ANALYSIS THE SPEED MANAGE OF BLDC MOTOR DRIVE USING SENSORS

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ABSTRACT -Brushless DC Motor (BLDC) is one of the best electrical drives that have increasing popularity, due to their high efficiency, reliability, good dynamic response and very low maintenance. Due to the increasing demand for compact & reliable motors and the evolution of low cost power semiconductor switches and permanent magnet (PM) materials, brushless DC motors become popular in every application from home appliances to aerospace industry. The conventional techniques for controlling the stator phase current in a brushless DC drive are practically effective in low speed and cannot reduce the commutation torque ripple in high speed range. This paper presents the PI controller for speed control of BLDC motor. The output of the PI controllers is summed and is given as the input to the current controller. The mathematical modeling of BLDC motor is also presented. The BLDC motor is fed from the inverter where the rotor position and current controller is the input. The complete mathematical model of the proposed drive system is developed and simulated using MATLAB/Semolina software. The operation principle of using component is analyzed and the simulation results are presented in this to verify the theoretical analysis.

Keywords:BLDCM- BRUSHLESS DIRECT CURRENT MOTOR, PM- PERMANENT MAGNET, PI- Proportional Integrated controller, VR- Variable Reluctance.

1. INTRODUCTION

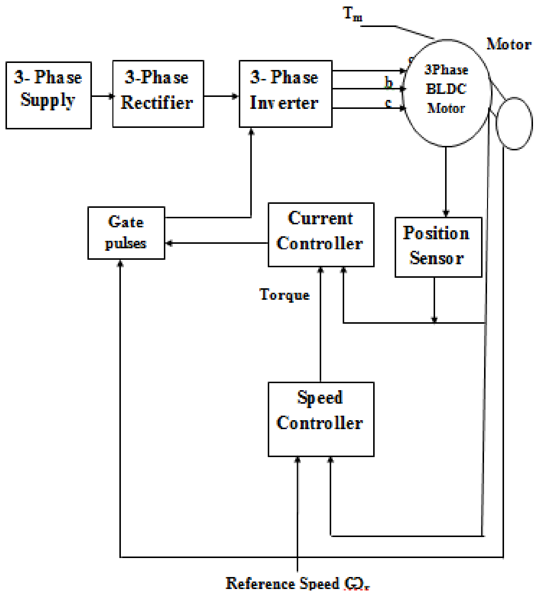
BLDC motors have many advantages over brushed DC motors and induction motors, such as a better speed versus torque characteristics, high dynamic response, high efficiency and reliability, long operating life (no brush erosion), noiseless operation, higher speed ranges, and reduction of electromagnetic interference (EMI).

The control of BLDC motors can be done in sensor or sensor less mode, but to reduce overall cost of actuating devices, sensor less control techniques are normally used. The advantage of sensor less BLDC motor control is that the sensing part can be omitted, and thus overall costs can be considerably reduced.

The disadvantages of sensor less control are higher requirements for control algorithms and more complicated electronics. All of the electrical motors that do not require an electrical connection (made with brushes) between stationary and rotating parts can be considered as brushless permanent magnet (PM) machines , which can be categorized based on the PMs mounting and the back-EMF shape.

The PMs can be surface mounted on the rotor (SMPM) or installed inside of the rotor (IPM), and the back-EMF shape can either be sinusoidal or trapezoidal. A PMAC motor is typically excited by a three-phase sinusoidal current, and a BLDC motor is usually powered by a set of currents having a quasi-square waveform .

Brushless DC motors were developed from conventional brushed DC motors with the availability of solid state power semiconductors. Brushless DC motors are similar to AC synchronous motors. The major difference is that synchronous motors develop a sinusoidal back EMF, as compared to a rectangular, or trapezoidal, back EMF for brushless DC motors. Both have stator created rotating magnetic fields producing torque in a magnetic rotor.



