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Performance Evaluation of Three Phase Induction Motor Using MOSFET & IGBT Based Voltage Source Inverter

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Abstract - *Induction motors are the most widely used motor drives in industry because of its simple construction and other advantages such as reliable operation, low initial cost, easy operation and simple maintenance and having good speed control. Invention of modern semiconductor switches like MOSFET and IGBT increases the freedom for controlling electric machines. In this paper the main focus is on the semiconductor switches which is used to design a six step inverter to control the voltage level for three-phase induction motor. Performance evaluation of the motor with different power semiconductor switches is studied. Reducing the losses of 3 phase inverter by replacing the semiconductor switches which are MOSFET with the IGBT power switches has been studied here. The IGBT power switches can replace the MOSFET in 3 phase six step inverter system for better efficiency and the MATLAB simulations showed similar results showing that IGBT is efficient than MOSFET based three phase six step inverter. The level of harmonics in the supply currents and voltages have been evaluated for different semiconductor switches.*

Key Words: **Insulated Gate Bi Polar Transistor (IGBT), Metal Oxide Semi-Conductor Field Effect Transistor (MOSFET), Six step Inverter, Three phase Induction Motor, THD.**

1.INTRODUCTION

The control of high-performance asynchronous motor drives for general industry applications and production automation has received wide spread research interests. Many schemes have been proposed for the control of induction motor drives, among which the field oriented control or vector control, is accepted as one of the most effective method [1]. Three-phase dc- ac six step inverter is one of the simplest way control the induction motor. The evolution in solid state converters has led to their use in Variable Frequency Drives (VFDs) employing various control techniques such as vector control and Direct Torque Control (DTC) due to their superior performance. Induction motor are widely used in industrial, commercial, utility application, residential application. It is used in various applications because the motor have low cost, high efficiency, wide speed range and robustness. In the present time, in the most of the applications, AC machines are useful than DC machines due to their simple and most robust construction without any mechanical commutators. Harmonics causes losses in the device, so to control them is essential. Now thyristor, MOSFET and IGBT more commonly employed in soft starting of induction motor. These techniques are more economical, convenient and reliable. Voltage and harmonics as well as THD can be controlled by controlling firing angle of power semiconductor switches. This paper evaluates the performance of controlled convertor using MOSFET and IGBT as semiconductor devices and calculated the THD with the help of simulation.

2.THREE PHASE VOLTAGE SOURCE INVERTER

The main components of power electronics systems are power converters, which allow to produce a desired effect by controlling adequately some of the system variables (voltages and currents) [2], [3]. To generate the six-step control signals, six simulink pulse generators were connected directly to the IGBT/MOSFET gates. The main purpose of this method is to provide a 3-ϕ voltage source where it is easy to adjust the amplitude, phase and the output voltage frequencies. It consists of six IGBT/MOSFET switches. The conduction mode of VSI is 180 degree. The main advantages of VSI is that the output voltage of VSI can be varied by varying the dc link voltage and the output voltage waveform frequency rely on rating of the switches of semiconductor devices. [3] Voltage source inverter is generally used for speed control by varying the frequency and voltage of the voltage source. The main application of Voltage Source Inverter is in adjusting the speed of Induction Motor or Synchronous motor, in Uninterruptible power supply which is also known as UPS, frequency changer circuit [4].

The IGBT's have very fast switching speed and their voltage and current ratings are also high so they are preferably used in variable frequency drives

Line-to-Line rms Voltage is given by:

$$V_L = \left[\frac{2}{2\pi}\int_0^{2\pi/3} Vs^2 d(wt)\right]^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$V_L = \sqrt{\frac{2}{3}}Vs = 0.8165Vs \quad \ldots\ldots\ldots\ldots (2)$$

Line-to-Neutral Voltages is given by:

$$V_P = \frac{Vs}{\sqrt{3}} = \frac{\sqrt{2}Vs}{3} = 0.4714Vs \quad \text{..... (3)}$$

3.THREE PHASE DRIVE SYSTEM

Three phase induction motors are more common employed in adjustable speed drives than three phase synchronous motor. When a three phase supply is connected to three phase stator winding, the speed of this rotating field, called synchronous speed is given by

$$N_S = \frac{120 * f}{P} \quad \text{rpm..... (4)}$$

Where Ns = Synchronous Speed in rpm.
f = Supply Frequency in Hz.
P = No. of stator poles.
Rotor cannot attain synchronous speed. It must run at a speed Nr less than Ns, Where

$$N_r = N_s(1-s) \text{ ..... (5)}$$
$$\omega_m = \omega_s(1-s) \text{ .....(6)}$$

