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Simulation and Analysis of SPWM Inverter Fed Induction Motor Drive

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Abstract— *Sinusoidal Pulse Width Modulation variable Speed drives are progressively applied with superior performance in many new Industrial applications. Variable voltage and frequency supply to ac drives is invariably obtained from a three-phase voltage source inverter. Here use of three-phase voltage source inverter which is carrier-based sinusoidal PWM (Sinusoidal PWM) with power IGBTs is described. SPWM inverters make it possible to control both frequency and magnitude of the voltage and current applied in ac motor drives. As a result, PWM inverter-powered motor drives offer in a wide range better efficiency and higher performance, more variable and when compared to fixed frequency motor drives. Three phase voltage-fed PWM inverters are recently showing growing popularity for multi-megawatt industrial drive applications.*

Keywords-- Matlab, Spwm, IGBT, Induction Motor, Drive.

I. INTRODUCTION

Three phase induction motors are most widely used motors for any industrial control and automation because simple design, rugged, low-price, easy maintenance, Wide range of power ratings: fractional horsepower to MW's, run essentially as constant speed from no-load to full load,by changing the frequency of the power source speed can be changed. It is often required for the constant voltage/frequency (V/F) control to control the output voltage of inverter of an induction motor. PWM (Pulse Width Modulation) based firing of inverter provides the best constant V/F control of an induction motor. Amongst the various PWM techniques, the sinusoidal PWM is good enough and most popular.

Three phase induction motors are reliable, robust, and highly durable and of course need less maintenance. They are often known as workhouse of motion industries. When power is supplied to an induction motor with specified frequency and voltage, it runs at its rated speed. Many advanced semiconductor devices are available today in power electronics market like BJT, MOSFET, IGBT, etc. For this paper IGBT (Insulated Gate bipolar transistor) is used as a semiconductor device.

II. SINUSOIDAL PULSE WIDT MODULATION

A fixed input dc voltage is given to the inverter in Pulse width modulation technique in which a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is most popular method of controlling the output voltage and this method is termed as pulse width modulation technique. For better result we use PWM than an external control methods. There are number of PWM methods for variable frequency voltage-sourced inverters. To obtain the required output voltage a suitable PWM technique is employed in order in the line side of the inverter.

A triangulation is also known as the Sinusoidal Pulse Width Modulation technique, sub oscillation, sub harmonic method is very popular in industrial applications. In this technique a sinusoidal reference wave is compared with high frequency

triangular carrier wave determines the switching instant. When the amplitude of triangular carrier wave is Ac and modulating signal is a sinusoidal of amplitude Am, and, then the ratio m=Am/Ac, is 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.

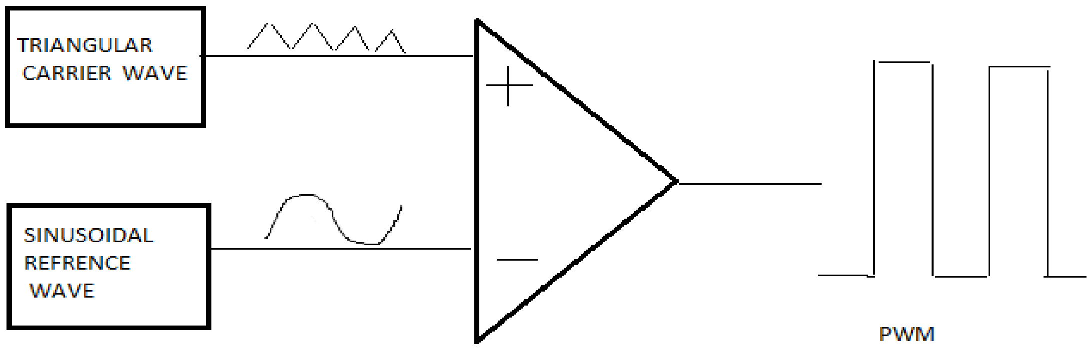

FIGURE 1: Sinusoidal Pulse width modulation

III. SIMULATION RESULTS AND ANALYSIS

Here we developed inverter fed Induction motor in Simulink / Matlab with a three phase PWM inverter control. For generation of PWM pulses the technique was used comparing sinusoidal control voltage (at the desired output frequency and proportional to the output voltage magnitude) with a triangular waveform at a selected switching frequency. The basic simulink circuit is shown in figure 2.

