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A Genetic Algorithm Based Neuro Fuzzy Controller for the Speed Control of Induction Motor

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Abstract: In this paper a genetic algorithm based self-tuned Neuro fuzzy controller (NFC) for the speed control of an induction motor drive (IMD) is presented. The normalization parameters and the membership functions of fuzzy controller were translated into binary bit strings which are primitive by the genetic algorithm (GA) in order to be optimized for the fitness (or) objective function. In the proposed NFC system, a Fuzzy logic and Artificial Neural Network (ANN) structure based on Genetic Algorithm scheme is used.Speed error is given as input to the proposed NFC unlike conventional NFCs which employ both speed error and its derivative speed error as inputs of NFC. A genetic algorithm based NFC controller for an indirect vector control of induction motor is simulated in order to observe the validity or reliability of the proposed NFC method. The simulation results shows a very important improvement in shortening development time and system performance in the proposed NFC over a conventional NFC. In the practical applications the proposed NFC based Genetic Algorithm has less computational burden and it was easier to implement in the Simulink. Using MATLAB/SIMULINK software the effectiveness of the proposed NFC based induction motor drive is tested at various operating conditions.

KEY WORDS: Indirect Field Oriented Control,Proportional-Integral (PI) control, self-tuning, Neuro - fuzzy Control, Back propagation (BP), Genetic algorithm.

I.INTRODUCTION

Due to theirsimple and strong constructionInduction Motors occupy virtually 92% of the industrial motor drives among the various ac motors. But due to their non-linear behaviour and the parameters of the IM the control of Induction Motor is very troublesome with the different operating conditions andchooses the best one for Induction Motor control of Artificial Intelligent Controllers (AIC). This is because, as compared to the conventional NFC, PI and their adaptive network versions AIC showsmany advantages. Researchers have been working to apply Artificial Intelligent Controllers for IMD over the few decades [1]-[5]. Self-learning (or) self-organising control techniques using expert systems, Intelligent, artificial intelligence, fuzzy logic, neural networks, hybrid networks have recently been recognized as the important tools forimproving the performance of the power electronic based drive systems in the industrial sector applications. Combinations of this artificial intelligent controllers with the adaptive controllers appears today as the most promising research area in the practical sector and also in control of power electronic drives. In this circumstances,the fuzzy concepts paired with Artificial Neural Networks (ANN) based on genetic algorithm plays a very crucial role in developing the controller of the plant.In many cases, it is necessary to discover rules governing their actions for automatic control by observe human experts or may be experienced operators of the plants[6]. A fuzzy logic controller which was used for the speed controller of induction motor drive has various asymmetric membership functions which need much more manual adjustment by trial and error if optimise accomplishment is wanted [7]-[13]. On another hand, it was extremely difficult to create a serial training data for ANN that could handle all the operating modes of the controller. The Genetic based Neuro Fuzzy Controllers which overcome the drawbacks of Fuzzy Logic Controllers and ANN controllers and they have been utilized by the researchers over the last few decades for the motor drive applications.Genetic algorithms (GAs) were introduced as an efficient optimization technique [14]-[15]. The consequence of Genetic Algorithm to various control system problem techniques havebeen proved the efficiency of Genetic Algorithms as a method for control design technique. To include Genetic algorithms into NFC design adds an intelligent technique to the controllers and reduces the timeutilized in the design process of the controller.

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Design of a NFC using Genetic Algorithm and demonstrates its operative behaviour for the performance advancement of the IMDis presented. Various membership functions like triangular, trapezoidal and linear membership functions were defined to reflect the actions of the control technique rules.In order to develop the NFC a new fuzzy self-tuning parameter is introduced to resolute not only the control rules, but also the best location for each rule of NFC. Genetic Algorithm is usedin order to search for desirable settings of the control parameters of the IM drives. By using MATLAB the simulation results shows that the proposed NFC controller increases the performance of the induction motor which was studied over the various range of operating conditions.In thepresent paper, to reduce the settling time of the responses and make the speed of response very high a sincere attempt was developed by developing an efficient controller called Genetic based NFC control strategy.

