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Magnitude reduction of stator current in BLDC Motor Using Hall-Stator Current Control Strategy

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ABSTRACT- In the current past, variable speed drives have grown in many applications as automobile industries, domestic appliances etc. The electronics devices are mostly built up to preserve the energy consumption of various devices. This increase to the growth in Brushless DC motor BLDC motor and the BLDC motor improves different factors ranging from Having High dynamic response, Having Higher efficiency, low weight, compact construction, Long operating life, Noiseless operation, Higher speed ranges instead of other motors. The BLDC motor can operate as a choice for traditional motors like induction and switched reluctance motors. In this paper the conventional control strategy which is Hall sensor output control strategy is implemented using the Hall-Stator current output control strategy. It is observed that the magnitude of stator current is reduced using the Hall-Stator current output control strategy so for the same operating condition and speed the BLDC motor is taking less current hence losses due to current is less when compared with conventional control strategy. The simulation of BLDC motor is done using MATLAB R2009b.

Keywords:- PI controller, BLDC motor, Hall-Stator current control, Hall effect sensor, feedback loop, torque ripple, speed.

1 INTRODUCTION

In the conventional brushed DC motor, the brushed motors require more maintenance. To overcome this problem, brush assembly is replaced with electronic switching. The brushless DC motors have rotor with permanent magnets, connected with switching devices. The BLDCM is mostly used motors in industry, Medical, Automotives, instrumentations. This types of motor do not have brushes and commutator because BLDC motors use electronic commutation based on rotor position information. These are very useful where weight and space is a problem. The BLDC motor has several advantages than brushed motor. There are few advantages of BLDC motor: higher speed, Higher efficiency, low weight, compact construction, Long life. The BLDC motor has main drawback of torque ripples. The current takes some time to increase or decrease to the steady state condition in the actual BLDC motors, because current is affected by resistance and inductance of the winding [1]. Therefore the ripples in current occur due to effect of motor inductance. So further torque ripples are directly affected by current ripples if back EMF is a trapezoidal waveform. Smooth torque profile must be produced to get improved operation.

2 PRINCIPLE OF OPERATION

In brushed motor, commutator and the brushes are used to reverse the current polarity while in BLDCM polarity of current is reversed by voltage source inverter which is controlled according to rotor position of the motor. The absence of commutator gives good benefit when talking about higher reliability. Due to the commutator and brushes, DC motor is unable to produce maximum speed. Hence the BLDCM is used where more speed is required because there is no friction [2]. Further the positioning of rotor is experienced to line up supplied voltage with back-EMF. In this situation BLDCM acts like a DC motor.

3 TORQUE/SPEED CHARACTERISTICS

BLDCM Torque/speed characteristics is in fig.1. BLDC motor is defined by using two torque parameters, max & rating torque. BLDCM can be used upto rating torque during continuous operation

[3]. When BLDCM is operating at rated speed then torque remains constant. The BLDCM can rotate upto highest speed. A higher torque can be delivered by the motor, maximum upto the peak torque, when motor follows the speed torque curve.

