CLOSED LOOP SPEED CONTROL TECHNIQUE FOR BRUSHLESS DC MOTOR DRIVE

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Abstract—**This thesis focuses on an improved control scheme for a sensorless speed control technique of brushless DC motor (BLDC) by estimating speed from the hall sensor signals. Initially, speed is determined using precision speed encoders which cost almost entire half of drive system. In closed loop control system , state of the output directly affects the input condition. The conventional speed and current controllers are pi controllers, which obtain gains via a trial and error approach or extensive studies. Hence control parameters for the optimal performance at a given operating point may not be effective at a different operating point. paper proposed focus for a low cost speed estimation technique for closed loop control of bldc motor drive based on adaptive pi controller, which can self adjust the control gains. In the simulation, the adaptive pi control shows consistent excellence under various operating conditions such as different initial torque and speed levels. The proposed system is designed, modelled and performance of system is simulated in matlab/simulink and is analysed for different speed and torque references.**

***Keywords*—BrushlessDCMotor(BLDC);speedestimation;hall sensors;currentcontrolledPWM;inverter**

I.INTRODUCTION

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Conventional DC motors are highly efficient, however, their only drawback is that they need a mechanical commutator and brushes which are subject to wear and require frequent maintenance.it is difficult to use dc machine in hazardous situations as there may be sparking at brush surface due to reactance voltage in critical operating conitions like fluctuating load and sudden speed reversal. The function of commutator and brushes in blc motor are implemented by solid state switches..the energy consumption has become important issue which are facing by consumershas been reduced.

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motor belongs to the class of special electrical machines. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation etc. As the name implies, BLDC motors do not use brushes for commutation; instead they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are: High efficiency, long operating life, low maintenance and higher speed range. Since BLDC motors have replaced other motors in different aaations a strong need for design and development of new strategies for performance enhancement becomes essential

Pmsm with trapezoidal excitation known as bldc motor. Brushless DC motor employs electrical commutation with permanent magnet rotor and stator with a sequence of coils where magnet rotates and current carrying conductors are fixed an fields of both generates the magnetic fiel to produce the require torque. Three phase windings constitutes stator. Permanent magnet ranges from 2 to 8 pole pairs with alternate north and south poles constitutes rotor.operation of bldc motor requires sequential excitation an coils to get excite requires details of current rotor position which is estimate by effect of hall based sensors placed on stator. When the rotor rotates corresponding to north and south near to sensor give out high or low signal.base on signal combination,determines the correct order commutation..Commutation is the process of producing rotational torque in the motor by changing phase currents.this has the following sequence,positive current carried by one winding,negative cureent carreie by another wining and thir remains unexcitated.

Pi controllers needs manual changes for proportional an integral values of speed an torque. So, they need trial and error approach.hence, this problem is overcome by using adaptive pi controller for sensorless control technique.since, permanent magnet machine ,the hall signal frequency correspond to quasi squared injected into currents of stator phase

Various Speed Control Techniques: BLDC motors can be controlled using a speed feedback (speed sensor) or by a sensorless mode (without a speed feedback). It needs a voltage source inverter and a hall position sensor to exhibit commutation.

In normal speed control of such drives, an encoder measures the speed and compares it with a reference speed in-turn controlling the PWM switching. The speed encoders come with high cost and their mounting arrangement is involved. So this problem is overcome by using speed sensorless control technique.

Many sensorless control techniques observed to be: 1) Speed estimation using back EMF technique was proposed but this technique fails for low speed applications as the counter EMF is close to zero for low speed.

2) Many research works have been carried out in adaptive-controller-based speed estimation technique but these techniques require complex computations and a high speed processor is required.

3) Many literatures proposed speed estimation using state variables from voltage and current models. But this estimation requires the machine parameters, which may not be reliable.

A simple low cost sensorless algorithm is proffered in my work. Here the speed estimation in a sensorless mode is done by measuring the frequency of hall sensors.

