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A Study on Speed Control of BLDC Motor Using Fuzzy Logic

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Abstract : Due to the properties like high efficiency, reliability, high starting torque, less electrical noise and high weight to torque, Brushless DC Motor (BLDCM) has been used widely in industries. Importance of the speed controls of BLDCM is highly required because it indirectly controls efficiency by the mechanical output required. Controllers such as PWM, PI, Fuzzy and Neural Networks (NN) are used to control the parameter related to speed. This paper work deals with FLC design by using a simple analogy within the control surfaces of the FLC and a PI controller for the same. MATLAB / SIMULINK package program has been used for the simulation and analysis of model.Also, various study shows that the FLC offers better adaptability than conventional PI controller and due to this the BLDCM drive offers better steady state and dynamic performances.
Keywords: BLDC Motor, Speed Control, PI Controller, FLC

I. INTRODUCTION

Nowadays the use of BLDC motor instead of brushed DC motor has increased in number of power electric drive applications. BLDC motor comprise of sinusoidal (PMSM) or trapezoidal (PM BLDC) motor, depending u1pon the rotational voltage (back EMF) induced. Due to the fact of recent advancements in technology, these motors which are categorized as special electrical motors are much more suitable for efficient drive operation. These motors are characterized by a much higher efficiency, greater reliability, and more power density requiring less maintenance. Due to the fact that PM BLDC has higher torque delivered to motor size ratio, high efficiency and long life; these motors find their application in various electrical systems depending upon the requirements. In this context it can also be noticed that from last few years, research in this area have experienced an expansion.
The desired level of performance from BLDC motor could be achieved by the use of suitable speed controllers in the overall electric drive-system. Many controllers like PI, FLC and NNare available for the speed control of such electric drives. The Proportional plus Integral (PI) controller; is the most commonly used standard controller applicable for speed control of electrical drives. Due to the simple control structure and ease of implementation; PI controllers are widely used in the industrial sector. These controllers at the same time pose some difficulties such as control complexity nonlinearity, load disturbances and parametric variations.
The use of faster dynamic response controller in motioncontrol like Artificial Intelligence (AI), Adaptive NeuroFuzzyInference Systems (ANFIS); is the substitution of astandard (PI)controller. FLC speed controller is one thefrequently accessed controller used for the speed control ofan electric drive. Fuzzy logic speed control can sometime beseen as the ultimate solution for high-performance electricaldrives. PI controller when compared with these recentemerging controllers, found to be comparatively inefficient.The reason for low efficiency in the PI controller is the highovershoot from the reference point, which leads to transientsand large delay time to get into steady state. The slowresponse on the sudden change of load torque and thesensitivity to controller gains (Kpand *Kc)* are the other reasonsfor the obsoleteness of PI controllers. This has resulted inthe increased demand of modern nonlinear control structureslike Fuzzy logic controller. These controllers are inherentlyrobust to load disturbances. BLDC motors being non-linearin nature can easily be affected by the parameter variationsand load disturbances.

II. CONSTRUCTION AND PRINCIPLE OF OPERATION

Brushless motor is considered to be an electronically commutated motor. It requires electrical switches for realizingcommutation of current and hence motor is rotated continuously. These switches are connected in H-bridge structure.Figure 1 shows BLDC connected to driver circuit.

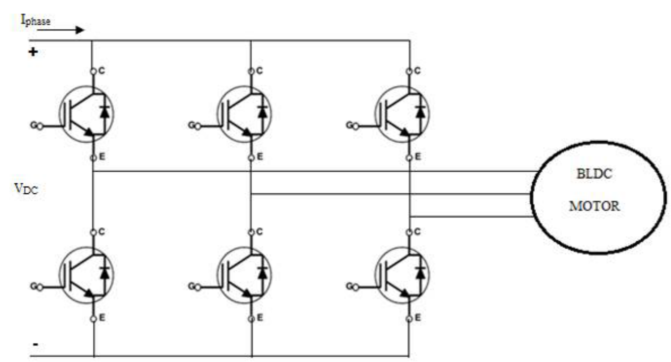

Figure 1: BLDC motor with driver circuit

Three hall sensors are required for a three phase BLDC motor which is used to detect the position of rotor. Threesensors are placed on stator at 120-degree intervals. These windings are placed in a star formation. Each hall sensorschanges its state for every 60-degree rotation and completes the whole cycle by taking six steps. Rotor pole pairs areused to determine number of cycles required to complete a mechanical rotation. Hence, number of cycles is same asrotor pole pairs.