II. MOTOR DYNAMICS AND CONTROL STRUCTURE

2.1Induction Motor Modelling

A mathematical model is needed in order to control the power electronic drive system. This mathematical model is further required to design various type of controllers to control the process of the system. In this section, the mathematical modelling of the squirrel cage induction motor(SCIM) is presented. The mathematical model of the SCIM system consists of field oriented control of induction motor, hysteresis current controller, PWM voltage source inverter.

The mathematical modelling ispresented in (1)-(4) forthe three-phase star-connected SCIM in a -synchronously rotating reference frame.

= (1)

= + + (2)

=(-) (3)

= (4)

Where

and are the direct and quadrature-axis stator voltages

and are the direct and quadrature-axis stator currents

and are direct and quadrature-axis rotor currents

and are the stator and rotor resistances per phase

, are the self and mutual inductances of the stator and rotor

is speed of the rotating magnetic field

is rotor speed of IM

P is number of poles

is differential operator (*d/dt*)

is the load torque

is the rotor inertia of IM

is rotor damping coefficient

and is rotor position of IMD

The direct and quadrature axis stator voltages and currents were related to the 3-phase representations by formula (5) where x represents voltage or current.

=(5)

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This induction motors model is further progressed to design a adaptive controller using Genetic Algorithm in the next section.

2.2Control Structure

Maintain the magnetizing current at a constant rebuked value by settling is the main feature of the indirect field-oriented controller. Thus torque-yielding current component can be adjusted according to the torque demand.The mathematical equations can be written as

= (6)

= (7)

= (8)

Where

is slip speed and

is direct axis rotor flux linkage.

Equations (1) – (8) are used to simulate the total drive. The block diagram of the indirect FOC of induction motor based on proposed NFC is shown in Fig.1. The configuration of the total drive consists of an induction motor fed by a current controlled VSI. In order to produce the reference torque the normalised speed error was processed by the Neuro Fuzzy Controller and the commanded current is calculated as follows from (9):

=(n) (9)

Where the currents and were transformed into , and by inversePark's transformation in the vector rotation block. Later the corresponding actual currents , and are then compared with the phase command currents , and to createthe pulse width-modulation (PWM) logicsignals, which were used to trigger the power semiconductorswitches of the three-phase inverter. To run the motor the inverter produces theactual voltages. Genetic Algorithm (GA) was used to efficient controller parameters in every closed loop avector control scheme at every operating condition. In order to ensurezero steady state error, minimum speed deviation, and settling time a performance index is developed in an optimal procedure of the genetic algorithm.

III. NEURO-FUZZY CONTROLLER DESIGN

The proposed Neuro Fuzzy Controllerconsists of 4-layer artificial neural network (ANN) structure and fuzzy logic with a learning algorithm for the neural network is shown in fig.2. In order to closely match the desired performance of the systemthe learning algorithm simplifies the Neuro Fuzzy Controller. The perceptible discussions on various layers of the Neuro Fuzzy Controller are shown below.

Input Layer:

Thestandard speed error is given as input for the NFC, which is given by:

= * 100% (10)

Where is the measured speed, is the command speed, *I* denotes the first layer.

Fuzzification (second) Layer:

In the proposed Neuro Fuzzy Controller, triangular linear and trapezoidal functions are chosen as the membership functions. To determine the fuzzy number for the input layer membership functions like triangular, linear and trapezoidal were based on fuzzy set is used..

Rule Layer (third) Layer:

Each rule in this layer performs the pre-condition matching of the fuzzy set rules. Because there is only single input in the input layer no "AND" logic is never needed in the rule layer. Every node in this layer determines the weights of fuzzy layer which were standardized. The equations in the rule layer were named as:

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(11)

Where is input of the third layer and the output of second layer is same as input of third layer.

