

Analysis & Validation of Speed Control of Three Phase Induction Motor using Two Level Inverter & MATLAB based SPWM Technique

Mr. Ankur P. Desai¹ Dr. Rakesh J. Motiyani²

¹Assistant Professor ²Associate Professor & Head of Department

^{1,2}Department of Electrical Engineering

^{1,2}GIDC Degree Engineering College, Navsari, Gujarat, India

Abstract— This paper presents the theoretical and practical aspects of implementation of Sinusoidal Pulse Width Modulation (SPWM) in controlling the speed of three induction motor. SPWM is implemented by using 32 bit ARM Cortex Microcontroller Discovery Board (STM32F4072F407XX MCU). The algorithm to generate SPWM has been implemented as Simulink model constructed in MATLAB and applied two level inverter module which is connected to three phase induction motor. Digital Storage Oscilloscope Tektronix is used to trace and analyze all output waveforms.

Key words: SPWM (Sine Pulse Width Modulation), Three Phases Inverter & Three Phase Induction Motor

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 (PWM) control. Continuous improvement in terms of cost and high switching frequency of power semiconductor devices and development of machine control algorithms leads to growing interest in more precise PWM techniques. PWM has been studied extensively during the past decades. Many different PWM methods have been developed to achieve the following aims: wide linear modulation range; less switching loss; less total harmonic distortion (THD) in the spectrum of switching waveform.

A. Basic of SPWM Method

The SPWM technique involves generation of a digital waveform, for which the duty-cycle is modulated such that the average voltage of the waveform corresponds to a pure sine wave. The simplest way of producing the SPWM signal is through comparison of a low-power reference sine wave (V_r) with a high frequency triangle wave (V_c) output will be a 2-level SPWM signal. The intersection of V_r & V_c waves determines the switching instants and commutation of the modulated pulse.

The carrier and reference waves are mixed in a comparator. When sinusoidal wave has magnitude higher than the triangular wave, the comparator output is high, otherwise it is low. The comparator output is processed in a trigger pulse generator in such a way that the output voltage wave of the inverter has a pulse width in agreement with the comparator output pulse width. In sinusoidal-pulse width modulation, the width of each pulse is varied proportional to the amplitude of a sine wave. By comparing sinusoidal reference signal with a triangular carrier wave of frequency f_c , the gate signals are generated, as shown in Fig. 1. The frequency of the reference signal f_r , determines the output frequency. The numbers of pulses per half cycle depends on

the carrier frequency. By varying the modulation index MI, the RMS output voltage can be varied.

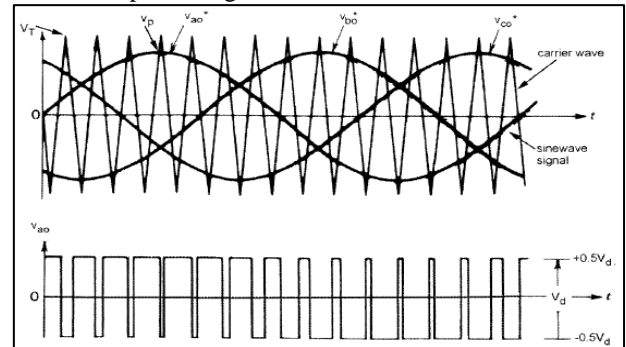


Fig. 1: Basic of SPWM

When triangular carrier wave has its peak coincident with zero of the reference sinusoid, there are $N = \frac{f_c}{2f_r}$ pulses per half cycle. When zero of the triangular wave coincides with zero of the reference sinusoid, there are (N-1) pulses per half cycle.

B. Modulation Index

The ratio V_r/V_c is called amplitude-Modulation Index (MI) and it controls the harmonic content of the output voltage waveform. The ratio $\frac{f_c}{f_r}$ is called frequency modulation index.

The magnitude of fundamental component of output voltage is proportional to MI, but MI can never be more than unity. The output voltage is controlled by varying MI.

