2001년도 대한전기학회 하계학술대회 논문집 2001.7.18-20

퍼지 논리를 이용한 유도 전동기의 지능제어

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Intelligent Control of a Induction Motor Using a Fuzzy Set

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Abstract - Induction motor has been using for industrial field. Up to the present time, the PID controller has been used to operate this system. However, it is very difficult to achieve an optimal PID gain without any experience, since the gain of the PID controller has to be manually tuned by trial and error procedures. This paper focuses on the fuzzy control for optimal control of the induction motor in plant. In order to attain optimal control, flux, torque and speed controller has been used and an fuzzy logic based controller has been applied to this system. The results of the fuzzy are compared with the PID controller tuned by the Ziegler-Nichols method, through various simulation based on the various disturbance and step response. The simulation results of the fuzzy control represent a more satisfactory response than those of the conventional controllers.

1. Introduction

Recently, a fuzzy logic based controller has been used for meeting a growing interest in many industrial applications. The key attention toward this technique is due to its nonlinear features, independence from an accurate system modeling, and reduction of development and maintenance time[1]. Fuzzy logic based controllers have more robustness than conventional PID controllers because parameter detuning and load disturbance occur. However it is not yet clear which design choices affect their robustness and stability. Many papers have been trying to increase robustness of fuzzy logic controllers on industrial field. In particular, because of their easy implementation and low cost, indirect field oriented induction machine drives using fuzzy logic are finding numerous industrial applications. Two or three feedback loops are used to implement an induction machine variable speed drive system and torque control The inner loop is a current regulation for speed control, where either a synchronous current regulator or a feedforward current regulator is often used. Decoupled control of flux and torque can be obtained using accurate slip calculation. To accomplish variable speed operation in induction motor, PI controllers are used in the outer speed loop of control loop to generate a command current. However, as many studies have pointed out, whether commands iqs and ids are truly realized relies heavily on the performance of the PI controller and, more importantly, the accuracy of the slip calculation. Recently, many papers have explored the potentials of fuzzy control for control systems. However, the performance may still be unsatisfactory when the machine parameters in the induction motor vary too much. The basic reason for the unsatisfactory performance is that the control algorithms lack the ability to learn how to deal with the system complexity. In this paper, an fuzzy logic scheme has been designed for load disturbance rejection and variable speed tracking.

2. Fuzzy Logic Based Induction Machine Drive

Fig.1 represents the proposed fuzzy logic scheme for a variable speed induction machine drive. It consists of two feedback control loops. The inner loop is a conventional synchronous current regulation loop. The torque command current iqs, is produced by fuzzy logic in the outer speed control loop, based on the command speed and the actual speed. The fuzzy logic shows the shape of membership function for Fig.1. The desired speed performance of the drive system is characterized by of the membership function. The fuzzy logic controller uses the actual speed as feedback signal, utilizes the learning mechanism to characterize the present speed performance based on the prepecified speed performance from the reference model. Then the fuzzy logic controller automatically synthesizes and adjusts to generate proper torque command current. Computer simulations are used to verify the speed performance of the reference model and the results are shown in Fig. 4. As seen from fig. 4, the speed performance of the reference model is indeed very satisfactory. The learning mechanism performs the function of modifying the knowledge base of the direct fuzzy controller so that the closed-loop system behaves like the reference model. The learning mechanism includes a fuzzy inverse model and a knowledge base modifier. The speed performance of the drive system is computed with respect to the reference model by generating a speed error.

3. The Direct Fuzzy Controller design and simulation

The direct fuzzy controller generates the necessary torque current to satisfy the speed performance. Other than a conventional fuzzy logic structure, a learning mechanism is included in the fuzzy controller to adapt performance deviations.
They are a scale version of the speed error and the change in speed error as defined by (5) and (6). The gains ge and gc can be adjusted to normalize the universes of discourse for each input to a certain range. Here, inputs are normalized to [-3, +3] for implementation in a digital signal processing (DSP) system.

