PERFORMANCE ANALYSIS OF SPWM INVERTER FED 3-PHASE INDUCTION MOTOR DRIVE USING MATLAB/SIMULINK

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ABSTRACT

This paper deals with the performance analysis of three phase induction motor drive fed by SPWM inverter using different simulation technique in Matlab/Simulink. The performance of three phase induction motor drive represented in terms of inverter current, rotor and stator current, rotor speed, electromagnetic torque and total harmonic distortion (THD) in line voltage and phase current for modulation index $m_a < 1$. *Analysis is done using PI controller and fuzzy logic controller in close loop control of drive. After analysis of both controller the fuzzy logic controller give better performance than PI controller.*

Keywords– *Matlab, Induction Motor Drive, Fuzzy logic controller, SPWM*

I. INTRODUCTION

During the last few decades, the feasible control of induction machines receives a lot of attentions due to the extension of power electronics. With the development of power electronics, the power semiconductor devices are being broadly used in the power electronic converters, which convert power from one form to another. Many advanced semiconductor devices are existing today in power electronics market like BJT, MOSFET, IGBT, etc. The fast-switching devices and the techniques of Digital Signal Processor (DSP) provide the suitable ways to realize the complex control algorithms such that the induction machines can be controlled in different ways to satisfy certain requirements [2]. This is done through controlling the voltages (magnitude, frequency and angle) applied to the machine through a Voltage Source Inverter (VSI). Using VSI, can manage both frequency and magnitude of the voltage and current applied to induction motor drive. PWM inverters are very popular to control induction motor drives, as PWM inverter-fed induction motor drives are more reliable and offer a wide range of speed. Nowadays, various control techniqes used in the AC drives. Fuzzy control gives dynamic performance for a linear or nonlinear plant with parameter variation. Fuzzy logic controller provides an alternative to PI controller since it is a good implement for the control of systems that are not easy in modelling [7].

II. THREE PHASE SPWM INDUCTION MOTOR DRIVE

Majority of industrial drives use ac induction motor because these motors are rugged, reliable, and relatively inexpensive. Induction motors are mainly used for constant speed applications because of unavailability of the variable frequency supply voltage but many applications need variable speed operations. Historically, mechanical gear systems were used to obtain variable speed. Recently, power electronics and control systems have developed to allow this component. In the present time, in the most of the applications, AC machines are preferable over DC machines due to their simple and most vigorous construction without any mechanical commutators. Induction motors are the most extensively used motors for appliances like industrial control, and automation; hence, they are often called the workhorse of the motion industry[3]. As far as the machine efficiency, robustness, reliability, durability, power factor, ripples, stable output voltage and torque are concerned, three- phase induction motor stands at the a top of the order, to be used for motor control in place of mechanical gears. Present day drive types are the Induction motor drives with voltage source inverters. Three phase voltage-fed PWM inverters are recently showing rising popularity for multi-megawatt industrial drive applications[9]. The main reasons for this popularity are easy sharing of large voltage between the series devices and the improvement of the harmonic quality at the output as compared to a two level inverter. In the lower end of power, GTO devices are being replaced by IGBTs because of their rapid evolution in voltage and current ratings and higher switching frequency. Block diagram of Three phase PWM inverter fed 3-phase induction motor drive is given in Fig. 1 [1].

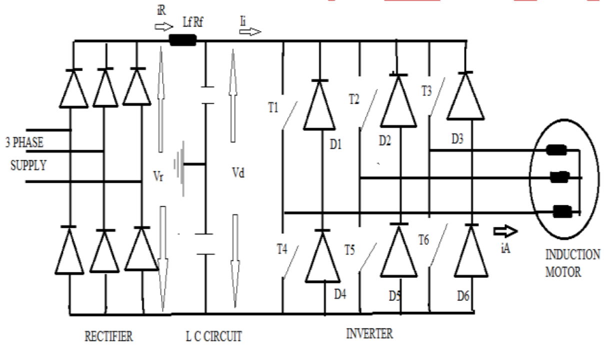


Fig.1. Block diagram of Three phase PWM inverter fed 3-phase induction motor drive

2.1. SINUSOIDAL PULSE WIDTH MODULATION

A Sinusoidal Pulse Width Modulation method is also known as the triangulation, sub oscillation, sub harmonic method is very popular in industrial applications. In this technique a high frequency triangular carrier wave is compared with the sinusoidal reference wave determines the switching instant. When the modulating signal is a sinusoidal of amplitude Am, and the amplitude of triangular carrier wave is Ac, then the ratio m=Am/Ac, is well-known as the modulation index. It is to be noted that by controlling the modulation index one can control the amplitude of applied output voltage. The block diagram of sinusoidal pulse width modulation is given here [9].

