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# Three Phase Voltage Source Inverter with a Novel 150° Conduction Mode

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***Abstract*: -- In today's world, where power demand has enhanced significantly, the reliance on flexible energy options has also increased. Our design is an attempt to take a DC input and convert it into a three-phase AC output by a novel 150° conduction topology. This paper presents a new conduction topology for most common, simple and well known three-phase voltage source inverter. In this modification, each switch conducts 150° instead of the usual 180° or 120° conduction modes. For a star connected load, the output phase voltage becomes seven levels and twelve steps waveform- which are closer to the sinusoidal waveform. This results in a 50% reduction of the total harmonic distortion. A comprehensive study of the three modes of conduction is proposed. To confirm the validity and feasibility of this modification, the simulation is carried out with a three-phase balanced load. The results obtained shows that in comparison with 180° and 120° conduction mode, 150° Conduction mode is better and feasible.**

***Keywords:* - Three Phase VSI, 150° conduction mode.**

## I. INTRODUCTION

The most common, simple and well known three phase six switch voltage source inverter has been widely used in AC drives. For this reason, many research's have been presented recently investigating different types of topologies that commonly used in inverter. In many applications like Variable Frequency Drives(VFD), Uninterruptible Power Supplies (UPS), Active Power Filters(APF), Flexible AC Transmission System (FACTS) devices, HVDC transmission system etc[1]. Inverters are mostly used. Because of this, the reduction in harmonic distortions and improvement in the output voltage is most important factor to be considered. The common modes of conduction of inverter employing almost all applications are mainly 180° and 120° Conduction mode decides the output voltage and harmonics of the system. The THD in output phase voltage by conventional 180° and 120° conduction mode of three phase VSI is approximately 30%.[2] 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.

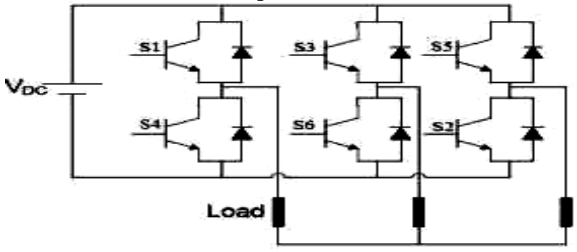


***Figure 1: Three Phase Voltage Source Inverter***

This paper innovates a new strategy, which intentionally opens one of the three inverter legs per time in a pre-planned sequence. This strategy combines the commonly used 180° and 120° modes of conduction to generate a new operating mode, defined as a 150° conduction mode. This produces for star connected loads seven levels of voltage instead of the only five levels originally generated by the simple structure, simple drive circuit, cheep and most commonly used VSI. The output phase voltage wave shape is a 12-step one, i.e. much more closer to the sinusoidal waveform compared to the highly distorted usually generated 6-step one. It should be noticed that; without any additional costs or structure changes or complexity, the THD of the output waves has been reduced about 50%.

## II.THREE PHASE VOLTAGE SOURCE INVERTER

There are three conduction modes of three 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. [2]

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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`***

**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 switch is turned off and other switch will start conducting. [2][3] In this conduction mode there is a delay of π/6 between turning on and turning off of switches of same leg. So there are no chances of short circuit. 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 | 60° | S1 S2 |
| 2 | 60° | S2 S3 |
| 3 | 60° | S3 S4 |
| 4 | 60° | S4 S5 |
| 5 | 60° | S5 S6 |
| 6 | 60° | S6 S1 |

***Table II. Conduction of Switches 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.[3] The switching patterns are exhibited per cycle with each pattern duration is 30°. These switches conduct in one interval, while only two switches conduct in the next one, as in 180° and 120° conduction modes respectively Operation of switches in 150° conduction modes is shown in Table III.

| Interval | Duration | Conducting switches |
|---|---|---|
| 1 | 30° | S1 S2 S3 |
| 2 | 30° | S2 S3 |
| 3 | 30° | S2 S3 S4 |
| 4 | 30° | S3 S4 |
| 5 | 30° | S3 S4 S5 |
| 6 | 30° | S4 S5 |
| 7 | 30° | S4 S5 S6 |
| 8 | 30° | S5 S6 |
| 9 | 30° | S5 S6 S1 |
| 10 | 30° | S6 S1 |
| 11 | 30° | S6 S1 S2 |
| 12 | 30° | S1 S2 |

***Table III. Conduction of Switches in 150° Conduction Mode***

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 to a greater extent.
- Highly reduces the DF & THD of output voltage waveform.

