A Design Optimal PID Controller For Speed Control of BLBLDC Motor

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Abstract- *The Brushless BLDC (BLBLDC) motor speed driving systems have sprouted in various small scale and large scale applications like automobile industries, domestic appliances etc. This leads to the development in Brushless BLDC motor (BLBLDCM). The usage of BLBLDC Motor enhances various performance factors ranging from higher efficiency, higher torque in low-speed range, high power density ,low maintenance and less noise than other motors. The BLBLDC Motor can act as an alternative for traditional motors like induction and switched reluctance motors. PID controller is implemented with speed feedback loop and it is observe that torque ripples are minimized. Simulation is carried out using MATLAB / SIMULINK. The results show that the performance of BLBLDC Motor is quite satisfactory for various loading conditions. Brushless BLDC motor drives are typically employed in speed controlled applications.*

Keywords- BLBLDC Motor, PID Controller , PWM technique, MATLAB SIMULINK, Back EMF of Decoder for MATLAB Drive

I. INTRODUCTION

The most obvious advantage of the brushless configuration is the removal of the brushes, which eliminates brush maintenance and the sparking associated with them. Having the armature windings on the stator helps the conduction of heat from the windings. Because there are no windings on the rotor, electrical losses in the rotor are minimal. The BLBLDC motor compares favorably with induction motors in the fractional horsepower range. The former will have better efficiency and better power factor and, therefore, a greater output power for the same frame, because the field excitation is contributed by the permanent magnets and does not have to be supplied by the armature current. These advantages of the BLBLDC motor come at the expense of increased complexity in the electronic controller and the need for shaft position sensing. Permanent magnet (PM) excitation is more viable in smaller motors, usually below 20 kW. In larger motors, the cost and weight of the magnets become excessive, and it would make more sense to opt for excitation by electromagnetic or induction means. However, with the development of high-field PM materials, PM motors with ratings of a few megawatts have been built. The direct torque control (DTC) techniques, implemented in six-switch inverter, for brushless BLDC (BLBLDC) motors with non-sinusoidal back-EMF using two and three-phase conduction modes.

II. MODELLING OF BLBLDC MOTORDRIVE

To understand the BLBLDC motor in details lets consider the diagram (shown in Fig.2.1)

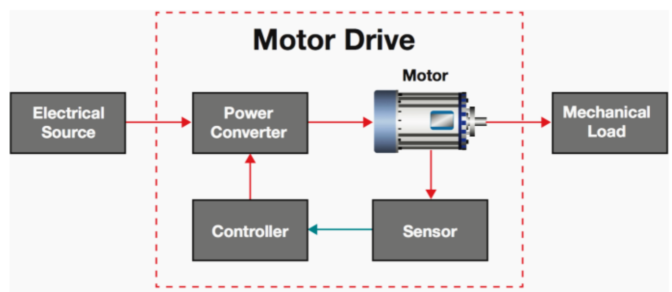

Fig.2.1 Block Diagram of motor Conversion

The direct current motor is represented by the circle in the center, on which is mounted the brushes, where we connect the external terminals, from where supply voltage is given. On the mechanical terminal we have a shaft coming out of the Motor, and connected to the armature, and the armature-shaft is coupled to the mechanical load. On the supply terminals we represent the armature resistance Ra in series. Now, let the input voltageE, is applied across the brushes. Electric current which flows through the rotor armature via brushes, in presence of the magnetic field, produces a torque Tg . Due to this torque Tg the BLDC motor armature rotates. As the armature conductors are carrying currents and the armature rotates inside the stator magnetic field, it also produces an emf Eb in the manner very similar to that of a generator. The generated Emf Eb is directed opposite to the supplied voltage and is known as the back Emf, as it counters the forward voltage. The back emf like in case of a generator is represented by

$$E_b = \frac{P.\emptyset.Z.N}{60.A}$$

Where,

- P = no of poles
- φ = flux perpole
- Z= No. ofconductors
- A = No. of parallelpaths
- and N is the speed of the BLDCMotor.

