# Comparison of SPWM VSI and SVPWM VSI FED Induction Machine Using Volt per Hertz Control Scheme

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***Abstract- In this paper, open loop V/f control of IM with sinusoidal pulse width modulation (SPWM) and space vector pulse width modulation (SVPWM) techniques are simulated using Matlab/Simulink. The recent advances in power electronics and semiconductor technology has lead to increased use of variable frequency variable voltage induction motor drives in various industrial applications. The Variable Voltage Variable Frequency (VVVF) supply to ac drives is obtained from 3 phase voltage source inverter (VSI). The performance of induction motor using SPWM VSI and SVPWM VSI is compared for %THD and fundamental of line voltage and motor speed.***

***Keywords: IM, %THD, VVVF, SPWM, SVPWM***

## 1. INTRODUCTION

In last few decades, the control of induction motor (IM) is continuously improved and IM is now being used as one of the most popular variable speed ac drive. New techniques of static frequency conversion have evolved IM as variable speed motor. Along with adjustable frequency operation a suitable control technique is required. The constant V/f control is the most used scalar control method and is based on steady state equivalent circuit of IM. It is commonly used for open loop speed control with low dynamic requirement.

In order to provide variable frequency variable voltage (VVVF) supply to IM for variable speed application, inverter is used. Basically there are two types of inverters: voltage source inverter (VSI) and current source inverter (CSI). VSI employs a dc link capacitor and dc source at its input has small or negligible impedance. CSI employs dc link inductance and is fed with adjustable current from a dc source of high impedance. VSI provides a switched voltage waveform and CSI provides a switched current waveform [6].

A VSI with constant V/f control is commonly used for adjustable speed ac drives especially for applications where position control is not required [1]. VSI can be operated as a stepped wave inverter or a pulse width modulated (PWM) inverter. When inverter is operated as PWM inverter, harmonics are reduced, associated losses are reduced, low frequency harmonics are almost

eliminated and smooth motion is obtained at low speeds also. So, a suitable PWM technique is employed to get the required frequency and voltage in the line side of the inverter. The basic principle of PWM technique is to compare a high frequency ($f_s$) triangular carrier signal to a low frequency ($f_m$) modulating signal. In sinusoidal pulse width modulation (SPWM), triangular carrier wave is compared with a sine wave. The output frequency of converter is equal to the frequency of modulating sine wave [2]. Space vector pulse width modulation (SVPWM) technique was basically achieved by introducing vector approach to PWM technique. SVPWM is based on vector selection in d-q stationary reference frame [3].

## 2. MODULATION TECHNIQUES

### *2.1 SINUSOIDAL PULSE WIDTH MODULATION (SPWM)*

In SPWM, sine wave is compared with triangular wave. The switching points are obtained by intersection of the triangular carrier wave of frequency $f_c$ and the reference modulating sine wave of frequency $f_m$. The output voltage and frequency depends on magnitude and frequency of sine wave. The output voltage is proportional to the magnitude of sine wave and output frequency is equal to sine wave frequency, $f_m$. The ratio of amplitude of modulating sine wave, $A_m$ to amplitude of triangular carrier wave, Ac is called modulation index [6].

$$\text{Modulation Index, } m = \frac{Am}{Ac}$$

Modulation index, m should be kept less than 1. For m greater than 1, pulse width is no longer sinusoidal function of angular position of pulse and hence lower order harmonics appear in output waveforms [6]. By controlling the modulation index the amplitude of applied output voltage and %THD can be controlled [4].

### *2.2 SPACE VECTOR PULSE WIDTH MODULATION (SVPWM)*

SVPWM is different from and better than SPWM. SVPWM generate PWM load line voltages that are in average equal to reference load line voltage [3]. The realization of SVPWM is based on proper selection of switching states of inverter, calculation of appropriate switching time periods and space vector transformation [3]. SVPWM is very beneficial in many respects like it reduces switching losses by preventing unnecessary switching and output capability of inverter increases [5].

SVPWM provides a more efficient use of the supply voltage than SPWM method. Also, SVPWM reduces harmonic content in the output voltage waveforms [2,3,5]. The harmonic content present in the output of inverter determine the copper losses of machine and copper losses consists major

portion of machine losses. Lower %THD more the voltage is close to sine wave. In [2,3] SVPWM is presented to be best among all PWM techniques for variable frequency ac drive.

## 3. SIMULATION OF 3 PHASE SWPM VSI & SVPWM VSI FOR OPEN LOOP V/F CONTROLLED IM

Simulink model of open loop V/f control of IM with two different modulation techniques i.e. SPWM and SVPWM are developed and are given in figure 1 and 2 below.