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## III. SIMULATION RESULTS

Fig. 2 shows simulation model of three phase VSI in PSIM environment.

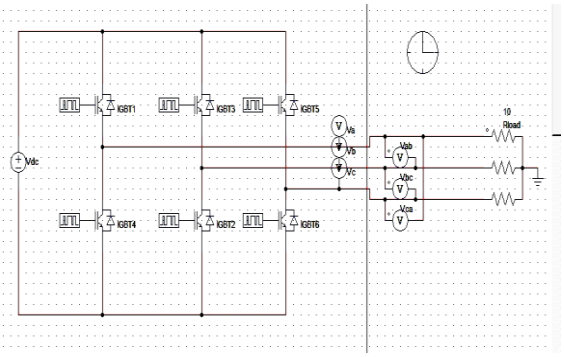


*Figure 2: PSIM Model of Three Phase VSI*

In simulation input DC voltage is taken as Vdc = 120 V. IGBT is taken as switch and R load is connected to the inverter. The value of load is taken as R = 10 Ω. Fig. 3, Fig. 4 and Fig. 5 shows the comparison of phase voltages of 180°, 120° and 150° conduction modes respectively.[5]

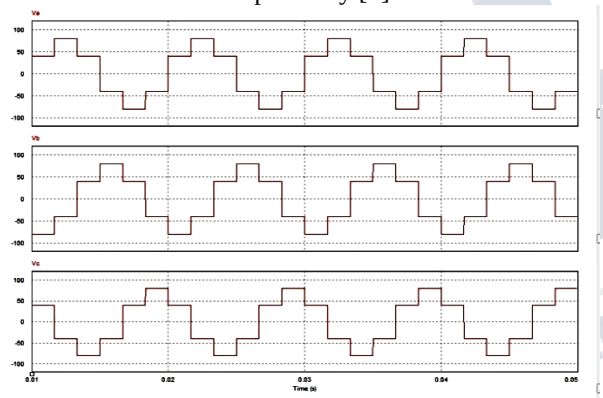

*Figure 3: Phase Voltages of 180° Conduction Mode*

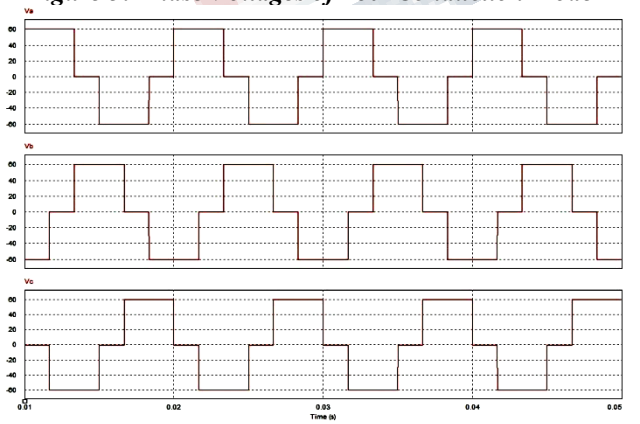

*Figure 4: Phase Voltages of 120° Conduction Mode*

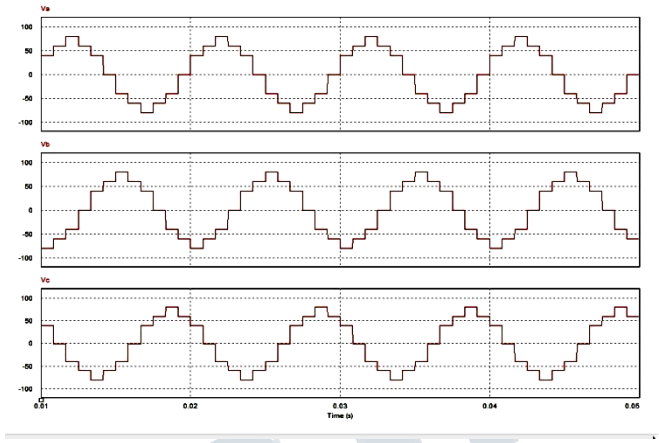

*Figure 5: Phase Voltages of 150° Conduction Mode*

Also Fig. 6, Fig. 7 and Fig. 8 shows the comparison of line voltages of 180°, 120° and 150° conduction modes respectively.

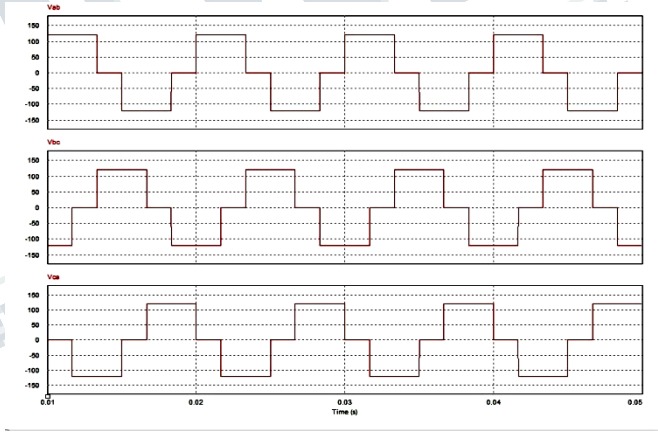

