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The Rapid Growth of Different Controllers for (BLDC) Brushless DC Motor– A Review

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ABSTRACT

This paper presents the different strategies for regulating the speed of BLDC motor with the help of some higher and forward-looking controllers. The BLDC motor is fresh trend in the advanced technical marketing because of its superlative performance. Therefore, to control the speed of motor, some progressive controllers are necessary. In this paper, various control techniques of fuzzy logic are described for brushless dc motor to study speed performance. These various control techniques are designed as a controller for procuring appropriate controlling actions to run the motor.

KEYWORDS: *Brushless dc (BLDC) motor; adaptive fuzzy PID, adaptive neural-fuzzy inference system (ANFIS); fuzzy PID supervised online ANFIS and GA-PSO optimized online ANFIS*

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1. INTRODUCTION

The brushless DC motor has many more advantages in upcoming advanced techniques due to its excellent performance as well as its finest characteristics. The use of brushless DC motor is very beneficial and serviceable in case of electric vehicle applications because of its compact size and shape. To get best performance, motor should be precisely controlled [1]. Hence to provide precisely controlling action, the better controllers are necessary so that the controllers can survive if there is non-linearity or large disturbances occurred. Therefore, artificial intelligent technique is used i.e. fuzzy logic which is widely used for machine controlling task [2][3]. This fuzzy logic controller provides a way of dealing with nonlinearities and imprecision when the system is under the complex situation [4].

In this review paper, Adaptive Fuzzy PID controller, Adaptive Neural-Fuzzy Inference System, Fuzzy PID Supervised Online ANFIS controller and GA-PSO Optimized Online ANFIS controller, these are different control strategies of fuzzy logic techniques which are described. The analysis of these different controllers are categorized into three parameters, they are; maximum peak overshoot (%Mp), rise time (Tr) and settling time(Ts).

2. CONVENTIONALCONTROLLERS

Now days, the 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 advanced technical field, there are many

controllers which have their own traditional languages. By using such controllers, the speed of BLDC motor is controlled. The fig.1 shows the traditional controllers [5].

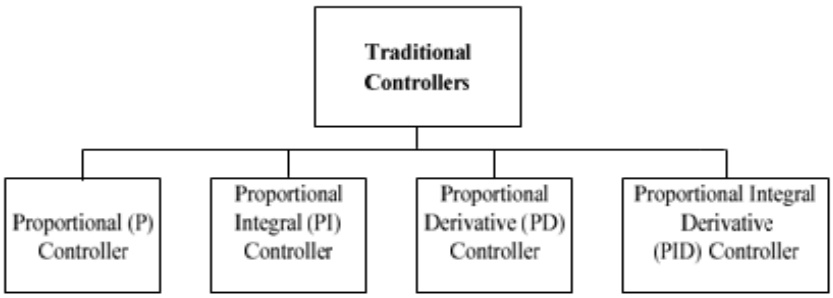

Figure 1: Traditional Controllers

These all combinations of controller designs are used to provide the required control actions to the brushless DC motor. These traditional controllers work on the basis of linearity of system. The mathematical model of system or plant is taken into the account for designing such type of controllers. The performances of these controllers are lagging, if some disturbances or parameter variations are occurred during working platform of system or plant. 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 [6].

3. SOFT COMPUTINGCONTROLLERS

Rapid enlargement is seen in case of soft computing methods. This method consists of various types of learning mechanisms. The technique used in soft computing is coming from human brain for this reason; the executed technique in soft computing method is much closer to the human thinking. This is the most reliable and trust worthy approach to figure out modern controllers consequences. The fig.2 shows different methodology of soft computing to design sharp and vigorous version of controllers.

The fig.2 shows soft computing techniques. Out of these, some important techniques are taken into the account to design sophisticated controllers which are reliable and useful in any operative modes of brushless DC motor. They are Adaptive Fuzzy PID controller, Adaptive Neural-Fuzzy Inference System (ANFIS) controller, Fuzzy PID Supervised Online ANFIS controller and GA-PSO Optimized Online ANFIS controller.

