OPERATION OVERVIEW OF THREE PHASE INVERTER WITH 120°, 150° AND 180° CONDUCTION MODE

Prof. Roshani Parikh
Lecturer, Electrical Department, RCTI, Ahmedabad, Gujarat, India

Abstract: Today most of the appliances and machine works on AC power. If the AC supply is not available for limited time period at that time we need to convert stored DC power in to AC power. This can be done by the power electronics equipment called as an Inverter. Basically inverter uses a power electronic switch as a form of an array. Different types of inverters are available in market for different purpose. By applying different patterns of switching of array gives an appropriate output. In this paper we are going to represents the basic overview of three phase inverter with conduction mode of 120°, 150° AND 180°. The Three phase inverter working and output waveforms are justify the three different mode of operation. 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.

I. INTRODUCTION

DC-AC inverters have been widely used in industrial applications such as uninterruptible power supplies, static frequency changes and AC motor drives. Recently, the inverters are also playing important roles in renewable energy applications as they are used to link a photovoltaic or wind system to a power grid. Like DC-DC converters, the DC-AC inverters usually operate in a pulse width modulated (PWM) way and switch between a few different circuit topologies, which means that the inverter is a nonlinear, specifically piecewise smooth system. In addition, the control strategies used in the inverters are also similar to those in DC-DC converters. For instance, current-mode control and voltage-mode control are usually employed in practical applications. In the last decade, studies of complex behavior in switching power converters have gained increasingly more attention from both the academic community and industry.The function of inverter is to change a DC input voltage to symmetric AC output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the dc input voltage and maintaining the gain of inverter constant. On the other hand, if the DC input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse with modulation control within the inverter. The inverter gain may be defined as the ratio of the AC output voltage to the DC input voltage. The output voltage waveforms of an ideal inverter should be sinusoidal. However, the waveforms of practical inverter are non-sinusoidal and contain certain Harmonics. For low and medium-power applications, square-wave or quasi-square-wave voltages may be acceptable; and for high-power applications, low distorted sinusoidal wave-forms are required. With the availability of high-speed power semiconductor devices, the harmonic contents of output voltage can be minimizedOr reduced significantly by switching techniques.

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.

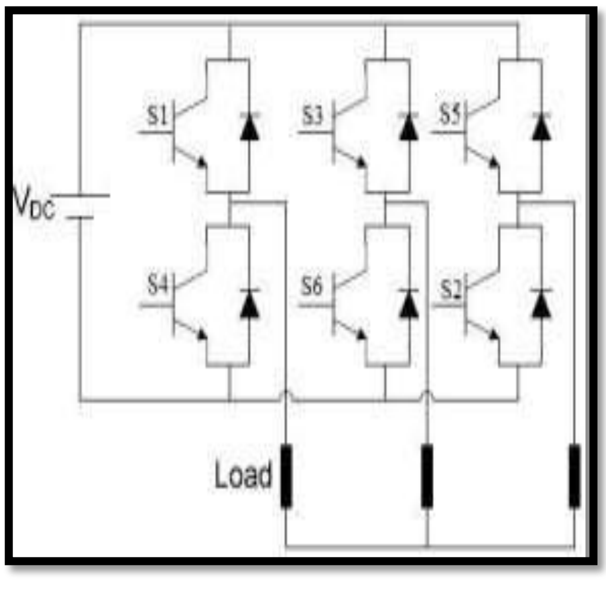

Figure 1.Three Phase Voltage Source Inverter

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 π- 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 π/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.

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

………………………….. (1)

