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Analysis of Closed Loop Current Controlled BLDC Motor Drive

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Abstract - Brushless direct current (BLDC) motors are mostly preferred for dynamic applications suchas automotive industries, pumping industries, and rolling industries. It is predicted that by 2030, BLDC motors will become mainstream of power transmission in industries replacing traditional induction motors. Though the BLDC motors are gaining interest in industrial and commercial applications, the future of BLDC motors faces indispensable concerns and open research challenges.Considering the case of reliability and durability, the BLDC motor fails to yield improved fault tolerance capability, reduced electromagnetic interference, reduced acoustic noise, reduced flux ripple, and reduced torque ripple.

To address these issues, closed-loop vector control is a promising methodology for BLDC motors. In the literature survey of the past five years, limited surveys were conducted on BLDC motor controllers and designing. Moreover, vital problems such as comparison between existing vector control schemes, fault tolerance control improvement, reduction in electromagnetic interference in BLDC motor controller, and other issues are not addressed. This encourages the author in conducting this survey of addressing the critical challenges of BLDC motors. Furthermore,comprehensive study on various advanced controls of BLDC motors such as fault tolerance control, Electromagnetic interference reduction, field orientation control (FOC), direct torque control (DTC), current shaping, input voltage control, intelligent control, drive-inverter topology, and its principle of operation in reducing torque ripples are discussed in detail. This paper also discusses BLDC motorhistory, types of BLDC motor, BLDC motor structure, Mathematical modeling of BLDC and BLDC motor standards for various applications.

***Key Words*:** Brushless direct current, industries, direct torque control.

1.INTRODUCTION

Motor is an electromechanical machine which converts electrical energy to mechanical energy. Basically, every motor works on the same conversion principle. The electrical energy which is given as an input produces torque due to interaction of current carrying coils with the magnetic field. In the process of conversion, the electro-magnetic field (EMF) inside the conductors will be an alternating quantity. For a DC motor, supply will be DC type but the EMF should be AC type. This operation is done by commutator and brushes in a conventional DC motor. Commutator is mechanical part placed on the rotor segment for the purpose of commutation.

This commutator along with brushes produces wear and tear on the commutator surfaceand hence commutation might not be effective. Also, this mechanical commutator produces highamount of losses. Since both brushes and commutator are good conductors, they produce copper losses. The wear and tear of the commutator surface produces sparks due to uneven current distribution. Sparks produces heat which is a major drawback. The above said disadvantages aremainly due to the presence of commutation process by commutator and brushes. This led to the realization of motors without brushes called brushless DC (BLDC) motor [1-2]. Electrical commutation in BLDC motor is carried out by electronic solid-state switches. Due to the usage of electronic switches for commutation, the drawbacks in conventional DC motor are eliminated thus improving the system performance. Though conventional DC motors show very good speedtorque characteristics and can be used for servo applications, consequences due to brush and commutator requires maintenance. DC motors have very good speed control and especially BLDC exhibits many advantages over conventional DC motor like high efficiency, reliability, low acoustic noise, good dynamic response, lighter, improved speed-torque characteristics, higher speed range and requires very less maintenance.

2. PROPOSED METHODOLOGY

BLDC motor requires DC supply but generally available supply is of AC type. To feed the BLDC,this available AC supply is to be rectified and then fed to the BLDC motor which is commutated electronically. The basic diagram of BLDC motor fed with AC supply is shown in figure 2. BLDC is similar to that of AC Synchronous machine. Stator consists of windings to produce flux but the rotor does not have any windings wound on them instead permanent magnets on rotor. The rotation of the rotor depends on the attraction or repulsion of stator poles and rotor poles. Rotor consists of one or multiple poles. When a pair of poles of stator windings are excited, this attracts the nearest opposite pole of rotor. By continuously switching the poles of stator attracts or repulses the nearest poles and thus the rotor continuously rotates producing torque.

