Speed Control of BLDC Motor using Fuzzy Logic

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***Abstract*—BLDC motor have permanent magnet rotor and stator windings are wound such back emf is generated which is rectangular, trapezoidal, triangular in nature. In this paper the Fuzzy Logic is used for speed control of the BLDC motor. As we get the precise or accurate value by fuzzy logic and accuracy is more compared to other controllers also the fuzzy has become more effective, reliable controller. This controller is designed to observe the variation of speed and to make the motor stable when load is varied. Fuzzy logic is not only way to reason with ambiguous concept but it seems to be most precise function To make this logic implement successfully the simulation model is done in matlab program. The advantage of simulation in matlab is that, we can get the result of speed of speed controller in BLDC motor by varying loads in it, and we can control it and the controlled result can be displayed in terms of graphical method which helps to detect the change in speed and can be used for implementation. Fuzzy logic gives better disturbance rejecting capabilities and smaller overshoot in speed response.**

Keywords— Fuzzy logic, BLDC motor, Mamdani controller, speed control, etc

I. INTRODUCTION

BLDC motors are frequently used in industrial applications, since it has various advantages such as:-

1) They have higher efficiency.
2) They have long life due to lack of electrical and frictional losses.
3) This motors are spark free because of absence of brushes.
4) This motors are noiseless.

BLDC motor consists of permanent magnet rotor which provides the necessary air gap flux and stator in form of polyphase armature windings. BLDC motor does not use brushes for commutation, here commutation is done electronically. Basically, BLDC motors can be constructed in two ways:-By placing the rotor outside the core and By placing winding outside the core.

In this paper the fuzzy logic is used to speed control of BLDC motor. The term fuzzy logic was introduced in 1965 by LotfiZadeh. Fuzzy logic has been applied to many fields, from control theory to artificial intelligence. By using the fuzzy logic controller we get the precise value of the output parameters. The fuzzy logic controller is flexible, convenient; hence it is widely used. Fuzzy controllers are used to control consume of products, such as washing machine, cameras, as well as in industrial processes.

II. CONSTRUCTION

BLDC are one of a type of synchronous motor. The BLDC motor are further classified as 1.Stator and 2.Rotor.

A. Stator

The stator of BLDC motor consists of steel laminations and windings are placed in slots of motor. This slots are axially cut along inner-periphery. Most of the BLDC motor are star connected. This windings are distributed over the periphery to form even no. of poles. There are two types of stator windings namely: - Trapezoidal and Sinusoidal. The difference between this two types are made by interconnection of coils in stator windings and this windings gives various back emf. This are used to make the torque output of sinusoidal more smoother as compared to trapezoidal motor. The motor with correct voltage rating of stator depend on power supply capability of motor.

B. Rotor

Rotors are made up of permanent magnets, and the construction of rotor varies from 2 to 8 pole pair with alternate north and South Pole. The magnetic material is chosen based on the magnetic field density in the rotor. Ferrite magnet are normally used for manufacturing the permanent magnet because this magnet is less expensive but it has low flux density which is the only disadvantage. These magnets improves the size-to-weight ratio and gives higher torque.

III. OPERATING PRINCIPLE

A brushless DC motor is defines as a permanent synchronous machine with the rotor position feedback. It is generally controlled using a 3 phase power bridge semi-conductor. This motor requires rotor position sensors which helps for starting and providing the commutation sequence. This led's to turn on the power devices in the inverter bridges. The power devices are commutated sequentially every 60^0, based on the rotor position. Due to this the problem associated with the brush and commutator is eliminated for example sparking. This makes BLDC motor more rugged as compared to a dc motor. The BLDC consists of four main components as Power converter, permanent magnet-synchronous machine sensor, and control algorithm.The role of power converter is to transform the power from source to the permanent magnet-synchronous machine sensor. The structure of control algorithm depends on the type of brush less dc motor, there are two classes voltage source based drives and current source based drives.

IV. FUZZY LOGIC

Fuzzy logic is computing based on “degree of truth” rather than the usual “true or false” (1 or 0) Boolean logic. Fuzzy logic is one of the most successful technologies in the control system. This is because, the fuzzy logic gives the perfect solutions for its applications. The fuzzy logic has the ability to generate precise solution for approximate information. Fuzzy logic is a superset of Boolean logic which can be used to handle the truth of partial truth.