II. SYSTEM DESCRIPTION

A. :MATHEMATICAL MODELLING

A BLDC motor has three phase distributed stator winding connected in star. The stator voltage equations can be derived using Kirchhoff's Voltage Law as shown in equations (1), (2),(3).

Van = Ra ia + La (dia /dt) + ean ----------(1)

Vbn = Rbib + Lb (dib /dt) + ebn ----------(2)

Vcn = Rcic + Lc (dic /dt) + ecn ----------(3)

where Van , Vbn , Vcn are phase voltages, Ra , Rb , Rc are stator resistances, ia , ib , ic are the statorrents, La , Lb , Lc are thephase inductances, ean , ebn , ecn are the phase back-EMFs. TheElectro-magnetic torque developed by the machine at steady state is given by equation (4).

T = k ΦIa --------------(4)

where T is the torque (electromagnetic), k is the EMF constant , @ is the flux, Ia is the stator current.

B. GENERAL SCHEMATIC DIAGRAM OF BLDC MOTOR DRIVE:

The schematic of BLDC motor drive is shown Fig 1. Since BLDC motor is an electronically commutated machine, the switching of each phase depends the current rotor position.

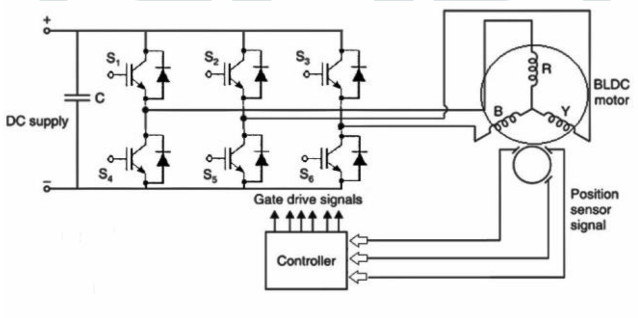

Fig.1.Bldc motor drive – general schematic

The rotor position is determined using hall position sensors. Electronic commutation is done by using a Voltage Source Inverter (VSI). Each switch of VSI conducts for a period of 120 degree and each switching pair conducts for 60 degree. The logic used for developing the commutation. The logic used for developing the commutation strategy is described by equations (5), (6), and (7)

Out 1 = H_A - H_B---(5) Out 2 = H_B - H_C---- (6)Out 3 = H_C – H_A ----- (7)

Out1, Out2, Out3 are the signals generated by the hall block as shown in Fig. 2. This entire logic is done by the controller block and is simulated for the BLDC motor with parameters as shown in Table1.

C. Proposed System:

The closed loop speed control of BLDC motor with adaptive PI is described in Fig. 3. A speed reference is set and it is compared with the

Table I
MACHINE PARAMETERS

Parameters	Description
Number of poles	8
Number of phase	3
Voltage (rated)	48V
Speed (rated)	3000rpm
Torque (rated)	1.4Nm
Power (rated)	440W
Resistance (line-line)	0.2Ÿ
Inductance (line-line)	0.48mH
Torque constant	0.13Nm/A
Mass	2.6kg

V = volt, rpm= revolution per minute, N= newton, s = second, m = meter, A = ampere, kg = kilogram, H = henry, Ÿr= ohm.

