FLYBACK CONVERTER BASED BLDC MOTOR DRIVES FOR POWER DEVICE APPLICATIONS

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Abstract - *Brushless DC (BLDC) motors are coming high energy permanent magnet materials, power semiconductor and digital integrated circuits. In any application requiring an electric motor where the space and weight are at a premium, the BLDC motors becomes the ideal choice. A BLDC motor has high power to mass ratio, good dissipation characteristics and high speed capabilities. Limitations of brushed DC motors overcome by BLDC motors include lower efficiency, susceptibility of the commutator assembly to mechanical wear, consequent need for servicing, less ruggedness and requirement for more expensive control electronics. Due to their favourable electrical and mechanical properties, BLDC motors are widely used in servo applications such as automotive, aerospace, medical field, instrumentation areas, electro mechanical actuation systems and industrial automation requirements. Many control schemes have been developed for improving the performance of BLDC Motor Drives. In this paper, a novel controller for brushless DC (BLDC) motor has been presented. The proposed controller is based on Fuzzy logic controller and the rigorous analysis through simulation is performed using simulink tool box in MATLAB environment. The performance of the motor is analysed using simulation results obtained. The dynamic characteristics of the brushless DC motor is observed and analyzed using the developed MATLAB/simulink model.*

Key Words: BLDC, Fuzzy logic, Speed control …

1. INTRODUCTION

The economic constraints and new standards legislated by governments place increasingly stringent requirements on electrical systems. New generations of equipment must have higher performance parameters such as better efficiency and reduced electromagnetic interference. System flexibility must be high to facilitate market modifications and to reduce development time. All these improvements must be achieved while, at the same time, decreasing system cost. Brushless motor technology makes it possible to achieve these specifications. Such motors combine high reliability with high efficiency, and for a lower cost in comparison with brush motors. This document describes the use of a brushless DC (BLDC) motor.

Although the brushless characteristic can be applied to several kinds of motors (the AC synchronous motors, stepper motors, switched reluctance motors, AC induction motors), the BLDC motor is conventionally defined as a permanent magnet synchronous motor with a trapezoidal back EMF waveform shape. Permanent magnet synchronous machines with trapezoidal back EMF and (120 electrical degrees wide) rectangular stator currents are widely used as they offer the following advantages first, assuming the motor has pure trapezoidal back EMF and that the stator phases commutation process is accurate, the mechanical torque developed by the motor is constant. Secondly, the brushless DC drives show a very high mechanical power density.

2. LITERATURE REVIEW

Back-emf is sensed without using neutral point of the motor, is applicable for wide speed range but still have accuracy problem at low speed [1] [4] [13]. of dynamic performance of the Modelling is very essential in studying high performance drive before evaluating the concept motor. Modelling helps further to use the drive in high performance applications [3].

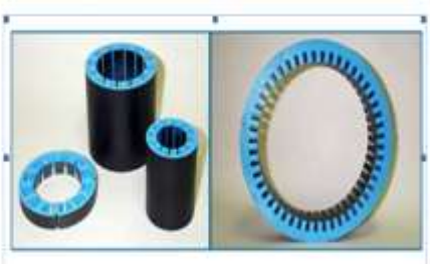
A Simple method to implement and improved motor efficiency. In this method, access to motor winding neutral point is required; this will complicate the motor structure and increase the cost [2]. More uniform current waveform, better torque performance but low pass filters are required so that the back-emf difference can be detected with lower sensor diode [6] [7].Implementation of Fuzzy and it is compared with PID controller which show the superiority of fuzzy to be used for controlling drives [5].The inductances are not constant, the machine saliency being limited in order to simplify the control design and implementation, constant average inductance values were considered.

The FEM- speed control, with seamless transitions between them assisted motion-sensorless control method is used together with the *I-f* control for start-up and for low [9].This method has successfully deduced a position detection strategy which can be easily incorporated in the development of a novel sensorless starting scheme for a BLDC motor using FEM. The implementation of the algorithm is simple and hence the controller cost is considerably reduced [12].The special calculation for extracting the position and speed used here implies the generating of an orthogonal flux system, the atan2 trigonometric function, and a phase-locked loop observer [8].