II. SPWM MATLAB SIMULATION

Fig.2 shows MATLAB simulation of SPWM technique. DC Link voltage supply of $V_{dc}=600$ Volt, resistive load of 50 ohm and $MI=1$, for fundamental frequency sine wave of 50 Hz, carrier frequency is 7 kHz.

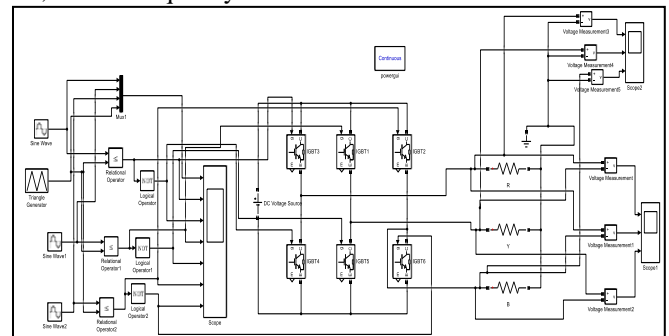


Fig. 2: Matlab Simulation of SPWM

Fig.3 shows six gate pulses of inverter carried out through the comparison of three phase sine signals with triangular signals which are applied to six IGBTs of three phase inverter module.

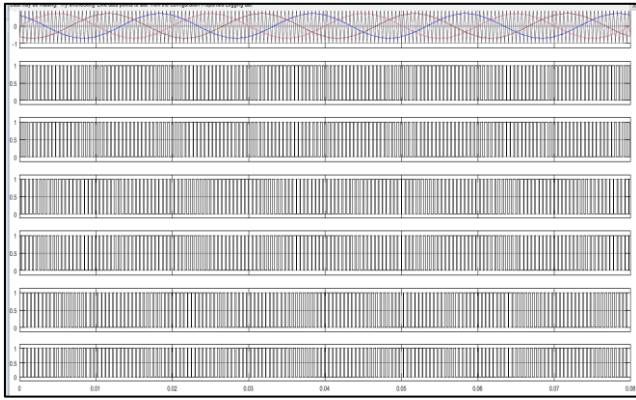


Fig. 3: Six Gates Pulses of SPWM

Fig.4 shows phase voltages of inverter carried out using MATLAB simulation. Fig.5 shows line voltages of inverter which are used for FFT analysis of powergui block's FFT tool in MATLAB.