De-fuzzification (fourth) layer:

Here the centre of gravity method was used to reckon or enumerate the output of NFC. This layer was also called as output layer where it sums up the inputs which were coming from the layer 3 and changes the fuzzy classification results into a crisp set values. The node equation was named as:

y = (12)

Where is the input of the fourth layer and the output of third layer is same as input of fourth layer.

The performance of NFC is investigated using Genetic Algorithm for reducing the computational burden of proposed Neuro Fuzzy Controller.

IV. GENETIC ALGORITHM (GA)

Gold-berg stipulatesbroadly give the brief summary and introduction to Genetic Algorithm.

The Genetic Algorithm owe their occurrence to the ideas taken from the study of evolutionary and biological processes furnish or to empower a species to develop over numerous generation techniques which were better suited to the environment.In system identification, design and real timeimplementation and understanding Genetic Algorithm have been proven most powerful [10].

Genetic Algorithm concepts can be adapted into the various formsthat are suitable for the computer implementation.

1) To developthe initial random population consists of individuals whose characteristics were coded by the string of 0's and 1'sthe initialization process is taken up.
2) The Elitism given a objective function (i.e., fitness function)and calculate a fitness function value for each string within the population based on a suitable performance criterion.
3) Based on a probability basischoose pairs of individuals to bread offspring strings, where individuals with a higher fitness value will be more selected than those with a lower fitness value in the Reproduction.
4) By dividing the binary coding of each parent into two or more segments and then the Crossover combines to give a new offspring string that has inherited part of its coding from each parent.
5) With a low probabilitythe Mutation inverse bits is coded.
6) Stop when an allowable generation is attained or search goal is achieved, otherwise go to step ii).

V. GA BASED CONTROLLER PARAMETERS

In Fig.1, the proposed speed controller is given as input to the fuzzy controller where the current command is made by control parameters was acquired by the Genetic Algorithm and given as input to the indirect vector field oriented control of induction motor. For speed error,an individual bit length of 72 bit which shows 8 bit normalization factors and 8 bit normalization factor for speed error derivative, 8 bit de-normalisation factor for output and 48 bit membership functions.

Table 1 shows parameter of Genetic Algorithm used in this paper

Possibility over Cross-over	0.845
Possibility over Mutation	0.0082
Number of Generations	100
Individual Generations	20
Length of Generator	72bit

The equation of Genetic Algorithm which was based ondifferent strings to NFC controller is given by

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$P(k) = cp(k) + gap(k)$ (13)

Where *gap(k)* is the parameter, *cp(k)* is the generally obtained parameter*and p(k)* is the parameter of membership function got through GA, *gap(k)* is restricted toin the Genetic Algorithm concept . In order to assessindividual fitness value functionsthere are various methods are used.

*Fitness value=(*14*)* Where are constant values, is the rising time and e is the speed error.

For the proposed NFC control technique various tuning parameters are given in table 1.

VI. SIMULATION DIAGRAM AND RESULTS

The simulated diagram of indirect field oriented control of induction motor is shown in the Figure.1

