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Sensor less Speed Control for Permanent Magnet Motors with Non- Sinusoidal Back EMF

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ABSTRACT

Brushless DC motor has a rotor with permanent magnet and has no mechanical commutator which leads to many advantages like less maintenance, long life, high reliability, low inertia, low friction and low noise. Since the brush system/commutator assembly is replaced by an electronic controller which can be easily integrated into other required electronics, thereby improving the effective power to weight and power to volume ratio. In this paper the direct torque control method is employed to improve its torque ripple content which is been compared with conventional method by using MATLAB. In this project the three phase brushless DC motor model is designed with proportional integral controller and tested in MATLAB software. The PI controller is used to control the speed of the brushless DC motor. On the other hand parameters like Back EMF, current; speed and torque are evaluated for the designed models of BLDC motor. Due to the easy implementation and simple control structure the convectional PI controller are used in industries.

Keywords : Back-EMF, Hall sensor, VSI, BLDC motor

I. INTRODUCTION

Brushless dc (BLDC) motor drives have gained importance in the last decade due to power quality improvements Brushless dc electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMS, EC motors) are that are powered by a dc electric source via an integrated switching power supply, which produces an ac electric signal to drive the motor. In this context, ac, alternating current, does not imply a sinusoidal waveform, but rather a bidirectional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of dc bus usage/efficiency) and frequency (i.e. Rotor speed). BLDC motors have the following advantages longer life-2 to 3 times longer than brushed motors, no maintenance-no carbon brushes to be changed, cleaner, quieter, no arcing (spark-free)- safe and less radio interference ,very high reliability-no commutation or brushes to wear out. In the view of bus operators, downtime is not only troublesome but also costly. Smart bus operation companies are willing to pay higher prices in exchange for reducing the maintenance burden, in our case the time spent on changing brushes and replacing faulty motors from time to time. the cost and trouble saved on maintenance are the main criteria that will drive them to switch to reliable BLDC motors. Unlike other products, our targeted customers will only consider switching to our product after careful calculation. This means it takes some time for the market to understand the benefits of using BLDC motors. Brushless motors fulfill many functions originally performed by brushed dc motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications particularly devices such as computer and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used in for gramophone record.

II. EXISTING SYSTEM

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications. With a known magnetic field, its distance from the Hall plate can be determined. Using groups of sensors, the relative position of the magnet can be deduced. A Hall sensor is combined with circuitry that allows the device to act in a digital (on/off) mode, and may be called a switch in this configuration. Hall sensors are commonly used to time the speed of wheels and shafts, such as for internal combustion engine ignition timing, tachometers and anti-lock braking systems. The Hall sensor is used in brushless DC electric motors to detect the position of the permanent magnet.

Disadvantages:

In sensored control, sensors determine the position of the motor rotor with respect to the motor stator. This makes for fairly simple control of the motor. A processor need only wait for a Hall effect sensor to change state, determine which sector the rotor is in based on the output of the three Hall effect sensors and commutate the motor windings appropriately. Sensored control has several drawbacks. Sensors cost money. In addition to the sensor itself, there is the further cost of mounting the sensors to the motor during manufacturing as well as the cost of sensor wires. . Sensors add another potential failure point to the motor. If a sensor fails, the motor fails..

III. PROPOSED METHOD

Direct torque control (DTC) is defined as directly control of the flux linkage and electromagnetic torque. Considering the electrical machine, the power electronic inverter, and the control strategy at the system level, a relationship is established between the torque, the flux and the optimal inverter switching so as to achieve a fast torque response. It exhibits better dynamic performance than conventional control methods.

BLOCK DIAGRAM:

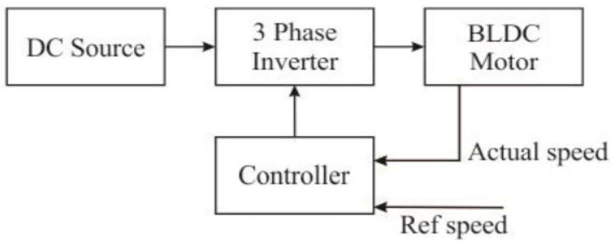


Fig.1. Block Diagram

BLDC motors that have a high efficiency might have a very low resistance and very low inductance. The final speed of a BLDC motor is determined by the applied supply voltage and by the BEMF constant of the motor. The speed can be adjusted by adjusting the applied supply voltage. Normally, one has a fixed voltage source e.g. a battery, a rechargeable battery, or a power supply unit – with a constant voltage. The advantage of the PWM is its low power dissipation compared to voltage adjustment by a linear regulator. A current regulation can be achieved by adjusting the effective voltage by varying the PWM duty cycle depending on a measured current. Pulse width modulation can be in two modes, voltage mode and current mode. When the PWM signal controls the voltage, the motor is driven in voltage mode. When it is controlling the current, the motor is driven in current mode. Voltage mode allows you to control the speed easily by changing the motor reference voltage. It does not give you fine control of the current but you can limit the current and consequently the torque to a maximum value. The voltage control is done by the PWM duty cycle.

