SPEED CONTROL OF A BLDC MOTOR USING FUZZY PID AND PID CONTROLLER

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Abstract: -This project deals with the design of voltage control of three phase inverter applied to a variable-speed low inductance brushless dc (BLDC) motor. In this design/modeling three phase inverter, pid and Fuzzy PID controller and BLDC motor are used. In this work DC voltage is converting to AC voltage and AC voltage is connected to variable speed drive, this speed is input controller and controller generate SPWM as output of the controller, this PWM are connected three phase inverters. By varying the speed and controller parameters operate the motor with stable and check the motor stator voltage and Torque. These works are executing in MATLAB environment and to validate the proposed approach with a superior performance when compared to two other control strategies.

1. INTRODUCTION

Brushless dc (BLDC) engines are favored as little-drive control engines due to their high effectiveness, quiet operation, compact shape, unwavering quality, and moo upkeep. In any case, the issues are experienced in these engines for variable speed operation over the final decades proceeding innovation improvements in control semiconductors, chip, flexible speed drivers control plans and permanent-magnet brush less electric engine generation have been combined to empower solid, cost-effective arrangement for a wide extend of flexible speed applications.

Household apparatuses are anticipated to be one of fastest-growing end-product advertising for electronic engine drivers over the following five a long [4]. The major machines incorporate dress washer's room discuss conditioners, fridges, vacuum cleaners, coolers, etc. Family machines have customarily depended on chronicled classic electric engine innovations such as single stage AC acceptance, counting part stage, capacitor-start, capacitor–run sorts, and widespread engine. These classic engines ordinarily work at constant-speed straightforwardly from primary AC control without with respect to proficiency. Shoppers presently request for lower vitality costs, better execution, decreased acoustic commotion, and more comfort highlights. Those conventional advances cannot give the solutions.

1.1.A Comparison of BLDC with conventional DC motors

In an ordinary (brushed) DC-motor, the brushes make mechanical contact with a set of electrical contacts on the rotor (called the commutator), shaping an electrical circuit between the DC electrical source and the armature coil-winding. As the armature turns on the hub, the stationary brushes come into contact with diverse areas of the pivoting commutator. The commutator and brush-system frame a set of electrical switches, each terminating in an arrangement, such that electrical-power continuously streams through the armature-coil closest to the stationary stair (lasting magnet). In a BLDC engine, the electromagnets do not move; instead, the lasting magnets pivot and the armature remains inactive. This gets around the issue of how to exchange current to a moving armature. In arranging to do this, the commutator gathering is supplanted by a shrewdly electronic controller.

The controller performs the same power-distribution found in a brushed DC-motor, but utilizing a solid-state circuit or maybe than a commutator. BLDC engines have numerous preferences over DC engines. A few of these are:

- High dynamic response
- High efficiency
- Long operating life
- Noiseless operation
- Higher speed ranges

BLDC's fundamental drawback is higher fetched which emerges from two issues. To begin with, BLDC engines require complex electronic speed controllers to run. Brushed DC- motors can be directed by a comparatively unimportant variable resistor (potentiometer or rheostat), which is wasteful but moreover palatable for cost-sensitive applications.

1.2.A brief review on control of BLDC motor

The ac servo has set up itself as a genuine competitor to the brush-type dc servo for mechanical applications. In the fractional-to-30-hp run, the accessible ac servos incorporate the acceptance, permanent-magnet synchronous, and brushless dc engines (BDCM) [8]. The BDCM has a trapezoidal back EMF, and rectangular stair streams are required to create a steady electric torque. Regularly, Hysteresis or beat width-modulated (PWM) current controllers are utilized to keep up the genuine streams streaming into the engine as near as conceivable to the rectangular reference values. In spite of the fact that a few steady-state investigation has been done [9], [10], the confirmation of this servo drive has been dismissed in the literature.