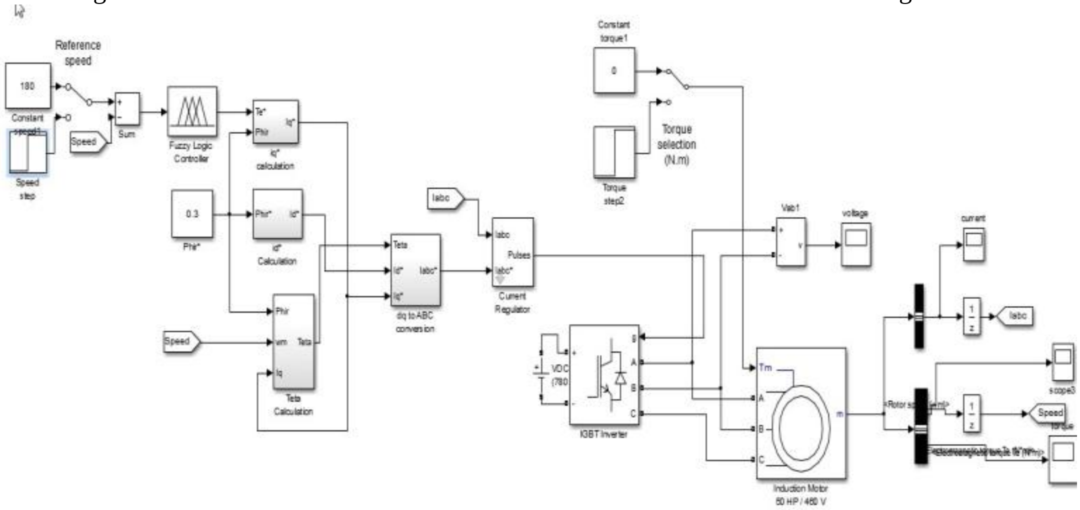

Fig.1. Simulink diagram of the proposed NFC based induction motor drive using Genetic Algorithm.

The proposed Neuro Fuzzy Controller includes fuzzy logic and a learning algorithm with a 4-layer Artificial Neural Network structure, as shown in Figure. 2 & Figure.3.

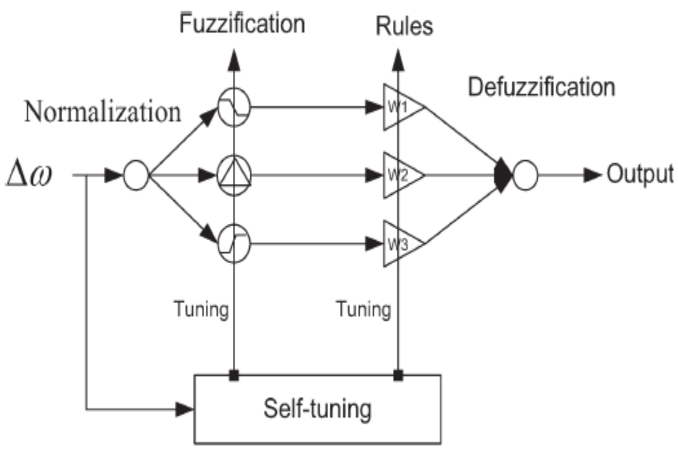

Fig.2.Basic Structure of self tuned proposed NFC with four layer structure

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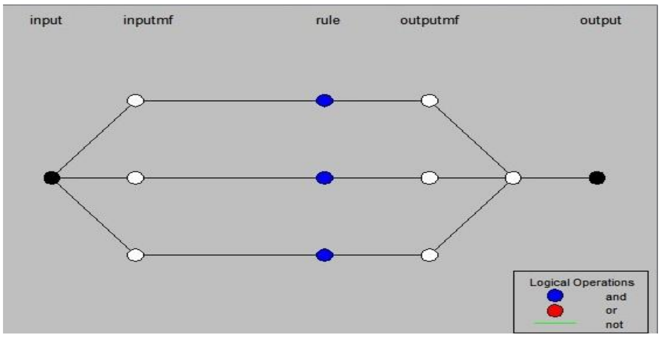
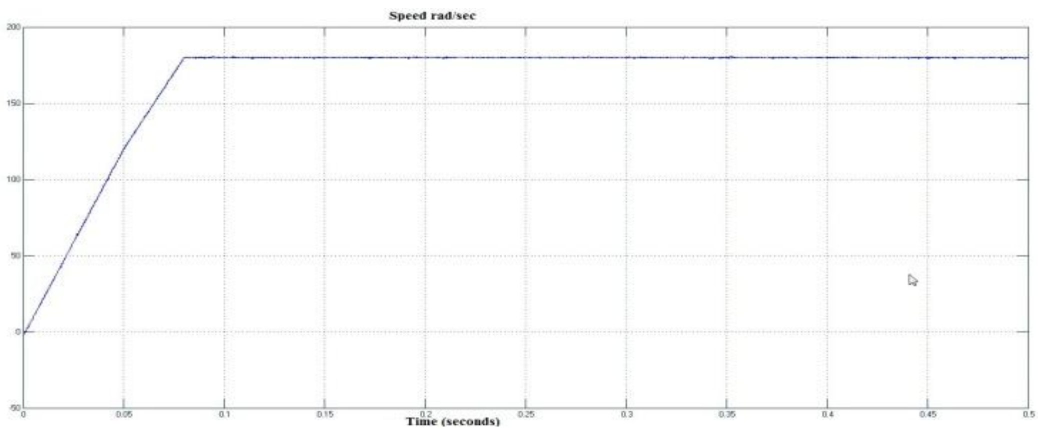


