

Study and Analysis of Three Phase Voltage Source Inverter Fed Induction Motor Drive in Various Pulse Width Modulation Techniques

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ABSTRACT-*The Three Phase Voltage Source Inverter supplies invariably required variable voltage and frequency of the adjustable speed drive system. A number of pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply from an inverter. The most widely used PWM scheme for a Three Phase Voltage Source Inverter is carrier based sinusoidal PWM and Space Vector Pulse Width Modulation (SVPWM). There is an increasing trend of using SVPWM, because of their easier digital realization and better DC bus utilization. The study of SVPWM technique reveals that this technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with sinusoidal PWM techniques. The SVPWM technique has become one of the important PWM technique for Three Phase Voltage Source Inverter for the control of AC induction motor, Brushless DC motor, Switched Reluctance motor and Permanent Magnet Synchronous motor. In this paper having collection of different schemes in SVPWM. Specifically various schemes are Center aligned two level SVPWM, Level shifted multi-carrier concepts based SVPWM, and Third order harmonic injection based modulated reference waveform generation and comparison in SVPWM. This paper having simulation results of all the three schemes of SVPWM by using MATLAB/SIMULINK software. The performance of Three Phase Voltage Source Inverter fed induction motor drive based on various SVPWM schemes are analyzed by various reference parameters like DC bus utilization, Total harmonic distortion (THD), switching stress and efficiency. As a result of these analysis this paper recommends which scheme is more suitable for variable voltage and various frequency drives. The simulation results are provided to validate the proposed model approaches.*

Keywords: Three Phase Voltage Source Inverter, Space vector Pulse width Modulation (SVPWM), Modulated reference waveform, Center aligned, Third harmonic injection, Total Harmonic Distortion (THD), and Switching Stress.

I. INTRODUCTION

Three phase voltage source inverters are widely used in variable speed AC motor drive applications since they provide variable voltage and variable frequency output through pulse width modulation control [1] [2]. The most widely used PWM method is the carrier-based sine-triangle PWM method due to simple implementation in both analog and digital realization [2] [3]. However in this method the DC bus utilization is low ($0.5V_{dc}$). This has led to the investigation into other techniques

with an objective of improving in the DC bus utilization [1] [3]. The PWM technique termed as Space Vector PWM based on space vector theory was proposed by de Broeck et. Al (1988) and Ogasawara et.al (1989) which offers superior performance compared to the carrier –based sine-triangle PWM technique in terms of higher DC bus utilization and better harmonics performance [3]. Further, this technique offers easier digital realization. The research in PWM schemes has intensified in the last few decades. The main aim of any modulation technique is to obtain a variable output with a maximum fundamental component and minimum harmonics [3] [4].

The problem of underutilization of the DC bus voltage led to the development of the Third harmonic-injection PWM (THIPWM) and Space Vector PWM (SVPWM) [5] [6]. In 1975, Buja developed this improved sinusoidal PWM technique which added a third –order harmonic content in the sinusoidal reference signal leading to a 15.5% increase in the utilization rate of the DC bus voltage. In 1988, Van Der Broeck developed the SVPWM technique which has also increased the utilization of DC bus voltage by 15.5% [7] [8].

In the last three decades there are different SVPWM schemes are developed by various authors. But this paper is mainly focus on important five schemes in SVPWM. The various schemes in SVPWM are a) Center aligned two level SVPWM, b) Level shifted multi-carrier concepts based SVPWM, and c) Third order harmonic injection based modulated reference waveform generation and comparison in SVPWM. Here these three techniques have similar results, but their methods of implementation are completely different. With the development of microprocessors SVPWM has become one of the most important PWM methods for three phase inverter. The maximum peak fundamental magnitude of the SVPWM technique is about 90.6% increase in the maximum voltage compared with conventional sinusoidal modulation [9] - [10].