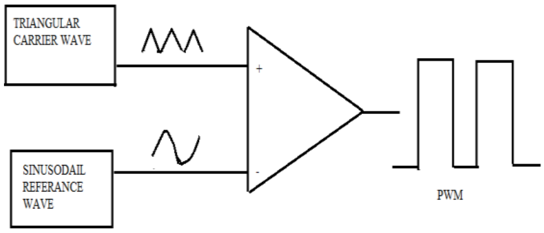


Fig. 2. Sinusoidal Pulse width modulation

2.2 INVERTER

A device that converts DC power into AC power at desired output voltage and frequency is known as Inverter. Phase controlled converters when operated in the inverter mode are called line commutated inverters. But line commutated inverters require at the output terminals an existing AC supply which is used for their commutation. This means that line commutated inverters can't role as isolated AC voltage sources or as variable frequency generators with DC power at the input. Therefore, voltage level, frequency and waveform on the AC side of the line commutated inverters can't be changed. On the other hand, force commutated inverters provide an independent AC output voltage of adjustable voltage and adjustable frequency and have therefore Much wider application. Inverters can be broadly classified into two types based on their operation:

- Voltage Source Inverters(VSI)
- Current Source Inverters(CSI)

Voltage Source Inverters is one in which the DC source has small or negligible impedance. In other words VSI has inflexible DC voltage source at its input terminals. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e.; from an inflexible DC current source. In a CSI fed with stiff current source, output current waves are not affected by the load.

III. PI CONTROLLER

The combination of proportional and integral expression is important to increase the speed of the response and also to reduce the steady state error. The PID controller block is reduced to P and I block only as shown in fig 3[4].

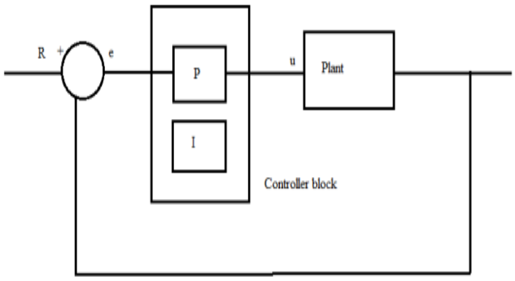


Fig. 3. Proportional Integral controller block diagram

The proportional and integral term is given by

$$u(t) = K_p e(t) + K_i \int e(t)dt$$

K_p and K_i are the tuning knobs , are used to obtain the desired output.

IV. General Structure of Fuzzy Logic Control System

- Every fuzzy system is composed of four principal blocks (Figure 4).
- Knowledge base (rules and parameters for membership functions).
- Decision making unit (inference operations on the rules).
- Fuzzification interface (transformation of the crisp inputs into degrees of match with linguistic variables).
- Defuzzification interface (change of the fuzzy result of the inference into a crisp output)

V. Simulation and Results

Simulation is done on a three phase induction motor fed by SPWM inverter in Matlab/Simulink environment. A three phase induction motor of 3HP, 220V, 50 Hz , 1725 rpm is fed by a 3-phase IGBT inverter connected to a controlled voltage source. Its stator leakage inductance is set to twice of its actual value to simulate the effect of smoothing reacter placed between the inverter and the machine . The load torque applied to the machine shaft is constant and set to its nominal value of 11.9 Nm. Observe that the rotor and stator currents are quite "noisy", despite the use of a smoothing reactor. The noise introduced by the PWM inverter is also observed in the electromagnetic torque waveform (Te). However, the motor's inertia prevents this noise from appearing in the motor's speed waveform. The modulation technique used for the generation of three phase balanced output from the inverter is the SPWM technique.

Fig-4 shows the MATLAB/Simulink model of close loop control of SPWM inverter fed 3-phase induction motor using PI controller.

