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Performance Analysis of BLDC MLI Drive

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ABSTRACT
BLDC motors are used in wide range from very small motors used in hard disk drives to large motors used in electric vehicles as it has more advantages over induction motors because it has permanent magnets in rotor assembly generates steady magnetic field. The multilevel inverters are preferred over conventional inverters as the voltage stress across each semiconductor switches is the voltage of one capacitor. The mli gives high voltages with low harmonics and as no of levels increases output tends to sinusoidal. The most used multilevel inverter configurations are diode clamped, flying capacitor, cascaded mli. In this paper five level diode clamped mli, cascaded mli are simulated using MATLAB/SIMULINK. The performance characteristics of bldc motor is observed when fed by each of these configurations.
Keywords: Brushless DC Motor, diode clamped, flying capacitor, cascaded, permanent magnets.

I. INTRODUCTION

Conventional DC motors have attractive properties such as high efficiency and linear torque-speed characteristics. The control of dc motors is also simple and does not require complex hardware. However, the main drawbacks of the DC motor is the need of periodic maintenance. The brushes of the mechanical commutator eventually wear out and need to be replaced. The mechanical commutator has other undesirable effects such as sparks, acoustic noise and carbon particles coming from the brushes. Brushless DC motor can in many cases replace conventional DC motors. Despite the name, BLDC motors are actually a type of permanent magnet synchronous motors. They are driven by dc voltage but current commutation is done by solid state switches. The mechanical commutator is replaced by electronic commutator. The commutation instants are determined by rotor position and position of the rotor is detected either by position sensors or by sensorless techniques. BLDC motor have many advantages over conventional dc motors:

- High dynamic response
- High efficiency
- Higher speed operation
- Higher speed range
- Higher torque-weight ratio

The PMSMs are classified on the basis of the wave shape of their induced emf, i.e., sinusoidal and trapezoidal. The sinusoidal type is known as PMSM and the trapezoidal type are called PM dc brushless machine.

II. SIMULATION OF DIODE CLAMPED MLI

Fig. 1 shows a five-level diode-clamped converter in which the dc bus consists of four capacitors C1,C2,C3,C4. For dc-bus voltage Vdc, the voltage across each capacitor is, Vdc/4 and each device voltage stress will be limited to one capacitor voltage level Vdc/4 through clamping diodes. To synthesize staircase voltage, the neutral point n is considered as the output phase voltage reference point. There are five switch combinations to synthesize five level voltages across a and n.

1) For voltage level Van= Vdc/2, turn on all upper switches S1-S4
2) For voltage level Van= Vdc/4, turn on three upper switches S2-S4 and one lower switch S1'.
3) For voltage level Van= 0, turn on two upper switches S3,S4 and two lower switch S1' and S2'
4) For voltage level Van= -Vdc/4, turn on one upper switches S4 and three lower switch S1'-S3'.
5) For voltage level Van= -Vdc/2, turn on all lower switches S1'-S4'.

