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Comparative Review of Three PWM Approach On 3-Φ VSI Fed with Induction Motor Drive

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Abstract

Induction motor demand is increasing day by day with increasing demand an essential requirement arises too inefficient motor controlling method. A comparison study of three diverse Pulse width modulation (PWM) techniques of 3-ϕ inverter for better performance of induction motor is presented here using MATLAB/Simulink. Sinusoidal PWM, Third Harmonic injected PWM (THIPWM), Space Vector PWM (SVPWM) techniques simulation is show here, Motor parameter like speed vs time, torque vs time, Output voltage (THD), Output current (THD) of an inverter was observed by changing the carrier frequency and motor drive load. Simulation result shows that SVPWM flaunt better performance comparing other PWM technique.

Keywords: *Pulse Width Modulation (PWM), Sinusoidal PWM (SPWM), Third Harmonic Injected PWM (THIPWM), Space Vector PWM (SVPWM), Total Harmonic Distortion (THD).*

1. Introduction

In industries 3- ϕ induction motor are used due to its less maintenance Cost, high efficiency and their robustness [1]. PWM is most effective method used to change both the voltage (v) and frequency (f) within a 3-ϕ inverter. In 3-ϕ inverter semiconductor switch are used to convert DC input to AC output. When DC input is inverted to AC output it consists of certain amount of harmonic content that can influence the performance metrics of an inverter. The performance of the inverter is influenced by THD across various loading conditions in the motor drive. [1-2]. If the THD is lower at output of the inverter then we get better efficiency, therefore THD plays a vital role in power electronics system. There are so many PWM techniques [2]. Among which Sinusoidal PWM (SPWM) is most popular PWM techniques but SPWM has low fundamental output voltage therefore other PWM techniques such as THIPWM and SVPWM have been developed to enhance performance while minimizing harmonic content. Comparative analysis of several PWM method fed inverter is studied [3]. A comparative study among three PMW technique used in Inverter. Our paper explores three PWM techniques utilized in a 3- ϕ VSI to improve induction motor drive performance. We conducted an investigation by continuously changing the carrier frequency and load to observe rotor speed, speed over time, torque over time, among other factors. Additionally, we examine the percentage of total harmonic distortion (%THD) in both output voltage and current. After simulation we can conclude that SVPWM perform better among other PWM techniques. Figure 1 shows basic model of this 3- ϕ voltage source inverter.

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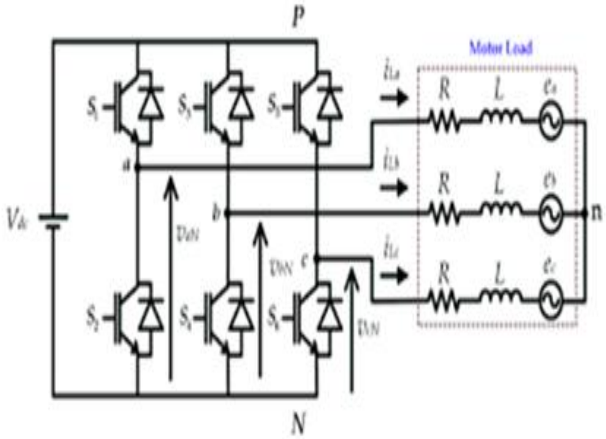

Figure 1 **3-ϕ VSI**

2. PWM Techniques

2.1. Sinusoidal (SPWM) PWM Technique

The SPWM technique utilizes sine waves (V_A, V_B, V_C) as reference signals, each phase shifted by 120 degrees, along with a carrier signal to produce switching signals [3,4]. However, a limitation of this modulation process is...show in Figure 2.

$$V_A = Vm\ sin(\theta);$$
$$V_B = Vm\sin(\theta - 120°)$$
$$V_C = Vm\sin(\theta + 120°)\,;$$

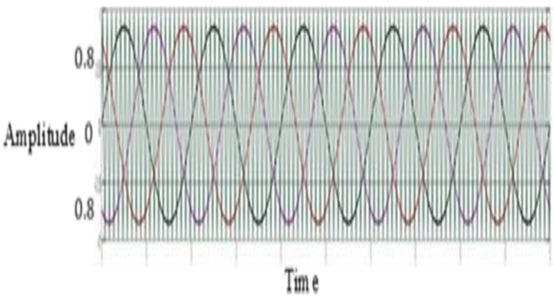

Figure 2 **SPWM Techniques**

2.2. Total Harmonic Injected (THIPWM) PWM Technique

In THIPWM technique, switching signals are produced by superimposing the original reference voltages (Va, Vb, Vc) with a third harmonic signal [3,4,5]. This method effectively eliminates the third harmonic component, resulting in a sinusoidal line-to-neutral voltage in Figure 3.