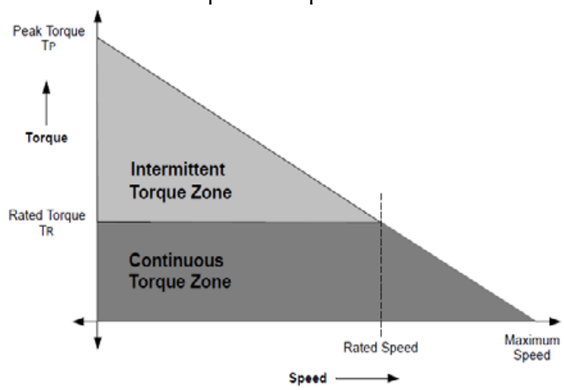

Fig: 1 Torque-speed characteristic

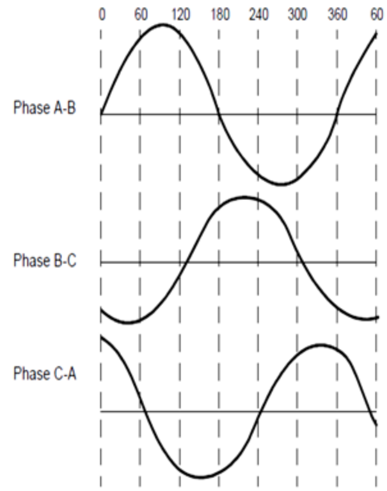

Fig: 3 sinusoidal back EMF waveform

4 BLDC MOTOR

Magnets are placed on the face of rotor that provides life-long field excitation to the BLDC motor. In low-cost BLDCM Ferrite and ceramic magnetic material are the superior choices [6]. These magnets exist with reminisce of 0.38 T. Ndy.Fe.Bo material uses for particular purposes. Fault current can demagnetize the Magnets like short-circuit current created because of inverter fault. that's why, caring determination is generally used for inverter and manages electronically to bind magnitude of armature's current for a secure quantity [4]. The four poles in BLDC motor is the superior choice and it also have six or eight poles. BLDCM has trapezoidal back-emf.

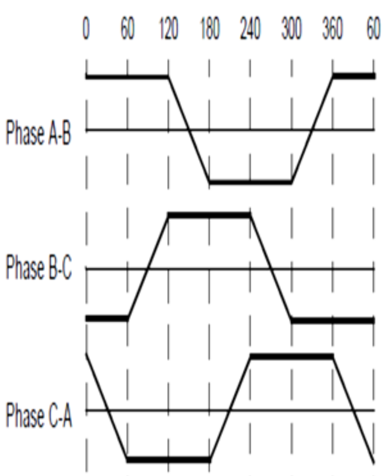

Fig: 2 Trapezoidal back EMF waveform

5 TORQUE RIPPLE SOURCES IN BLDC MOTOR

The torque ripple in BLDCM is classified in three categories (A) Motor's nature, (B) Motor's structure and (C) Motor's control.

5.1 Motor's nature

Torque ripple linked with BLDCM nature pertain to the physical property & also factor of the motor's constructed stuff [5]. Better performance leads by superior choice of materials.

5.2Motor structure

This is related to design parameters of motor, like shape and dimensions. These parameters are cautious deliberation which leads to good performance design.

5.3 Motor control:

For minimization of torque ripples several techniques have been utilized.

6 SIMULATION AND RESULTS

The Hall-stator current control strategy of three phase voltage source inverter fed BLDC motor is simulated using MATLAB/SIMULINK for the validation of work and results are presented. Two control strategies are used to generate the gate signals:

1. Using hall effect sensor output
2. Using comparision of hall sensor and stator current output

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1 Using hall effect sensor output

The output of measurements for the BLDC motor is given to the bus selector. The bus selector is used to give the required measured value from BLDC motor as separate signal. There are two bus selectors used. First bus selector provides three hall sensor sensed signals and Second bus selector gives four measured values as stator curent, stator back emf, rotor speed, electromagnetic torque. The scope is used to see the waveforms of the measured value.