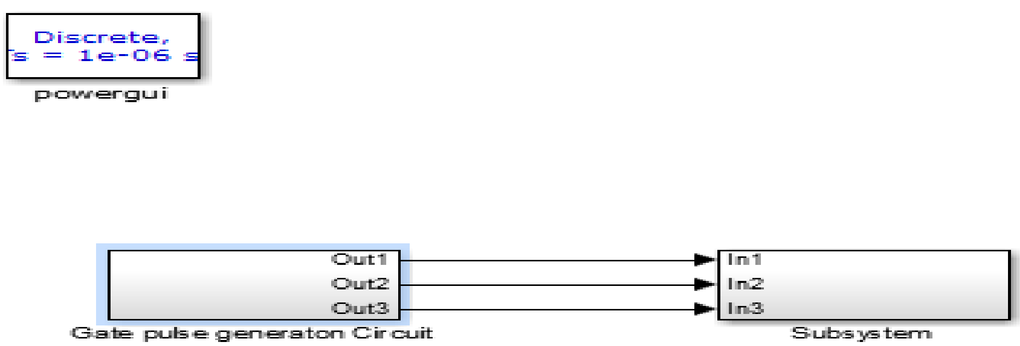

FIGURE 2: Main Simulink Model

It has two blocks. First is gate pulse generation circuit and second is subsystem which has induction motor model. The gate pulse generator has sub circuit inside it. The sub circuit is shown below:

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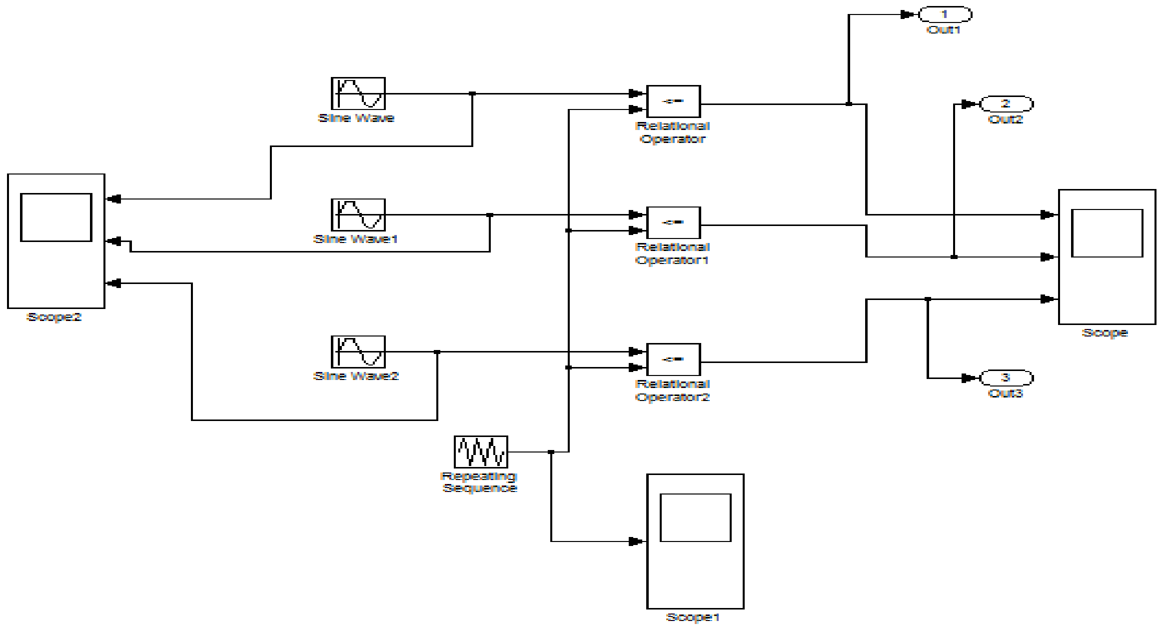

FIGURE 3: Gate Pulse Generation Block

The above block consist of three sin wave which are 120 degree phase shifted. A repeating sequence block of 1 kHz frequency is taken and both these blocks are compared to get the PWM pulses. The waveform of sinewave, repeating sequence and PWM pulses are shown below respectively [1].

