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Induction Motor Mathematical Model Fed By Cascaded MLI

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ABSTRACT
Multilevel inverters have drawn tremendous interest in the power industry as it is easy to produce a high-power, high voltage inverter with the multilevel structure because of the way in which device voltages stresses are controlled. The unique structure of multilevel inverters allow them to reach high voltages with low harmonics. Cascaded multilevel inverters has gained more interest because of its advantages over other MLI configurations like diode-clamped, flying capacitor inverter. In this paper seven level cascaded MLI is simulated and is fed to mathematical model of induction motor and the results are evaluated.
Keywords:cascaded mli, diode clamped, flying capacitor, high power, low harmonics, induction motor

I. INTRODUCTION

The multilevel voltage source inverters unique structure allows them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized switching devices, for high-voltage, high power applications. The general structure of the multilevel converter, which has a multiple of the usual six switches found in a three-phase inverter, is to synthesize a sinusoidal voltage from several levels of voltages, typically obtained from capacitor voltage sources. The main motivation for such converters is that current is shared among these multiple switches, allowing a higher converter power rating than the individual switch VA rating would otherwise allow with low harmonics. As the number of levels increases, the synthesized output waveform, a staircase like wave, approaches a desired waveform with decreasing harmonic distortion, approaching zero as the number of levels increases. There are three main types of transformer less multilevel inverter topologies, which have been received considerable interest from high-power inverter systems are the flying-capacitor inverter, the diode-clamped inverter, and the cascaded H-bridge inverter. In this paper we choose to work on cascaded H-bridge inverter due to its advantages:

1. It uses fewer components than the other types.
2. It has a simple control, since the converters present the same structure.
3. Soft-switching technique can be used to reduce switching losses and devices stresses.

Because of these advantages, the cascaded inverter bridge has been widely applied to such areas as HVDC, SVC, stabilizers, and high-power motor drives.

II. CASCADED H-BRIDGE MLI

Cascaded MLI consists of series H-Bridges, each H-Bridge consists of four switches connected as in fig.1

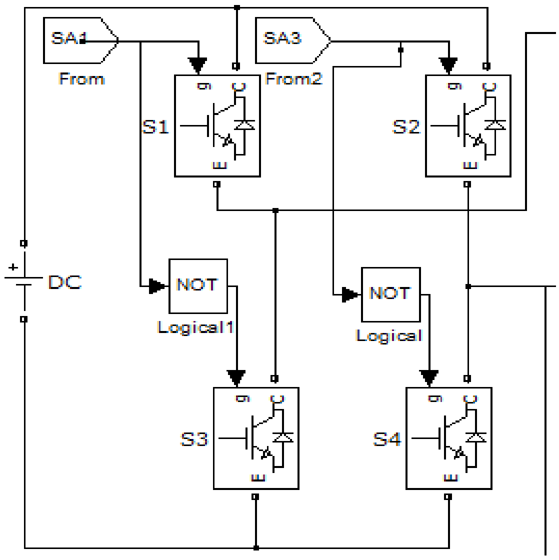


Fig.1. single cascaded bridge

The output generated by each H-Bridge is of three different levels i.e, +Vdc, 0, -Vdc by connecting dc source to the ac output side by different combinations of the four switches, S1,S2,S3,S4. Turning on S1, S4 gives +Vdc. Turning on S2,S3 yields –Vdc. Turning off all switches gives 0V. In the same manner output at each level is obtained. The switching sequence for a single bridge is as follows the firing pulse for upper

switches S1,S3 has phase delay of 180^0 . The lower switches are compliments firing pulse given through NOT gate. The same holds good for any no of bridges connected either in single phase or three phase. Here three phase cascaded MLI is simulated. For N-level output no of bridges required per phase is given by N=2n+1.
Where n= no of bridges
For 7 level three bridges are connected in each leg