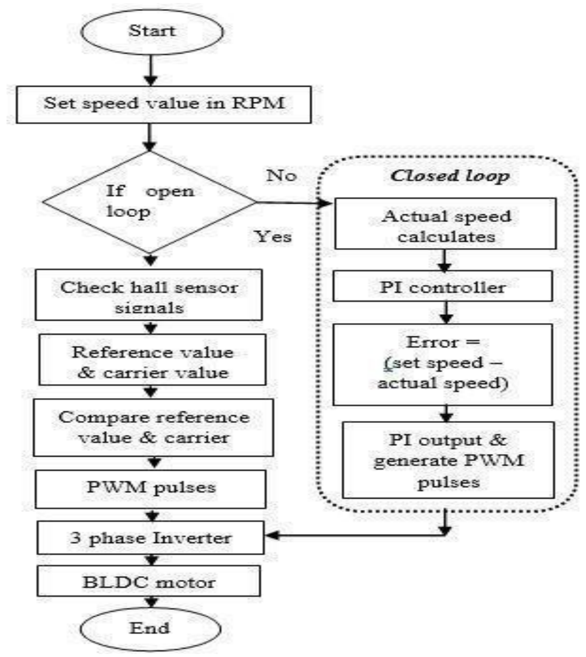

FIG 2.1: FLOW CHART OF A BLDC MOTOR

BLDC motor drive with closed loop speed control is shown in figure 3. This ensures that the drive can operate at any desired speed. In open loop control the speedis set to the reference value and in closed loop operation; this reference speed can be changed at any desired time for the drive to operate at desired speed. In closed loop speed control drive, the actual motor speed is fed back to the input. By using a proper control system, this speed can be varied and brought to desired speed. The actual speed is fed back to the input and is measured with the referencespeed value producing an error signal. This is fed to a PI controller which controls the speed with proper proportional and integral gain value. This PI controller nullifies the present error and the pasterror.

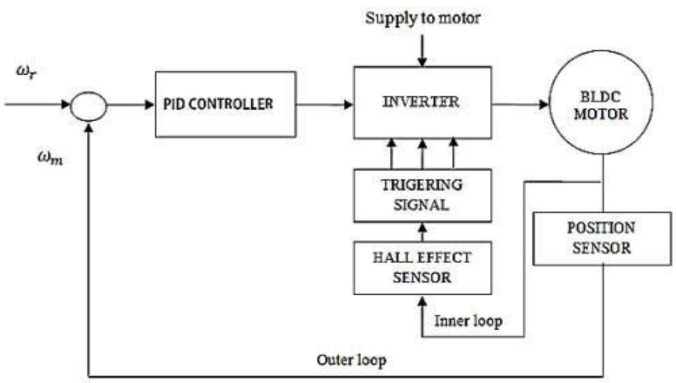

FIG 2.2 : BLOCK DIAGRAM OF BLDC MOTOR

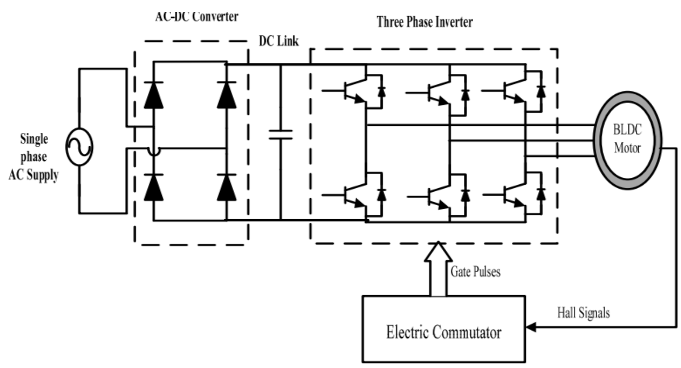

FIG 2.3: DIAGRAM OF BLDC MOTORWITH AC SUPPLY

3. SIMULATION AND RESULTS

MATLAB models with simulation results were discussed for the BLDC motor without current control, BLDC motor with closed loop control run at fixed speed and BLDC motor withclosed loop operation run at variable speed.

