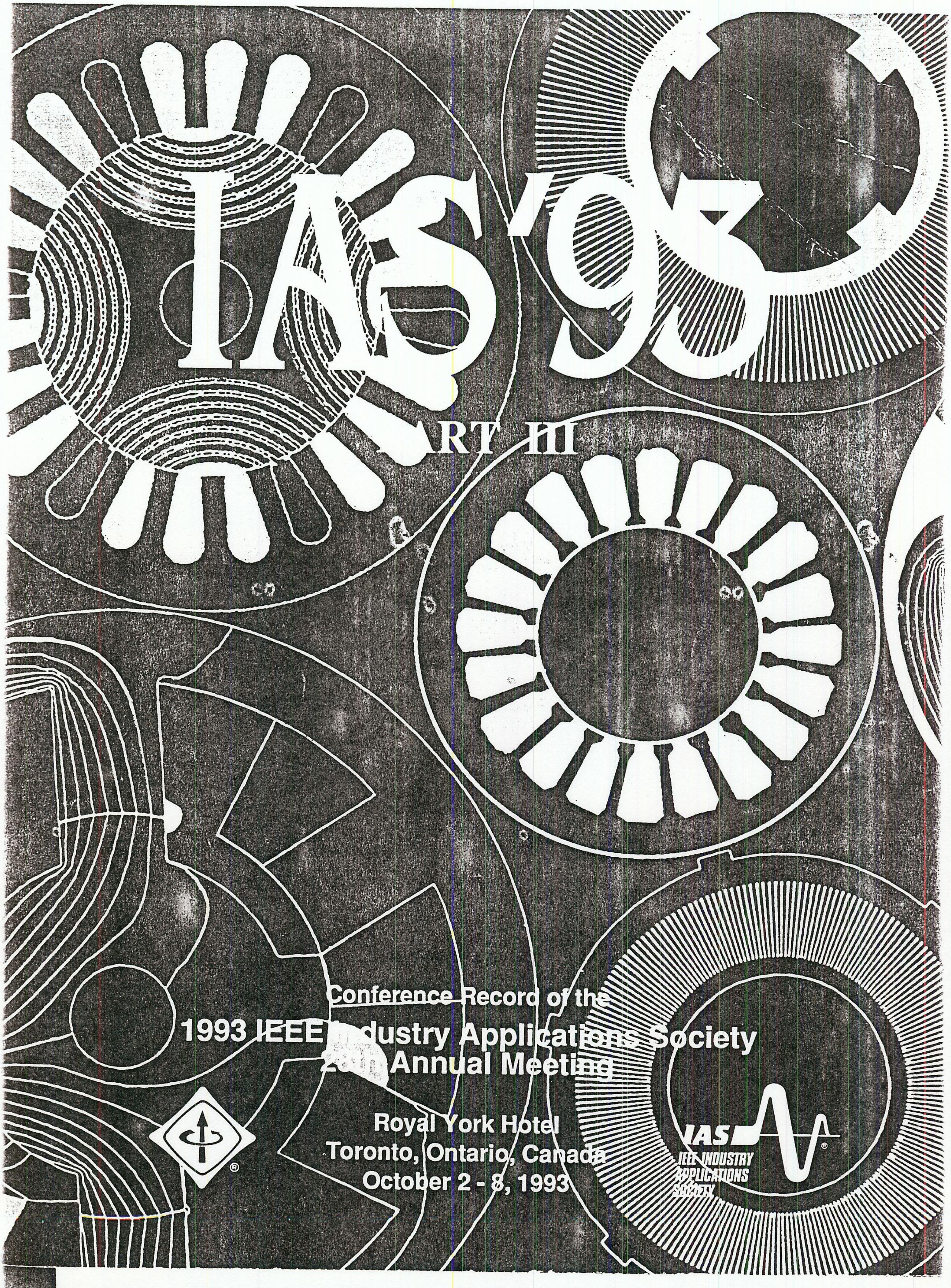

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Control of Rotating Machinery Using Fuzzy Controllers

Industrial Control Software & Applications

Control System Theory & Applications

A Robust Speed Control of AC Motor Drives based on Fuzzy Reasoning

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Abstract— **This paper presents a fuzzy-logic based control of an induction motor. The controller uses the Indirect Vector Control Method to decouple the motor current components. The fuzzy controller uses a simple rules set obtained by a modification of the parameters of a linear controller. Results obtained via simulation are reported showing the excellent behavior of the fuzzy controller,**

I. INTRODUCTION

Classical control systems have been based on a linear control approach, such as the proportional-integral (PI) control. Main drawbacks of the linear control approach are the sensitivity in performance to the system parameters variation and inadequate rejection of external disturbances and load variations. To face these problems the variable-structure control approach, such as sliding-mode control, has been successfully applied for controlling electric drive systems ([1]-[5]).

