Research Result

Analysis of Performance of PI And FLC Controller For BLDC Motor System Drive

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ABSTRACT

The performance of a BLDC Motor under a loaded condition is analysed in this paper using both PI Controller and Fuzzy controller. In addition, for the BLDC motor, a mathematical model is developed, and the performance of various controllers for a given BLDC motor is analysed and compared. In the beginning, a basic and standard PI controller is developed for the purpose of controlling the BLDC motor's speed that is being used. After that, a PI controller that is based on fuzzy logic is constructed. The fuzzy logic controller is more resistive for changes in plant parameters than conventional controllers. The simulation of the suggested system was performed with the assistance of the Matlab/Simulink tool. When compared to a traditional PI controller, it was found, the fuzzy logic controller provides superior performance through an extensive amount of simulation testing.

KEYWORDS

PI Controller, FLC Controller, BLDC, Drive System, Speed Controlling, rotor, fuzzy logic, sensorless

1. INTRODUCTION

The domestic appliance industry, which includes refrigerators, air conditioners, fans, and washing machines, has seen an increase in the need for high-efficiency electric motors in recent years. Scientists have put forth a lot of time and energy to create those very efficient motors you listed. Because of their low efficiency and sluggish dynamic response, conventional motors aren't a good fit for industrial applications, hence alternative solutions involving specialised machinery are being pursued.

Because of their low cost, low maintenance, and high speed, Induction motors are commonly used in applications involving variable speed drives. When compared to other types of motors, like the Brushless DC motor, the switching reluctance motor, and the Permanent magnet synchronous motor, induction motors are not very efficient due to their slip power losses and trailing power factor. The BLDC and PMSM drives are rising in popularity due to their low cost, high efficiency, low noise, high operating speed, high power to weight ratio, and decreased sensitivity to electromagnetic interference.

This research compares and contrasts the results of a BLDC motor controlled by a fuzzy controller and a PI controller when under load. Additionally, of the BLDC motor a mathematical model is built, and the efficiency of these controllers for a standard BLDC motor is compared.

2. BLDCMOTORDRIVECONTROLSCHEME

3. In Figure 1, you can see a block diagrammatic sketch of the BLDC Motor drive control scheme that have been proposed.

4. Hall sensors, a controller, a three-phase inverter, and a Brushless Direct Current Motor (BLDC) make up the essential components of the fundamental representation for a BLDC motor drive of speed control. The power is transferred from the supply by the electrical unit to the BLDC Motor, where it is transformed from electrical energy into mechanical energy. The BLDC motor's speed is determined by utilizing a Hall Sensor to measure it, and then calculating it on the basis of the results of the Hall Sensor, that is sensing the speed based on the information regarding the rotor position of the BLDC motor.

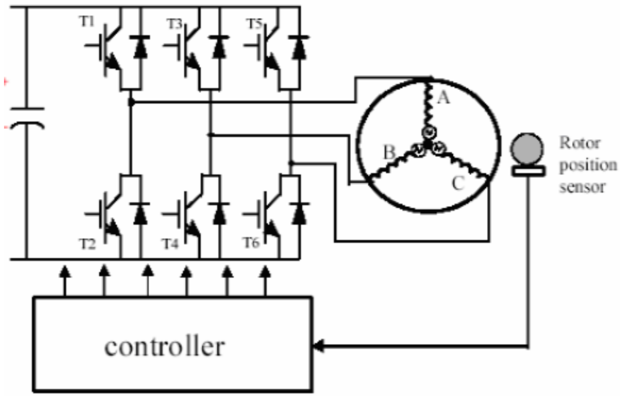

Fig.1. Diagrammatic representation of BLDC Drive

The pi controller is used to generate difference among the reference and the actual speed. In FLC, fuzzy controller is used to generate the difference between error and change in error. The results of the inverter is determined by the variations among the actual phase currents and the reference currents. For the generation of the pulses that are utilized for triggering the switches of the inverter, PWM (pulse width modulation) control schemes are frequently used. Because of the ease with which it can be constructed, it has rotor position sensors that are controlled by command signals such as those for torque, voltage, and speed. The structure of the algorithms that are attributable to that determines the type of BLDC motor that will be used. There are primarily two categories of drives: those that are powered by voltage supply and those that are powered by current supply. Every single voltage supply and current supply based drive uses a static magnet synchronous machine that has back-emf waveforms that are either curved or not sinusoidal. Either a PIcontroller or a fuzzy logic controller can be utilised to accomplish the task of controlling the speed.