modeling, nitty gritty reenactment, and test

2. INTRODUCTION TO BLDC MOTOR DRIVE

2.1. Brushless dc motor background

BLDC engine drives, frameworks in which a lasting magnet energized synchronous engine is bolstered with a variable recurrence inverter controlled by a shaft position sensor. There shows a need for commercial reenactment bundles for the plan of controller for such BLDC engine drives. One primary reason has been that the tall program advancement fetched caused is not legitimized for their normal have taken a toll on fractional/integral kW application region such as NC machine instruments and robot drives. Indeed, it seems to suggest the possibility of demagnetizing the rotor magnets amid commissioning or tuning stages. All things considered, recursive prototyping of both the engine and inverter may be included in novel drive arrangements for progress and specialized applications, coming about in tall formative fetched of the drive framework. Made strides magnet fabric with tall (B.H), moreover, makes a difference thrust the BLDC engines showcase to tens of kW application zones where commissioning mistakes get to be restrictively exorbitant. Modeling is hence fundamental and may offer potential to toll savings.

A brushless dc engine is a dc engine turned interior out, so that the field is on the rotor and the armature is on the stator. The brushless dc engine is really a lasting magnet ac engine whose torque-current characteristics mirror the dc engine. Instep of commutating the armature current utilizing brushes, electronic commutation is utilized. This dispose of the issues related to the brush and the commutator course of action, for example, starting and wearing out of the commutator-brush course of action, in this manner, making a BLDC more tough as compared to a dc engine. Having the armature on the stator makes it simple to conduct warm absent from the windings, and if wanted, having cooling course of action for the armature winding's is much simpler as compared to a dc motor.

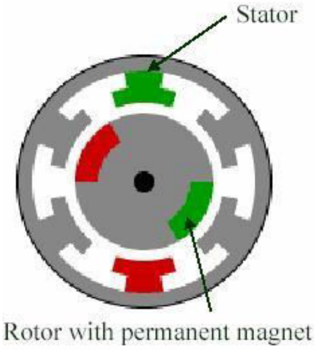


Fig 2.1 Cross-section view of a brushless dc motor

2.2. Principle operation of Brushless DC (BLDC) Motor

A brush less dc engine is characterized as a changeless synchronous machine with rotor position nourish back. The brushless engines are for the most part controlled utilizing a three- stage control semiconductor bridge. The engine requires a rotor position sensor for beginning and for giving legitimate commutation arrangement to turn on the control gadgets in the inverter bridge. Based on the rotor position, the control gadgets are commutated successively each 60 degrees. Instep of commutating the armature current utilizing brushes, electronic commutation is utilized for this reason it is an electronic engine. This dispenses with the issues related to the brush and the commutator course of action, for illustration, starting and wearing out of the commutator brush course of action, subsequently, making a BLDC rougher as compared to a dc engine.

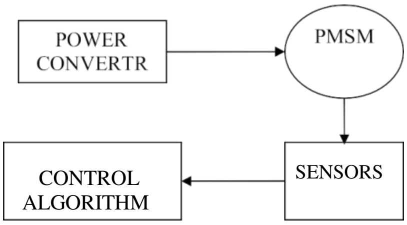
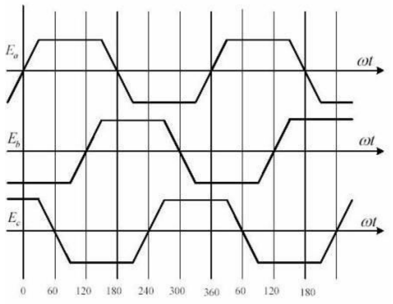


Fig.2.2. Basic block diagram of BLDC motor

The structure of the control calculations decides the sort of brush less dc engine of which there are two primary classes: voltage source- based drives and current source-based drives. Both the voltage source and current source- based drive are utilized with a changeless magnet synchronous machine with either sinusoidal or non-sinusoidal back emf



3.FUZZY LOGIC CONTROL SCHEME

3.1. Introduction to Fuzzy Logic Controller

Among the most effective methods available today for creating complex control systems is fuzzy logic, which has grown quickly. It can be implemented in remarkably simple, inexpensive, and quickly produced controllers because it helps with complex requirements. The number and variety of applications of fuzzy logic have increased dramatically in the last several years. Applications include medical instrumentation, industrial process control, decision-support systems, and consumer goods including cameras, camcorders, washing machines, and microwave ovens. Many tasks involving decision-making and problem-solving are too complicated to be fully grasped statistically.

