Speed Control of Induction Motor using Fuzzy PI and Optimized using GA

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Abstract—**In recent years, the field oriented control of induction motor drive is widely used in high performance drive system. Induction motor has many advantages like it is very simple. It has sufficiently high efficiency.. Linear Proportional –Integral (PI) control is not a well established control method in motor drive because of the nonlinearity of induction motor. Whereas fuzzy logic control has the capability to control nonlinear, uncertain systems even in the case where no mathematical model is available for the control system. Fuzzy Logic Control(FLC) is introduced in the system for keeping the motor speed to be constant when the load varies. GA is a stochastic global adaptive search optimization technique based on the mechanisms of natural selection. Recently, GA has been recognized as an effective and efficient technique to solve optimization problems. Finally this controller can be optimized using a Genetic Algorithm Technique. When compared to Fuzzy PI controller Genetic Algorithm produces better performance.**

Keywords: **Induction motor ,Fuzzy PI controller, Genetic Algorithm**

I. INTRODUCTION

Induction motors are used in many applications such as HVAC (heating, ventilation and air-conditioning), Industrial drives (motion control, robotics), Automotive control (electric vehicles), etc[1]. The standard fuzzy logic controller, which has the error and the change in the error as inputs and the control signal or its change as an output, can not react to changes in the operating point. The fuzzy controller needs more information to compensate nonlinearities when the operation conditions change[2]. Recently, Fuzzy logic control has found many applications in the past decade. This is so largely because fuzzy logic control has the capability to control non linear, uncertain systems even in the case where no mathematical model is available for the controlled systems[3]. Disadvantage of the fuzzy logic controllers is the lack of systematic, effective and useful design methods, which can use a prior-combining them together. In this approach, the fuzzy logic can change the controller parameters even if the dynamics is not changed[4]. GA is a stochastic global adaptive search optimization technique based on the mechanisms of natural selection. Recently, GA has been recognized as an effective and efficient technique to solve optimization problems[5,6]. Finally this controller can be optimized using a Genetic Algorithm Technique. When compared to Fuzzy PI controller Genetic Algorithm produces better performance.

II. FUZZY LOGIC CONTROLLER

Fuzzy Logic control (FLC) has proven effective for complex, non-linear and imprecisely defined processes for which standard model based control techniques are impractical or impossible. The complete block diagram of the fuzzy logic controller is shown and The function of each block and its realization is explained below.

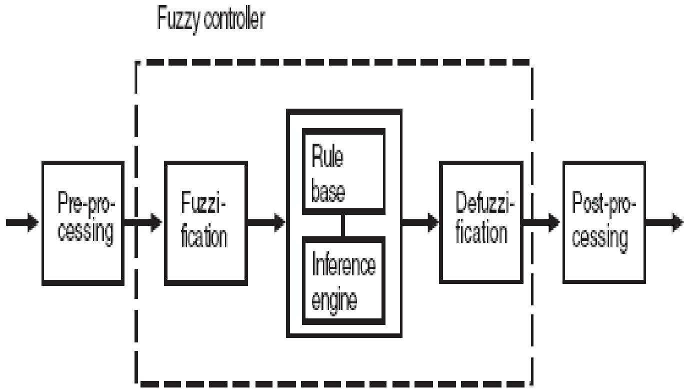


Fig.1.General Fuzzy Block Diagram

A) CONFIGURATION OF FLC:

It comprises of four principal components:

- A fuzzification interface
- A knowledge base
- A decision-making logic and
- A defuzzification interface.

B) FUZZIFICATION

Fuzzification interface involves the following functions.

(a) Measures the values of input variable.

(b) Performs the function of fuzzification that converts input data into suitable linguistic values

C) KNOWLEDGE BASE

Knowledge base consist data base and a linguistic control rule base.

(a) The database provides necessary definitions, which are used to define linguistic control rules.

(b) The rule base characterized the control goals and control policy of the domain experts by means of a set of linguistic control rules.

D) DECISION MAKING

The decision-making logic is the kernel of an FLC. It has the capability of simulating human decision-making based on fuzzy concepts and of inferring fuzzy control actions employing fuzzy implication and the rules of inference in fuzzy logic.

E) DEFUZZICATION

Defuzzification interface performs the following functions.

(a) A scale mapping, which converts the range of values of output variables into corresponding universe of discourse.

(b) Defuzzification, which yields a non-fuzzy control action from an inferred fuzzy control action.

F) RULES CREATION AND INFERENCE:

- Expert experience and control engineering knowledge.
- Operator’s control actions.
- Learning from the training examples.

In this thesis the fuzzy rules are derived by learning from the training examples. The general form of the fuzzy control rules in this case is

III. DESIGN OF FUZZY PI CONTROLLR:

The basic block diagram of a PI type FLC for Induction motor speed control is shown . It is known that a FLC consists of the fuzzification process, the knowledge base and the defuzzification process.

