Improving The Performance Characteristics of Two Leg Inverter Fed BLDCM Drive

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Abstract: In small scale and large scale applications like automobile industries, domestic appliances such as Refrigerators, washing machine and air conditioning units which use conventional motor technology. These conventional motors have a chacterstics of Low torque, high maintenance and low efficiency. The usage of BLDCM enhances various performance factors ranging from higher efficiency, higher torque, high power density, low maintenance and less noise than conventional motors. The main drawback is high cost. In this paper a two leg inverter fed BLDCM drive is proposed which uses only four switches and two current sensors compared with six switches, three current sensors in case of three leg inverter fed BLDCM drive. Less number of switches and current sensors means less switching loss and low cost. In this paper a two leg inverter fed BLDCM drive with two input DC source is proposed. The proposed PMBLDCM drive is modeled and its performance is simulated in MATLAB / SIMULINK . This proposed method is a simple, low cost and enhanced performance of dive is obtained i.e., reduced torque ripple, less voltage stress, Low current THD and fast dynamic performance of PMBLDCM drive.

Keywords: Closed loop, PMBLDC motor, Torque ripple, Two leg inverter

I.INTRODUCTION

Using of Permanent Magnet in electrical machines have so many benefits and advantages then electromagnetic excitation machines these are zero excitation losses result in high efficiency, simple construction, less maintenance requirement , low cost and high torque or high output power per unit volume . Due to high power to weight ratio, high torque, good dynamic control for variable speed applications, absence of brushes and commutator make Brushless dc motor (BLDCM), good choice for high performance applications. Due to the absence of brushes and commutator there is no problem of mechanical wear of the moving parts [1], [2]. As well, better heat dissipation property and ability to operate at high speeds [3] make them superior to the conventional dc machine. However, the BLDC motor constitutes a more difficult problem than its brushed counterpart in terms of modeling and control system design due to its multi-input nature and coupled nonlinear dynamics. Due to the simplicity in their control, Permanent-magnet brushless dc motors are more accepted used in high-performance applications. In many applications, the production of ripple-free torque is of primary concern.

Electrical motors are the part of industry and every year worldwide nearly five billion motors built. This cause the reason for need of low-cost brushless dc motors drives industrial applications [4]. Use of digital control concept is one method because cost of digital control is decreasing day by day. There are two different methods of implementing digital controller one is current mode control and second one is conduction angle control [5]. A zero-voltage- and zero-current-switching full-bridge (FB) converter with secondary resonance is another method in this primary side of the converter have FB insulated-gate bipolar transistors, which are driven by phase-shift control and secondary side is composed of a resonant tank and a half-wave rectifier [6]. Without an auxiliary circuit, zero-voltage switching and zero-current switching are achieved in the entire operating range. In this without using additional inductor, the leakage inductance of the transformer is utilized as the resonant inductor. It has many advantages, including high efficiency, minimum and number of devices this topology is attractive for high-voltage and high-power applications.

For closed loop speed control operation, in current control loop, three phase stator current information is required. The current sensors and the associated accessories increase the complexity of the system, cost and size of the motor drives and decrease the reliability of the system and also more number of power electronics switches means more switching losses and costly. Therefore to overcome this problem a new drive system is proposed which uses four switches and two current sensor, less switches and less current sensors means less switching losses and low cost.

This paper deals with an application of closed speed control of a PMBLDCM Drive using two leg inverter which uses four power electronic switches and two current sensor with two input DC source. The performance of the proposed drive is very better with less torque ripple, smooth speed control, less voltage stress and low Current THD. Another advantage of this method is that due to two sources reliability of the system increases.

II.BLDC Motor Drive Strategies

Fig. 1(a) shows the general BLDC drive system fed by inverter. Fig. 1(b) shows the trapezoidal back emf and corresponding currents for operation of BLDC drive system. For getting constant output power, current is fed through the motor at flat portion of the back EMF as shown in fig. 1(b). Using digital control each phase of motor is energized according to those sequences. Therefore the position of rotor is important for driving the motor. Here for sensing position of rotor hall sensors are used. The desired current profile is achieved by proper switching of voltage source inverter.