On the other hand, people who use vague information instead of precise knowledge succeed. The key to fuzzy logic is understanding the relative value of accuracy. Fuzzy logic can be understood in two ways. Fuzzy logic is a logical system that is a restricted application of multi-valued logic. However, fuzzy logic and the theory of fuzzy sets are interchangeable in a broader sense. Lotfi Zadeh first presented fuzzy set theory in 1960. It uses approximations of information and uncertainty to produce judgments, much as approximate reasoning [15].

3.2.Motivations for choosing fuzzy logic controller (FLC)

A Fuzzy logic controller can model nonlinear systems. The plan of ordinary control framework basic is ordinarily based on the scientific demonstrate of plants. If an exact numerical demonstrate is accessible with known parameters, it can be analyzed., for illustration by bode plots or Nyquist plot, and controller can be planned for particular exhibitions. such strategy is time expended.

The fuzzy logic controller has adaptive characteristics. The adaptive characteristics can achieve robust performance in system with uncertainty parameters variation and load disturbances.

Rather than using mathematical formulas to convey operational laws, fuzzy logic uses verbal expressions. Even with intricate mathematical equations, many systems are too complex to adequately model; for this reason, standard methodologies are no longer practical in these systems. Nonetheless, the lexicon of fuzzy logic offers a workable way to characterize the functional features of such a system.

One particular kind of symbolic controller is the fuzzy logic controller. Fig. 3.1 displays the block diagram for the fuzzy logic controller.

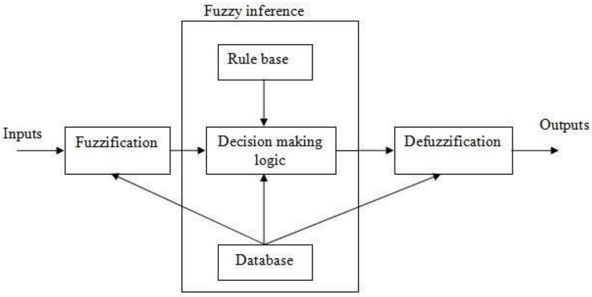


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Fig.3.1 Structure of Fuzzy logic controller

The fuzzy logic controller has three main components

1. Fuzzification
2. Fuzzy inference
3. Defuzzification

3.3.1 Fuzzification

The following functions:

1. Multiple measured crisp inputs first must be mapped into fuzzy membership function this process is called fuzzification.
2. It performs a scale mapping that transfers therange of values of input variables into corresponding universes of discourse.
3. Performs the function of fuzzification that converts input data into suitable linguistic values which may be viewed as labels offuzzy sets.

3.3.2. Fuzzy inference

The technique of utilizing fuzzy logic to formulate the mapping of a given input to an output is known as fuzzy inference. After that, the mapping offers a foundation on which judgments can be formed or trends identified. Two are present.

Mamdani-type and Sugano-type fuzzy inference systems are two varieties that can be used with the Fuzzy Logic Toolbox. The methods used to determine the outputs of these two kinds of inference systems differ slightly. Systems for fuzzy inference have been effectively used in a variety of domains, including computer vision, expert systems, data classification, automatic control, and decision analysis. Fuzzy inference systems are known by many different names due to its multidisciplinary nature: fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, and simply (and ambiguously) fuzzy.

3.3.3 Defuzzification

The output of the inference mechanism is the fuzzy output variables. The fuzzy logic controller must convert its internal fuzzy output variables into crisp values so that the actual system can use these variables. This conversion is called defuzzification. This operation can be carried out in a few different ways. Fuzzy logic control of the BLDC mot**or**

The traditional polarization index (PI) controller was swapped out for the fuzzy logic controller when it came to the speed loop. The fuzzy logic controlled BDCM drive system block diagram is shown in Fig 3.4

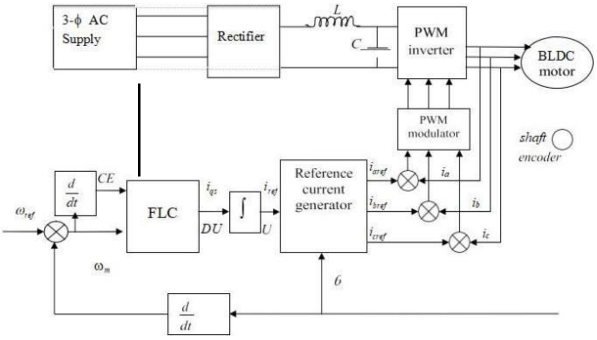


Fig.3.4. Fuzzy speed control block diagram ofthe BLDC motor

The traditional polarization index (PI) controller was swapped out for the fuzzy logic controller when it came to the speed loop. The fuzzy logic controlled BDCM drive system block diagram is shown in Fig 3.4.