Four complementary switch pairs exist in each phase. The complementary switch pair is defined such that turning on one of the switches will exclude the other from being turned on. The four complementary pairs are (S1,S1'), (S2,S2'), (S3,S3'), and (S4,S4').
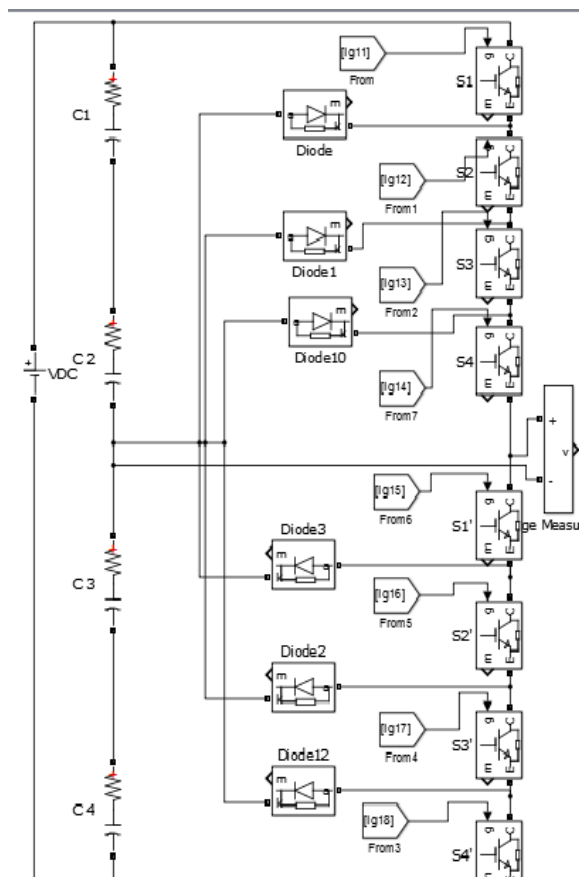
pulses where reference wave is compared with carrier wave. In this technique sinusoidal is taken as reference wave and triangular wave as carrier signal. For n level diode clamped inverter n-1 carrier waves are compared with reference signal.
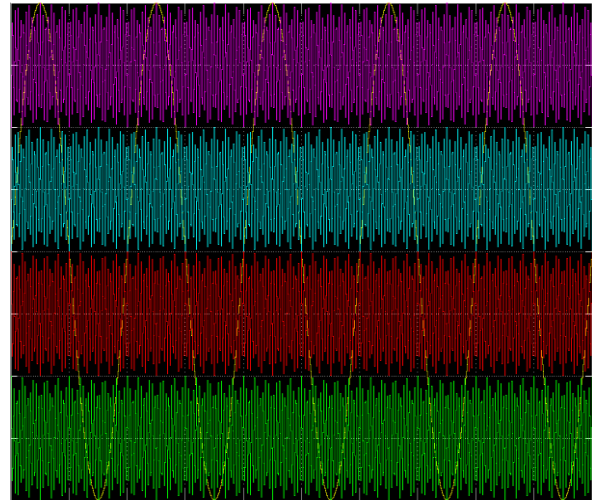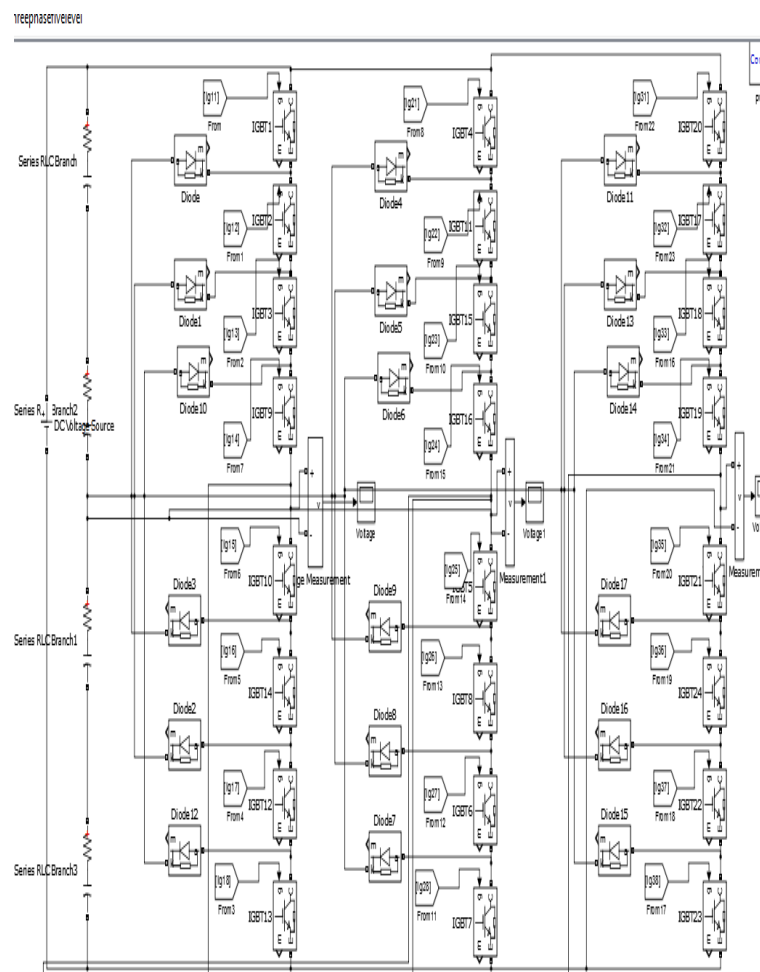

Fig.2 Comparision of reference and carrier wave

Fig.1 Diode Clamped Inverter Leg

Switching Technique: sinusoidal pulse width modulation technique is used for generating firing