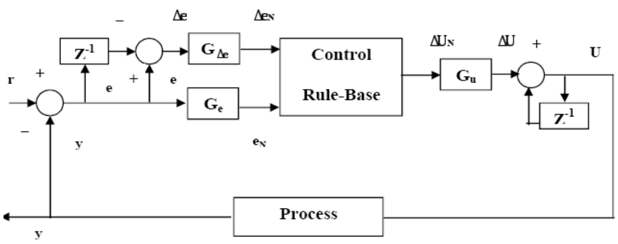


Fig.2 Block diagram of Fuzzy PI Controller

The FLC has two inputs, the error e(k) and change of error Δe(k), which are defined by $e(k) = r(k) - y(k)$, $\Delta e(k) = e(k) - e(k-1)$, where r and y denote the applied set point input and plant output, respectively. Indices k and k−1 indicate the present state and the previous state of the system, respectively. The output of the FLC is the incremental change in the control signal Δu(k).The controller has two input variables and one output variable.

The input and output variables of fuzzy PI controller can be defined as:

$$E(k) = e(k).Ge \quad \text{....(1)}$$

$$CE(k) = ce(k).Gce \quad \text{....(2)}$$

$$\triangle i(k) = \triangle I(k).G\triangle i \quad \text{....(3)}$$

where e(k) is the error between reference speed and rotor speed, ce(k) is the change of error in speed, I(k) is the output of the fuzzy logic controller, and Ge, Gce and GΔi are scaling factors.

If *e* is *E* and Δ*e* is Δ*E*, then Δ*u* is Δ

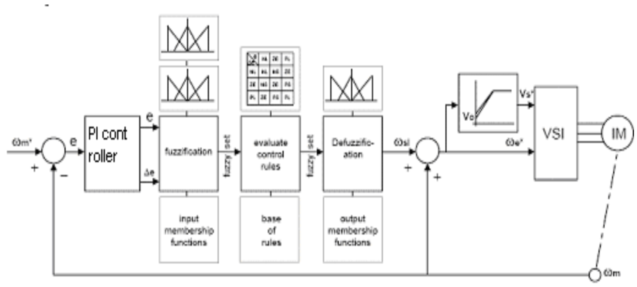
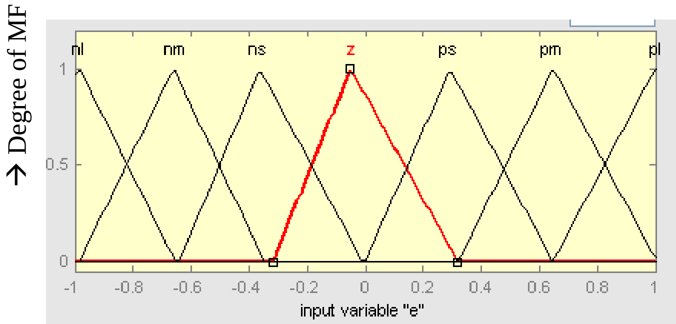
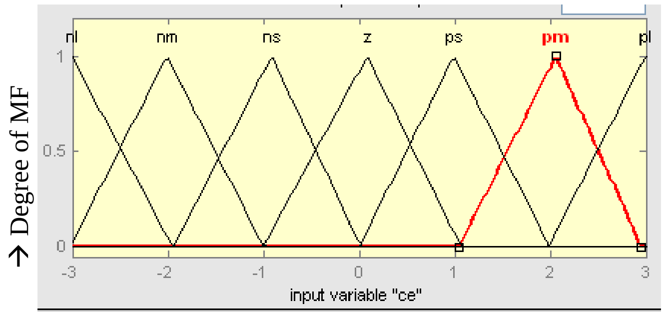


Fig.3 Speed Control of Induction Motor using Fuzzy PI

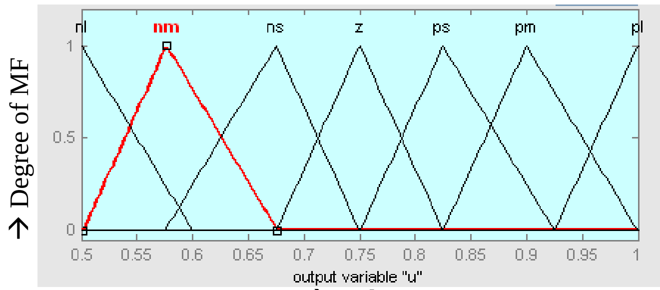
A fuzzy logic controller is proposed to control the speed of the motor to be constant when the load varies. The speed error e and the change of speed error are processed through the fuzzy logic controller whose output is the voltage command. Current error is usually processed by current regulator to produce a control frequency. [7]



→ Speed Error
(a)



