PERFORMANCE IMPROVEMENT OF BLDC MOTOR USING FUZZY LOGIC CONTROLLER

1S.SHRINE, S.AARTHISURIYA 2
1,2, Assistant Professor, Department of Electrical Engineering, BIST, BIHER, Bharath University Chennai-73. shrine.eee@bharathuniv.ac.in

Abstract— This project deals with a fuzzy controller based sensorless control of brushless DC motor. It works on “Indirect position sensing” method. Using voltage and current waveform position detection can be derived. Using voltage difference measured at the motor terminals position information can be found. Fuzzy controller is used here for precise control and to get better performance. This Controller is effectively implemented using MATLAB. Since fuzzy controller is used no need for separate processors like i.e. FPGA or DSP. So this drive system has more advantage than the conventional sensor less control. The proposed drive system is cost effective, more flexible and robust.

Index Terms— BLDC, Electro Magnetic Force, Pulse Width Modulation, Low Pass Filter, Fuzzy Logic Controller

I. INTRODUCTION

The brushless DC (BLDC) motor is becoming widely used as a small horse power control. This device has the physical appearance of a 3-phase permanent magnet synchronous machine. It is generally driven from a six step inverter which converts a constant voltage to 3-phase voltages with frequency corresponding instantaneously to the rotor speed. The inverter machine combination has the terminal and output characteristics resembling those of a DC shunt motor, hence the name brushless DC motor [1, 2].

Brushless dc motor is most widely used in automotive applications specially on vehicle fuel pumps, due to its high efficiency, small size less maintenance when compared to brush dc motor. Using hall sensor mounted on a rotor, accurate and ripple-free instantaneous torque for position information can be obtained. This results in high cost, poor reliability in vehicle applications [3],[4].To avoid the above mentioned problems, many position sensorless algorithms have been considered as potential solution[5]. The performance of the sensorless drive decreases with the phase shifter in the transient state. Also it is sensitive to the phase delay of the low pass filter (LPF) especially at high speed. Several phase shifters are used in the conventional induced by the LPF method to compensate for phase error of back-EMF are proposed [6]-[9].The position information is found by integrating the back-EMF. This method has an error accumulation problem at low speed [1], [10] and [11]. The sensorless control techniques using the phase-locked loop (PLL) and the third-harmonic back-EMF are suggested [12], [13]. The motor commutation drifts away from the desired phase angle due to the conduction of the freewheel diode. Furthermore, the drift angle varies as the motor parameters, speed, and load conditions change.

Recent developments in permanent magnet materials, power electronics and modern control technologies have significantly influenced the widespread use of Permanent Magnet BLDC (PMBLDC) motor in order to meet the competitive world wide market demands of manufactured goods, devices, products and processors. Large, medium, small as well as micro PMBLDC motors are extensively sought for applications in all sorts of motion control apparatus and systems [3]. The marvelous increase in the popularity of the PMBLDC motor among engineers bears testimony to its industrial usefulness in terms of superior performance and relative size. High efficiency due to reduced losses, low maintenance and low rotor inertia of the PMBLDC motor have increased the demand of PMBLDC motors in high power servo and robotic applications. The invention of modern solid state devices like MOSFET, IGBT and high energy rare earth permanent magnets have widely enhanced the applications of PMBLDC motors in variable speed drives [11-16].

The complete BLDC motor drive system consists of a permanent magnet motor fed by a three-phase PWM inverter, rotor position sensor, hysteresis current controller and speed...
controller. The inverter which is connected to the dc supply feeds controlled power to the motor. The magnitude and frequency of the inverter output voltage depends on the switching signals generated by the hysteresis controller [22-29]. The state of these switching signals at any instant is determined by the rotor position, speed error and winding currents. The controller synchronizes the winding currents with the rotor position. It also facilitates the variable speed operation of the drive and maintains the motor speed reference value even during load variations and supply fluctuations [17-21]. Fig.1 shows the block diagram of the closed loop drive of the PMLDC motor.

II. MODELLING OF BLDC MOTOR

BLDC drive with sensor, consist of a BLDC motor, control circuit and Hall sensor for position information. By knowing the position information, inverter switches are commutated by generating PWM signals with the suitable duty ratio. Three Hall sensors are used for position detection of the BLDC motor. A general BLDC motor has three phase stator windings and is driven by an inverter which constitutes of six switches. Fig. 1 shows the equivalent circuit of a star connected BLDC motor and the inverter topology [30-35].

The modeling is based on the following assumptions:

1. The motor is not saturated.
2. Stator resistances of all windings are equal and self and mutual inductances are constant.
3. Power semiconductor devices in the inverter are ideal.
4. Iron losses are negligible.

Fig 3- Three phase Inverter and BLDC Motor

The voltage equation of a BLDC motor can be expressed as:

\[
\begin{bmatrix}
V_a(t) \\
V_b(t) \\
V_c(t)
\end{bmatrix} =
\begin{bmatrix}
I_a(t) \\
I_b(t) \\
I_c(t)
\end{bmatrix} + \begin{bmatrix}
e_a(t) \\
e_b(t) \\
e_c(t)
\end{bmatrix}
\]

Where

- \(V_a, V_b\) and \(V_c\) are the stator phase voltages;
- \(R\) is the stator resistance per phase;
- \(I_a, I_b\) and \(I_c\) are the stator phase currents;
- \(L\) is the self-inductance per phase and \(e_a, e_b\) and \(e_c\) are the back electromotive forces.