BRUSHLESS DC MOTOR-OVERVIEW

It is a permanent magnet DC motor. It consists of Stator and Rotor.

3.1 STATOR: The BLDC Motor Stator is made out of laminated steel stacked up to carry the windings. Windings in a Stator can be arranged in two patterns; i.e., A star pattern (Y) or delta pattern (Δ).The major difference between the two patterns is that the Y pattern gives high torque at low rpm and the Δ pattern gives low torque at low rpm.



Steel laminations in the stator can be slotted or slotless. A slotless core has lower inductance, thus it can run at very high speeds. Because of the absence of teeth in the lamination stack, requirements for the cogging torque also go down, thus making them an ideal fit for low speeds too.

3.2 ROTOR: The rotor of a typical BLDC Motor is made out of permanent magnets. Depending upon the application requirements, the number of poles in the rotor may vary. Increasing the number of poles does give better torque but at the cost of reducing the maximum possible speed.

Figure 2: Rotor

3.3 BLDC CONTROL: The BLDC Motor is characterized by two phase ON operation to control the inverter. In this control, torque production follows the principle that current should flow in two of three phases at a time and there should be no torque production in the region of back-emf zero crossings.

4. FUZZY LOGIC CONTROLLER

Figure 3 shows the structure of fuzzy logic controller with the help of which the speed control could be done. Fuzzy logic expressed operational laws in linguistic terms instead of mathematical equations. Many systems are too complex to model accurately, even with complex mathematical equations; therefore traditional methods become infeasible in these systems.

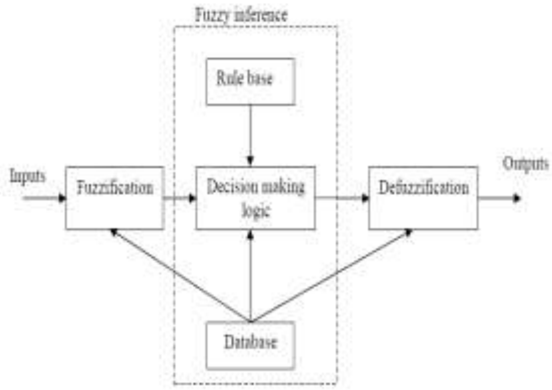


Figure 3: Structure of Fuzzy Logic Controller

However fuzzy logic linguistic terms provide a feasible method for defining the operational characteristics of such system. Fuzzy logic controller can be considered as a special class of symbolic controller. The configuration of fuzzy logic controller block diagram is shown in Fig.3. The fuzzy logic controller has three main components.

1. Fuzzification
2. Fuzzy inference
3. Defuzzification

Fuzzy logic control of the BLDC Motor:

The fuzzy logic controlled BDCM drive system block diagram is shown in Fig.4.The input variable is speed error (E), and change in speed error (CE) is calculated by the controller with E .The output variable is the torque component of the reference (i_{ref}) where i_{ref} is obtained at the output of the controller by using the change in the reference current.

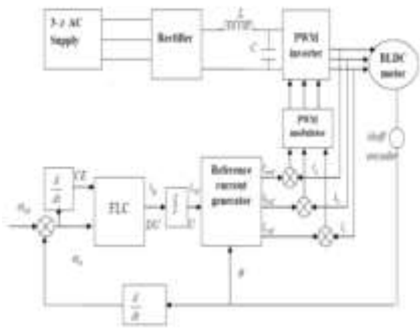


Figure 4: Fuzzy speed control of the BLDC motor

The controller observes the pattern of the speed loop error signal and correspondingly updates the output DU and so that the actual speed ω_m matches the command speed ω_{ref}. There are two inputs signals to the fuzzy controller, the error $E = \omega_{ref} - \omega_m$ and the change in error CE. The controller output DU in brushless dc motor drive is current ΔI^*_{qs}. The signal is summed or integrated to generate the actual control signal U or current I^*_{qs}, where K_1 and K_2 are nonlinear coefficients or gain factors including the summation process shown in Fig.4.