This paper having some collective information regarding various schemes as mentioned above presents in the two level SVPWM based Three Phase Voltage Source Inverter fed induction motor drive. This paper covers entire concepts presents in all the three schemes and also this paper gives a comparative statement regarding all those five schemes. The comparative statement is developed by the following valuable parameters. The parameters are THD, DC bus utilization, switching stress and efficiency. As a result of this comparative statement the reader can identify which scheme is more suitable for particular drive operation. The simulation results are provided to validate the proposed approaches.

II. CENTER ALIGNED TWO LEVEL SVPWM

The figure-2 space vector diagram for two-level inverter shown below should satisfy the above two requirements. This space vector diagram is common to all the four possible switching sequences. Only changes in this space vector diagram are the various possibilities of reference

vector rotation in each sectors. The possible switching sequence in each sector is like, starting with [000] switching sequence and also ends with [000] switching sequence. This will be shown in figure-6.1 The seven segments switching sequence and switching time calculation for each switch for each sector is shown in figure 2.1 to 2.6. The circuit diagram is shown in figure.

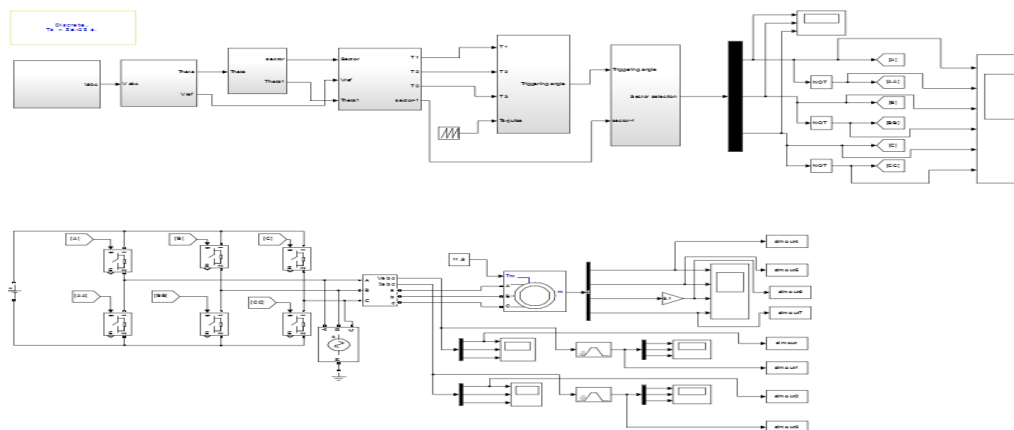


Figure-2 Center aligned SVPWM fed induction motor drive

Figure 2.1 to 2.6 shows a typical seven segment switching sequence and inverter output waveforms for $\overline{V_{ref}}$ in each sectors.

Here $\overline{V_{ref}}$ is synthesized by $\overline{V_1}, \overline{V_2} \& \overline{V_0}$. The sampling period T_s is divided into seven segments for the selected vectors. The following can be observed. The dwell time for the seven segments adds up to the sampling periods, $T_s = T_a + T_b + T_0$. The design requirement (a) is satisfied. For instance the transition from [000] to [100] is accomplished by turning S1 ON and S4 OFF, which involves only two switches. The redundant switching state are utilized to reduce the number of switching's per sampling period. For $T_0/4$ segment in the center of the sampling period, the switching state [111] is selected, whereas for the $T_0/4$ segments on both sides, the state [000] is used. Each of the switches in the inverter turns ON and OFF once per sampling period. The switching frequency f_{sw} of the devices are

thus equal to the sampling frequency f_{sp} , ie) $f_{sw} = f_{sp} = 1/T_s$ [18]. The performance parameters of the three phase two level inverter fed induction motor drive are measured and shown in the figure-3.1 to 3.6.