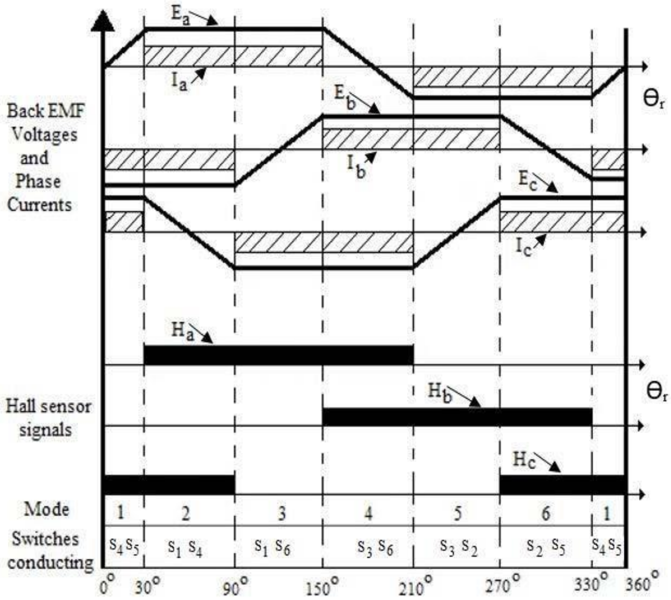

Fig.2 Circuit configuration of the proposed converter.

Actual machine speed, which is estimated by using speed estimator, thus removing the need of a speed encoder. The speed error is reduced to zero by generating a suitable current reference using a adaptive controller which decides the polarity of the reference current that may be positive, negative or zero. The actual stator current of the machine is measured using a current sensor. The reference and actual currents are compared and the current-error is given to a hysteresis controller. This controller generates PWM pulses so as to force the actual current follow the band limits. These PWM pulses fed to the VSI drives the BLDC motor so that actual speed of the machine tracks the reference speed

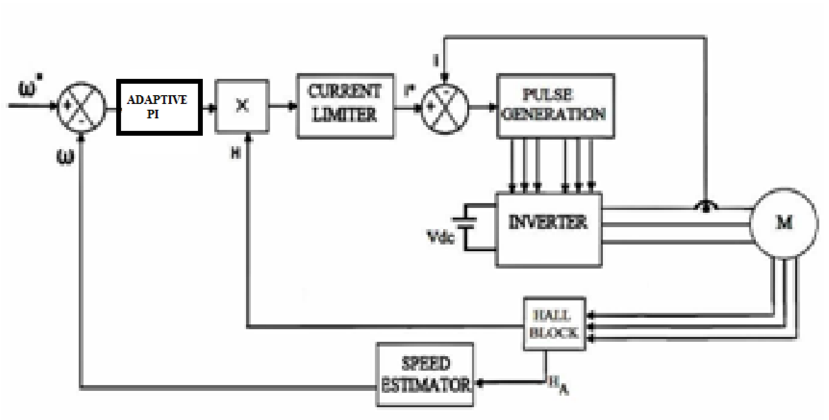

Fig.3. Proposed Block Diagram

D. Speed Estimation Technique:

This system estimates the speed of the machine by measuring the frequency of the Hall signals. Since BLDC motor is a kind of Permanent Magnet Synchronous Machine, frequency of the Hall signals will be same as that of the stator frequency. This estimation technique is explained in Fig. 4.

