Direct Torque Control of PMBLDC Motor using Hybrid (GA and Fuzzy logic) Controller

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***Abstract*— This paper deals with the Direct torque control of PMBLDC motor using hybrid controller (Genetic algorithm and fuzzy logic) and to reduce the torque ripple. Though the conventional controllers are commonly used in practice, they have failed to perform satisfactorily under non linear conditions and parameter variations. In the proposed work, a hybrid controller (using genetic algorithm and fuzzy logic controller) is introduced to control the torque and the flux linkage angle of the PMBLDC motor. Torque error and flux linkage angle of the PMBLDC motor is fuzzified and it is auto tuned by GA to improve the dynamic characteristic. Simulation results of the conventional fuzzy logic controller are compared with the hybrid (GA and fuzzy logic) controller and the later is found to be satisfactory with improved performance.**

***Index Terms*— PMBLDC motor, Fuzzy logic control, Direct Torque Control (DTC), Genetic algorithm.**

I. INTRODUCTION

Permanent magnet brushless DC (PMBLDC) motors are extremely used in a variety of industrial applications because of its key features like high efficiency, high power density, and low size etc [1]. One main problem is the torque ripples which deteriorate the performance of PMBLDC motor. To minimize the torque ripple and improve the performance, several torque ripple minimization methods have been proposed [2]. Direct torque control was originally developed for induction machines drive which directly controls the flux linkage and electromagnetic torque of the machine. Direct Torque Control is one method used in variable frequency drives to control the torque of a 3 phase motor [3]. This is possible by estimating the motor magnetic flux and torque based on the measured Voltage and current of the motor. DTC method has some attractive features like fast dynamic response, lesser parameter dependence, does not require rotor position sensors, better dynamic performance than the vector control method, less sensitive to parameter variations, low losses, no co-ordinate transforms are needed, smooth and fast control of torque and flux angle.

Fuzzy logic and Fuzzy set was introduced by Zadeh [4]. In recent years some efforts have been made on the use of fuzzy algorithms for modeling and control of the systems. In a Fuzzy Logic Controller (FLC), the control parameters of the systems are adjusted by a fuzzy rule based system. The advantages of FLC over the other conventional systems are, the former does not need a detailed mathematical model; it can be applied to any complex and non linear problems. The application of a FLC in the field of electric drives especially in switched reluctance motor, induction motor and PMBLDC motors have increased in recent times [5] [6]. However the conventional FLC with multiple inputs having multiple membership functions and multiple rules have been facing some disadvantages due to its high computational burden [7]. To overcome the above difficulties GA based FLC has been implemented in the proposed work.

II. FUZZY LOGIC BASED DTC

Fuzzy logic controller converts a linguistic control strategy based on expert knowledge in to automatic control strategy. The components of FLC are fuzzification, inference (knowledge base & decision making logic) and defuzzification. Fuzzification converts the input data in to suitable linguistic values. Knowledge base consists of database and rule base. Data base provides necessary definitions that are used to define linguistic control rules with syntax such as,

IF < fuzzy proposition > THEN < fuzzy proposition >

The IF part is called the antecedent and the then part is consequent. Decision making logic infers a system of rules through the fuzzy operators, namely ‘AND’ and ‘OR’ and generates a single truth value which determines the outcome of rules. The outcome of decision making logic is the inferred fuzzy control action. Defuzzification yields a crisp, non fuzzy control action from an inferred control action. The centre of area method has been used for the defuzzification. Investigation of sensor less direct torque control of PMBLDC motor using fuzzy logic

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controller has been successfully done [8]. However our proposed work aims at implementation of GA based fuzzy logic controller for the Direct Torque Control of permanent magnet brushless DC motor.

