IMPROVING THE PERFORMANCE OF VECTOR CONTROLLED INDUCTION MOTOR DRIVE USING GA-ANFIS STRUCTURE FOR TUNING OF PI COEFFICIENTS

Seydi Vakkas Ustun[1], Mustafa Kaya[2], Ahmet Nur[3]

[1]*Professor, Department of Electrical-Electronics Engineering, Adiyaman University, Adiyaman, Turkey*
[2]*Research Assistant, Department of Electrical-Electronics Engineering, Adiyaman University, Adiyaman, Turkey*
[3]*Research Assistant, Department of Electrical-Electronics Engineering, Adiyaman University, Adiyaman, Turkey*

Abstract

In this paper, a new approach for adjusting controller parameters in indirect vector controlled induction motor drives is investigated. In the control of the induction motor, it is important to set the PI controller coefficients to achieve the desired performance.The PI speed control block in the outer loop of the vector control structure is used to match the speed of the motor to the reference speed. In this study, the relationship between PI coefficients (Kp-Ki) and system performance is modeled using the ANFIS structure. The system performance-fitness value is evaluated as a value between 0 and 1 according to settling time and maximum overshoot detected by monitoring the change in the speed of the induction motor. PI coefficients are then optimized using this ANFIS model and Genetic Algorithms (GA). There are very small differences between the ANFIS output values and the actual values obtained by the experimental setup. This shows that the ANFIS model can be used effectively in such a system model. Experimental results are presented for the proposed method. The results show that the proposed GA-ANFIS approach is very suitable for adjusting the control coefficients.

Keywords: - *ANFIS, GA, Indirect Vector Control*

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1. INTRODUCTION

Vector control is a control strategy developed to decouple the torque and flux of an induction motor, similar to the operation of a DC motor. The great advantage of this is that the induction motor can be controlled as easily as a DC motor in addition to its high efficiency, robustness, maintenance-free and low cost advantages. An induction motor with these features has many applications in the industry[1].

Motor control is traditionally performed by constant gain proportional integral (PI) and proportional integral derivative (PID) control techniques. Such constant gain controllers are very sensitive to parameter changes, load changes, and so on. Thus, the controller parameters must be adapted continuously. This problem can be addressed by various control techniques such as model reference adaptive control, slip mode control, variable structure control and self-adjusting PI controllers. All of these solutions can be done with a complete mathematical model of the system. However, due to uncertain load variation, saturation and different temperature conditions, the inevitable parameter changes are often the result and the creation of the mathematical model of the system is often difficult [2-5].

In high performance applications, it is important to model complex relationships that represent driver behavior. Different learning algorithms can also be a powerful tool to automatically model variable speed drives [6]. They can automatically extract the relationship that represents driver behavior in the form of a functional relationship. Hence, it has some advantages over classical methods because it does not need exact values of mathematical models and parameters. It is also a fact that the electromechanically systems include nonlinear and parameter deviated situations which are difficult to model mathematically [7, 8].

Because of the some neglected parameters and due to parameter deviations, the mathematical model may not be able to fully represent the physical system. However, a complete system model is needed so that the controller coefficients can be adjusted correctly. Failure to obtain a complete system model causes driver coefficients not to be adjusted appropriately.Fuzzy logic is successful in evaluating and processing expert's experience and the relationships obtained from input-output data as fuzzy information. System modeling, system control, system identification and system estimation with fuzzy logic systems have been extensively studied. Fuzzy systems can easily handle human knowledge, but fuzzy systems have no learning ability. Neural networks also have the ability to learn and adapt for a given input-output [9, 10].

Although artificial neural networks are a learning ability using data sets and feedbacks, it is quite difficult for people to understand the information they learned. Because of these features, artificial neural networks and fuzzy logic are used together in creating membership functions and fuzzy rule sets required to obtain predicted input-output mates. This hybrid method is called adaptive-network-based fuzzy inference system (ANFIS) [11, 12].

In this study, the relationship between PI coefficients and fitness values is modeled with ANFIS for the whole system. Then, using this generated model, optimum PI coefficients are obtained by genetic algorithms.

2. EXPERIMENTAL SETUP

The experimental setup consists of a motor and a DC generator connected together by a coupling. Also, there is an incremental encoder mounted on the motor. The motor is a three-phase squirrel cage induction motor with label values of 1.5 kW, 6.2 A, 50 Hz, Cosφ = 0.8). The power stage of the drive of the induction motor is based on IPM (intelligent power modules). The control card is based on the dsPIC33FJ128MC804 Digital Signal Processor (DSP). The SD card unit has been added to the control card to receive the drive data to the PC. The block diagram of this application setup and its picture are shown in Fig.1.

