Operation of Induction Motor with Different Modulation Index

Saurabh Pande[1], Saket Singh[2]

[1]*Assistant Professor, Dept. of Elec. Engineering,D.M.I.E.T.R college,Wardha*
[2]*Assistant Professor, Dept. of Elec. Engineering,Priyadarshini college,Wardha*

---***---

Abstract - *Three phase voltage source Inverter supplies variable voltage and variable frequency for controlling modern ac drives. This is achieved with various Pulse width modulation techniques. Sinusoidal Pulse Width Modulation is carrier signal based techniques most widely used. Wide range of speed, Torque, Flux control is possible with these techniques. These PWM techniques are easier to implement. This paper deals with the Analysis of Induction Motor parameters by considering under, moderate and over modulation Index, where Current, Speed and Electromagnetic Torque are parameters of comparison. Induction Motors are supplied by the Inverters having SPWM based control techniques and is implemented in the MATLAB Simulation. Results obtained are compared by taking different Modulation index.*

Key Words: **Induction Motor, SPWM, Modulation Index.**

1.INTRODUCTION

To control Induction motor drives, Pulse width modulation inverters are very popular. The energy, which is delivered by the PWM inverter to the IM motor, is controlled by PWM signals of different amplitude along with durations, applied to the gates of the power switches of Inverter to produce the desired output voltage waveform. Using Voltage Source Inverter it is possible to control both frequency and magnitude of the voltage and current applied to Induction motor drive. As a result, PWM inverter-fed IM drives are more reliable and offer a wide speed range along with for smooth starting. Also it gives better efficiency and higher performance when compared to fixed frequency operation. A number of Pulse width modulation (PWM) schemes are available to obtain variable voltage and frequency from an Inverter. Sinusoidal pulse width modulation technique is one of such techniques widely used for such purposes. This paper deals with the variation of Induction motor parameters like current, speed and Electromagnetic Torque by using Sinusoidal pulse width modulation technique. Simulation is made in the MATLAB Environment and results obtained are compared by providing the gate pulses to switches of voltage source inverter with different modulation index.

2. METHODOLOGY

The circuit model of a typical three-phase voltage source bridge inverter is shown in Figure.1 below, S1 to S6 are the six power switches that shape the output, which are controlled by the switching variables a, a', b, b', c and c'.The switching variables are obtained from SPWM technique with under ,moderate and over modulation index and simulation is made in the MATLAB Environment.

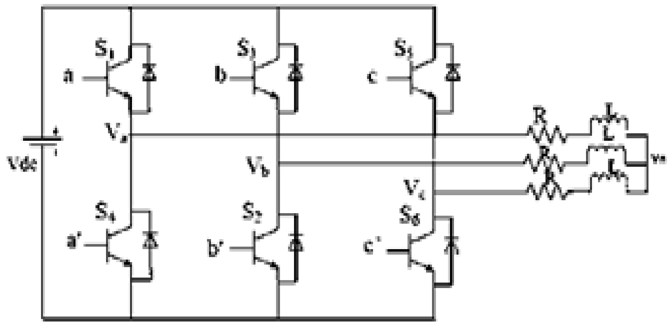

Fig -1: Three Phase Inverter Bridge

2.1 SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

Control pulses required for switching the inverter are derived using Pulse width Modulation technique that generates the required control signals required by the inverter switches by comparing a "reference sinusoidal signal having amplitude (A_m) with a "carrier wave signal (A_c) as shown in Figure 2.0.Both signals are compared in the comparator and whenever $A_m > A_c$ at the intersection of the both signals correspondingly the control pulses are generated at the output of comparator. With proper phase sequences required inverter switches are made on. The ratio of the "sinusoidal reference signal (A_m) of frequency (f_r)" to that of a "triangular carrier wave signal(A_c) of frequency (f_c)" *so called* Amplitude modulation index (M_a)" and "Frequency modulation index (M_f)" i.e.:-

