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Speed Control of BLDC Motor-A Fuzzy Logic Approach

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ABSTRACT

The main objective of this paper is to apply the principle and technology of fuzzy logic controller (FLC) using PID controller for the speed control of brushless direct current (BLDC) permanent magnet motor drive. The controller is designed to track variations of speed references and to stabilize the output speed during load variations. The BLDC has some advantages compare to the other type of motors, because of its nonlinear drive characteristics, it is difficult to handle by using conventional PID controller. The BLDC motor is fed from the inverter where the rotor position and current controller are the inputs. Tuning parameters and its computation using conventional controller is difficult and also it does not give satisfied control characteristics. In order to overcome this here it is proposed to use FLC, it gives better control performance compared to conventional controller. The effectiveness of the proposed scheme is verified by simulating the model in MATLAB-simulink, which says that the proposed scheme gives a significant improvement in control performance compared to the conventional controller.

Keywords: Brushless DC motor (BLDC), Fuzzy logic controller (FLC), PID controller.

I. INTRODUCTION

In heavy industries there are two types of DC motors are mainly used, one is Conventional DC motor where current produces the flux through the stationary pole structure's field coil and another one is Brushless DC motor where instead of wire wound field poles, permanent magnet produces the air gap flux. Definition of BLDC motor can be conventionally given as Permanent magnet synchronous motor with Trapezoidal Back Emf wave form shape. BLDC motor do not have brushes instead of it commutation is done electronically. The most recognizable improvement of the brushless arrangement is the elimination of the brushes, which excludes brush maintenance and the sparking allied with them. Ensuring the armature windings on the stator supports the transmission of heat from the windings. Because there are no windings on the rotor, electrical losses in the rotor are minimal [1].

In recent days BLDC motors with high performance were used in variable speed drive systems of the industrial applications and electric vehicles.

Now a day for the speed control design of BLDC motor different modern control solutions are proposed [2]. However, speed control system used in conventional PID controller has simple, stable and highly reliable algorithm. Achieving the optimal state under field conditions is difficult due to poor robustness and complexity in tuning PID controller parameters[3].

In this paper fuzzy PID controller is designed for speed regulation of BLDC motor. T o keep the motor speed constant even when the load varies and to show the dynamic response of speed. Number of inputs and membership functions are framed and also set of rules are formulated owing to different conditions[4] [5].

II. SPEED CONTROL OF BLDC MOTOR

The Fig.1 shows the block diagram for the speed control of BLDC motor having two control loops. The inner loop is used to synchronize the system based on the status of motor and outer loop is used to provide a feedback.

Two phases of BLDC motor are energized concurrently using the six power transistors which are in three phase power converter of driving circuit of speed control. In stator of BLDC motor three Hall sensors are placed to sense the rotor position which is used to find the switching sequence of MOSFET transistors. Reference current is produced by reference current generator and with the hall sensor information signal vector of back EMF is produced by decoder block. To run the motor in opposite direction we have to give opposite current. Based on that, we have Table I for clockwise rotation to calculate back EMF and Table II for gate logic to transform EMF to 6 signals on the gates.

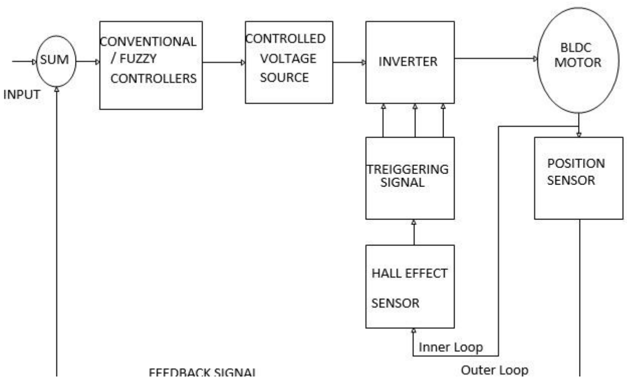


Figure 1. Speed control of BLDC motor.

Table 1. Truth table for clockwise rotation

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

III. CONTROLLER CIRCUIT

A. Modeling of Conventional PID Controller

A PID controller is a standard control loop feedback mechanism to correct the error between a measured process variable and a desired value. The best control system demands small rise time, small settling time, small peak time, small maximum overshoot percentage and minute steady state error. To attain significant values of time domain specifications, a PID controller utilizes the conception of proportional controller, Integral controller and/or derivative controller.