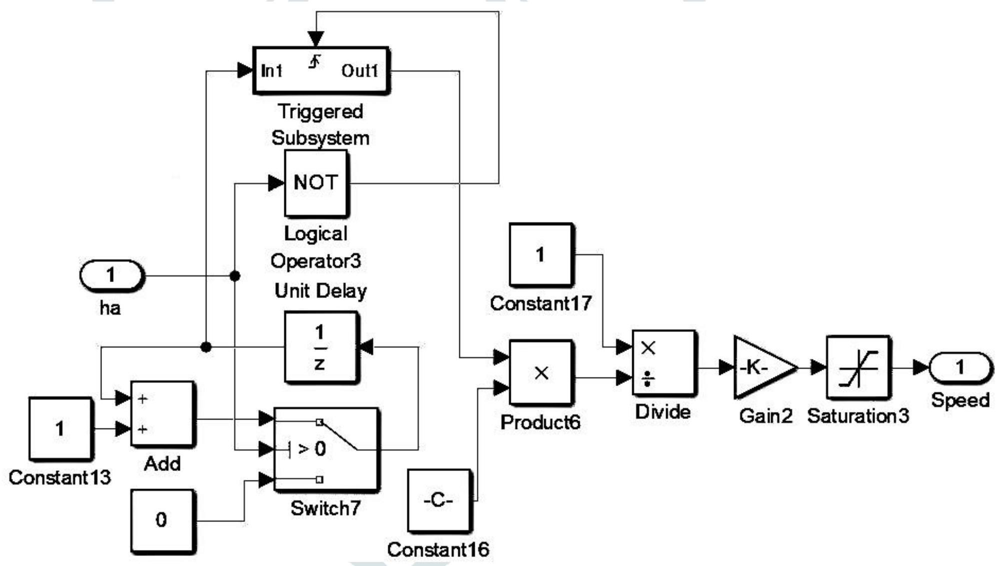

Fig. 4. Speed Estimator

Here a counter counts the number of pulses from the leading edge of the Hall signal till the next falling edge. Knowing this count value and the sampling period of the counter the time period of the Hall signal is calculated as shown in equation (8).

$$T = 2\, n\, T_s \qquad (8)$$

where T is the actual time for 1 cycle, n is the number of counts, Ts is the sampling time. The speed is estimated by calculating the frequency from this time period.

III. Simulation Results

The entire closed loop system is simulated in matlab for different rotor speed. The system was initially run with the reference speed of 1000rpm and starting torque of 3 n-m, after that the observation is carried by changing different value of torque and obtained speed is measured.