PI CONTROLLER

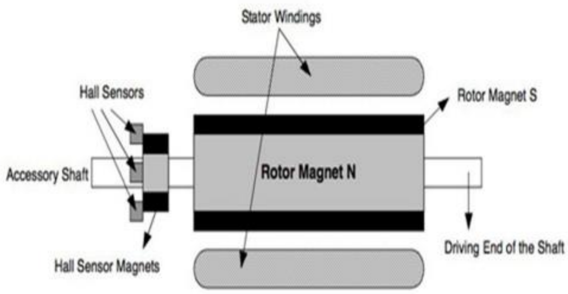


Fig.2. The basic model of permanent magnet brushless DC motor

In industrial system PI is a control loop feedback mechanism. Actually between measured process variable and desired set point error exist. So to correct that error Proportional integral controller is used in industries. The proportional mode and integral mode are two separate modes involved in proportional integral mode calculation. The reaction to the current error is calculated by Proportional mode and reaction to the recent error is calculated by integral mode. So the sum of these two modes output is considered as corrective action to the control element and PI controller is implemented as,

$$output(t) = K_p e(t) + K_I \int_0^t e(\tau) d\tau$$

e (t) =set reference value – actual calculated value. The basic model of permanent magnet brushless DC motor is shown in figure.2. In that model it consist of BLDC motor, position sensor, pulse width modulation current controller, voltage source inverter, reference current generator and PI controller. The speed error is processed to PI controller after comparing the speed of the BLDC motor with its reference speed.

$$e(t) = \omega_{ref} - \omega_m(t)$$

$$T_{ref}(t) = T_{ref}(t-1) + K_p[e(t) - e(t-1)] + K_1 e(t)$$

K_p & K_I -gain of speed controller

The reference torque is nothing but output of the controller. The three phase reference current , Ia, Ib, Ic is generated by reference current generator with the limits of peak current magnitude decided by the controller and position sensor. The switching commands are generated to drive the inverter devices by comparing motor current and its reference current.

Three Phase Inverter

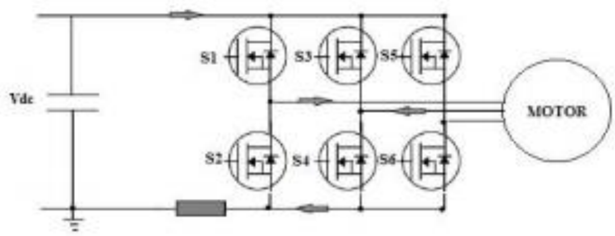


Fig.3. Three Phase Inverter

Consider a three-phase inverter shown in figure 3, Q1 through Q6 are the six power transistors that shape the output current, which are controlled by the switching signals a, a/ , b, b/ , c and c / . When an upper transistor is switched on, the corresponding lower transistor is switched off. Hence, the three-phase inverter can produce eight output states. Switching state 100 means, upper switch in phase a is closed, and upper switches in phase b and c are open. For each of the possible switching states, thus, eight output states of inverter represent eight space vectors; two are null vectors and remaining six are of equal magnitude and arranged 60o apart in space. The space diagram is shown in the Figure

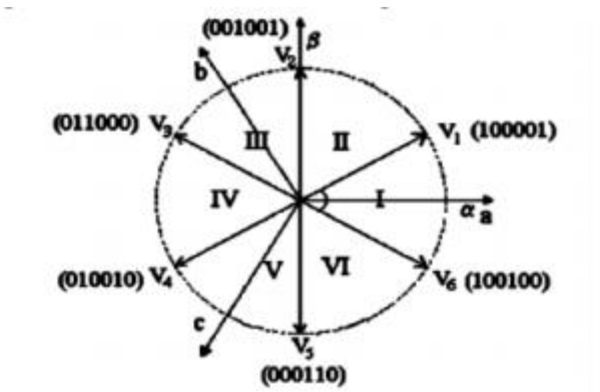


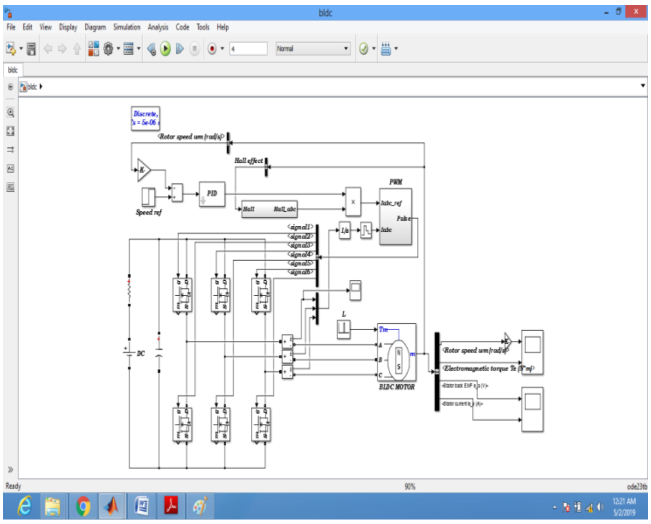
Fig.4. Sector selection

Concept of Direct Torque Control:

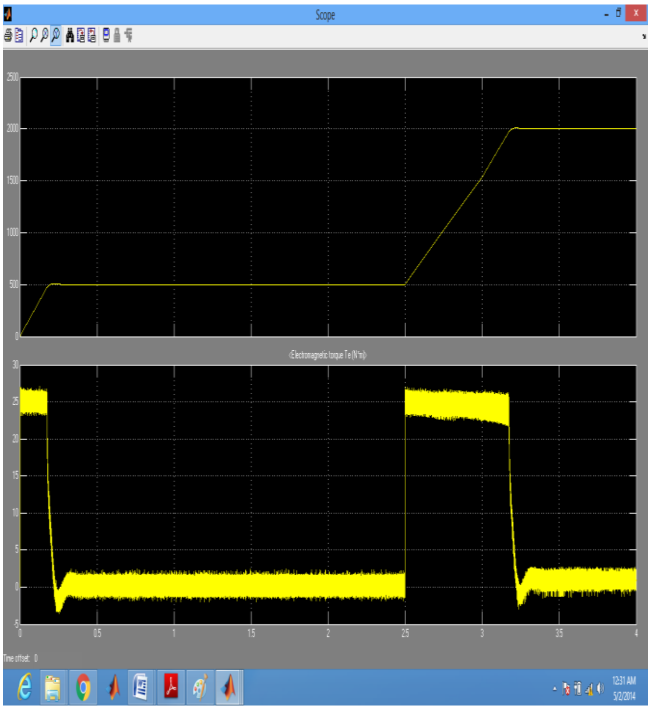
The command stator flux reference is generated by the speed to flux look up table and the command torque reference is generated by the speed controller which converts speed error into torque. Torque and flux are estimated by taking motor line voltages and currents. After transforming these three phases The reference flux and torque commands are compared with the estimated values and the errors are processed through hysteresis-band controllers. Selection of the appropriate voltage vector in the inverter is based on stator equation in stator coordinates. components into two phase stationary components stator flux, torque and angle in which the stator flux lies are estimated

IV. SIMULATION RESULTS

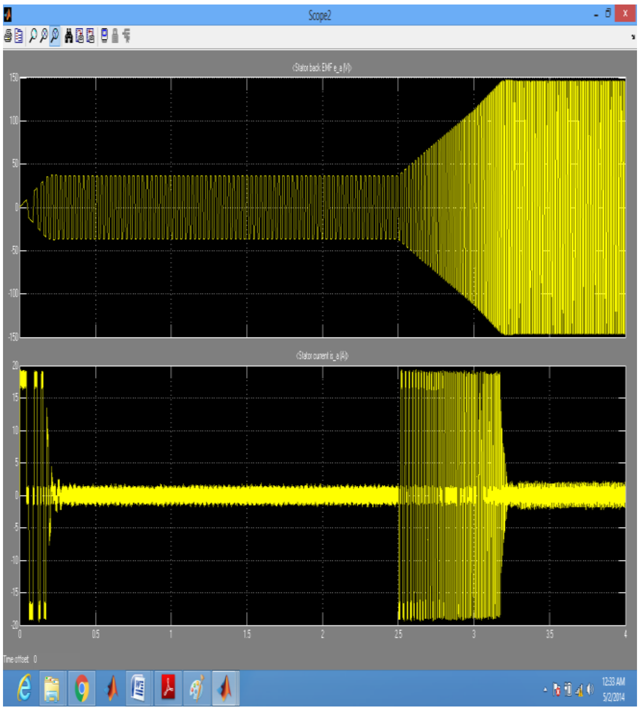
SIMULINK DIAGRAM:



MOTOR SPEED AND TORQUE:



STATOR BACK EMF & STATOR CURRENT:



V. CONCLUSION

In general to provide mechanical work in industry and generate electric power in power plants electrical machines are used. Due to high efficiency and good dynamic response the permanent magnet brushless DC motor gains attractiveness in the recent years. Because of low cost and high reliability the brushless DC drives are preferred. In this mission speed control of permanent magnet brushless DC motor is achieved using Proportional integral controller in MATLAB software and also tested successfully by evaluating the parameters like back EMF, current, torque and speed. The simulation is done for the variation of set speed range from 0 to 3000 RPM .The Output of the BLDC motor are fed to the subsystem which is made up of measurement block in order to obtain the rotor position for the proper commutation of the phase current and or current control, the terminal voltages are first converted into the line voltage and there difference is taken and then these line voltage difference is used to obtain the pulses required for the inverter operation. In this the three motor terminal voltages R,Y and B generated after the motor is started is shown in the fig a[waveform]. The corresponding back EMF waveform for all the three phase is shown in fig.

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