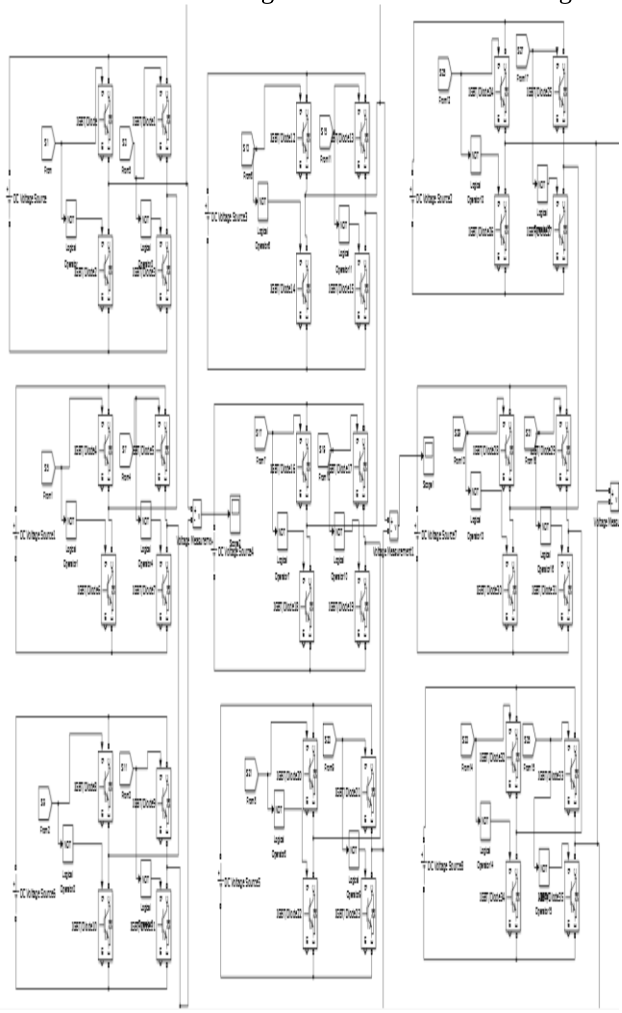


Fig2. Three phase Cascaded MLI

Controlling the conducting angles at different inverter levels can minimise the harmonic distortion of the output voltage. As the no of levels increases the output voltage tends to sinusoidal.

2.1 Switching is implemented by sinusoidal pulse width modulation. In pulse width modulation the firing pulses required for semiconductor switches is obtained by comparing reference wave with carrier wave. In sinusoidal pulse width modulation technique sinusoidal wave is taken reference wave and triangular wave as carrier wave. The output of inverter i.e. amplitude and frequency can be varied by changing the reference wave amplitude and carrier wave frequency respectively. Amplitude modulation index is ratio of reference wave amplitude to carrier wave amplitude $m_a = V_r / V_c$. The frequency modulation is defined as ratio of carrier wave frequency to reference wave frequency $m_f = f_c / f_r$. In this paper the amplitude modulation is taken as $m_a = 1$ and the frequency modulation $m_f = 21$. The pulses are generated as below in figure

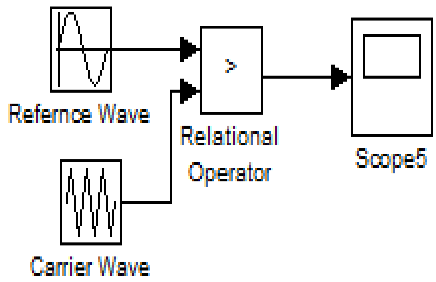


Fig.3. pwm comparator

The firing pulses are given with phase delay of 120^0 to each leg. The switches in a single leg are connected as shown in fig.4