So from the above equation we can see Eb is proportional to speed 'N'. That is whenever a direct current motor rotates, it results in the generation of back Emf. Now lets represent the rotor speed by ω in rad/sec. So Eb is proportional to ω.the same speed under variable load. Now armature current Ia is represented by

$$I_a = \frac{E - E_b}{R_a}$$

Now at starting, speed ω = 0 so at starting Eb = 0.

$$I_a = \frac{E}{R_a}$$

Now since the armature winding electrical resistance Ra is small, this motor has a very high starting current in the absence of back Emf. As a result we need to use a starter for starting a BLDC Motor.

Now as the motor continues to rotate, the back Emf starts being generated and gradually the current decreases as the motor picks up speed.

III. THE BACK ELECTRO MOTIVE FORCE

Typically, a 3-phase BLBLDC 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 defined as the switching sequence. Most of the cases motor starter is monitoring by using three hall sensor devices. The hall sensors provide the information to the decoder block the back electromotive force (BEMF). To operate the motor for producing the sign of reference current signal vector to in the opposite direction, the current is changed in reverse direction or the switching order of the controller is changed.

The MATLAB simulation block diagram for generating the back EMF of the decoder is shown in Fig. 3, and Table I shows the decoder sequences of the proposed 3-phase PID controller for the BLBLDC motor to rotate in the clockwise direction.

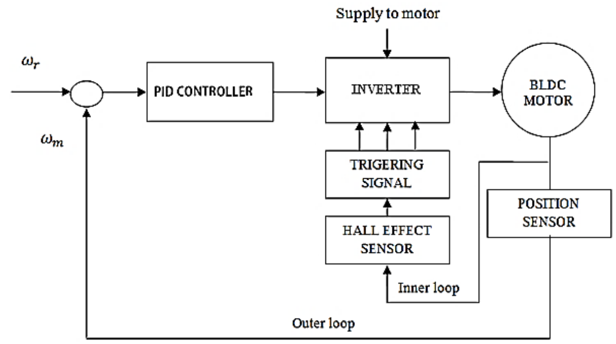

Fig.3.10 Block Diagram of BLBLDC Motor Speed Control.

IV. BACK EMF OF DECODER FOR MATLAB DRIVE

When a voltage (an electro-motive force) is applied to a motor's armature, current begins to flow, creating a magnetic force which causes the armature to rotate. A counter force in the form of eddy currents is generated by the armature rotating in the magnetic field. This counter force is called Back Electro-motive Force or Back-EMF (BEMF).

The faster the armature turns, the more BEMF is produced. The eddy currents in turn oppose the current flowing in the winding. The net effect is the BEMF limits just how fast the motor or generator can turn.

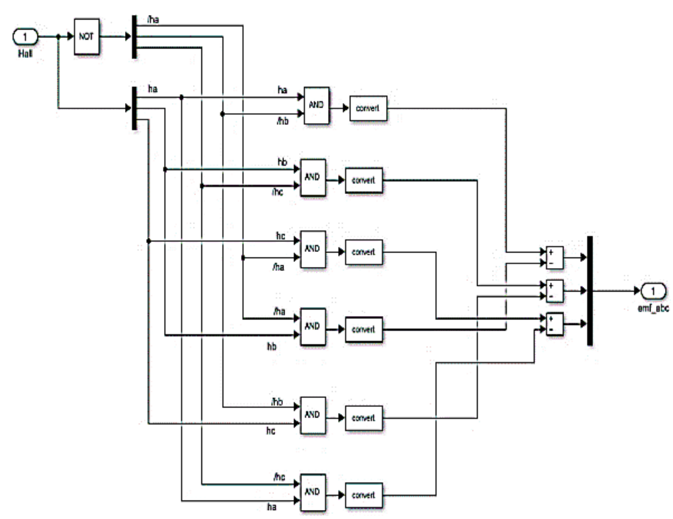

Fig. 3.11 Back EMF of Decoder for MATLAB Drive.