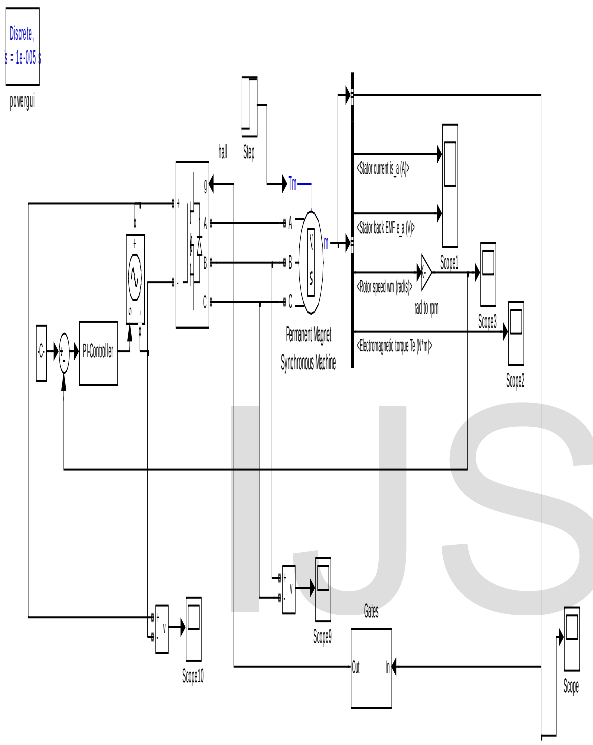

Fig: 4 simulation with hall effect sensor output

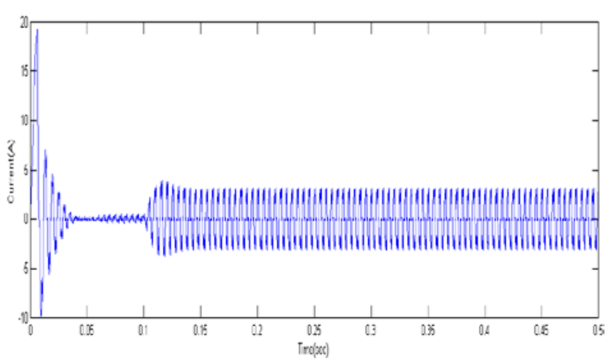

Fig: 5 stator current of BLDC motor for phase a using hall sensor control strategy

When three phase supply is applied to the stator winding then maximum starting stator current increases up to 19 amp and decreases up to -10 amp. Further it is 0.4amp in interval from 0.04 to 0.1 and becomes steady state stator current at 3 amp after 0.1 sec as shown in above fig 5.

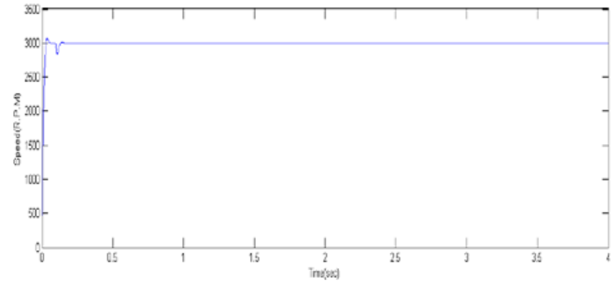

Fig: 6 rotor speed

The rotor speed is obtained for 4sec simulation time, at the start rotor speed rises in interval from 0 to 0.04sec and it becomes constant for very small period in interval (0.05, 0.1). Then speed decreases for very small period from 0.1 to 0.13sec, after 0.13sec the rotor speed becomes constant at 3000 rpm.

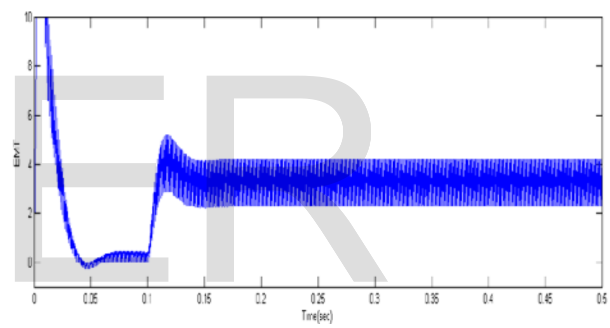

Fig: 7 electromagnetic torque waveform using hall sensor control strategy

The electromagnetic torque is obtained for 0.5sec simulation time. The maximum starting electromagnetic torque is 27 N-m. As clear from waveform fig.7 the torque starts decreasing from 0.006 to 0.04 time interval and develops a torque of 0.5 Nm at no load condition. The electromagnetic torque becomes continue fluctuating after 0.1 sec at 4.2 N-m.

2 Using hall-stator current control strategy

In this control strategy the hall effect sensor signal and three phase stator current signal are compared to generate the gate signal. For this purpose decoded hall effect sensor signal is transfered from the decoder block using GOTO and FROM block as hall1, hall2, hall3 signals. Mux is used to combine these signals which gives only a single output signal. Scope shows the output waveform of the decoded signal. Further this signal is fed to the positive terminal of the sum. Modulated hall-stator current output signal then generates gate signal for the voltage source inverter. When the gate signal is applied to gate terminal of the voltage source inveter, the voltage source inverter gives controlled proper phase sequences for the BLDC motor.