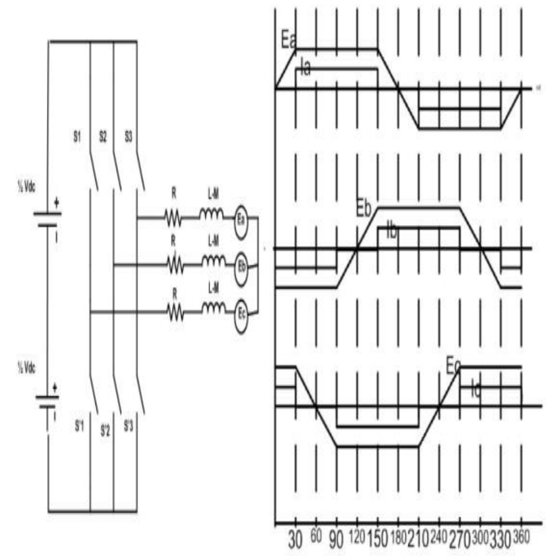

Fig. 1(a) BLDC Motor Drive System **Fig.1 (b)** BLDC Motor back emf and the motor phase currents Fig. 2 shows the closed loop speed control of conventional three leg inverter fed BLDC drive system using hysteresis current control scheme, in this we required three hysteresis current controller and we have to sense stator currents for this three current sensors are required. This method has following drawbacks, current sensors are bulky, heavy, expensive, and torque fluctuations is due to differences in current sensor sensitivities.

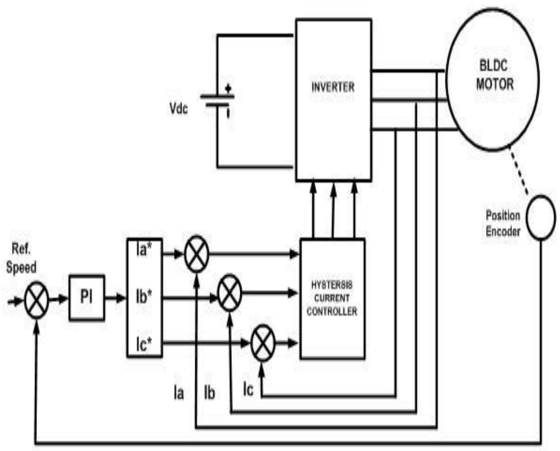

Fig. 2 Conventional Three leg inverter fed BLDC drive

Fig.3 shows the proposed schematic diagram of closed loop speed control of two leg inverter fed PMBLDCM drive with two input DC source. The advantage of this schematic is, in this two current sensors and four power electronic switches are used means low cost and less switching losses and the performance of the drive is improved i.e., reduced torque ripple, less voltage stress and fast dynamic performance of PMBLDCM drive.

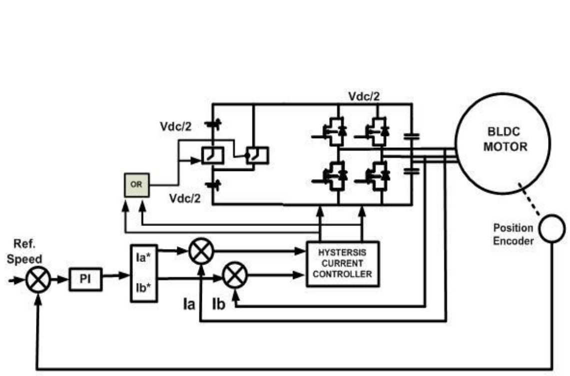

Fig.3 Schematic of proposed method

III.Operation Of Drive

Fig. 3 shows the schematic diagram of two leg inverter fed PMBLDC drive with two input DC source. Here actual motor speed is compared with the reference speed of the motor which gives speed error and it is fed to the Proportional integral controller, which gives the ref. torque signal, this ref. torque signal is compared with the actual motor torque, which gives the reference magnitude of currents, which is compared with the stator current, this error signal is fed to hysteresis controller to produce gate pulses to the two leg inverter to control the output voltage.

IV.Results And Analysis

To evaluate the performance of the proposed PMBLDCM drive system, simulation models have been developed and the simulation is carried out using MATLAB/ SIMULINK. Fig. 4 shows MATLAB/SIMULINK model of closed loop speed control of PMBLDCM drive using three leg inverter. Fig. 5 shows MATLAB/SIMULINK model of closed loop speed control of PMBLDCM drive using two leg inverter. Fig. 6 shows proposed MATLAB/SIMULINK model of closed loop speed control of PMBLDCM drive with two input DC source using two leg inverter. The performance of the drive is simulated for constant rated torque (2 Nm) at rated speed. The parameters of the BLDC motor used for simulation are, Rs = 0.75Ω, Ls =200e-6mH, P = 4, J = 0.4e-3Kg-m2.