Fig.3 Three phase diode clamped Inverter

III. SIMULATION OF CASCADED H-BRIDGE MLI

Simulation of MLI is carried out by using MATLAB. Cascaded MLI consists of series H Bridges, each H-Bridge consists of series H- Bridges, each Bridge consists of four switches as shown in fig.4
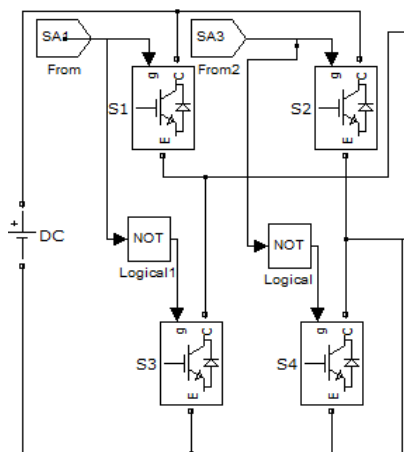
Fig.4 Single cascaded bridge

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.

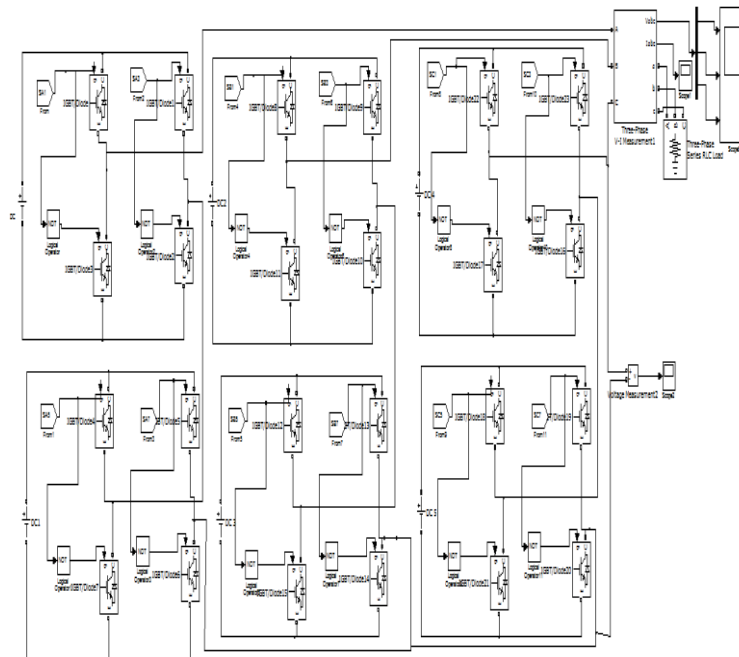Where n= no of bridges

For 5 level require 2 bridges per phase.

Fig.5 Three phase 5 level 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.

A. *Switching Technique*

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
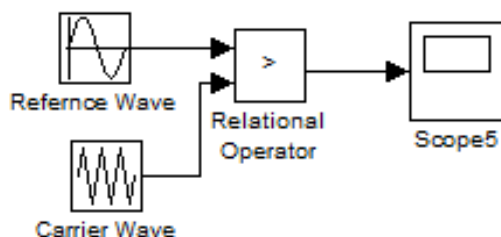

Fig6. Pwm comparator

Here the MLI is three phase 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.7
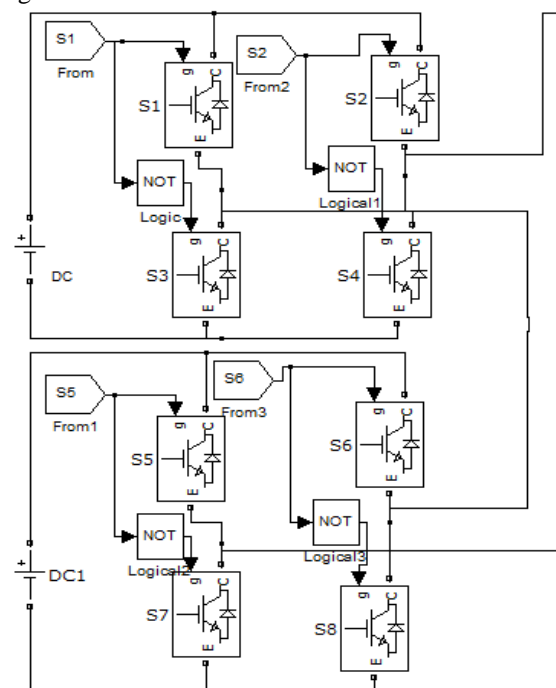

Fig7. Single leg of three phase cacaded mli

The switch S1 and S2 has phase delay of 180^0. Switch S1 and S5 has phase delay of 90^0. Switches S3,S4 are compliment for switch S1, S2 respectively and similarly S7,S8 are compliment to switch S5,S6. In the same the other two legs are

connected and switching is done in the similar fashion.