Where Nr =Rotor Speed in rpm
ω_m= Rotor speed in rad/s

$$s = \text{slip} = \frac{N_S - N_r}{N_S} = \frac{\omega_s - \omega_r}{\omega_s} \text{.....(7)}$$

Three Phase Induction Motors are admirably suited to fulfill the demand of loads requiring substantially a constant speed. Several applications however, need adjustable speeds for their efficient operation [5]. The various methods of speed control are as follows.
1.Stator Voltage Control
2.Frequency Control
3.Constant V/f Control
4.Vector Control
5.Changing the stator poles
In this paper three phase squirrel-cage induction motor with open loop voltage fed inverter is modelled in MATLAB/SIMULINK software. The tested motor has the following characteristics:

Table- 1: AC Motor Parameters.

Motor Parameters	Value
Horse Power	5.4 HP (4KW)
D.C. motor input voltage	400 V
Rated speed	1430 rpm or 149.7 rps
Frequency	50 Hz
Slip	0.046
Stator resistance Rs	1.405 Ω
Stator Inductance Ls	0.005839 H
Moment of inertia J	0.0131 kg–m^2
Load Torque(TL)	26.7 N-m

These rated and evaluated parameters of motor are employed in the Simulink model.

4. TOTAL HARMONIC DISTORTION

Total Harmonic distortion is the important method to calculate the order of harmonics present in the voltage or current waveform. It is also useful in analyzing the quality of ac output voltage or current. Non sinusoidal wave quality can also be observed through Total harmonic distortion (THD). The total harmonic distortion is a measurement of the harmonic distortion and is described as the ratio of rms value of all harmonic components to the rms value of fundamental component. Total Harmonic distortion is defined as summation of all the harmonic content of current with respect to fundamental component of current [4].

$$THD_V\% = \frac{\sqrt{\sum_{n=2}^{\infty}(V_{oh\ rms})^2}}{V_{or\ rms}} \quad \text{..... (8)}$$

$$THD = \frac{V_{oh}}{V_{or}} \quad \text{(Voltage THD) ..... (9)}$$

Voh= rms value of all harmonic components present in the Output voltage of inverter.
Vor = rms value of fundamental component of o/p voltage.

$$THD_I\% = \frac{\sqrt{\sum_{n=2}^{\infty}(I_{oh\ rms})^2}}{I_{or\ rms}} \quad \text{..... (10)}$$

$$THD = \frac{I_{oh}}{I_{sr}} \quad \text{(Current THD) ..... (11)}$$

Ioh = rms value of all the harmonic components.
Isr = rms value of fundamental component of supply current.

Total harmonic distortion, or THD, is the summation of all harmonic components of the voltage or current waveform compared against the fundamental component of the voltage or current wave:

$$\%THD = \frac{\sqrt{V_2^2 + V_3^2 \text{.....} + V_n^2}}{V_1} * 100 \quad \text{.....} \quad \text{(12)}$$

The formula above shows the calculation for THD on a voltage signal. The end result is a percentage comparing the harmonic components to the fundamental component of a signal. The higher the percentage, the more distortion that is present on the mains signal.