5. MATHEMATICALMODELOF THESYSTEM

There are a few identification procedures that need to be carried out, like system identification and obtaining the plant model, before a mathematical model of the system can be obtained. Due to the fact that LotfiZadeh established the idea of fuzzy logic. Numerous researchers have made effective use of it to design controllers for various applications, which has led to favourable outcomes. As a result, the FLC model continues to be a common choice when it comes to control methodologies for controls development. The study which were performed by a variety of authors using hybrid controls, adaptive controls, sliding mode control, PID control, PI control, scalar control, etc. have been reviewed along with their respective benefits and drawbacks. Controls such as hybrid controls, adaptive controls, sliding mode control, scalar control, etc. are examples of these types of controls. In this article, an effort is taken to address few of the shortcomings and challenges found in the process of building the controllers for the speed control of BLDC Motor utillizing the Takagi–Sugeno-based fuzzy notions. These drawbacks and challenges include: The outcomes of this endeavour turned out quite well.

The three phase Voltage and the Torque Equations are given below.

$$V_a = R_a\, i_a + L_a \frac{di_a}{dt} + M_{ab} \frac{di_b}{dt} + M_{ac} \frac{di_c}{dt} + e_a$$

$$V_b = R_b\, i_b + L_b \frac{di_b}{dt} + M_{ba} \frac{di_a}{dt} + M_{bc} \frac{di_c}{dt} + e_b$$

$$V_c = R_c\, i_c + L_c \frac{di_c}{dt} + M_{ca} \frac{di_a}{dt} + M_{cb} \frac{di_b}{dt} + e_c$$

Where V_a, V_b, and V_c are the voltages that correspond to each phase of the three-phase BLDC motor. Resistances of the three phase stator windings are denoted by the letters R_a, R_b, and R_c, while self-inductances of the three phase stator windings are represented by the letters L_a, L_b, and L_c. Mutual inductances are represented by the letters M_{ab}, M_{ba}, M_{ca}, M_{ac}, M_{bc}, and M_{cb}. I_a, i_b, and i_c are the currents flowing through the motor's three phases, while e_a, e_b, and e_c are the back emf generated by the motor's three phases.

$$T_{em} = J\frac{d\omega_m}{dt} + B\omega_m + T_L$$

Where T_L is the loadtorque, ω_m is angular velocity of the motor, B is the frictional constant, and J is the moment of inertia [1].

6. FUZZY LOGICBASEDCONTROLSTRATEGY

The fuzzy logic theory is utilized to manage the BLDC motor's speed when it is operating in an environment with disturbances. This theory is comprised of a defuzzifier, a fuzzifier, a fuzzy inference engine, and a fuzzy rule base. Fuzzifier is used to compares the speed error variables, as well as the change in speed error variables, with a predetermined set of triangle membership functions into seven sets of linguistic variables. The following list contains membership functions for the input and output variables.

Fuzzy inference engine serves as the link between the controller's input variables and the controller's output, and it does so with the assistance of the fuzzy rule database mamdani model, which was selected for this suggested control system [4].