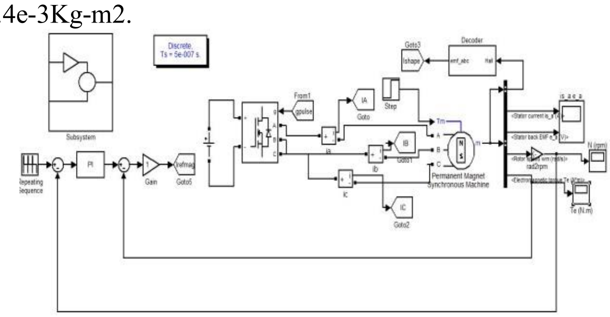

Fig 4: MATLAB/SIMULINK model of closedloopspeed control of three leg inverter fed PMBLDCM driveusing three current sensors method.

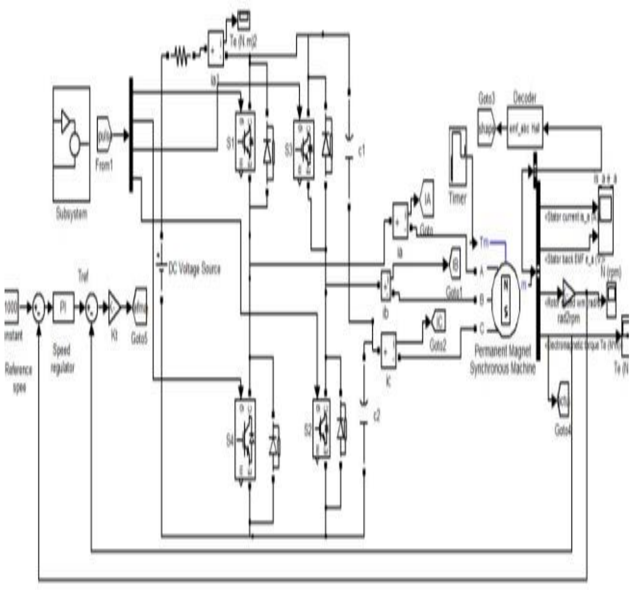

Fig 5: MATLAB/SIMULINK model of closed loop speed control of two leg inverter fed BLDCM drive with single DC source.

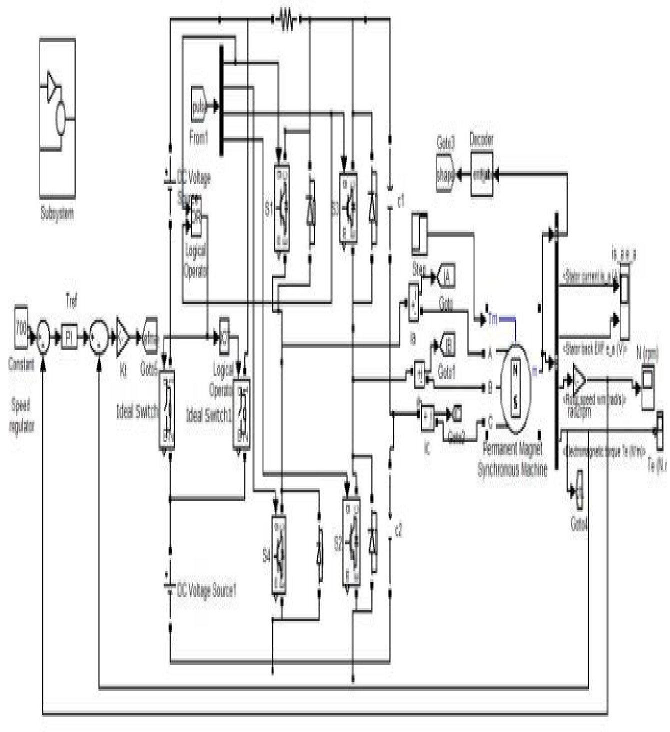

Fig 6: Proposed MATLAB/SIMULINK model ofclosed loop speed control of two leg inverter fed PMBLDCM drive with two input DC source.

A. Pmbldcm Drive Using Two Leg Inverter With Single Dc Source

I.Performance of PMBLDCM drive at Constant Torque with variable speed condition

The performance of the two leg inverter fed PMBLDCM drive with single DC source under constant torque with variable speed is evaluated, while the motor is feed from 500V, DC supply at rated torque of 2 Nm with a speed variation from 500 rpm to 1000 rpm.