In our proposed work, Seven triangular fuzzy sets have been used to partition the input and output spaces: negative large (NL), negative medium (NM), negative small (NS), zero (ZE), positive small (PS), positive medium (PM), positive large (PL).the rule set then contains forty nine (7x7) rules to account for every possible combination of the input fuzzy sets. The rules are of the form, IF (x is {NL, NM, NS, ZE, PS, PM, PL}) and (v is {NL, NM, NS, ZE, PS, PM, PL}) THEN {output}, where output is one of the fuzzy sets used to partition the outer space. The two input space uses a total of fourteen triangles, so the string to represent a given rule set and membership function combination would have forty nine bits as shown in Fig. 1 and Table I. No additional bits are needed for the output triangles because their base length is fixed.

TABLE I
RULE BASE FOR DTC SCHEME

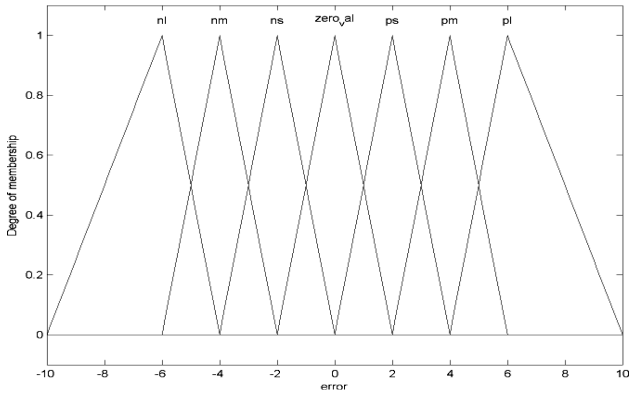
e(u) / ce(u)	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

III. GENETIC ALGORITHM(GA)

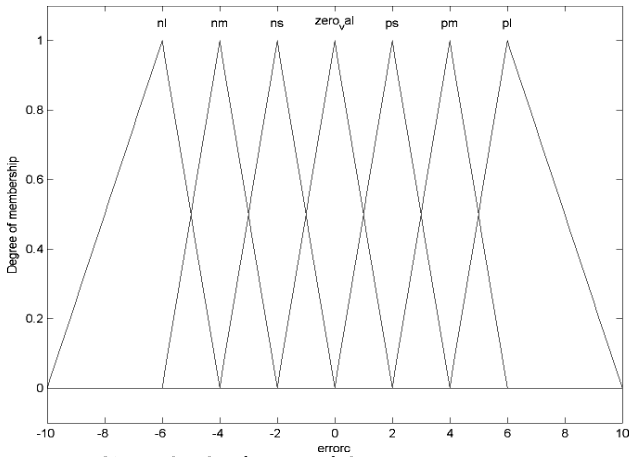
Genetic algorithms are based on the theory of natural selection and work on generating a set of random solutions and making them compete in an arena where only the fittest survive. Each solution in the set is equivalent to a chromosome. A set of such solutions form a population. The algorithm then uses three basic genetic operators viz.

a. Reproduction
b. Cross over
c. Mutation.

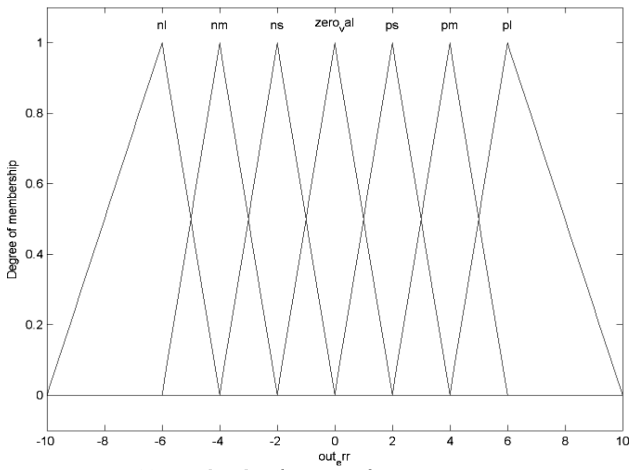
Together with a fitness function to evolve a new population or the next generation. Starting from a random set of solutions the algorithm uses these operators and the fitness function to guide its search for the optimal solution. The genetic operators copy the mechanisms based on the principles of human evolution [9]. The basis for the software used in this paper is the Simple Genetic Algorithm (SGA) developed by Goldberg as shown in Fig. 2. The SGA program allows the user to define the values for population size, maximum number of generations, probability of crossover, and probability of mutation. In order to select the individuals for the next generation, tournament selection was used instead of SGA's roulette wheel selection. In tournament selection, two or more members of the population are selected at random and their fitness is compared. The member with the higher fitness advances to the next generation.