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

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	S1	
6	60°						S6	S1	S2

Table I. Conduction of Switches in 180° Conduction Mode

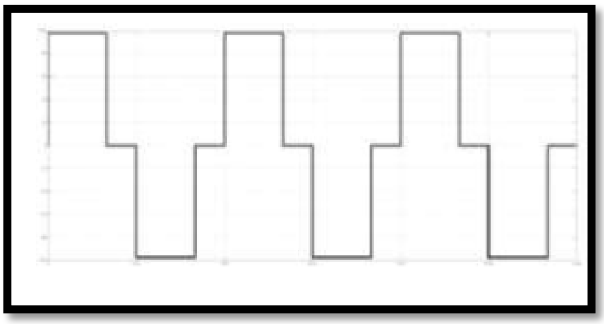

Figure-2 Line Voltage in 180° conduction mode

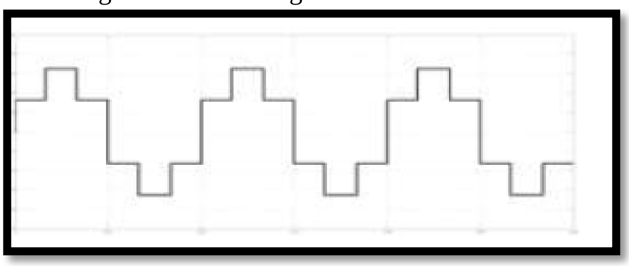

Figure-3 Phase Voltage in 180° conduction mode

B. 120° Degree Conduction Mode

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

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

…………………. (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.

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

Table II. Conduction of Switches in 120° Conduction Mode

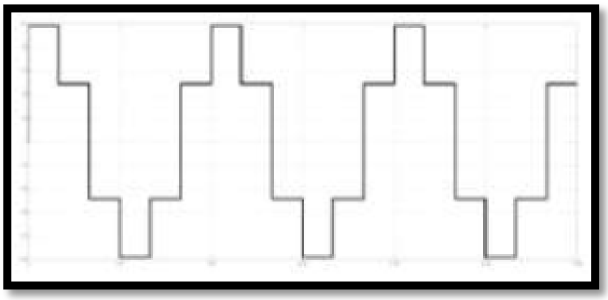

Figure-4 Line voltage in 120° conduction mode

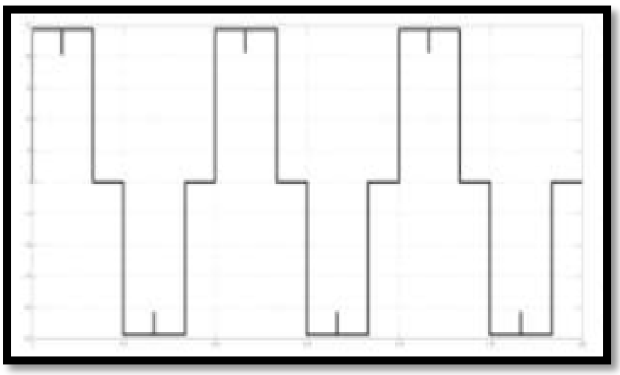

Figure-5 Phase voltage in 120° conduction mode

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.

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

…………… (3)

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

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

Table III. Conduction of Switches in 150° Conduction Mode

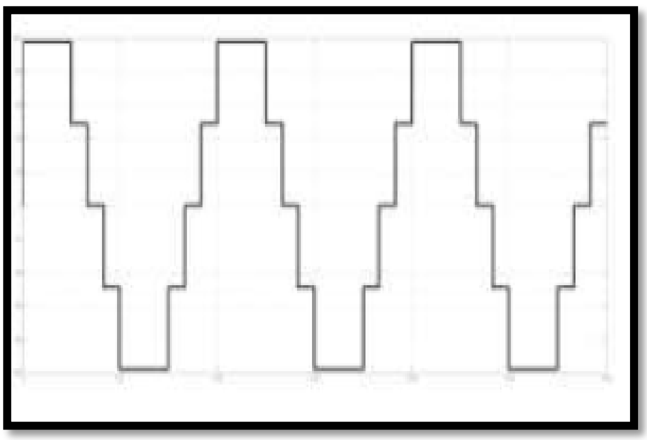

Figure-6 Line voltage in150° conduction mode

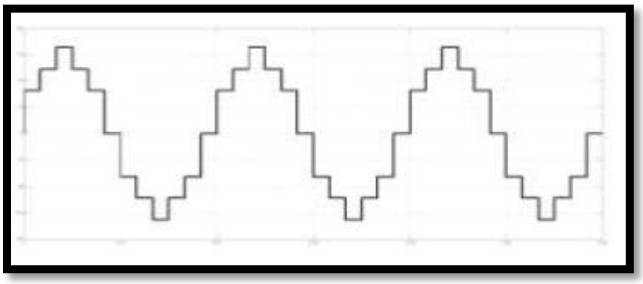

Figure-7 Phase voltage in 150° conduction mode

From above figures we can conclude that in 150° conduction mode gives more sinusoidal line voltages compared to 180° and 120° conduction modes. 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.

III. CONCLUSIONS

In this paper we have briefly discuss the operation of three phase voltage source inverter (VSI) with three conduction mode their switching and also shows their line and phase voltage waveform. 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.

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