→ Change in Speed Error
(b)



→ Voltage
(c)

Fig.4 Membership functions

(a) MF for speed error (b) MF for change in speed error
(c) MF for voltage

TABLE 1 RULE BASE

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

IV. GENETIC ALGORITHM:

Genetic algorithms are perhaps the most commonly used EA for solving optimization problems. The natural phenomenon which forms the basis of GA is the concept of survival of the fittest. GAs were first suggested by John Holland and his colleagues in 1975. The main operators of GA are Selection, Reproduction and Mutation. GAs work with a population of solutions called chromosomes. The fitness of each chromosome is determined by evaluating it against an objective function. The chromosomes then exchange information through crossover or mutation. This methodology is a derivative free optimization technique based on the concept of natural selection and evolution processes. The basic element processed by a GA is a string formed by concatenating substrings, each of which is a binary coding of a parameter. Each string represents a point in the search space.GA is a stochastic global adaptive search optimization technique based on the mechanisms of natural selection. Recently, GA has been recognized as an effective and efficient technique to solve optimization problems. Compared with other optimization techniques, such as simulating annealing and random search method techniques, GA is superior in avoiding local minima which is a common aspect of nonlinear systems. Furthermore, GA is a derivative-free optimization technique which makes it more attractive for applications that involve non smooth or noisy signals. GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem which performance is evaluated by a fitness function. Basically, GA consists of three main stages: Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops when reaching individuals that represent the optimum solution to the problem.

The algorithm differs substantially from more traditional search and optimization methods as follows.

1) A GA searches a population of points in parallel instead of searching for a single point.
2) A GA does not require derivative information or other auxiliary knowledge; only the objective function and corresponding fitness levels influence the directions of search.
3) A GA uses probabilistic transition rules instead of deterministic rules.
4) The nature of the function being optimized is immaterial: both unimodal and multimodal functions can be dealt with successfully. The parallel search capability of a GA avoids the iterations being trapped in local optimum points.

The Selection, Crossover and Mutation are the main operations of GA

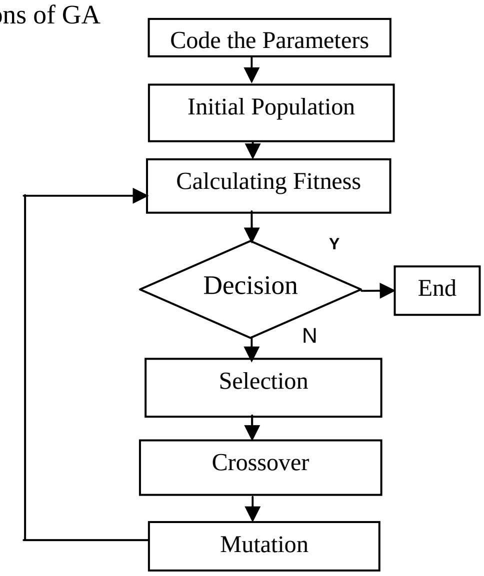


Fig.5 Flowchart of Genetic Algorithm

1) Population Representation of the Natural Parameter: The five diagonal elements of the matrix G' , five diagonal elements of covariance matrix Q , and two diagonal elements of covariance matrix R are coded into a long real-valued string, known as a chromosome.

2) Initial Generation: The GA begins by randomly generating an initial population of the long real-valued strings. Selection directs the search of Gas toward the best individual. In the process, strings with high fitness receive multiple copies in the next generation while strings with low fitness receive fewer copies or even none at all.

3) Fitness Evaluation: In the current generation, each of the strings is decoded back to the corresponding diagonal elements of the three matrices, , and . Then, these diagonal elements from each string are separately sent to the speed estimator of the induction motor drive to yield the objective function (which is the mean squared error of the estimated speed). Finally, these strings are ranked according to the value of the objective function by a linear ranking method.

4) Reproduction: Reproduction is a process by which parent structures are selected to form new offspring. In this paper, the stochastic universal sampling method is employed.

5) Recombination (Crossover): The single-point recombination method is used to exchange the information between two chromosomes. Crossover can cause to exchange the property of any two chromosomes via random decision in the mating pool and provide a mechanism to product and match the desirable qualities through the crossover..

6) Mutation: The Breeder Genetic Algorithm is used to implement the mutation operator for the real-coded GA, which uses a nonlinear term for the distribution of the range of mutation applied to gene values. This mutation algorithm is able to generate most points in the hypercube defined by the variables of the individual and range of the mutation. By biasing mutation toward smaller changes in gene values, the mutation can be used in conjunction with recombination as a foreground search process. Mutation is a random alternation of a bit in the string assists in keeping delivery in the population.

7) Iteration: The real-coded GA runs iteratively repeating the procedures 3)–7 until a population convergence condition is met or the maximum number of iterations is reached.