The main purpose of using vector control in induction motors is to control torque and current independently, as in DC machines. For this purpose, a controller structure is used as shown in Fig. 2.

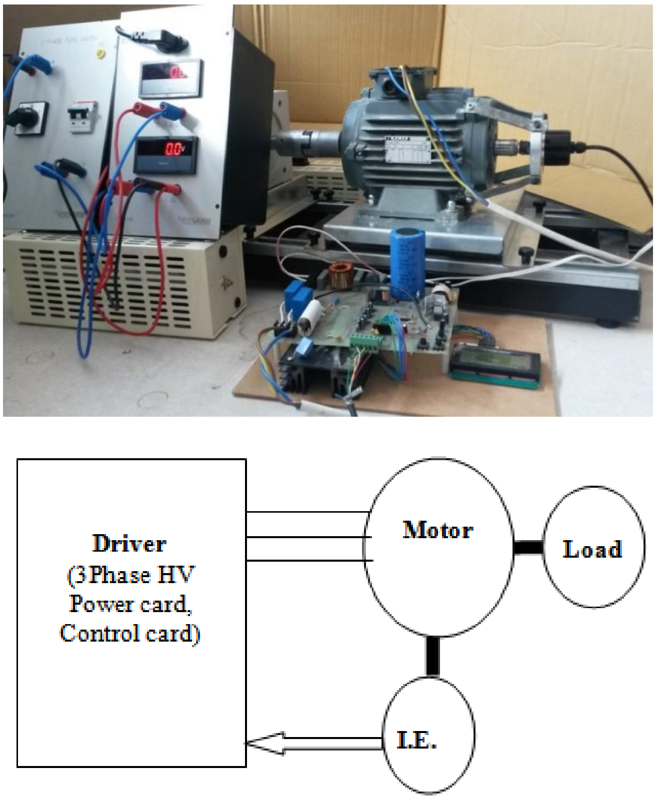

Fig -1: The application setup and the block diagram

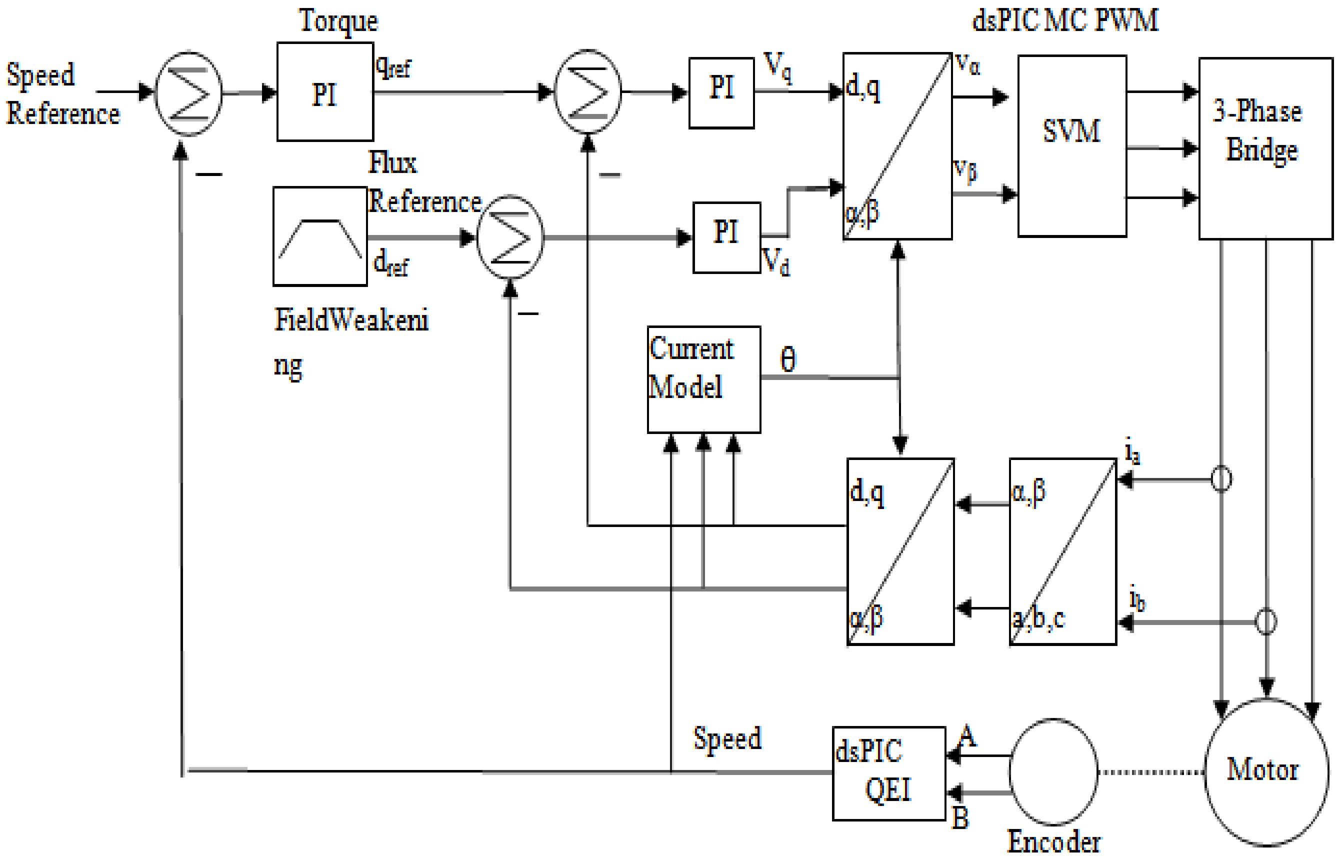

Fig -2: The vectored controlled drive system [13]

The application works with a PWM time base of 170 microseconds. The control is performed once every 30 PWM time bases. The dead time is generated hardware by the controller. This was set 5 microseconds. The driver software is written in assembly language and C language. Developing and compiling the software was conducted in the MPLAB environment.

3. MODELING THE WHOLE SYSTEM USING ANFIS

ANFIS has a structure that can model nonlinear relations between input and output.In this study, the PI coefficients (Kp and Ki) that determine the performance of the control system were considered as input. The fitness value of the system operating with these input values was taken as output. By changing the reference speed, the maximum overshoot (Mo) occurring in the speed and the setting time (Ts) at the reference speed with a certain tolerance are taken as the success criterion of the control system [14, 15]. The fitness value is obtained from 0 to 1 as a function of these two variables. The fitness function that gives the fitness value is given in Eq.1.