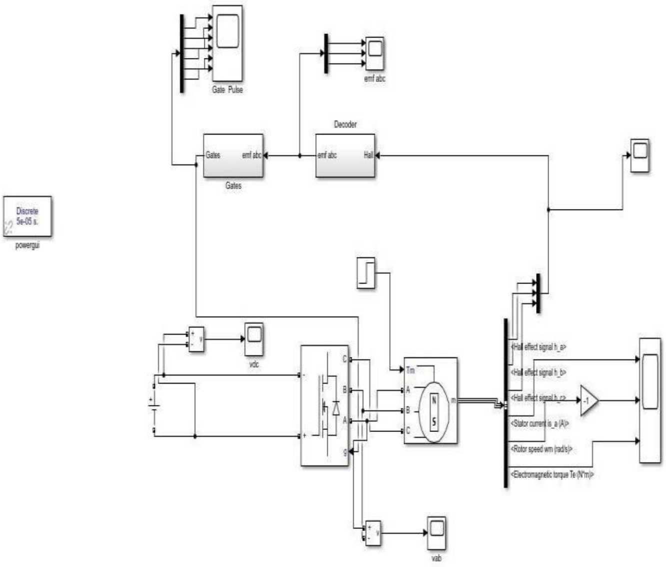

Fig 3.1: MODEL OF CLOSED-LOOP BLDC MOTOR

The model of BLDC motor drive with closed loop control and running with fixed speed was shownin the model discussed is with current control. The Simulink results of stator current and back EMF of BLDC motor with closed loop control was shown in Trapezoidal back EMF can be observed at the output of motor.

The Back Electro Motive Force (BEMF)

Typically, a 3-phase BLDC motor uses six electronic switches (power transistors) to produce 3-phase voltage simultaneously to a full- bridge configuration power converter. The transistors have a rotor position, which will be definedas the switching sequence.

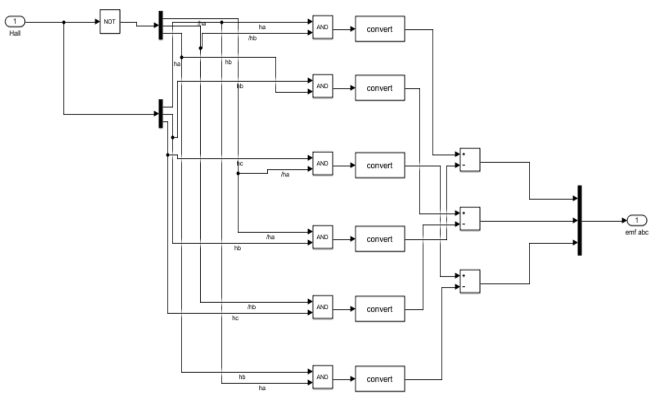

Fig 3.2:BACK EMF OF DECODER FOR MATLAB DRIVE

TABLE I. TRUE TABLE FOR DECODER

Table I.	True Table For Decoder					
	ha	*hb*	*hc*	*emf_a*	*emf_b*	*emf_c*
	0	0	0	0	0	0
	0	0	1	0	-1	+1
	0	1	0	-1	+1	0
	0	1	1	-1	0	+1
	1	0	0	+1	0	-1
	1	0	1	+1	-1	0
	1	1	0	0	+1	-1
	1	1	1	0	0	0

Similarly, Fig.3.3 shows the functional block diagram of the Inverter switching for MATLAB simulation, and Table II shows the decoder sequences of the proposed 3-phase PID controller forthe BLDC motor to rotate in the counterclockwise motion.