5. CIRCUIT DIAGRAM:

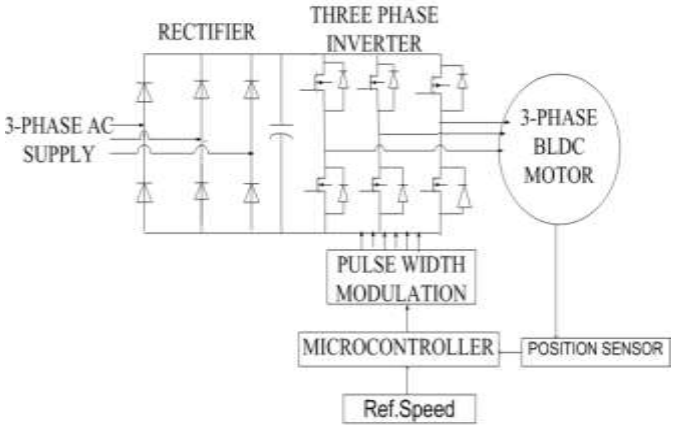


Figure 5: Circuit Diagram

6.1 Membership Functions:

The fuzzy member's ship function for the input variable and output variable are chosen as follows:

1) Positive Big: PB
2) Negative Big: NB
3) Positive Medium: PM
4) Negative Medium: NM
5) Positive Small: PS
6) Negative Small: NS
7) Zero Error: ZE

The input variable speed error and change in speed error is defined in the range of $-1 \leq \omega_e \leq +1$ and $-1 \leq \omega_{ce} \leq +1$ and the output variable torque reference current change Δi_{qs} is define in the range of $-1 \leq \Delta i_{qs} \leq +1$.

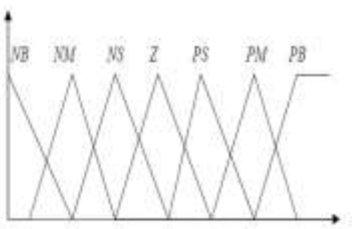


Figure 6: Seven levels of fuzzy membership function

The triangular shaped functions are chosen as the membership functions due to the resulting best control performance and simplicity. The membership function for the speed error and the change in speed error and the change in torque reference current are shown in figure 6.

6.2 Fuzzy Rule Table:

For all variables seven levels of fuzzy membership function are used.Table shows the 7*7 rule base table that was used in the system.

e/ce	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Steps for speed controller:

The steps for speed controller are as follows

1) Sampling of the speed signal of the BLDC.
2) Calculations of the speed error and the change in speed error.
3) Determination of the fuzzy sets and membership function for the speed error and Change in speed error.
4) Determination of the control action according to fuzzy rule.
5) Calculation of the Δi_{qs} by centre of area defuzzyfication method.
6) Sending the control command to the system after calculation of Δi_{qs}

7. SIMULINK MODEL - PROPOSED SYSTEM:

The current control block computes the three reference motor line currents in phase with back-emf, corresponding to torque reference and then feeds the motor with these currents using a three phase current regulators.

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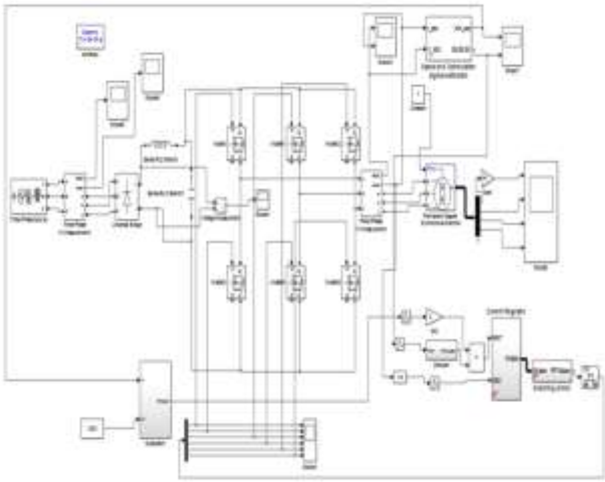

Figure 7: Simulink Model

Current regulator controls the current by delivering current pulses to the switches in order to keep the current inside a user-defined hysteresis band. Motor speed and position are estimated from terminal voltages and current using back-emf observer. The commutations signals are generated from the rotor position every sixty degree electrical. The speed control loop uses a PI regulator to produce the torque reference for the current control block.