The input variable is speed error (E), and the change in speed error (CE) is calculated by the controller with E. The torque component of the reference (Iref), which is obtained at the controller's output by utilizing the change in the reference current, is the output variable.

The functions with a triangle form are selected as the membership functions because of the simplicity and optimum control performance that resulted. Fig. 4.5 displays the membership function for the torque reference current, speed error, and change in speed error. Seven tiers of fuzzy membership function are applied to all variables. The 7 □ 7 rule foundation table utilized by the system is displayed in Table II.

Table 4.1.7×7 Rule base table used

e/ce	NB	NM	NS	ZO	PS	PS	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

in thesystem

The steps for speed controller are as

1.Sampling of the speed signal of the
BLDC. 2.Calculations of the speed error
and the changein speed error.
3.Determination of the fuzzy sets and
membership function for the speed error and
changein speed error.
4.Determination of the control action
accordingto a fuzzy rule.
5.Calculation of the Δi_{as} by center
of areadefuzzification method.
6.Sending the control command to the
system after calculation of Δi_{as}

4.EXPERIMENTAL STUDY

4.1Experimental system

Instep of utilizing an analog PI controller for the proposed drive, an advanced controller was executed on a TMS320LF2407 DSP processor from Texas Rebellious. In spite of the fact that the analog PI controller may have a more noteworthy transfer speed than an advanced PI controller, it is subject to deviation due to the floats in ostensible values of its components. Another reality is that it is much more troublesome to adjust an analog PI controller to changes in the framework parameters, for case, substitution of the engine by other BLDC engine and other components. Foran advanced PI controller, all that needs to be done in arranging to adjust it to a modern framework is to alter the parameters of the controller by reconstructing the DSP

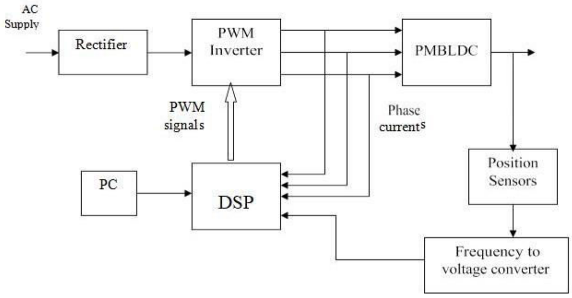


Fig.4.1. A simple structure diagram of an experimental setup

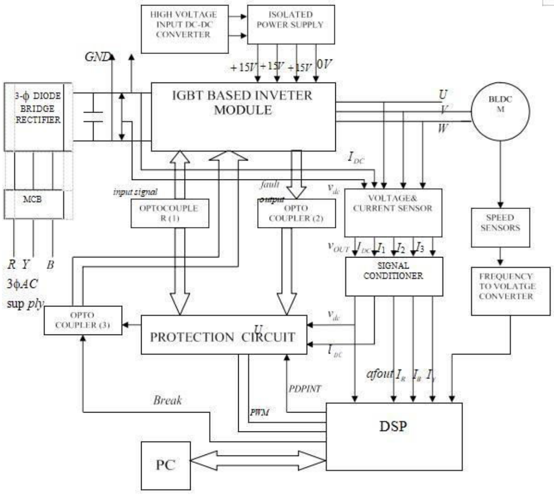


Fig. 4 .2 The overall system block diagram for the testing configuration

These investigations employ the IPM type PEC16DSM01. Its rated voltage is 1200V, the rated current is 25A, the control voltage is 20V and the switching frequency is 20 KHz. The experimental setup block diagram of BLDC motor diagram as shown in Fig.5.12 and it consists of the following systems

