Speed Control of Brushless DC Motor Using Soft Computing Techniques

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***Abstract*:-** The main objective of this project is controlling speed of BLDC motor. The BLDC motor has various application used in industries like in drilling, lathes, spinning, elevators and etc. The speed control of the BLDC motors is very essential. This proposed system provides a very precise and effective speed control system. Brushless DC Motor is used in wide range of applications due to its numerous advantages. In this project, we used Fuzzy Logic Controller & Neural Network for control the speed. Though conventional controllers are also used but they do not possess the accurate answer. We used MATLAB Simulink for simulation.

Keywords:- Brushless DC motor, Fuzzy Logic Controller, PI Controller MATLAB.

I. INTRODUCTION

Brushless DC (BLDC) motor drives have been widely used in Aeronautics, Electric vehicles, robotics, and food & chemical industies. P, PI,& PID controller are being used with the BLDC motor drive control system to achieve satisfactory transient and steady state response. Now a days PID & FUSSY logic controllers are maincontroller being used to control BLDC. It is essential to know the exact mathamatical model of the system or response of the system for designing these controller. the permanent magnet brushless motors are categorized into two kinds depending upon the back emf waveform, brushless ac (pmblac) and permanent magnet brushless dc (pmbldc) motors. pmbldc motors have trapezoidal back emf and quasi-rectangular current waveform. fuzzy logic and artificial neural network can be considered as a mathematical theory combining probability theory, multi-valued logic and artificial intelligence for simulation of the human approach in the solution of various problems by using an approximate reasoning to relate different data sets and to make decisions.

II. WHAT IS BLDC?

	Conventional motors	Brushless motors
Mechanical structure	Field magnets on the stator	Field magnets on the rotor similar to AC synchronous motor
Distinctive features	Quick response and excellent controllability	Long lasting Easy maintenance(usually no maintenance required)
Winding connections	Ring connection The Simplest:Δ connection	The highest grade:Δ or γ- connected Three phase-connection Normal: γ-connected Three-phase winding with grounded neutral point or four-phase connection The simplest: Two-phase connection
Commutation method	Mechanical Contact Between brushes and commutator	Electronic switching using transistors
Detecting method of rotor's position	Automatically detected By brushes	Hall element, optical encoder, Etc.
Reversing method	By a reverse of terminal Voltage	Rearranging logic sequencer

Table: 1 comparison of conventional and Brushless DC motors

III. WHAT IS SOFT COMPUTING?

Soft computing differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation. In effect, the role model for soft computing is the human mind.

The guiding principle of soft computing is: –

Exploit the tolerance for imprecision, uncertainty, partial truth, and approximation to achieve tractability, robustness and low solution cost:

IV. MATHEMATICAL MODELING OF BLDC

- **Modeling of Brushless DC Motor:**

The construction of BLDC motor is similar to the AC motor, known as the permanent magnet synchronous motor. The stator windings are similar to those in a poly phase AC motor, and the rotor is composed of one or more permanent magnets. BLDC motors are different from AC synchronous motors in that the former incorporates some means to detect the rotor position (or magnetic poles) to produce signals to control the electronic switches as shown in Fig. The most common position/pole sensor is the Hall element, but some motors use optical sensors.

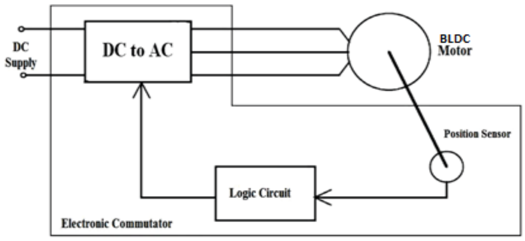


Figure: 1 Diagram of The system

- Mathematical Modeling of BLDC motor drive system:

Typical mathematical modeling of the motor is described by the following equation,

$$\begin{bmatrix} ua \\ ub \\ uc \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \times \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} + \begin{bmatrix} L_m - M & 0 & 0 \\ 0 & L_m - M & 0 \\ 0 & 0 & L_m - M \end{bmatrix} \frac{d}{dt} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} + \begin{bmatrix} ea \\ eb \\ ec \end{bmatrix}$$

Where R & M is the resistance & mutual inductance of the stator, & u_x, i_x & e_x are the phase voltage, phase current & back emf voltage of the stator.