$$M_a = \frac{(A_m).}{(A_c)} \qquad (1)$$

And

$$M_f = \frac{f_r}{f_{cr}} \qquad (2)$$

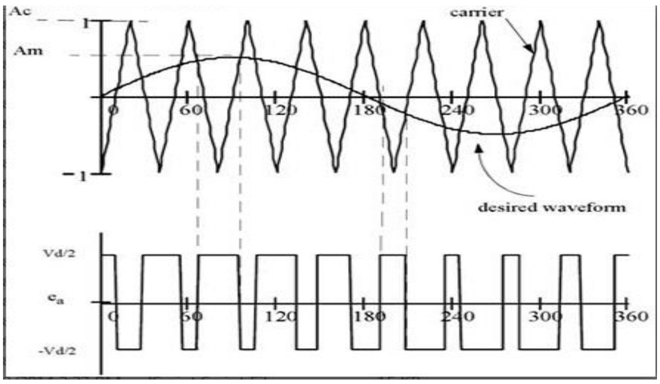

Fig -2: Control signal using SPWM

The RMS output voltage can be varied by varying the "modulation index (M_a)". With SPWM output voltage varies linearly with the modulation index along with the harmonics with well defined frequencies and amplituide.The output voltage is restricted to 50% at this mode and higher output voltages are obtained by over modulating mode i.e $M_a > 1$ but lower order harmonics appear at the output voltage is the limitation of this mode. The important key points while using SPWM Technique are:-

1. The amplitude of reference sinusoidal signal is less than or equal to the amplitude of triangular carrier signal. So instantaneous amplitude of required modulating signal never exceeding the amplitude of the carrier signal.

2. The modulating signal having comparatively lower frequency i.e. in the range of frequency of 50 Hz which is quite lower than the frequency of carrier signal which is in the order of 1-6 KHz so magnitude of modulating signal remains same throughout the instant.

3. A three phase SPWM inverter requires balanced set of three sinusoidal modulating signals along with high frequency carrier signal.

The RMS value of output Voltage is given as,

$$V_o = V_s\left(\sum_{m=1}^{2p} \frac{\delta m}{\pi}\right)^{1/2} \quad (3)$$

The "harmonic profile(f_h)" of a sine triangle inverter's output voltage can be described as:

$$f_h = (j m_{f+\_} k) f_h \quad (4)$$

For a sine triangle inverter, the lowest harmonic present in the output voltage is shifted to the inverter switching frequency. The harmonics in the inverter output voltage waveform appear at sidebands of the switching frequencies and its multiples i.e., around m*f*, 2m*f*, 3m*f* and so on. Thus, the harmonics for a sine triangle inverter are shifted to higher frequencies which are easy to filter and also their effect due to high frequency is not dominant in the torque pulsations.

3. SIMULATION

The simulation of Induction motor has been developed in MATLAB Environment. The specifications & rating of Induction motor considered for the analysis have been reported in Table 1. Analysis of Induction motor is carried out using SPWM technique with three different modulation index i.e. under, moderate and over modulation index and parameters like speed, current and Electromagnetic torque are compared amongst each other. The harmonics in the output voltage appears as side bands of the switching frequency and its multiples in a PWM inverter. Therefore a high switching frequency results in an essentially sinusoidal current (plus a superimposed small ripple at a high frequency) in the motor.

Case: 1 Under- Modulation index

With the following induction motor parameters simulation of motor is made in the MATLAB Environment and all the parameters with undermodulation index are shown in figure 3.1. The carrier signal having frequency of 1Kz.The modulation index is having 0.71 value and following are the results observed. The current waveform reaches 105A at 0.01 sec and shows oscillatory response till 0.3sec and then settles down to steady state value with settling time of 0.32sec.The speed waveform shows oscillatory response till 0.06 sec and settles to 1440 rpm with settling time of 0.32sec.The torque waveform achieves maximum peak value of 170N-m at 0.01 sec and shows oscillatory response till 0.15 sec. It settles down to steady state value with settling time of 0.32 seconds.

