Modeling and Simulation of SPWM VSI Fed Induction Motor

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Abstract— This paper presents simulation and modeling of SPWM VSI fed three phase induction motor in MATLAB. This paper also involves the speed control of three phase induction motor using six step($120°$ conduction). The SPWM based VSI fed induction motor drive is modeled using the Simulink block. SPWM is the most efficient and more reliable technique to controlled the output voltage of VSI. This technique also minimizes the lower order harmonics and improves the VSI response. The simulation results can be obtained by using MATLAB/SIMULINK. The performance of the three phase induction motor is obtained in terms of rotor current, stator current, rotor speed & electromagnetic torque.

Keywords- *MATLAB, SPWM, IGBT, Induction Motor Drive.*

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I. INTRODUCTION

Recently, there exists a demand for high performance electric drives capable of accurately achieving speed. Special attention was directed to the induction motor because of known reason such as size, cost, efficiency, etc. The induction motor is called the workhorse of industries because they are mostly used motors for industrial control and automation. Induction motor also have the simple in construction, it is almost unbreakable, it is robust. In this induction motor the power is supplied with specified voltage and frequency then it is run at its rated speed[1]. An inverter is a DC to AC converter, which is used to convert the DC input voltage to the symmetrical AC output voltage of the desired frequency and magnitude. The waveform of the output of AC voltage of the inverter is sinusoidal. But in practical application the inverter gives the output which is non-sinusoidal and contains the harmonics. This waveforms of output voltages are square, quasi square or distorted sinusoidal. Basically inverter is used in low and medium power application. But in high power applications sinusoidal waveform is necessary so that inverters are designed carefully to give the sinusoidal output with contains the low distortion.

Inverters are mostly used in various household and the industrial applications such as Battery-vehicle drives, Standby power supplies, AC drives, Active power line filter, Induction heating etc. The input given to the inverter is DC voltage which is given by battery, fuel cell, solar cell or any other sources which are the dc. The inverter used the switching devices which may be BJTs, IGBTs, MOSFETs, SCRs, GTOs, SITs, MCTs[2]. In power electronics the most common switching technique is the pulse width modulation technique(PWM). PWM is employed in the mostly wide variety of applications such as electric drives, HVDC reactive power compensation, UPS and the ranging from communication and measurement to power control and the conversion. The PWM technique make possible to control the frequency and the magnitude of the voltage and current of the motor[3].Inverter are mainly classified as current source inverters(CSI) and voltage source inverters(VSI). A voltage source inverter is the one which the dc source has small or negligible impedance. Thus the VSI has a stiff dc voltage source at its input terminal. On other side the current source inverter is supplied with a controlled current from a dc source of high impedance. Voltage source inverter can be classified into PWM inverter and the two stepped wave inverter. Examples of voltage source inverter are Adjustable speed drives for ac motors. electronic frequency changer circuits & uninterruptable power supply (UPS) units[4].

II. THREE PHASE SPWM INVERTER

A device that converts dc power into the ac power at the desired output of voltage and frequency is known as the inverter. The input to the inverter is the dc power which is obtained from the Rotating alternator through battery or rectifier, fuel cell, photovoltaic array, magneto hydrodynamic (MHD) generator. There are two types of the inverter i.e voltage source inverter and the current source inverter. A voltage source inverter is the one which is the dc source has the small or negligible impedance so that VSI has stiff dc voltage at the input terminals and the current source inverter is supplied with the controlled current from a dc source which has high impedance.

The simplified circuit diagram for the three-phase, two-level voltage source converter as shown in Fig.2. The converter having six switches, S_1 to S_6, with an anti parallel free-wheeling diode for each switch to handle the reactive power of load. The switches can be IGCT or IGBT devices, depending on the power and voltage ratings of the converter. This type of converter are used in industrial application.