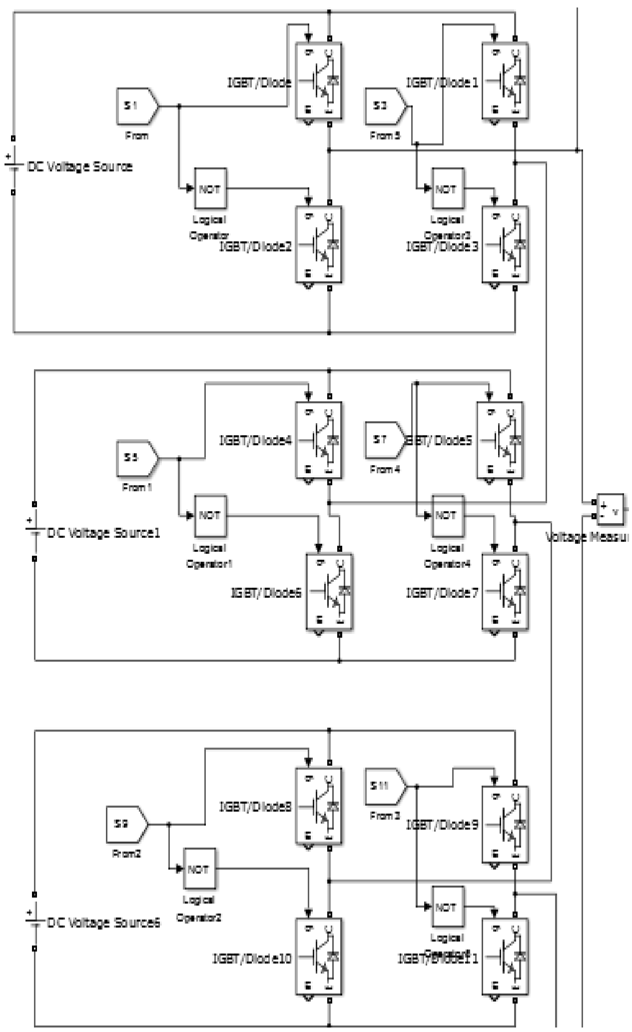


Fig.4. single leg of three phase inverter

In a single bridge the switches in two legs are phase shifted by 1800, switches in single leg are complimentary . The phase delay among three series connected bridges is 600. In the same way the other two legs are connected and switching is done in the similar fashion.

III. MODEL OF TWO-PHASE INDUCTION MOTOR

The following assumptions are made to derive the dynamic model:

(i) uniform air gap:

(ii) balanced rotor and stator windings. withsinusoidally distributed mmf:

(iii) inductance vs. rotor position is sinusoidal: and

(iv) saturation and parameter changes are neglected.

The modeling is done in two axis model where stator and rotor windings are placed on two rotating axis i.e. α-axis and β-axis. The rotor windings are displaced by some electrical degrees from the stator windings. Θr is the electrical rotor position at any instant . The terminal voltages of the stator and rotor windings can be expressed as the sum of the voltages drops in resistances and rates of change of flux linkages, which are products of currents and inductances. The equations are as follows

$$Vqs = Rqiqs + p(Lqqiqs) + p(Lqdids) + p(Lq\alpha i\alpha) + p(Lq\beta i\beta) \quad (1)$$

$$Vds = p(Ldqiqs) + Rdids + p(Lddids) + p(Ld\alpha i\alpha) + p(Ld\beta i\beta) \quad (2)$$

$$V\alpha = p(L\alpha qiqs) + p(L\alpha dids) + R\alpha i\alpha + p(L\alpha\alpha i\alpha) + p(L\alpha\beta i\beta) \quad (3)$$

$$V\beta = p(L\beta qiqs) + p(L\beta dids) + p(L\beta\alpha i\alpha) + R\beta i\beta + p(L\beta\beta i\beta) \quad (4)$$

Where p- differential operator d/dt

iqs, ids- stator currents

iα,iβ- rotor currents

Lqq,Ldd,Lαα,Lββ are self inductances

The mutual inductances between the stator and rotor windings are a functions of the rotor positions, Θr and they are assumed to be sinusoidal functions because of the assumption of sinusoidal mmf distribution in the windings. Symmetry in windings and construction causes the mutual inductances between one stator and one rotor winding to be the same. The above equations shows that induced voltages are rotor position dependent, to avoid such dependency transformation is done into d-q axis. The machine equations referred to stator are obtained as

$$Vqs = (Rs+Lsp)\, iqs + Lmpiqr \quad (5)$$

$$Vds = (Rs+Lsp)ids + Lmpidr \quad (6)$$

$$Vqr = Lmpiqs - Lm\Theta rids + (Rr+Lrp)iqr - Lr\Theta ridr \quad (6)$$

$$Vdr = Lm\Theta riqs + Lmpids - Lr\Theta riqr + (Rr+Lrp)idr \quad (7)$$

Simulink Implememtation: The three phase voltage equations are transformed into two phase. By state space model currents are obtained from the voltage equations(5-7).