Fig. 7. Performance of PMBLDCM drive using two leg inverter with single dc source at constant torque with variable speed condition (a) Torque response (b) Speed response (c) Stator current response (d) Back EMF response (e) Stator line voltage

Fig.7. shows the performance of PMBLDCM drive using two leg inverter with single DC source at constant torque with variable speed condition. Fig 7(a) shows the torque response of the two leg inverter fed PMBLDCM drive with single DC source. A reference speed of 500 rpm is set at the time of starting and a load torque of 2Nm is applied at t=0.01 sec. During stating and at no load motor is developing a no load torque of 2.5 Nm. At t= 0.01 sec motor is developing approx motor torque of 2Nm. At t=0.2 sec motor is developing a torque of 2.5 Nm this is because at t=0.2 sec reference speed is changed from 500 rpm to 1000 rpm and the drive is reached to a set speed of 1000 rpm at t=0.3 sec after this motor is develops a constant load torque of 2Nm. At t =0.4 sec motor develops a negative torque of 2.5 Nm because at t=0.4 sec set speed reduced from 1000 rpm to 500 rpm, at t=0.41 sec motor develops constant load torque of 2Nm

Fig. 7(b) shows the speed response of the drive at constant load torque with variable speed condition. At starting the reference speed is set to 500 rpm and the motor reaches to a set speed of 500 rpm at t=0.02 sec. To know the dynamic performance of the drive, at t=0.2 sec speed is increased to 1000rpm from 500 rpm. At t= 0.4 sec speed is decreased from 1000 rpm to 500 rpm and it is observe that drive reach the set speed within a time of 0.1 sec .

Fig. 7(c) shows the stator current response, at constant torque with variable speed condition. At the time of starting motor takes a starting current of 1.75 amp and from t=0.02 sec motor takes a steady state current of 1.4 amps because the motor reaches to a set speed of 500rpm. At t=0.2 sec set speed is change from 500 rpm to 1000 rpm, at t=0.2 to 0.3 sec motor takes a current of 1.75 amps because at t=0.3 sec motor reached to set speed of 1000 rpm, after t=0.3 sec motor takes a steady current of 1.5 amps. At t= 0.4 sec set speed is reduced to 500 rpm and motor takes a steady state current of 1.4 amps.

Fig. 7(d) shows the Back EMF response at constant torque with variable speed condition. As we know that back EMF is proportional to the speed, at t= 0.2 sec, the set speed is 1000 rpm and motor reaches to set speed of 1000 rpm at t=0.3 sec and the magnitude of back emf is 75V . At t=0.4 sec motor speed is reduced to 500 rpm from 1000 rpm , back emf also reduced to 37V . Fig. 7(e) shows the stator line voltage and this voltage varies between 0 to 500V.

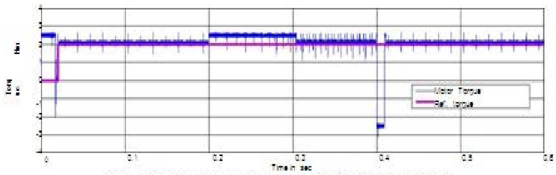

Fig 7 (a): Torque response under variable speed condition

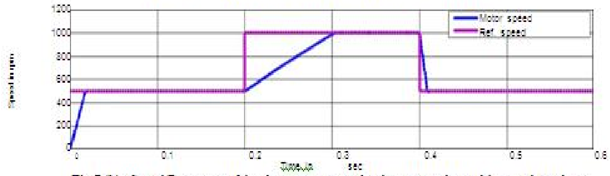

Fig 7 (b): Speed Response of the drive at constant load torque and variable speed condition

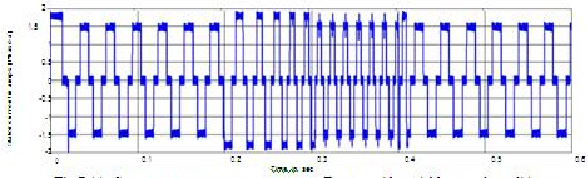

Fig 7 (c): Stator current response at constant Torque with variable speed condition

