ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 1, January 2014

Stability Analysis of Brushless DC motor Using Proportional & Integral and Adaptive Fuzzy Logic Controllers

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Abstract: Brushless dc (BLDC) drives have, high efficiency, electromagnetic interference, and high mechanical reliability due to the absence of brushes. They are very suitable for integrated starter alternators in hybrid electric vehicles. This paper discusses about comparison of both PI and fuzzy logic control for a BLDC drive. This control strategy is simple and effective. The advantage of FUZZY logic system is that they do not require any current sensors. This technique can be implemented on a low cost PIC microcontroller. This paper deals about the potential stability issues due to the simplicity of this control under various conditions of load disturbances and also owing to the reduction in processor capability. Lyapunov stability criteria have been used to analyze the closed-loop stability of the system.

1. INTRODUCTION

Normally PI controllers have poor response due to overshoot, more drops in speed and oscillations. Intelligent control like Fuzzy Logic controllers is gaining momentum as it can overcome these disadvantages. Because of its simplicity, this control strategy is easy to implement onto a PROGRAMMABLEINTERFACE CONTROLLER (PIC). It also does not require the use of any additional hardware, which makes it an attractive solution to overcome most demerits. And also use to increase the stability of a process.

BLDC motors have electronic commutator, instead of brushes, thus they have higher efficiency, long operating life, rugged construction and noiseless operation. BLDC motor implements the basic principle of conventional DC motors except that the stator has three phase windings whereas the rotor has pole magnets. The hall sensors embedded in the motor detects the rotor position. The decoder decodes the position of the rotor and produces gate pulses to trigger the six-switch inverter to produce AC voltage that energizes the stator windings to produce current.

Fuzzy logic provides a medium to represent imprecision and vague values in terms of linguistic constructs. The crisp error values given to the fuzzy inference system follows three steps. First, the crisp values are fuzzified to give relatively graded membership values. Secondly, rule set contained in the fuzzy rule based system takes decision to produce an output. Thirdly, this output value is defuzzified to deliver crisp outputs. Defuzzification Types like max-min membership, weighted average, centroid method, etc.

Adaptive Fuzzy has the ability to satisfied control characteristics and it is easy for computing. The experimental results verify that an Adaptive Fuzzy PID controller has better control performance than the conventional PID controller.

2. BLOCK DIAGRAM

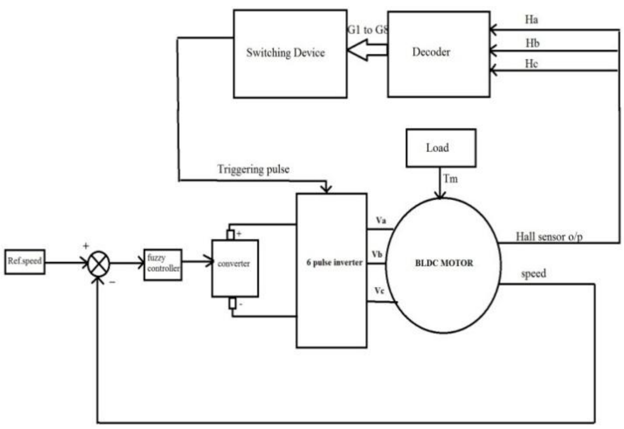

Fig 1.0
Block diagram of BLDC motor control using fuzzy logic

There are three major sections in the block diagram

1. **Controlling section**
2. **Inverting section**

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3. Switching section

Controlling section:
Reference speed is the input set point given by the user to obtain the desired output. The reference speed is given in rpm (revolutions per minute). The Comparator compares the measured speed and the reference speed and gives the output signal to the controller.

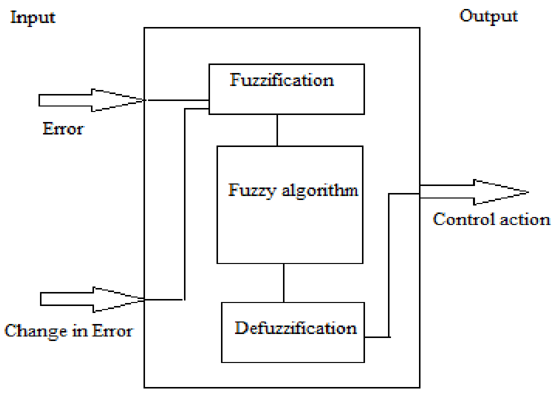

Fig 1.1: block diagram of fuzzy controller

The measured speeds will the feedback given to the comparator. The feedback is always negative feedback. Controller receives the input from the comparator (i.e.) the compared value of set point and the feedback. The controller, used in this project is Fuzzy Adaptive Controller for simulation purpose alone.

