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A Soft Switching Control Strategy Based On Interleaved Boost Converter for BLDC Motor Drive

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ABSTRACT

In this paper, Zero-Voltage-Transition (ZVT) based two-cell interleaved boost Power Factor Correction (PFC) converter for permanent magnet brushless DC motor (PMBLDCM) drive has been proposed.For achieving soft switching, only one switch is used in auxiliary circuit which reduces the torque ripple and switching losses. In this proposed control strategy, the DC link voltage is which is proportional to the desired speed of the BLDC motor controlled with interleaved boost converter. In this paper, six switch and four switch VSI is implemented with interleaved boost converter topology. A comparison is made between the six switch and four switch VSI fed PMBLDC Motor drive and torque Analysis as been done. To validate the proposed work, simulation study is presented. The results showed that proposed converter control strategy operating under soft switching mode improves the efficiency in wide range of the speed control.

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1. INTRODUCTION

A number of soft-switching techniques, gaining the features of zero-voltage switching (ZVS) or zero-current switching (ZCS) for DC-DC converters, have been proposed to reduce the switching losses and to attain high efficiency at increased frequencies [1].In the case of resonant converters the voltage stress on power switches are subjected very high voltage stress especially when these comments are used for high voltage application [2] [3]. The advantage of ZCS and ZVS is in corporated in many resonant converter. There are no extra switches required and hence reduces the cost and making the control scheme simple.

The problem with these converters is voltage stresses on the power switches are very high in the resonant converters, particularly for the high-input dc-voltage applications. Passive snubbers achieving ZVS are attractive [4], [5], as there is no extra active switches are required. In [6], the boost converter for the proposed voltage controlled drive, boost converter is selected because of its high power handling capacity [7] It can be operated as PFC converter when connected between the VSI and the DBR fed from AC mains, besides controlling the voltage at DC link for the desired speed of the airconditioner compressor [8].A detailed performance evaluation of the proposed drive is presente in for an air conditioner compressor driven by a PMBLDC motor [9]-[10].

This paper presents speed control presented of PMBLDC drive fed from six switch VSI and four switch VSI PMBLDC motor drive. PMBLDC motor has high effiency, low maintaince and long life. Due to futures PMBLDC motor has become a very popular. PMBLDC motor many advantages when compared with other type of AC motors. Torque ripple in PMBLDC motor may be related to inverter or motor design factors of the motor, which results non ideal current wave forms. The causes speed oscillations and wear and tear of mechanical portions of the drive, which results in vibration and noise of the motor. Therefore minization of vibrations and noise are considerable issues in PMBLDC drive.

In this paper a new soft switching control strategy has been proposed by a BLDC motor drive for implementation of both six switch and four switch voltage source converter. Further comparison is made between the six switch and four switch three phase inverter fed drive. This reduction of power switches from six to four improves the reliability of the inverter, size of the inverter is reduced and cost of the inverter is also reduces.

2. DESCRIPTION OF PROPOSED INTERLEAVED BOOST CONVERTER

The proposed interleaved boost converter is shown in Figure 1. Inductors L_1 and L_2, MOSFET active switches S_1 and S_2 diodes D_1 and D_2 comprise step-up conversion unit. D_{s1}, D_{s2}, C_{s1} and C_{s2} are the diodes connected back to back and output capacitance of MOSFETs S_1 and S_2, respectively. The input voltage source V_{in}, via the two paralleled converters, replenishes output capacitor C_0 and the load.Inductor L_s is connected in parallel with the two switches to discharge the electric charge stored within the output capacitors C_{s1} and C_{s2} prior to the turn-ON of S_1 and S_2 to fulfill zero-voltage turn- ON (ZVS), and therefore, raises the converter efficiency. To simplify the analysis, L_1, L_2 and C_0 are replaced by current and voltage sources, respectively, as shown in Figure 2.