2. Analysis of BLDC Motor Drive System

The three phase inverter topology is a six-switch voltage-source configuration with constant dc-link voltage (Vdc), which is identical with the induction motor drives and the permanent magnet ac motor drives. The analysis is based on the following assumption for simplification. 1. The motor is not saturated. 2. Stator resistances of all the windings are equal, and self- and mutual inductances are constant. 3. Power semiconductor devices in the inverter are ideal. 4. Iron losses are negligible.

3.PROBLEM RELATED TO SPEED CONTROL OF BRUSHLESS D.C. MOTOR DRIVE USING SENSORS.

1. Low-cost Hall-effect sensors are usually used. 2. Electromagnetic variable reluctance (VR) sensors 3. Accelerometers have been extensively applied to measure motor position and speed. **Hall-effect sensors** These kinds of devices are based on Hall-effect theory, which states that if an electric current- carrying conductor is kept in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers that tends to push them to one side of the conductor. A build-up of charge at the sides of the conductors will balance this magnetic influence producing a measurable voltage between the two sides of the conductor.

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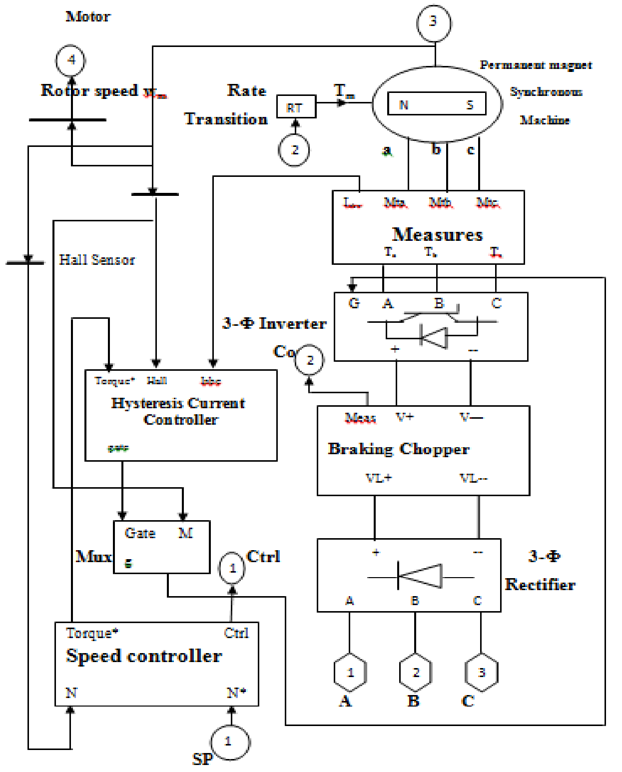


DC MOTOR

To rotate the BLDC motor the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall-effect sensors embedded into the stator .

The connecting principle between the brushless motor and this sensor is reminiscent of the miniaturized magnetic angular encoder based on 3-D Hall sensors. A permanent magnet is fixed at the end of a rotary shaft and the magnetic sensor is placed below, and the magnet creates a magnetic field parallel to the sensor surface. This surface corresponds to the sensitive directions of the magnetic sensor. Three-phase brushless motors need three signals with a phase shift of 120° for control, so a closed-loop regulation may be used to improve the motor performance

4. PROBLEMS OCCUR IN SELECTING THE VALUE OF PI CONTROLLER GAIN SPEED CONTROLLER

The rotor rotation of the BLDC motor, while the motor speed depends only on the amplitude of the applied voltage. The required speed is controlled using a speed controller. The speed controller is implemented as a conventional PI controller.

4.1PI controller and BLDC

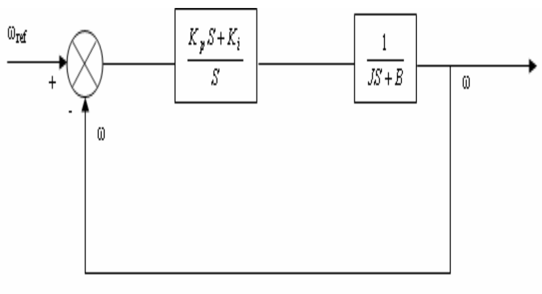
S2+ 2ζωn + ωn2 = 0 (second order system characteristics equation)

T(s) = (Kp S + Ki) /[J(s2 + (B + Kp/J)S + Ki /J)] .

