STUDIES ON A CLASSICAL VSI- FED ADJUSTABLE SPEED DRIVES

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***Abstract*:** The proposed work deals with simulation of a classical voltage source inverter fed adjustable speed drive system. A classical voltage source inverter fed speed drive system is simulated and the corresponding results are presented. The simulation results of voltage, current, speed and FFT spectrums are presented. FFT spectrums for the outputs are analyzed to study the reduction in Total Harmonic Distortion (THD) of the inverter system.

Index terms: THD, Induction motor, Classical inverter,Multilevel inverter,Matlab Simulink.

I. GENERAL

Adjustable Speed Drives (ASDs) are the essential and endless demand of the industries and researchers. They are playing a dominant role in controlling the speed of conveyor systems, blower speeds, machine tool speeds and other applications that require adjustable speeds. They have a greater impact and playing major role in revolutionizing the control strategies for various industrial processes. Traditionally, DC motors were the work horses in many industrial applications for the Adjustable Speed Drives (ASDs) due to their excellent torque and speed response. But the wear and tear of their commutator and mechanical brushes with the passage of time is the major disadvantage. In most applications, AC motors are preferable to DC motors, particularly, an induction motor due to its reliability, ruggedness, low cost, low maintenance and high efficiency. All these features make the use of induction motor a mandatory in many areas of domestic and industrial applications. The recent development in semiconductor technology and industrial electronics has triggered the development of high speed and high power semiconductor devices in order to achieve continuous and very smooth variation in motor speed. In large spectrum of industrial applications, solid state converters are wide spread due to their excellent speed characteristics.

In a conventional two-level inverter fed induction motor drive system the presence of significant quantity of harmonics makes the induction motor to suffer from severe torque and speed fluctuations, especially at low speeds, which could result in cogging of the shaft. The presence of harmonic also causes electromagnetic interference and undesirable motor heating. Large sized filters are required to reduce the magnitude of harmonicas. This results in larger size and higher cost of the drive system.

II. HARMONIC AND ITS EFFECTS

Harmonics play significant role in deteriorating power quality, called harmonic distortion. Harmonic distortion in electric distribution system is increasingly growing due to the widespread use of nonlinear loads. Large considerations of these loads have the potential to raise harmonic voltage and currents in an electrical distribution system to unacceptable high levels that can adversely affect the system. One of the biggest problems in the power quality aspects is the harmonic content in the electrical systems. Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. The frequency of each harmonic component is the integral multiple of its fundamental frequency. The term harmonic is normally applied to waveform components that have frequencies other than fundamental frequency. A waveform that contains any components other than the fundamental frequency is non-sinusoidal and considered to be distorted.

The most frequently encountered harmonics in three-phase distribution networks are the odd orders. Harmonic amplitudes normally decrease as the frequency increases. Above order 50, harmonics are negligible and measurements are no longer meaningful. Sufficiently accurate measurements are obtained by measuring harmonics up to order 30. Utilities monitor harmonic orders 3, 5, 7, 11 and 13. Generally speaking, harmonic conditioning of the lowest orders (up to 13) is sufficient. Harmonics in the electric power system combine with the fundamental frequency to create distortion. The level of distortion is directly related to the frequencies and amplitudes of the harmonic current. The contribution of all harmonic frequency currents to the fundamental current is known as "Total Harmonic Distortion" or THD.

Harmonics are classified into voltage harmonics and current harmonics. They are generated from either load side or source side. Load side harmonics are due to nonlinear operation of switching devices, arc furnaces, gas discharge lighting devices and overheating of the transformer cores and motors. Source harmonics are mainly generated due to non-sinusoidal voltage waveforms in the power supply.

The harmonics present in the output waveform of the inverter have the following effects on the performance of AC motor drives.

1 Increased motor heating: As the core losses are proportional to frequency, the core heating takes place due to the presence of high frequency harmonic components.

2 Torque pulsations**:** Due to the presence of harmonics the torque produced by the motor does notremain constant. It fluctuates, introducing speed fluctuations.