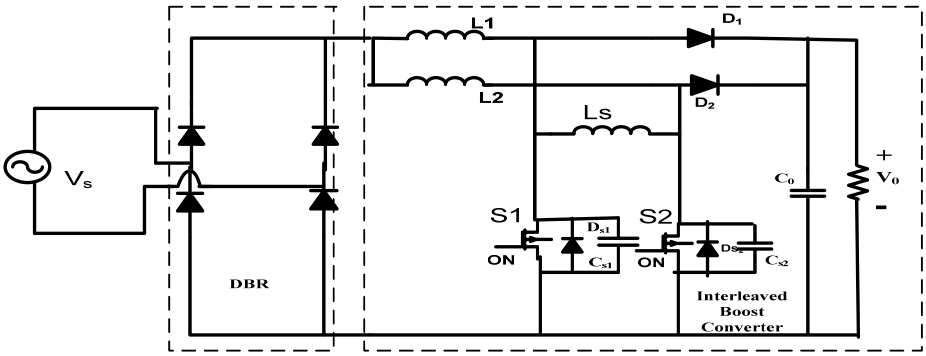

Figure 1. Interleaved boost converter

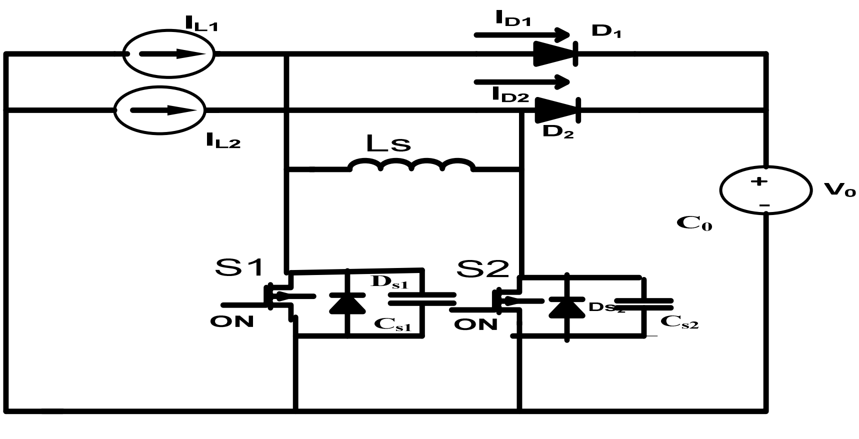

Figure 2. Simplified circuit diagram

The following assumptions are considered before analyzing the circuit operation

1) The output capacitor C_0 is large enough to neglect the voltage ripple at output.
2) The forward voltage drops across diodes D_1, and D_2 and MOSFET S_1, S_2, are neglected.
3) Inductors L_1, and L_2 must have large inductance and currents flowing them are identical constants, i.e., $I_{L1} = I_{L2} = I_L$.

4) Output capacitances of switches C_{S1}, and C_{S2} have the same values, i.e., $C_{S1} = C_{S2} = C_S$.

The two active MOSFET switches S_1 and S_2 are operated with pulse width-modulation (PWM) technique. The gate signal frequencies and duty ratio are similar for the two active switches. There eight modes of operation of the converter, the equivalent circuits of converter and theoretical waveforms are shown in Figures 3 and 4.

3. PROPOSED CONTROL SCHEME OF PMBLDC MOTOR

Figure 3 shows the general PMBLDC drive system fed by inverter with interleaved boost converter. The proposed circuit diagram is comprised of a bridge rectifier, interleaved boost converter fed to the VSI. Figure 4 shows back emf waveform of the and the corresponding current wave form of the BLDC motor. The current and back emf wave forms are oriented to the reign of trapezoidal wave shape in order obtain constant power. Therefore, the position of the rotor is sensed using position sensors which work on the principle of Hall effect the signals from hall effect sensors are used for switching pulse generation of voltage source show in Table 1.