V. RESULTS AND DISCUSSION:

To evaluate the performance of the system, a series of measurements has been accomplished. Figure. 6 as shown performance of the fuzzy logic controller with a fuzzy tuning rule based on Reference speed of 1200rpm with no load torque. Figure. 7 as shown performance of the fuzzy logic controller with a fuzzy tuning rule based on Reference speed of 1200rpm with load torque. Figure 8 is the optimized result of genetic algorithm.

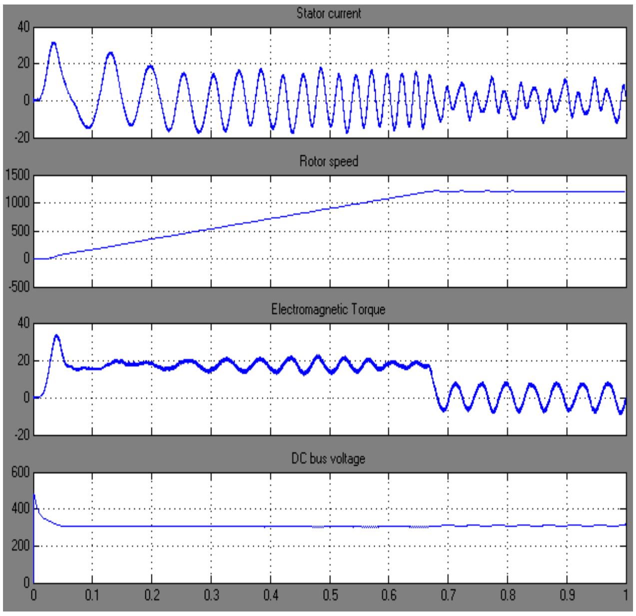


Fig.6 Speed of 1200rpm with no load torque

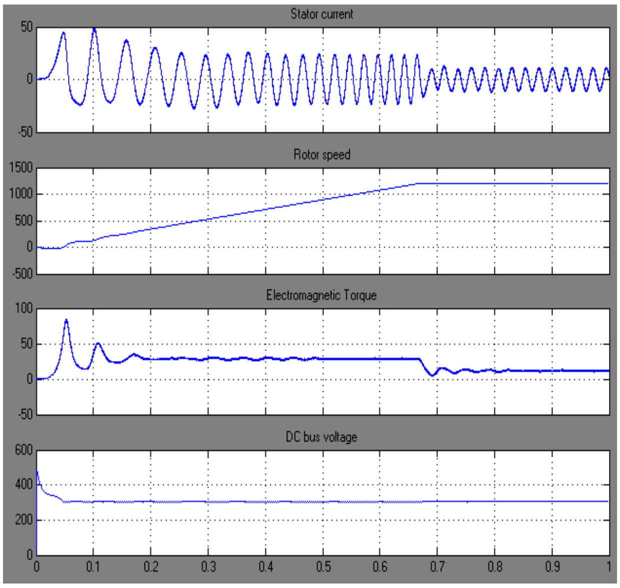


Fig.7 Speed of 1200rpm with load torque

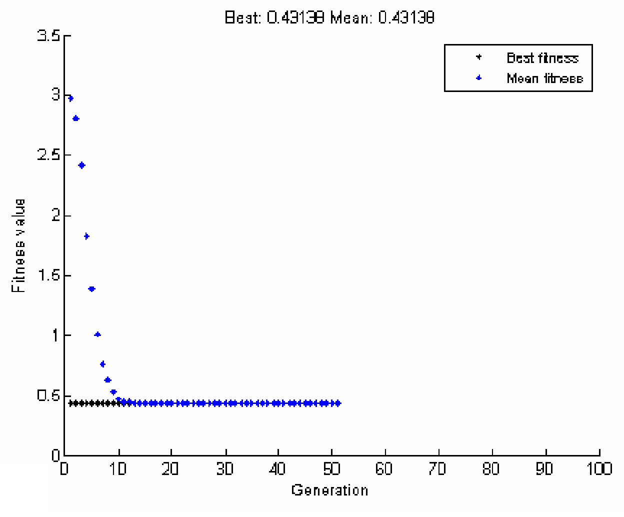


Fig.8 Optimized result of genetic algorithm

VI. CONCLUSION

This paper presents simulation results of fuzzy logic control for speed control of induction motor and then it is optimized using genetic algorithm. In fuzzy control it is not necessary to change the control parameters as the reference speed changes, however with the classical PI controller this does not happens. With results obtained from simulation, it is clear that for the same operation condition the induction motor speed control using fuzzy logic technique had better performance than the PI controller, mainly when the motor was working at lower speeds. In addition, the motor speed to be constant when the load varies. Finally this controller can be optimized using a Genetic Algorithm Technique.

When compared to Fuzzy PI controller Genetic Algorithm produces better performance.

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