V. FLC

Fuzzy logic controller (FLC) is a rule based controller. The fuzzy logic controller is a control algorithm which is based on linguistic control method. The other controllers has difficult mathematical calculations, while fuzzy logic tries to account the human knowledge without knowing mathematical model. The application of fuzzy logic controllers are as follows:-

A. Washing machines.
B. Video camera.
C. Underground trains.
D. Robots.

The fuzzy logic controller contains various rules & they are useful in operator controlled plants. Fuzzy logic has the capability to improve its performance without identifying the model of the plant.

VI. STRUCTURE OF FLC

Fuzzy logic controller (FLC) has four main components, they are as follows:-

A. Fuzzification.
B. Inference engine.
C. Rule base and data base.
D. Defuzzification

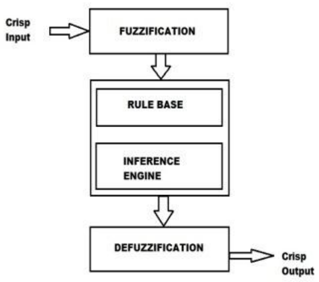

Fig (1): Structure of FLC

A. *Fuzzification:-*

This is the first block of the controller, this block converts each piece of input data of degrees of membership in one or several membership function. It also matches the input data with conditions with rule base. The fuzzification involves following functions:

a. Measures the values of input variables.
b. It performs a scale mapping that transfers the range of input variables into corresponding universes of discourse.
c. It converts input data into suitable linguistic values.

B. *Rule base:-*

The collection of rules is called rule base & these rules are in the familiar IF-THEN format. In this if-side is called condition and then-side is called as conclusion. The rules reflects the strategy to control signal should be a combination of reference error and change in error. It comprises of knowledge of application domain. It consist of data base and linguistic control rule base.

a. The data provides the useful definitions and this definitions are used to define linguistic control rules and fuzzy data manipulation in FLC.
b. The rule base defines the control goals and the control policy of the domain experts.

If-then rule base for fuzzy logic are as follows:-

e/ce	NB	NM	NS	ZO	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZO
NM	NB	NB	NB	NM	NS	ZO	PS
NS	NB	NB	NM	NS	ZO	PS	PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM	NS	ZO	PS	PM	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PB	ZO	PS	PM	PB	PB	PB	PB

Where,

N = negative, Z = zero, P = positive
B = big, M = medium, S = small.

C. *Inference Engine:-*

The fuzzy inference engine is the kernel of a FLC, it has a capability of making human decisions based on fuzzy concepts or inferring fuzzy control actions employing fuzzy implantation.

D. *Defuzzification:-*

Defuzzification inference means to convert the conclusions of inference mechanism in real inputs for the process. Defuzzification means all the actions that are activated combined together and converted into a single non fuzzy output signal.
The defuzzification interface performs the following functions:-
Defuzzification is when inferred fuzzy control action yields to give non fuzzy control action.
The fuzzy control system is transformed into a crisp control action:

$$Z_o = \text{defuzzifier}(C) \qquad \ldots\ldots (1)$$

Where defuzzifier is a defuzzification operator. The most used defuzzification operators are:

A. Center-of-Gravity: $Z_0 = \frac{\sum_{j=1}^{N} Zj\mu c\,(Zj)}{\sum_{j=1}^{N} \mu c(Zj)}$ …… (2)

B. Middle-of-Maxima: The defuzzified value is defined as mean of all values of the universe of discourse, having maximal membership grades $Z_0 = \frac{1}{N1}\sum_{j=1}^{N1} Zj, \quad N1 \le N$ …. (3)

C. Max-Criterion: This method chooses an arbitrary value, from the set of maximizing elements of C, i.e. Where Z = {z1...zN} is a set of elements from the universe V.

VII. MAMDANI FLC

This is the most commonly used fuzzy inference technique which was proposed by Mamdani & Assilian. The very first attempt to control steam engine and boiler by synthesizing a set of linguistic control rules given by experienced human operator. The fuzzy model implication is modeled by Mamdanis minimum operator. In order to explain working with this model, we consider example where simple two input to one output problems.

Rule 1: IF x is A_3 OR y is B_1 THEN z is C_1
Rule 2: IF x is A_2 OR y is B_2 THEN z is C_2
Rule 3: IF x is A_1 THEN z is C_3

Step1: Fuzzification
The first step is to take the crisp inputs, x_0& y_0

μA1 (x0) = 0.5, μA2 =0.2, μB1 (y0) =0.1, μB2 (y0) =0.7... (4)