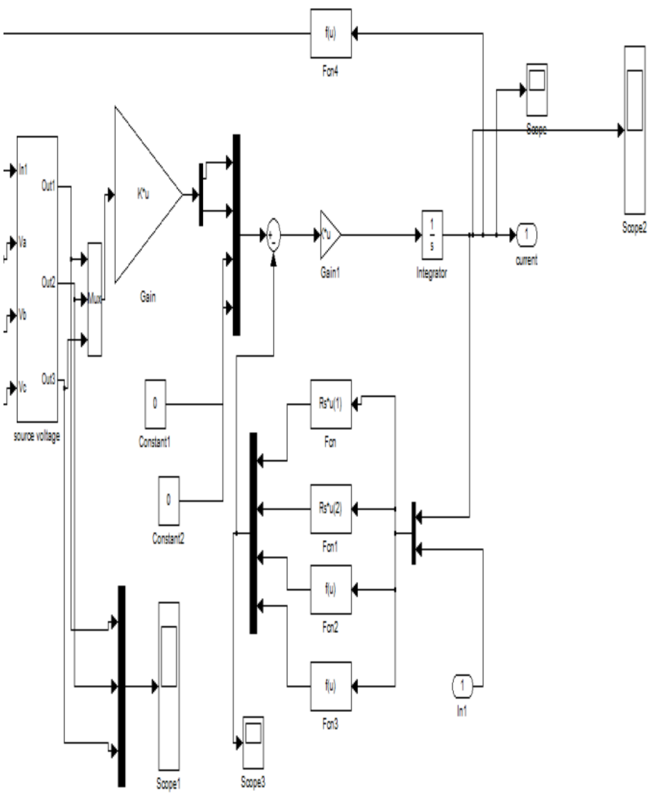


Fig.5 Current block

From the obtained currents electromagnetic torque is found and is given as

Te = PLm/3(idriqs-iqrids)

ids, iqs, idr,iqr- stator and rotor currents

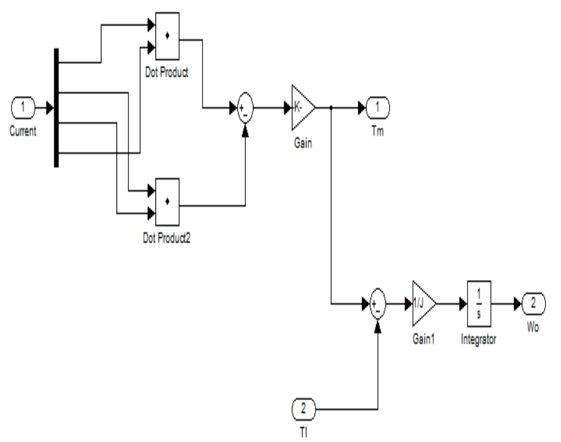


Fig6. Torque Block

From the torque balance equations and neglecting viscous friction, the rotor
speed Vo may be obtained as follows :

$$\omega_0 = \int_{\tau=0}^{t} \frac{T - T_L}{J} \mathrm{d}\tau$$

where J is the moment of inertia of the rotor
TL is the load torque.