$$f = \frac{1}{(Mo + Ts)} \quad (1)$$

Two inputs (Kp, Ki) and one output (fitnees value), Sugeno fuzzy model with ANN structure are used in the application. For 42 different Kp-Ki pairs, training set is formed with fitness values obtained from application circuit. Kp and Ki values are selected in the range of (0.2-0.5) and (0.0045-0.024) respectively. Ki values are normalized to a range of 0.04 to 0.48, thus reducing the ANFIS training error to a minimum. With this training set, ANFIS membership function parameters, rules and weights are adjusted in MATLAB toolbox environment [16].

At the end of the training, the ANFIS model predicts the fitness value of the system response for a random Kp-Ki couple with a slight deviation.The 42 Kp-Ki pairs and fitness values used for training are shown in Fig.3. The fitness values obtained from the system and produced by ANFIS model are shown in Fig.4. There seems to be little difference between these two values. This demonstrates that ANFIS can successfully model nonlinear relationships [17].

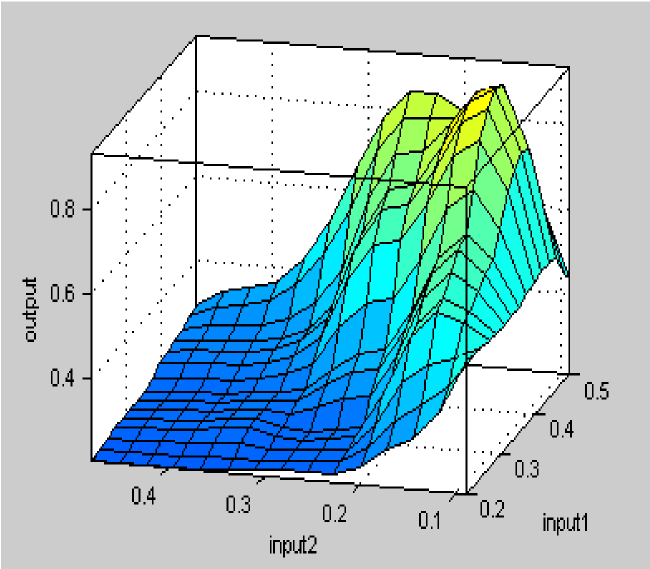

Fig -3: Surface view of Kp-Ki coefficients (input1, input2(Twenty times normalized.)) and fitness value (output) for 42 sets