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III. BLDC SPEED CONTROLLERS

There are several controllers available nowadays likeproportional integral (PI), proportional integral derivative(PID) Fuzzy Logic Controller (FLC) or the combinationbetween them: Fuzzy-Neural Networks, Fuzzy GeneticAlgorithm, Fuzzy-Ants Colony, Fuzzy-Swarm. But aswithin the scope of this paper the discussion on the PI andFuzzy Logic Controller will be discussed as below.

A. PI Speed Controller

A Proportional Integral (PI) is a feedback control loopmechanism used in electrical control system. PI Controllerfinds its applications in many industrial processes where acontroller attempts to correct the error between ameasured process variable and reference set point. Thealgorithm involves a calculation and outputting of acorrective action which is done in order to adjust theprocess accordingly. The PI controller, as the nameindicates, involves two separate modes that are: theproportional mode and integral mode. The proportional mode determines the reaction to the current error whereasthe integral mode determines the reaction based recenterror. Due to its simple structure and ease of use; PIcontroller is widely used in industry.The speed of the motor is compared with its referencevalue and the speed error is processed inproportionalintegral(PI) speed controller.

B. Fuzzy Logic based Speed Controller

Non-Linear Systems can be very easily modeled byFuzzy Logic Controller (FLC). The conventional controlsystem design is usually based on the mathematical model of plant which is generally complex mathematicalequations. On the other hand, FLC expresses operationallaws in terms oflinguistics terms instead of mathematicalequations.Sometimes it has been experienced thatthere are many systems which are too complex to modelaccurately, even with complex mathematical equations;therefore, conventional methods become infeasible in thesesystems. Henceforth, fuzzy logics linguistic terms providea feasible and easy method for defining the operationalcharacteristics of such system to design and implement.

The generalized block diagram of a BLDC Motorwith a controller as shown in Fig. 2, can be replaced byany other controller as required. Any control mechanismcan be adopted in the system such as PI, PID or FuzzyLogic Controller which will be suitable to maintain andcontrol the speed of the BLDC Motor.

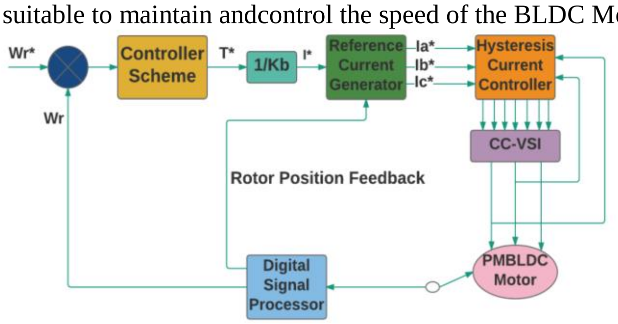

Figure 2: Block Diagram of a BLDC Motor with Controller Scheme

The section ahead explains the Simulink model of aBLDC Motor with a PI and a Fuzzy Logic Controlleralong with the simulations results which is discussed.FLC is an algorithm which is dependent on lingual strategy of control. It acquires human thinking about controlling thesystems without mathematical modeling. Fuzzy logic's lingual terminology is often exhibited using some of the logicalinsinuation like If-Then rules. These logical rules describe a scale of values which is known as fuzzy membershipfunction. Block diagram of fuzzy logic controller is given below,

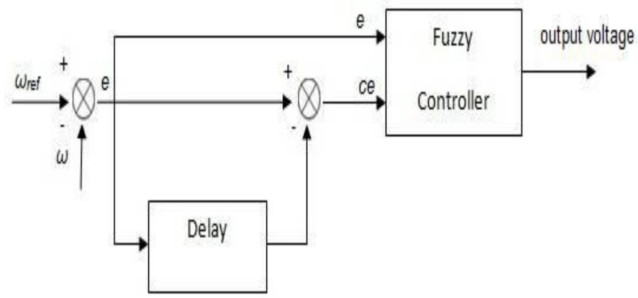

Figure 3: Fuzzy controller block diagram

There are two types of fuzzy logic controller. They are Sugeno Takagi architecture and Mamdani architecture. Forcontrolling speed, Mamdani architecture of fuzzy logic is used. Inputs are error *(e)* and change in error *(ce)*. Difference of reference speed *(ωref)* and the original speed *(ω)* gives the speed error. Output voltage is the controlleroutput.