Case: 2 Moderate- Modulation index

With the Moderate value of Modulation index i.e 0.85 the simulation of Motor with same rating is made and the parameters are shown in figure 3.2.The modulation index is having 0.85 value. The current waveform rises to 130 A at 0.01 sec and oscillates till 0.2sec and then settles down to the steady state value with the settling time of 0.215 sec.The speed waveform having oscillations till 0.05sec and then settles to 1460 rpm with settling time of 0.215 sec. The Electromagnetic torque attains maximum peak value of 250 N-m at 0.015 sec and oscillates till 0.1sec and settles to steady state value with settling time of 0.215 sec.

Case: 3 Over-Modulation Index

With over Modulation index the simulation of Motor with same rating is made and the parameters are shown in figure 3.3.The modulation index is having 1.2 value. The current waveform rises to 175 A at 0.01 sec and oscillates till 0.13 sec and then settles down to the steady state value with the settling time of 0.135 sec..The speed waveform having oscillations till 0.05sec and then settles to 1480 rpm with settling time of 0.13 sec. The Electromagnetic torque attains maximum peak value of 250 N-m at 0.015 sec and oscillates till 0.1sec and settles to steady state value with settling time of 0.215 sec. The FFT Analysis of the current waveform is carried out for steady state period for all the three cases and following results were the observations .With under-modulation index within the steady state value of current for five cycles the THD is found to be 4.35%, with moderate Modulation index value the THD is found to be 6.49% and with over Modulation index the THD is 12.67%. All the above result is as shown in figures 3.4, 3.5 & 3.6.

Table -1: Induction Motor Parameters:-

Parameters	Rating	Parameters	Rating
Input Capacity	5 KW,	Friction Factor	0.0001 N.m.s
Supply voltage	415 V	Current	7.5 A
Frequency	50 Hz	Power factor	0.85
Poles	4	Stator resistance	0.435 ohms
Stator Reactance	0.0022 ohms	Rotor resistance	0.816 ohms
Rotor Reactance	0.0022 ohms	Mutual Reactance	0.069 ohms
Inertia	0.089 kg.m^2	Torque	25 N-m

