode

Interval	Duration	Conducting Switches					
1	120°	S1	S2				
2	120°		S2	S3			
3	120°			S3	S4		
4	120°				S4	S5	
5	120°					S5	S6
6	120°					S6	S1

**C. 150° Degree Conduction Mode**

For 150° mode, each thyristor conducts for 150° of a cycle in voltage source inverter (VSI). For completing one cycle of the output ac voltage unlike 180° mode & 120° mode inverter, 150° has twelve steps with each of 30° duration. The 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.

$$V_{AN} = \sum_{n=1,3,5,\dots} \frac{V_{DC}}{6n\pi} \begin{bmatrix} 4 + \cos\left(\frac{n\pi}{6}\right) + \cos\left(\frac{n\pi}{3}\right) - \cos\left(\frac{2n\pi}{3}\right) \\ -2\cos\left(\frac{5n\pi}{6}\right) - \cos\left(\frac{4n\pi}{3}\right) + \cos\left(\frac{5n\pi}{3}\right) \\ + 2\cos\left(\frac{11n\pi}{6}\right) \end{bmatrix} \sin\left(\omega t + \frac{\pi}{6}\right) \dots\dots\dots(0)$$

Operation of switches in 150° conduction modes is shown in Table III.

**Table ii. Conduction Of Switches In 120° Conduction Mode**

Interval	Duratio	Conducting Switches						
1	150°	S1	S2	S3				
2	150°		S2	S3				
3	150°		S2	S3	S4			
4	150°			S3	S4			
5	150°			S3	S4	S5		
6	150°				S4	S5		
7	150°				S4	S5	S6	
8	150°					S5	S5	
9	150°					S5	S6	S1
10	150°						S6	S1
11	150°						S6	S1 S2
12	150°							S1 S2

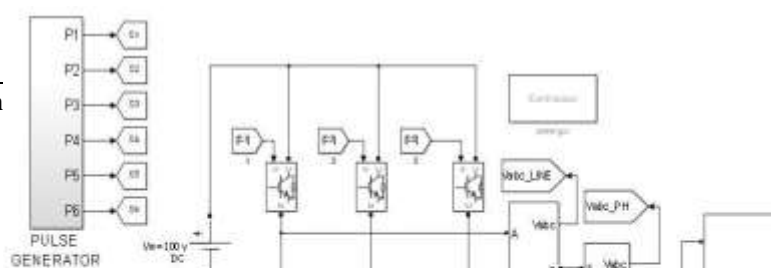
Power factor of load cannot be determined by the designers but conduction mode is a facility for designer. So the suitable conduction mode should be selected considering high RMS and low THD of the output voltage. Usually THD of the output voltage depends on the power factor and the conductive angle.

Compared to conventional 180° and 120° conduction modes, 150° conduction mode has the following advantages.

- A dead-time period of 30° is provided between two series switches. This is large enough to avoid short circuit on dc supply.
- Compared to 120° mode, it increases the RMS values of output voltages to almost those obtained by 180° mode.
- Produces seven level output phase voltage waveforms compared to only four and three levels in 180° and 120° modes respectively.
- It eliminates Lower Order Harmonics (LOH) to a larger extent.
- Highly reduces the DF & THD of output voltage waveform.

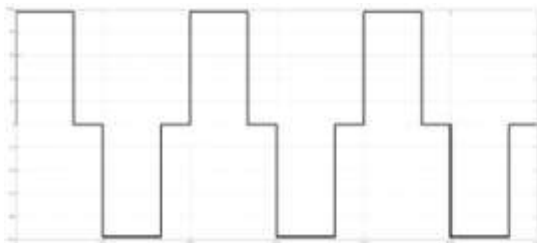
#### IV. SIMULATION RESULTS

Fig. 2 shows simulation model of three phase VSI in MATLAB/SIMULINK environment.

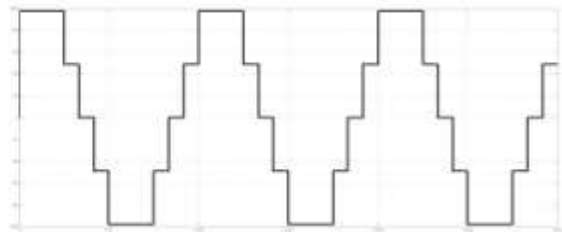


## 2. Matlab/Simulink Model of Three Phase VSI

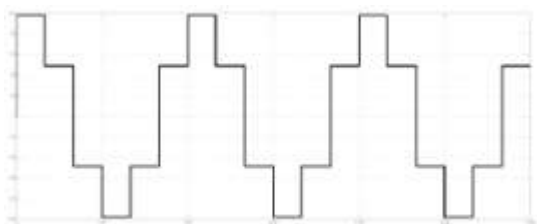
In simulation input DC voltage is taken as  $V_{DC} = 120\text{ V}$ . IGBT is taken as switch and RL load is connected to the inverter. The value of load is taken as  $R = 12\ \Omega$  and  $L = 2\text{mH}$ . Fig. 3, Fig. 4 and Fig. 5 shows the comparison of line voltages  $180^\circ$ ,  $120^\circ$  and  $150^\circ$  conduction modes respectively.