8. SPECIFICATION OF THE MOTOR

The table represents the specification of the motor.

PARAMETERS	RATINGS
Power	60W
DC Voltage	460V
Stator Resistance(R_s)	0.2Ω
Stator Inductance(L_{ls})	8.5e-3H
Flux linkage	0.175 V.s
Back EMF flat area	120 degrees
Viscous damping	0.005 F(N.m.s)
Inertia	0.089 J(kg.m^2)
Pole	4

9. RESULTS

The following are the waveforms obtained during simulation.

9.1 Speed Waveform:

Figure 8: Output-Speed

Reference speed – 1200 rpm.
Motor speed after controlling – 1205 rpm.

9.2 Current waveform:

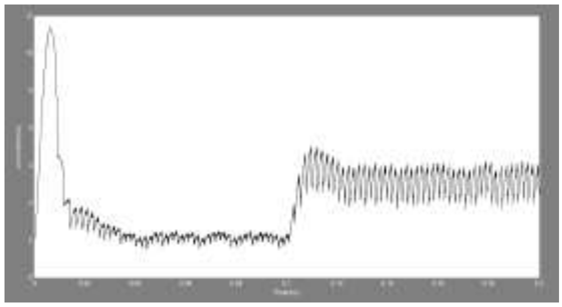

Figure 9: Output-Current

9.3 Torque waveform:

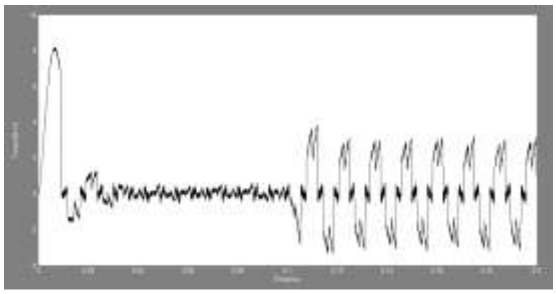

Figure 10: Output – Torque

9.4 TRAPEZOIDAL BACK-EMF:

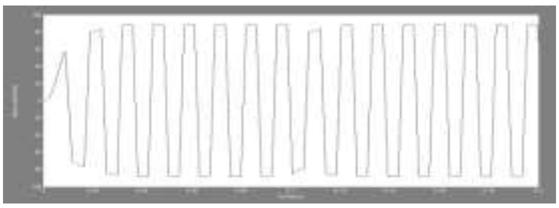

Figure 11: Output-Back-Emf

From the above results obtained during simulation, it is shown that the speed of BLDC Motor have been controlled using fuzzy logic controller.

1) Fuzzy logic has rapidly become one of the most successful of today's technology for developing sophisticated control system.

2) With it aid complex requirement so may be implemented in amazingly simple, easily minted and inexpensive controllers.
3) Both in simulations and experimental results that Fuzzy Logic control yields superior results with respect to those obtained by conventional control algorithms.

10. CONCLUSION

The modelling and simulation of the complete drive system is described in this presentation. Simulation runs confirming the validity and superiority of the fuzzy logic controller over conventional controller.This will be helpful in solving problems associated with sensored control and conventional controllers in order to reduce cost and complexity of the drive system without compromising the performance. The proposed work can be implemented in hardware and can be used for better control applications. In future, this can be implemented using Artificial Neural Network (ANN) which results in better performance in the sensorless control area. This method will be more cost effective and have good dynamic response.

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