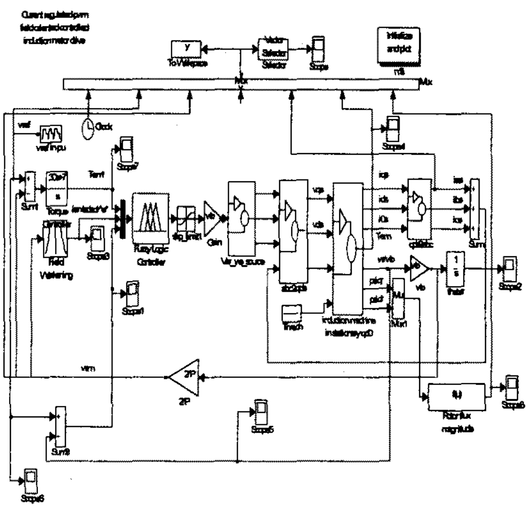


Fig. 1. Fuzzy controller with time delay.

With $\lambda_{qr}^{'e}$ zero, the first equation for the developed torque is given by

$$T_{em} = -\frac{3}{2}\frac{P}{2}\lambda_{dr}^{'e} i_{qr}^{'e} \quad N.m \qquad (1)$$

Desired torque of T_{em}^{*} at the level of rotor flux, the desired value of i_{qs}^{e*} in accordance with

$$T_{em}^{*} = \frac{3}{2}\frac{P}{2}\frac{L_m}{L_r}\lambda_{dr}^{'e*} i_{qs}^{e*} \quad N.m \quad (2)$$

The look-up table for field-weakening of fuzzy controller matches the desired value of the rotor d-axis flux, $\lambda_{dr}^{'e}$, to that of the mechanical speed of the rotor, w_{rm}. For speed less than the base or rated speed, $\lambda_{dr}^{'e}$ is set equal to its no-load value with rated supply voltage. Beyond the vase speed, the flux speed product is held constant at the base speed value.
The values of $\lambda_{dr}^{'e}$ and mechanical speed are generated by the fuzzy logic, which is also used to set up the parameters and other run conditions of the simulation in the Simulink.

The values for $\lambda_{dr}^{'e}$ in the field-weakening look-up table are

Table 1. Look-up table for fuzzy controller.

0.1624	0.1710	0.1805	0.1911	0.2030	0.2166	0.2320	0.2499
0.2707	0.2953	0.3248	0.3248	0.3248	0.3248	0.3248	0.3248
0.3248	0.3248	0.3248	0.3248	0.3248	0.3248	0.3248	0.3248
0.3248	0.3248	0.3248	0.3248	0.3248	0.3248	0.3248	0.2953
0.2707	0.2499	0.2320	0.2166	0.2030	0.1911	0.1805	0.1710
0.1624							

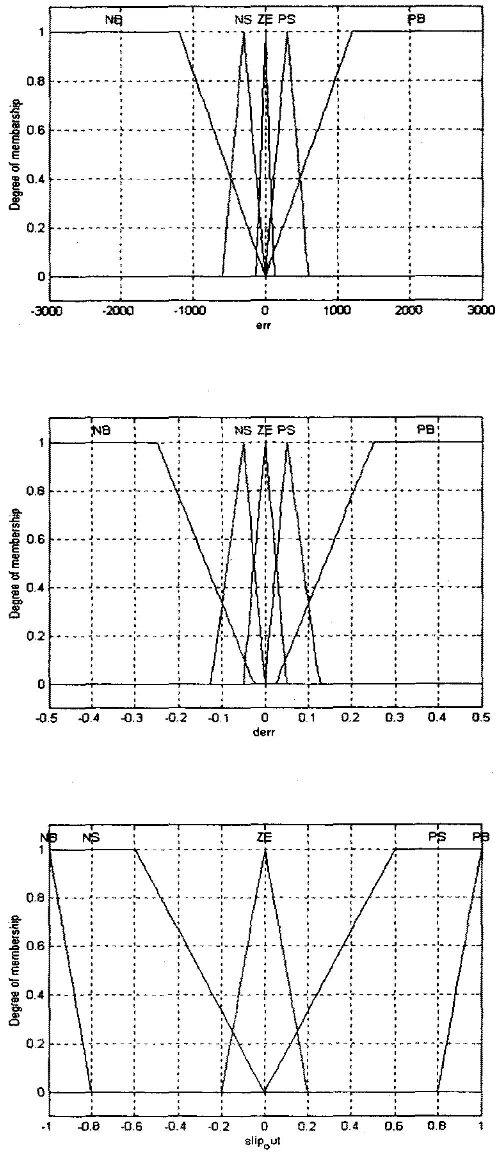
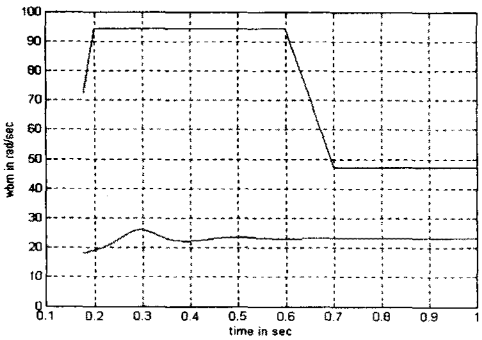
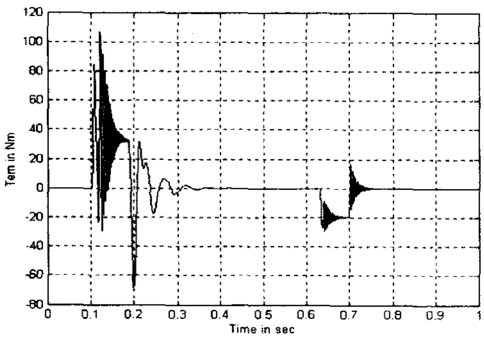