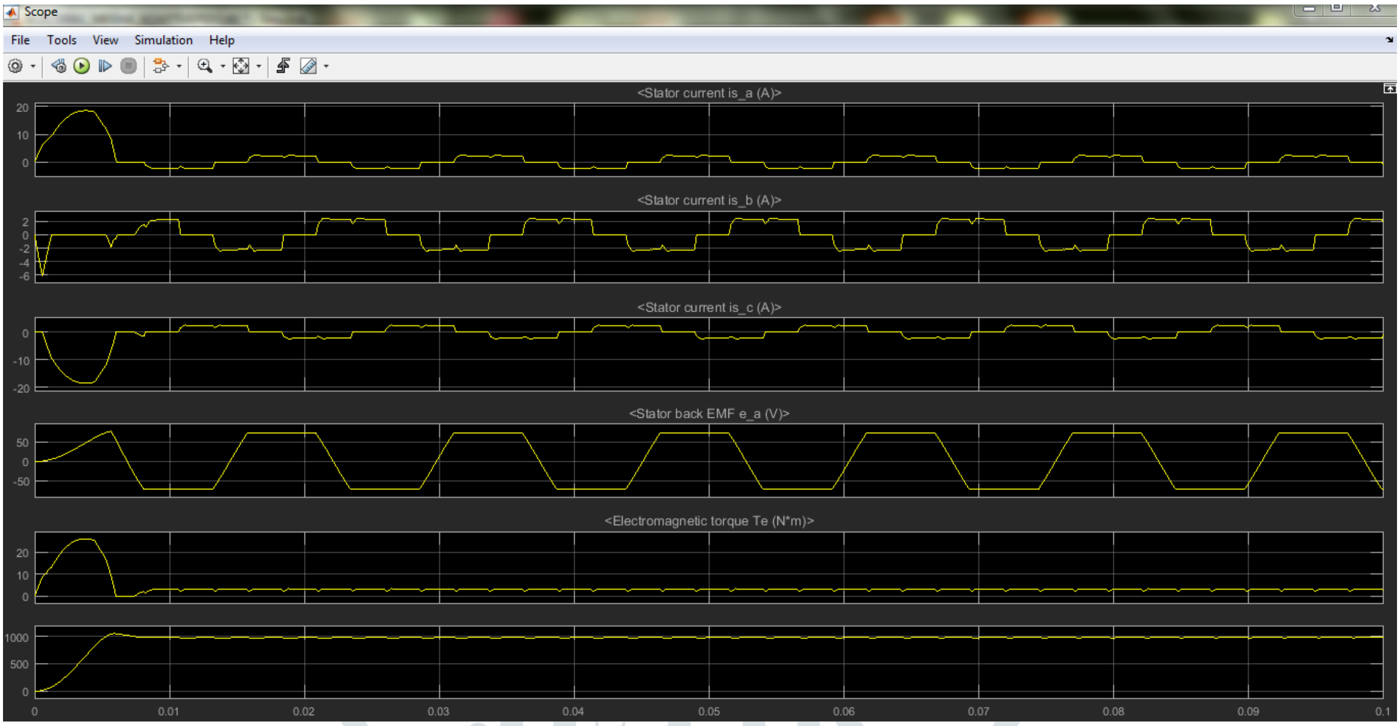

FIG 5: current a,b,c ,back EMF,electromagnetic torque and speed responce at 1000rpm and 3 N-m load

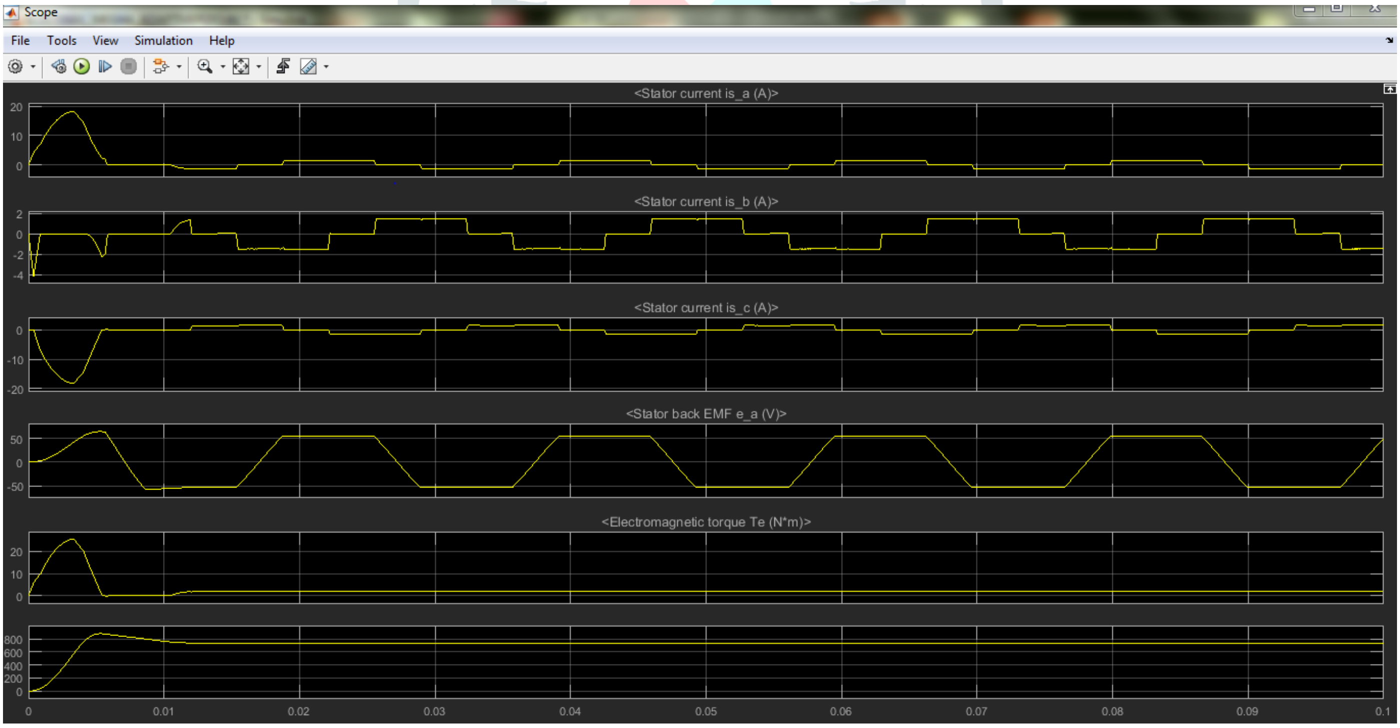

FIG 6: current a,b,c ,back EMF,electromagnetic torque and speed responce at 750rpm and 2 N-m load