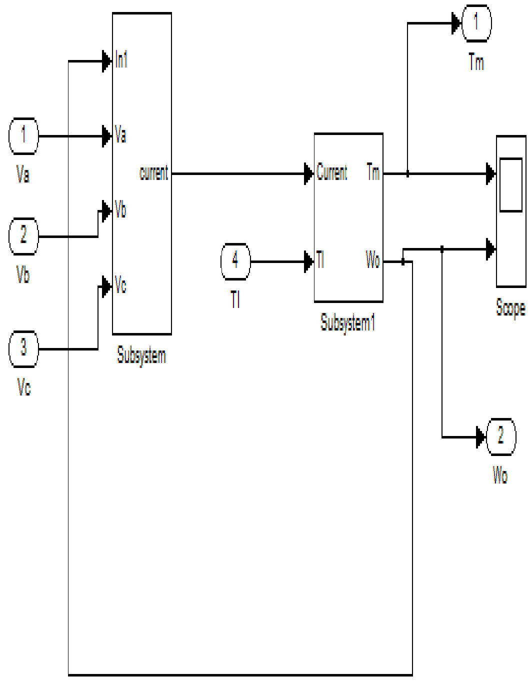
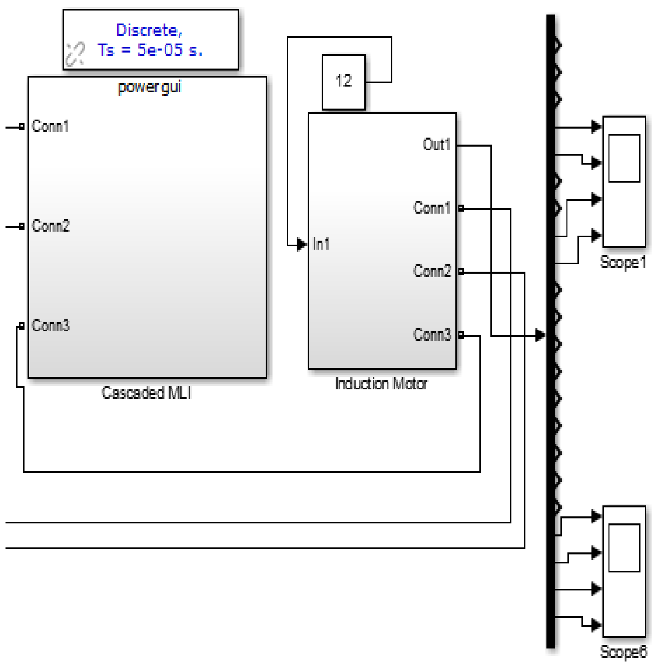