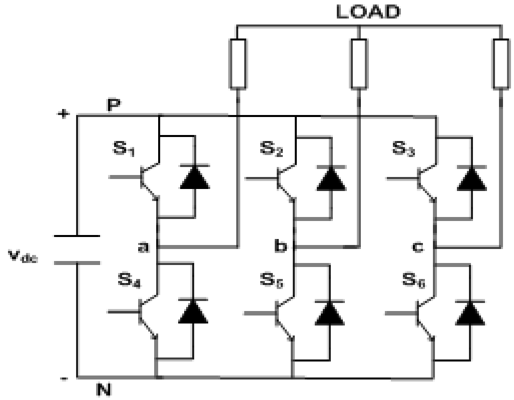


Fig.1: Two level voltage source converter

A. *Pulse Width Modulation*

Objectives of PWM

Pulse width modulation (PWM) is a method for

- Controlling output voltage of inverters
- Reduction of harmonics

In pulse width modulation control, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjustment of on and off periods of the inverter components.

Disadvantages of PWM

- High PWM frequency leads to increment in switching losses
- Reduction in voltage
- Causing of EMI problems due to high-order harmonics

Commonly-used Techniques:

- Single-Pulse-Width-Modulation
- Multiple-Pulse-Width-Modulation
- Sinusoidal Pulse-Width-Modulation
- Space Vector Modulation

B. *Sinusoidal Pulse Width Modulation*

In this paper the sinusoidal PWM scheme for the two-level converter is used where v_{ma}, v_{mb}, and v_{mc} are the three-phase sinusoidal modulating waveforms and v_{cr} is the triangular carrier signal. The fundamental-frequency component in the inverter output voltage can be controlled by the amplitude-modulation index:

$$m_a = \frac{\hat{V}_m}{\hat{V}_{cr}}$$

Where,

$\hat{V}_m$and $\hat{V}_{cr}$ are the peak values of the modulating and carrier waves, respectively.

The amplitude-modulation index ma is usually adjusted by varying $\hat{V}_m$ while keeping $\hat{V}_{cr}$ fixed. The frequency-modulation index is defined by

$$m_f = \frac{f_{cr}}{f_m}$$

Where,

f_m and f_{cr} are the frequencies of the modulating and carrier waves, respectively.

The operation of switches S_1 to S_6 is determined by comparing the modulating waves with the carrier wave. When $v_{ma}>v_{cn}$ the upper switch S_1 in inverter leg a is turned on. The lower switch S4 operates in a complementary manner and thus is switched off. The resultant inverter terminal voltage v_{aN}, which is the voltage at the phase-a terminal with respect to the negative DC bus N, is equal to the DC voltage v_{dc}. When $v_{ma}<v_{cn}$ S_4 is on and S_1 is off, leading to $v_{aN} = 0$ as shown in Fig.3. Since the waveform of v_{aN} has only two levels, v_{dc} and 0, the inverter is often referred to as a two-level inverter. It is noted that to avoid possible short-circuiting during switching transients of the upper and lower devices in an inverter leg, a dead time should be implemented, during which both switches are turned off.Three phase spwm induction motor drive

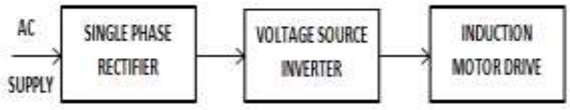


Fig.2: Block diagram of VSI fed induction motor drive

Three phase induction motor are most commonly used for adjustable speed drive than that of the three phase synchronous motor. When the three phase supply is given to the motor the speed at which the rotating flux rotates called the synchronous speed, It is given by

$$N_s = \frac{120f}{P} \text{ rpm} \quad \text{or} \quad n_s = \frac{2f}{P} \text{ rps} \qquad (1)$$

&

$$\omega_1 = \frac{4\pi f}{p} = \frac{2\omega_1}{P} \qquad (2)$$

Where,

f = Supply Frequency in Hz.

ω1 = Supply Frequency in rad/s

P = No. of stator poles.