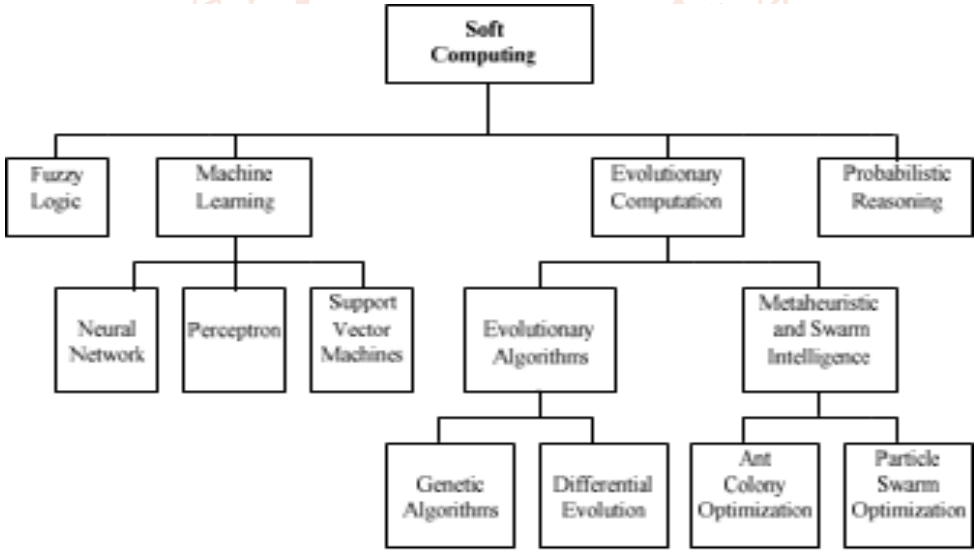

Figure 2: Soft Computing Techniques

The adaptive fuzzy PID controller is adapted for BLDC motor. The adaptive technique is created by a combination of fuzzy logic and PID controller. The adapt control is new approach for new controllers. This adapt control can changeits parameters according to the system parameters. It can give better speed control features when the motor is in working condition with varying load. But the adaptive fuzzy PID controller illustrates the large steady state error during the operating condition[7].

The adaptive neural-fuzzy inference system (ANFIS) controller is designed for non-linear system. This controller is an addition of soft computing techniques i.e. artificial neural network and fuzzy logic controller [12]. Hence this controller is suitable for brushless DC motor. The minimum numbers of rule base of fuzzy logic are sufficient to implement the controlling action of this controller. The limitation of this ANFIS controller is, it can only operate for specific working state or condition. If the changes are made in specific working conditions due to some requirements or some issues, the controller will not deliver the expected performance [8].

The fuzzy PID supervised online ANFIS controller is the recent modified controller which is planned for brushless DC motor. This controller is formed by three different controller's combination (Fuzzy logic, PID controller and ANFIS controller) with very effective supervised learning mechanism. This supervised learning mechanism comes under the soft computing machine learning technique [10]. The fig.3 shows supervised learning system. In offline operation, the structure learning technique requires large amount of data for execution of concept. Also, the parameter learning technique of offline operation takes big time interval delay. Therefore online operation is preferred in this controller [9].

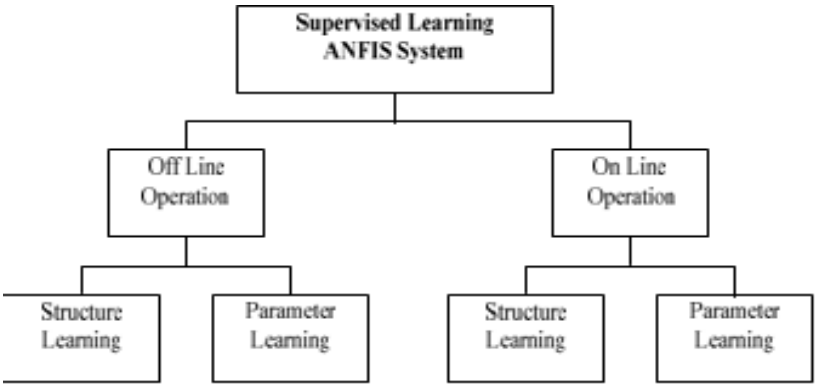

Figure 3: Diagram of Supervised Learning ANFIS System

The GA-PSO optimized online ANFIS controller is new- fashioned controller which is newly prepared for BLDC motor. The learning parameters of online ANFIS are enhanced for speed controlling of BLDC motor by using GA-PSO algorithms. The purpose of genetic algorithms (GA) is, to achieve the desired and best level for existing and upcoming problems. Particle swarm optimization technique (PSO) provides quicker convergence rate. Therefore the hybrid GA- PSO algorithms are executed to achieve optimum results of speed controlling[11].

4. COMPARATIVESTUDY

Comparative study evaluation for Adaptive Fuzzy PID controller, Adaptive Neural-Fuzzy Inference System (ANFIS) controller, Fuzzy PID Supervised Online ANFIS controller and GA-PSO Optimized Online ANFIS controller. This analysis is going through the three aspects named as, maximum peak overshoot (%Mp), rise time (Tr) and settling time(Ts).

A. Adaptive Fuzzy-PID Controller

The adaptive fuzzy-PID controller is able to give better performance of speed regulation when the BLDC motor is in working state with varying load (at lower and higher speed). The table I shows the comparison of fuzzy-PID and adaptive fuzzy-PID controller for 1500 rpm speed under no load condition and with load condition, the settling time of speed response is 0.10 sec which is less than the settling time of speed response for fuzzy-PID controller. Similarly, for 3000 rpm speed under no load and with load condition, the overall results for both fuzzy-PID and adaptive fuzzy-PID controllers are indicating that the adaptive fuzzy-PID controller has better control performance than fuzzy-PID controller.