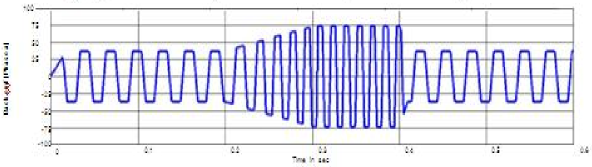

Fig 7 (d): Back EMF at constant torque with variable speed condition

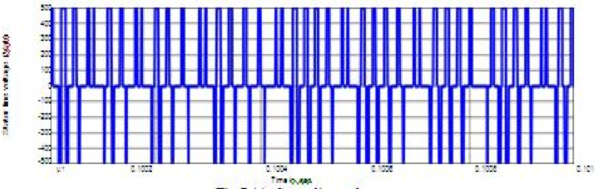

Fig 7 (e): Stator line voltage

II. Performance of PMBLDCM drive at Constant speed with variable torque condition

Fig.8 shows the performance of PMBLDCM drive using two leg inverter with single DC source at constant speed with variable torque condition. Fig.8 (a) shows the motor torque response of the two leg inverter fed PMBLDCM drive with single DC source. A constant speed of 1000 rpm with variation of load torque at t= 0.1 sec of 2Nm, at t=0.5 sec torque of 1 Nm, and at t=0.7 sec torque of 1.5Nm is applied. Motor is developing the approximate torque equal to the load torque with some ripple as shown in fig. 8(a).

Fig. 8(b) shows the speed response of the drive at constant speed with variable torque condition and it is observe that the drive maintains a constant set speed of 1000rpm during the whole period of variation of load.

Fig. 8(c) shows the stator current response, at constant speed with variable load condition. At the time of starting motor takes a starting current of 1.75 amp and from t=0.1 sec motor takes a steady state current of 1.6 amps because of load torque of 2Nm. At t=0.5 sec motor takes a current of 0.9 amps because load torque of 1Nm. At t=0.7 sec motor takes a steady current of 1.4 amps because load torque of 1.5Nm.

Fig. 8(d) shows the Back EMF response at constant speed with variable load torque condition. As we know that back EMF is proportional to the speed, as speed is constant of 1000 rpm, therefore back emf is also constant at 75V.

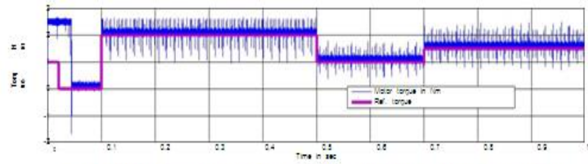

Fig 8 (a): Torque response under constant speed with variable torque condition

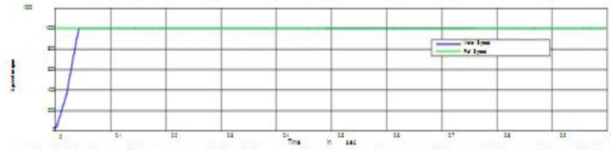

Fig 8 (b): Speed Response of the drive at constant load torque with variable speed condition

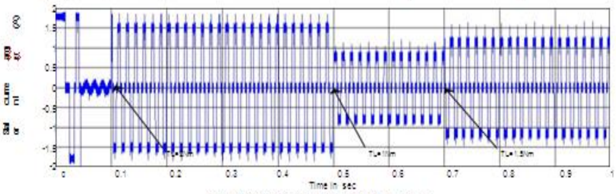

Fig 8 (c): Stator Current Response

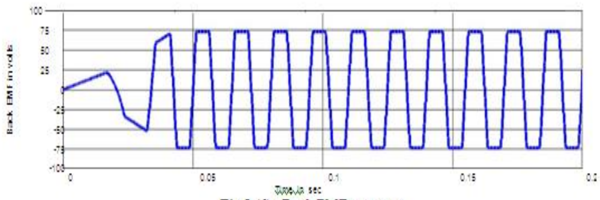

Fig 8 (d): Back EMF response

Fig.8. Performance of PMBLDCM drive using two leg inverter with single dc source at constant speed with variable torque condition (a) Torque response (b) Speed response (c) Stator current response (d) Back EMF response

B. Pmbldcm Drive Using Two Leg Inverter With Two Dc Supply

a) Performance of PMBLDCM drive at Constant Torque with variable speed condition

The performance of the two leg inverter fed PMBLDCM drive with two Dc supply is evaluated, while the motor is feed from two separate DC source of 250v each at rated torque of 2 Nm with variation of speed from 500 rpm to 1000 rpm and from 1000 rpm to 500 rpm.