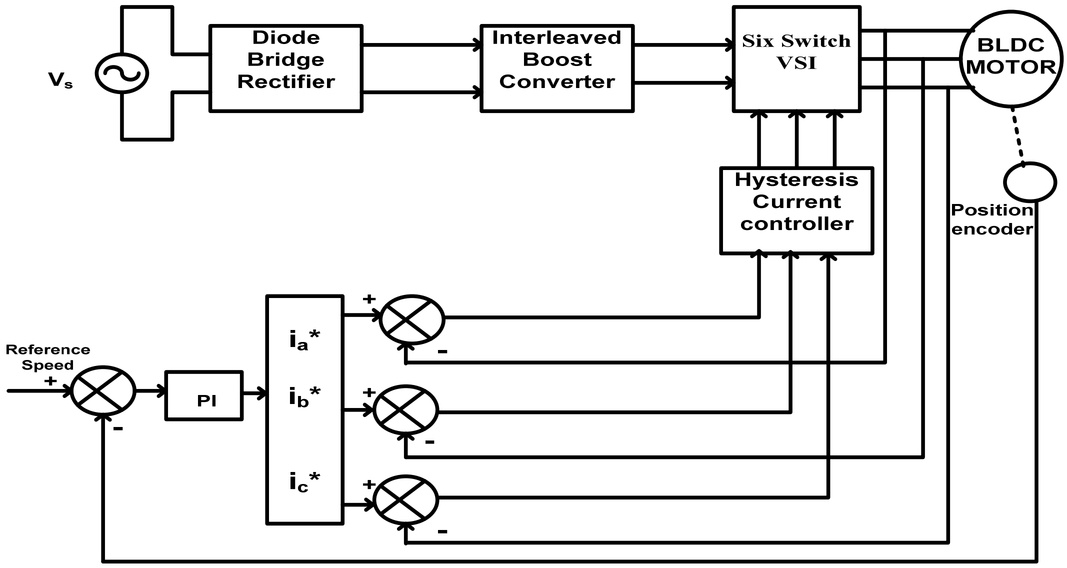

Figure 3. Six switch VSI fed BLDC drive with interleaved boost converter

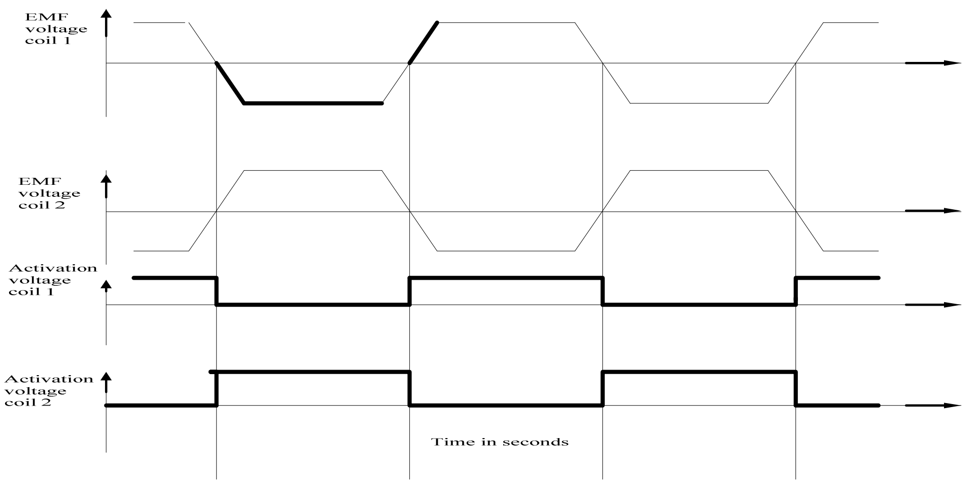

Figure 4. BLDC Motor back emf and the motor phase current

Table 1. VSI switching sequence based on the Hall Effect sensor signals

H_a	H_b	H_c	E_a	E_b	E_c	S_1	S_2	S_3	S_4	S_5	S_6
0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	-1	+1	0	0	0	1	1	0
0	1	0	-1	+1	0	0	1	1	0	0	0
0	1	1	-1	0	+1	0	1	0	0	1	0
1	0	0	+1	0	-1	1	0	0	0	0	1
1	0	1	+1	-1	0	1	0	0	1	0	0
1	1	0	0	+1	-1	0	0	1	0	0	1
1	1	1	0	0	0	0	0	0	0	0	0