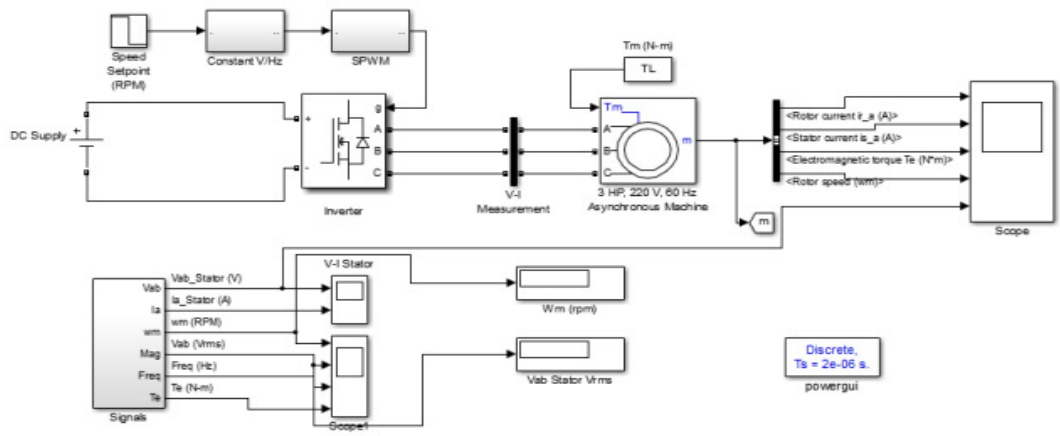


**Figure 1. Simulink model of Open loop V/f controlled IM with SPWM VSI**

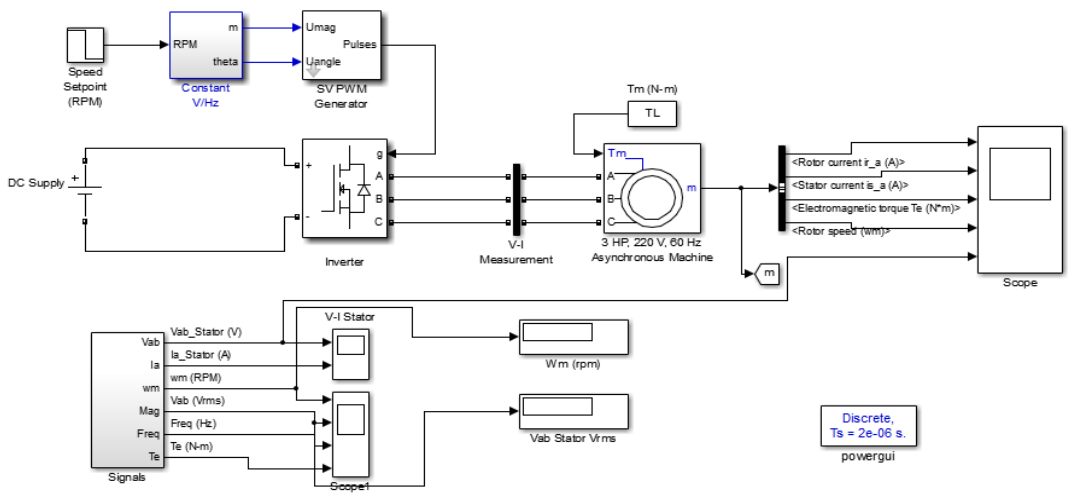


**Figure 2. Simulink model of Open loop V/f controlled IM with SVPWM VSI**

The %THD and fundamental line voltage for two modulation techniques are compared at different value of modulation index, keeping all other parameters constant. Also the speed response of motor for both SPWM AND SVPWM are compared for modulation index, m=0.8.