III. LEVEL SHIFTED MULTI-CARRIER CONCEPTS BASED SVPWM

With reference to the figure 2.1 to 2.6 takes the output from the switches 1 to 6 and compare with carrier signals to produce the pulses for each switches presents in the three phase 2-level SVPWM Inverter power circuit. The circuit diagram is shown in figure-4. The performance parameters of the three phase two level inverters are measured and shown in the figure-4.1 to 4.6.

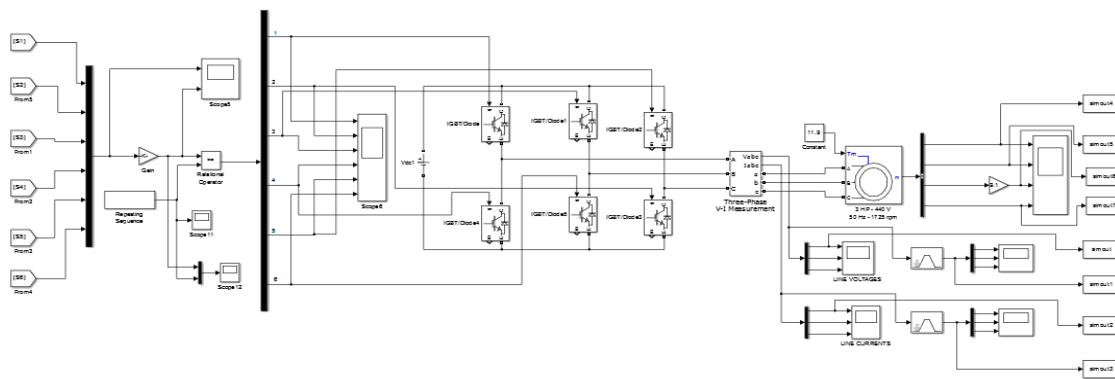


Figure-4 Level shifted multi-carrier concepts based SVPWM

IV. Third Order Harmonic Injection Based Modulated Reference Waveform Generation And Comparison In Svpwm

The Matlab/Simulink diagram for this third order harmonic injection SVPWM fed induction motor drive is shown in figure-11. The main blocks available in the diagram are three phase 50 Hz sinusoidal waveform generator, single phase 150 Hz sinusoidal waveform generator, summer, carrier

waveform generator, comparator, three phase bridge circuit and induction motor drive. The measurement units are connected to measure the various performance parameters of the three phase voltage source inverter fed induction motor drive.

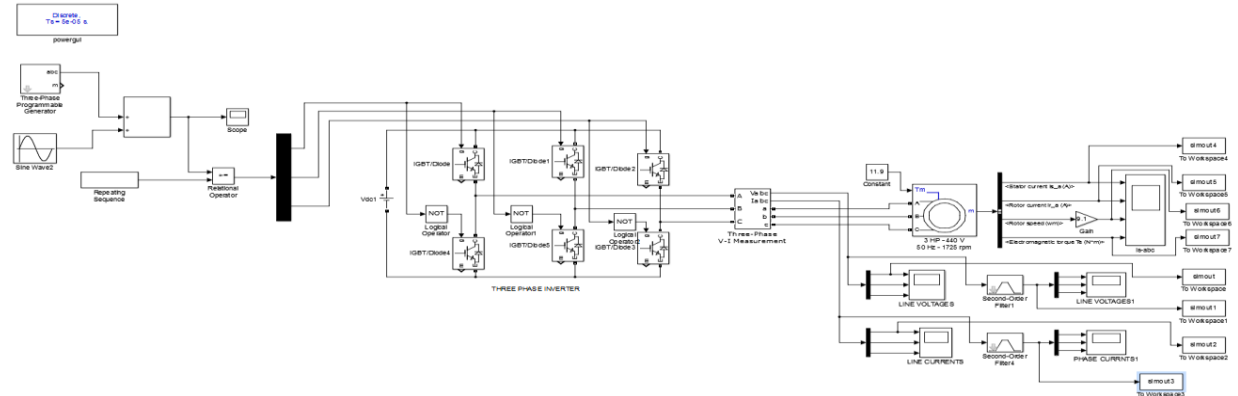


Figure-6. Third order harmonic injection based SVPWM fed induction motor drive

The simulation procedure for the above Matlab/Simulink circuit is given below.