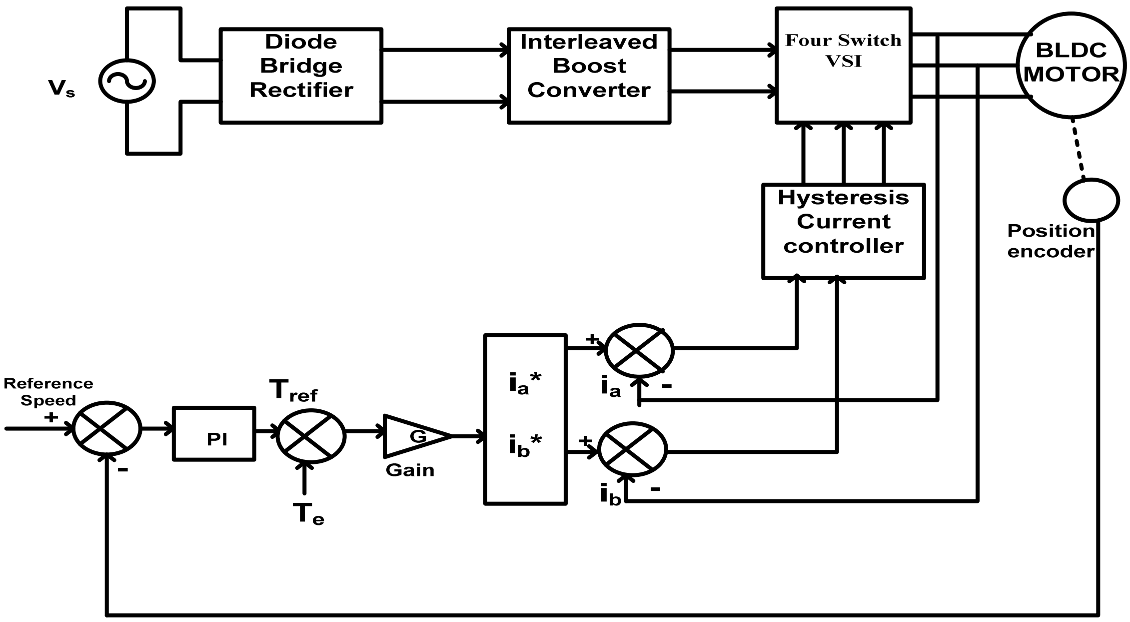

Figure 5. Four Switch VSI fed BLDC drive with interleaved boost converter

Figure 3 shows the closed loop speed control of six switch three phase inverter fed BLDC drive system with interleaved boost converter using hysteresis current control scheme, In this, we require three hysteresis current controllers and we have to sense stator currents three current sensors are required. This method has following drawbacks, current sensors are bulky, heavy, expensive, and torque fluctuations due to differences in current sensor sensitivities. Figure 5 shows the closed loop speed control of four switch three Phase Inverter fed PMBLDCM drive with interleaved boost converter. Figure 5 shows the three phase inverter four switch fed BLDC motor with interleaved Boost Converter. With closed loop mode of speed control. The motor of speed control is advantageous because of low cost (2 -capacitor and only 4 -switches are utilised) and Lower losses during switching operation. The faster dynamic response of drive reduces ripples in toque, lower voltage stress and increase in the overall performance of the system.

4. RESULTS AND DISCUSSION

4.1. Six Switch VSI Fed PMBLDCM Drive

The performance of the three leg inverter fed PMBLDCM drive with interleaved boost converter under constant torque with variable speed is evaluated with a speed variation from 300 rpm to 750 rpm at rated torque of 3 Nm. Figure 4 shows the performance of PMBLDCM drive using six switch VSI fed PMBLDCM drive with interleaved boost converter at constant torque with variable speed condition. Figure 6 shows the torque response of six switch three phase inverter fed PMBLDCM drive with interleaved boost converter. Figure 6 shows the torque output of BLDC motor. It is observed that the toque raises initially at t=0.01 sec from 0 N-m to 4.5N-m and later it fluctuates between 2.5N-m and 3.8N-m there onwords. During the t=0.45sec speed transition from 350rpm to 750rpm the torque momentarily raises to 9.5N-m.

