A Implementation of Speed Regulation of Brushless DC Motor Using Fuzzy Logic Controller

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Abstract- *Brushless DC motors have much more demand because of its smart features and excellent working abilities. These motors only need the proper generation of the controlling action In case of fuzzy logic controller, it can deal with such systems which have complex and nonlinearity nature. Even if the parameter variation or some disturbance occurred in system then the fuzzy logic controller can overcome such problems very efficiently as compare to other controllers. To implement fuzzy logic controller, four stages are necessary to execute. Brushless dc motors are preferred over conventional dc motor due to their high efficiency, silent operation, compact size, reliability and low maintenance. But the speed control of these motors is not an easy task, the advancements in microcontroller, power electronics and electrical drives over the decade have made reliable and cost effective solution for adjustable speed application*

Keywords- Brushless DC motors, Fuzzy Logic Controller, Membership Functions for E, Equivalent Circuit of PMBLDC Motor

I. INTRODUCTION

The permanent magnets synchronous motor and brushless DC motor, both are used for industrial applications. The permanent magnets synchronous motor has sinusoidal flux distribution and brushless DC motor has trapezoidal flux distribution because the winding are wound in trapezoidal fashion [1]. Those conventional technologies cannot provide cost effective solution. One of the ways to get higher efficiency is by selecting the right hall sensor which can significantly affect reliability and performance of many critical applications including robotics, medical equipment, heating, ventilation and air conditioning system fans. These applications all call for a highly efficient and quiet motor.

The change of external condition will not have impact on controller as this Fuzzy Logic controller is insensitive, robust to disturbances. The modeling and simulation of speed control of BLDC Motor using Fuzzy Logic controller.[2]

The design and implementation of four different advanced control techniques. The controller objective to achieve a good speed regulation/tracking of BLDC motor, regardless the presence of external disturbances and/or parameters variation.the three different cost functions are tested during optimization process.[3]

II. MODELLING OF BLDC MOTOR DRIVE

The BLDC has three stator windings and a permanent magnet rotor on the rotor. Rotor induced currents can be neglected due to the high resistivity of both magnets and stainless steel. No damper winding are modeled the circuit equation of the three windings in phase variables are obtained. The Fig.2.1 represents the equivalent circuit of Permanent Magnet Brushless DC Motor drives for phase A.

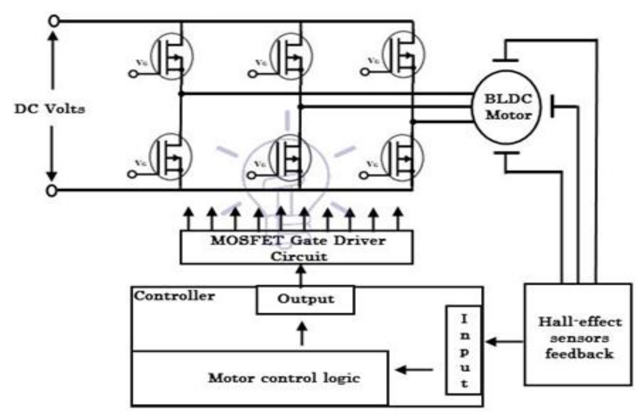

Fig.2.1 BLDC Motor circuit diagram with using MOSFET Driver Circuit.

The figure 2.1 shows the simple BLDC motor drive **circuit** which consists of MOSFET bridge (also called as inverter bridge), electronic controller, hall effect sensor and BLDC motor.

Here, Hall-effect sensors are used for position and speed feedback.

The electronic controller can be a microcontroller unit or microprocessor or DSP processor or FPGA unit or any other controller. This controller receives these signals, processes them and sends the control signals to the MOSFET driver circuit.