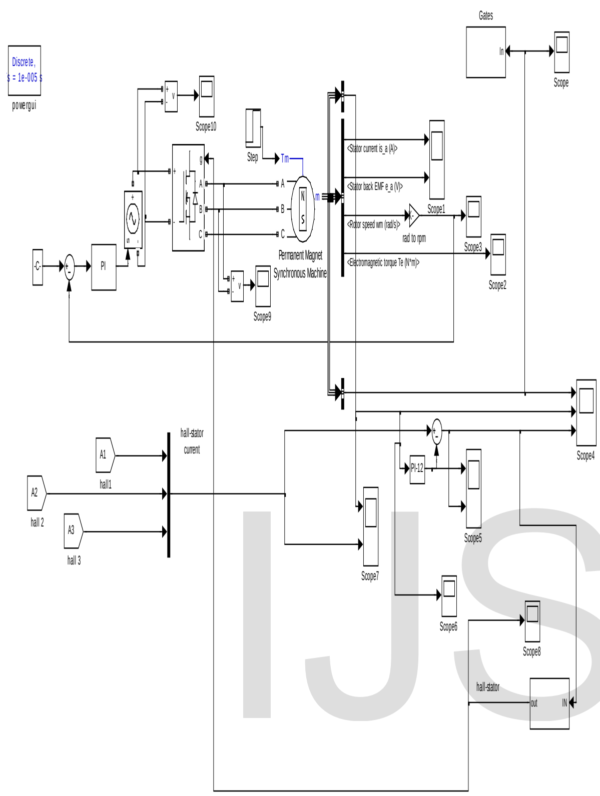

Fig: 8 simulation with Hall-stator current control strategy

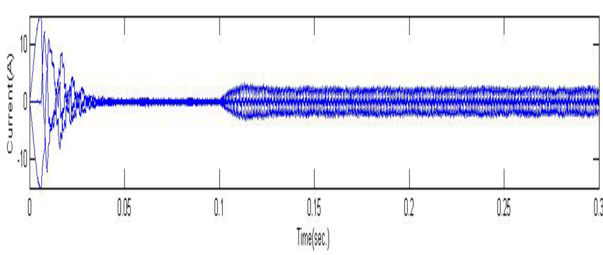

Fig: 9 stator current of BLDC motor for phase a using hall- stator current control strategy

When hall-stator current control strategy is applied and when three phase supply is applied to the stator winding then maximum starting stator current increases up to 15 amp and decreases up to -12amp. Further stator current is 0.5amp in interval from 0.04 to 0.1 and becomes steady state stator current at 2.5amp after 0.1 sec. It is observed that the magnitude of stator current is less as compare to the conventional hall control strategy; here the magnitude of stator current is 2.5amps as shown in above fig 9.

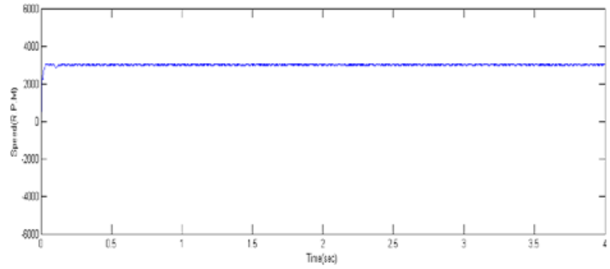

Fig: 10 rotor speed

The rotor speed is obtained for 4sec simulation time, at the start rotor speed rises in interval from 0 to 0.03. The rotor speed gets constant for (0.03, 0.05) interval and speed decreases for small period from 0.05 to 0.08, after 0.08 the rotor speed becomes constant at 3000 rpm.