Fig7. Induction motor Block



SIMULATION RESULTS

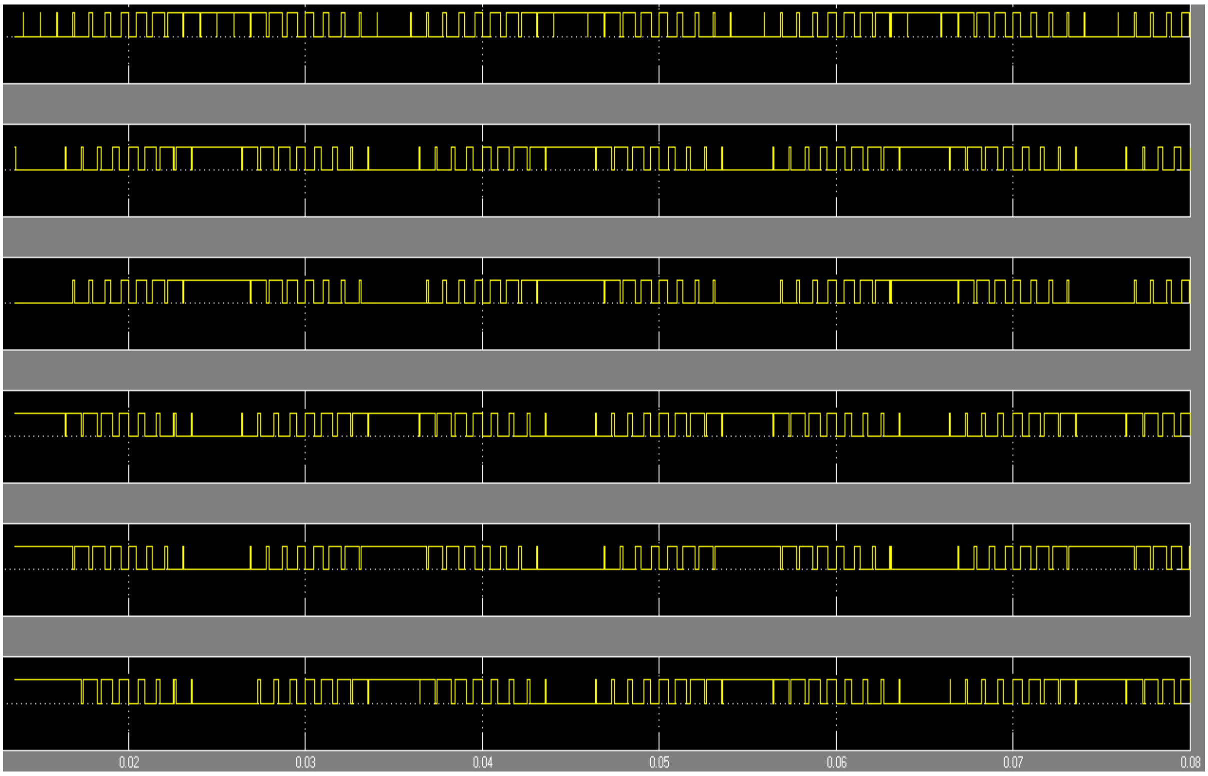


Fig8. Pulses for single leg

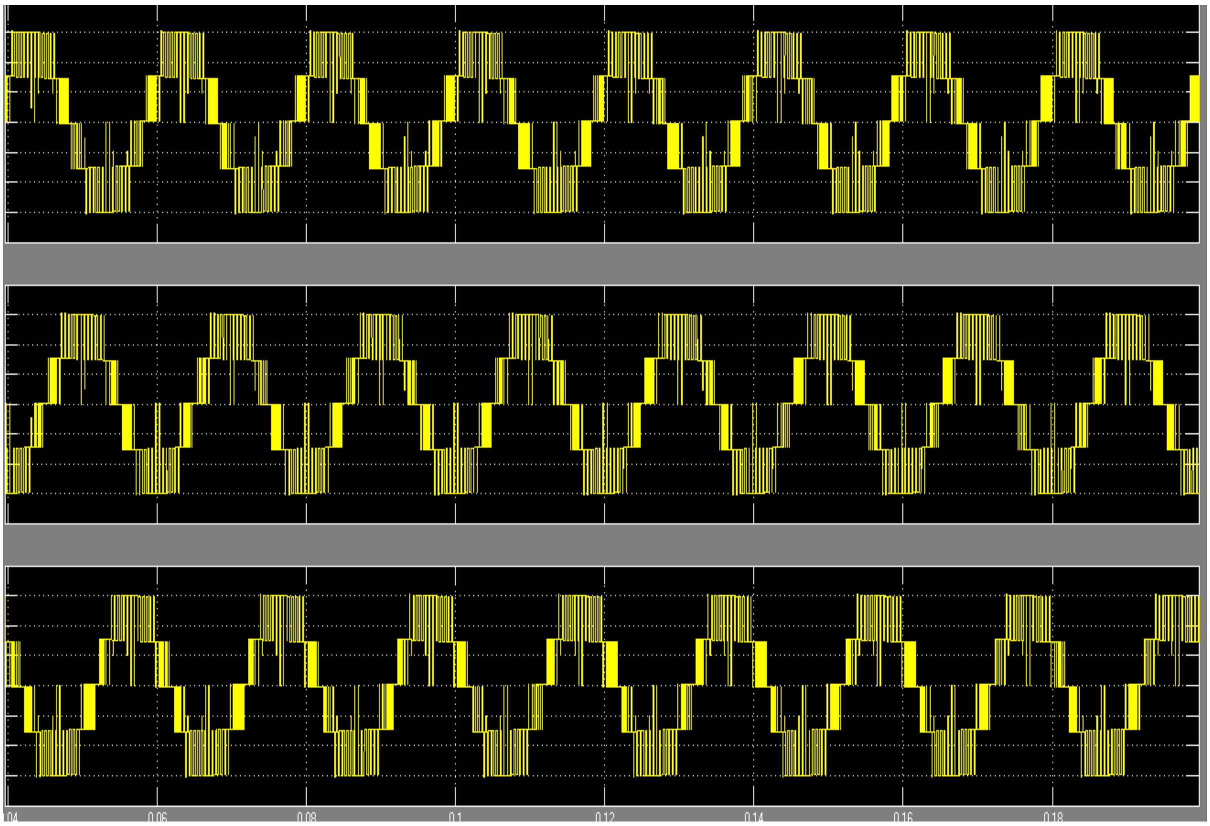


Fig9.Threephasesevenlevelvoltages

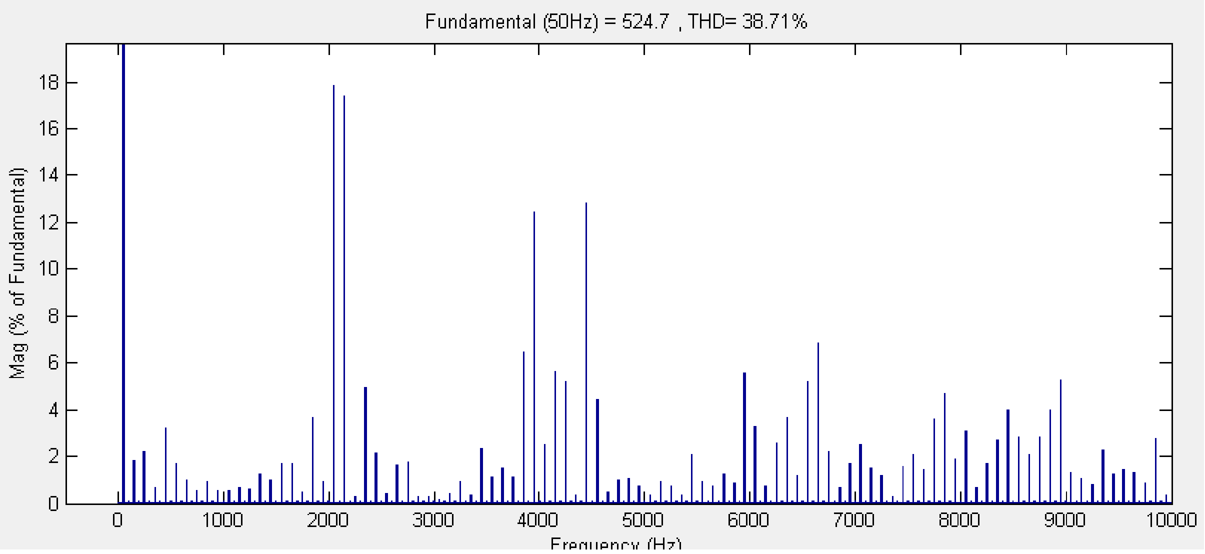


Fig.10THDanalysis