Membership function chosen is the triangular shaped function because of its simplicity and good controlling operation.Error, change in error and output voltage is the membership function used here. Seven level of membership functionare applied for all the variables.

IV. SIMULATION

Simulink model of a Permanent magnet BLDC Motorwith the FLC is designed in a MATLAB Simulinktool. The Simulink model consists of a 3phase supply viainverter and a BLDC motor. The model is coupled with aFLC for the speed control of the motor.The model has been designed using the following parametersas shown in Table I.

Table 1: PARAMETERS CHART

Speed (N in RPM)	1500
Voltage (Vin volts)	160
Poles of the Motor (P)	4
Motor phases (ϕ)	3
Stator Phase Resistance (Rsin ohm)	0.7
Torque Constant (k)	0.84
Load Torque	2 N-m
Back EMF area (degree)	120
Rotor Initial Position (Θ in	0

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degrees)	
Kp=Proportional Constant	0.002
Ki=Integral Constant	5

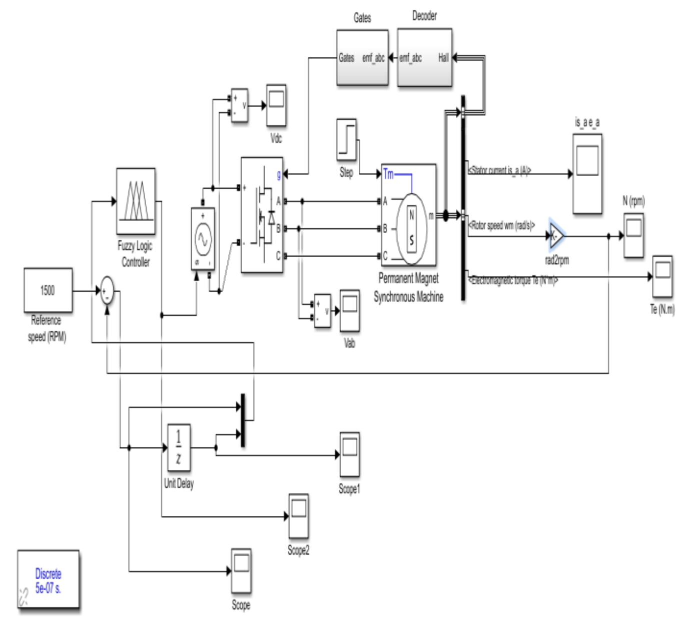

Figure 4: Simulation Model of the Speed Control of BLDC using FLC

Fig. 4 shows the PM BLDC Simulink model with a FLC and the simulation results for the same have beenshown ahead. The simulations results comprise of speed,torque and current characteristic curve of a BLDC motorwith FLC.

V. CONCLUSIONS

The speed control of a Permanent Magnet BLDCMotor is studied in this paper, using both PI controller,and Fuzzy Logic Controller. The paper explains about theperformance analysis of a BLDC Motor in brief Further acomparative study has been discussed between the PIcontroller and Fuzzy Logic controller used on the MATLAB Simulink tool for the speed control of a BLDCmotor. The inference which canbe concluded after comparison is that speed control ofBLDC using Fuzzy Logic Controller has betterperformance. To add current control function to theproposed speed controller in order to keep the currentwithin a certain range for a specific speed, could be awork for future. The proposed future work would therebyenhance the motor start-up current, reduce the motorcurrent ripples and overall enhance the motor torquecharacteristics performance. Current control methodologywill also reduce the speed and torque variations causeddue to any sudden changes in the motor current value.

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