Fig. 2. Membership function for speed fuzzy controller.

4. Results





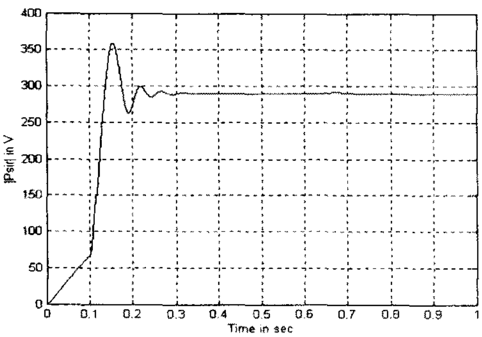
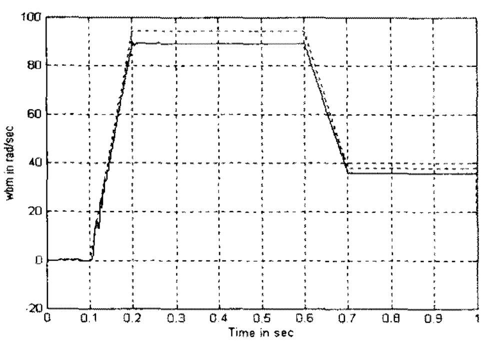
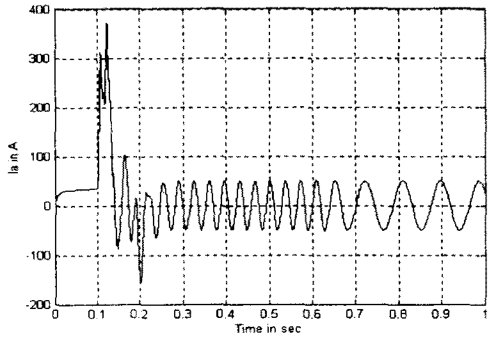


Fig. 3. The results of fuzzy control.





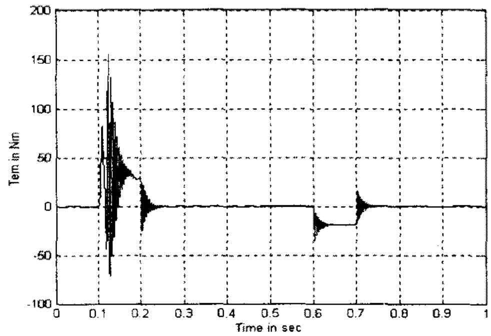


Fig. 4. The result of fuzzy control.

In this paper, we compared the designed controller and Fig. 3 shows the result of simulation. From figure 3, the result represents the unsatisfactory response in speed. However, the response of torque and current.

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