1. Intelligent power mo. dule
2.Voltage and current sensor
3.Signal conditioner
4.Protection circuit
5.opt coupler
6.3ϕ diode bridge rectifier
7.Speed sensor
8.Frequency to voltage converter

4.2.1Analog-to-Digital converter

Numerous of the real-world input signals are in the analogy space, though the CPU does all the handling in the advanced space. In arranging that the CPU get the analog space signals for handling, it is fundamental to decipher them into a organize that makes sense to the CPU. This is accomplished by utilizing an Analog-to-Digital converter (ADC) that does the required Interpretation. The analog input signals are buffered utilizing ICs 3403. Each buffer IC comprises of four buffers. The ADC yield flag is given to the assurance areaof the processor.

4.2.2.Digital-to-analog converter

IC AD8582 is used to convert the processor’s digital output to analog. It is a 2 channel DAC IC. The output from the DAC is of low voltage, hence IC TL084 is placed at the output of the DAC to amplify the DAC output.

4.2.3.PWM section

Three different 74LS14 IC numbers are included in the PWM section. The processor's PWM output is high signal by default. In order to prevent shoo through failure, the 74LS14 is supplied to invert the PWM outputs.

HP	2
No. of Poles	4
No. of Phases	3
Type of connection	Star
Vdc	160V
Resistance/Ph	0.7Ω
Flux linkages constant	0.105wb
Self-Inductance	2.72mH
Mutual inductance	1.5mH
Moment of Inertia	0.000284 kg-m/sec2
Damping constant	0.02 N-m/rad/sec

Table.4.1. BLDC motor specification

4.2.4Analog-to-Digital converter

Numerous of the real-world input signals are in the analogy space, though the CPU does all the handling in the advanced space. In arranging that the CPU get the analog space signals for handling, it is fundamental to decipher them into a organize that makes sense to the CPU. This is accomplished by utilizing an Analog-to-Digital converter (ADC) that does the required Interpretation. The analog input signals are buffered utilizing ICs 3403. Each buffer IC comprises of four buffers. The ADC yield flag is given to the assurance area of the processor.

4.3 Overview of the system and softwaredevelopment process

The advancement of the vital computer program required for the proposed speed control BLDC drive. The C dialect is utilized to create the fundamental code for the TMS320LF2407. The Digital-to-Analog converter (DAC) for ease of testing and improvement, a XDS 510 PP emulator unit for meddling the PC, making it conceivable to create code utilizing a PC based environment. The compiler utilized is Code Composer Form 3.12. Real-Time screen, a utility from TI, is included to empower online tuning of different control parameters.

5.RESULTS AND CONCLUSION

5.1.Performance with PID controller

The simulation of speed control characteristics PID speed control is based on the system configuration shown in Fig.3.1. The governing equations of the BDCM are listed in chapter 2. The inverter output terminal voltages are generated according to the PWM switching algorithm.

Using both the fixed gain PI controller and the FLC speed controller, a MATLAB program is created to mimic the PMBLDC drive model [included as annexure1]. The section above contains the equations guiding the drive system model. For the variables Ia, ib, ic, and Te, the Fourth Order Rung-Kutta method was employed as a numerical methodology to obtain the solution of these equations. In this simulation, the speed controller and the current controller's switching logic are employed.