T(s) = G(s).H(s) = (*kp S+kiS*).

(1*JS*+*B*) = Kp S+KiS (JS+B) = Kp S+KiJ S2+ B+Kp J S+(KiJ) ωn= KiJ 2ζωn = B+Kp J ζ = B+Kp 2 J JKi = (B+Kp 2) 1J.Ki

Here, J = Rotor Inertia of BLDC Motor = 0.087 kg.m2 B = Viscous Friction of BLDC Motor = 0.005 N.m.s



5.PROPORTIONAL INTEGRAL CONTROLLER DESIGN

The model of PI speed controller is given by,

G(s) =Kp+(Ki / s)

Where G(S) is the controller transfer function which is torque to error ratio in s-domain, Kp is the proportional gain and Ki is the integral gain. The tuning of these parameters is done using Ziegler Nichols method using the phase and gain Margin specifications. The specifications of the drive application are usually available in terms of percentage overshoot and settling time. The PI parameters are chosen so as to place the poles at appropriate locations to get the desired response. These parameters are obtained using Ziegler Nichols method which ensures stability. From the dynamic response obtained by simulation, the percentages overshoot Mp and settling time ts which are the measures of Transient behaviors are obtained. The speed loop of the typical BLDC motor under no load condition. The closed loop transfer function of the system is given by

$$T(s) = (Kp\, S + Ki) / [J\, (s2 + (B + Kp/J)\, S + (Ki / J)]$$

5.1 METHODOLOGY MATHEMATICAL MODELING OF THE AC MACHINE

The electrical system dynamics may be described by two voltage equation:

$$v1 = r1\, i1 + p\lambda 1$$
$$v2 = r2\, i2 + p\lambda 2$$

Where p is the Heaviside notation for the time differentiation operator d/dt. Assume that the stator flux linkages are linearly related to the currents, the flux linkage λ1 and λ2 may be expressed:

$$\lambda 1 = L11\, i1 + L12\, i2 + \lambda pm1$$
$$\lambda 2 = L21\, i1 + L22\, i2 + \lambda pm2$$

The stator windings are symmetric, i.e. they have the same total self-inductance, resistance, and number of turns. Since the self –inductance is the same for windings, L11 and L22 will denote as Lss. Since the stator windings are tightly wound on highly permeable stator steel, the numerical value of the mutual inductance is nearly equal to the total self-inductance. However, since the magnetic axes are in opposite directions for positive current in each winding, the mutual inductance is negative. A minus sign and the symbol Lm will replace L12 and L21 . The symmetry and configuration of the windings indicate that both have the same permanent–magnet component of flux linkage but with opposite signs. The symbol λm will be used for the permanent-magnet flux linkage term.

$$v1 = rsi1 + Lss\, p\, i1 - Lm\, p\, i2 + p\lambda m$$
$$v2 = rsi2 - Lss\, p\, i1 + Lm\, p\, i2 - p\lambda m$$

pλmcan be expressed as ωr(dλm/dθr) and represents the no-load or back emf of the motor. The induced voltage due to armature reaction are related to the terms containing Lss and Lm which, when added to the back emf , establish the total induced voltages in the stator windings. For the mechanical system, the torque developed by the electromagnetic system counters the inertial acceleration torque, the torques due to windage and friction (modeled as being proportional to rotor velocity), and the load torque , i.e.

$$Te = Jp\omega r + B\, \omega r + TL$$

The interaction of currents in the stator electrical system with the magnetic field of the rotor permanent magnets creates an electromagnetic torque, Te. The electromagnetic torque may be established by expressing the partial derivative of the co energy w.r.t. position. The resulting expression for the electromagnetic torque is:

$$Te = (I1 - I2)\, d\lambda m d\theta r - dWpm d\theta r$$

Where Wpm represented the coupling field energy due to the permanent magnets. Total derivatives because λm and Wpm are functions only of θr. The first term on the right-hand side of equation represents the electromagnetic torque produced by the interaction of electric current in the stator windings with the magnetic field of the rotor permanent magnets.