It should be noted that the rotor can not attain the synchronous speed. It is always run at a speed less than the synchronous speed .i.e.

$$N_r = N_s\,(1\text{-S}) \qquad (3)$$

$$\omega_m = \omega_s\,(1\text{-S}) \qquad (4)$$

Where,

Nr =Rotor Speed in rpm

ω_m = Rotor speed in rad/s

$$slip = s = \frac{N_s - N_r}{N_s} = \frac{\omega_s - \omega_r}{\omega_s} \qquad (5)$$

III. MODELING OF INDUCTION MOTOR

The stator equations are as

$$V_{a1} = R_1 i_{a1} + L_a \frac{di_{a1}}{dt} + e_{a1} \qquad (6)$$

$$V_{b1} = R_1 i_{b1} + L_b \frac{di_{b1}}{dt} + e_{b1} \qquad (7)$$

$$V_{c1} = R_1 i_{c1} + L_c \frac{di_{c1}}{dt} + e_{c1} \qquad (8)$$

$$V_{a2} = R_2 i_{a2} + L_a \frac{di_{a2}}{dt} + e_{a2} \qquad (9)$$

$$V_{b2} = R_2 i_{b2} + L_b \frac{di_{b2}}{dt} + e_{b2} \qquad (10)$$

$$V_{c2} = R_2 i_{c2} + L_c \frac{di_{c2}}{dt} + e_{c2} \qquad (11)$$

IV. SIMULATED PERFORMANCE OF PROPOSED INVERTER FED INDUCTION MOTOR

Here, we developed a dc to ac inverter fed induction motor in MATLAB with three phase PWM inverter controlling both the frequency and magnitude of the voltage output. The generation of SPWM pulses this was basically used for comparing sinusoidal control voltage (at desired output frequency and proportional to output voltage magnitude) with the triangular waveform at the selected switching frequency.

Fig.1 shows the Two level voltage source inverter and Fig.3. shows the simulation results for three phase two level SPWM inverter.

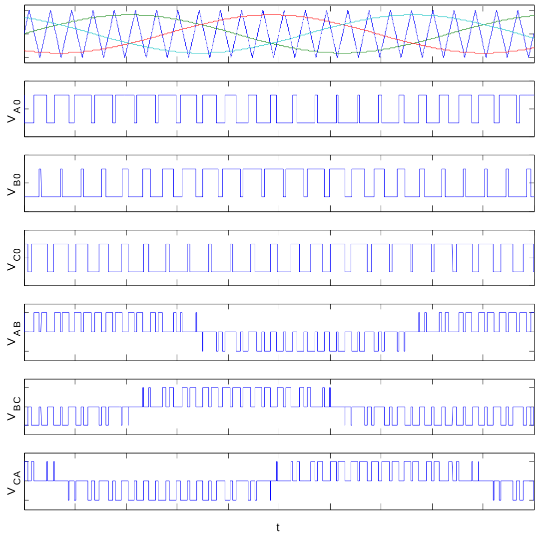


Fig.3: Waveforms of three-phase sine PWM inverter

Fig.4 shows the Simulink model for SPWM based inverter fed Induction Motor and Fig.5 & 6 shows the simulation results for it.

The squirrel cage induction motor is chosen for the simulation are 1 HP, 220 V, 50 Hz, 1500 rpm, Rs=10 ohm, Rr = 6.3 ohm, Ls=0.4642 H, Lr =0.4612 H, Lm = 0.4212H, J= 0.02 kg2/s, P=4.The simulation result for the electromagnetic torque, speed, stator current, rotor current as shown in fig.5 and fig.6.