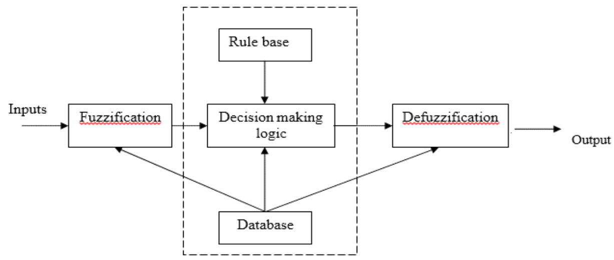

Fig.2. Fuzzy Control Scheme

Fuzzy rule data base are formed by the basis control strategy follows:

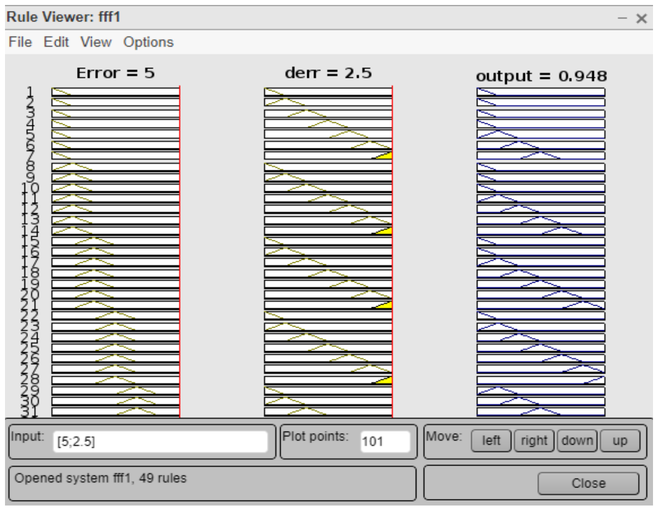

Fig.3.RuleViewerin Simulink Toolbox.

The output (linguistic variable) of the inference engine is sent to the defuzzifier, which then turns it into a series of discrete values that are used as the control signal. It was decided to go with the centroidapproach. To accurately forecast the performance with FLC of the BLDC Motor drive, a simulation of the drive must take place before it can be implemented in real time. The MATLAB/SIMULINK simulation used for testing the researched BLDC Motor drive was successful.

The simulation model is made up of a PI controller, a Fuzzy logic speed controller, a Three Phase BLDC Motor, and a

Three Phase Inverter. The inputs for the model are the reference speed, the motor parameters, the fuzzy logic rule, and the membership function. The outputs of the model are the motor speed, torque, voltage, and currents. The simulation model has input parameters applied to it under a variety of various operating situations, and the performance of the drive system has been validated as a result.

7. SIMULATION MODEL

Figure 4 and Figure 5 illustrates the simulation model that makes use of the PI and Fuzzy control schemes. Both the PI control scheme and the fuzzy control scheme go through the simulation process here.