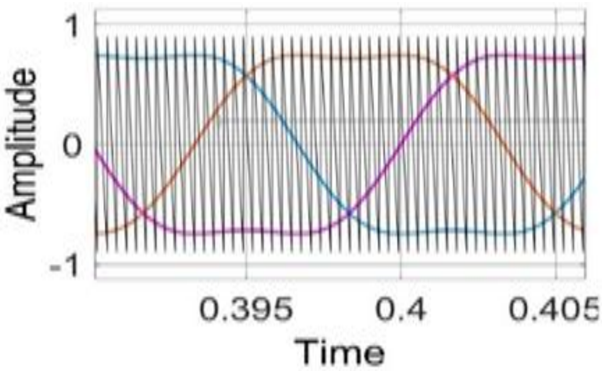

Figure 3 **THIPWM Techniques**

2.3. Space Vector PWM (SVPWM) Technique

Space vector pulse width modulation is a mostly used method in field-based control for Induction motors and permanent -magnet synchronous motors [6-7]. SVM plays a vital role for generating PWM signals to operate the switches of an inverter, after which it generates the appropriate modulated voltage to control the motor at the coveted speed and torque [8-10] in Figure 4.

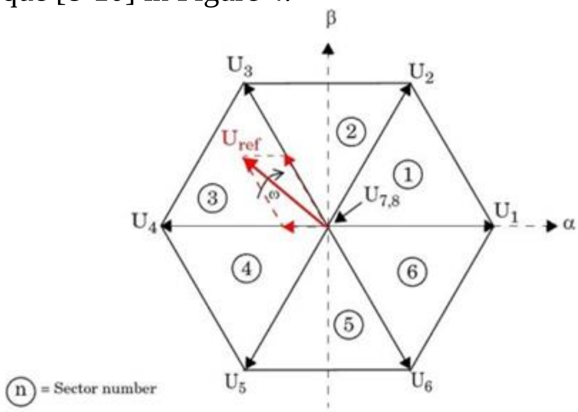

Figure 4 **Space Vector PWM**

2.4. Simulations Analysis

In the simulation, parameters were set as follows: the input DC voltage at 600V, frequency (f) at 50 Hz, carrier frequency (kHz) at 1 kHz, motor power rated at 3000VA. Stator resistance (R) was measured at 2.405 ohms, stator inductance (L) at 0.006893H, rotor resistance (R) at 2.395 ohms, rotor inductance (L) at 0.005839H, and mutual inductance at 0.1822H. These values were applied with a modulation index of 0.86.

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3. Characteristics of Induction Motor Drive Utilizing SPWM Technique

Table 1 Shows Voltage, Current THD and Rotor Speed of SPWM Technique at Varying Carrier Frequency at Tm=49.49Nm, M=0.8

$f_{CARRIER}$ in (Hz)	Output of Inverter THD %		Induction motor execution
	voltage	current	rotor speed (rpm)
10000	84.3	39.49	1390
15000	84.3	37.18	1390
20000	84.3	35.98	1390

Table 1. Shows that when we increase carrier frequency THD value of output current start decreasing significantly from 39.49% to 35.98% at full load but THD value of output voltage and speed of rotor at different carrier frequency remain same.

Table 2 Shows Load And Induction Motor Performance of SPWM Technique at Varying Loading Condition F=20Khz, M=0.86

Load (%)	Induction motor Performance			
	Speed	Torque	stator current	rotor current
NO Load (0%)	1499	0.06637	4.2	0.0309
Quarter Load (25%)	1475	12.25	5.987	3.0694
Half Load (50%)	1450	24.87	9.447	9.564
Full Load (100%)	1390	49.59	18.04	13.41

From Table 2. It shows that when load increase stator current, rotor current also increases and speed decreases.

4. Characteristics of Induction Motor Drive Utilizing THIPWM Technique

Table 3 Shows voltage, current THD and rotor speed of THIPWM technique at varying carrier frequency at Tm=49.49Nm, m=0.86

$f_{CARRIER}$ in (Hz)	Output of Inverter THD %		Induction motor execution
	voltage	current	rotor speed (rpm)
10000	77.6	30.38	1406
15000	77.6	28.98	1406
20000	77.6	24.16	1406

Table 3 Shows that when we increase carrier frequency THD value of output current start decreasing significally from 30.38% to 24.16% at full load but THD value of output voltage and rotor speed at different carrier frequency remain same.