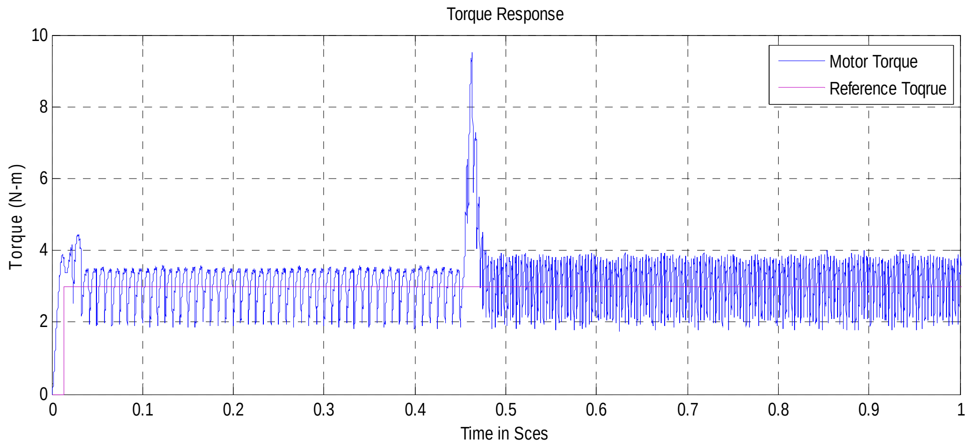

Figure 6. Torque waveform under variable speed condition with Six Switch VSI

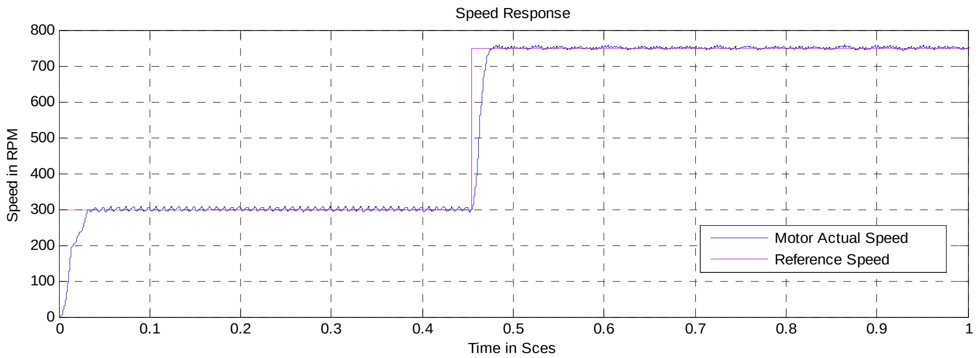

Figure 7. Speed waveform of the drive at constant load torque and variable speed condition with Six Switch VSI

Figure 7 shows the speed wave form of BLDC motor in comparision with referennce speed. The speed raise from 200rpm at t=0.01sec and suddenly falls to 300rpm. Further the speed raises to 300rpm at t=0.03sec the speed is maintained a round 300rpm from t=0.03sec. At t=0.45 sec the speed raises from 300 to 750 rpm and gradually settles down at t=1 sec to a steady state value of 750rpm.

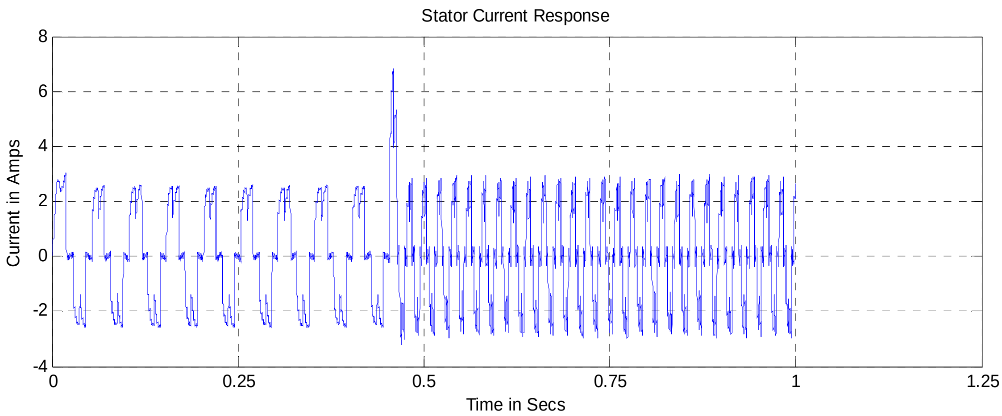

Figure 8. Stator current waveform at constant Torque with variable speed condition with Six Switch VSI

Figure 8 shows the stator current waveform one of the phase of BLDC motor drive system. The stator current at t=0.01 sec is maintained at constant value of 2.8Amps. During the abrupt change in speed from 300rpm to 700rpm at t=0.45 sec. The stator current raises to 6.9Amps and reaches to previous value of the current wave form.

