International Journal of Engineering Research and Science & Technology

ISSN : 2319-5991
Vol. 1, No. 2
April 2015

2nd National Conference on "Recent Advances in Science Engineering & Technologies" RASET 2015

Organized by

Department of EEE, Jay Shriram College of Technology, Tirupur, Tamil Nadu, India.

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International Journal of Engineering Research and Science & Technology

ISSN 2319-5991 www.ijerst.com
Special Issue, Vol. 1, No. 2, April 2015
2nd National Conference on "Recent Advances in Science, Engineering&Technologies" RASET-2015

Research Paper

PERFORMANCE ANALYSIS OF PI AND FUZZY LOGIC CONTROLLER IN A BLDC MOTOR FOR ELECTRIC POWER STEERING APPLICATION

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Electric power steering (EPS) is an advanced steering system that uses an electric motor to provide steering assist. A Brushless DC motor (BLDC) find wide applications, due to their high power density and ease of control. To achieve desired level of performance, the motor requires suitable speed controllers. In this paper PI controllers are used as a closed loop controller for speed control of BLDC motor. This system is also analysed by using Fuzzy logic controller for better performance .The effectiveness of the system is verified through simulation results using control oriented simulator like MATLAB/Simulink Tools. The circuit operation, controllers design and the comparison of both the controllers are mentioned in this paper.

Keywords: Electric Power Steering (EPS), Brushless DC (BLDC) motor, PI (Proportional controller), FLC (fuzzy logic controller), MATLAB

INTRODUCTION

The electric power steering (EPS) is also called electric power-assisted steering (EPAS). EPS has many advantages compared with hydraulic power steering system, such as saving energy, protecting environment, and be easy to rectify by changing the design of controller software to adjust the system's characteristic of power assistance in any condition. As a new technology, EPS undoubtedly represents the development direction of steering system in the future.

The power source of EPS is electric motor, which is the major factor affecting the EPS performance. In recent years, the previous brush DC motor used in EPS has been gradually replaced by the brushless DC (BLDC) motor. The BLDC motor is a new type of DC motor which uses the electronic commutation technology instead of mechanical commutation, with operation high efficiency, high starting torque, wide speed range, simple structure, reliable operation, etc.

COMPONENTS USED FOR EPS

BLDC Motor

BLDC motors are a kind of synchronous motor. This indicates the magnetic field produced by the stator and the magnetic field produced by the rotor

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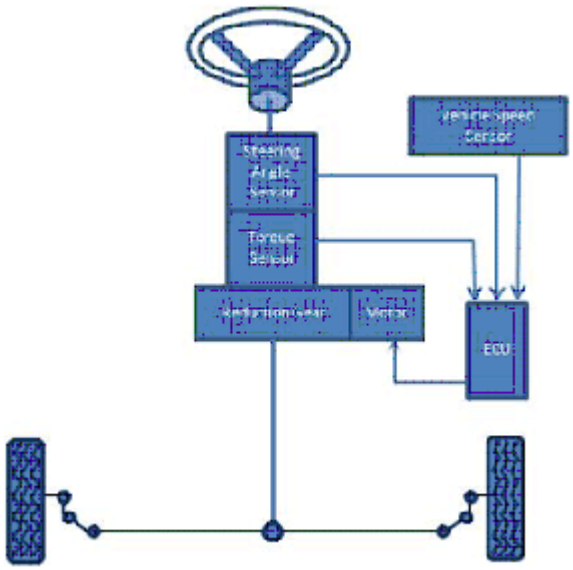
Figure 1: Block Diagram of EPS (Electric Power Steering)



twirls at the same frequency. BLDC motors do not experience the "slip" that is normally observed in induction motors. BLDC motor is built with a permanent magnet rotor and wire wound stator poles.

Stator

The stator of a BLDC motor comprises of stacked steel laminations with windings kept in the slots that are axially cut along the inner periphery as shown in Fig.1. Most BLDC motors have three stator windings linked in star fashion. Each of these windings is assembled with various coils interconnected to derive a winding. One or more coils are kept in the slots and they are interconnected to form a winding. Each of these windings is distributed over the stator periphery to form an even numbers of poles.