Electromagnetic torque is expressed by,

$$T_e = \frac{Z_p}{2\omega_e}(e_a i_a + e_b i_b + e_c i_c)$$

Where ω_e & Z_p are the electrical speed & number of magnetic poles.

The motion equation is expressed as,

$$\frac{dw_m}{dt} = (p/2j)(T_e - T_l - Bw_r) and \frac{d\theta}{dt} = w_r$$

Where ω_m and ω_r are rotor speed in mechanical rad/s & in electrical rad/s.

Trapezoidal back- emf is expressed as,

$$\begin{pmatrix} ea \\ eb \\ ec \end{pmatrix} = E \begin{bmatrix} f_a(\theta) \\ f_b(\theta) \\ f_c(\theta) \end{bmatrix} \quad , \quad (E = K_e \omega_r)$$

Where K_e is the back emf constant & $f_a(\theta), f_b(\theta)$ and $f_c(\theta)$ are the function of rotor position.

V. MATHEMATICAL MODELLING SIMULINK INTO MATLAB

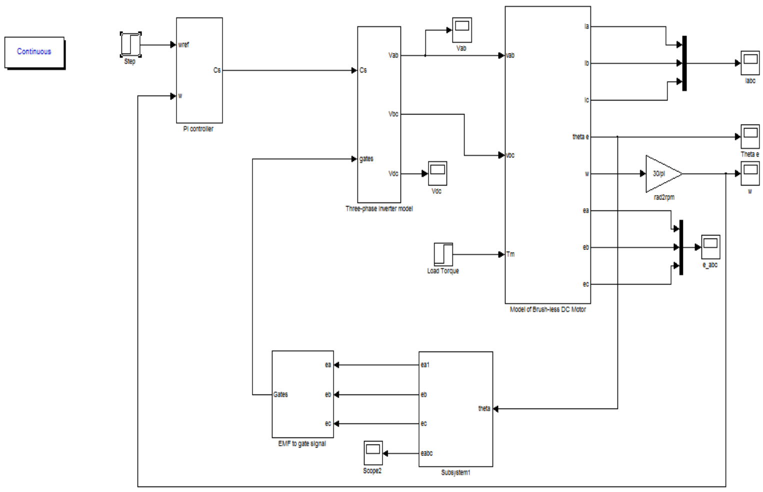


Figure: 2 Mathematical model of bldc motor

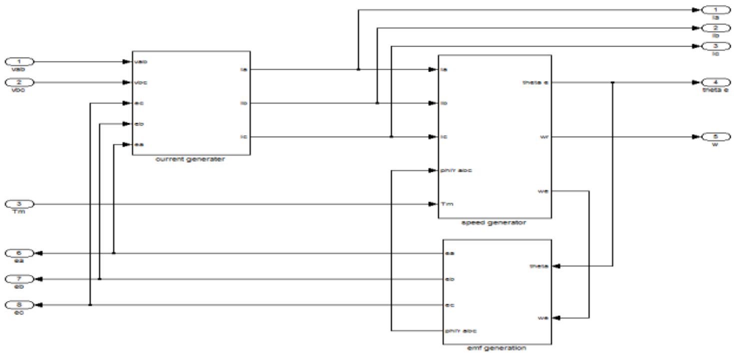


Figure: 3 Simulink model of BLDC motor

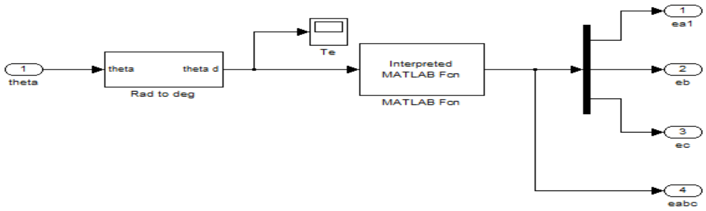


Figure: 4 Block diagram inside the subsystem

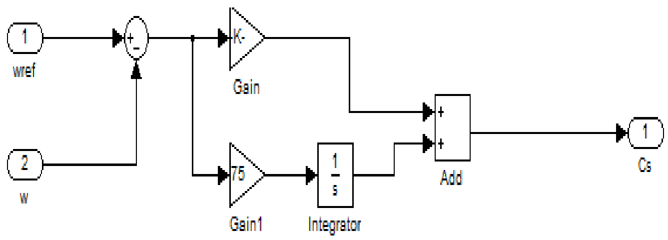


Figure: 5 Block diagram inside the subsystem with PI controller

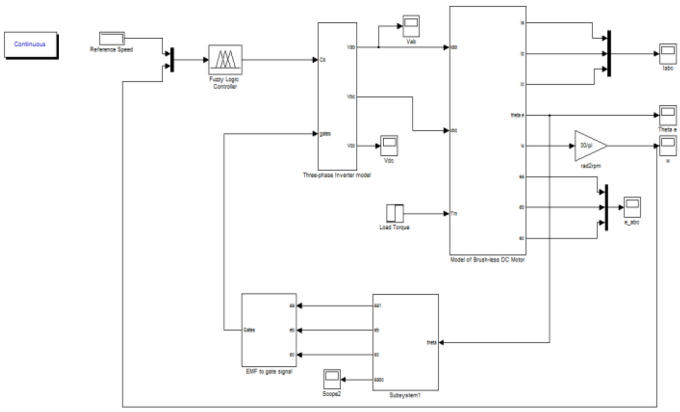


Figure: 6 simulink model of bldc motor using fuzzy logic controller

VI. Fuzzy Logic Controller