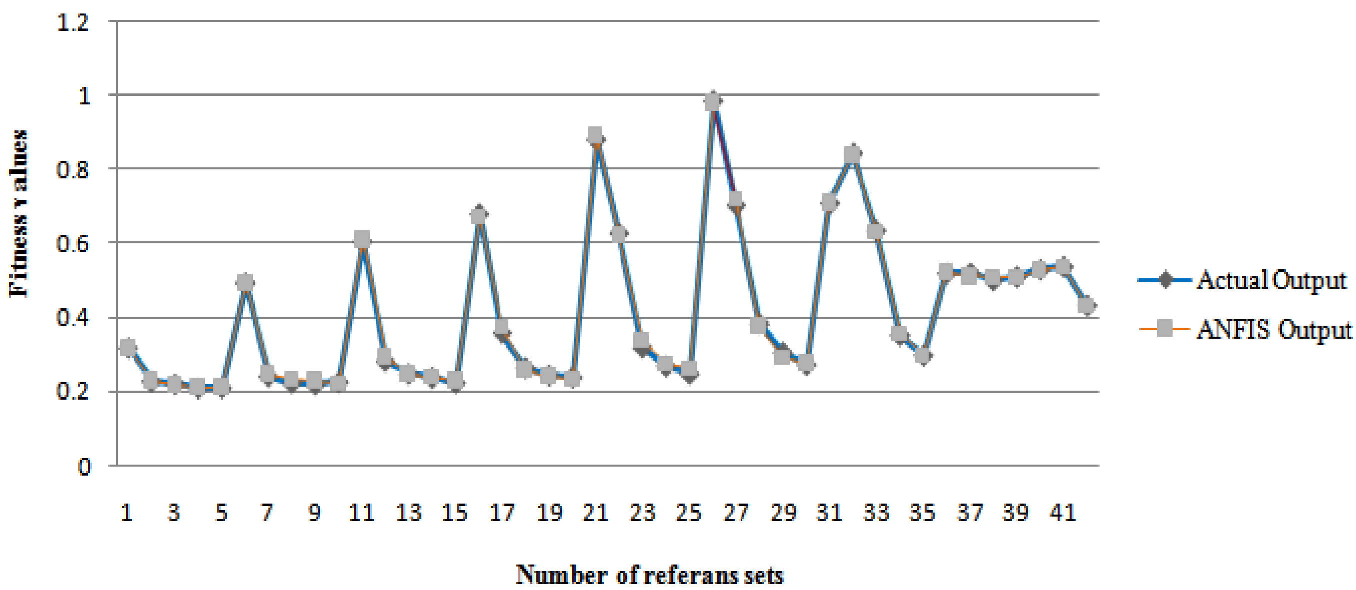

Fig-4: Actual system and ANFIS model output values

4. TUNING OF PI COEFFICIENTS USING GA

Genetic algorithms (GA) are a numerical optimization method based on the natural selection principle. The genetic algorithm uses natural selection operators such as crossover and mutation with an initial generation of solution sequences.In this paper, a basic structure is used as genetic algorithms. Different crossover and mutation rates are used to optimize genetic algorithms.[18]. The flow chart of the GA is shown in Fig.5.