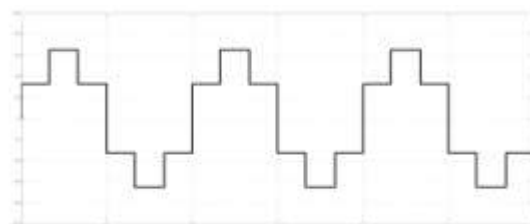
**Figure 3.** Line voltage in  $180^\circ$  conduction mode



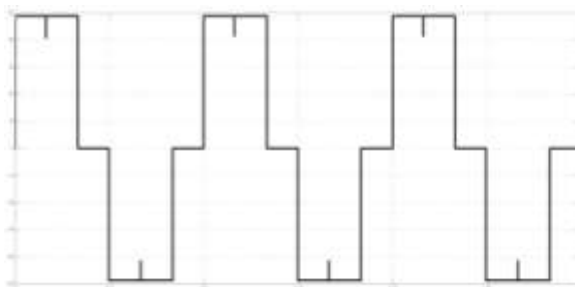
**Figure 5.** Line voltage in  $150^\circ$  conduction mode



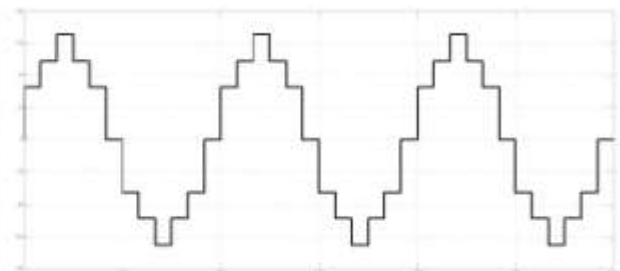
**Figure 4.** Line voltage in  $120^\circ$  conduction mode



**Figure 6.** Phase voltage in  $180^\circ$  conduction mode



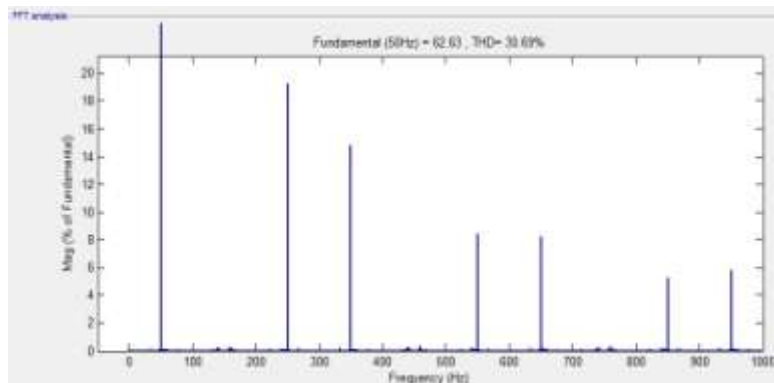
**Figure 7.** Phase voltage in  $120^\circ$  conduction mode



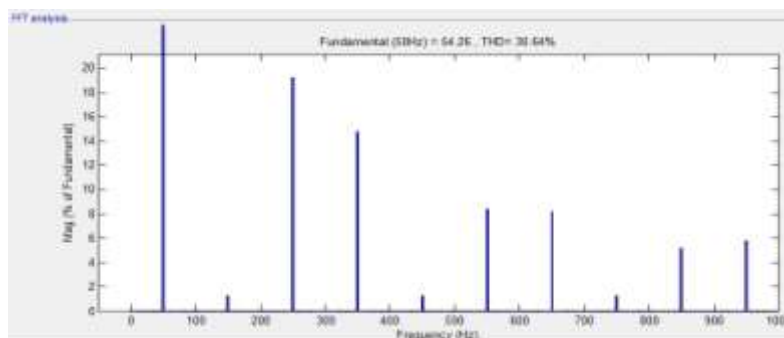
**Figure 8.** Phase voltage in  $150^\circ$  conduction mode

From above figures we can conclude that in  $150^\circ$  conduction mode gives more sinusoidal line voltages

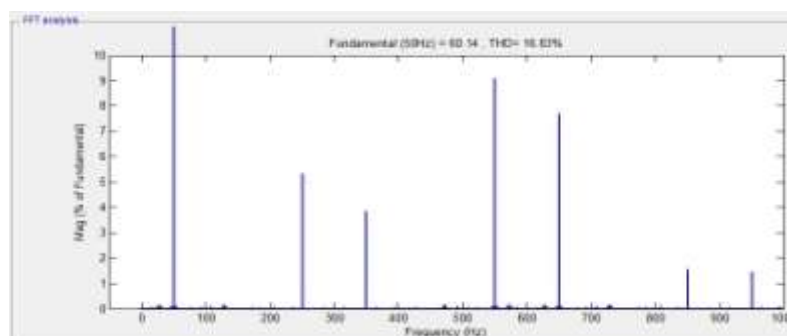
compared to 180° and 120° conduction modes. Fig. 9, Fig. 10 & Fig. 11 shows the FFT analysis of phase voltage of 180°, 120° & 150° conduction mode.



**Figure 9.** FFT analysis of phase voltage of 180°



**Figure 10.** FFT analysis of phase voltage of 120°



**Figure 11.** FFT analysis of phase voltage of 150°

The Total Harmonic Distortion (THD) in this mode reduces to 16.83 % compared to 30.69 % and 30.64 % in 180° and 120° conduction modes respectively. Here Table IV shows overall comparison between all the conduction modes.

**Table Iv.** Detail Comparison Between Conduction Modes

Parameter	180°	120°	150°
$V_L/V_{DC}$ (RMS)	0.80	0.689	0.7469
$V_{PH}/V_{DC}$ (RMS)	0.46	0.40	0.43

THD in Phase Voltage	30.69 %	30.64 %	16.83 %
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## V. CONCLUSIONS

Compared to 180° and 120° conduction modes, here three phase voltage source inverter (VSI) in 150° conduction mode with a star-connected load gives 7 level, 12 steps output phase voltage waveform which is more closer to sinusoidal waveform. This results into reasonable Total Harmonic Distortion (THD) level value of the output phase voltages. Because of this the performance and efficiency of VSI is greatly improved over wide load conditions.

## VI. REFERENCES

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