IV. MODELLING OF BLDC MOTOR

The modelling is carried based on assumptions that

a) the induced currents in the rotor due to stator harmonics are neglected.
b) Iron and stray losses are also neglected.

The stator voltage equations in terms of electrical constants are

$$\begin{bmatrix} Vas \\ Vbs \\ Vcs \end{bmatrix} = \begin{bmatrix} Rs & 0 & 0 \\ 0 & Rs & 0 \\ 0 & 0 & Rs \end{bmatrix} \begin{bmatrix} ias \\ ibs \\ ics \end{bmatrix} + p \begin{bmatrix} La - Lm & 0 & 0 \\ 0 & Lb - Lm & 0 \\ 0 & 0 & Lc - Lm \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} + \begin{bmatrix} eas \\ ebs \\ ecs \end{bmatrix}$$

Where Rs - Rotor resistance

La, Lb, Lc – Self inductance of each phase windings
Lm – Mutual inductance
ias, ibs, ics – Currents in stator windings
eas, ebs, ecs – induced back emf's.
The electromagnetic induced emfs is given as

$$e_{as} = f_{as}(\Theta)\lambda_p w_m$$
$$e_{bs} = f_{bs}(\Theta)\lambda_p w_m$$
$$e_{cs} = f_{cs}(\Theta)\lambda_p w_m$$

where f(Θ) indicates that induced emf is dependent on rotor position
The electromagnetic torque is given by

$$T_e = [e_{as}i_{as} + e_{bs}i_{bs} + e_{cs}i_{cs}] \, 1/w_m (N\text{-}m)$$

Speed of motor is obtained as

$$w_m = \int ((T_e - T_l - Bw_m)/ J)$$

Where wm – rotor speed in mechanical rad/s
    B – friction coefficient
    J – Inertia of motor shaft
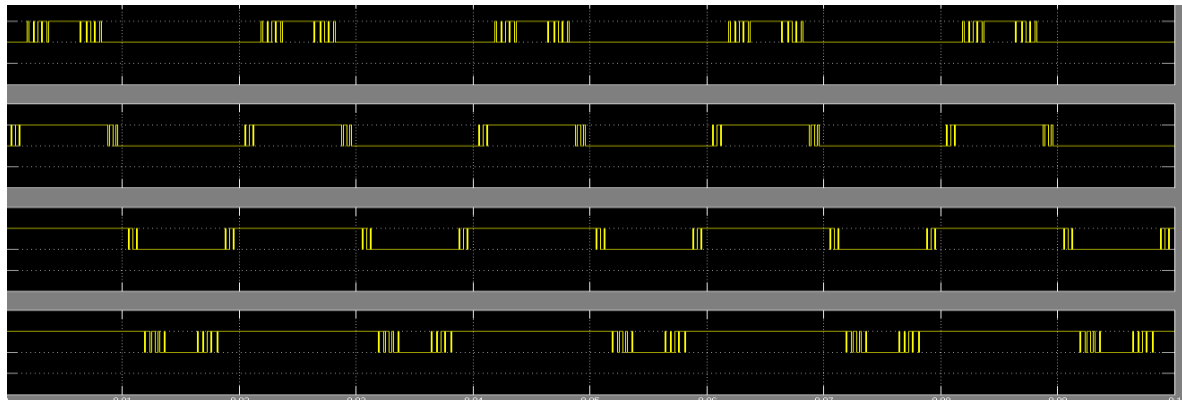
V. SIMULATION RESULTS