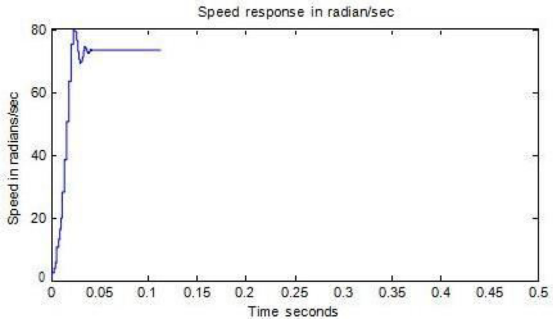


Fig.5.1. Speed responseradians /seconds versus time

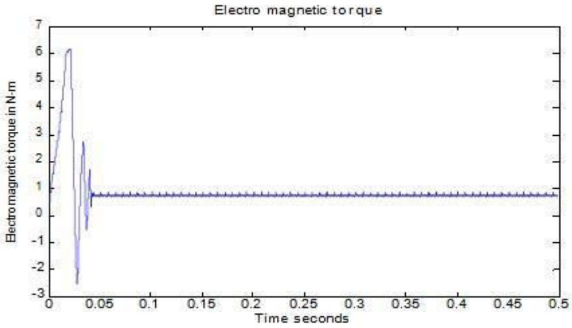
The simulation result for speed reference input of 700 rpm with a load torque of 0.7 N-m are shown on Fig 5.1. The controller gains are KP =0.8, KI = 0.02 and current controller bandwidth is 0.3A. The rotor is standstill at time zero with onset of the speed reference, the speed error, torque reference, and attains maximum value. The current controller forces the current to follow the reference. The fore electromagnetic follows the reference value.

Fig.5.2. Electromagnetic torque developed inN-m

5.2.Performance with FLC

The speed control performance achieved by using the fuzzy logic controller (described in chapter 4) is presented here. The type and characteristics of the FLC we have designed are as follows.

FLC Type=Mamdani. Number of Inputs=2.Num of outputs=1.
Num of Rules=49. AND Method=min.ORMethod=max.
Defuzzification Method= height defuzzification



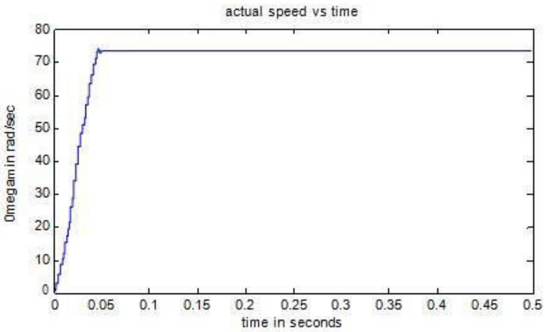


Fig 5.2.1.Speed response radians /seconds versus time

The speed control performance achieved by using the fuzzy logic controller (described in chapter 4) is presented here. The type and characteristics of the FLC we have designed are as follows.

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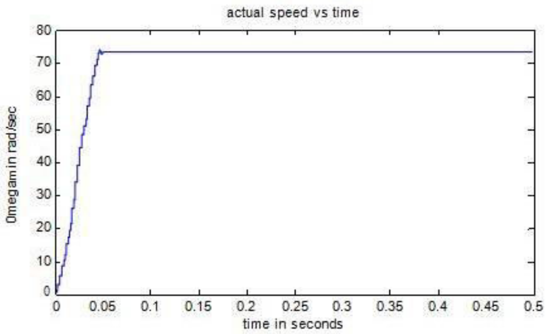

Fig.5.2.2. Speed response radians /secondsversus time

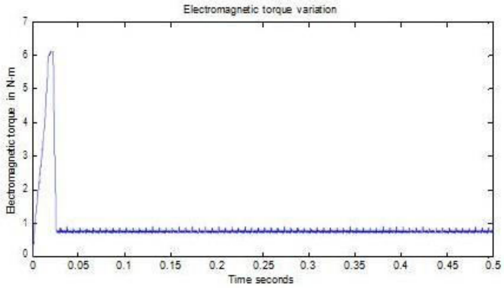

Fig.5.2.3. Electromagnetic torque developed in N-m

5.3. Experimental results

The brushless DC motor speed control experimental setup is depicted in Fig. 5.1. The findings of the experiment and simulation used a load torque of 0.6 N-m and a speed reference input of 1500 rpm. The experimental results are displayed in Figures 5.2.1 and 5.2.2. At time zero, the rotor is in a standstill state as the speed reference, speed error, torque benchmark and reaches its highest value. The current controller forces the current to follow the reference.

5.4.CONCLUSION

The PMBLDC motor drive's speed control is managed by a fuzzy logic controller (FLC), and the study of the fuzzy controller's performance is given. This thesis describes the modeling and simulation of the entire driving system. Performance prediction over a broad variety of operational situations establishes the model's effectiveness. Simulation runs have been used to compare the performance of the fuzzy logic controller with the conventional PI controller, demonstrating the validity and superiority of the fuzzy logic controller for implementing the adjustment of the fuzzy logic controller to reduce the manual tuning time of the classical controller significantly. PI controller, FLC controller, and PMBLDCM drive performance in relation.

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