Fig.3. Basic Structure of proposed NFC in MATLAB/SIMULINK

The conventional NFC is checked with GA based NFC forproving the validity of the proposed controllerand show the better performance of the proposed controller by using Genetic Algorithm. For the simulated starting responses of the drive at full load the proposed genetic based NFC and conventional NFC based drive system are shown in Fig.'s 4(a)-(c). Genetic Algorithm based NFC have low settling time without any undershoot/overshoot and any steady state error have been observed in the simulation results. Only output is tuned and the speed response shows a little variation at the beginning when it reaches the speed command and therefore each input of the NFC has three membership functions like triangular, linear & trapezoidal membership functions. The zoom in view of speed responses of the load and with the step increase in the load from zero to rated level using the proposed Genetic based Neuro Fuzzy Controller and conventional two- input Neuro Fuzzy Controller are shown in Figures. 5(a)-(c) respectively. It is evident from the results that negligible amount of speed deviation is observed in the proposed GA based Neuro Fuzzy Controller as compared to conventional NFC which was capable of handling load disturbance at the starting response. In the speed responses of the Genetic Algorithm based NFC a small oscillation occurs at the beginning of the steady state and also proposed GA based NFC exhibits low settling time without any undershoot/overshoot and also steady state error. The variation of rotor resistance is a crucial issue for induction motor drive performance. The performance of the drive is tested for all three controllers with double rotor resistance and the speed responses in order to test the performance of the drive with parameter variations was shown in figures 6(a)-(c). The speed responses of the drive with step decrease in speed from 180 rad/sec to 150 rad/sec and then a step increase in speed from 150 rad/sec to 180 rad/sec using proposed NFC & conventional NFC is shown in Fig. 7(a)-(c).

Based upon these tests, the simplified genetic based NFC provides superior performance compared to conventional Proportional Integral controller and it is shown that the proposed NFC doesn't decrease the system performance as compared to the conventional Neuro Fuzzy Controller.



(a) GA tuning for proposed NFC

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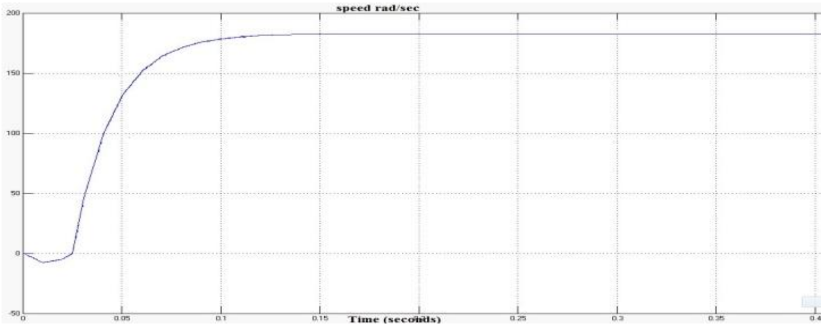
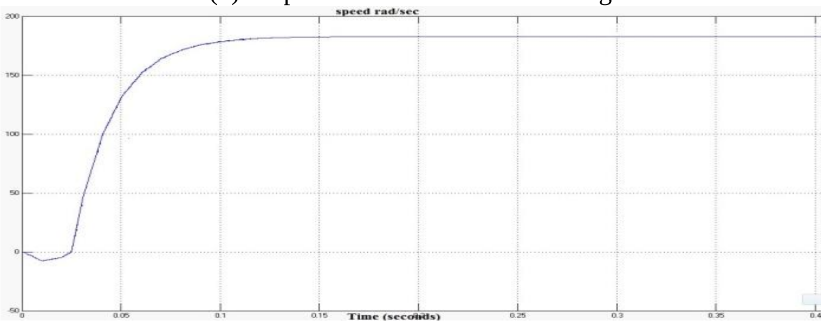
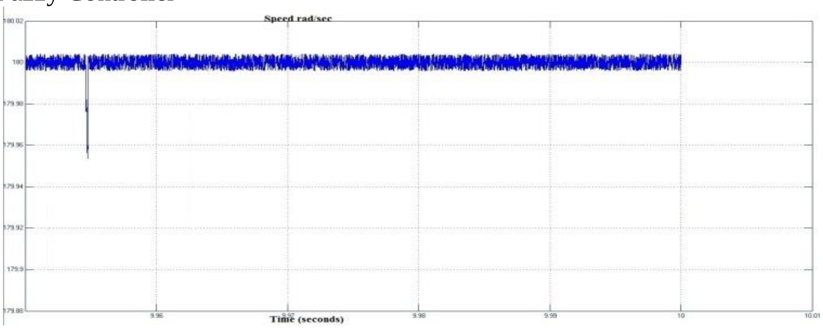