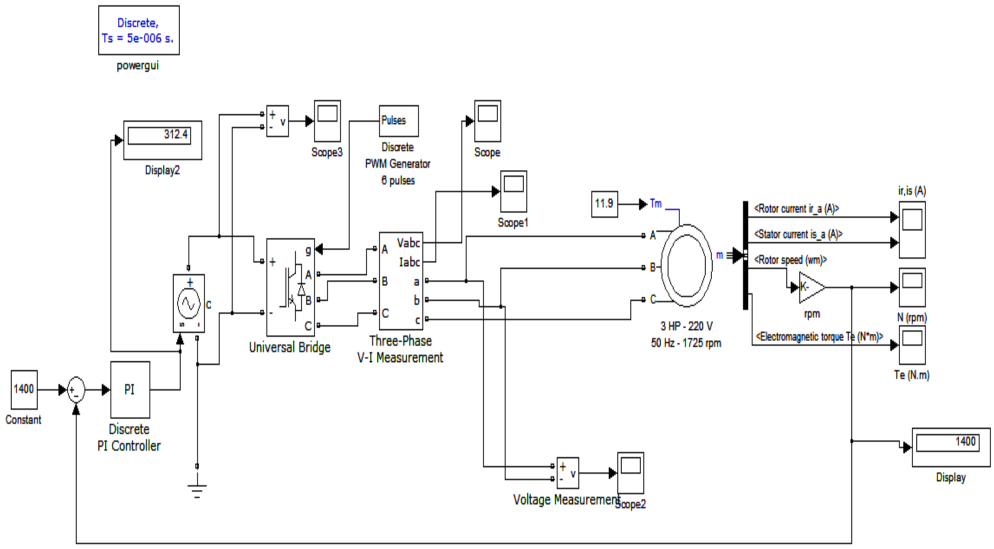


Fig. 4. Simulink model of close loop control of SPWM inverter fed 3-phase induction motor using PI controller

The performance curves of induction motor drive with PI controller shown in fig-5 to fig-10.