TABLE I

Ref. No.	Speed	Fuzzy-PID			Adaptive Fuzzy-PID		
		Tr	Ts	%Mp	Tr	Ts	%Mp
[6]	1500 (No Load)	0.0061	0.15	13.13	NR	0.10	NR
	1500 (With Load)	0.0390	0.25	1.37	NR	0.10	NR
	3000 (No Load)	0.0077	0.17	3.60	0.0432	0.15	1.23
	3000 (With Load)	0.0522	0.25	0.42	0.0553	0.20	0.33

The comparison of adaptive fuzzy-PID controller with ANFIS controller is shown in table II. Hence, it is cleared that the speed response settling time for adaptive fuzzy-PID is high as compare to ANFIS controller. According to this observation, the ANFIS controller can deliver better controlling output. The adaptive fuzzy-PID controller illustrates the large steady state error during operating condition whereas the ANFIS controller reduces the issues related with load variations and speed variations by setting minimum numbers of rules and enhances the steady state response.

TABLE II

Speed	Adaptive-Fuzzy-PID	ANFIS
	Ts	Ts
1500 (with load)	0.10	0.0611

B. For Adaptive Neuro-Fuzzy Inference System Controller

The comparison of ANFIS and fuzzy-PID controllers are shown in table III. In this table, three speed conditions are given, 1500 rpm speed (with load), 1000-1500 rpm (increase in speed) and 1500-1000 rpm (decrease in speed). From this table, it is concluded that ANFIS controller has good recovery time in sec. and steady state error inrpm.

TABLE III

Ref. No.	Speed	Fuzzy-PID			ANFIS		
		Tr	Ts	%Mp	Tr	Ts	%Mp
[7]	1500 (With Load)	0.048	0.064	0.4	0.05	0.0611	0.73
		Steady State Error (RPM)	**Recovery Time**		**Steady State Error (RPM)**		**Recovery Time**
	1000-1500 (Increase in speed)	20	0.55		3		0.54
	1500-1000 (Decrease in speed)	10	0.53		2		0.52

C. For Fuzzy-PID Supervised Online ANFIS Controller

Using the ANFIS technique, poor transient response is obtained. The fuzzy-PID supervised online ANFIS controller is more efficient than ANFIS controller. The two conditions are evaluated in this table IV, 1500 rpm speed (noload) and

1500 rpm speed (with load). The readings of rise time, settling time and percentage overshoot of fuzzy-PID-ANFIS controller are less than ANFIS controller.

TABLE IV

Ref. No.	Speed	ANFIS			Fuzzy-PID-ANFIS		
		Tr	Ts	%Mp	Tr	Ts	%Mp
[8]	1500 (No Load)	0.0300	0..0384	1.5789	0.0300	0.036	0.1103
	1500 (With Load)	0.0418	0.0538	0.6351	0.0300	0.036	0.1103

D. For GA-PSO Optimized Fuzzy-PID Online ANFIS Controller

The supervised online ANFIS controller has learning parameters, they are; forgetting factor (λ), learning rate (η) and steepest descent momentum constant (α). These parameters vary when the operating point of BLDC motor is changing. Therefore, it is very essential to vary these learning parameters according to the operating point of BLDC motor. These parameters affect the time domain specifications. The learning parameters of online ANFIS controller are modified by combination of GA-PSO algorithm.

The table V shows that the results of percentage maximum peak overshoot for speed 1500 rpm under no load and with load condition of advanced GA-PSO optimized fuzzy-PID online ANFIS controller is very less as compare to ANFIS controller.

TABLE V

Ref. No.	Speed	ANFIS			GA-PSO-Fuzzy-PID- ANFIS		
		Tr	Ts	%Mp	Tr	Ts	%Mp
[10]	1500 (No Load)	NR	NR	1.5	NR	NR	0
	1500 (With Load)	NR	NR	1	NR	NR	0

5. BENEFITS ANDCHALLENGES

The different controllers are planned for not only speed controlling of motors but also in many fields from where the progressive and liberal ideas are arriving and successfully implementing. The soft computing concept is based on human brain. It combines all various methodologies and creates the hybrid methodology which is very beneficial in many fields such as the wireless communication, consumer appliances field, aircraft, transportation, medical field, data mining etc.

In recent days, the new versions of power conversion technologies are arriving. Hence, switch mode power supply is built in every power electronic devices such as printers, telecommunication systems but it is non-

linear in nature. This non-linearity is needed to be controlled.

These soft computing controller designs have future scope because new advanced ideas are exploring. In future work, there is a challenge for tractable adaptive controller in addition with non-linear design is taking into the consideration for electric vehicles will be designed for optimum performance.

6. CONCLUSION

The review on these four techniques of controller's i.e. adaptive fuzzy PID technique, ANFIS system, fuzzy PID supervised online ANFIS technique and genetic algorithm and particle swarm optimization optimized online ANFIS technique imply that the soft computing controllers are able to control the required speed as compare to other traditional controllers very effectively. Here, the fuzzy logic technique is used for different combinations of controllers have controlled the speed of motor whereas BLDC motor has nonlinear characteristics. Though the motor has tendency of nonlinearity, The GA-PSO-online-ANFIS controller can direct and implement the proper controlling action for any changeable or fluctuating load conditions.

The capability of soft computing controllers is subjected to the sustained ability and own decision making for various upcoming and existing environment of operative plant or system.

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