(b) Proposed NFC without GA tuning

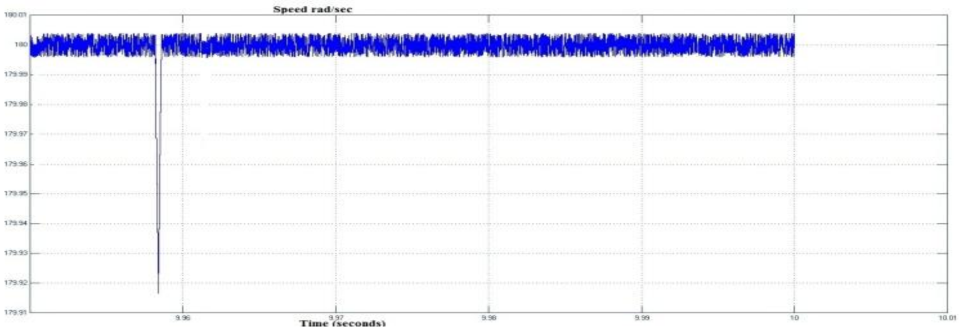


(c) Conventional Neuro Fuzzy Controller

Fig.4.Speed responses of the drive. (a)GA tuning with Proposed NFC (b) Proposed NFC without GA tuning (c) Conventional Neuro Fuzzy Controller