5. MATLAB SIMULATION OF VSI FED INDUCTION MOTOR

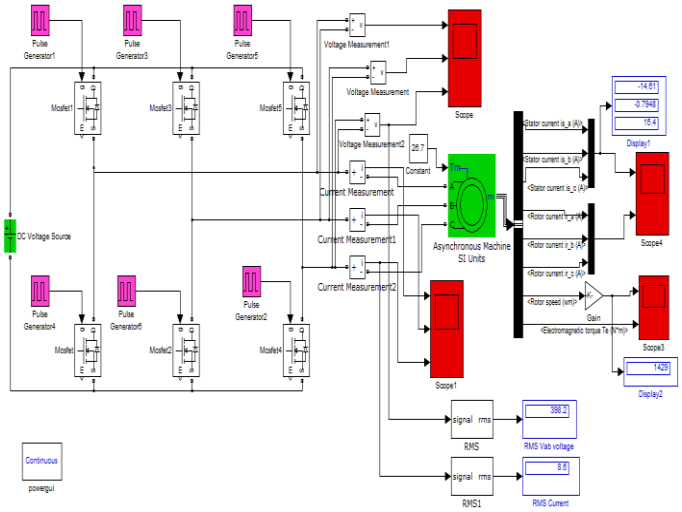

Fig-1: Simulink Model with MOSFET

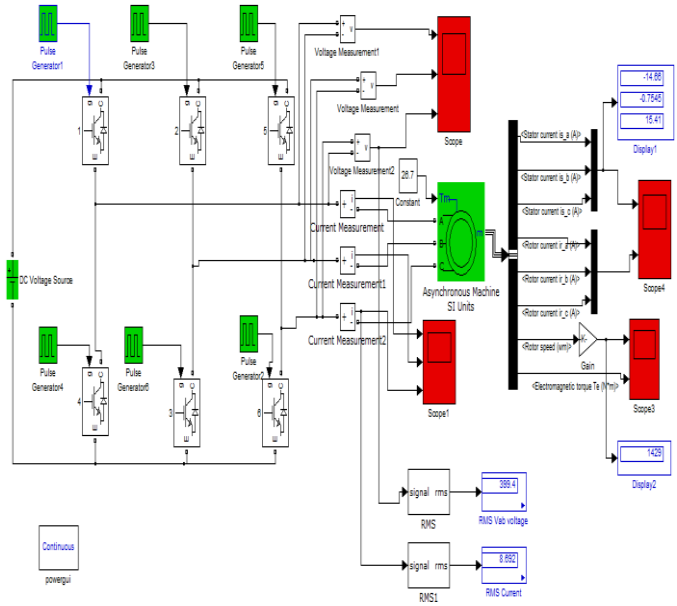

Fig -2: Simulink Model with IGBT

The Simulink model of MOSFET based VSI model is design in MATLAB software and is shown in Fig. 1. In this model MOSFET are ON in pair and for 180-degree conduction. MOSFET/IGBT inverter is modelled in MATLAB. For modelling the simulink model Sim power system toolbox is used.

Inverter is design with the use of MOSFET switches. Deigning and the simulation work are performed in MATLAB/ Simulink. The design model of IGBT is same as MOSFET based inverter and is shown in Fig.2. The design proposed here are used to have a comparison between IGBT and MOSFET based inverter fed drive.

IGBT is used in inverter as switches. By using FFT analysis overall THD of the output voltage and THD of three phase induction motor stator and rotor current is calculated.

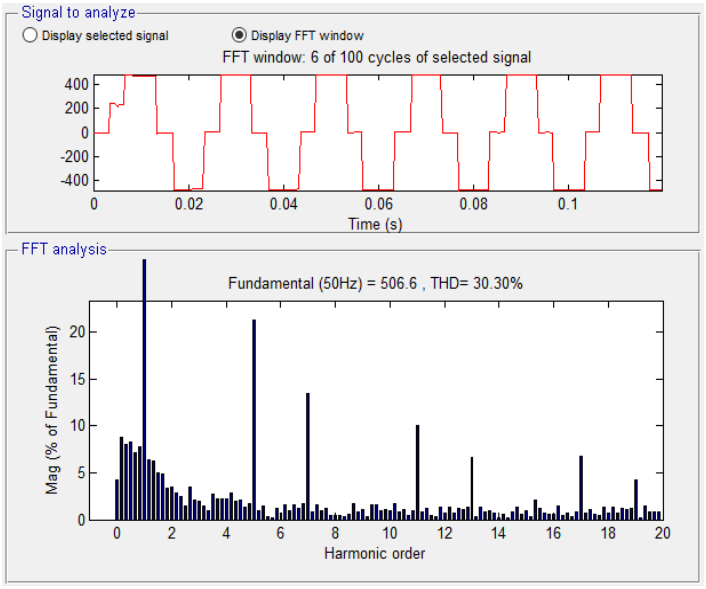

Fig-3: THD of Output Voltage using MOSFET Switch

FFT analysis of output voltage for MOSFET based VSI fed Induction motor is simulated in MATLAB. Fig. 3 shows that the THD obtained for line voltage through simulation is 30.30.%. THD and the fundamental component for the output voltage are shown in the spectrum window in Fig 3.