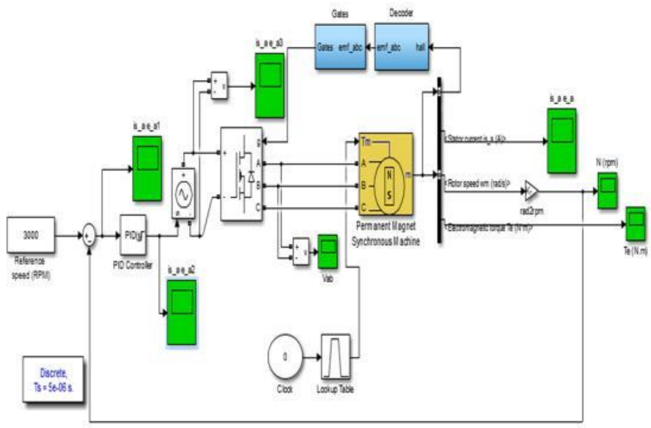


Figure 2. Simulation model of conventional PID controller

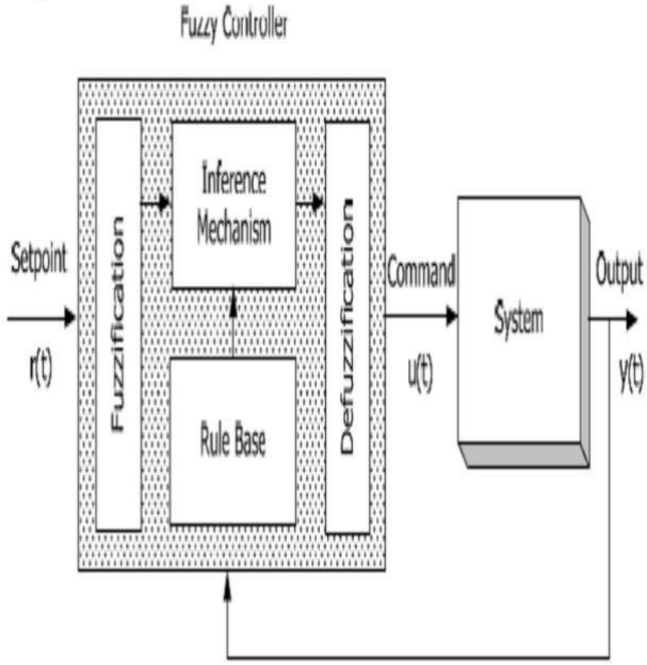
Table 2. Truth table for Gate logic

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

The model developed to study the performance of the motor on sudden change in load with PID controller is shown in Fig.2. The motor speed, sent through the feedback path, is compared with a reference speed of 3000 rpm with the help of comparator which is fed to the PID controller. Thiscontroller improves the transient performance of the motor. The output of controller is fed to the controlled voltage source. The inverter circuit is fed by this voltage source. The firing (gate pulse) of MOSFET/Diode inverter circuit are decided by Gate/Decoder (Hall Sensor) which are activated by the rotor's position. The output of inverter circuit is fed to Permanent Magnet Synchronous Motor (PMSM). The output of PMSM in terms of back emf, rotor speed and electromagnetic torque are taken out for measurements. One set of the outputs of PMSM is fed to Decoder/Gate block so that it decides the gate pattern of inverter circuit. The simulation is carried out under the different operating conditions such as starting and load application.

B. Modeling of Fuzzy PID Controller

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. A block diagram for a fuzzy control system is given in Fig.3. The fuzzy controller consists of the following four components:



Figuew 3. Structure of Fuzzy Logic

Fuzzification: The first block inside the controller is fuzzificationwhich converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable.

Defuzzification: The reverse of Fuzzification is called Defuzzification. The useof Fuzzy Logic Controller produces required output in alinguistic variable (fuzzy number). According to real worldrequirements, the linguistic variables have to be transformedto crisp output.

Inference Mechanism: Inference mechanism is defined as the Software code whichprocesses the rules, cases, objects or other type of knowledgeand expertise based on the facts of a given situation. Whenthere is a problem to be solved that involves logic rather thanfencing skills, we take a series of inference steps that mayinclude deduction, association, recognition, and decision making. An inference engine is an information processingsystem that systematicallyemploys inference steps similar to that of a human brain.

Rule Base:A decision making logic which is, simulating a human decision process, inters fuzzy control action from theknowledge of the control rules and linguistic variabledefinitions. The rules are in the "If Then" format andformally the If side is called the conditions and the Then sideis called the conclusion. In a rule-based controller the controlstrategy is stored in a more or less natural language. A rulebase controller is easy to understand and easy to maintain for anon- specialist end user and an equivalent controller could beimplemented using conventional techniques. The rules areillustrated in Table III (7*7=49).The linguistic variables that isused in the rules are:

1. LN Large Negative
2. MN Medium Negative
3. SN Small Negative
4. ZE Zero
5. SP Small Positive
6. MP Medium Positive
7. LP Large Positive