(a) GA tuning with Proposed NFC



(b) Proposed NFC without GA tuning

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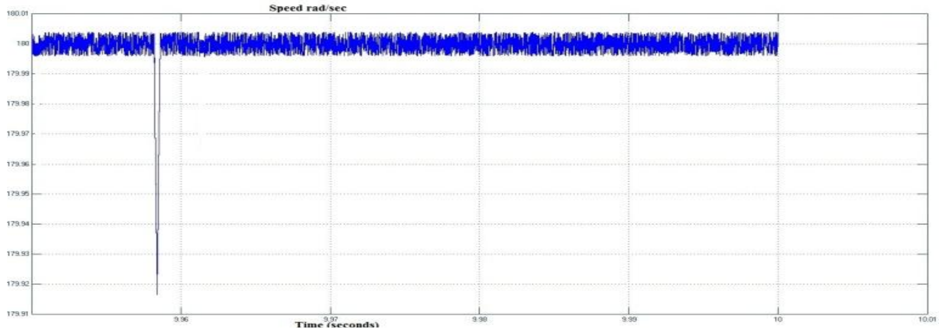
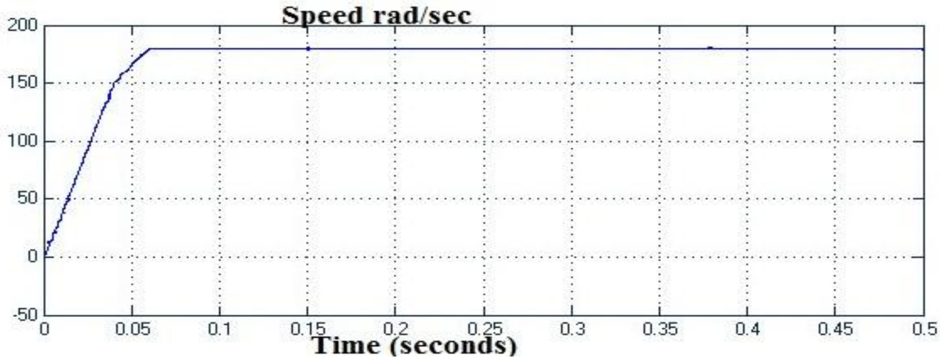
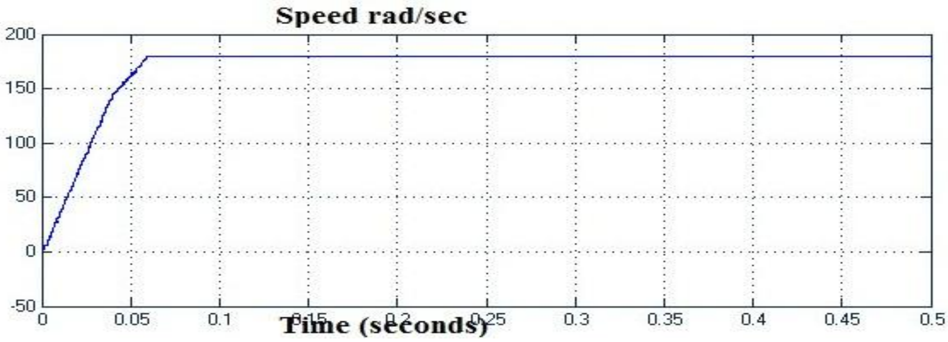


(b) Conventional NFC

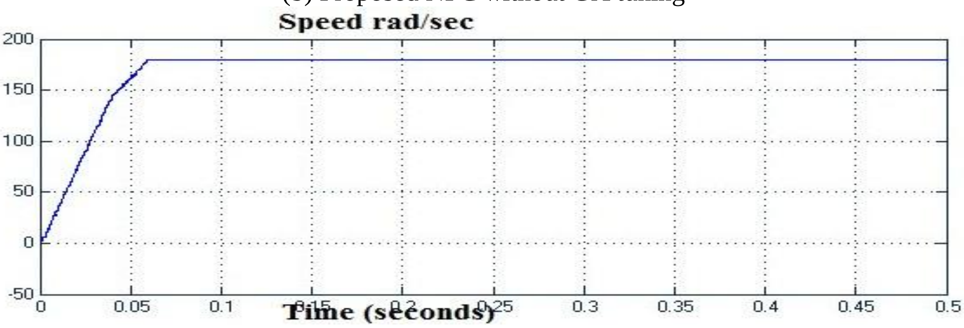
Fig.5. Speed responses of the drive at step increase in load. (a) GA tuning with Proposed NFC(b) Proposed NFC without GA tuning (c) Conventional Neuro Fuzzy Controller