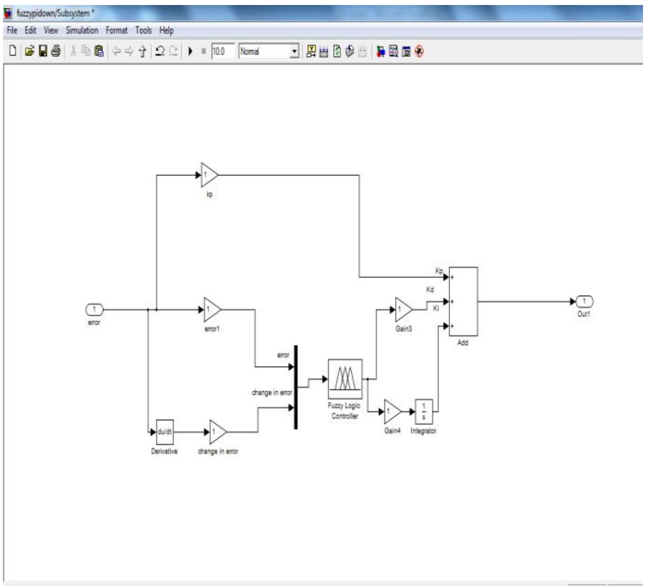

Fig 1.2: mat lab simulation of Fuzzy PID controller

Logic controller is gaining momentum as it can overcome these disadvantages.

Inverting section:
The converter converts the Controller output into equivalent DC voltage and given to the 6pulse inverter which drives the BLDC motor. The 6 pulse inverter act as the power supply to the BLDC motor. It consists of six SCR's hence it is called as 6 pulse inverter. The gate triggering pulse is obtained from the switching device which triggers the gate voltage to activate the SCR's. The BLDC motor runs on three phase voltage Va, Vb, Vc which is obtained from the 6 pulse inverter. There are two sensors connected to the BLDC motor which gives the speed of the motor and position of the shaft. The position of the shaft is determined by the HALL SENSOR.

Switching section:
The hall sensor digital output is given to the 3X8 DECODER which converts hall sensor output into 8 gate pulse (G1 to G8).The gate pulse are given to the switching deSwitching devices produces the switching pulse to drive the inverter. The switching device actives the SCR's by giving switching or triggering pulses vice. This is an important part in the entire block diagram since they are the actuators which control the current flow to the BLDC motor.

PIC 16f877a:
The fuzzy control strategy can be implemented using low cost PIC 16f877a microcontroller. It is a 40 pin IC and has 14 kb memory. The compare, capture and pulse width modulation feature of this IC can be implemented for continuous control of the BLDC motor. They are more efficient than any other controllers at that cost. The periodic control can be obtained from the timer concepts of the controller.

Controller input:

1. Error

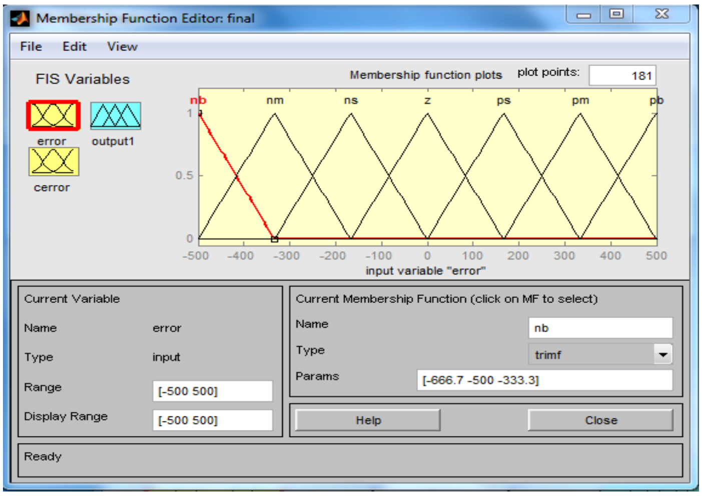

Fig 1.3: Fuzzy PID controller error

The range of the error is set to -500 to 500. The error part is differentiated into seven major parts that is given below in the fuzzy lookup table.