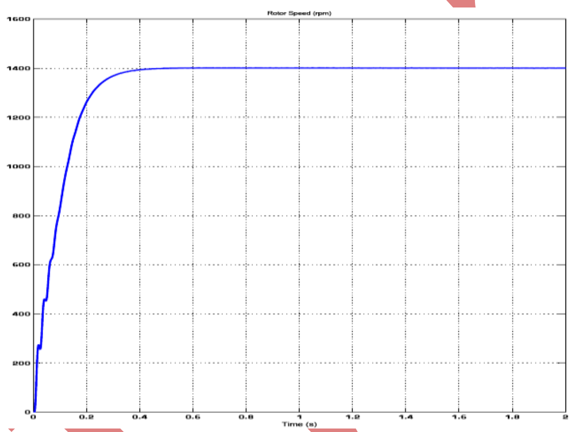


Fig.5. Rotor speed with time in closed loop using PI controller

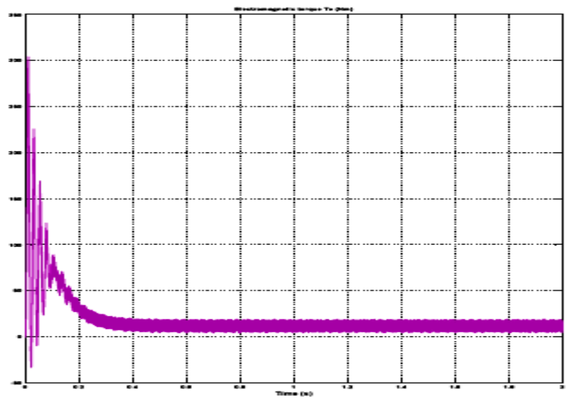


Fig.6. Electromagnetic torque with PI controller

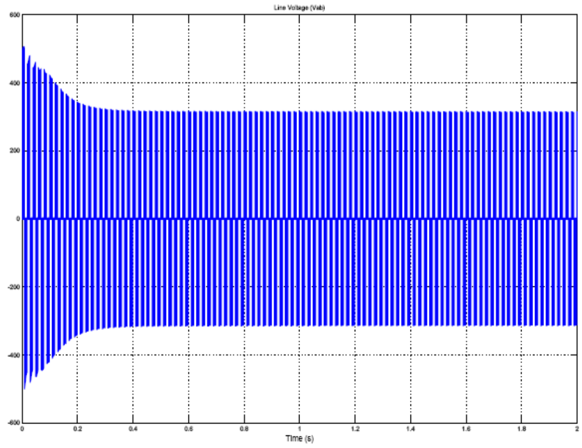


Fig.7. Line voltage (V_{ab}) with PI controller

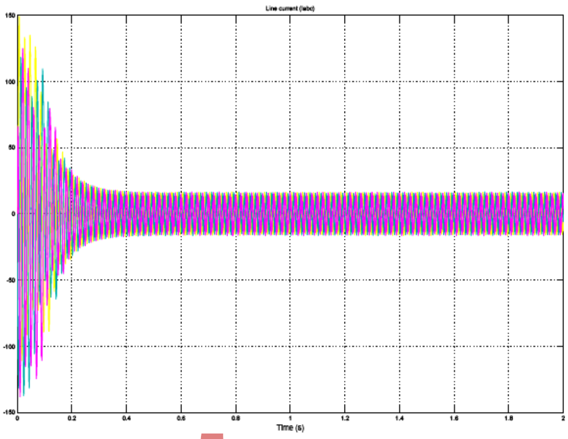


Fig.8. Line current with PI controller

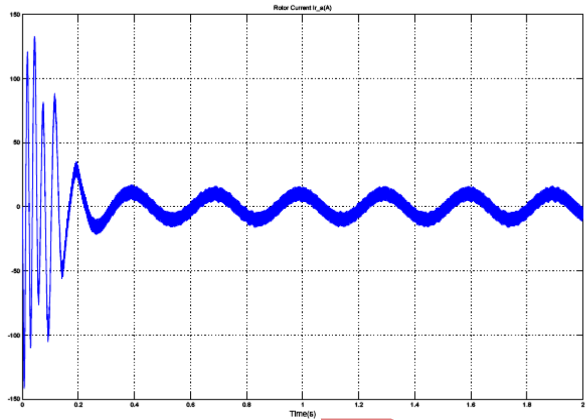


Fig. 9. Rotor phase current with PI controller

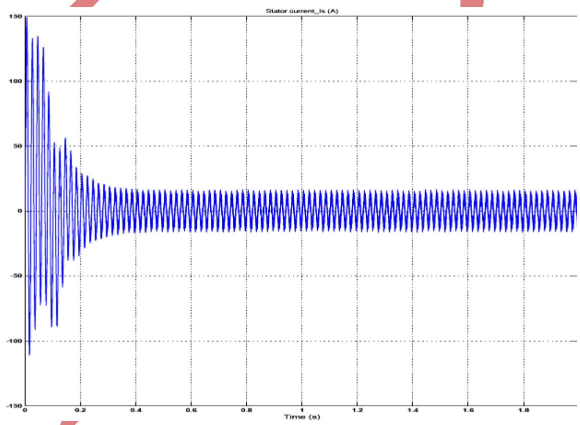
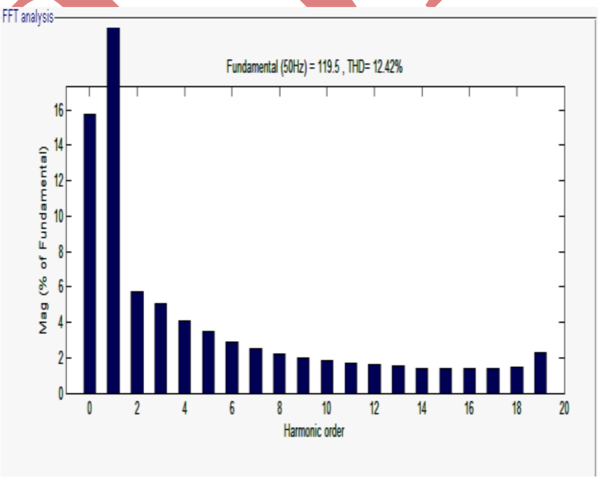


Fig. 10. Stator phase current with PI controller

Fig.9 and 10 shows the variation of the rotor and stator current with time for the phase ‘a’. The rotor current has transient time of 0.2 sec and the stator current has 0.23 sec. This transient is due to the noise introduce by the SPWM inverter.