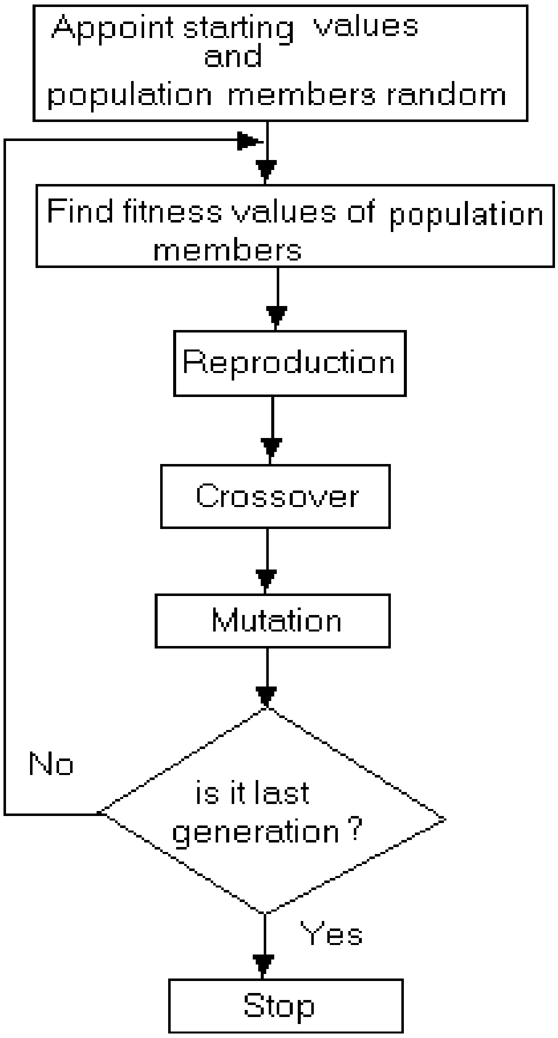

Fig-5: The flow chart of the GA technique

GA is used to adjusted the PI coefficients of the vector controlled asynchronous motor drive. The optimization of the Kp and Ki coefficients is performed with the aid of a program that uses Matlab's GA and ANFIS functions. The Kp-Ki coefficients are adjusted by working with the GA operators at bit level. A population of 30 elements consisting of Kp-Ki pairs is randomly determined. As an input to the generated ANFIS model, these Kp and Ki pairs are derived and the fitness values are obtained from the ANFIS output. This value is used in the GA operators by determining the fitness value of this hand in the population. The genetic algorithm parameters selected for the purpose of adjustment are shown the table [19].

Table-1: The parameters of GA

GA Property	Value
Population Size	30
Maximum Number of Generations	100
Crossover Probability	0.12
Mutation Probability	0.06

5. RESULTS

While the rotor speed was 800 rpm, the reference speed was increased to 1300 rpm, and the performance of the proposed controller was monitored. The ANFIS model was trained on these conditions using the data obtained from the running application. A very small error is observed between the actual data and the values produced by the ANFIS model. This indicates that ANFIS has successfully modeled the system. From this training set, the system outputs for the randomly chosen Kp and Ki pairs are shown in Fig.6.

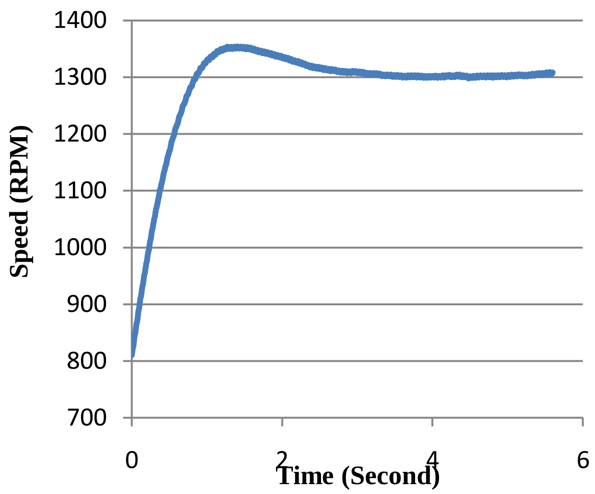

Fig-6: Speed of rotor for Kp=0.25 and Ki=0.024

With the program written using Matlab functions, by using the ANFIS Model as the GA fitness function, it has adjusted the Kp-Ki coefficients offline. Optimal Kp and Ki pairs produced by the proposed GA-ANFIS method were found to be Kp = 0.44 and Ki = 0.00801. The motor speed variation for these values is shown in Fig.7. Fig.8 shows the change of the stator current Ia for the Kp-Ki pair.