(a) Membership function of torque error



(b) Membership function of change in torque error



(c) Membership function of output torque

Figure. 1. Membership functions of fuzzy controller

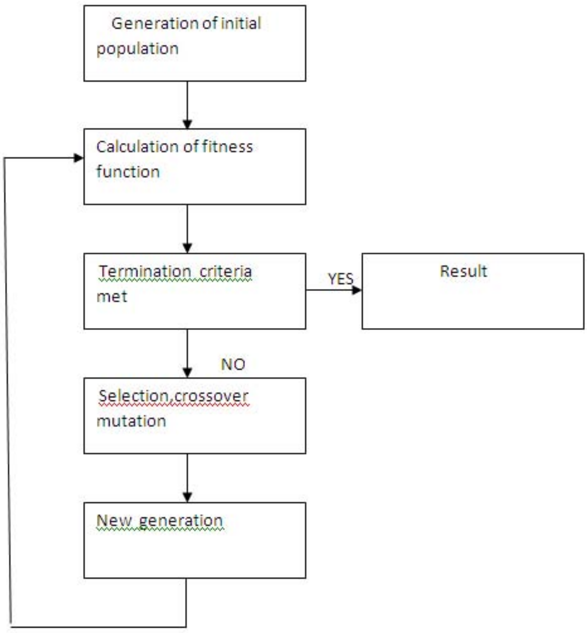


Figure. 2. Flowchart of a Simple Genetic Algorithm

The basic block diagram of the proposed GA based FLC is shown in Fig. 3. And GA parameters in table II It consists of a voltage and current measurement block from where the measured Dc bus voltage and current are given to the torque and flux calculator and the abc variables are transformed to dq variables. The torque and flux angle are the two inputs given to the fuzzy logic controller where it is fuzzified and given to the GA for optimization. The optimized values are defuzzified and again transformed to abc variables and the same is given to the switching circuit.

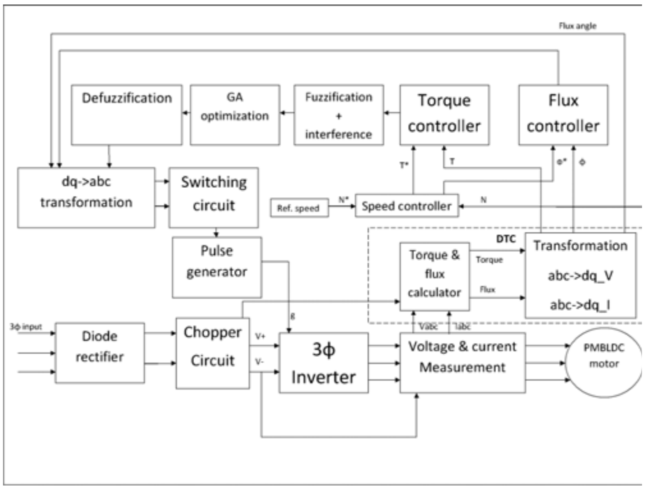


Figure. 3 Basic block diagram of the proposed DTC scheme

The simple genetic algorithm uses binary strings to encode the parameters which are to be optimized. While this method could also be used in the determination of fuzzy controller design, a more representative method was chosen. The application of genetic algorithm to fuzzy controllers holds a great deal of promise in overcoming two of the major problems in fuzzy controller design, design time and design optimality [10]. A GA's robustness enables it to cover a complex search in a relatively short period of time while ensuring an optimal or a near optimal solution. Because of this capability GA's are a natural match for fuzzy controllers.