Fuzzy-logic, first proposed by L.A.Zadeh in [6], has received a great deal of attention in the recent past, because fuzzy controllers are easy to design and cheap to produce ([7], [8]). A few recent applications in the electric drive control field can be found in the literature ([10]-[12]).

In this paper a fuzzy logic-based controller of an induction motor using the indirect vector control method is proposed. Simulated results are presented and they are compared with the response obtained with a linear controller.

II. THE CONTROLLER

Figure 1 shows the block diagram of an Induction Motor Drive Control using the well-known Indirect Vector Control (IVC) method, which is described elsewhere [13]. The IVC block includes the operations involved in the generation of the reference currents i_a, i_b and i_c. The machine is operated under constant rotor flux; therefore, the flux component of current i_{ds} is maintained constant.

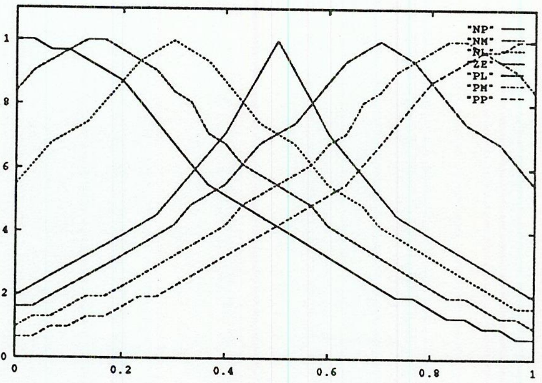

Figure 2: Membership functions

The controller uses fuzzy reasoning principles. The error (e) between the desired speed w_{ref} and the measured rotor speed w_r is used as an input signal. Another input signal is the increment of the speed error (Δe) measured in two succesive sampling intervals. In addition, the torque component of current i_{qs} is used as the output signal. Input and output signals are employed to perform fuzzy reasoning on the basis of the membership functions and the control rules shown in figures 2 and 3, respectively.

III. SIMULATION RESULTS

A digital simulation of the proposed controller has been carried out to find its performances. In order to compare, the motor parameters have been taken from the real system described in [14]. Following the experiments described there, in our simulation the controller is implemented on a microprocessor. The motor is driven by

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Δe \ e	NP	ZE	PP
NP	PP	PL	NL
ZE	PM	ZE	NM
PP	PL	NL	NP

Figure 3: Fuzzy rules

a current–reference PWM VSI. The hysteresis control action of the inverter is done by software computation. Sampling period is 600 μs and the motor speed is measured with an encoder that generates 8000 pulses per revolution.

Figure 4 plots the simulated speed response. A step torque of 2 $N.m$ is applied to the motor shaft at $t = 1.0s$. This figure also shows the results obtained using the PI controller designed in [14] (i.e., $K_p = 0.07$, $K_i = 0.7$). As no integral part is included in the fuzzy controller, a steady-state error can be observed in figure 4. To avoid it, an integral term is added to the fuzzy controller in two new rules.

IF e is ZE and Ie is PM THEN out is NL
IF e is ZE and Ie is NM THEN out is PL

where Ie is the accumulated speed error. The motor speed response using this improved fuzzy controller is shown in figure 5. No steady-state error can be observed in this figure.

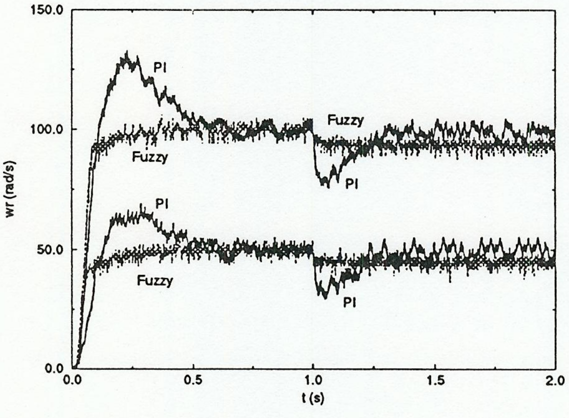

Figure 4: Time response using the rules of figure 3

Motor parameters are highly dependent on temperature and saturation levels of the machine [15]. Therefore, controller robustness should be an essential characteristic of real controllers. Fuzzy-logic controllers based on natural reasoning have an inherent robust nature as can be seen in figure 6. This figure plots the simulated response when the rotor time constant is halved. It can be observed the excellent behavior of the fuzzy controller with large parameter changes, especially when it is compared with the PI controller.