Fig. 9 shows the performance of PMBLDCM drive using two leg inverter with two DC source at constant torque with variable speed condition. Fig 9(a) shows the torque response of the two leg inverter fed PMBLDCM drive with two DC source. A reference speed of 500 rpm is set at the time of starting and a load torque of 2Nm is applied at t=0.01 sec. During stating and at no load motor is developing a no load torque of 2.5 Nm. At t= 0.01 sec motor is developing approx motor torque of 2Nm. At t=0.2 sec motor is developing a torque of 2.5 Nm this is because at t=0.2 sec reference speed is changed from 500 rpm to 1000 rpm and the drive is reached to a set speed of 1000 rpm at t=0.3 sec after this motor is develops a constant load torque of 2Nm. At t =0.4 sec motor develops a negative torque of 2.5 Nm because at t=0.4 sec set speed reduced from 1000 rpm to 500 rpm, at t=0.41 sec motor develops constant load torque of 2Nm

Fig. 9(b) shows the speed response of the drive at constant load torque with variable speed condition. At starting the reference speed is set to 500 rpm and the motor reaches to a set speed of 500 rpm at t=0.02 sec. To know the dynamic performance of the drive, at t=0.2 sec speed is increased to 1000rpm from 500 rpm. At t= 0.4 sec speed is decreased from 1000 rpm to 500 rpm and it is observe that drive reach the set speed within a time of 0.1 sec .

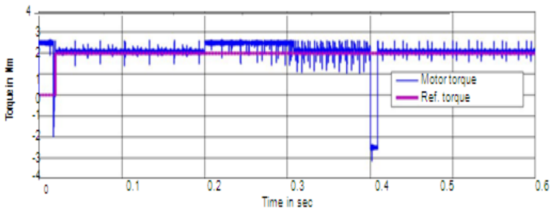

Fig 9 (a): Torque response under variable speed condition

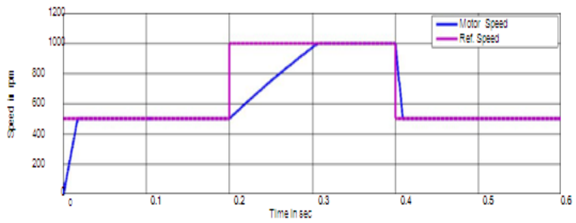

Fig 9(b): Speed response at constant load torque with variable speed condition

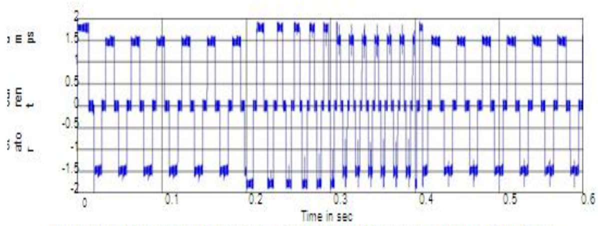

Fig 9(c): Stator current response at constant load torque with variable speed condition

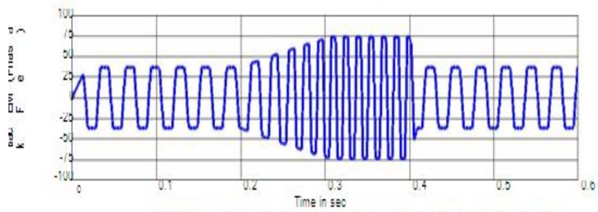

Fig 9(d): Back EMF at constant torque with variable speed condition

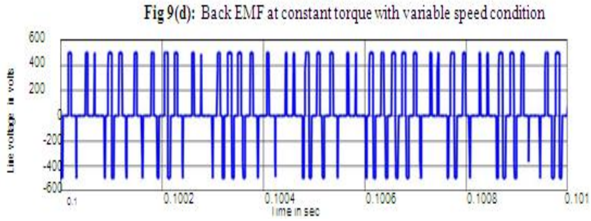

Fig 9(e): Stator line voltage

Fig. 9 Performance of PMBLDCM drive using two leg inverter with two dc source at constant torque with variable speed condition (a) Torque response (b) Speed response (c) Stator current response (d) Back EMF response (e) Stator line voltage.

Fig. 9(c) shows the stator current response, at constant torque with variable speed condition. At the time of starting motor takes a starting current of 1.75 amp and from t=0.02 sec motor takes a steady state current of 1.4 amps because the motor reaches to a set speed of 500rpm. At t=0.2 sec set speed is change from 500 rpm to 1000 rpm, at t=0.2 to 0.3 sec motor takes a current of 1.75 amps because at t=0.3 sec motor reached to set speed of 1000 rpm, after t=0.3 sec motor takes a steady current of 1.5 amps. At t= 0.4 sec set speed is reduced to 500 rpm and motor takes a steady state current of 1.4 amps.