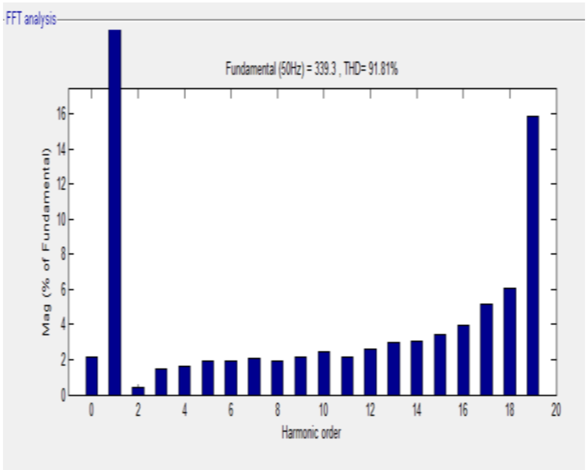


Fig.11. THD of phase current I_a for m_a =0.8 with PI controller

Fig. 12. THD of line voltage V_{ab} for m_a=0.8 with PI controller

Table.1: Total harmonic distortion of line voltage (V_{ab}) and phase current I_a with different modulation index

MODULATION INDEX	TOTAL HARMONIC DISTORTION OF PHASE CURRENT I_a USING PI CONTROLLER (%)	TOTAL HARMONIC DISTORTION OF LINE VOLTAGE V_{ab} USING PICONTROLLER (%)
0.6	14.67	120.81
0.8	12.42	91.81
0.9	11.37	79.71

The fig. 11 and 12 show the frequency spectrum of the phase current and the line voltage using PI controller. The value of the THD for line voltage is 91.81% while for the phase current it is 12.42% for modulation index 0.8. Table 1 shows the values of THD for line voltage and phase current for different modulation index.

Fig-13 shows MATLAB/Simulink model of close loop control of three phase induction motor drive using fuzzy controller.

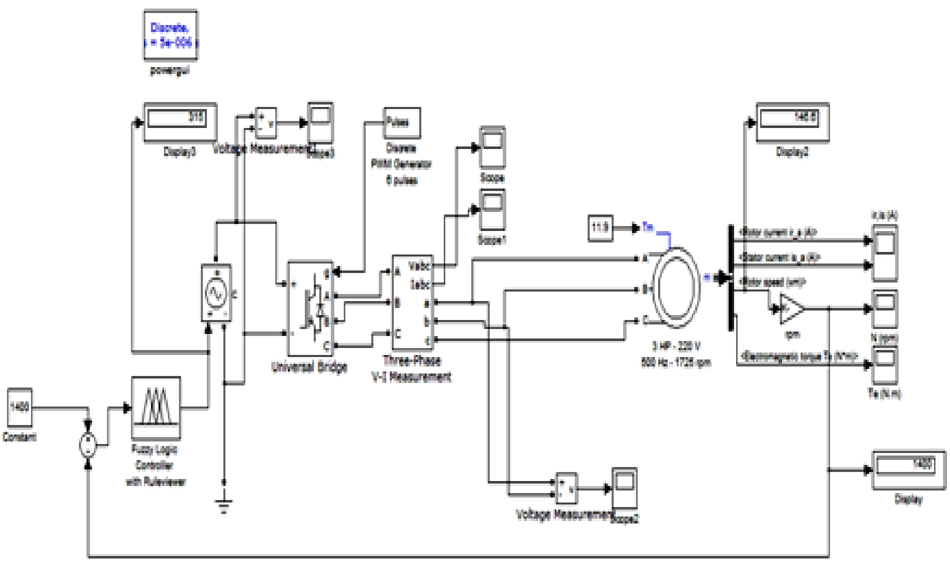


Fig. 13. Simulation of 3-phase induction motor drive using Fuzzy logic controller