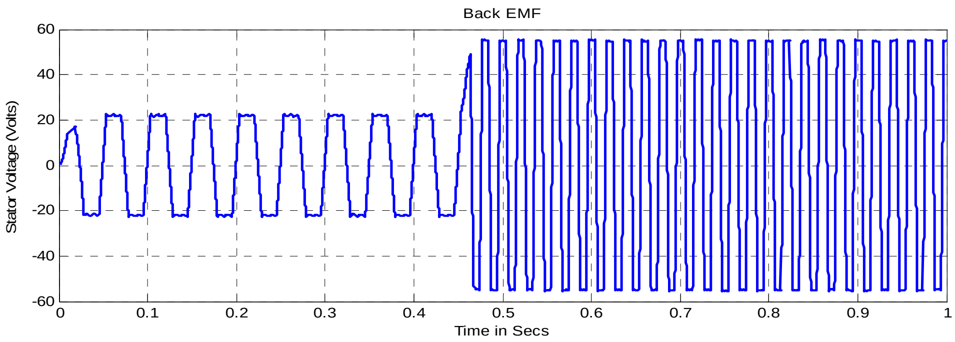

Figure 9. Back EMF at constant torque with variable speed condition with Six Switch VSI

Figure 9 shows the Back EMF wave form at the BLDC motor drive system. The back EMF wave form is trapezoidal in nature t=0.01sec and maintained a steady value of the 18V. But during the dynamic response of BLDC motor, at t=0.45sec back EMF reaches to55V and then after maintained that value.

4.2. Four Switch VSI Fed PMBLDCM Drive

The performance of Four Switch VSI fed PMBLDCM drive with interleaved boost converter under constant torque with variable speed is evaluated with a speed variation from 300 rpm to 750 rpm at rated torque of 3 Nm Figure 5 shows the torque response of Four Switch VSI fed PMBLDCM drive with interleaved boost converter. Figure 10 shows the torque output of BLDC motor. It is observed that the toque raises initially at t=0.01 sec from 0 N-m to 4.5N-m and later it fluctuates between 2.5N-m and 3.8N-m there onwords. During the t=0.45sec. Speed transition from 350rpm to 750rpm the torque momentarily rises to 9.5N-m.Torque ripple content is less when compared with six switch three phase inverter fed PMBLDCM Drive. But at starting motor rotates with very high speed.

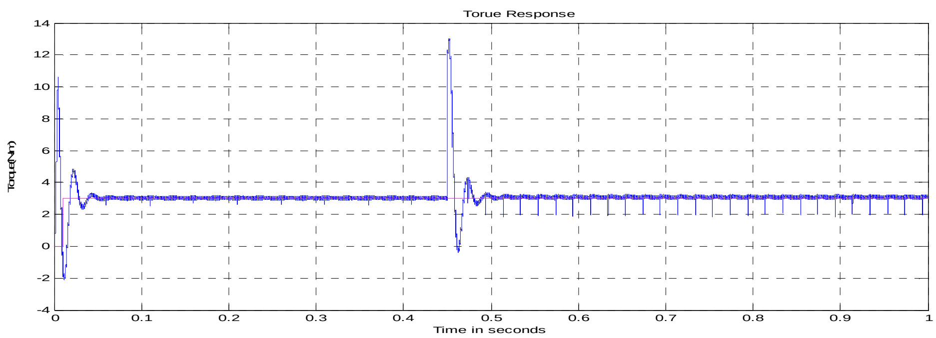

Figure 10. Torque waveform under variable speed condition with Four Switch VSI

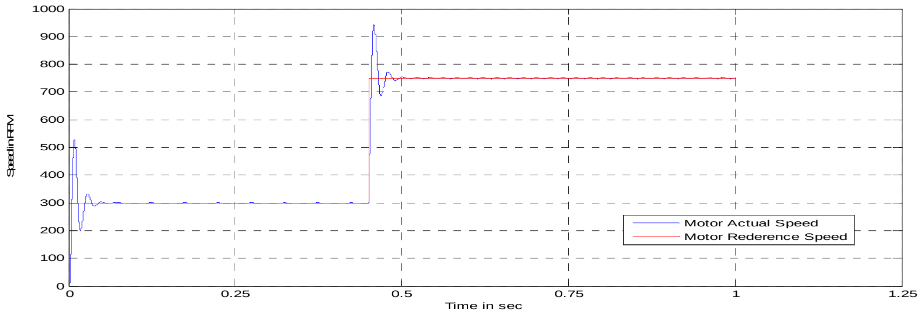

Figure 11. Speed wave form of the drive at constant load torque and variable speed condition with Four Switch VSI

Figure 11 shows the speed wave form of BLDC motor with proposed drive model. The speed raises from 500rpm at t=0.01sec and suddenly falls to 300rpm. Further, the speed raises to 300rpm at t=0.03sec the speed is maintained a round 300rpm from t=0.03sec. At t=0.45 sec the speed raises from 300 to 750 rpm and gradually settles down at t=1 sec to a steady state value of 750rpm.