Table 4 Shows Load And Induction Motor Performance of THIPWM Technique at Varying Loading Condition F=20Khz M=0.86

Load (%)	Induction motor performance			
	Speed	Torque	Stator current	Rotor current
No Load (0%)	1500	0.0783	6.54	0.0758
Quarter Load (25%)	1479	12.42	7.93	4.32
Half load (50%)	1457	24.94	8.08	7.54
Full Load (100%)	1406	49.39	20.3	18.42

Table 4 Shows that increasing torque load Tm as we increasing the load stator current, rotor current also increase and speed of motor decrease.

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5. Characteristics of Induction Motor Drive Utilizing SVPWM Technique

Table 5 Shows Voltage, Current THD and Rotor Speed of SVPWM Technique at Variable $f_{carrier}$ at Tm=49.49Nm, M=0.86

$f_{CARRIER}$ in (Hz)	Output of Inverter THD %		Induction motor execution
	Voltage (V)	Current (A)	rotor speed (rpm)
10000	73.29	24.96	1415
15000	73.29	22.01	1415
20000	73.29	20.98	1415

Table 5 Shows that when we increase carrier frequency THD value of output current start decreasing significally from 29.96% to 20.98% at full load but THD value of output voltage and speed of rotor at different carrier frequency remain same.

Table 6 Shows Load And Induction Motor Performance of SVPWM Technique at Varying Loading Condition F=20Khz M=0.86

Load (%)	Induction Motor Performance			
	Speed	Torque	Stator current	Rotor current
No Load (0%)	1501	0.0785	7.4	0.0795
Quarter Load (25%)	1481	12.45	8.43	5.24
Half load (50%)	1460	24.93	9.34	7.42
Full Load (100%)	1415	49.30	18.02	16.23

Table 6 Shows that increasing torque Tm as we increase the load and stator current, rotor current also increases and speed of motor decreases.

6. Overall Comprehensive Evaluation of Induction Motor Drive with Three PWM Methods

Table 7 Shows Comparison of THD Value a Voltage and Current Between Three PWM Techniques at M=0.86 F=20Khz at Full Load

Different PWM techniques	Inverter	THD %
SPWM	voltage	84.3
	current	35.98
THIPWM	voltage	77.6
	current	24.16
SVPWM	voltage	73.29
	current	20.98

Table 7 Shows the SVPWM gives finest output at full load compare to other PWM techniques (i.e. SPWM and THIPWM). SVPWM shows the lowest THD value for voltage 73.29% and lowest THD value for current 20.98% at full load.

Table 8 In This Table We Have Discuss About the Speed and Torque of the Different PWM Techniques at F=20khz at M=0.86 At Full Load

Different PWM techniques	Induction motor performance	
	Speed (RPM)	Torque (Nm)
SPWM	1390	49.49
THIPWM	1406	49.39
SVPWM	1415	49.30

In this Table 8 We have obtained speed and torque of different PWM techniques (i.e. SPWM, THIPWM, SVPWM) at full load condition and we can see that the speed is increasing but as we move from SPWM to SVPWM the torque start decreasing because as we know torque is inversely proportional to speed and we can see the speed of SVPWM among all the other PWM technique is better [11-12].

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7. Comparison of Speed vs Time of three PWM techniques at variable load

At different loading condition the speed varies from full load to no load of different PWM techniques (i.e. SPWM, THIPWM, SVPWM) at carrier frequency f=20khz at modulation index of m=0.86 and green circle shows the variation of speed of different PWM techniques at speed from 0 to 800