## 4. SIMULATION RESULTS AND ANALYSIS

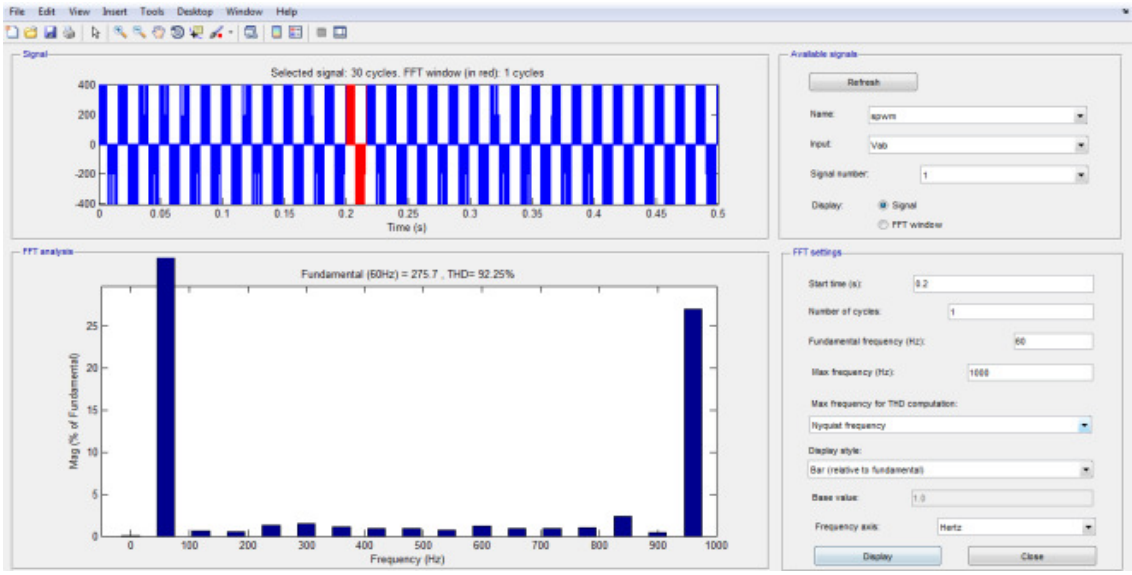


**Figure 3. FFT analysis with %THD and fundamental of line voltage for SPWM at modulation index=0.8**

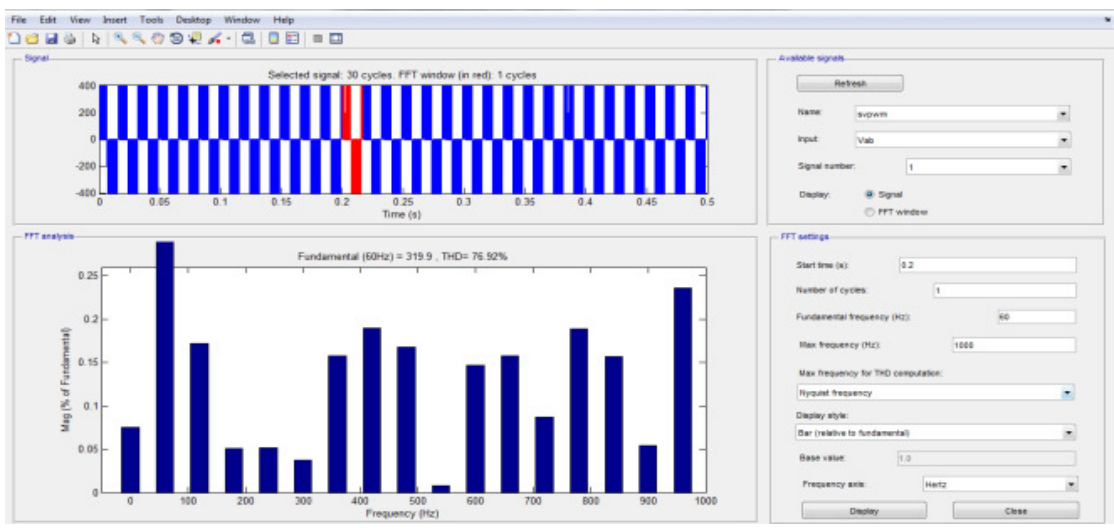


**Figure 4. FFT analysis with %THD and fundamental of line voltage for SVPWM modulation index=0.8**

### *4.1 DECREASE IN %THD WITH INCREASING MODULATION INDEX*

**Table 1. Modulation index vs. %THD for SPWM and SVPWM**

| Modulation Index | SPWM | SVPWM |
|---|---|---|
| 0.2 | 265.85 | 231.32 |
| 0.4 | 161.60 | 147.79 |
| 0.6 | 122.23 | 105.92 |
| 0.8 | 92.25 | 76.92 |
| 1 | 68.43 | 52.33 |