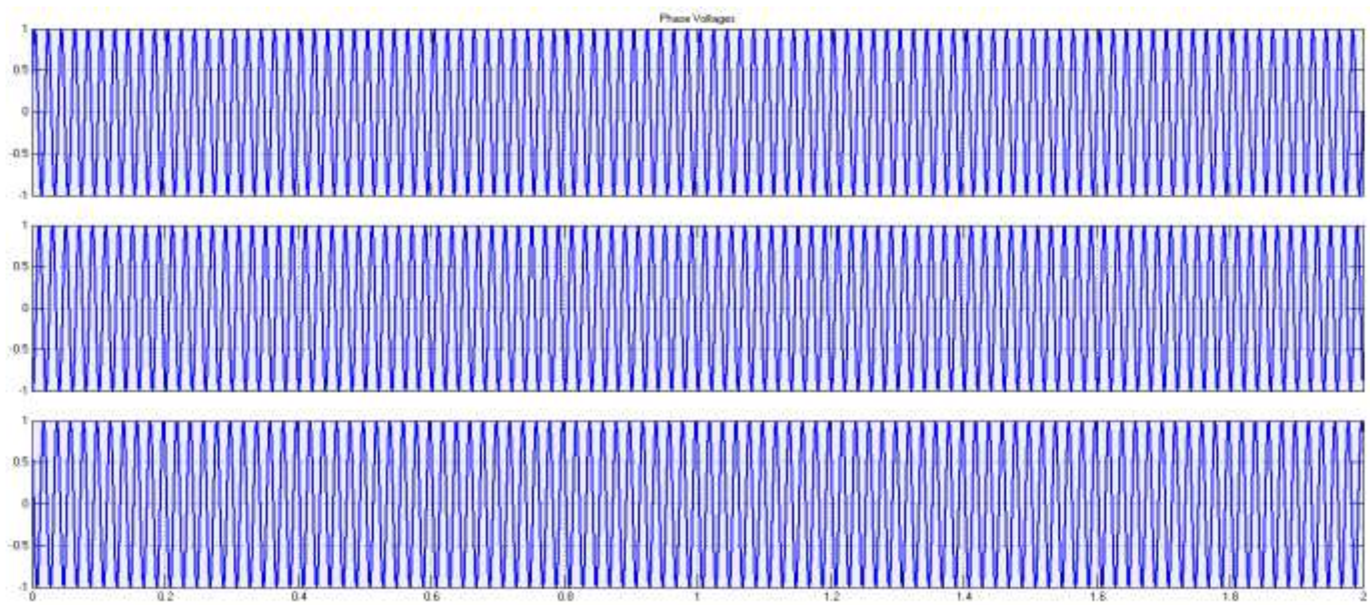

FIGURE 4: Three phase sine wave

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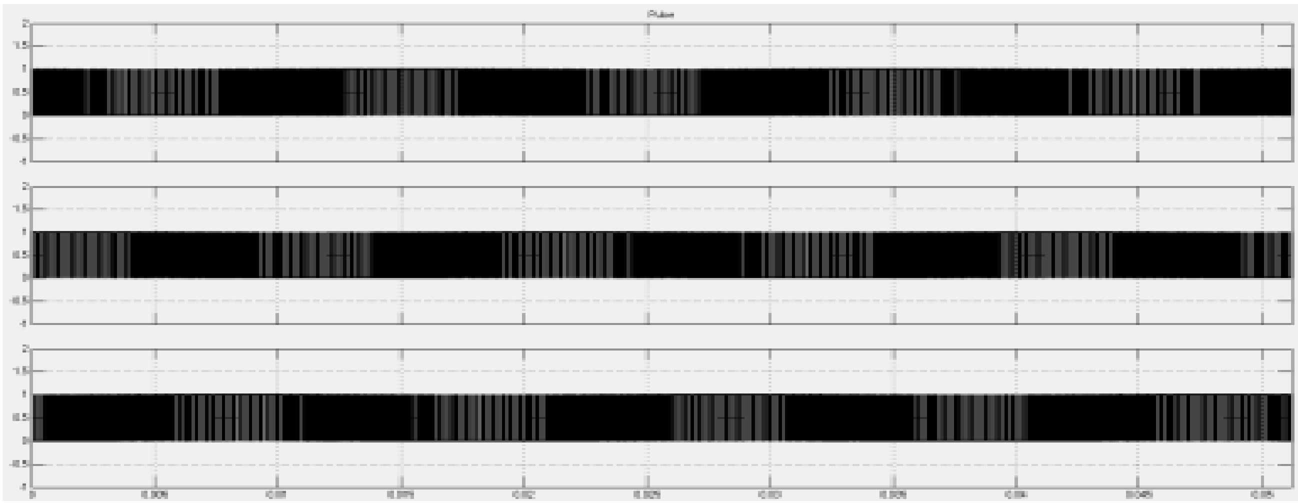