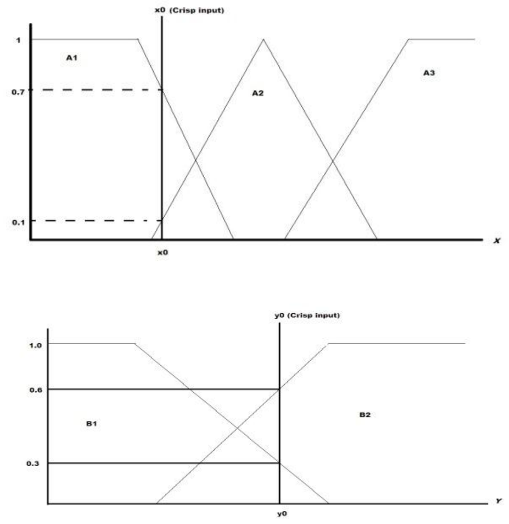

Fig (2): Examples of Fuzzification

Step 2: Rule evaluation Theantecedents of the fuzzy rules gets commands from the fuzzified inputs. The fuzzy operator is used to obtain the single number which represents the result antecedent's evaluation for multiple antecedents. Typically, the classical fuzzy operation union is used.

μAUB (x) = max {μA(x), μB(x)} …. (5)

Similarly, in order to evaluate the conjunction of the rule antecedents the AND fuzzy operation intersection is applied:

μA∩B (x) = max {μA(x), μB(x)} …… (6)

The result is given in following fig.

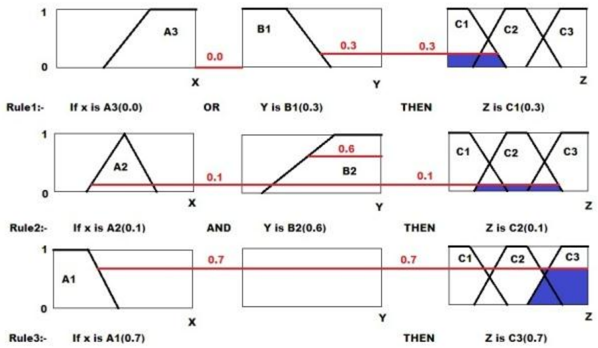

Fig (3): Example of rule evaluation

Clipping is to cut the consequent membership function of the antecedent truth level. Scaling Provides better improved approach for preserving original shape of fuzzy set; by multiplying all the membership degrees by truth values of the rule antecedents to adjust the original membership function of rule consequent.

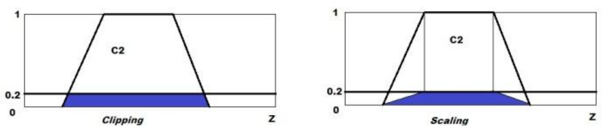

Fig (4) Example of clipping and scaling

Step 3: Aggregation of the rule Outputs: -
previously clipped or scaled membership functions of all rule consequents are combined to form a single fuzzy set.

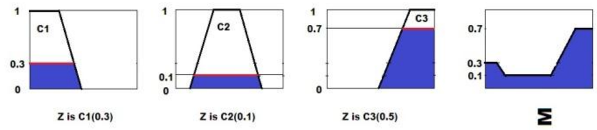

Fig (5): Aggregation of the rule Outputs

Step 4 :- Defuzzification Centroid technique is most commonly used technique. Center of gravity point of aggregated fuzzy sets are determined on the interval [a, b]

$$COG = \frac{(0+10+20)*0.3+(30+40+50+60)*0.1+(70+80+90+100)*0.7}{0.3+0.3+0.3+0.1+0.1+0.1+0.70+0.7+0.7} = 80.3$$

Fig (6): Defuzzification

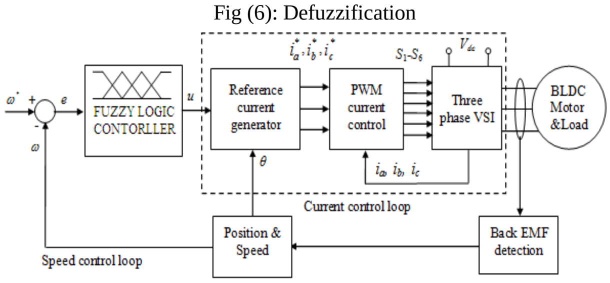

Fig (7): Block diagram of speed control of BLDC motor

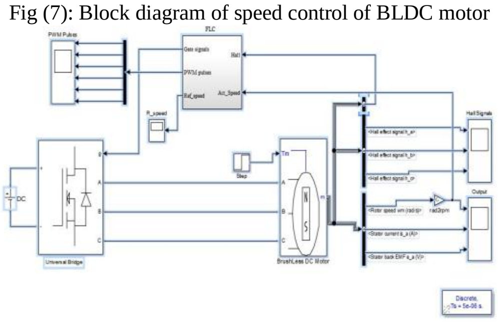

Fig (8): Simulation model of fuzzy logic controller

VIII.CONCLUSION

In this paper, the speed control of bldc motor has been performed using fuzzy logic controller. This speed control of bldc motor is done in MATLAB/SIMULINK because they allows various dynamic characteristics such as phase current, voltage, rotor speed and mechanical torque are considered. Here Mamdani algorithm has been used in fuzzy logic. As simulation is cheaper than actual experimental models and gives more accurate values.