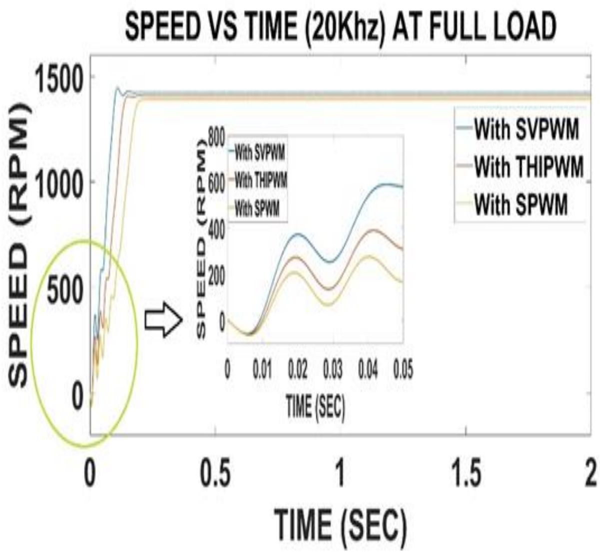

Figure 5 Speed Vs Time for SPWM, THIPWM, SVPWM at F=20Khz M=0.86 At Full Load

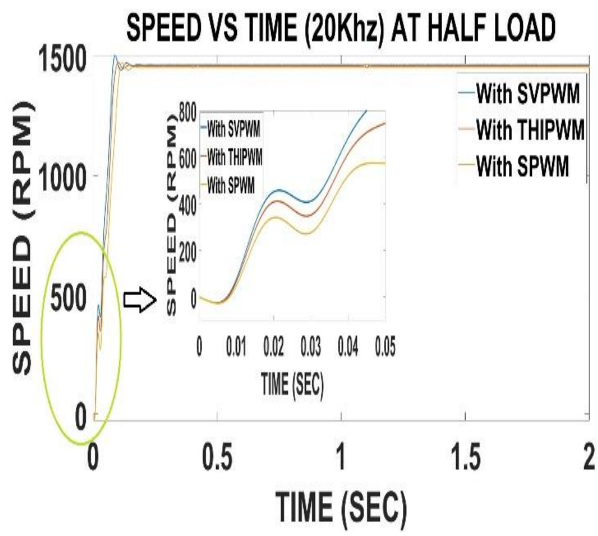

Figure 6 Speed Vs Time for SPWM, THIPWM, SVPWM at F=20 KHz M=0.86 at Half Load

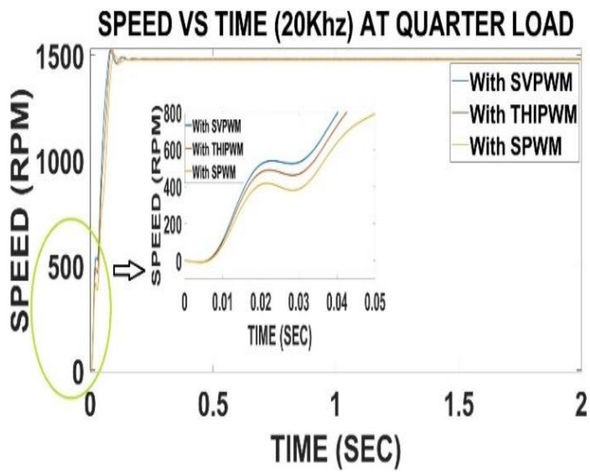

Figure 7 Speed Vs Time for SPWM, THIPWM, SVPWM at F=20Khz M =0.86 at Quarter Load

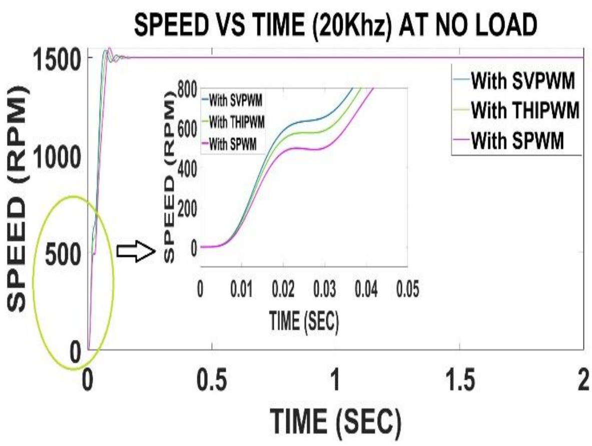

Figure 8 Speed Vs Time for SPWM, THIPWM, SVPWM at F=20Khz M=0.86 at no Load

From Figure 5-8. It can be seen that at speed vs time of different PWM techniques (i.e. SPWM, THIPWM, SVPWM) at different loading the speed varies from full load to no load at 20Khz carrier frequency at 0.86 modulation index and among other PWM SVPWM show better speed at different loading condition.

8. Comparison of Torque Vs Time of Three PWM Techniques at Variable Load

At different loading condition the Torque varies from full load to no load of different PWM techniques [13] (i.e. SPWM, THIPWM, SVPWM) at carrier frequency f=20khz at modulation index of m=0.86 and green circle shows the variation of

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torque of different PWM techniques at torque from 0 to 100.