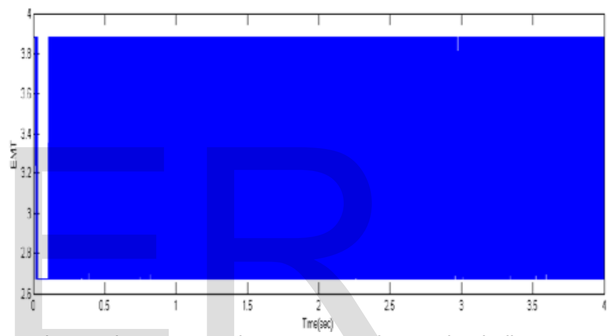

Fig: 11 electromagnetic torque waveform using hall-stator current control strategy

The electromagnetic torque is obtained for 4sec simulation time. The maximum starting electromagnetic torque is 3.88 N-m. As clear from waveform shown in fig. 11 at the starting situation the torque gets fluctuating from 0 to 0.03 time interval and becomes constant at 2.67Nm after 0.03 and remains constant until 0.055. The electromagnetic torque becomes continue fluctuating after 0.055 sec at 3.88 N-m.

7 CONPARISION

The fig. 12 shows the comparison between the magnitude of stator current with conventional control and hall-stator current control strategy. It is observed that the magnitude of stator current is less as 2.5amp with hall-stator current control strategy

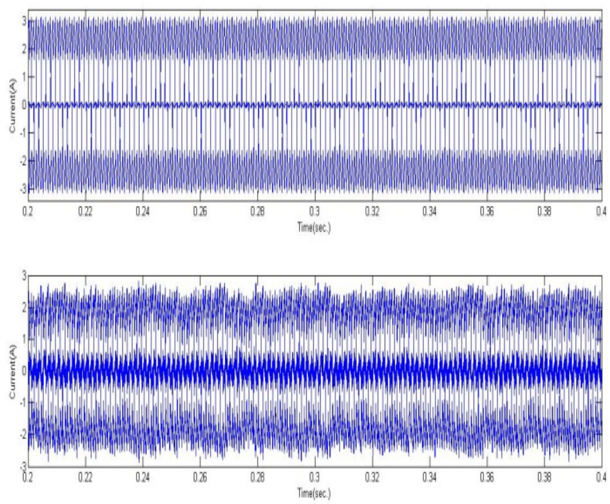

Fig. 12 explains the comparison between the magnitude of electromagnetic torque ripples

it is observed that the magnitude of electromagnetic torque decreases in hall-stator current control when compared with conventional control

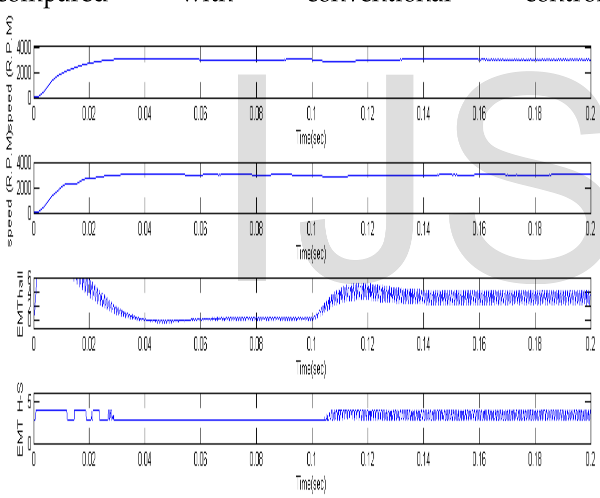

Fig: 13 comparison of speed and electromagnetic torque

8 CONCLUSION

Permanent-magnet brushless dc motors are extra broadly used in high-performance appliances due to the better speed with respect to torque characteristics, Having High dynamic response, Having Higher efficiency, low weight, compact construction, Long operating life, Noiseless operation, Higher speed ranges instead of other motors. In this paper the conventional control strategy which is Hall sensor output control strategy is implemented using the Hall-Stator current output control strategy. It is observed that the magnitude of stator current is reduced using the Hall-Stator current output control strategy so for the same operating condition and speed the BLDC motor is taking less current hence losses due to current is less when compared with conventional control strategy.

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