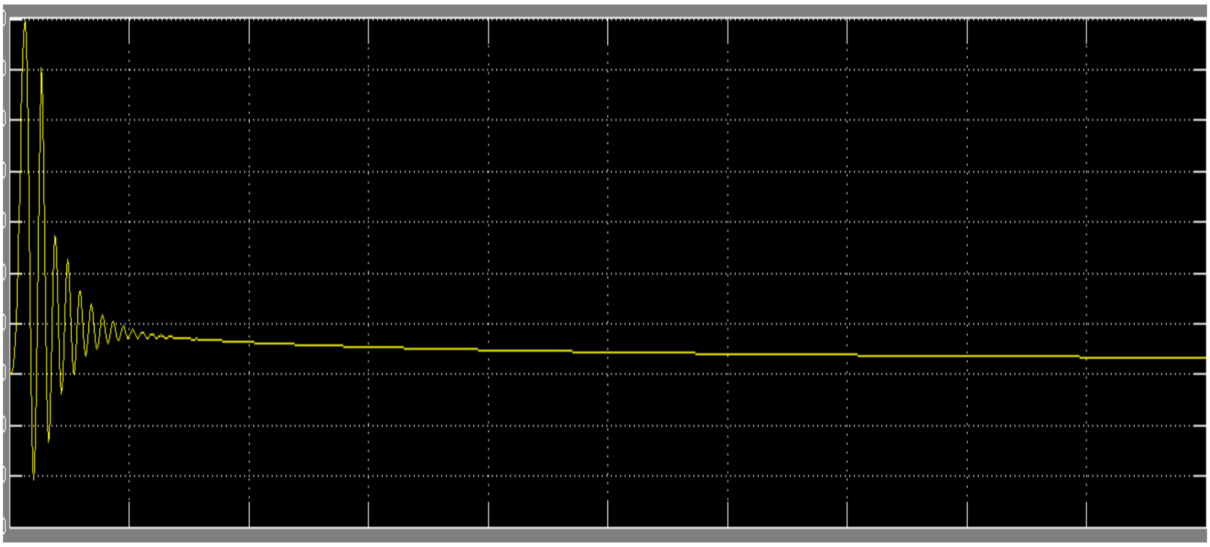


Fig11. Induction motor Torque curve

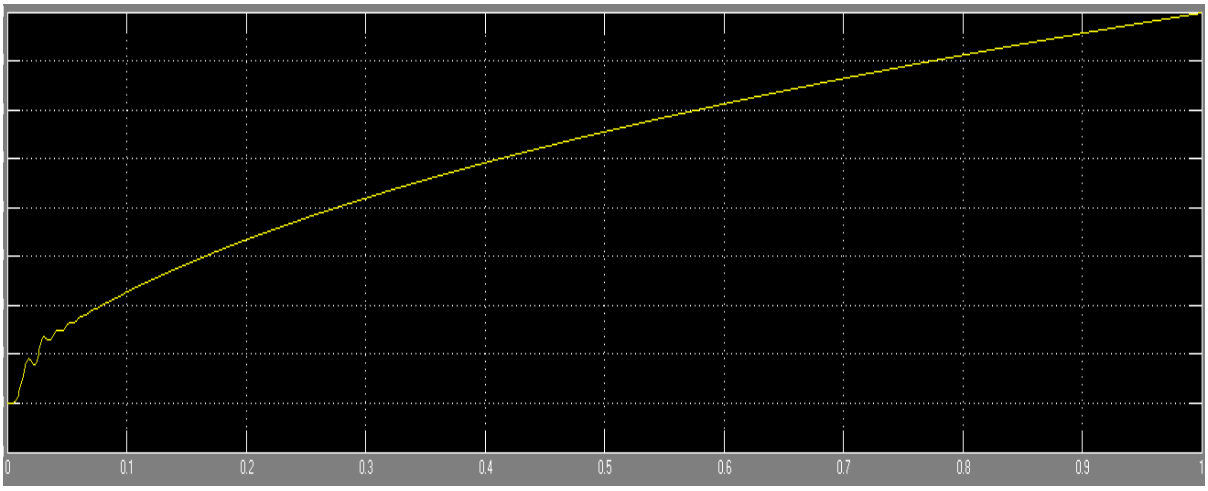


Fig112. Speed curve

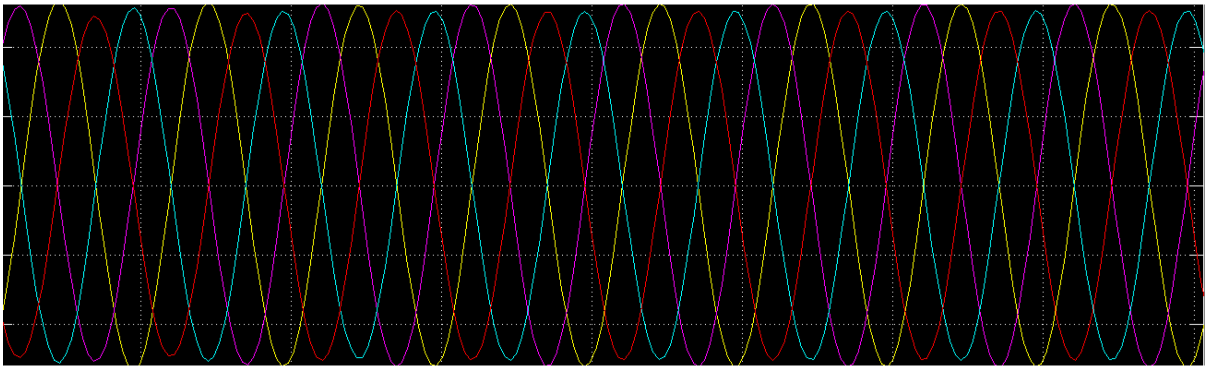


Fig13. Motor Currents

CONCLUSION

Three phase seven level cascaded multilevel inverter is simulated. The Total harmonic distortion is found. The three pahse voltages are fed to mathematical model of induction motor. The motor characteristics like torque, currents are obtained.

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