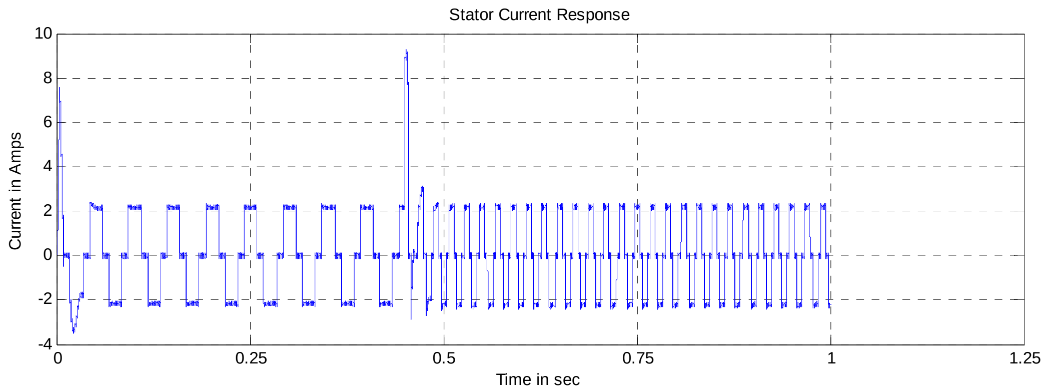

Figure 12. Stator current response at constant Torque with variable speed condition with Four Switch VSI

Figure 12 shows the stator current wave form proposed BLDC motor drive system. The stator current at t=0.01 sec is maintained at constant value of 2.8Amps. During the abrupt change in speed from 300rpm to 700rpm at t=0.45 sec the stator current raises to 8.9Amps and reaches to previous value of the current wave form.

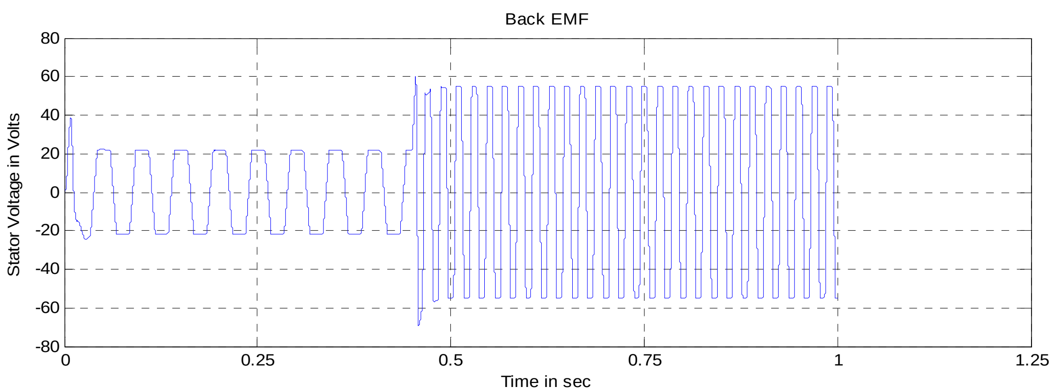

Figure 13. Back EMF at constant torque with variable speed condition with Four Switch VSI

Figure 13 shows the Back EMF wave form at constant torque. The back EMF wave form is trapezoidal in nature t=0.01sec and maintained a steady value of the 40V. But during the dynamic response of BLDC motor, at t=0.45sec back EMF reaches to55V and then after maintained at same value.

5. CONCLUSION

In this paper, a control strategy for PMBLDCM drive with six switch and four switch VSI fed BLDC Motor with interleaved boost converter with zero voltage turn-on has been developed. Comparison has been made between six switch and four switch VSI fed BLDC motor with proposed control strategy and it is found that four switch VSI fed BLDC motor is better than six switch VSI fed BLDC motor. From the result, it is observed that there is less torque ripple and switching losses in four switch VSI fed BLDC motor drive compared to six switch inverter fed drive and also it takes very less time to reach the steady state speed.

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