BEMF equation of each phase should be as follows:

\[
e_a = K_w f_a (\theta_e) \omega \\
e_b = K_w f_b (\theta_e - 2 \pi /3) \omega \\
e_c = K_w f_c (\theta_e + 2\pi /3) \omega
\]

where

- \(K_w\) is back EMF constant of one phase [V/rad.s-1],
- \(\theta_e\) - electrical rotor angle [° el.],
- \(\omega\) - rotor speed [rad.s-1].

The back EMF is a function of rotor position which is represented as \(f_a(\theta_e), f_b(\theta_e), f_c(\theta_e)\) with limit values between \(-1\) and \(+1\).

Total torque output is given by:

\[
T_e = \frac{e_a I_a + e_b I_b + e_c I_c}{\omega}
\]

where

- \(T_e\) is total torque output [Nm],
- \(T_L\) - Load torque [Nm],
- \(J\) - Inertia of rotor and coupled shaft [kgm2],
- \(B\) - Friction constant [Nms.rad-1].

The electrical rotor angle is equal to the mechanical rotor angle multiplied by the number of pole pairs \(p\):

\[
\theta_e = \frac{p}{2} \theta_m
\]

Where \(\theta_m\) is mechanical rotor angle [rad].

III. PROPOSED SYSTEM

BLDC motor has characteristics like a DC motor, Where as it is controlled the same as AC motors. One electrical cycle of the motor is divided to six 600 modes that at each mode, only two phases are conducting the current. Sensorless techniques based on back-EMF and terminal voltages are the most popular due to their simplicity, ease of implementation and lower cost. Back-EMF estimation methods typically rely on the zero crossing detection of the EMF waveform[36-41].
The technique of estimating back-EMF by sensing the terminal voltages. The neutral point will not be stable during PWM switching. Low pass filters have been used to eliminate the higher harmonics and to convert the terminal voltages. Delay is introduced in the sensed signal due to heavy filtering, which also varies with the operating speed. The line voltage difference is measured and given to the zero crossing detectors. Several other add-on toolsets can be incorporated for developing the specialized applications, the fuzzy logic, and PID toolkits are used in the present application [42-45].

IV. EXPERIMENTAL SETUP

The block diagram of sensorless BLDC MOTOR using fuzzy logic controllers is shown in the figure. As shown in the figure DC supply is given to the inverter.

BLDC motor has characteristics like a DC motor, Where as it is controlled the same as AC motors. The trapezoidal back-EMF, current profiles, and Hall-sensor signals of the three-phase BLDC motor. One electrical cycle of the motor is divided to six 60° modes that at each mode, only two phases are conducting the current. Three phase bridge inverter fabricated using n – channel MOSFET is operated in 120 degree mode to provide square wave current excitation to the stator winding. Low pass filters have been used to eliminate the higher harmonics and to convert the terminal voltages into sine waveform signals. Delay is introduced in the sensed signal due to heavy filtering, which also varies with the operating speed. Sensorless techniques based on back-EMF and terminal voltages are the most popular due to their simplicity, ease of implementation and lower cost. Back-EMF estimation methods typically relay on the zero crossing detection of the EMF. The technique of estimating back-EMF by sensing the terminal voltages with respect to a virtual neutral point. The neutral point will not be stable during PWM switching. PI controller is used as a speed controller for recovering the actual motor speed to the reference. The reference and the measured speed are the input signals to the PI controller. The Fuzzy logic controller signal produces the corresponding PWM pulses and the actual speed information.

V. SIMULATION RESULT

In the system simulink model as shown in the figure 5 in BLDC Motor using Fuzzy logic controllers. The speed PI controller determines the PWM duty ratio. After reading the states of the three-phase commutation signals, the six gating signals are calculated by using logic equations. The pulse width of the upper three switches in the inverter is modulated with PWM duty ratio, and the six PWM signals are generated for driving the inverter as shown in figure 7. The inverter output is 3 phase voltage see the figure 8 and the harmonics are reduced output as shown in the figure 9.
Then the motor output is shown in figure 6. But in the system simulink model as shown in the figure 6. It consists of fuzzy logic controller. The PWM pulse is to produce and the actual speed information. The two controlled voltages are filtered by LPF as shown in the figure 9. The speed waveform and the pulses are displayed as shown in the figure 6. The start-up current at the same angle is higher under the heavy load condition. In conclusion, when the start-up technique proposed by this paper is applied, it is able to start up the BLDC motor with the low current and the possibility for the start-up failure may be reduced. Figure 6 shows the experimental results for responses of the reference and rotor speeds, reference voltage, and a-phase current in order to verify the start-up technique.
VI. CONCLUSION

This project presents a sensorless control based on a fuzzy logic controller of a terminal voltage and a potential start-up method with a high starting torque for an automotive fuel pump application. After aligning the rotor position for achieving the maximum starting torque, the BLDC motor accelerates from a standstill up to a nominal speed within 0.07sec. The magnitude of the stator current for aligning the rotor position can be easily controlled by modulating the pulse width of specific switching devices. Through the experimental results, it can be seen that the proposed sensorless and start-up techniques are ideally suited for the automotive fuel pump application.

VII. REFERENCES


7253