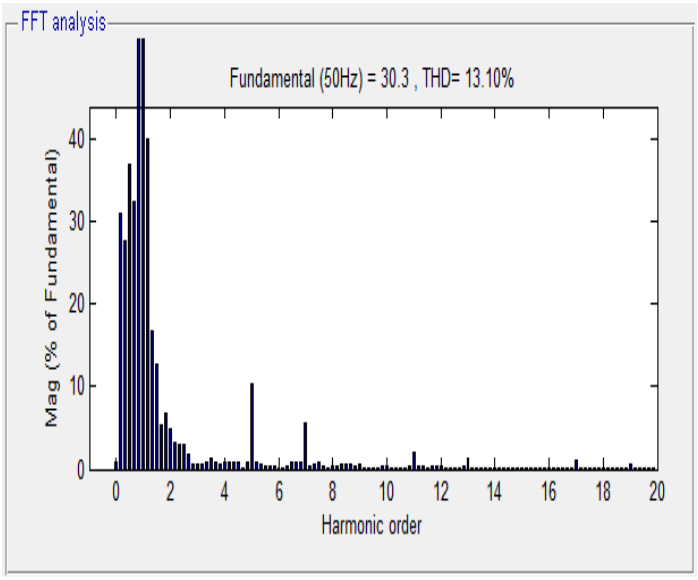

Fig-4: THD of Stator Current using MOSFET Switch

Fig.4 shows that total harmonic distortion of stator current using MOSFET switch is 13.10%.

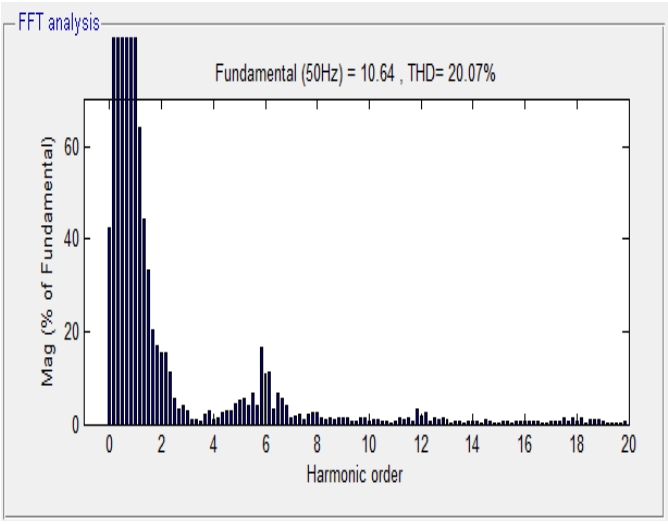

Fig-5: THD of Rotor Current using MOSFET Switch

Fig.5 shows that total harmonic distortion of rotor current using MOSFET switch is 20.07%.

