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Self-Adjusting Diagnostic System in the Manufacture of Crystal Resonators <i>B. H. Gwee, M. H. Lim, B. H. Soong - Nanyang Technological University</i> .....	2014
Development of Fuzzy-Logic Processing Objects for Industrial Control Applications <i>Paul I-Hai Lin - Indiana-Purdue University at Fort Wayne</i> .....	2021
Neural Network Compensation of Gear Backlash Hysteresis in Position-Controlled Mechanisms <i>David R. Seidl, Sui-Lun Lam, Jerry A. Putman, Robert D. Lorenz - University of Wisconsin - Madison</i> .....	2027
When and When Not to Use Fuzzy Logic in Industrial Control <i>Gordon Chen, George Kairys* - Niagara College; *OMRON Canada, Inc.</i> .....	2035

## Control of Rotating Machinery Using Fuzzy Controllers

Neural Net Adaptive Schemes for DC Motor Drives <i>L. E. Borges da Silva, G. Lambert Torres, E. C. Saturno, A. P. Alves da Silva, G. Olivier* - Escola Federal de Engenharia de Itajuba; *Ecole Polytechnique de Montreal</i> .....	2043
Fuzzy Logic Control of a Switched Reluctance Motor Drive <i>Silverio Bolognani, Mauro Zigliotto - University of Padova</i> .....	2049
A Robust Speed Control of AC Motor Drives Based on Fuzzy Reasoning <i>E. Galvan, F. Barrero, M. A. Aguirre, A. Torralba, L. G. Franquelo - University of Seville</i> .....	2055
A Fuzzy Velocity Controller for DC Drives <i>T. H. Ortmeier, S. Ahmed-Zaid, R. Mukundan, D. Boutwell - Clarkson University</i> .....	2059
A Rule-Based Fuzzy Logic Controller for a PWM Inverter in a Stand Alone Wind Energy Conversion Scheme <i>Rohin M. Hilloowala, Adel M. Sharaf - University of New Brunswick</i> .....	2066

## Industrial Control Software & Applications

A New Method of State Machine Controller Design and Implementation Using Programmable Logic Devices for Industrial Applications <i>Akram Hossain, Suzali Suyut - Purdue University Calumet</i> .....	2077
Fieldbus Applications for Electrical Industrial Systems <i>B. Delfino, P. Pinceti - Universita di Genova</i> .....	2084
The Adaptive Control for Retrofit Traditional Milling Machine <i>Shiuh-Jer Huang, Mu-Tyan Yan - National Taiwan Institute of Technology</i> .....	2091
Speed Control Systems for Three Phase Induction Motor Using Fixed Pattern P.W.M. Wave <i>Shahriar Mohammadi - Telecommunication Company of Iran</i> .....	2099
An Iterative Learning Control Method with Application for CNC Machine Tools <i>Dong-Il Kim, Sungkwun Kim - Samsung Electronics</i> .....	2106

## Control System Theory & Applications

Control of Wound-Rotor Induction Motor with Rotor Impedance Variation <i>S. Lesan, W. Shepherd* - University of Mozandaran; *University of Bradford</i> .....	2115
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# 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.

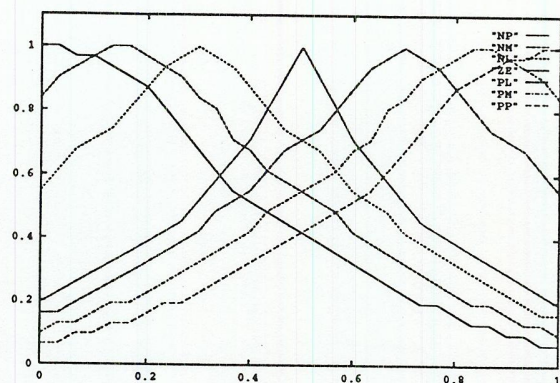


Figure 2: Membership functions

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 ( $\Delta e$ ) measured in two successive 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

$\Delta e \backslash e$	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  $600 \mu s$  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  $I_e$  is PM THEN out is NL  
 IF  $e$  is ZE and  $I_e$  is NM THEN out is PL

where  $I_e$  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.

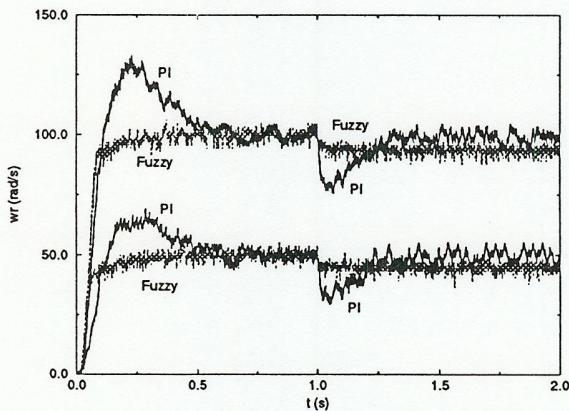


Figure 4: Time response using the rules of figure 3

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.