The second term represents a torque due to the attraction between the rotor permanent magnet and the stator steel and acts to drive the rotor to a position having the lowest permanent magnet component of coupling field energy. This torque hereafter referred to as the cogging torque Tec, ensures that the rotor position of the unexcited motor is such that an electromagnetic torque sufficient for starting is developed when the stator windings are suddenly energized. The cogging torque does not depend upon the stator currents and is a function only of θr. It is incorporated in the state model as a position dependent load torque.

The cogging torque is assumed to very sinusoidalw.r.t. Rotor position. The peak value of the cogging torque and the rotor position at which the cogging torque is maximum were measured experimentally for the given four-pole motor. The variation of cogging torque w.r.t. rotor position is not exactly sinusoidal; the only time that the cogging torque is important is during start-up.

In practically, the cogging torques acts to drive the rotor of an unexcited machine to a position such that when the source voltage is suddenly applied, the resulting electromagnetic torque accelerates the rotor in the proper direction. After some algebraic manipulation may be expressed in state-model from as:

$$pi1 = 1Lss\,(1-k2)\,[(v1 - rs) + k(v2 - rest\ i2) - (1-k)\,\omega rd\lambda md\theta r]$$

PERFORMANCE OF BLDC MOTOR The actual shaft output torque is:

$Tload = Tem - Tlosses$

Where Tlosses is the total losses due to friction, windage, and iron losses. Dropping the amplitude signs, we have $Tem = mp2\ \lambda m\ I$ Speed-torque curve:- The voltage equation can be simplified as $V = E + IR$ Substituting the relations of E -ωr and T-I, we obtain.

$$v = P2\omega r\lambda m + 2Rmp\lambda m\, T_{em}$$
$$\omega r = 2vp\lambda m - 4Rm\, p\lambda m\, 2\, T^{em}$$

6.MECHANICAL INPUT

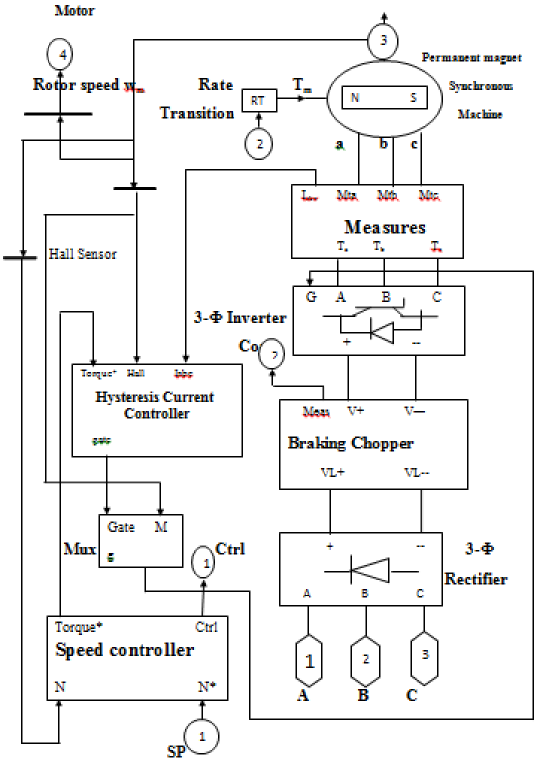
Allows you to select either the load torque or the motor speed as mechanical input. Note that if you select and apply a load torque, you will obtain as output the motor speed according to the following differential equation that describes the mechanical system dynamics: $Te = Jddt\omega r + F\,\omega r + Tm$ This mechanical system is included in the motor model. However if you select the motor speed as mechanical input then you will get the electromagnetic torque as output, allowing you to represent externally the mechanical system dynamics. Note that the internal mechanical system is not used with this mechanical input selection and the inertia and viscous friction parameters are not displayed.