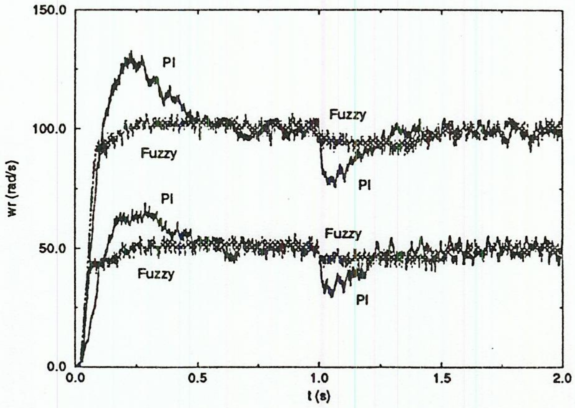

Figure 5: Time response adding integral rules

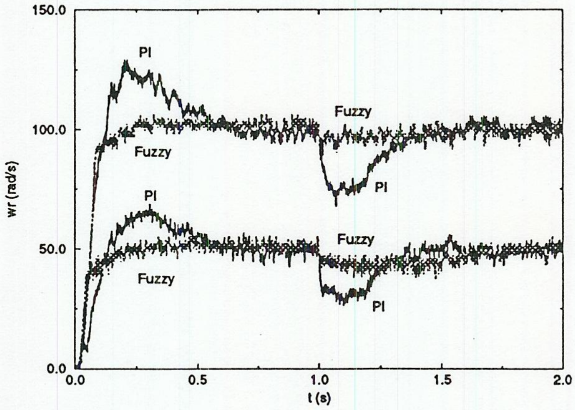

Figure 6: Time response when rotor resistance is halved

As it can be expected, the system response improves using an independent current fed inverter. Figure 7 shows the simulated response when the inverter is operated at 20 KHz.

Presently this kind of controller is being applied to a 3–phase induction motor (figure 8) whose constants have been experimentally measured and are shown in Table I.

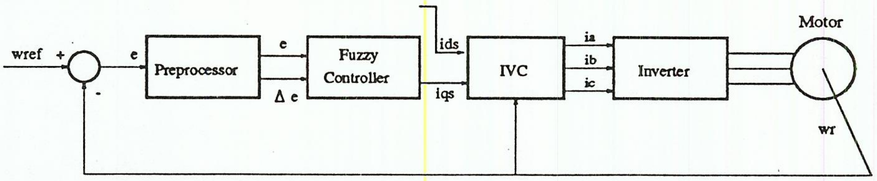

Figure 1: Block diagram of Induction Motor Control

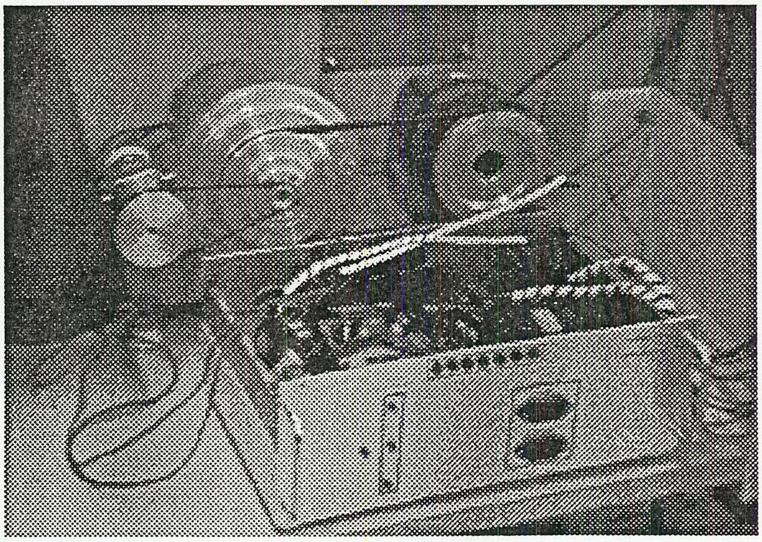

Figure 8: Motor–inverter prototype

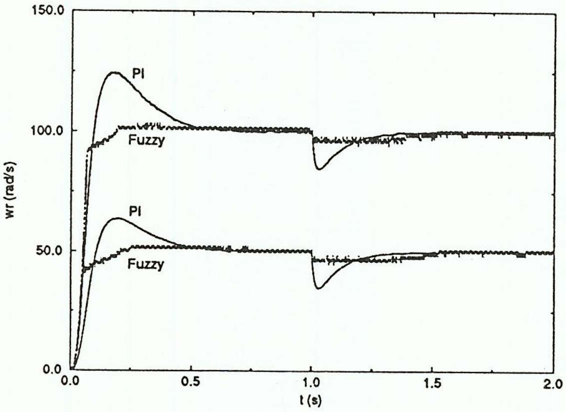

Figure 7: Time response with a 20 KHz inverter

$L_m(H)$	1.5142	$J(Kgm^2)$	0.068
$L_s(H)$	1.5887	$B_m(Ns)$	0.0073
$L_r(H)$	1.5887	p	2
$R_s(\Omega)$	29.06		
$R_r(\Omega)$	21.4331		

Table I. Induction motor parameters.

IV. CONCLUSIONS

A fuzzy logic–based controller of an induction motor has been proposed. Simulated reponses have been obtained showing excellent behavior when faced with load and motor parameters variations. Presently this kind of controller is being applied to a prototype system.

ACKNOWLEDGMENT

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