2. Change in error

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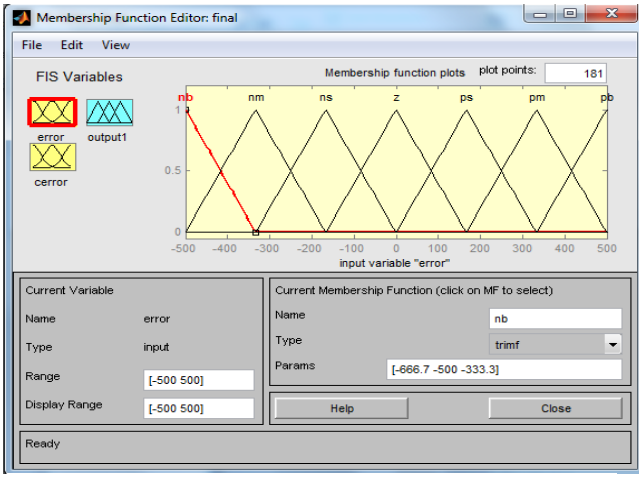


Fig 1.4: Fuzzy PID controller change in error

Controller output:

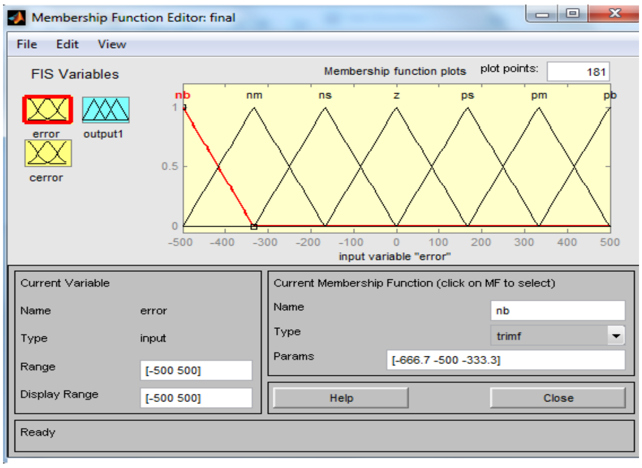


Fig 1.5: Fuzzy PID controller output

Fuzzy lookup table:

CE / E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

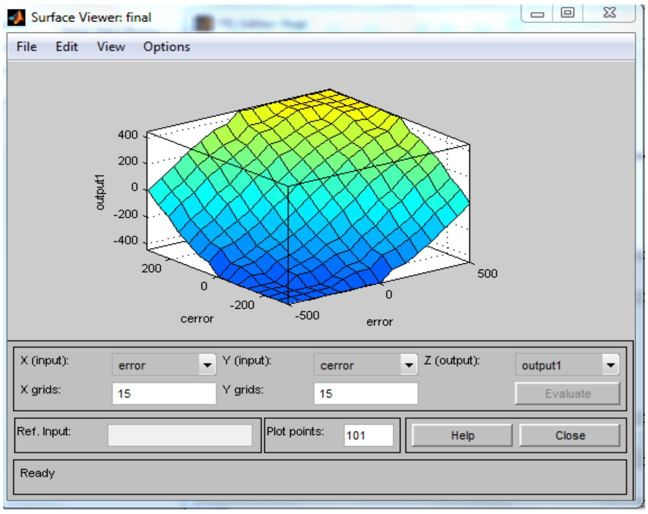
Fuzzy lookup table consist of 49 rules.

NB-negative big
NM-negative medium
NS-negative small
Z-zero
PB-positive big
PM-positive medium
PS-positive small

Control action:

The following is the control action taken by the controller in the simulation. There are two types of viewer in the mat lab.

Surface viewer:



Rule viewer:

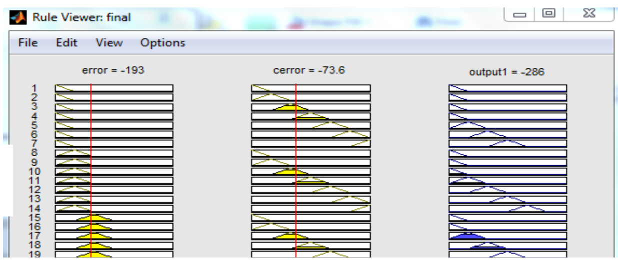


Fig 1.6: Fuzzy controller control action (surface viewer)

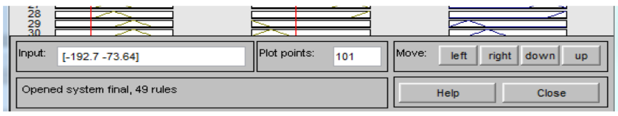


Fig 1.7: Fuzzy controller control action (rule viewer)

Hall sensor A	Hall sensor B	Hall sensor c	EMF A	EMF B	EMF C
0	0	0	0	0	0
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1
1	1	1	0	0	0

Fig 1.8: Simulation result of PI Controller (speed vs.