Fig. 9(d) shows the Back EMF response at constant torque with variable speed condition. As we know that back EMF is proportional to the speed, at t= 0.2 sec, the set speed is 1000 rpm and motor reaches to set speed of 1000 rpm at t=0.3 sec and the magnitude of back emf is 75V . At t=0.4 sec motor speed is reduced to 500 rpm from 1000 rpm , back emf also reduced to 37V . Fig. 9(e) shows the stator line voltage and this voltage varies between 0 to 500V.

b) Performance of PMBLDCM drive at Constant speed with variable torque condition

Fig. 10 shows the performance of PMBLDCM drive using two leg inverter with two DC source at constant speed with variable torque condition. Fig. 10(a) shows the motor torque response of the two leg inverter fed PMBLDCM drive with two DC source. A constant speed of 1000 rpm with variation of load torque at t= 0.1 sec of 2Nm, at t=0.5 sec torque of 1 Nm, at t=0.7 sec torque of 1.5Nm is applied. Motor is developing the approximate torque with some ripple as shown in fig. 10(a).

Fig. 10(b) shows the speed response of the drive at constant speed with variable torque condition and it is observe that the drive maintains a constant set speed of 1000rpm during the whole period of variation of load.

Fig. 10(c) shows the stator current response, at constant speed with variable load condition. At the time of starting motor takes a starting current of 1.75 amp and from t=0.1 sec motor takes a steady state current of 1.6 amps because of load torque of 2Nm. At t=0.5 sec motor takes a current of 0.9 amps because load torque of 1Nm. At t=0.7 sec motor takes a steady current of 1.4 amps because load torque of 1.5Nm.

Fig. 10(d) shows the Back EMF response at constant speed with variable load torque condition. As we know that back EMF is proportional to the speed, as speed is constant of 1000 rpm, therefore back emf is also constant at 75V.

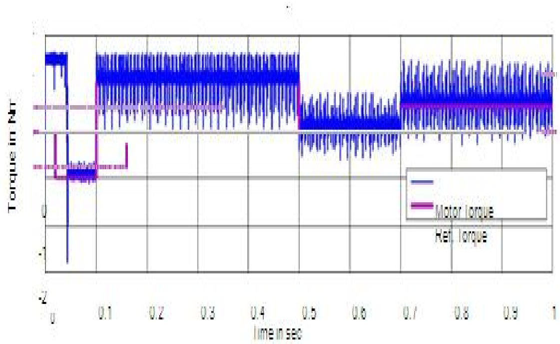

Fig 10(a): Torque response under constant speed with variable torque condition

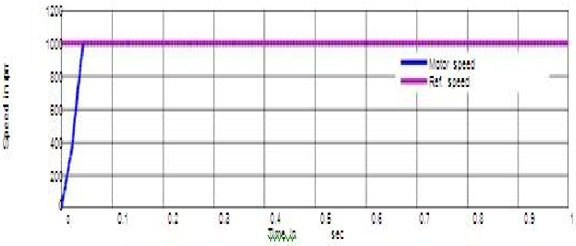

Fig 10(b): Speed Response of the drive at constant load torque with variable speed condition

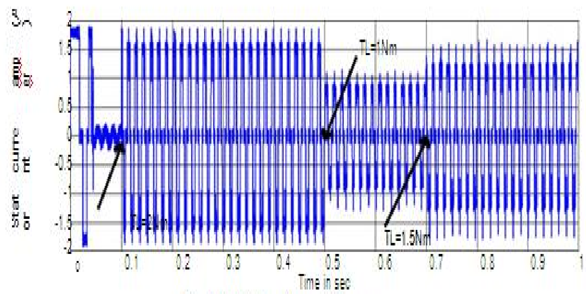

Fig 10(c): Stator Current Response

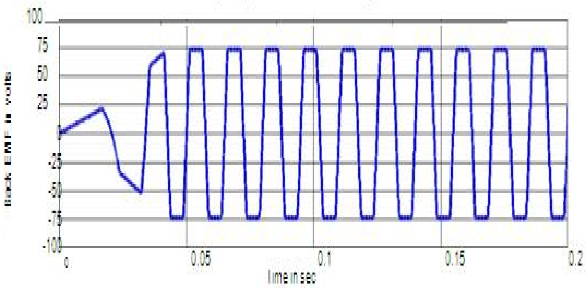

Fig 10(d): Back EMF response

Fig. 10 Performance of PMBLDCM drive using two leg inverter with two dc source at constant speed with variable torque condition.(a) Torque response (b) Speed response (c) Stator current response (d) Back EMF response