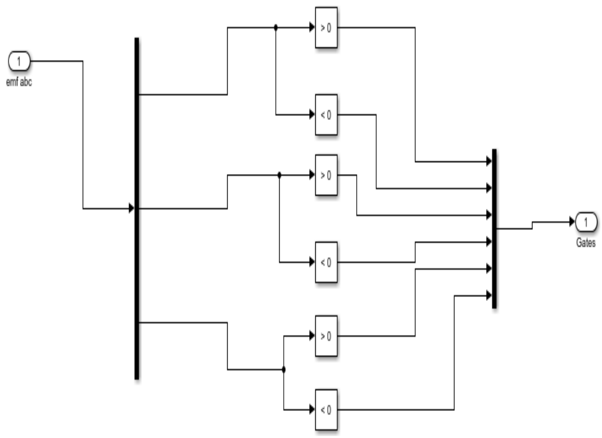

Fig 3.3: INVERTER SWITCHING FOR MATLAB DRIVE

TABLE II. TRUE TABLE FOR INVERTER SWITCHING

Table II.	True Table For Inverter Switching								
	emf_a	*emf_b*	*emf_c*	*Q1*	*Q2*	*Q3*	*Q4*	*Q5*	*Q6*
	0	0	0	0	0	0	0	0	0
	0	-1	+1	0	0	0	1	1	0
	-1	+1	0	0	1	1	0	0	0
	-1	0	+1	0	1	0	0	1	0
	+1	0	-1	1	0	0	0	0	1
	+1	-1	0	1	0	0	1	0	0
	0	+1	-1	0	0	1	0	0	1
	0	0	0	0	0	0	0	0	0

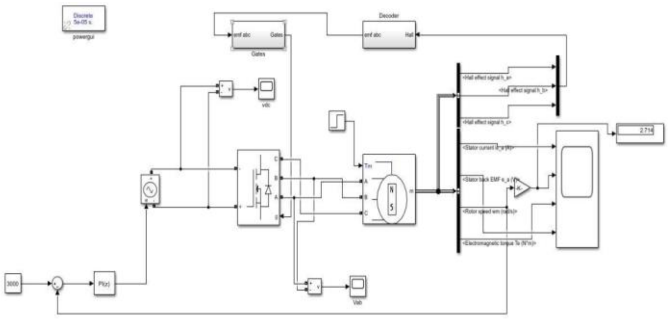

Fig 5.4: COMPLETE MATLAB DESIGN OF CONTROLLER FOR BLDC MOTOR.

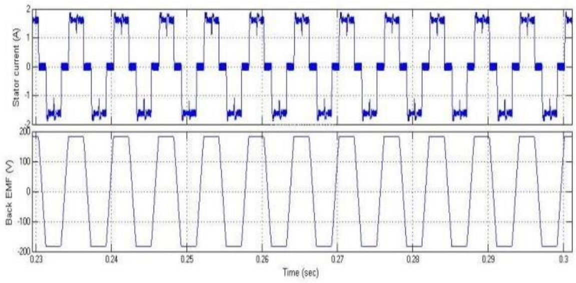

Fig 9: Simulation result of stator current and back EMF for closed loop BLDC motor drive with fixed speed

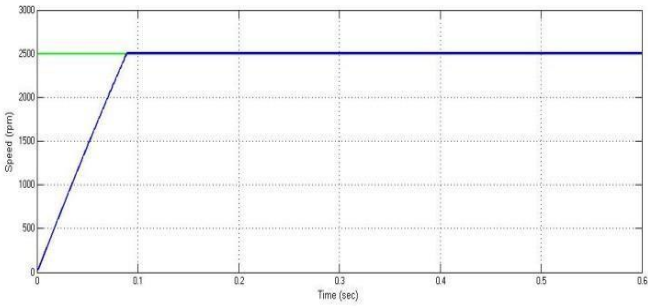

Fig 10: Simulation result of speed for closed loop BLDC motor drive with fixed speed