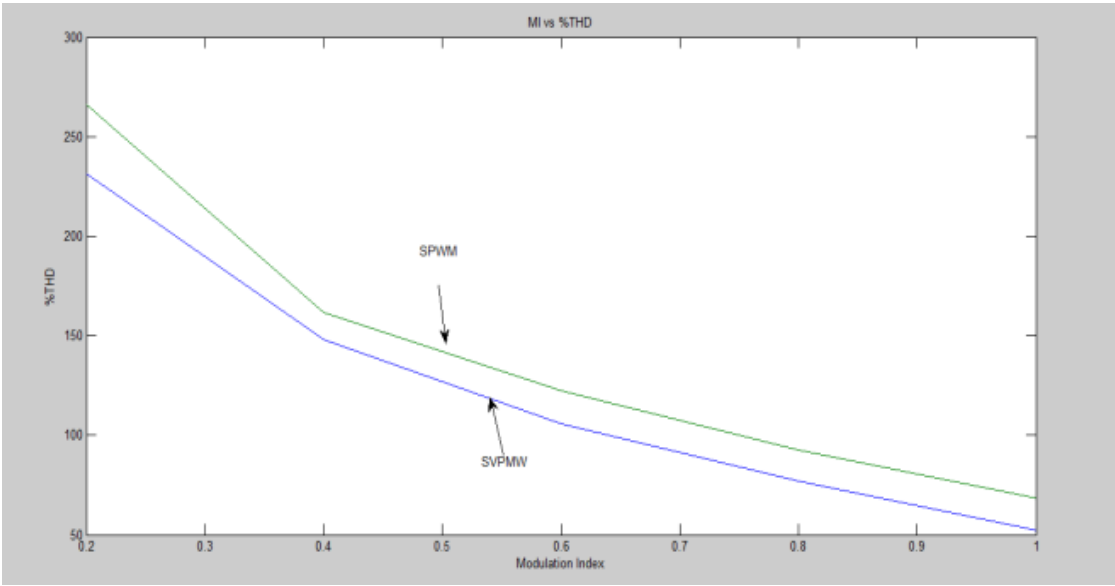


**Figure 5. Modulation index vs. %THD**

### *4.2 INCREASE IN FUNDAMENTAL PHASE-TO-PHASE VOLTAGE WITH INCREASING MODULATION INDEX*

**Table 2. Modulation index vs. fundamental line voltage for SPWM and SVPWM**

| Modulation Index | SPWM | SVPWM |
|---|---|---|
| 0.2 | 65.32 | 80.28 |
| 0.4 | 141 | 159.70 |
| 0.6 | 203.80 | 240.10 |
| 0.8 | 275.70 | 319.90 |
| 1 | 346.80 | 399.90 |

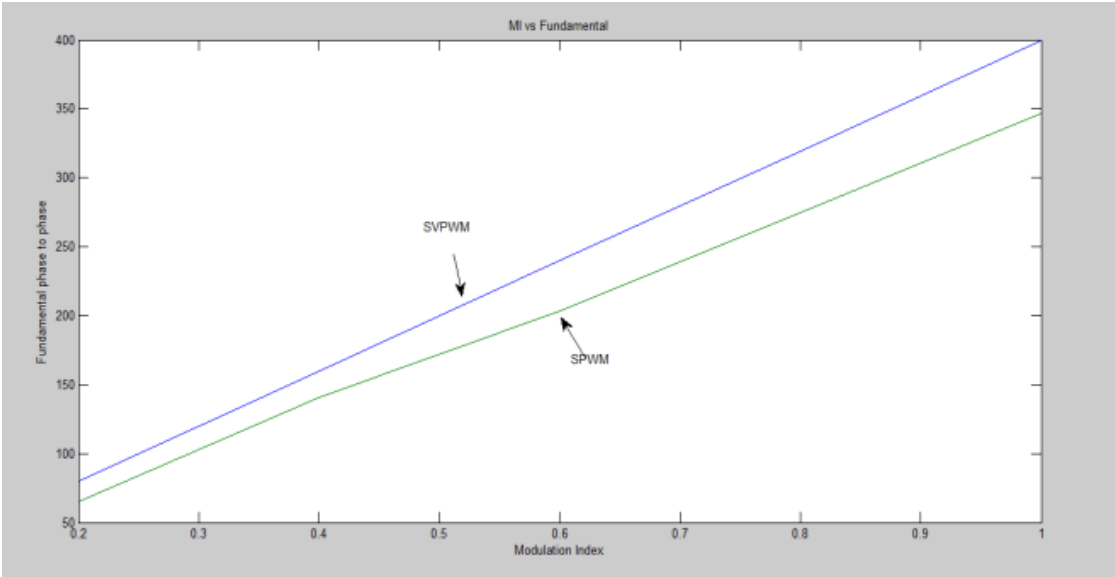


**Figure 6. Modulation index vs. fundamental line voltage**

From above tables 1 & 2 and graphs shown in figure 5 and 6, it is observed that SVPWM produce less harmonic distortion in output voltage and fundamental line voltage is comparatively higher. Also by increasing modulation index we can minimize % THD of line voltage.