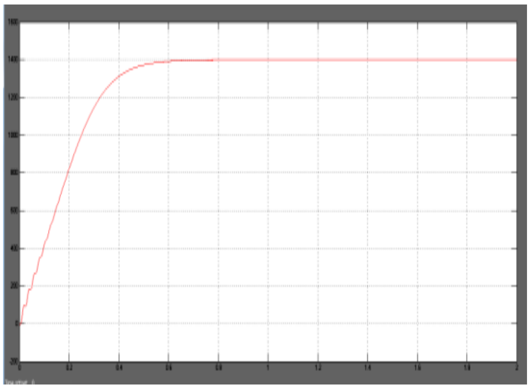


Fig.14. Rotor speed with fuzzy logic controller

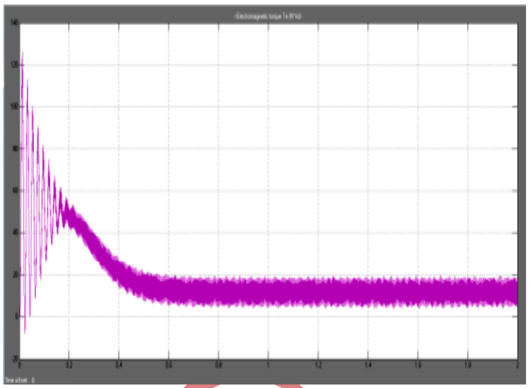


Fig.15. Electromagnetic torque (Te) with fuzzy logic controller

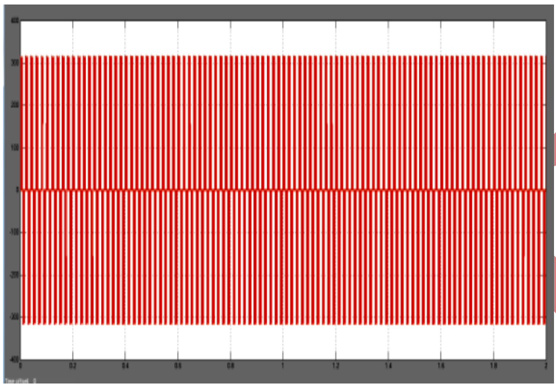


Fig .16. Line voltage V_{ab} with fuzzy logic controller

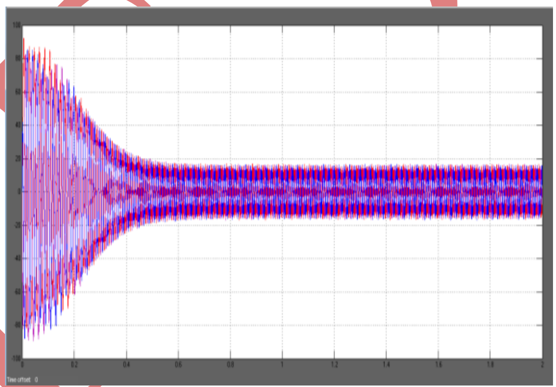


Fig. 17. Line current with fuzzy logic controller

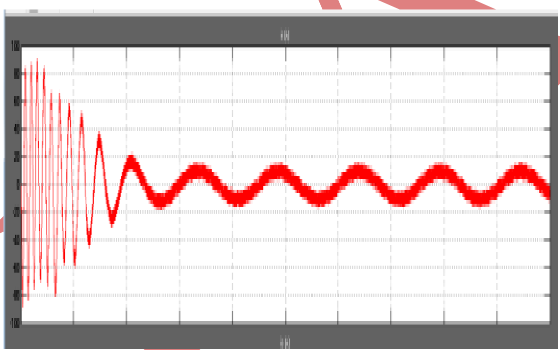


Fig. 18 Rotor current with fuzzy logic controller

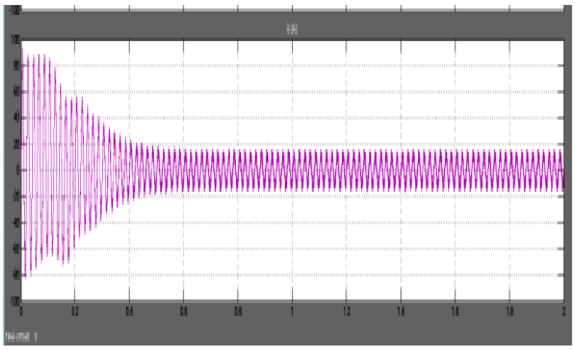


Fig. 19. stator phase current with fuzzy logic controller

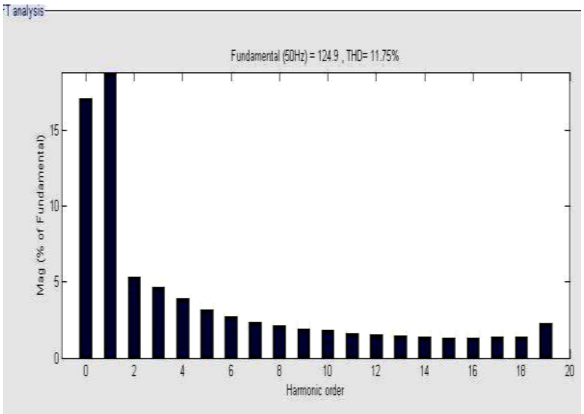


Fig 20. THD of phase current I_a for m_a =0.8 with FL controller

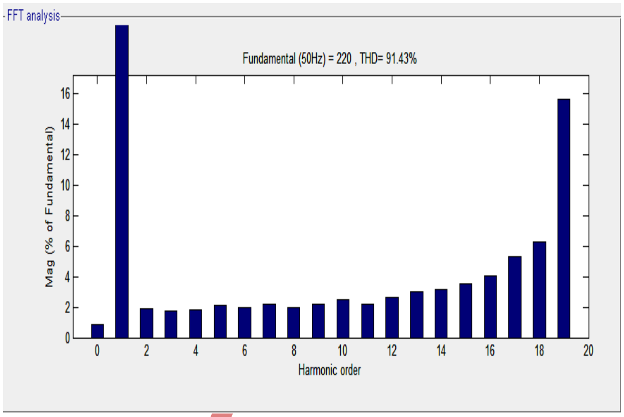


Fig. 21. THD of line voltage V_{ab} for m_a =0.8 with FL controller

The fig. 20 and 21 show the frequency spectrum of the phase current and the line voltage using fuzzy logic controller. The value of total harmonic distortion (THD) for line voltage is 91.43% while for the phase current it is 11.75% for modulation index 0.8. Table 2 shows the values of THD for line voltage and phase current for different modulation index.

Table.2. THD (total harmonic distortion) of line voltage (V_{ab}) and phase current (I_a) with different modulation index

MODULATION INDEX	TOTAL HARMONIC DISTORTION OF PHASE CURRENT I_a USING FUZZY CONTROLLER (%)	TOTAL HARMONIC DISTORTION OF LINE VOLTAGE V_{ab} USING FUZZY CONTROLLER (%)
0.6	13.46	119.76
0.8	11.75	91.43
0.9	10.75	79.50

Table. 3. Total Harmonic Distortion (THD) of line voltage and phase current with PI and Fuzzy controller at different modulation index

MODULATION INDEX	THD OF LINE VOLTAGE V_{ab}		THD OF PHASE CURRENT I_a	