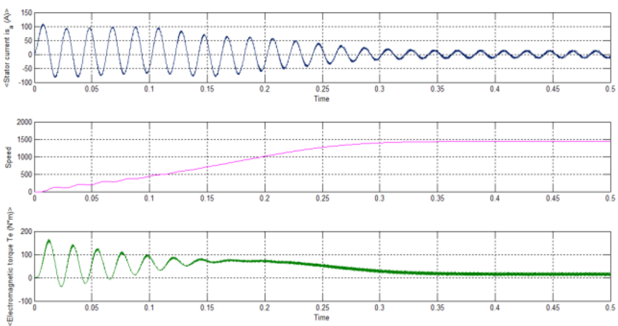

Fig -3.1: Waveforms with under-modulation index

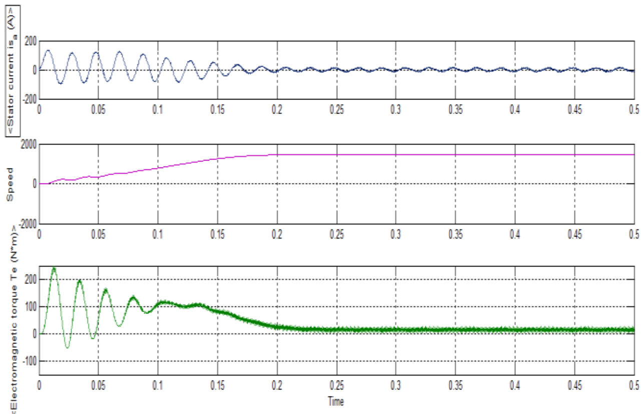

Fig -3.2: Waveforms with moderate-modulation index

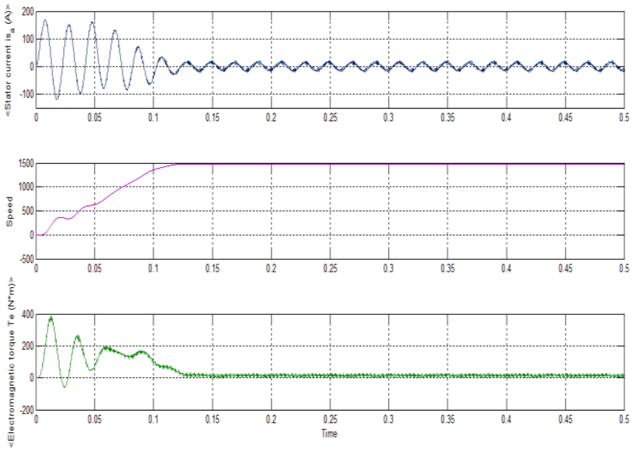

Fig -3.3: Waveforms with over-modulation index

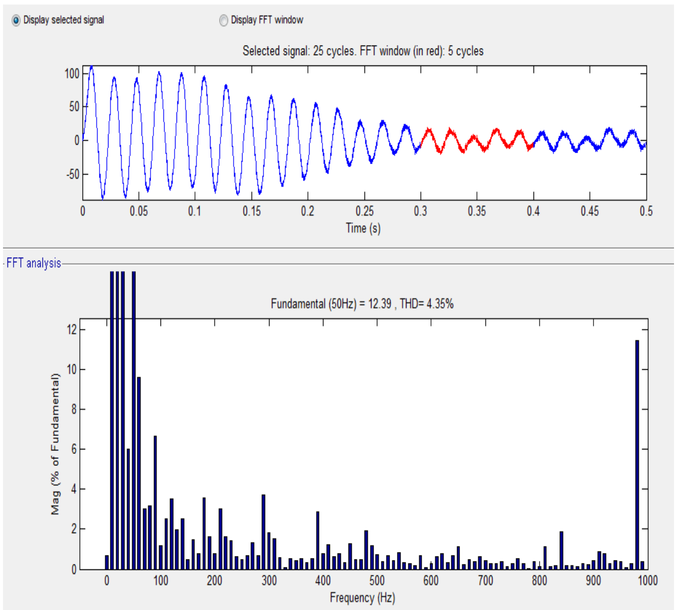

Fig -3.4: FFT Analysis with under-modulation index

-

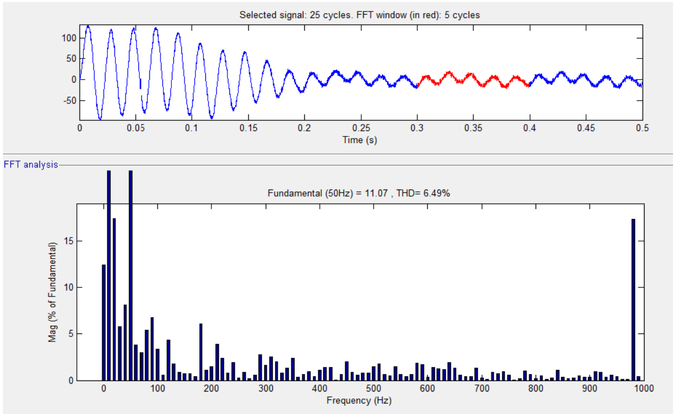

Fig -3.5: FFT Analysis with moderate-modulation index

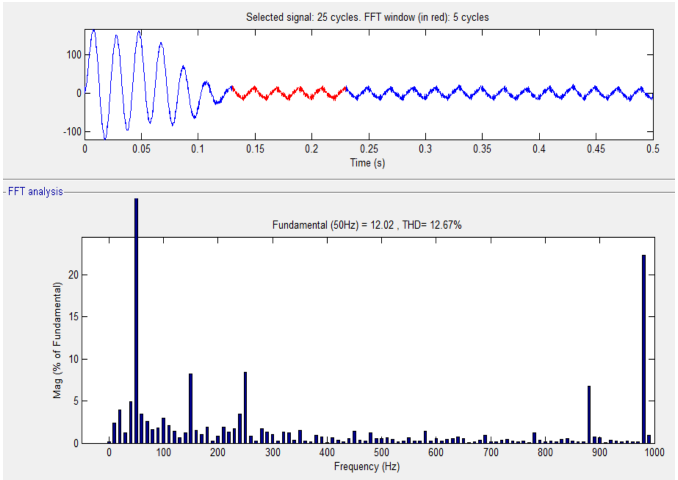

Fig -3.6: FFT Analysis with over-modulation index

4. COMPARISON OF RESULTS & CONCLUSION:-

Here simulation and analysis of SPWM inverter fed Induction motor drive is carried out. With simulation result the parameters like stator current, speed and torque is analysed by varying modulation index than percentage THD present in the phase current is calculated through FFT analysis. The main aim of this paper is to check the performance of Induction Motor with different modulation index. Variation in parameters like Current, speed and Electromagnetic torque are shown in the waveforms and percentage THD is also calculated for current waveforms. The variations in modulation index also affect the speed of induction motor drive. The % THD increases with the increase in modulation index though there is reduction in settling time duration it will not create any problem in small drive system but such distortion and harmonics in parameters will be harmful for the Medium and large power drives. So Modulation Index (0<M<1) should be selected for proper functioning of Drive system. The overall summary is reported in Table 2.

Table -2: Over Summary:-

Modulation Index	0.71	0.85	1.2
% THD(Current)	4.35	6.49	12.67
Modulation Index 0.71			
Parameters	Settling Time (sec)		
Speed	0.32		
Electromagnetic Torque	0.32		
Current	0.32		
Modulation Index 0.85			
Parameters	Settling Time		
Speed	0.215		
Electromagnetic Torque	0.215		
Current	0.215		
Modulation Index 1.2			
Parameters	Settling time		
Speed	0.13		
Electromagnetic Torque	0.13		
Current	0.13		