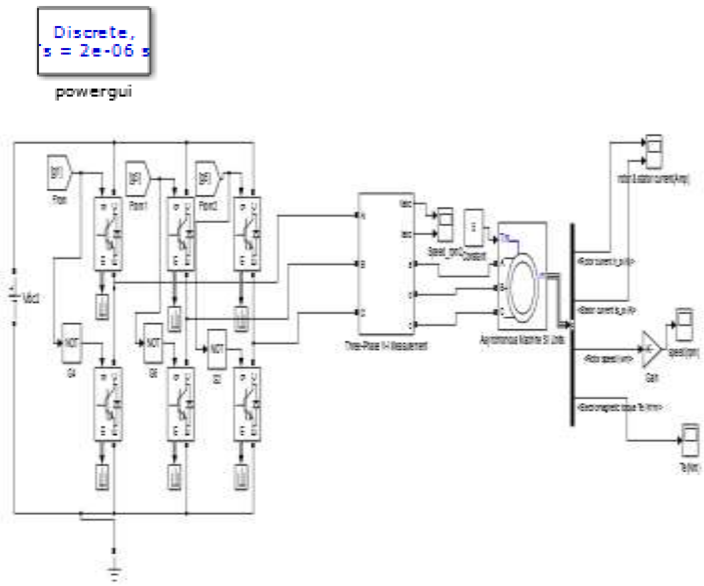
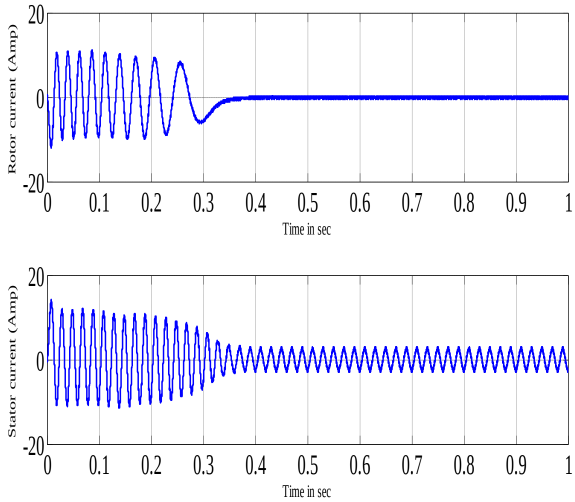
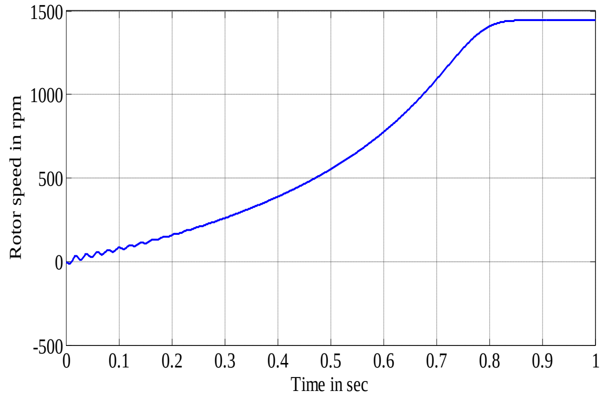


Fig.4: Complete Drive model of SPWM based inverter fed Induction Motor

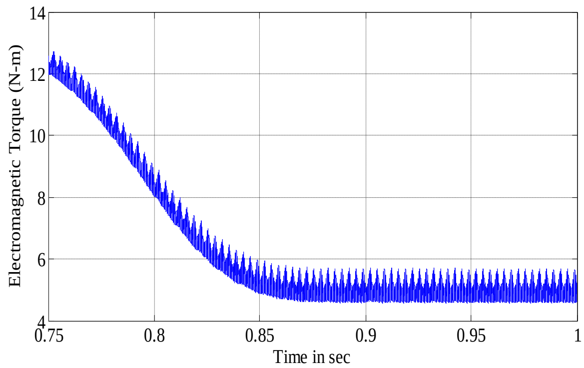
At No load,



(a)



(b)