(a)Proposed NFC with GA tuning



(b) Proposed NFC without GA tuning



(b) Conventional NFC

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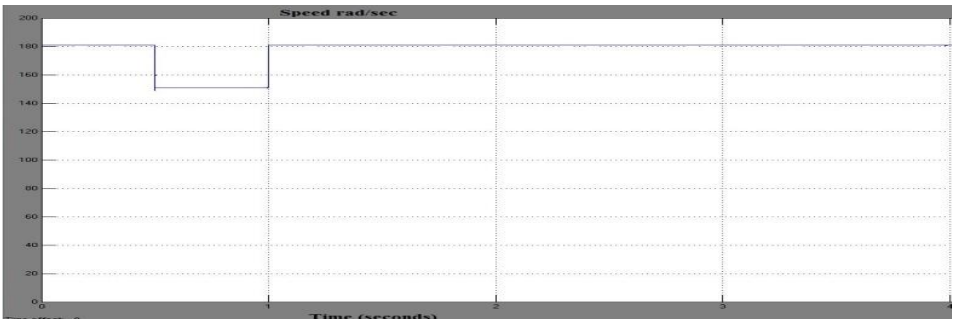
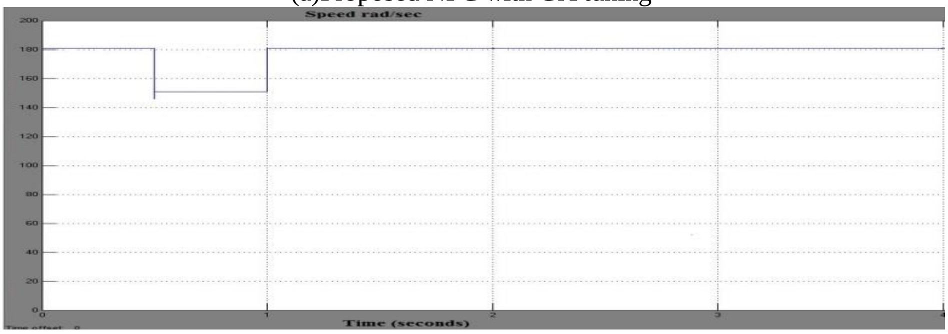
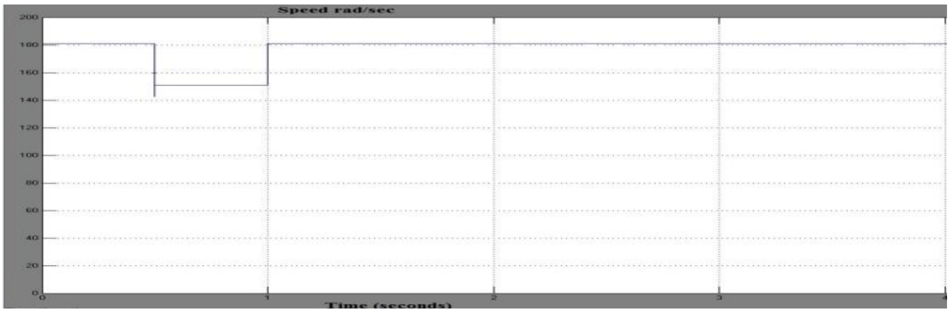
ig.6. Speed responses of IM drive at doubled rotor resistance. (a)Proposed NFC with GA tuning (b) Proposed NFC without GA tuning (c) Conventional NFC



(a)Proposed NFC with GA tuning



(b)Proposed NFC without GA tuning



(c) Conventional NFC

Fig.7. Speed responses of drive with step change in speed reference from 180 rad/s to 150 rad/s and 150 rad/s to 180 rad/s. (a)GA tuning with Proposed NFC (b) Proposed NFC without GA tuning (c) Conventional NFC

VII. CONCLUSION

A new advance technique was proposed for the design of GA based neuro fuzzy controller for the induction motor drive is presented in this paper. Over a various range of operating conditions and disturbances a good dynamic response of the system were studied by using Genetic Algorithm based NFC. In order to optimise the set of un-known controller parametersa modified version of Genetic Algorithm is adapted. The structure of proposed controller is based on the self-tuning controller that can tune its control gain to be autonomous according to system parameter variations. Based on operating conditions both the weights and membership functions are tuned online in the proposed controller by using self-tuned back propagation algorithm. By adjusting the tuning rates the proposed NFC controller could also be applied to various types of motor drives in various applications. For training the weights of the neural network Back propagation Algorithm is used. GA based NFC exhibits better performance than conventional NFC from the results shown in above figures. In order to verify the effectiveness of proposed controller various simulated speed responses of

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the IM drive is proposed at step change in load, by increasing the rotor resistance, by step increase in speed response and step decrease in speed by using MATLAB/SIMULINK software.

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