Figure 2: Stator of a BLDC Motor

Rotor

The rotor is formed from permanent magnet and can alter from two to eight pole pairs with alternate North (N) and South (S) poles. The suitable magnetic material is selected to form the motor depending upon the required field density in the rotor. Ferrite magnets are used to make permanent magnets. Now a day, rare earth alloy magnets are gaining popularity.

Hall Sensors

The commutation of a BLDC motor is in check electronically. In order to rotate the BLDC motor, the stator windings ought to be energized in an order. It is essential to understand the rotor position in order to know which winding will be energized following the energizing sequence. Rotor position is perceived using Hall Effect sensors embedded into the stator on the non-driving end of the motor as shown in fig.2. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, suggesting the N or S pole is passing near the sensors. The exact order of commutation can be estimated, depending upon the combination of these three Hall sensor signals.

Voltage source inverter

The voltage source inverter topology uses a diode rectifier that converts utility/line AC voltage (60 Hz) to DC. The converter is not controlled through electronic firing like the CSI drive. The DC link is parallel capacitors, which regulate the DC bus voltage ripple and store energy for the system.

The inverter is composed of insulated gate bipolar transistor (IGBT) semiconductor switches. There are other alternatives to the IGBT: insulated gate commutated thyristors (IGCTs) and injection enhanced gate transistors (IEGTs).

Triggering Signal

This is used to give the triggering pulse to the voltage source inverter to operate.

Position Sensor

The position sensor is used to sense the motor speed range and its position.

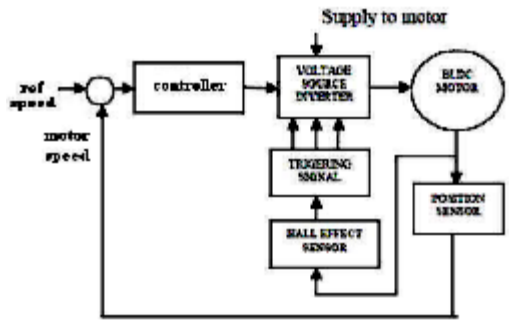
Proportional Controller

The PI control algorithm computes the controlled output by calculating the proportional integral errors and summing those two components to compute the output. The control mechanism uses the current error (proportional term) and history of errors (integral term) to determine the current output. PI controllers have two tuning parameters to adjust. PI controllers provide a balance of complexity and capability that makes them by far the most widely used algorithm in process control applications.

Fuzzy Logic Controller

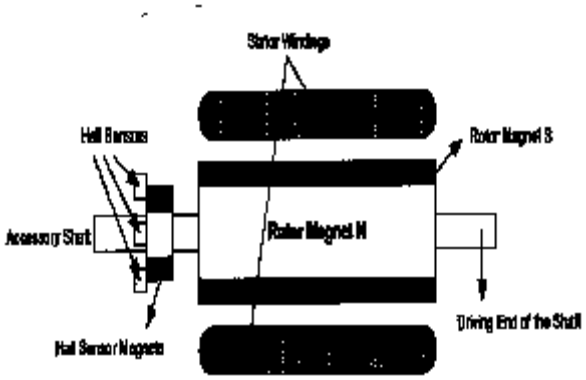
The Fuzzy Logic Controller (FLC) provides an adaptive control for better system performance.

Figure 3: Block diagram of BLDC Motor



Fuzzy logic is aimed to provide solution for controlling nonlinear processes and to handle ambiguous and uncertain situations. Fuzzy control is based on the fundamental of fuzzy sets. Fuzzy control involves three stages: fuzzification, inference or rule evaluation and defuzzification.

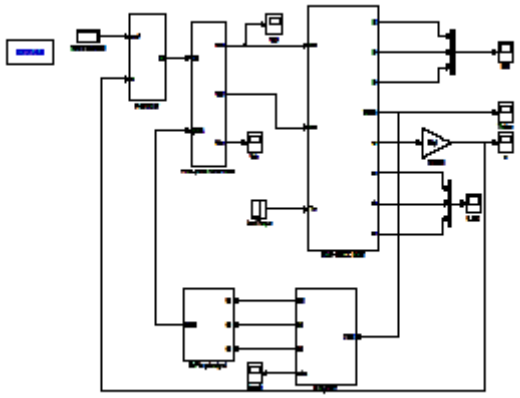
Figure 4: Rotor and Hall sensors of BLDC motor