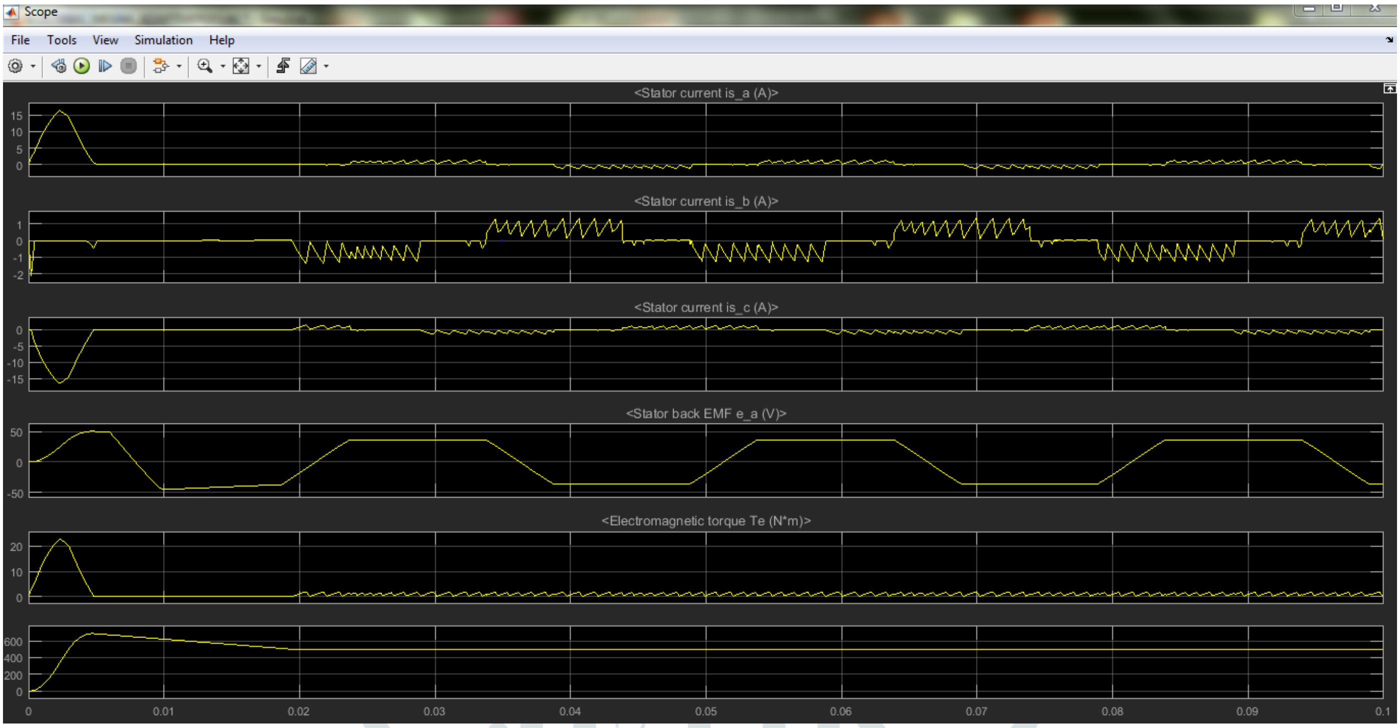

FIG 7: current a,b,c ,back EMF,electromagnetic torque and speed responce at 500rpm and 1 N-m load

IV. CONCLUSION

This paper proposes a implementation for a low cost speed estimation technique for BLDC motor drive. This method was found to be working for the entire range of speeds below the rated speed. The performance of the system is obtained by adaptive pi cintroller. Actual speed was found to maintain the reference speed for different values of load torques. This was verified successfully by using MATLAB/Simulink. Since the proposed speed estimation technique does not require the motor parameters like resistance, inductance etc., the system is suitable for robust applications, especially in industries.

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