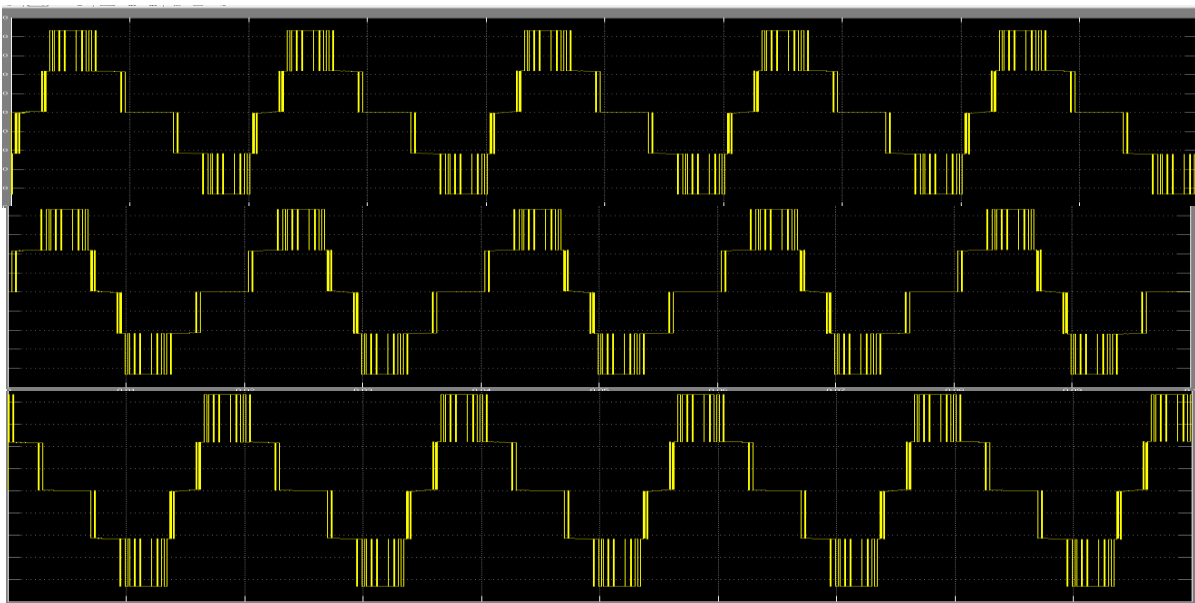Fig8. Firing pulses for five level diode clamped inverter

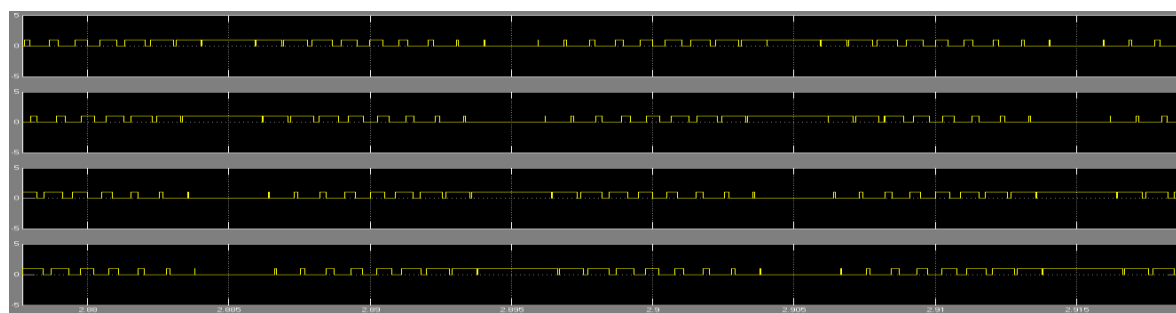Fig9. Three phase voltages of diode clamped inverter
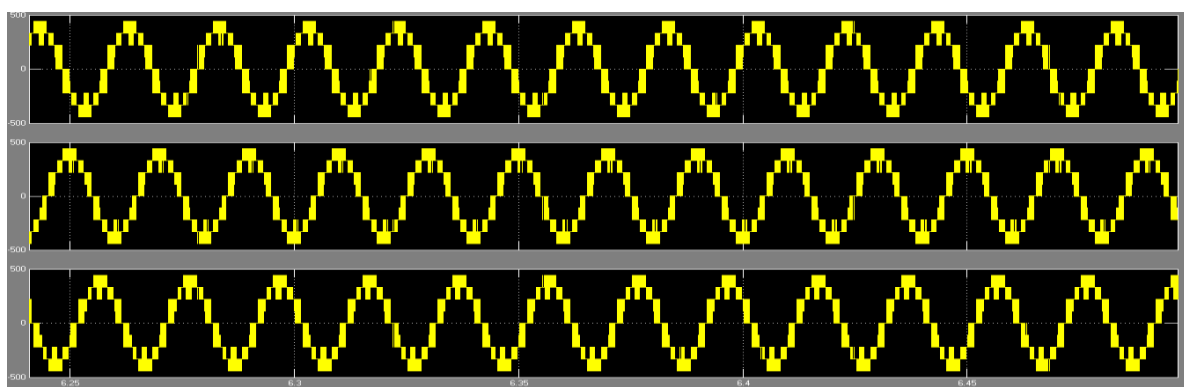
Fig10. Firing pulses for five level cascaded mli