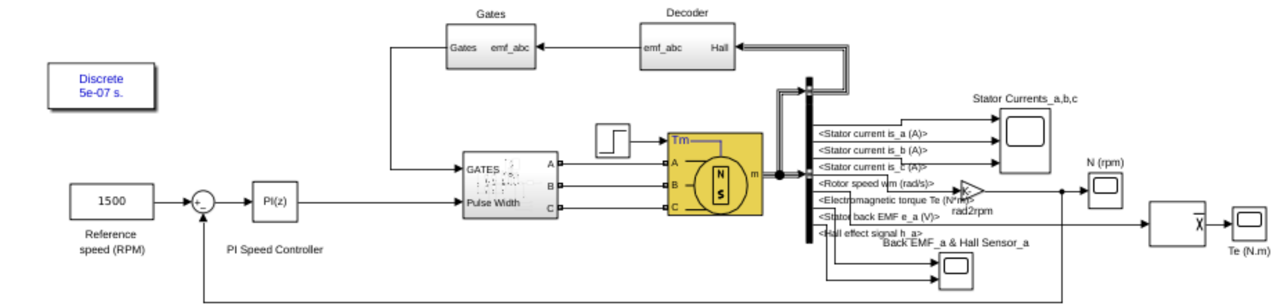

Fig 4. Simulation Model of PI Controller in Simulink

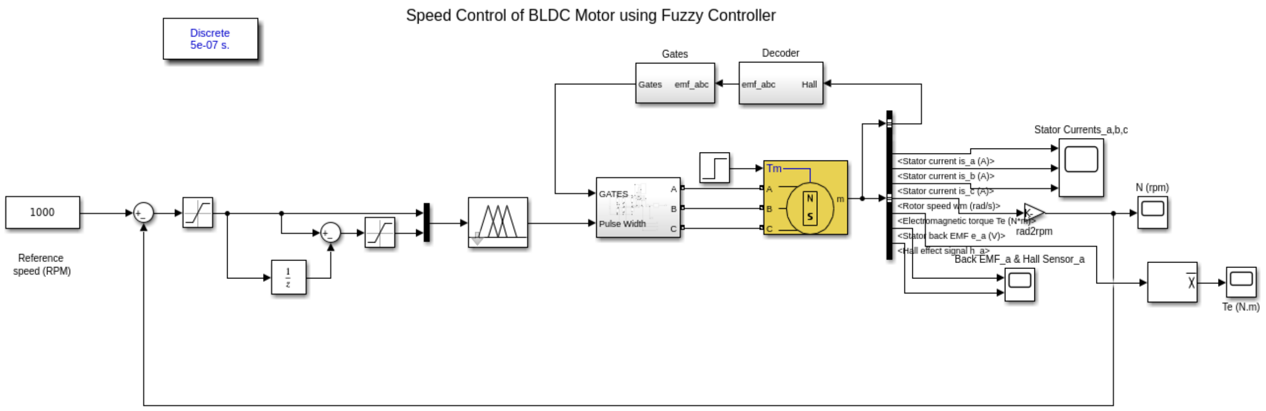

Fig.5.SimulationModel of FLC inSimulink

The MATLAB/SIMULINK environment is used for carrying out the simulation. The BLDC Motor, a three-phase inverter, a decoder, and a gate are all subsystems that are represented by the simulation model. Each subsystem is comprised of a variety of components, each of which fulfils a particular purpose. The following is a list of the various BLDC Motor parameters:

No.ofPhases =3

Back EMF Waveform = Trapezoidal

Back EMF Flat Area = 120 degree

Pole Pair = 4

Stator Phase Resistance (Rs) = 10.91 Ω

Stator Phase inductance (Ls) = 30.01 e-3 mH

Moment of Inertia (J) = 2 e-4 Kg.m2

Viscous damping(F)=1 e-3NMS

1. RESULTS AND DISCUSSION

The Simulation is done to compare the performance of PI and Fuzzy Logic Controller for BLDC Motor drive. Model has been simulated and waveform are provided below.

Applying a load torque of 2Nm after 0.1 sec. Motor Speed in RPM and Torque is generated at each case.

6.1. Performance with PI controller

At 0.5 Load Condition

Figure 5 depicts the simulation results for a 1000 rpm speed reference input and a load torque of 0.5 N-m. It has an integral gain of 0.35, and KP = 0.002. Performance of PI Controller is shown in Fig 5. Speed and Torque Response waveform is fluctuated at