SIMULATION MODEL

In this section, the overall model of BLDC motor with sliding mode controller and fuzzy logic and PI is implemented in MATLAB/Simulink. As mentioned above, chattering play important roles in sliding mode fuzzy controller. The major

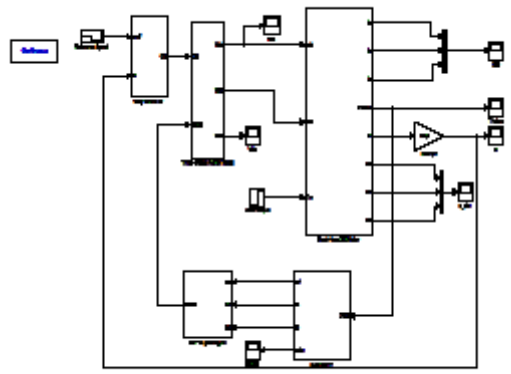
Figure 5: The simulation model of BLDC motor with PI controller



objective in this research is to reduce or remove the chattering in system's output with uncertainty and external disturbance. The subsystem blocks of BLDC motor, IGBT inverter, reference current and speed controller are created respectively based on their own characteristics.

The set speed and the actual speed determine the operating mode of the motor. Based on the quadrant in which the motor operates, the required reference currents are generated. The above figure 4 shows the simulation diagram of BLDC motor using PI controller and figure 5 shows the simulation diagram of BLDC motor using Fuzzy controller.*Fig.6 The simulation model of BLDC motor with Fuzzy controller*