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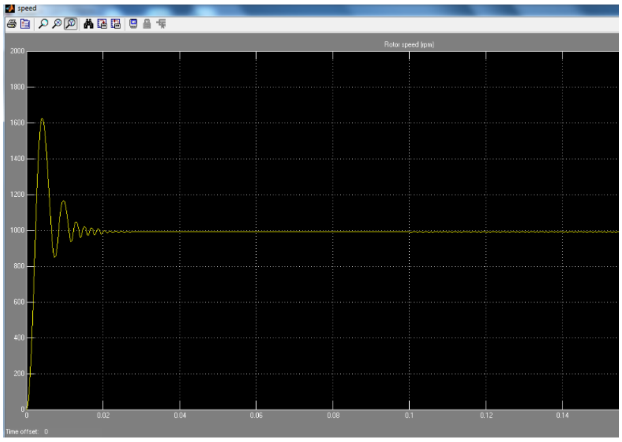
Switching logic table:

TABLE II. GATE LOGIC

EMF A	EMF B	EMF C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

3. SIMULATION RESULTS

Performance of the Fuzzy controller shown in fig 1.9 and fig 1.8 shows the performance of conventional PI controller of BLDC Motor on Reference speed of 1000rpm with torque load change at 1seconds and 0.1 seconds respectively in the figure it was clearly shown that fuzzy controller has no overshoot and it also detects the load change and responds very quickly and takes the corrective control actions but in case of normal pi control it takes more time to reach the reference speed and it also has high overshoot also the figure clearly shows that PI controller also takes more time to detect the load change when compare to proposed fuzzy controller.



The proposed fuzzy logic controller output with the reference speed of 1000 rpm with the load change at 0.1 second. Here the controller inputs error (e) and the change in error (ce) are fuzzyfied (real time value into fuzzy values) and the fuzzyfied values are send to the fuzzy inference engine in which according to the derived membership function which is described in the teble:2 the fuzzy inference engine gives the fuzzyfied control output which is again defuzzyfied using centroid method of defuzzyfication (fuzzy value into real time values).the different control actions will be taken based on the range of error and change in error. From the figure 1.9 we can clearly see that the fuzzy logic controller has overcome the demerits of PI controller

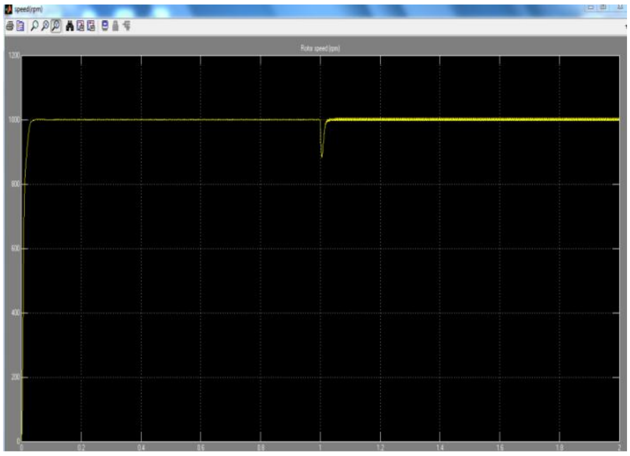


Fig 1.9: Simulation result of Fuzzy Controller (speed vs. time)

4. APPLICATIONS AND FURTHER ENHANCEMENTS

The Brushless DC (BLDC) motor is rapidly gaining popularity by its utilization in various industries, such as appliances, automotive, aerospace, consumer, medical, industrial automation equipment and instrumentation. Digital control of BLDC machines has several benefits, including simple implementation, requirement of no additional hardware, and not computationally intense. Brushless dc (BLDC) drives have, high efficiency, electromagnetic interference, and high mechanical reliability due to the absence of brushes. They are very suitable for integrated starter alternators in hybrid electric vehicles. Owing to these attributes, the technique can be implemented on a low-cost field-programmable gate array.

5. CONCLUSION

In this project the simulation of the drive is performed first with PI controller and then with fuzzy logic controller using MATLAB/Simulink. The speed control is achieved at various load torque conditions with constant speed reference and at constant load with varying speed references. From the speed curve, it is seen that there is a peak overshoot in the case of PI controller but in fuzzy control, it is smooth. The fuzzy controller responds faster and smoother to reference speed changes compared to the PI controller. Mamdani fuzzy model proved to be more flexible, while developing a speed controller for constant speed reference with changing load torque.

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