Starting Load

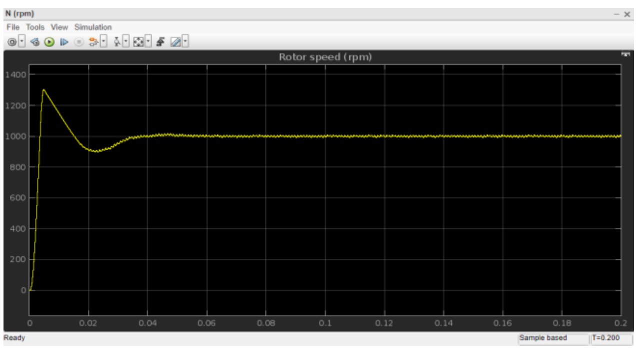

Figure 6.Speed represented as an aspect of time

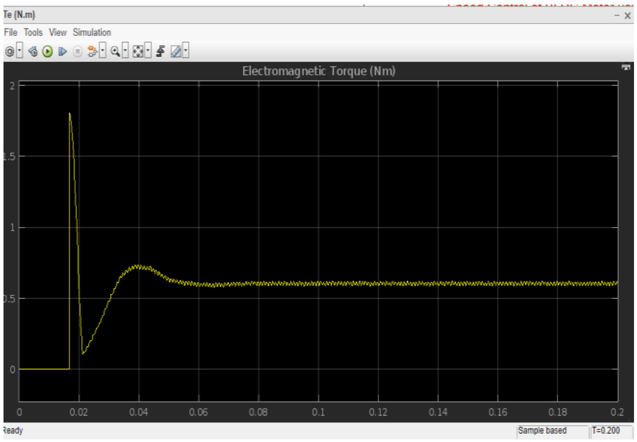

Figure 7.Electromagnetictorque with respect to time

At 0.5 to 2NM Load Condition

Load is change suddenly applied to the BLDC motor from 0.5 load to 2 N-m at 0.1 sec.

At 0.1 sec waveform is distorting for a few sec. is represented in Fig 7 & 8. Load change Suddenly at BLDC Motor waveform is fluctuated in motor speed. Torque Waveform showing that torque is fluctuated by PI Controller and also contain ripple.

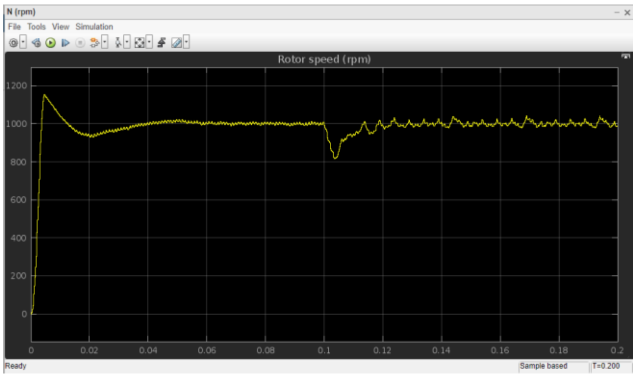

Fig 8. Speed in RPM w.r.t Time

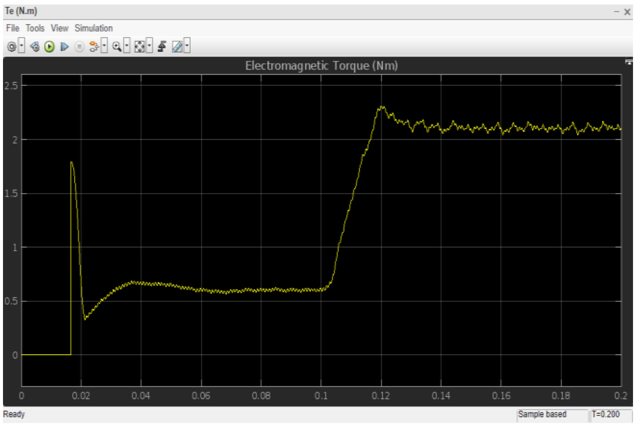

Fig 9. Electromagnetic Torque w.r.t Time

6.2 Performance with FLC

There are some examples of this controller's speed control performance (explained in chapter 4) here. The FLC we've created has the following features and specs.

Type of FLC: Mamdani -Type 1

There are two inputs in total.

The number of outputs is 1.

There are 49 rules in total.

AND method is used to set the min formula.

OR method is used to set the formula Method = max.

Centroid defuzzification is the method of defuzzifying.

At 0.5 Load Condition

Speed And Electromagnetic Torque are shown in in Fig 10 and 11, are Smoothly Change In waveform but better than PI Controller. As