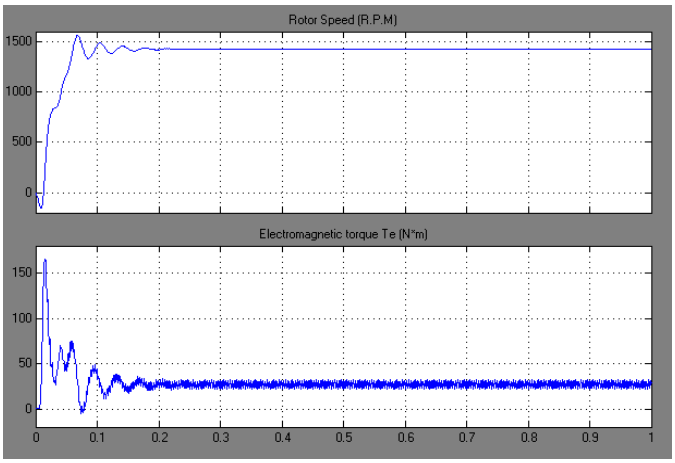

Fig-6: Speed and Torque Response using MOSFET Switch

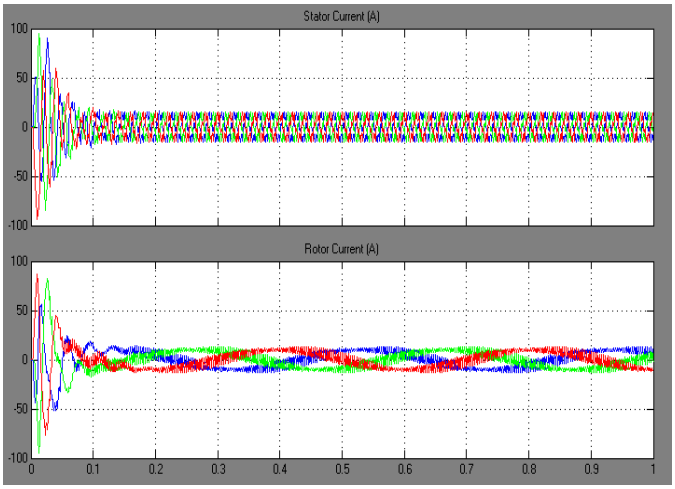

Fig-7: Three phase Stator Current and Rotor Current Response using MOSFET Switch

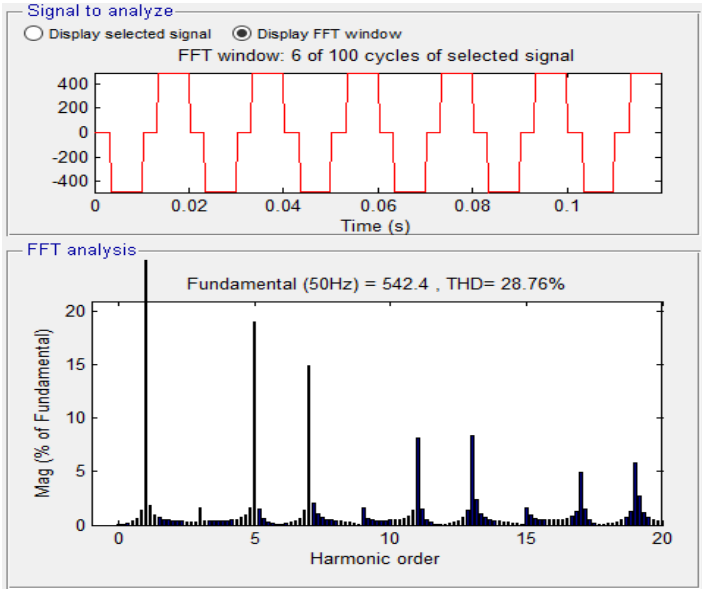

Fig-8: THD of Output Voltage using IGBT Switch

FFT analysis of output voltage for IGBT based VSI fed Induction motor is done in MATLAB. THD and the fundamental component for the output voltage are shown in the spectrum window in Fig.8. The THD obtained for line voltage through simulation is 28.76%. When the value of THD is lower, the core losses, peak current and heating reduces consequently in the motor.

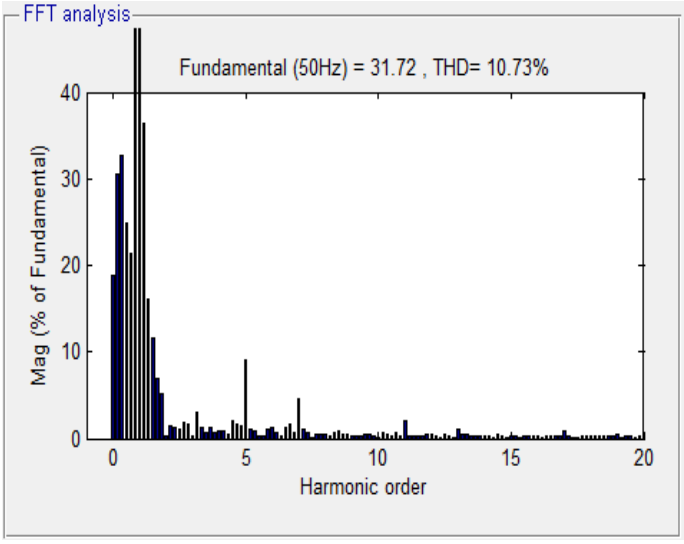

Fig-9: THD of Stator Current using IGBT Switch

Fig.9 shows that total harmonic distortion of stator current using IGBT switch is 10.73%.

Total harmonic distortion of rotor current using IGBT switch is 14.91% and it is shown in Fig.10.