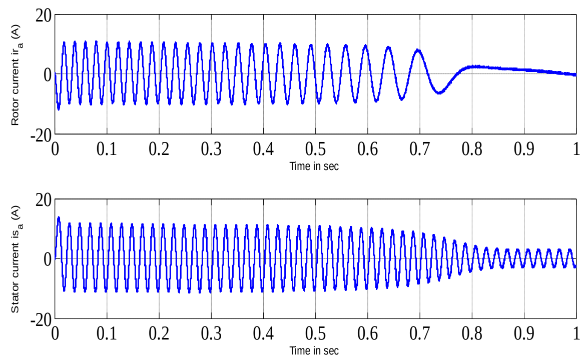


(c)

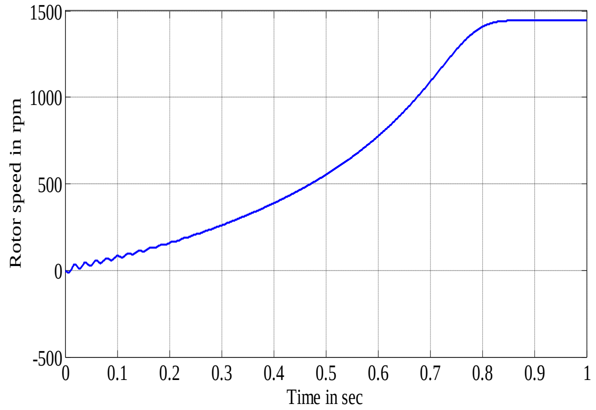
Fig.5: (a) motor rotor & stator current in ampere, (b)Speed in rpm (c)Electromagnetic Torque in N.M.

At no load, the settle point of stator current and rotor current is 0.35 sec. rotor speed is 1495 rpm, rotor current is 0.1337 A, stator current is 2.314 A, electromagnetic torque is 0.3521 N.m.

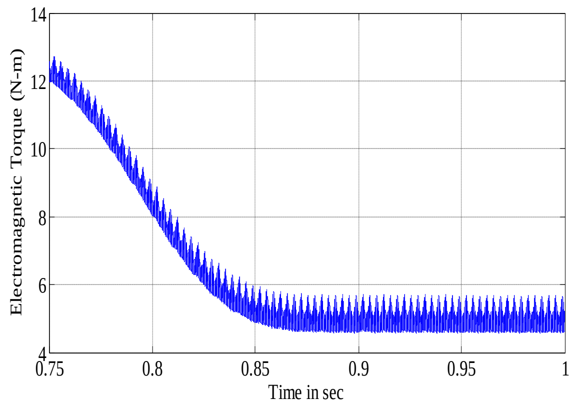
At Full Load,



(a)



(b)



(c)

Fig.6: (a) motor rotor & stator current, (b)Speed in rpm, (c)Electromagnetic Torque

At full load, the settle point of the stator current and rotor current is 0.8 sec. The rotor speed is 1444 rpm, rotor current is 0.4814 A, stator current is 2.431 A, electromagnetic torque 4.61 N.m.

Fig 5. shows the simulation results for Inverter fed Induction Motor at no load . In this Fig 5(a), 5(b) & 5(c) shows the simulation result for motor rotor & stator current in ampere, speed in rpm & electromagnetic torque in N.M.

Fig 6. shows the simulation results for Inverter fed Induction Motor at full load . In this Fig 6(a), 6(b) & 6(c) shows the simulation result for motor rotor & stator current in ampere, speed in rpm & electromagnetic torque in N.M.

When the simulation of inverter fed three phase Induction Motor is done for both no load & full load , it is observed that as the load increases it affects the stator & rotor current, speed & electromagnetic torque. i.e. As the load increases of the induction motor the speed should be decreases & the stator & rotor current & electromagnetic torque should be increases.

V. CONCLUSION

The performance for inverter fed three phase Induction Motor at no load & full load have been discussed along with its simulation in MATLAB. It is observed that as the load increases it affects the stator & rotor current, speed & electromagnetic torque.

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