### *4.3 SPEED RESPONSE OF IM WITH SPWM VSI AND SVPWM VSI*

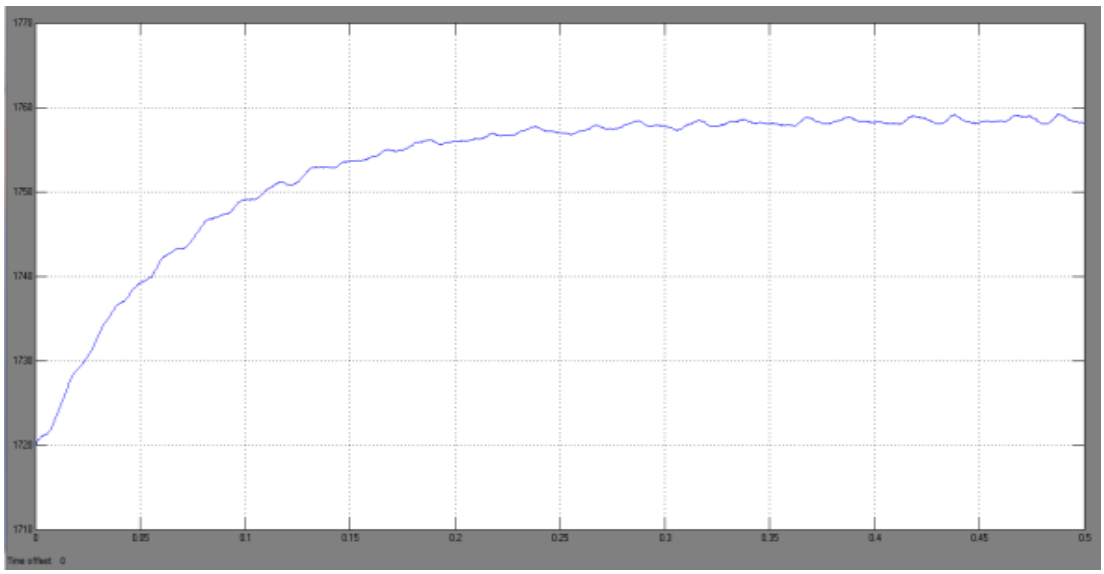

**Figure 7. Speed vs. Time for SPWM at modulation index=0.8, Reference speed= 1800 rpm**

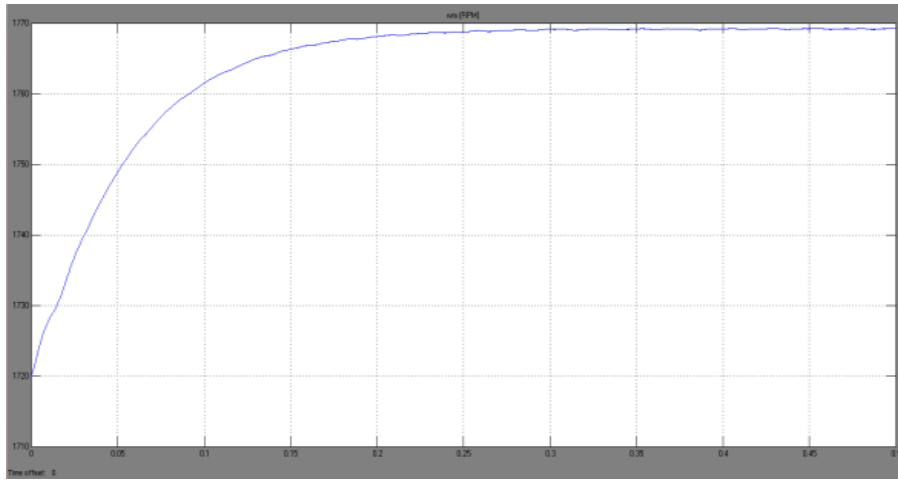

**Figure 8. Speed vs. Time for SVPWM at modulation index=0.8, Reference speed= 1800 rpm**

The speed response of motor is improved when SVPWM technique is used which is shown in figure 7 and 8. Settling time and pulsation in speed curve are reduced and speed regulation is improved with SVPWM. The increase in modulation index also improves the speed response of IM.

## 5. CONCLUSIONS

Open loop V/f control of IM drive with SPWM VSI and SVPWM VSI are compared. It is observed that SVPWM method gives higher performance than SPWM method in terms of THD, fundamental line voltage and speed response. And the performance can be further improved by varying modulation index from low to high value.

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