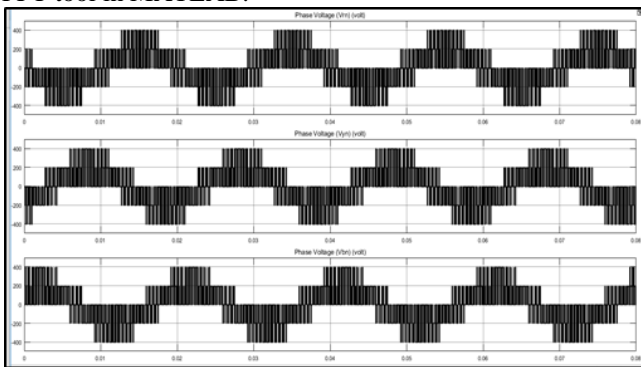


Fig. 4: Phase Voltages of SPWM

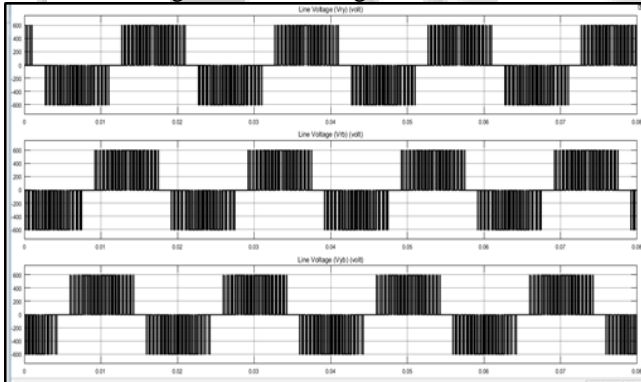


Fig. 5: Line Voltages of SPWM

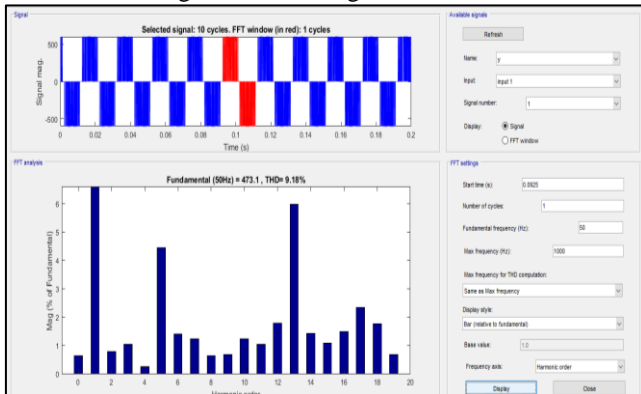


Fig. 6: FFT analysis of Line Voltages

Practical set up for Validation of SPWM using 32-bit ARM Cortex Microcontroller.

In this practical set up, three phase ac 2 HP, 220 Volt three phase induction motor is used. Synchronous speed of motor is 1500 rpm. Single Phase Bridge AC rectifier with 450 Volt, 450 microfarad capacitor, 35 amps is used to generate 324 V DC supply for three phase inverter module. Three phase sine wave signals displaced by 120 degree are compared with the higher carrier frequency of 7 kHz of triangular signal using Boolean logic comparator for generating the pulses.32-bit ARM Cortex microcontroller (STM32F4072F407XX MCU) is interfaced with MATLAB to generate codes of program. Six pulses generated by microcontroller are given to three phase inverter module which is connected with the three phase induction motor.

Table.1 and Table.2 shows practical readings of V_{dc} DC link voltage, speed, V_L Line voltage and I_L current of three phase induction motor for no load and load condition of three phase induction motor with variation of MI.

For the same MI, speed of motor is reduced form no load to full load condition.

SPEED (RPM)	VOLTA GE V_L (volt)	CURRE NT I_L (amps)	DC LINK VOLTA GE V_{DC} (volt)	MODULATI ON INDEX
1496	219	0.78	324	0.97
1492	204	0.67	324	0.9
1458	183	0.58	324	0.8
1440	159	0.53	324	0.7
1436	117	0.38	324	0.5
1430	93	0.32	324	0.4
1421	69	0.29	324	0.3

Table 1: Practical Readings for SPWM (on no Load Condition)

SPEED IN RPM	VOLTA GE V_L (volt)	CURRE NT I_L (ampere)	DC LINK VOLTA GE V_{DC} (volt)	MODULATI ON INDEX
1457	207	1.1	324	0.97
1411	171	1.28	324	0.8
1338	130	1.53	324	0.7

Table 2: Practical Reading for SPWM (Load Condition of 2 Nm Torque)

Fig. 7 shows variation of line voltages of three phase inverter output or motor terminal voltages in no load condition with MI= 0 to 1.

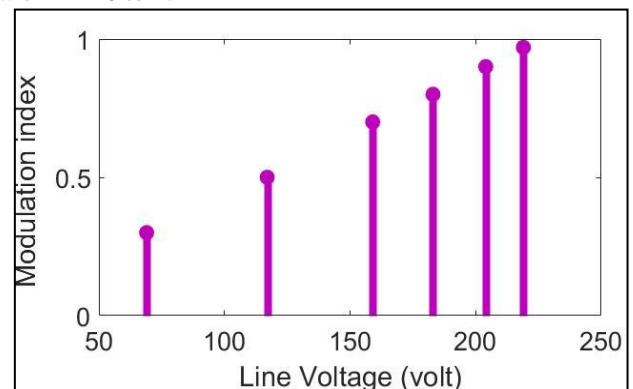


Fig. 7: Line Voltage-Modulation Index

Fig. 8 shows relations of speed, line voltages and MI in no load condition of three phase induction motor.