- The first step is to generate three phase 50 Hz sinusoidal waveforms.
- The second step is to generate single phase 150 Hz sinusoidal waveform.
- The third step is add these two waveforms, we get the waveforms like modulated sinusoidal reference waveforms.
- The next step is to compare this modulated reference waveforms with carrier waveform and generate the pulses for that switches presents in the three phase voltage source inverter circuit.
- The simulated waveforms are available in figure-6 that shows the performance characteristics of three phase voltage source inverter fed induction motor drive.

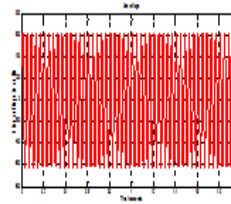


Figure-3.1 Line voltage in volts

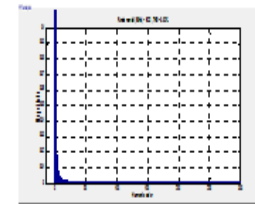


Figure-3.2 Line voltage THD

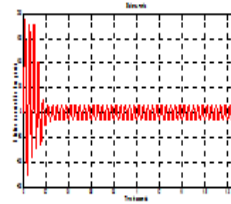


Figure-3.3 Stator current in Amperes

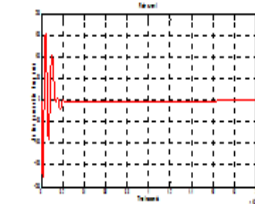


Figure-3.4 Rotor current in Amperes

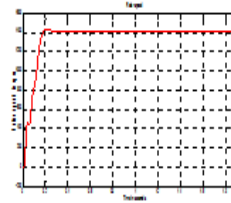


Figure-3.5 Rotor speed in rpm

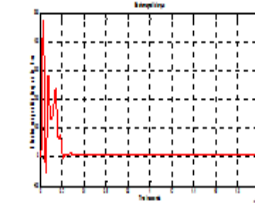


Figure-3.6 Electromagnetic torque in N-m

Figure-3.1 to 3.6 Performance of Three phase 2-level SVPWM Inverter fed induction motor drive

SWITCH	METHOD 1						METHOD 2					
	T0V4	T4V2	T2V0	T0V4	T4V2	T2V0	T0V4	T4V2	T2V0	T0V4	T4V2	T2V0
S1	000	000	000	000	000	000	000	000	000	000	000	000
S2	000	000	000	000	000	000	000	000	000	000	000	000
S3	000	000	000	000	000	000	000	000	000	000	000	000
S4	000	000	000	000	000	000	000	000	000	000	000	000
S5	000	000	000	000	000	000	000	000	000	000	000	000
S6	000	000	000	000	000	000	000	000	000	000	000	000

Figure-2.1 to 2.6 shows seven segments switching sequences for T_{12} in sector 1 to 6.