3 Electromagnetic interference.

III. INDUCTION MOTOR DRIVES

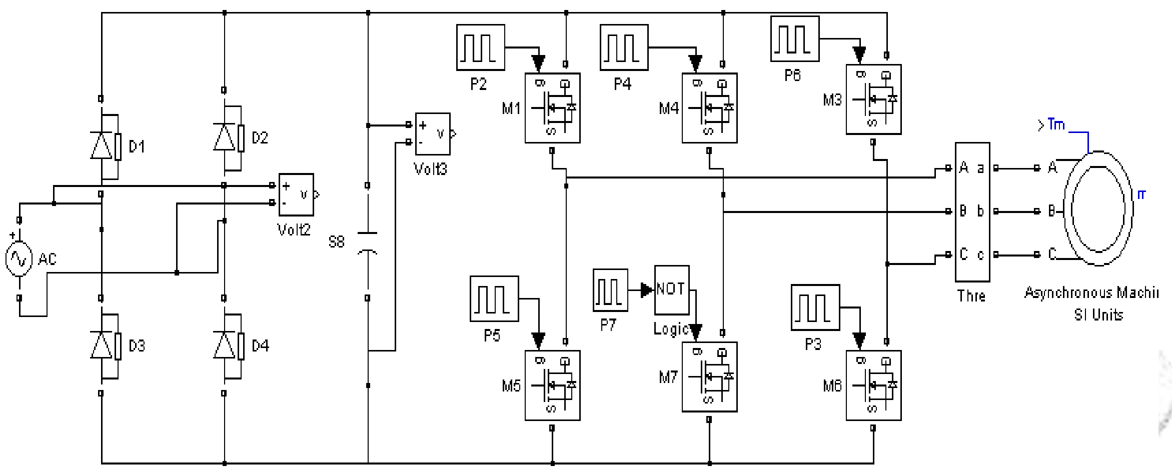
The three phase squirrel cage induction motor is the most popular electric motor type used industry and by utilities. Its popularity stems from several factors: ruggedness and simplicity of construction makes the induction motor a reliable, long-lived, easy-to-maintain and low-cost solution, while its ability to start and operate directly from the grid without any extra hardware is unique. Energy-efficient speed control of the induction motor is possible by adjusting the frequency of the supply voltage, which is usually done by means of a frequency converter. In the most common type of frequency converter, the line voltage is first rectified into DC voltage, which is subsequently inverted into an adjustable AC voltage using Pulse Width Modulation (PWM) techniques.

However, inverter fed induction motor suffers from the presence of significant amount of harmonics which causes undesired motor heating, torque pulsation and electro-magnetic interference. In order to reduce the harmonics, large sized filters are needed, which results in larger size and increased cost of the system. However the advanced achievements in the field of industrial electronics and power electronics made possible to reduce the magnitude of harmonics using multilevel inverter structures, in which the number of output voltage and current waveforms are increased without increasing the size of the filter. The performance of multilevel inverters will be better than a classical inverter. The THD for multilevel inverters will be lower than that of a classical inverter.

Nowadays, in high voltage and high power motor drive applications, multilevel inverters are the cost effective solution and most promising alternative to achieve good quality of output power [5]. Using the Multilevel inverter structure the power handling capability of the system can be raised in a systematic and powerful way [6]. The term multilevel starts with the three-level inverter introduced by Nabae et al [7]. By increasing the number of levels of the inverter, the output voltage waveform contains more steps generating a staircase waveform, which has a reduced harmonic distortion. The performance of multilevel inverters enhances with the increase in number of levels of the inverter.

IV. SIMULATION RESULTS OF A CLASSICAL INVERTER

VSI fed induction motor drive is shown in Figure 1. The diode rectifier with capacitive filter acts as the voltage source. Three phase inverter operating in 120^0 mode is used to feed the induction motor drive. Phase voltage waveforms are shown in Figure 2 and the stator phase currents are shown in Figure 3. Variation in speed is shown in Figure 4.. The speed increases and settles at 1120 rpm. FFT analysis is done for the current and the corresponding spectrum is shown in Figure 5. It can be seen that the magnitude of fundamental current is 28 Amperes. The Total Harmonic Distortion (THD) is 12.87 percent.