*Figure 6: Line Voltages of 180° Conduction Mode*

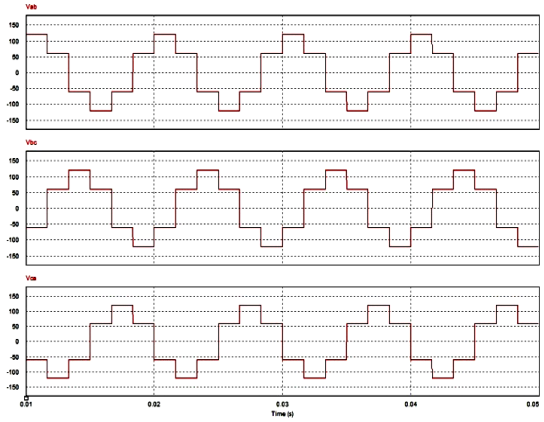

*Figure 7: Line Voltages of 120° Conduction Mode*

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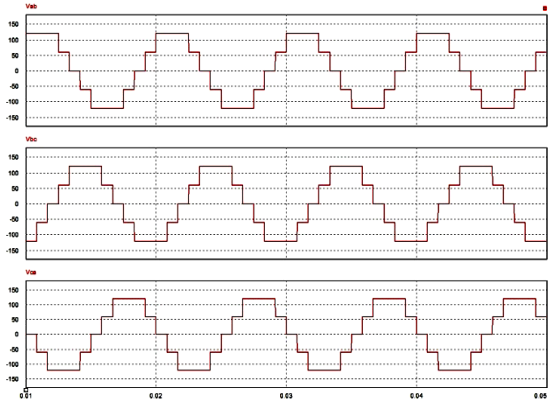

*Figure 8: Line Voltages of 150° Conduction Mode*

From above figures we can conclude that, In 150° conduction mode, output voltages are more sinusoidal as compared to 180° and 120° conduction modes.

## V. CONCLUSIONS

This paper presented a novel conduction mode for the most-common, simple, and well-known six-switch three-phase voltage source inverter. 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. By the comparative study and simulation of different conduction mode on three phase VSI, better performance is achieved in 150° mode without adding extra component. So, on the basis of simplicity, economy, easy to implement and less personates to total harmonics distortion at output side 150° is suitable topology.

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