In addition to the switching for a rated speed of the motor, additional electronic circuitry changes the motor speed based on required application. These speed control units are generally implemented with PID controllers to have precise control. It is also possible to produce four-quadrant operation from the motor whilst maintaining good efficiency throughout the speed variations using modern drives

III. SPEED CONTROLLING CONVENTIONAL METHODS FOR BLDC MOTOR

In case of the BLDC motor, this motor is nonlinear in nature therefore these types of traditional controllers are unable to control the system of motor in desired manner.

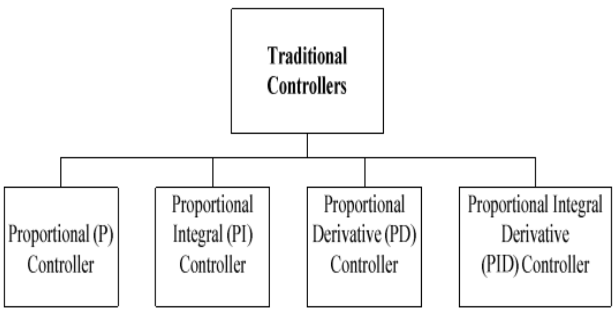

Figure3.3: Speed Controlling Conventional Methods

- ***P CONTROLLER**:*

P controller is mostly used in first order processes with single energy storage to stabilize the unstable process. The main usage of the P controller is to decrease the steady state error of the system. As the proportional gain factor K increases, the steady state error of the system decreases. As we increase the proportional gain, it provides smaller amplitude and phase margin, faster dynamics satisfying wider frequency band.

- ***PI CONTROLLER***

P-I controller is mainly used to eliminate the steady state error resulting from P controller. However, in terms of the speed of the response and overall stability of the system, it has a negative impact.

The mathematical modeling of BLDC motor:

- The voltage V is given by,

$$V = I_A . R_S + L_S . \frac{dI_A}{dt} + e_A \quad \text{------(1)}$$

Where;

Rs = Resistance of stator winding
Ls = Inductance of stator winding
eA = Back EMF of phase A

Voltage equations by using KVL,

$$V_a = R_a I_a + L_a \frac{dI_a}{dt} + M_{ab} \frac{dI_b}{dt} + M_{ac} \frac{dI_c}{dt} + e_a$$
$$V_b = R_b I_b + L_b \frac{dI_b}{dt} + M_{ba} \frac{dI_a}{dt} + M_{bc} \frac{dI_c}{dt} + e_b$$
$$V_c = R_c I_c + L_c \frac{dI_c}{dt} + M_{ca} \frac{dI_a}{dt} + M_{cb} \frac{dI_b}{dt} + e_c$$

Where;

Va, Vb, Vc = Phase Voltages

Ra, Rb, Rc = Resistancesmof three phase

Ia, Ib, Ic = Current of three phase

La, Lb, Lc = Self Inductances

ea, eb, ec = Back EMF in motor

Mab, Mac, = Mutual Inductances of stator winding

Electromagnetic Torque is,

$$T_e = \frac{(e_a I_a + e_b I_b + e_c I_c)}{\omega} \text{ Nm}$$

The equation of motion is,

$$T_e = j \frac{d\omega}{dt} + B\omega + T_l$$

Where;

j is the inertia,

B is friction constant and

T_l is load torque of BLDC motor.

The output power developed by motor is,

$$P = T_e \omega$$

Where P is the number of poles, ωr is the rotor speed in rad/sec

IV. FUZZY LOGIC CONTROLLER

The system needs to be controlled with proper manner as per requirement. But if it has complex nature and tendency of non-linearity then controlling action is not done properly by other traditional controllers. Hence, the desired performance cannot achieve by system.