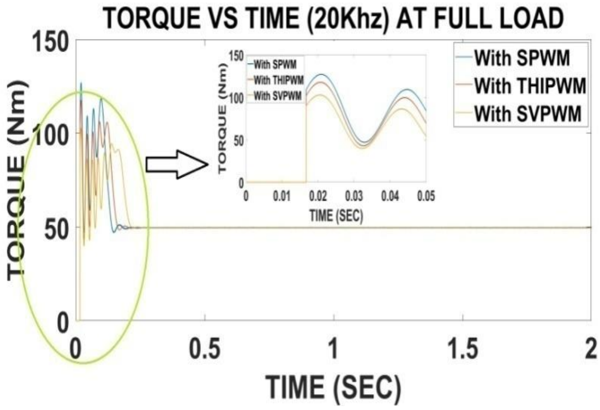

Figure 9 Torque Vs Time for SPWM, THIPWM, SVPWM at F=20khz, M=0.86 at Full Load

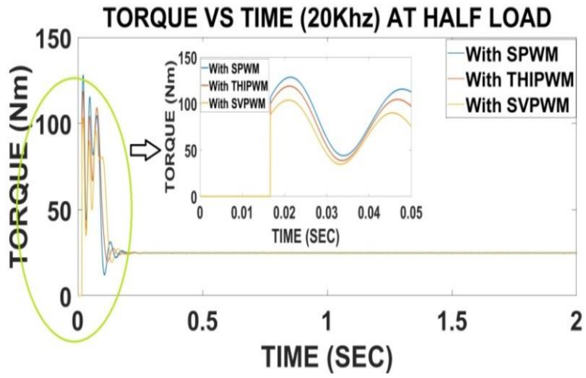

Figure 10 Torque Vs Time for SPWM, THIPWM, SVPWM at F=20Khz, M=0.86 at Half Load

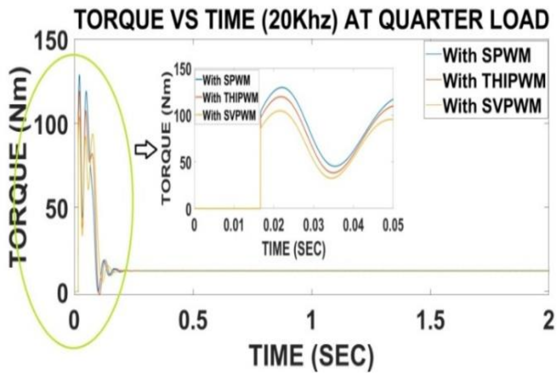

Figure11 Torque Vs Time for SPWM, THIPWM, SVPWM at F=20khz, M=0.86 at Quarter Load

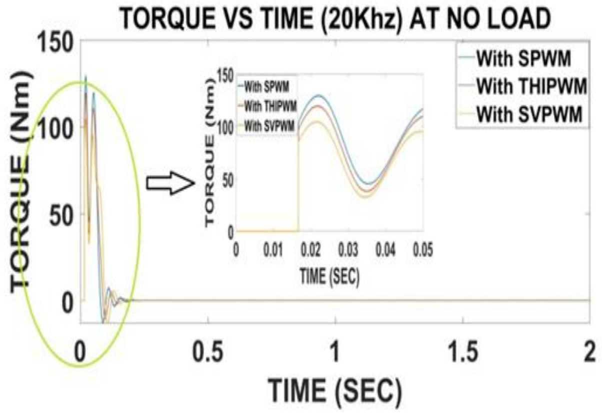

Figure12 Torque Vs Time for SPWM, THIPWM, SVPWM at F=20Khz, M=0.86 at no Load

From Figure.9-12. It can be seen that at torque vs time of different PWM techniques (i.e. SPWM, THIPWM, SVPWM) at different loading condition. The torque varies from full load to no load at 20Khz carrier frequency at 0.86 modulation index. Here SPWM has more torque as compared to other PWM techniques as we know torque is inversely proportional to speed and on above Fig, we have seen that SVPWM has highest speed so torque of SVPWM is less [14-15].

Conclusion

This paper presents a relative evaluation of three PWM techniques implemented in MATLAB/Simulink for driving induction motors. The performance evaluation is based on parameters such as speed versus time, torque versus time, output current total harmonic distortion (THD) percentage, and output voltage THD percentage of the inverter. Upon examining the results, it is evident that SVPWM exhibits superior performance compared to the other PWM techniques. SVPWM demonstrates the lowest inverter output THD value. Furthermore, increasing the carrier frequency reduces total harmonic distortion from the inverter, resulting in higher rotor speeds with reduced distortion. Therefore, based on our findings, we recommend employing SVPWM technique with higher carrier frequencies for improved induction motor drive performance.

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