IX. FUTURE SCOPE

As we are using fuzzy logic for speed control of BLDC to get the precise output, similarly whenever such type of precise outputs or results are required which cannot obtained by conventional methods or other controllers where we get result in only true or false i.e. (0 or 1) we can use fuzzy logic.

REFERENCES

[1] Yee-Pien Yang and Yi-Yuan TingKumar "Improved AngularDisplacement Estimation Based on Hall-Effect Sensors for Driving a Brushless Permanent-Magnet Motor," IEEE Transactions On Industrial Electronics, Vol. 61, No. 1, pp.504-511 Jan2014.

[2] Han Ho Choi and Jin-Woo Jung, "Discrete-Time Fuzzy SpeedRegulator Design for PM Synchronous Motor" IEEETransactions On Industrial Electronics, Vol. 60, No.2, pp.600-607, Feb 2013.

[3] M. Surya Kalavathi, and C. Subba Rami Reddy "PerformanceEvaluation of Classical and Fuzzy Logic Control Techniques for Brushless DC Motor Drive" IEEE Transactions OnIndustrial Electronics, Vol. 61, No. 1 , pp .488-491, Jul 2012.

[4] Chwan-Lu Tseng, Shun-Yuan Wang, Shao-ChuanChien, and Chaur-Yang Chang "Development of a Self-Tuning TSK-Fuzzy Speed Control Strategy for Switched ReluctanceMotor," IEEE Transactions on Power Electronics, vol. 27,No.4, pp 2141-2151,April 2012.

[5] Chang-Han Jou, Jian-Shiun Lu, and Mei-Yung Chen"Adaptive Fuzzy Controller for a Precision Positioner Using Electro-Magnetic Actuator," International Journal of FuzzySystems, Vol. 14, No. 1,pp.110-117, March 2012.

[6] N.T.-T. Vu, H.H. Choi, R.-Y. Kim, J.-W. Jung "Robust speedcontrol method for permanent Magnet synchronous motor," IET Electric Power Applications, vol.6, No.7, pp.399 -411, Feb 2012.

[7] Radu Duma, Petru Dobra, Mirela Dobra and Ioan ValentinSita "Low Cost Embedded Solution for BLDC Motor Control," International conference on System Theory, Control and Computing,pp.1-6,Aug 2011.

[8] Shun-Chung Wang and Yi-Hwa Liu "A Modified PI-Like Fuzzy Logic Controller for Switched Reluctance Motor Drives, IEEE Transactions on Industrial Electronics, Vol. 58, No.5, pp.1812 1825, May 2011.

[9] B. Mahesh Kumar, G. Ravi, and R. Chakrabarti "SensorlessSpeed Control of Brushless DC Motor with Fuzzy Based Estimation," Iranian Journal Of Electrical and ComputerEngineering, Vol. 8, N0. 2, pp.119-125, Summer-Fall, 2011.

[10] Xiang Wang, Mei Li "Rotor Position Simulation of Switched Reluctance Motor Based on Fuzzy Inference Rules," International Conference on Innovation Management, pp.75-78, Sep 2009.

[11] V. U, S. Pola, and K. P. Vittal, "Simulation of four quadrantoperation & speed control of BLDC motor onMATLAB/SIMULINK," in Proc.IEEE Region 10Conference,pp.1-6, Nov 2008.

[12] C. Xia, P. Guo, T. Shi, and M. Wang, Speed control of brushless dc motor using genetic algorithm based fuzzy controller, Proc. of Int. Conf. on Intelligent Mechatronics and Automation, pp.460-464, 2006.

[13] Timothy J. Ross, Fuzzy Logic with Engineering Applications, 2ⁿᵈed, England: John Wiley & Sons Ltd, 2004.

[14] Chung-Wen Hung, Jen-Ta Su, Chih-Wen Liu, Cheng-Tsung Lin and Jhih-Han Chen. 2010. Fuzzy Gain Scheduling PI controller for Sensorless four switches three phase BLDC motor, IEEE 978-1-4244-4783-1/10.