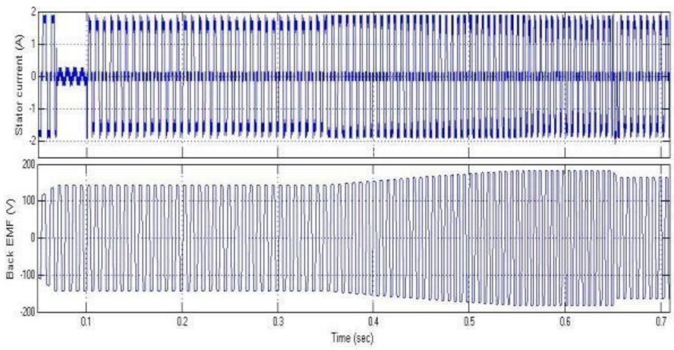

Fig: Simulation result of stator current and back EMF for closed loop BLDC motor drive withvariable speed.

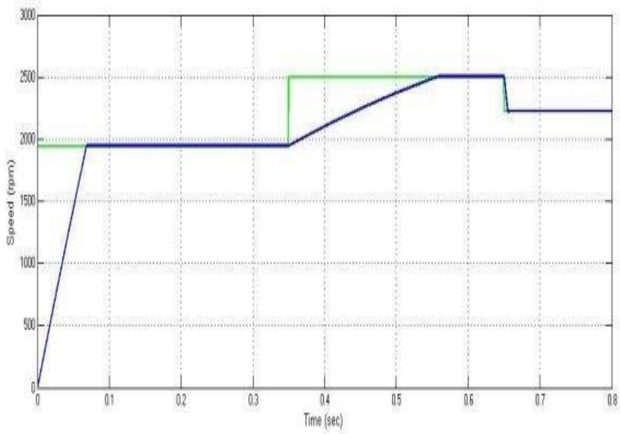

Fig: Simulation result of speed for closed loop BLDC motor drive with variable speed.

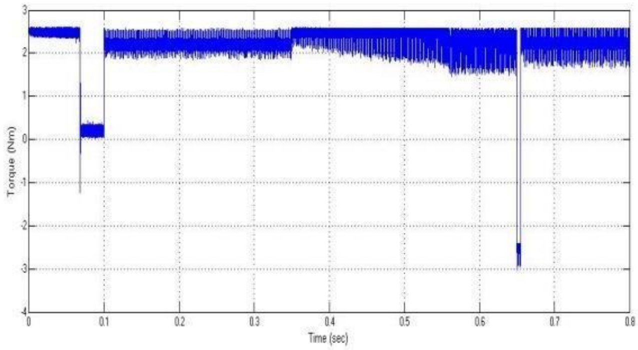

Fig : Simulation result of torque for open loop BLDC motor drive with variable speed.

4. CONCLUSION

The automobile industry is migrating towards eco-friendly transportation with less pollution, hence attention towards electric vehicles and hybrid electric vehicles is increasing. BLDC motorsare gaining more interest in EV applications due to their simple, robust, and high-efficiency ability. This paper reviews various types of BLDC motors, their standards, applications, torque ripple mitigation techniques, and BLDC motor control techniques, in addition to a discussion on the development of a design platform for BLDC motors. A current study reveals that, Currently, outersurface rotor-type BLDC motors such as Hub motors are used widely for commercial applications.The BLDC motor control drive is used to overcome fault-tolerant control, electromagnetic interference control, and acoustic noise control techniques are discussed. Outer surface rotor-type motors are more popular due to the minimum cogging torque leading to high loading effect, high power, and increased efficiency. These motors have a lower requirement of cooling for the rotor as they are exposed to the outer atmosphere receiving ambient air cooling. Torque ripples in BLDCmotors are more at low speeds and less at high speeds. However, Axial-type BLDC motors have higher efficiency and higher torque than the other types of EV motors. Hub motor is used in EV due to its advantage of compact size and retrofitting type model.

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