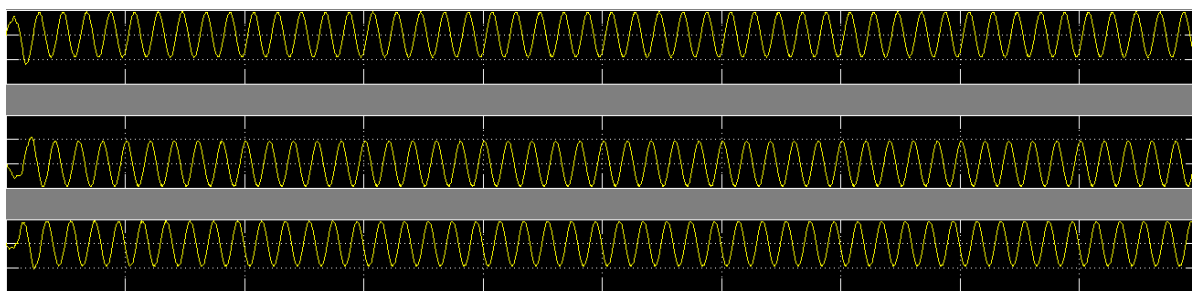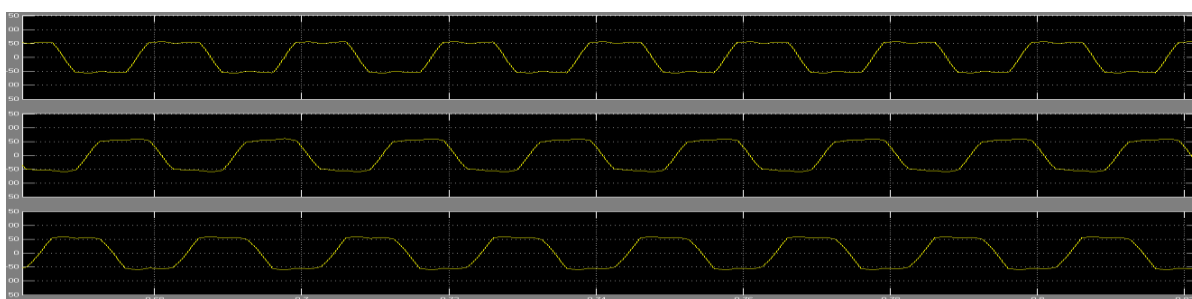Fig11. Three phase voltage waveforms of cascaded mli
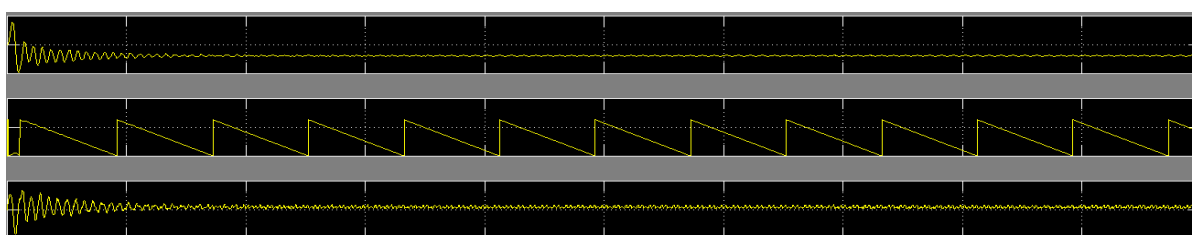