6.1Block diagram of BLDC Motor Drive

This circuit uses the AC7 block of SimPower System library. It models a brushless DC motor drive with a braking chopper for a 3HP motor. The permanent magnet synchronous motor (with trapezoidal back-EMF) is fed by a three phase inverter, which is built using a Universal Bridge Block. The speed control loop uses a PI regulator to produce the torque reference for the current control block.

6.2 Current Controllers

In the BLDC motor drive, duty cycle controlled voltage PWM technique and hysteresis current control technique can be regarded as the main current control strategies. In this thesis bipolar hysteresis current control is used for obtaining the fast dynamic responses during transient states.



6.3Brushless D.C. Motor Drive (SIMULINK)

Implement brushless DC motor drive using Permanent Magnet Synchronous Motor (PMSM) with trapezoidal back electromotive force (BEMF).

7.RESULIT

Stator Current of BLDC Motor

This graph represents the stator current (ia in Amp) vs time (in sec.) of Brushless Dc Motor. Stator currentwaveform is not smooth because some harmonics are present in input.

Rotor Speed of BLDC Motor

This graph represents the rotor speed (in rpm) vs time (in sec) of BLDC motor.Speed of themotor is varied in between Rated Speed 78.5 rad/sec. at 0 sec but without Torque. BLDC Motor is 8poles Motor and frequency is 50 Hz, then

Speed(N) = (120*frequency) / Numbers of poles.

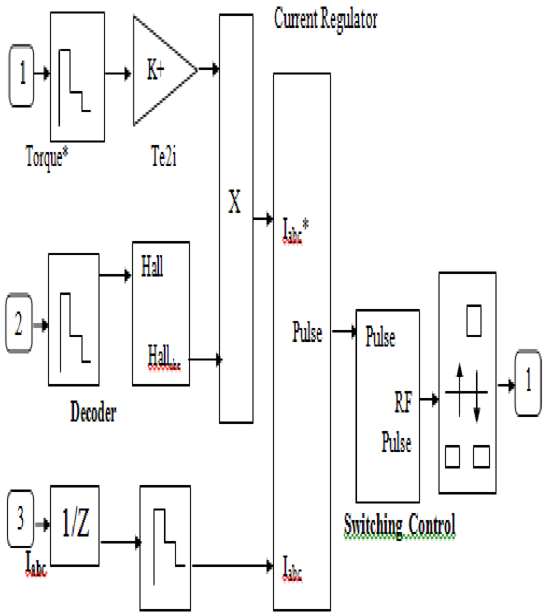
Wm = 2π* N

Electromagnetic Torque of BLDC motor

As shown in the following figure, the speed precisely follows the acceleration ramp. At t = 0.2 s, the nominal load torque is applied 1.4 Nm to the motor. At t = 1 s, the speed set point is changed to 0 rpm. The speed increases to 0rpm. At t = 1.2 s., the mechanical load passes from 0 N.m.

DC Bus voltage of BLDC Motor

This graph represents the variation of dc bus voltage (in volts) with respect to time. This D.C. bus voltage isobtained from Three- phase rectifier circuits.



8.CONCLUSION

In this paper a mathematical model of brushless DC motor is developed. The simulation of the brushless DC motor was done using the software package MATLAB/SIMULINK. a review of position control using Hall sensor methods for BLDC motors has been presented.It is obvious that the control for BLDC motors using position sensors, such as shaft encoders, resolvers or Halleffect probes, can be improved by means of the elimination of these sensors to further reduce cost and increase reliability. we have done result analysis and found results in different load conditions. We have also analyzed the steady state condition and transient condition. The steady state condition was found to be very close to the transient condition.

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