Rectifier Link filter PWM inverter

Figure 1 VSI-fed induction motor drive system

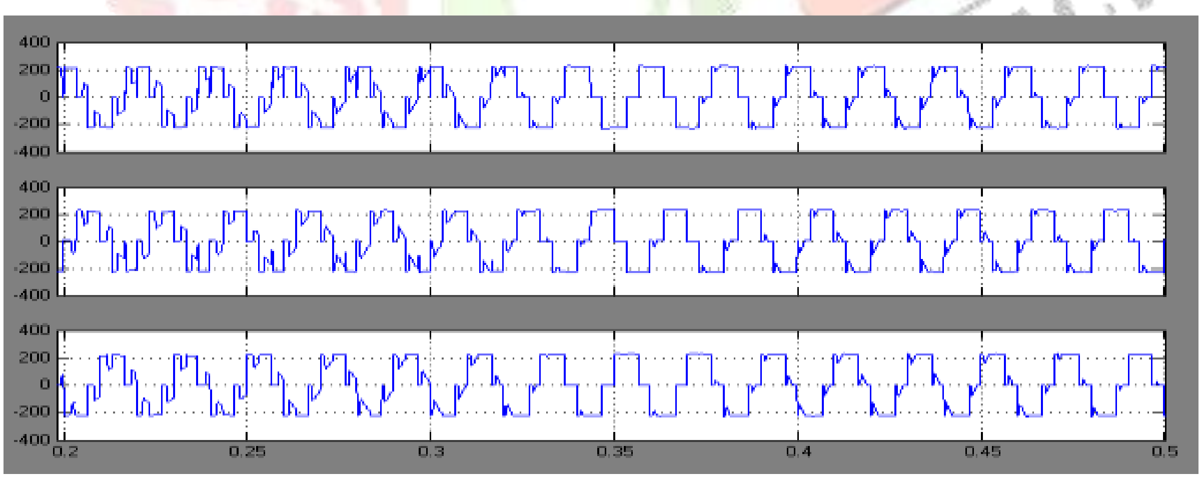


Figure 2. Phase voltage waveforms of VSI-fed IM drive

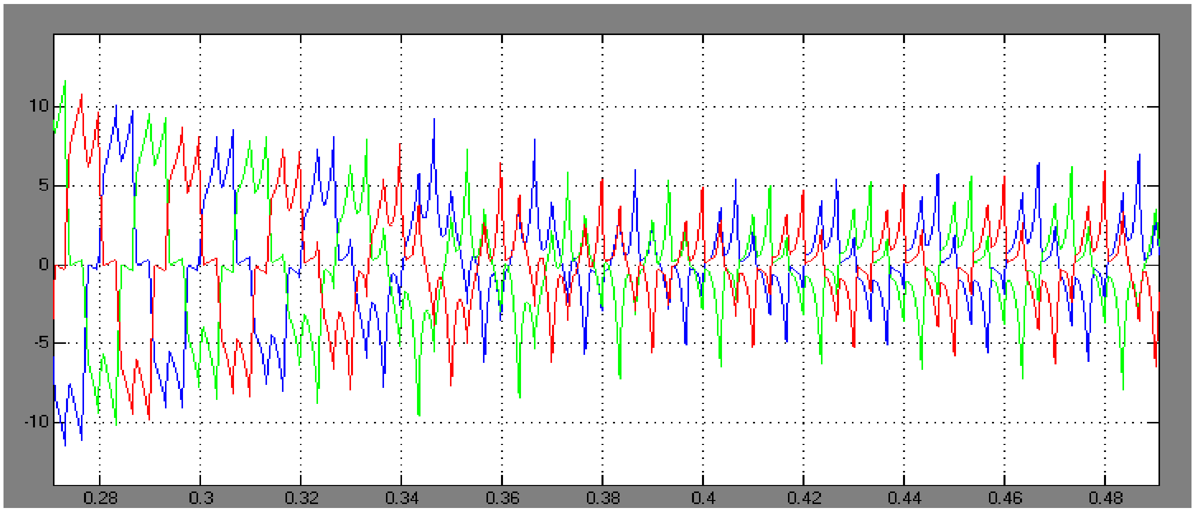


Figure 3. Stator current waveforms of VSI-fed IM drive

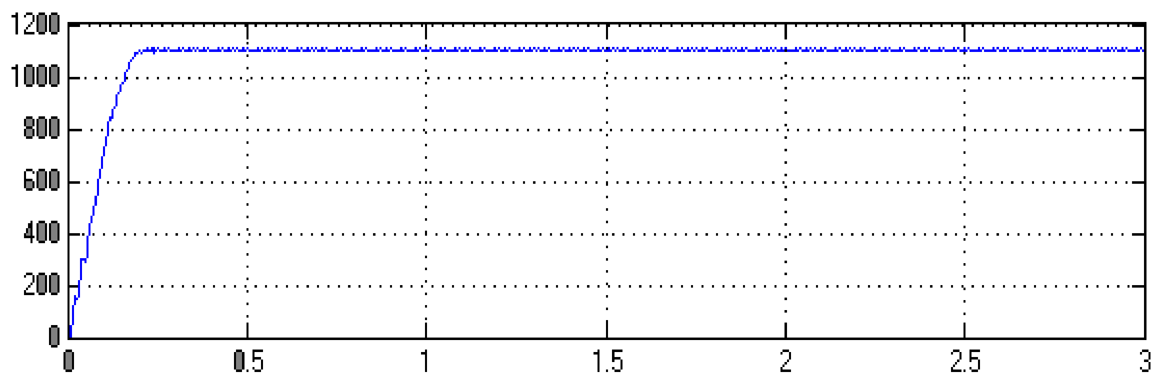


Figure 4. Rotor speed of VSI-fed induction motor drive

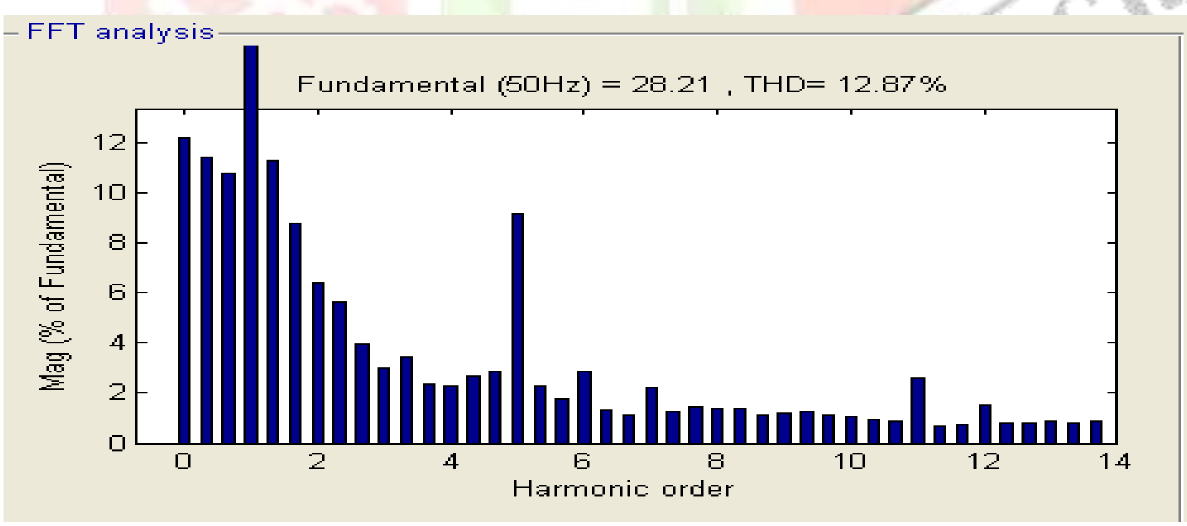


Figure 5. FFT analysis for stator current of VSI-fed IM drive

V. CONCLUSION

Three level inverter fed induction motor system is modeled and simulated using matlab Simulink. The simulation results of voltage, current, speed and FFT spectrums are analyzed.Variation in speed is also recorded. The speed increases and settles at 1120 rpm. FFT analysis is done for the stator current of the induction motor drive. The corresponding spectrum shows that the magnitude of fundamental current is 28 Amperes and the Total Harmonic Distortion (THD) is 12.87 percent.

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