Figure 6: The simulation model of BLDC motor with Fuzzy controller



SIMULATION RESULT

Figure 7a: Speed waveform of BLDC motor with PI controller

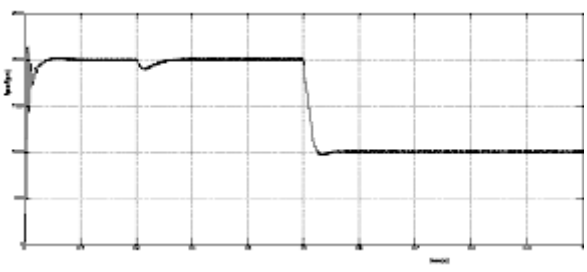


Figure 7b: Speed waveform of BLDC motor with fuzzy controller

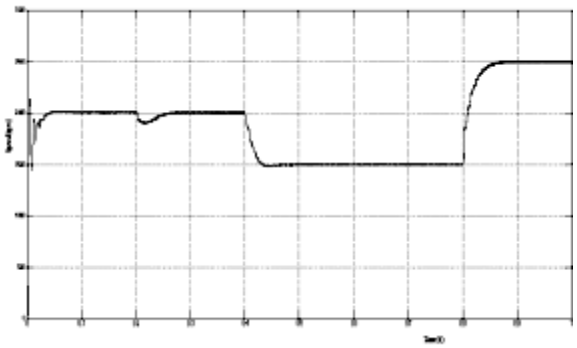


Figure 8a: Torque waveform of BLDC motor with Pi controller

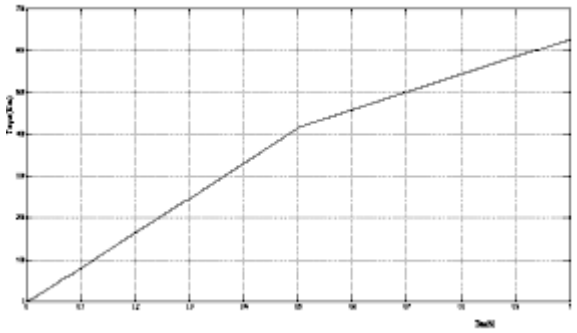


Figure 8b: Torque waveform of BLDC motor with fuzzy controller

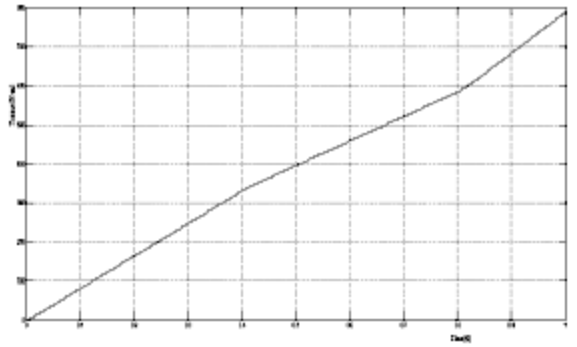


Figure 9a: Phase a Back-EMF waveform of BLDC motor with PI controller

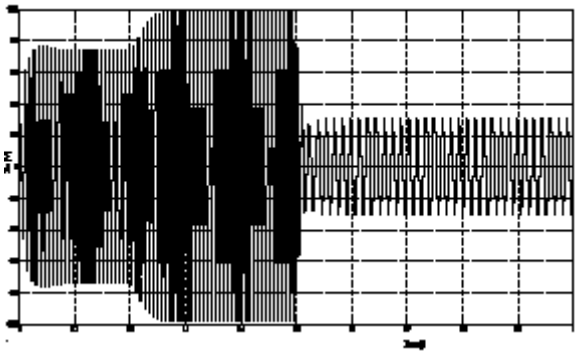


Figure 9b: Phase a Back-EMF waveform of BLDC motor with fuzzy controller

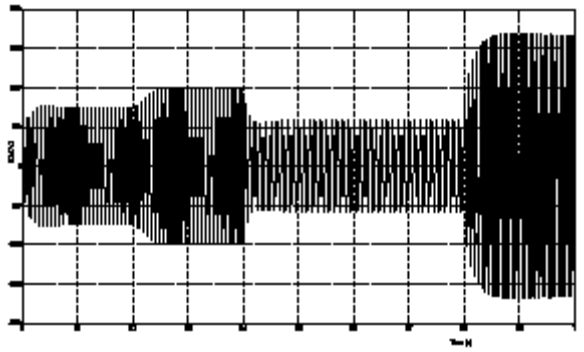


Figure 10a: Phase a Current waveform of BLDC motor with PI controller

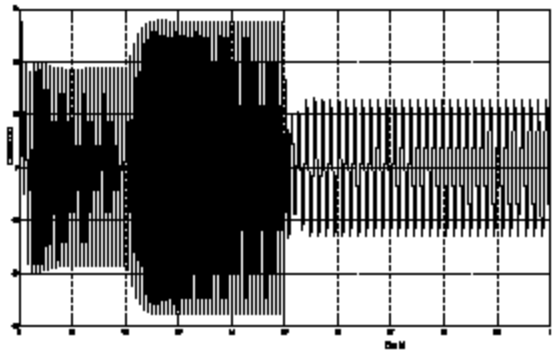
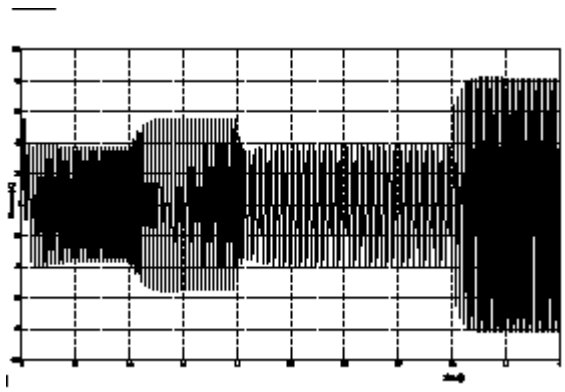


Figure 10b: Phase a Current waveform of BLDC motor with fuzzy controller



CONCLUSION

Electric power steering has replaced hydraulic power in many new vehicles today. One of the advantages of electric power steering is that it eliminates the power steering pump, which can use as much as 8 to 10 horsepower under load. This improves fuel economy while also eliminating the weight and bulk of the power steering pump and hosed. In this paper the need for using Electric power steering is explained the closed loop functions where used to understand the basics of PI controller. The design concepts are validated through simulation and result obtained shows that, by using fuzzy logic controller fast transient

Table 1: Specifications of BLDC Motor

Symbol	Description	Value	Unit
n_p	Number of pole pairs of the motor	2	-
M	Mutual inductance	0.175	mH
J	Motor inertia	0.085	$Kg.m^2$
N	Rated speed	1500	r\m
T_l	Sudden load	0.2	N.m
T	Simulation time	0.9	S
V	Supply Voltage	300	V

responses were obtained. The output of the system has a fast settling time.

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