V. INVERTER SWITCHING FOR MATLAB DRIVE

Inverters are three phase devices and operate at very high frequencies. SCR are not used as the switching devices in these units. IGBT's (Insulated-gate bipolar transistor) are used for this function. This power semiconductor device is used as an electronic switch. It is known for its high efficiency and fast switching.

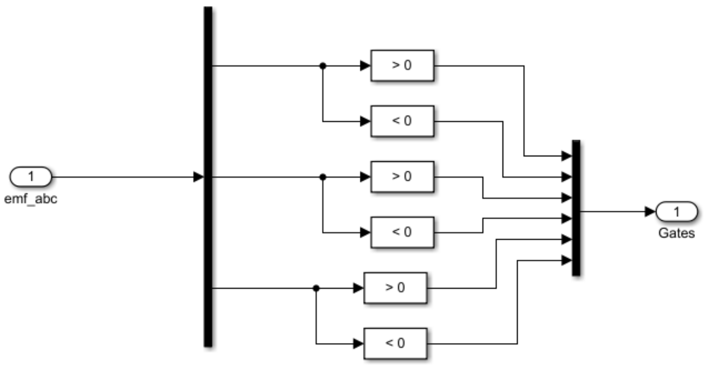

Fig. 3.12 Inverter Switching for MATLAB Drive.

VI. IMPLEMENTATION OF PROPORTIONAL-INTEGRAL-DERIVATIVE CONTROL MODEL

For getting better performance of BLDC motors it is essential to use a controller circuit. For this purpose, a variety of controller circuits and algorithms are used. However, among them PID controller is the most suitable controller circuit for BLBLDC motor. The PID controller is mainly composed of three block of circuits and they are proportional, integral and derivative blocks. Each block of circuit is used to perform different mathematical operations as their name mentioned. The complete MATLAB design of the proposed controller for 3-phase brushless BLDC motor is shown in Fig. 5. The diagram clearly shows how the reference source, PID controller, driver circuit, sensors, converter circuit, inverter circuit, display scope and motor are interconnected.

The foundational frequency transferring performance G(s) of the PID controller can be represented by (1) and (2),

$$G(s) = K_p + K_i/s + K_d s$$
$$G(s) = (K_d s^2 + K_p s + K_i)/s$$

Where,
K_p = proportional gain coefficient,
K_i = integral gain coefficient
K_d = derivative gain coefficient and s is the complex frequency.

VII. IMPLEMENTATION OF METHODOLOGY BY USING SIMULATION

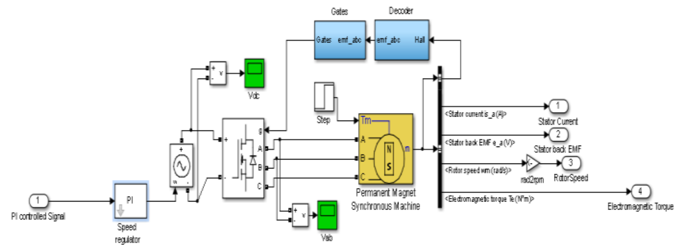

Fig. 4.1 Simulation model for speed control of blBLDC motor by using Proportional-Integral-Derivative Control network

The energetic equations of BLDC motor using assuming point scan be derived as

$V_a = RI_a + (L-M)diadt+e_a$ (5.1)
$V_b = RI_b + (L-M)dibdt+e_b$ (5.2)
$V_c = RI_c + (L-M)dicdt+e_b$ (5.3) Where,

- V_a , V_b, V_c = Stator phasevoltages
- I_a , I_b, I_c = Stator phasecurrents
- e_a , e_b, e_c = Back emf ofphases
- M= Mutual inductance

A controller of speed, the braking chopper, and the intelligent controller models are limited to the Electric Drives library. It is desirableto practise a simplified version of the drive involving an average-value model of the inverter for raPI simulation. A Brushless BLDC motor (BLBLDC) is a BLDC motor twisted inside out; therefore the field is on the rotor and the armature is on the stator. The BLBLDC motor is actually a permanent magnet AC motor in which a torque-current tendency mimes the BLDC motor Rather of commutating the armature current by using the brushes, commutation of electronic is used. This rejects the problems joined with the brush and the commutator adjustment for pattern, flickering and wearing out of the commutator-brush adjustment, thereby, making a BLBLDC motor more rugged as compared to a BLDC motor. BLBLDC motors have so many similarities to the AC induction motors and the brushed BLDC motors in terms of the construction and working principles respectively. Same as other motors, BLBLDC motors also consists of a rotor and a stator.