FIGURE 5: PWM Pulses

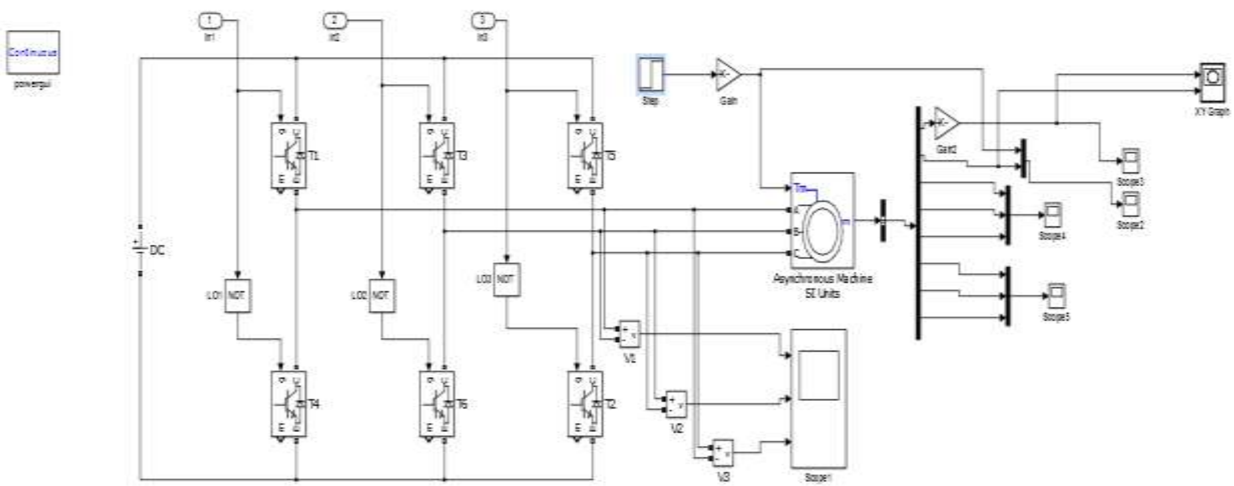

FIGURE 6: Simulink Model for open loop Spwm Inverter fed Induction Motor Drive

A 3-phase squirrel cage motor rated 215 HP (160KW), 400 V, 50Hz 1487 RPM is fed by a 3-phase IGBT inverter connected to a DC voltage source of 400V is taken for simulation. The inverter is modeled using 6 IGBT's and the motor by the "Asynchronous Machine" block as shown in fig 7. The load torque applied to the machine's shaft at step time of 1 sec [2].