A fuzzy logic controller is a control system based on fuzzy logic- a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1.   Fuzzy logic is a thinking process or problem solving control methodology to control systems when inputs are either imprecise or the mathematical models are not present at all. Fuzzy logic can be represented by a membership function. A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1.

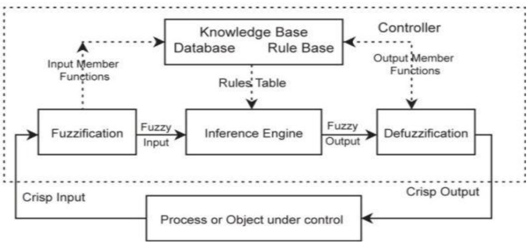


Figure: 7 Block diagram of Fuzzy logic controller

1. **Fuzzification :** It converts the crisp numerical values into the degree of membership related to fuzzy sets.
2. **Rule base and inference engine:** The rules are defined as,
   If error A and change in error is B the output is C.

- Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic.

3. **Defuzzification :** It is the process that convert linguistic variables into crisp value.

VII. Fuzzy Membership Functions

The membership functions illustrated in Fig. used to fuzzification two input values and defuzzification output of the fuzzy controller. For seven clusters in the membership functions, seven linguistic variables are defined as: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small(PS), Positive Medium (PM), and Positive Big (PB).