	PI controller	FL controller	PI controller	FL controller
0.6	120.81	119.76	14.67	13.46
0.8	91.81	91.43	12.42	11.75

0.9	79.71	79.59	11.37	10.75

Table 3 shows the comparision of total harmonic distortion of line voltage and phase current with PI and fuzzy logic controller at different modulation index. It shows that at different modulation index total harmonic distortion of line voltage and phase current has less value with FL controller as compare to PI controller.

VI. CONCLUSION

In the present work performance analysis of SPWM inverter fed three phase induction motor drive has been done in close loop system with PI and fuzzy controller. This work is carried out in MATLAB/SIMULINK environment. The switching devices used are the power IGBTs. For generation of switching pulses the SPWM technique has been used which produces three phase balanced output. Three phase balanced output is then used to operate an induction motor. The total harmonic distortion (THD) has been calculated for phase current I_a and line voltage V_{ab}. The modulation index varies between 0.1 to 1.0. The variation of modulation index on performance of induction motor presented in term of rotor speed, electromagnetic torque, line voltage, line current, rotor and stator phase current wave form with PI and fuzzy controller. Results shows that by varying modulation index from low to high value THD of phase current I_a and line voltage V_{ab} improved. Also, the results of PI controller and fuzzy controller has been compared which show that the fuzzy logic controller gives better performance than PI controller.

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