5. FUTURE SCOPE

Thus same analysis can also be carried out with different PWM based switching Technique.

ACKNOWLEDGEMENT
The authors can acknowledge any person/authorities in this section. This is not mandatory.

REFERENCES

[1] Stanislav Rusnok, Pavel Sobota, Martin Slivka, Pavel Svoboda, "Assessment Transients During Starting of Induction Motor in Matlab-Simulink And Verification by Measurement", Advanced Research in Scientific Areas December 2012, SECTION11. Electronics,

Electrical Systems, Electrical Engineering 3-7-2012 P.P 1672-76

[2] Fan Lin, Kun Li and Yang Liu,"A Design and Implementation of Edge Controller for SPWM Waves",Proceeding of the IEEE International Conference on Information and Automation Shenzhen, China June 2011.

[3] Pankaj H Zope, Pravin G.Bhangale, Prashant Sonare ,S. R.Suralkar "Design and Implementation of carrier based Sinusoidal PWM Inverter." International journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol. 1, Issue 4, October 2012

[4] "Control of VSI using spwm strategy for adjustable speed motors." 14th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2010, Mediterranean Cruise, 11-18 September 2010.

[5] "Modeling and Simulation of Modified Sine PWM VSI Fed Induction Motor Drive."International journal of Electrical Engineering & Technology , Volume 3, Issue 2, July – September 2012.

[6] Satean Tunyasrirut, Sompong Srilad and Tianchai Suksri," Comparison Power Quality of the Voltage Source Inverter type SVPWM and SPWM Technique for Induction motor Drive SICE Annual Conference 2008 Volume No. 1,Issue No. 08, August 20-22, 2008, ,241-246,PR0001/08/0000-0241 ¥400 © 2008 SICE

[7] Stanislav Rusnok, Pavel Sobota, Martin Slivka, Pavel Svoboda, "Assessment Transients During Starting of Induction Motor in Matlab-Simulink And Verification by Measurement", Advanced Research in Scientific Areas December 2012, SECTION11. Electronics, Electrical Systems, Electrical Engineering 3-7-2012 P.P 1672-76.

[8] V.Subrahmanyam,"Electric Drives,Concepts and Application",Fourteen Edition 2004,Tata.Mcgraw-Hill,pp 510-525.