In case of fuzzy logic controller, it can deal with such systems which have complex and non-linearity nature. Even if the parameter variation or some disturbance occurred in system then the fuzzy logic controller can overcome such problems very efficiently as compare to other controllers. To implement fuzzy logic controller, four stages are necessary to execute. The fig.4.1 shows structure of fuzzy logic is given as follows:

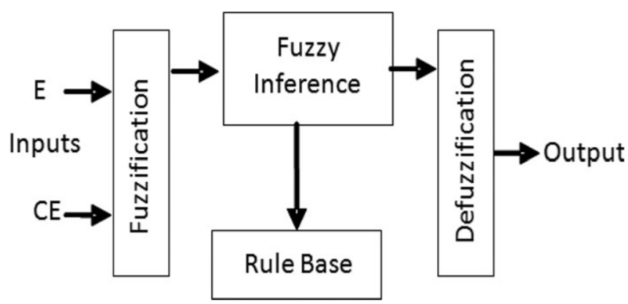

Fig4.1 Structure of Fuzzy Logic

- ***Fuzzification:***

Fuzzification is the first stage in fuzzy logic structure. In this first stage, the piece of input data i.e. crisp input data is converted in linguistic variables. The linguistic variable means the language which is used to design fuzzy logic. This language is very much closer to human thinking. Then by using this converted input (crisp) information further procedure is done

- ***Fuzzy Rule Base:***

Instead of using mathematical modeling of the system, the obtained information is designed using 'If-Then' rules. After defining the crisp input data as linguistic variable, these rules are designed on basis of required conditions so that good control takes place on the system because of designed rules. With the help of these rules, it can make their own decisions and provide controlling actions.

- ***Fuzzy Inference Engine:***

Fuzzy inference module formulates designed base rules and provides the outputs according to the decisions are made for appropriate conditions. In fuzzy logic toolbox, the fuzzy inference engine has two types: Sugeno-type and Mamdani-type. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy.

- ***Defuzzification:***

The defuzzification process is the last stage of fuzzy logic structure. In this process, the fuzzy inference engine output is again converted into crisp data. Because the system cannot understand fuzzy language (in terms of linguistic variables) therefore, it is converted into machine language (numerical value or number). Then obtained output is provided to the system or plant.

V. IMPLEMENTATION OF METHODOLOGY BY USING SIMULATION

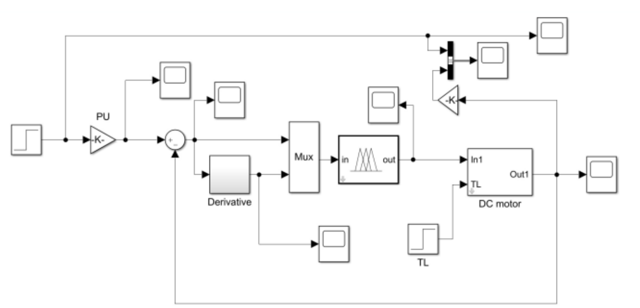

Fig. 5.1 simulation model for speed control of bldc motor by using a fuzzy logic controller.

Fig.5.1 shows simulation model of brushless DC motor for speed controlling using fuzzy logic controller. The brushless DC motor is fed from universal bridge. To control or give the gate pulses to the universal bridge or inverter, it is necessary to sense rotor positions of motor. Therefore, hall sensors are the main part of brushless DC motor which is used to sense the rotor positions of motor. According to the rotor positions, hall sensors give back EMF values of each three phases because the trapezoidal back EMFs are the functions of rotor positions. After calculating equivalent back EMFs of each three phases the switching signals are generated in gates block as well as the output generated from fuzzy logic controller generates the PWM pulses to trigger the switches of universal bridge or inverter. Basically, the output of fuzzy logic controller controls voltage applied across the phase winding of brushless DC motor.

- ***Fuzzy Logic Controller (FLC) Designing***

The fuzzy logic controller is designed in fuzzy logic toolbox available on MATLAB/SIMULINK. The fuzzy inference system (FIS) type is Mamdani type. In this controller design, error of speed (E) and change in error of speed (CE) these two inputs are taken. The output of controller is named as 'Duty Cycle i.e DC'. The fig.5.2 shows design of FLC.