Table 3. Fuzzy Rules

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

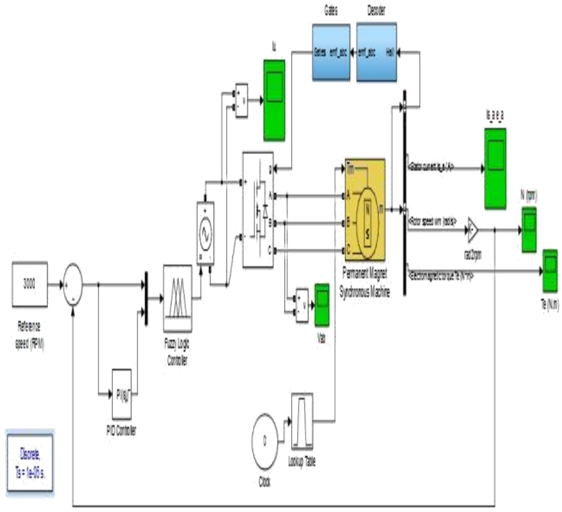


Figure 4. Simulation model of Fuzzy PID Controller

The simulation model of Fuzzy PID controller is shown in Fig4. The Fuzzy PID controller consists of two portions, one is Fuzzy controller and another is Conventional PID controller. Fuzzy PID controller is fed by two controlled inputs such as error(E), change in error(CE) and one output.

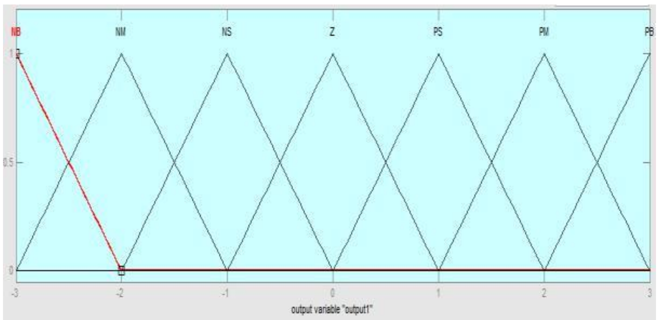


Figure 5. Membership Function

IV. SIMULATION RESULTS

The output responses obtained by running the simulation of the models developed for BLDC motorunder applied load at 0.2sec with PID controller and Fuzzy PID controller are shown in Fig 6and Fig 7respectively.

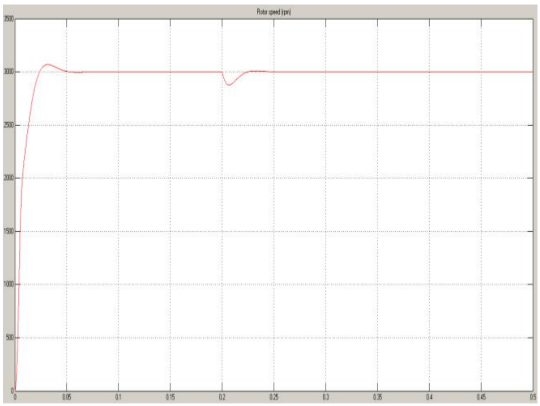


Figure 6. Speed Response Curve of PID Controller

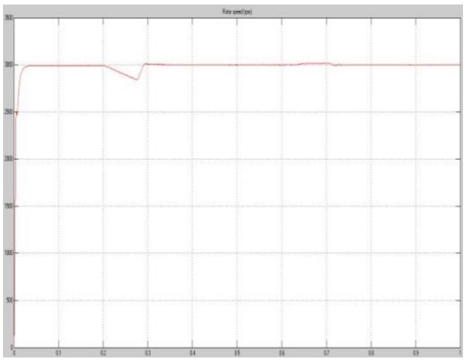


Figure 7. Speed Response Curve of Fuzzy PID Controller

Under applied load, it is observed that in Fuzzy PID Controller, the percentage overshoot, rise time, transient errors and steady state error are lower when compared with PID controller.

Table 4. Comparison between PID controller and Fuzzy PID controller

Controller	PID	Fuzzy PID
Tuning parameters		
Percentage Overshoot	2.27%	0%
Transient Error	0.04	0
Rise Time	0.023	0.034
Steady state error	0.27	0.35

V. CONCLUSION

An evaluation of Fuzzy Logic Techniques applied to the control of electrical machines is presented. As an example, a PID control scheme for BLDC motor is presented. Simulation results confirmed that the fuzzy logic approach is feasible and can be an interesting alternative to conventional control, even when the system model is known and linear.The proposed fuzzy logic control presented a slightly superior dynamic performance when compared with a conventional scheme (PID controller), namely in terms of percentage overshoot, rise time, transient error and steady state error. The MATLAB/Simulink, software tool is used for simulation and controller design.

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