TABLE II
PARAMETERS OF GENETIC ALGORITHM

GA parameters	Values
Population crossover	0.8
Population mutation	0.03
Generation	20
Maximum iteration	50

IV. SIMULATION RESULTS

To verify the applicability of the proposed DTC scheme using the hybrid (GA and fuzzy logic) controllers for the PMBLDC motor, simulations were carried out using Mat lab. Fig. 4 and 5 shows the performance comparison of the conventional Fuzzy controller and the proposed method using GA based Fuzzy Logic controller for DTC. Initially DTC scheme using conventional controller was analyzed fuzzy logic controller was developed and the performance were compared with the proposed hybrid (GA and fuzzy logic) controller, and the later has an improved performance than the conventional fuzzy logic controller overcoming the drawbacks of the conventional controller.

V. CONCLUSION

The proposed hybrid (GA and Fuzzy logic) Controller has been successfully implemented for the DTC of PMBLDC motor and its validity has been verified with simulated results. In order to prove the superiority of the proposed controller, a performance comparison with conventional FLC has been provided. results demonstrated that torque ripple is almost eliminated. The unique feature of this paper is that GA based FLC is very simple with lesser number of membership function and rules. Efforts have been devoted to develop methods to reduce the time spent on optimizing the choice of controller parameter.

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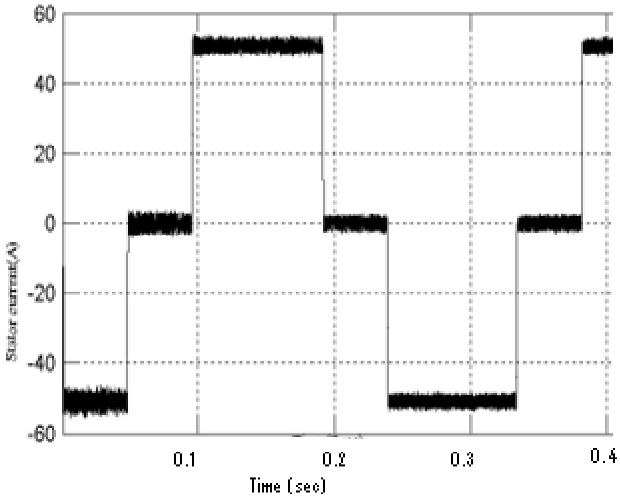
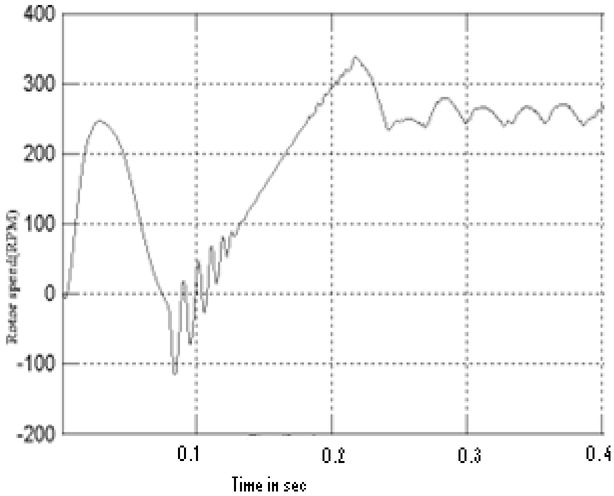
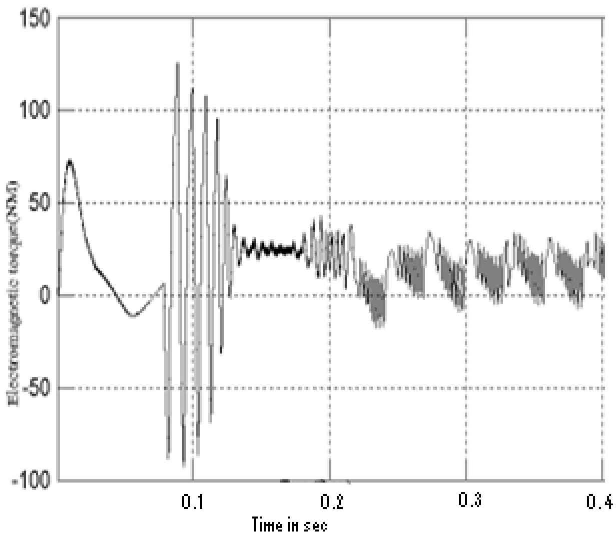