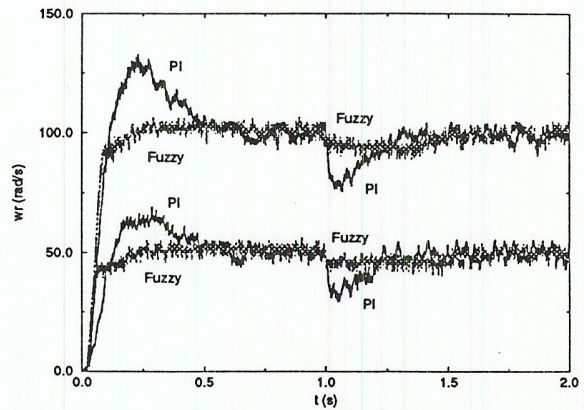


Figure 5: Time response adding integral rules

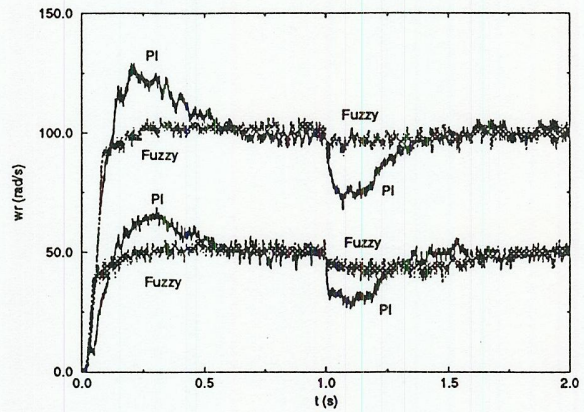


Figure 6: Time response when rotor resistance is halved

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.

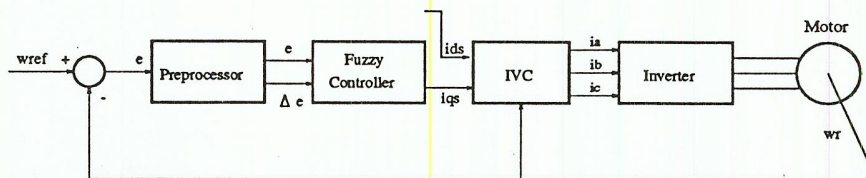


Figure 1: Block diagram of Induction Motor Control

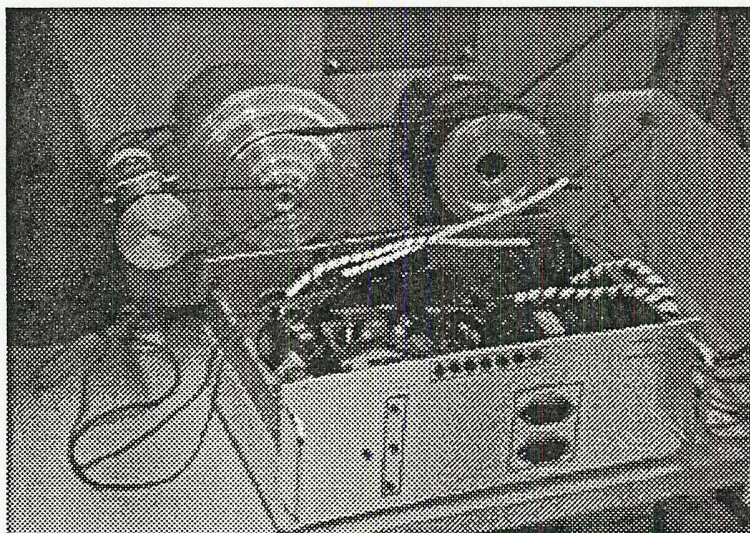


Figure 8: Motor-inverter prototype

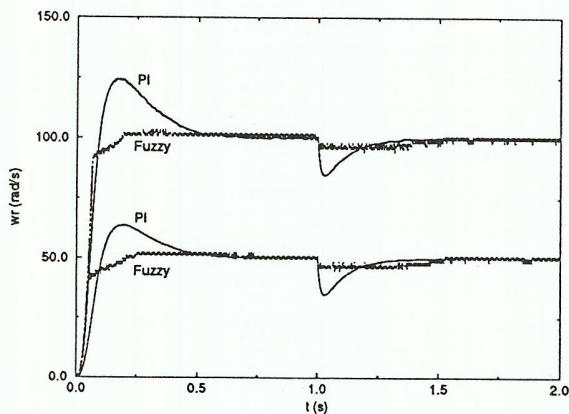


Figure 7: Time response with a 20 KHz inverter

$L_m(H)$	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 responses 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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