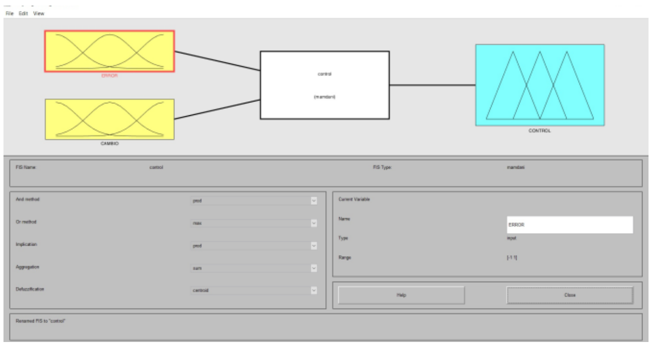

Figure 5.2: Fuzzy Logic Controller Design

VI. SIMULATION RESULTS AND DISCUSSION

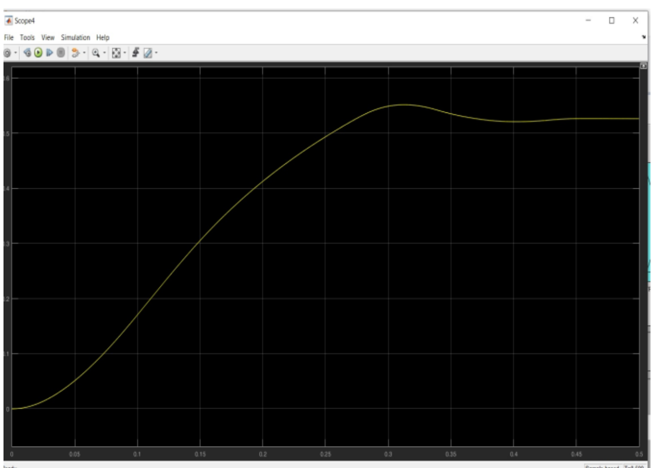

Fig. 6.1Waveform for Rotor Speed at no load condition

At no load condition the step input initial value and final value is zero (0). The load on the motor is Zero (0). The reference speed is set at 1500 RPM and speed is achieved 1491 RPM at no load using fuzzy logic controller. Hence, fig.6.1 shows the back EMF waveform and rotor speed waveform respectively

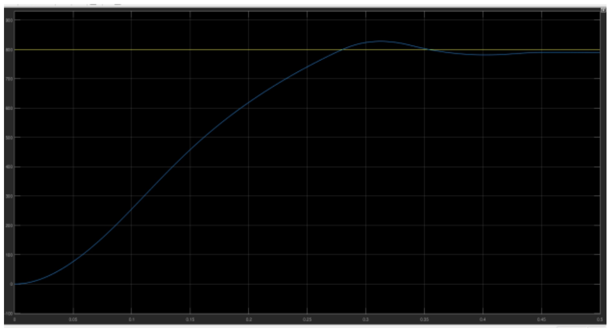

Figure6.2: Waveform for Rotor Speed (RPM) at full load

At full load condition, the step input initial value is set to zero (0) and final value is set to 0.01 to apply load on the motor. The reference speed is set at 1500 RPM and speed is achieved 1450 RPM at full load using fuzzy logic controller. Hence, fig.6.2 shows the back EMF waveform and rotor speed waveform at full load respectively

VII. CONCLUSION

The control scheme for speed control of BLDC motor using fuzzy logic controller is proposed. The significant advantages of the proposed work are: (1) simplicity of control i.e. the fuzzy rule base or Fuzzy set can be easily modified (2) Increased robustness. The regulation of speed is the need in the advanced technical marketing. To achieve the speed, different controllers are used. Such different controllers are useful for those systems which are linear in nature. If the system becomes nonlinear in nature due to some consequences or if the system has tendency of non-linearity, the fuzzy logic controller is useful in such cases. So, the BLDC motor has tendency of nonlinearity, the fuzzy logic controller is able to control the required speed as compare to other conventional controllers.

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