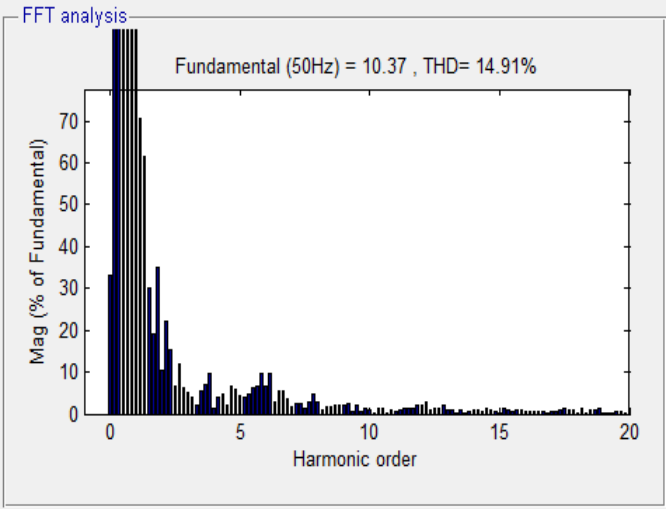

Fig-10: THD of Rotor Current using IGBT Switch

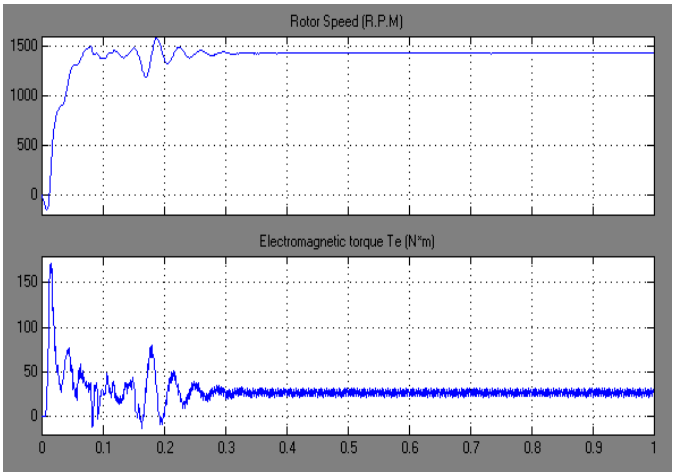

Fig-11: Speed and Torque Response using IGBT Switch

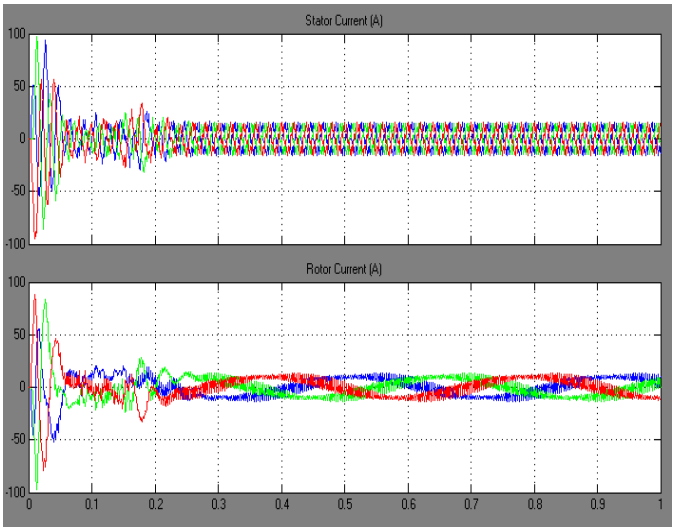

Fig-12: Three phase Stator Current and Rotor Current Response using IGBT Switch

Table-2: Comparison of parameters using semiconductor MOSFET and IGBT switches.

Parameters	MOSFET Based VSI	IGBT Based VSI
Voltage (V)	398.2 V	399.4 V
Current (A)	8.6 A	8.692 A
Speed (RPM)	1429 rpm	1429 rpm
% THD (Voltage)	30.30 %	28.76 %
% THD (Stator Current)	13.10 %	10.73 %
% THD (Rotor Current)	20.07 %	14.91%

6.RESULT

In this paper, simulation of MOSFET and IGBT based three phase six step inverter driving a three phase induction motor have been investigated and compared. During the investigations, it has been observed that IGBT has showed superior performances and better response due to less THD in voltage and current, as compared to MOSFET. After minimizing the THD of line voltages in Voltage Source Inverter the response of the Induction machine and its efficiency get improved.

7. CONCLUSIONS

IGBT and MOSFET based three phase inverter is simulated in MATLAB and THD of Inverter for output voltage, stator current and rotor current is compared by using both semiconductor switches. A significant improvement in Total Harmonic Distortion of the system is achieved by using IGBT. THD percentage of IGBT based VSI is less as compared to MOSFET based VSI. For betterment of any drive system total harmonic distortion should be minimum so we are considering IGBT switches is the best switch for three phase VSI as compare to MOSFET. Simulation has revealed an improvement in the switching performance of the motor drive. Hence, based on all obtained results, we can conclude that six step inverter using IGBT provides greater overall performance and improved efficiency as compared to six step inverter using MOSFET.

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BIOGRAPHIES

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