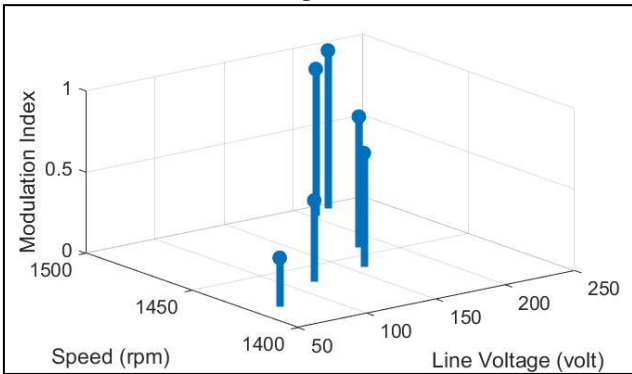


Fig. 8: Line Voltage –Speed (RPM)

Fig.9. show practical set up for validation of SPWM technique for speed control of three phase induction motor using three phase inverter module, ammeter, voltmeter, single phase rectifier unit, 32-bit ARM Cortex microcontroller (STM32F4072F407XX MCU) etc.

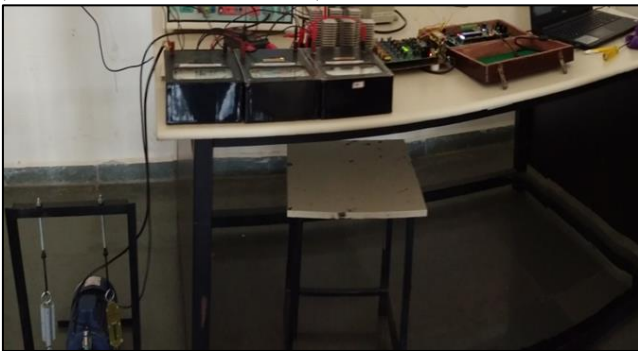


Fig. 9: Practical Set up for realization of SPWM Method

Fig.10 shows Line voltages and its FFT analysis using Digital Storage Oscilloscope Tektronix.

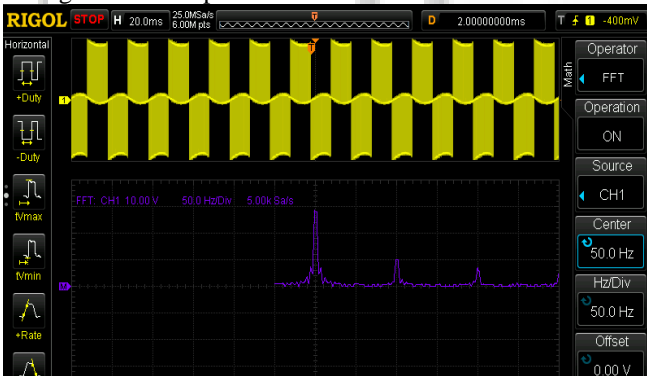


Fig. 10: Line Voltage and FFT analysis of SPWM

Fig. 11 shows Line to line voltage which are converted into 0 to 3 voltage using DAC of ARM Cortex microcontroller (STM32F4072F407XX MCU).

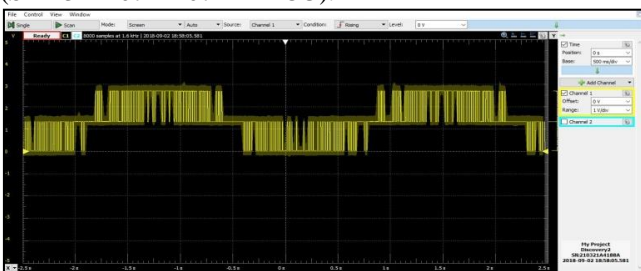


Fig. 11: Line Voltage using DAC Signal

Fig.12 shows normalized phase voltages in the range of 0 to 3 volts converted using DAC of ARM Cortex microcontroller & FFT of Analog Discovery2 board.