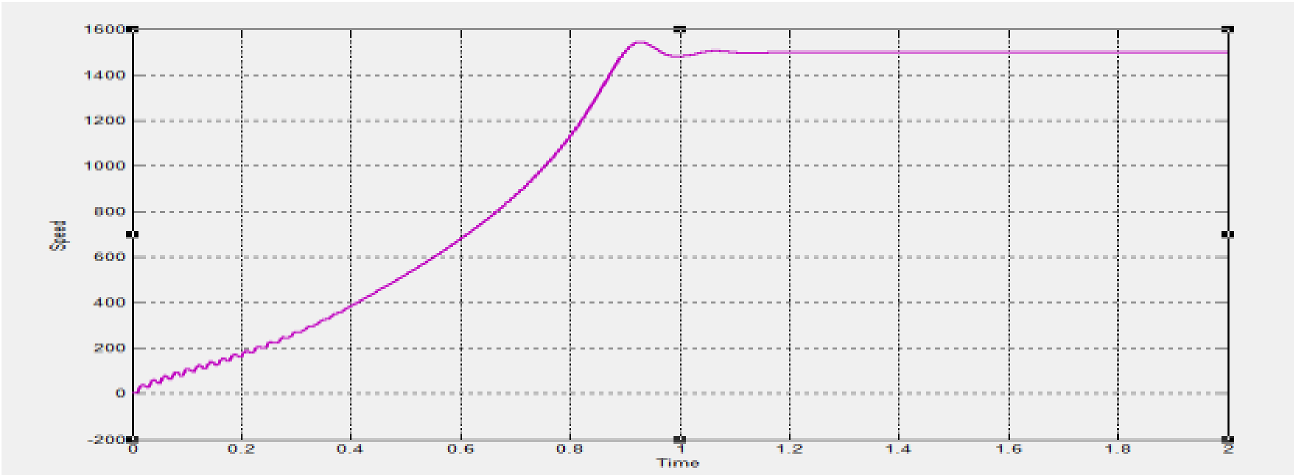

FIGURE 7: Speed of the motor

By starting from zero speed and applying the voltages, the acceleration of the machine can be obtained either with or without a load on the shaft. When there is no load, it is called the free acceleration. Since friction and windage losses were not included, the motor reaches synchronous speed. when the load is applied at time 1 sec ,there is slight reduction in speed which can be observed in figure 8 and after some time it reaches to synchronous speed and and speed becomes steady.

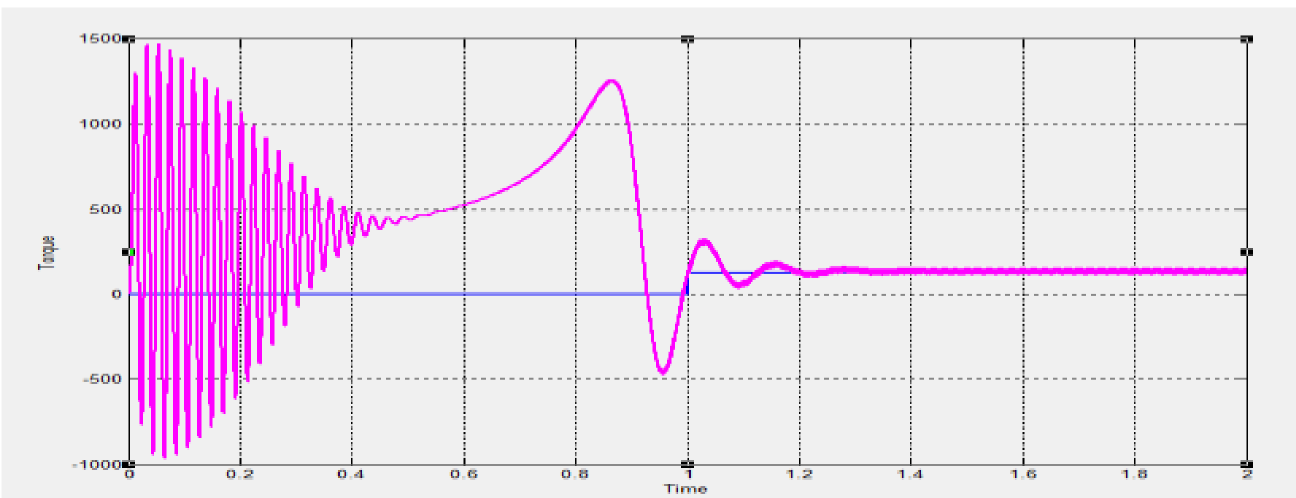

FIGURE 8: Torque (Tm and Te of the motor)

Theoretically, it show the steady-state torque-speed characteristic, but the reality is the motor is subjected to pulsating torques during the startup. In the electromagnetic torque waveform Te the noise introduced by the PWM inverter is also observed. However, the motor's inertia prevents this noise from appearing in the motor's speed waveform. The mechanical torque Tm is applied at time 1 sec. The transient oscillation of torque for a load change from no load torque to rated torque condition is observed. Transients occur more during the load less condition rather than the loaded condition.