C. Comparison of two leg inverter fed PMBLDCM drive using single DC source and proposed method

In this paper simulation is carried out extensively for both the cases with constant speed with variable load condition and with variable speed with constant load torque condition. It is observe that propose method has so many advantages when compared with two leg inverter fed PMBLDCM drive using single DC source. In proposed method voltage stress across stator winding is reduced to half, second one is reliability othe drive increase due to the presence of two sources, third one is the torque ripples are going to reduced, fourth one is low cost as number of switches are reduced and current sensors are also reduced, fifth one is that in current % THD is less. Table I shows the comparison of two leg inverter fed PMBLDCM drive using single DC source and proposed method.

Table I: Comparision Of Two Leg Inverter Fed PMBLDCM Drive Using Single Dc Source and Proposed Method.

S. No		2Leg 1DC		2Leg 2DC	
		Te=2Nm N=500 rpm T=0.5 sec	Te=2Nm N=1000 rpm T=0.35 sec	Te=2Nm N=500 rpm T=0.5 sec	Te=2Nm N=1000 rpm T=0.35 sec
1	Torque ripple	0.175	0.175	0.15	0.15
2	% THD in Ia current	55.00	70.88	58.04	45.62
3	% THD in Ib current	54.95	55.50	53.55	43.56
4	% THD in Ic current	54.07	98.61	58.40	84.52
5	% THD in phase a voltage	56.01	60.08	51.18	75.72
6	% THD in phase b voltage	55.38	45.60	52.71	42.22
7	% THD in phase c voltage	39.16	99.32	45.23	87.70

V.Conclusion

The usage of BLDCM enhances various performance factors ranging from higher efficiency, higher torque, high power density, low maintenance and less noise than conventional motors. The main drawback is high cost. To reduce the cost and to get better performance of the drive, In this paper a two leg inverter fed BLDCM drive is proposed which uses only four switches and two current sensors compared with six switches and three current sensors in case of three leg fed inverter BLDCM drive. Less number of switches and current sensors means, less switching loss and low cost. In this paper a two leg inverter fed BLDCM drive with two input DC source is proposed. This proposed method is a simple, low cost and enhanced performance of dive is obtained i.e., reduced torque ripple, less voltage stress, Low current THD and fast dynamic performance of PMBLDCM drive. In case failure of one dc source, the drive will operate, and stoppage of work can be avoided in industrial applications i.e reliability of the drive increases.

REFERENCES

[1]. C. L. Puttaswamy, B. Singh, and B. P. Singh, Investigations on dynamic behavior of permanent magnet brushless dc motor drive, Elect .Power Compon. Syst., vol. 23, no. 6, pp. 689–701, Nov. 1995.

[2]. “Mathematical modeling of bldc motor with closed loop speed control using pid controller under various loading conditions”, ARPN Journal of Engineering and Applied Sciences, vol. 7, no. 10, Oct 2012, pp 1321-1328

[3]. Bhim Singh and Sanjeev Singh. “State of art on permanent magnet brushless Dc motor Drives”, Journal of Power Electronics. 9(1): 1-17 ,Jan 2009.

[4]. Kim, Namhun, Toliyat, H.A. , Panahi, Issa M. , Min-Huei Kim, “BLDC Motor Control Algorithm for Low-Cost Industrial Applications ”, Applied Power Electronics Conference, APEC

2007 - Twenty Second Annual IEEE, pp 1400 – 1405,Feb. 25 2007-March 1 2007

[5]. Rodriguez, F. Emadi, A.” A Novel Digital Control Technique for Brushless DC Motor Drives “ IEEE Transactions on Industrial Electronics, Oct. 2007, Vol 54 , Issue: 5 , pp 2365 – 2373.

[6]. J.R. Hendershort and T. J. E. Miller, Design of Brushless Permanent Magnet Motors. Oxford, U.K.: Clarendon, 1994.

[7]. T. Kenjo and S. Nagamori, permanent magnet brushless DC motors. Oxford, U.K.: Clarendon, 1985.

[8]. N. Mohan, M. Undeland , and W. P. Robbins, Power Electronics: Converters, Applications and Design. Hoboken, NJ: Wiley, 1995.