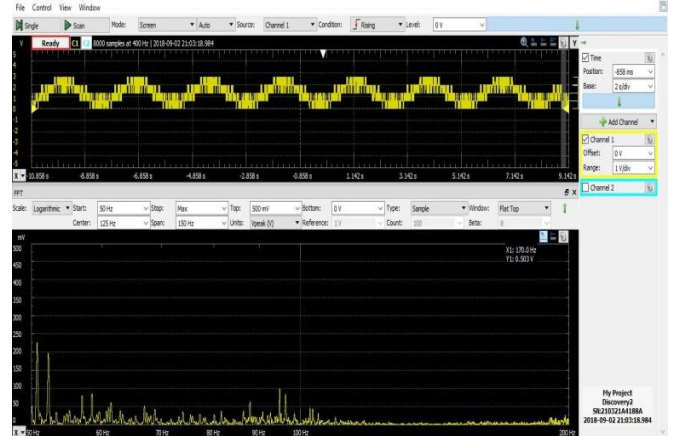


Fig. 12: Phase Voltage using DAC Signal and FFT Analysis of Phase Voltage

Fig.13 shows normalized line voltages in the range of 0 to 3 volts converted using DAC of ARM Cortex microcontroller & FFT of Analog Discovery2 board.

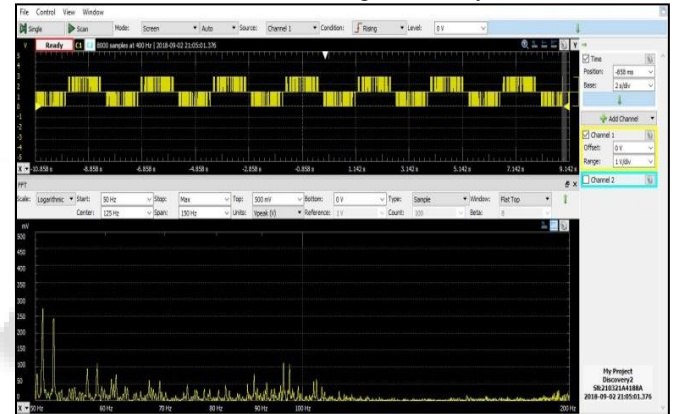


Fig. 13: Line voltage using DAC signal and FFT analysis of Line Voltage

III. CONCLUSION

In this paper, firstly MATLAB simulation SPWM technique is carried out with FFT analysis of THD 9.18% (Fig. 6). Speed control of three induction motor also carried out by varying MI between 0 to 1. Line voltages and speed are found linear with respect to MI (Fig.7 and Fig.8). This method is very easy to implemented and control. It has been observed that the line voltage and speed decreases with the increase in load for the same MI (Table 1 and Table 2). FFT analysis of Line voltage and phase voltages is also carried out.

It has been also observed that the selection of carrier frequency is depends on tradeoff between inverter switching losses and machine losses. Higher carrier frequency (same as switching frequency) increases inverter losses but reduces machine harmonics losses. It has been concluded that the optimum carrier frequency should be selected such that the total system losses should be minimal. Undesirable effect of SPWM switching frequency is the generation of acoustic noise by the magnetostriction effect when inverter supplies power to machine which can be eliminated by accommodating low pass filters.

ACKNOWLEDGEMENT

Authors are highly thankful to the GIDC Degree Engineering College & Gujarat Council on Science and Technology (GUJCOST) for facilitating the use of Design Laboratory situated in GIDC Degree Engineering College Campus, funded by GUJCOST.

REFERENCES

- [1] Dr. P.S. Bimbhra Power electronics, 5th edition. Thapar institute of engineering and technology Patiala: khanna publishers, 2012.
- [2] Muhammad H. Rashid. Power electronics handbook. University of Florida: academic, 2001.
- [3] User manual for STM32 Discovery card.
- [4] R. Krishnan. Electric Motor Drives modeling, analysis, and control. Virginia Tech, Blacksburg, VA: PHI Learning Private Limited, 2014.
- [5] 3-Phase AC Motor Control with V/Hz Speed Closed Loop Using the 56F800/E, Free scale Semiconductor.
- [6] MAT LAB references.