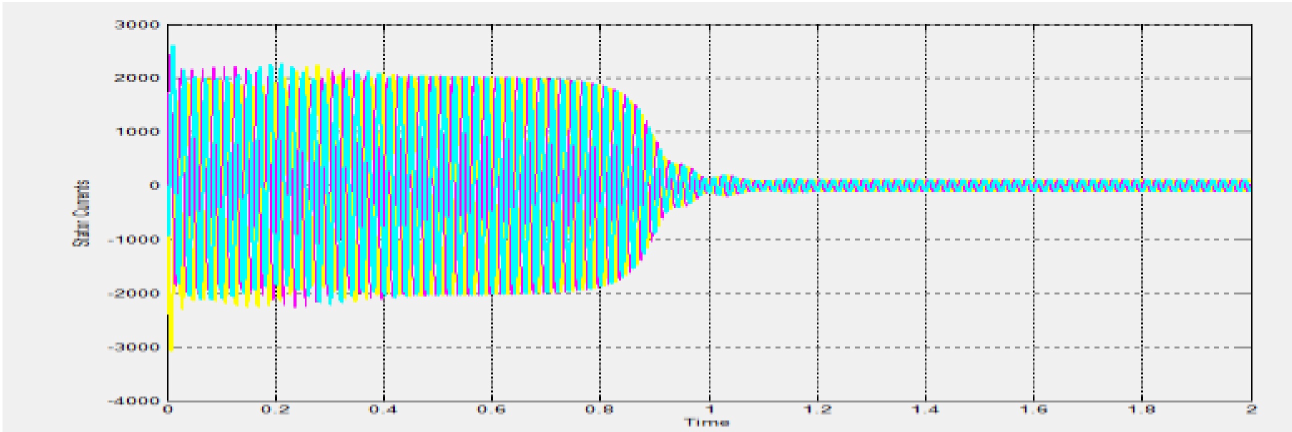

FIGURE 9: Stator Currents

Fig 9 during the free acceleration of the motor shows the stator phase currents as a function of time. Their frequency is essentially constant at 560 Hz, compare to the rated current the amplitude is much larger until the machine reaches breakdown torque[2]. Once the machine reaches synchronous speed, the motor draws only a small current to provide the excitation and the losses of the stator and rotor windings.