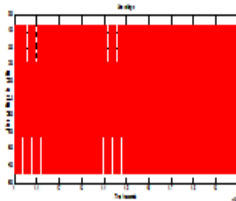


Figure-4.1 Line voltage in volts

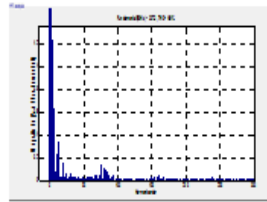


Figure-4.2 Line voltage THD

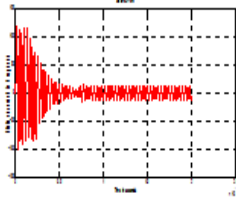


Figure-4.3 Stator current in Amperes

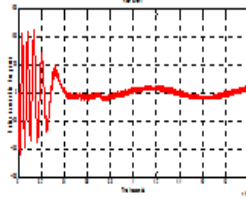


Figure-4.4 Rotor current in Amperes

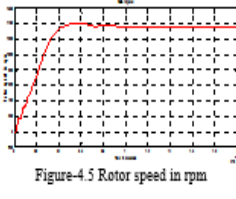


Figure-4.5 Rotor speed in rpm

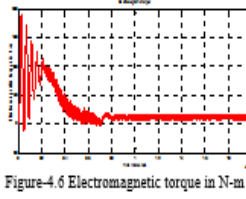


Figure-4.6 Electromagnetic torque in N-m

Figure-4.1 to 4.6 Performance of Three phase 2-level SVPWM Inverter fed induction motor drive

V. CONCLUSION

The SVPWM technique can only be applied to a three-phase inverter and it increases the overall system efficiency. The SVPWM is used for controlling the switching of the machine side converter. Advantages of this method include a higher modulation index, lower switching losses, and less harmonic distortion compared to SPWM. SVPWM research has been widespread in recent years, making it one of the most popular methods for three-phase inverters because it has a higher fundamental voltage output than SPWM for the same DC bus voltage. The SVPWM is significantly better than SPWM by approximately 15.5%. However, the SVPWM technique is complex in implementation, especially in the over-modulation region. SVPWM technique has become the most popular and important PWM technique for three phases VSI for the control of AC induction. This paper has provided a thorough review of the each technique with a special focus on the operation of SVPWM in all the three possible switching schemes. In this paper, Simulink models for all three possible switching schemes has been developed and tested in the MATLAB/SIMULINK environment. This paper discusses the advantages and drawbacks of each switching schemes and their simulation results are compared and analyzed by plotting the output harmonic spectra of various output voltages and computing their total harmonic distortions (THD). As seen from the simulation results the DC bus utilization will be variable for all the three possible switching schemes, but the THD will be varied for every switching sequence. From the simulation results we can come to the conclusion like the methods-II and III switching schemes having high THD when compared to the other method

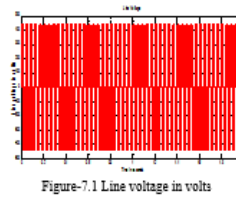


Figure-7.1 Line voltage in volts

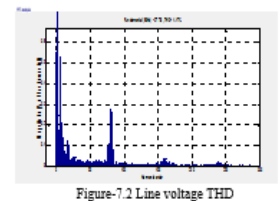


Figure-7.2 Line voltage THD

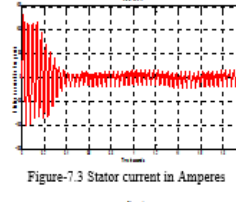


Figure-7.3 Stator current in Amperes

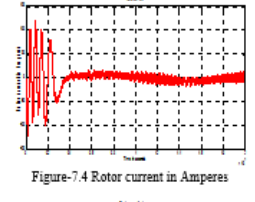


Figure-7.4 Rotor current in Amperes

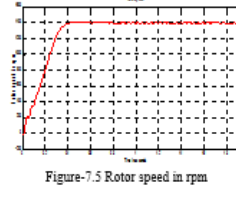


Figure-7.5 Rotor speed in rpm

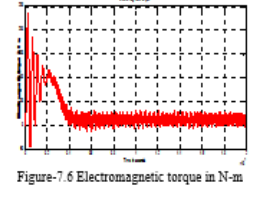


Figure-7.6 Electromagnetic torque in N-m

Figure-7.1 to 7.6 Performance of Three phase 2-level SVPWM Inverter fed induction motor drive

of switching schemes. In the future researches there are some possibilities are available for implementing the same switching schemes in three phase ZSI and TSI. Definitely the performance of ZSI and TSI fed induction motor drive will be varied with respect to its different switching schemes.

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