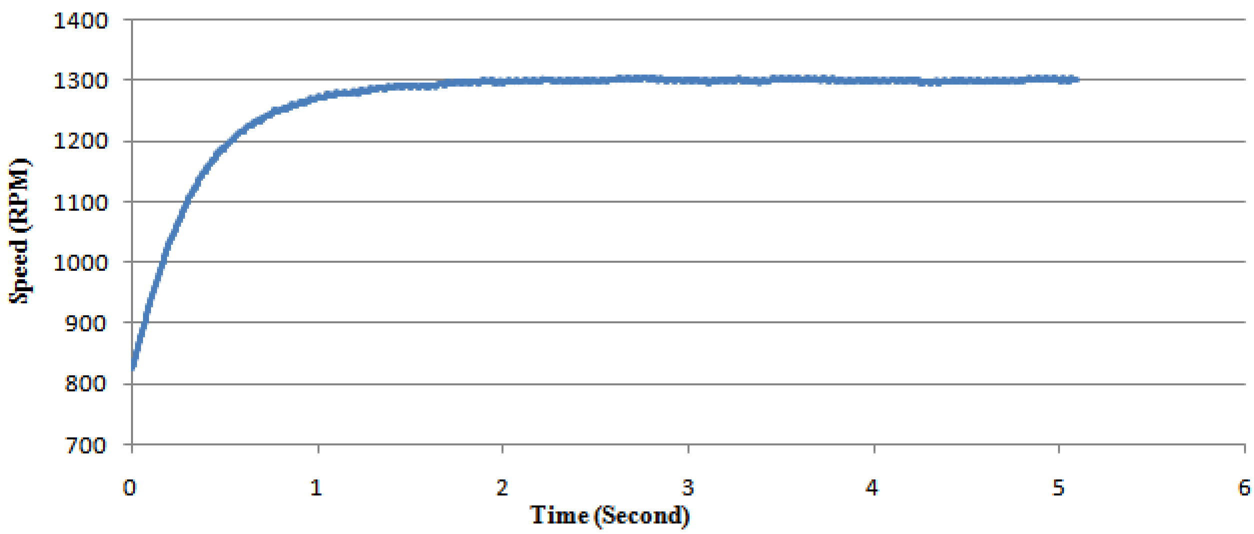

Fig-7: Speed of rotor for Kp=0.44and Ki=0.00801

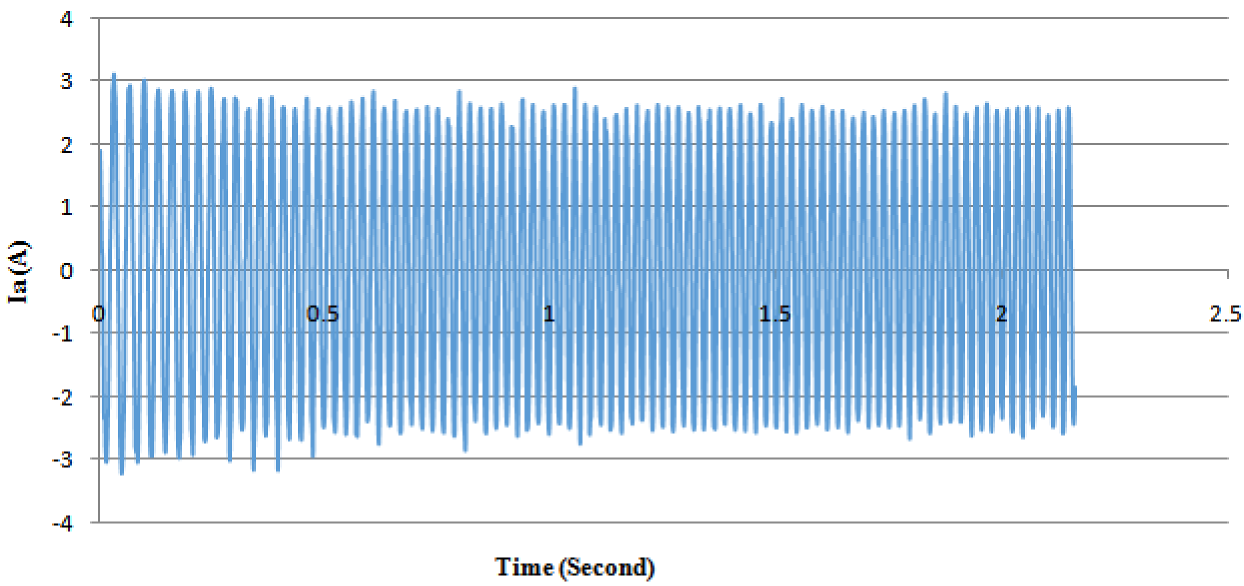

Fig-8: Ia phase current change for optimal Kp and Ki (Kp= 0.44 - Ki =0.00801)

The maximum overshoot for the Kp-Ki pair set by the GA-ANFIS method was less and the settlement time was the lowest. The results of this method show that this method is a good control system.

6. CONCLUSION

In this paper, a study using GA-ANFIS method is presented. In this method, a nonlinear relationship (controller parameters–system performance) can be modeled with ANFIS. A GA-based optimization operation is performed using the system model created with ANFIS. When the proposed GA-ANFIS method is used, it is found that the maximum exceeding and sitting time are very small.

The presented results show that ANFIS can produce accurate results from theI /O data of the real dynamic model of the system. GA is suitable for optimizing the controller coefficients of the system according to the performance criteria considered. This can be done in real time and in different systems.

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