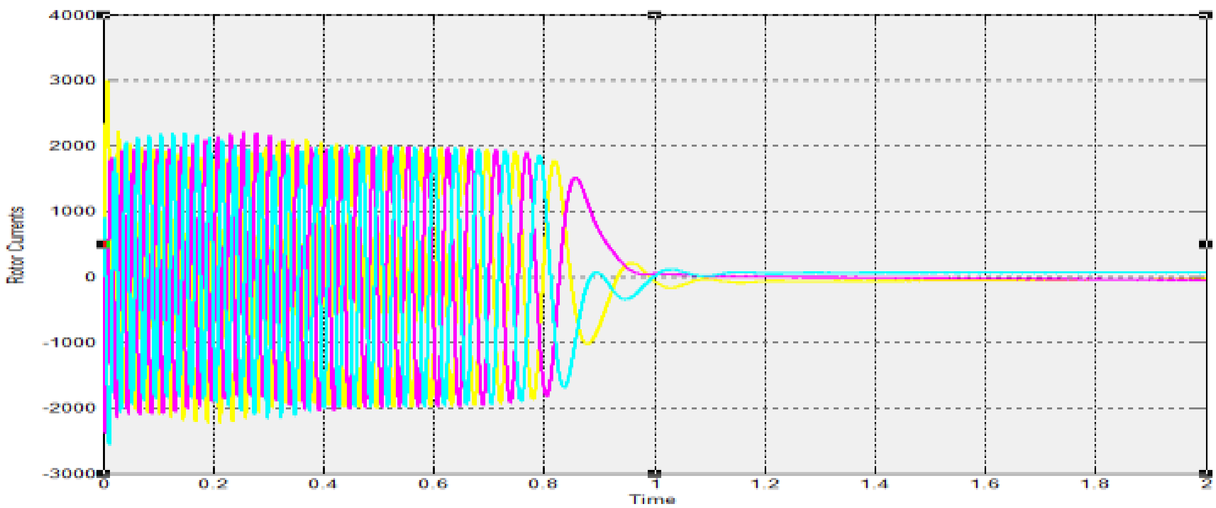

FIGURE 10: Rotor Currents

Fig 10 clearly show that the frequency of the rotor currents changes with the speed of the machine. At start, the rotor currents have a 60 Hz frequency, but the frequency drops as the motor accelerates, reaching very low frequencies as the motor nears synchronous speed. Of course, once the motor reaches synchronous speed there is no relative motion between the rotor squirrel- cage bars and the rotating magnetic field[3]. Thus the current in the rotor bars drops to zero as shown in the Fig 11.

Fig11 shows the Torque-Speed characteristic of the motor. There is a pulsating torque during starting of the motor, after it reaches synchronous speed there is an oscillatory behavior. The oscillating nature of speed torque curve is due to second order differential equation.

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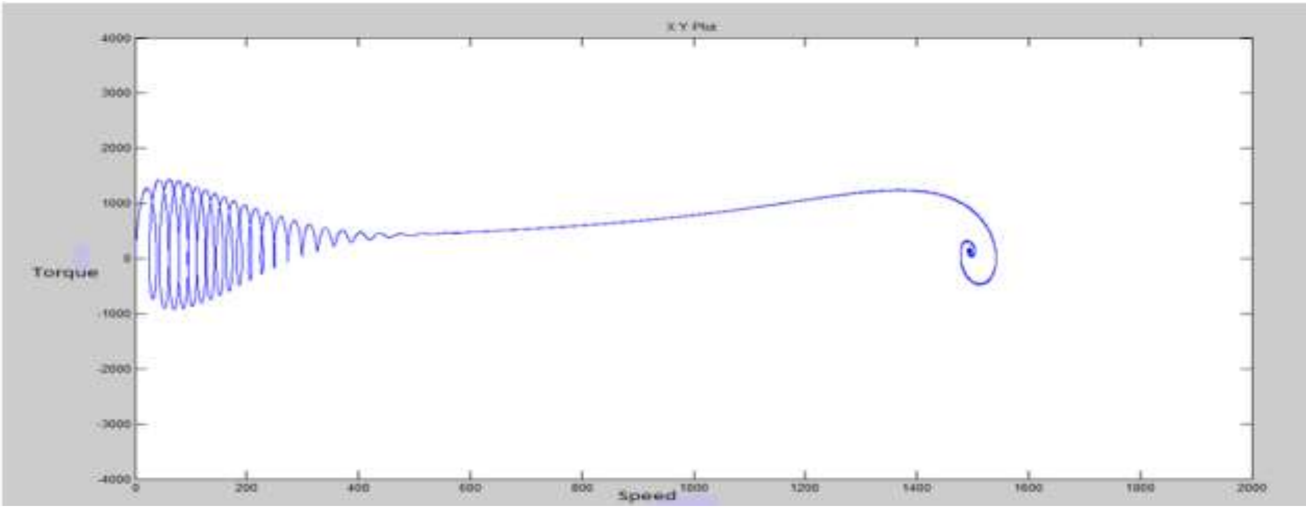

FIGURE 11: Torque-Speed Characteristics

IV. CONCLUSION

In this paper, implementation of modular Simulink model for induction machine simulation has been studied. A simulation of 215hp motor is done and analysis of speed, torque, Stator current, Rotor current and Torque speed characteristic is done .A SPWM technique is used to control the gating pulses of the inverter. There are fluctuations in the starting of rotor currents, electromagnetic torque but this is absent in speed. This is because of machine's inertia. This is clearly visible in scopes.

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