VIII. SIMULATION RESULTS ANDDISCUSSION

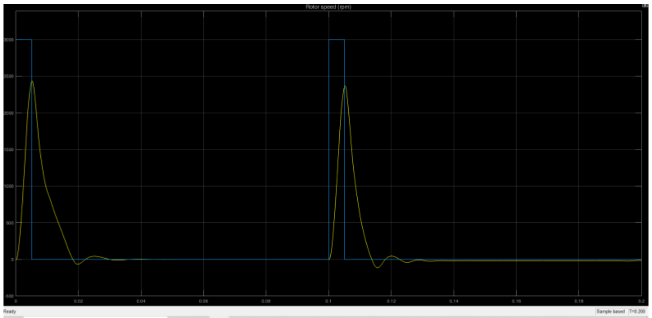

Fig4.2 speed VS time curve of speed control of blBLDC motor by using Proportional-Integral-Derivative Controller

Here, Performance plot shows a plot of training record error values against the number of training epochs, Training state plot plots the training state from a training record returned by train, Error histogram plots a histogram of error values, Regression plot displays the network outputs, with respect to targets for training, validation and test sets. After getting these plots by training the dataThen after pressing this command we will get the Proportional-Integral-Derivative Control simulink block which is blue in color .

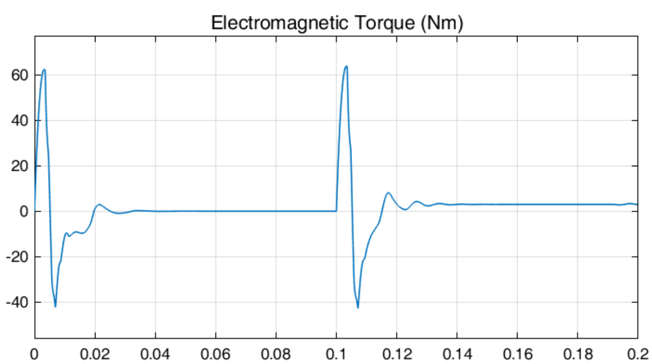

Fig 4.3 Torque VS Time curve of speed control of BLDC motor by using Proportional-Integral-Derivative Controller

Now placing this blue coloured block to the controller of speed controller by replacing PI by Proportional-Integral-Derivative Control. As in practical MATLAB, the variation in the speed of PI and Proportional-Integral-Derivative Control is seen. The speed variation is given for 1700rpm or 1600rpm. Therefore it is found that Proportional-Integral-Derivative Control works more efficiently than PI for the large number of data. In PI controller if any change occurs, then big variations occur in the result of speed. And once Proportional-Integral-Derivative Control gets trained, it gives efficient result.

IX. CONCLUSION

The speed of separately excited BLDC motor can be controlled from below and up to rated speed using chopper as a converter. The chopper firing circuit receives signal from controller and then chopper gives variable voltage to the armature of the motor for achieving desired speed. There are two control loops, one for controlling current and another for speed. The controller used is Proportional-Integral type which removes the delay and provides fast control. The complete layout of BLDC drive mechanism is obtained. The designing of current and speed controller is carried out. The optimization of speed controller is done using soft starter approach, in order to get stable and fast control of BLDC motor. After obtaining the complete model of BLDC drive system, the model is simulated using MATLAB(SIMULINK).The simulation of BLDC motor drive is done and analyzed under varying speed and varying load torque conditions like rated speed and loadtorque.

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