Fig12. Stator currents

Fig13. Trapezoidal Back Emf

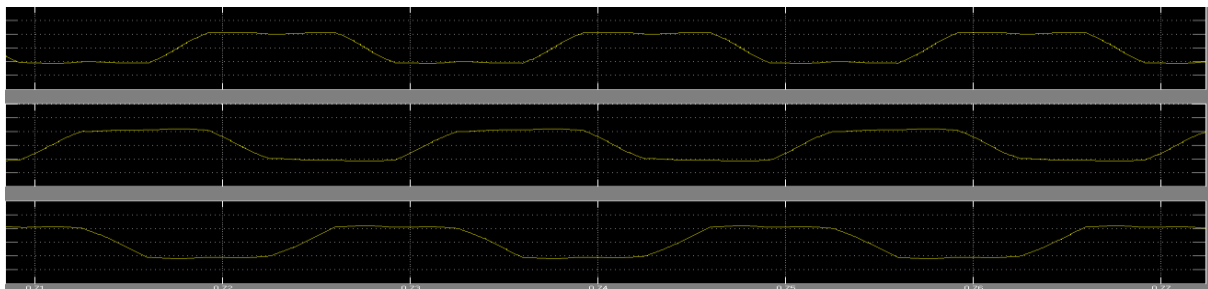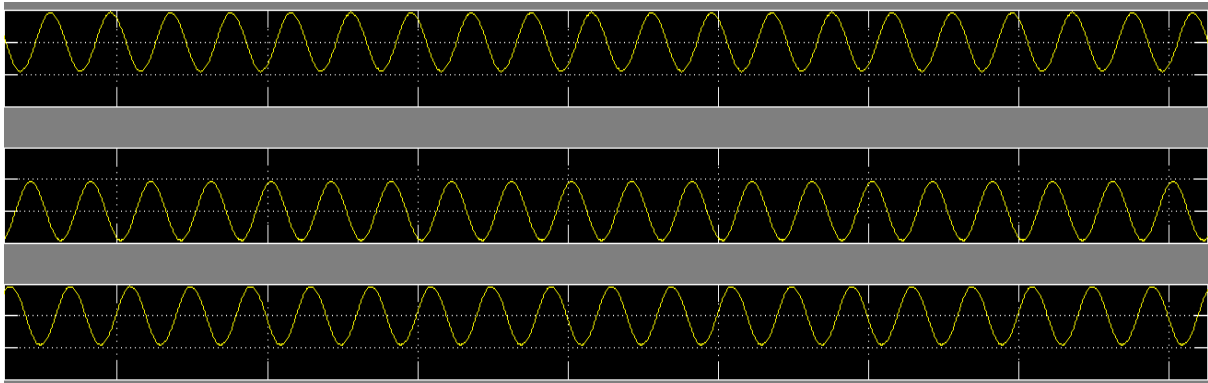Fig14.Speed, Rotor position, Electromagnetic torque

Fig15. Trapezoidal Back Emf
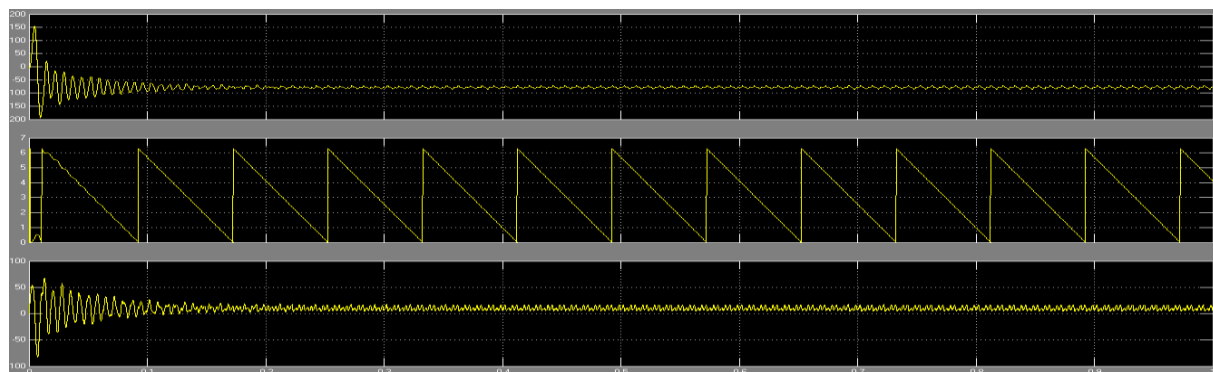

Fig16. Stator Currents

Fig17. Speed, Rotor position, Electromagnetic torque

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