(a) Stator current

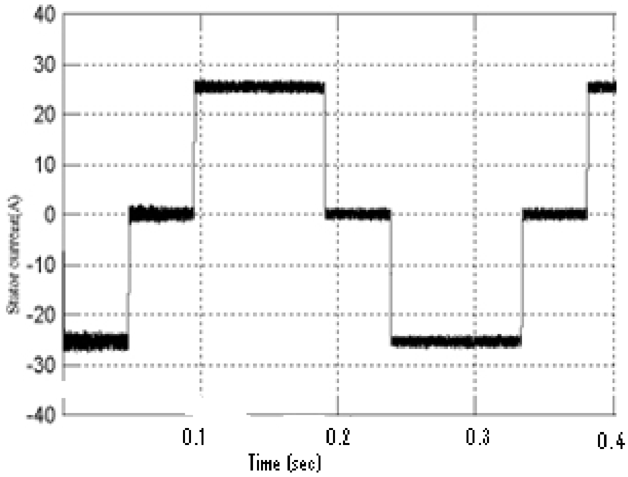


(b) Rotor speed

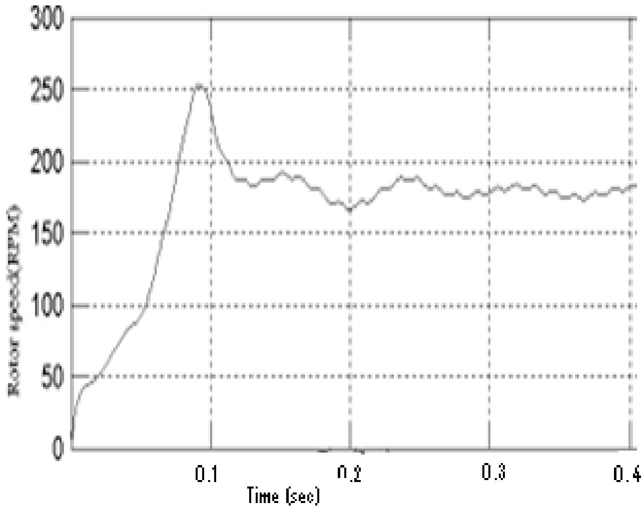


(c) Electromagnetic torque

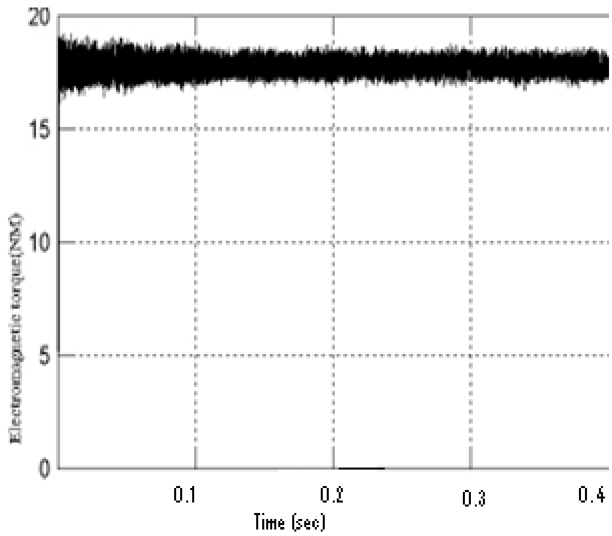
Figure.4 Simulated performance with conventional Fuzzy logic controller



(a) Stator current



(b) Rotor speed



(c) Electromagnetic torque

Figure.5 Simulated performance of the proposed GA based Fuzzy logic controller

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