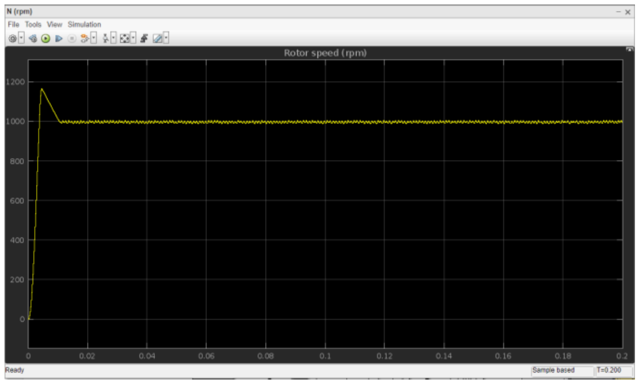

Figure 10. Speed in RPM w.r.t time

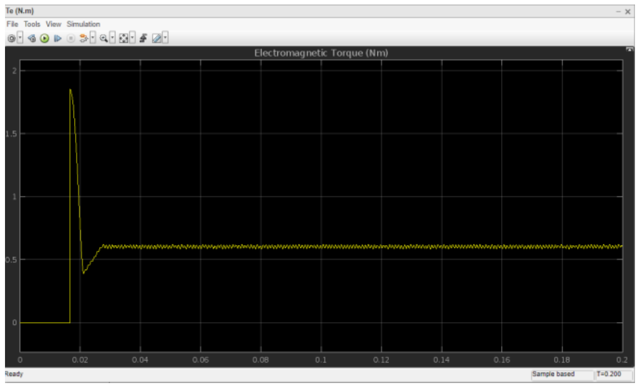

Figure 11.Electromagnetictorque with respect to time

At 0.5 to 2 N-m Load

Figure 12 & 13 are shown, In FLC Smoothly changing the Speed and torque with changing in load. At 0.1 sec.

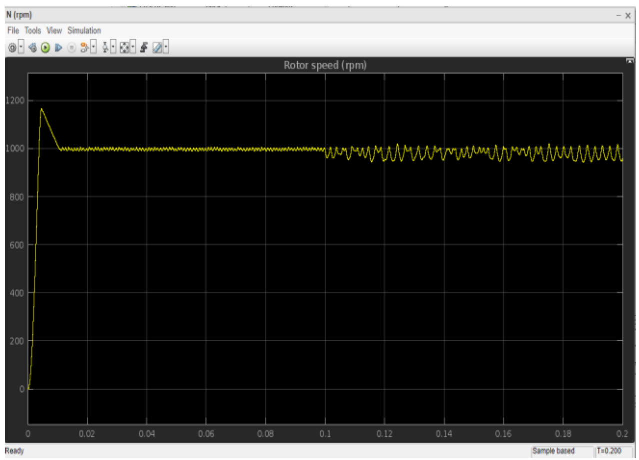

Fig 12. Speed in RPM w.r.t Time

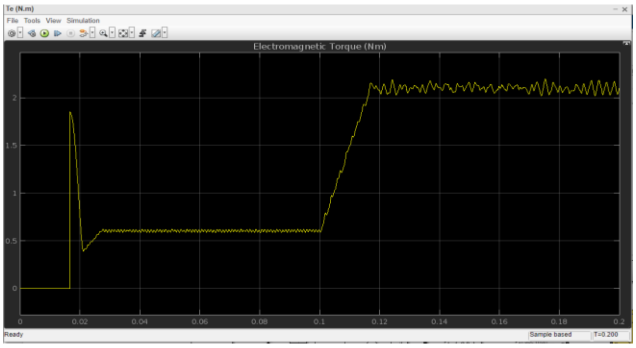

Fig.13. Electromagnetic Torque w.r.t Time.

8. CONCLUSION

In the case of the BLDC motor drive system, the PI and fuzzy control approaches have been successfully emulated. It is being researched how the results of the BLDC motor drive system is affected by the influence that load disturbances have on their changes. The results of the simulation are presented, which reveals that in comparison to a PI controller-based BLDC motor drive, the response based on FLC of BLDC motor drive's speed is discovered to be superior. The BLDC motor drive on the basis of PI controller was not successful in providing increased performance despite the changing loads applied to the system.

The results represents that a BLDC motor drive on the basis of fuzzy controller could endow a faster time for speed recovery and with consistently lower speeds, a better speed response when the system is in subjection in reference speed to a load disturbance. There are several situations in which a BLDC servomotor drive system based on a fuzzy controller would be preferable than one based on a PI controller,

Including automation and robotics. The advantages of the fuzzy control system are its ease of design and implementation, its robustness in the face of uncertainties and variations in input parameters, and its superior performance. BLDC servomotor drive systems based on a fuzzy controller are more economical as well.

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