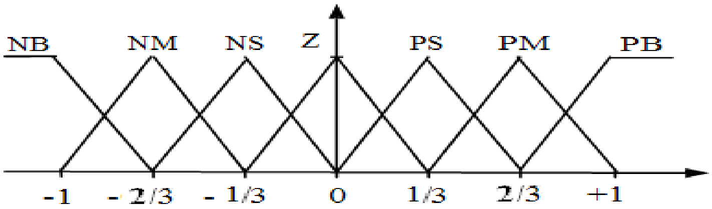


Figure : 8 Membership Function Of Flc

VIII. **FUZZY MEMBERSHIP FUNCTIONS IN MATLAB**

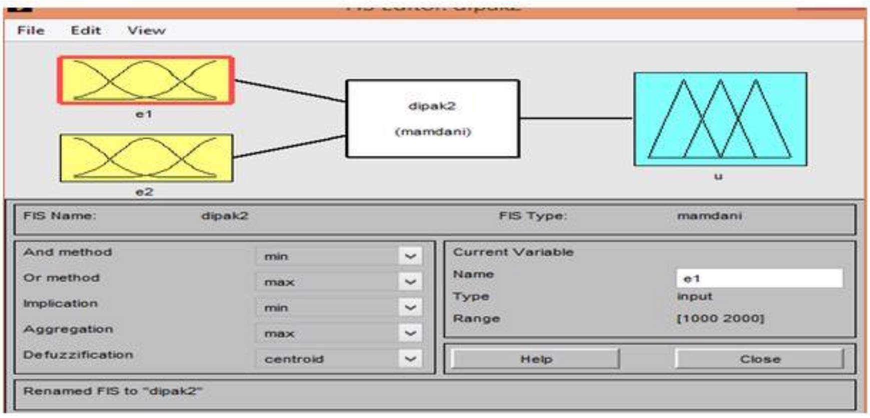


Figure: 9 fuzzy logic controller in matlab

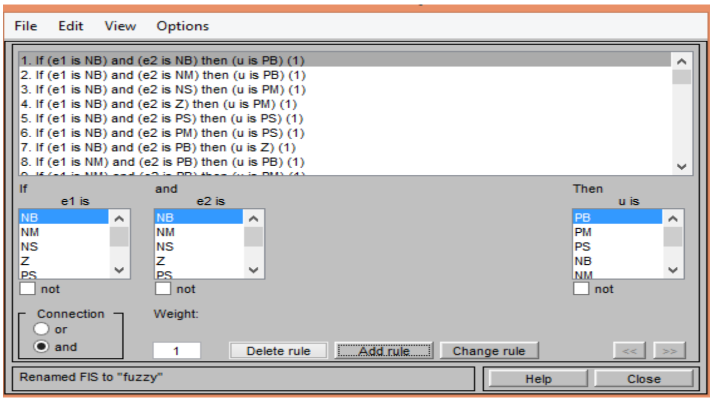


Figure: 10 The fuzzy inference operation is implemented by using the 4 rules

IX. PROGRAMMING FOR EMF GENERATOR

```
function y=emf_generator(theta)
if (theta>-180)&&(theta<=-120)
y=[-1;0;1];
elseif(theta>-120)&&(theta<=-60)
y=[0;-1;1];
elseif(theta>-60)&&(theta<=0)
y=[1;-1;0];
elseif(theta>0)&&(theta<=60)
y=[1;0;-1];
elseif(theta>60)&&(theta<=120)
y=[0;1;-1];
elseif(theta>120)&&(theta<=180)
y=[-1;1;0];
```

end

X. SIMULATION RESULTS

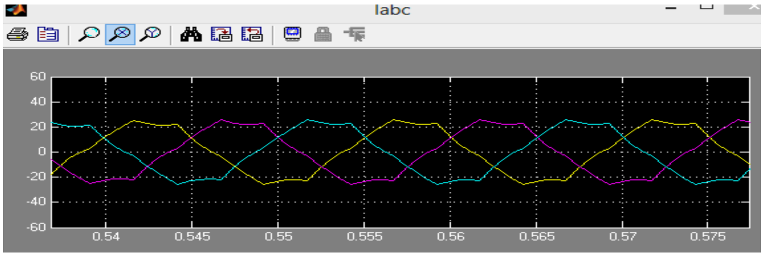


Figure: 11 waveforms of phase currents(Iabc)

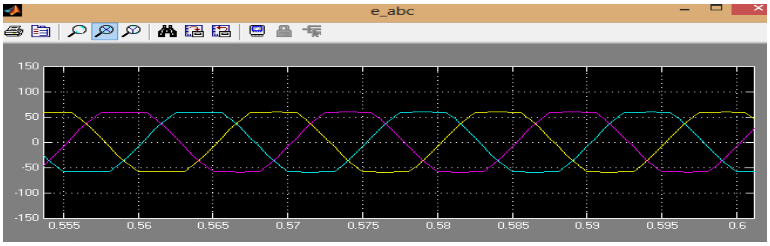


Figure.: 12 waveforms of phase EMF(eabc)

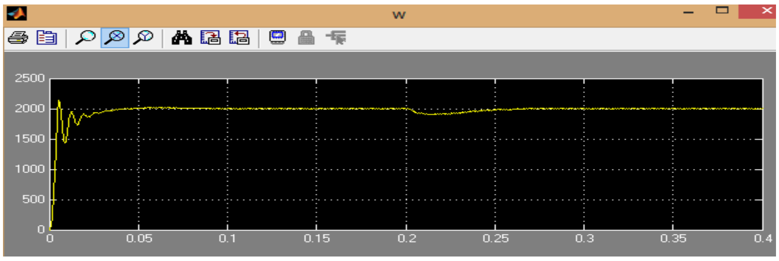


Figure: 13 waveforms of speed(w) using PI controller

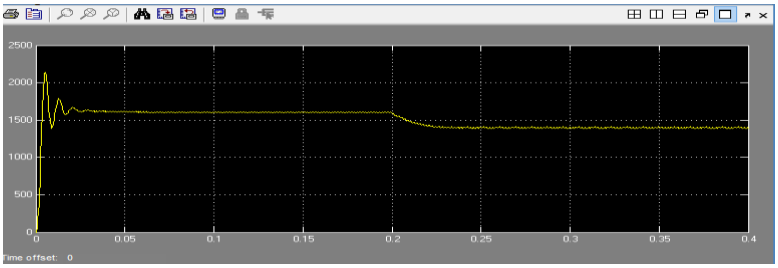
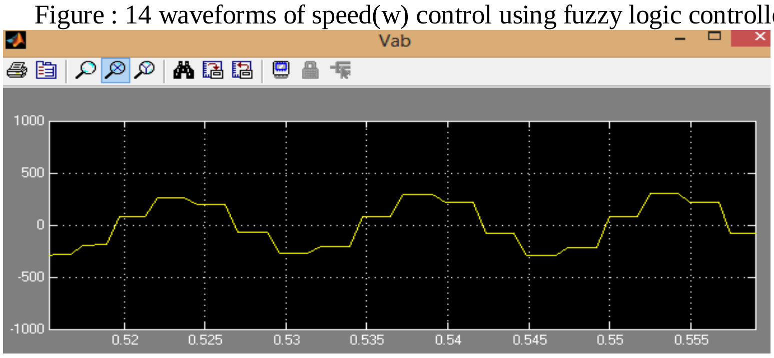


Figure : 14 waveforms of speed(w) control using fuzzy logic controller



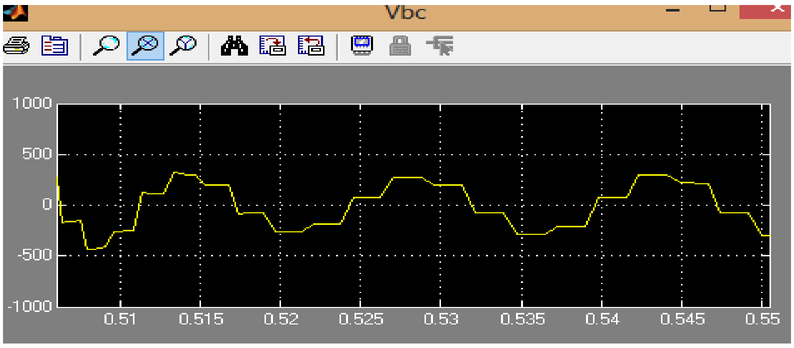


Figure : 15waveforms of phase voltage Vab & Vbc

Conclusion

Using mathematical modeling of BLDC simulink model has been developed. By applying PI controller oscillations are found in the steady state value. So to reduce the oscillation fuzzy logic controller has been implemented. By applying fuzzy logic controller oscillation are reduce after some times and speed of the bldc motor should be constant

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