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Application of Fuzzy Logic for Control Speed of an Indirect Vector Control Induction Motor

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Abstract: This study deals with the application of Fuzzy Logic to Control (FLC) speed regulation of an Indirect Field Oriented (IFO) induction motor and compares the simulation results with this obtained by conventional PI controller have been. The proposed fuzzy logic controlled constituted by fuzzy IF-Then rules with this learning capability, can learn and tune rapidly, even when the motor parameters variation.The speed control performance is demonstrated by some simulation results .

Key words: Variable speed drive, induction motor, IFO, fuzzy logic control, parameters variations

INTRODUCTION

Field orientation control of induction motors is one of the most important topics in the variable speed drive area today. Its key technique is the acquisition of flux position[1]. Most field orientation schemes in the literature are based on variable transformations. Several mathematical co-ordinate transformations are required to translate the AC electrical quantities of the induction motor to the DC quantities of the two-phase model in the synchronous reference frame. The vector controlled induction motor drive offers better dynamic performance and it is widely used in a number of industrial applications. The main problem for induction motor control is the on-line change of the model parameters and as a result, the system performance will deteriorate by presenting instability. Therefore for decoupling the stator current component torque generating and the magnetizing current suitably. This command is determined with the knowledge of rotor time constant which in fact varies with temperature, saturation, variation of the moment of inertia[2]. A fuzzy logic is used for reducing the sensitivity of the flux orientation to the variation of the parameter.

First, we will describe the system to regulate and the strategy of control and next we will give the structure of the controller and explained how it works. Finally we will compare its performances results to its conventional equivalent controller.

CONTROL SYSTEM

The control system is based for the indirect vector controlledit is composed of a squirrel-cage induction motor and a Pulse With Modulated (PWM) inverter. Field orientation is a technique that provides a method of decoupling the two components of stator current one producing the air gap flux and the other producing the torque. Therefore, it provides independent control of torque and flux[3]. Which is similar to a separately excited DC machine, the magnitude and phase of the stator currents are controlled in such a way that lux and torque components of current remain decoupled during dynamic and static conditions. However, changes in the parameter cause field orientation detuning and degrade system performance[4]. A conventional synchronous PI current regulator used to implement decoupled flux and torque control.

Figure1 haws the proposed PI controller for a current components I_{ds} and I_{qs} under an IFO controlled induction machine. The controller consists of two feedback loops. The speed is regulated by the external block loop. The regulator output is the electromagnetic torque with reference T^*_{em} or the current with reference i^*_{qs}. It is limited in manner to take account of caracteristic IGBT (Insulated Gate Bipolar Transistor) inverter and overload of the machine.This current is compared to the I_{qs} value which is given by reel current measurements. The error is affected to the regulator input the output of which of the regulator

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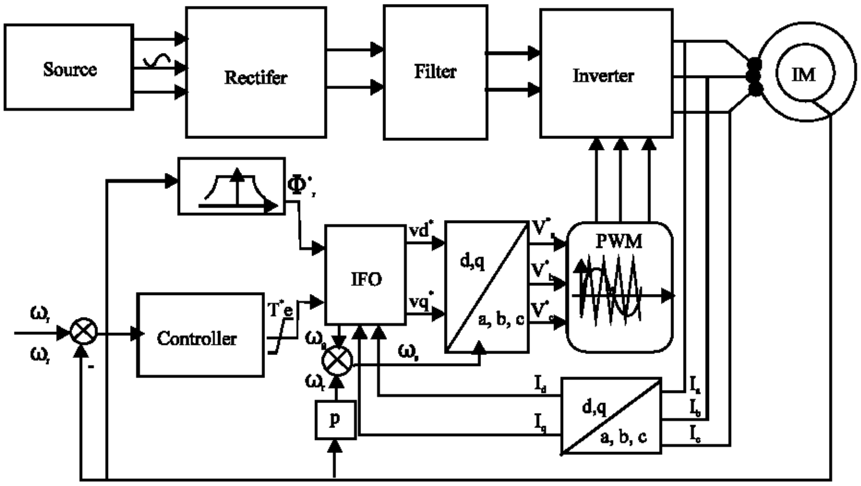

Fig. 1: Bloc of control system

is the reference voltage standard V^*_{as} is limited. In parallel with this internal loop, we find a regulator loop of I_{ds}. This reference current I^*_{ds} is computed from an imposed flux. This flux is related to its minimal value for a speed zone less then the bases speed. Over this zone, we start to defluxage of the machine in order to reaches the higher speeds.

The induction motor Park model in a rotating reference frame is expressed as follows[3] is given by:

$$\begin{cases} \dfrac{dI_{ds}}{dt} = \dfrac{1}{\sigma L_S}\left[-\left(R_S + \left(\dfrac{L_m}{L_r}\right)^2 .R_r \right) I_{ds} + \sigma L_S \omega_S I_{qs} + \dfrac{L_m R_r}{L_r^2}\phi_{dr} + \dfrac{L_m}{L_r}\omega_r \phi_{ds} + V_{ds} \right] \\ \dfrac{dI_{qs}}{dt} = \dfrac{1}{\sigma L_S}\left[-\sigma L_S \omega_S I_{ds} - \left(R_S + \left(\dfrac{L_m}{L_r}\right)^2 .R_r \right) I_{qs} - \dfrac{L_m}{L_r}\omega_r \phi_{dr} + \dfrac{L_m R_r}{L_r^2}\phi_{qr} + V_{qs} \right] \\ \dfrac{d\phi_{dr}}{dt} = \dfrac{L_m R_r}{L_r} I_{ds} - \dfrac{R_r}{L_r}\phi_{dr} + (\omega_S - \omega_r)\phi_{qr} \\ \dfrac{d\phi_{qr}}{dt} = \dfrac{L_m R_r}{L_r} I_{qs} - (\omega_S - \omega_r)\phi_{dr} - \dfrac{R_r}{L_r}\phi_{qr} \end{cases}$$

Where $\sigma = 1 - L^2_m / L_s L_r$

The mechanical modelling part of the system is given by:

$$\frac{d\Omega_r}{dt} = \frac{1}{J}.(T_{em} - T_l - k_f \Omega_r)$$

$$\text{with} \qquad T_{em} = \frac{3}{2} P \frac{L_m}{L_r}(\phi_{dr} I_{qs} - \phi_{qr} I_{ds})$$

The induction motor dynamics may be simplified by using the Indirect rotor flux-oriented representation in the d-q reference system[5], with $\phi_{dr} = \phi_r$ and $\Phi_{qr} = 0$.

The speed is controlled with a fuzzy or conventional controller that generates the reference torque T^*_{em} to be applied to the open loop structure (IFO).

The rotor flux reference ϕ^*_r esteemed from the nominal voltage and reference value of the machine is controlled simply by the block flux function , which is defined by the following relationship:

$$\phi^*_r = \phi_{rnom} \quad \text{if} \quad |\Omega_r| \le \Omega_{rnom}$$

$$\phi^*_r = \frac{\phi^*_r \Omega_{rnom}}{|\Omega_r|} \quad \text{if} \quad |\Omega_r| > \Omega_{rnom}$$

The rotor flux reference is constant in the constant torque region, but it is weakened as inversely proportional to speed in the constant power region.

The principle of the field oriented theory[6], is to direct the axis d-q so that the axis d is in place with flow, i.e. $\phi_{dr} = \phi_r$ and $\phi_{qr} = 0$. In order to eliminate the influence from reaction of the rotor and stator escape, one retains that the order with orientation of flow rotor[6].

Then, by imposing ϕ_{qr} =0, the equations of the machine in a referential related to the spinning field patterns become:

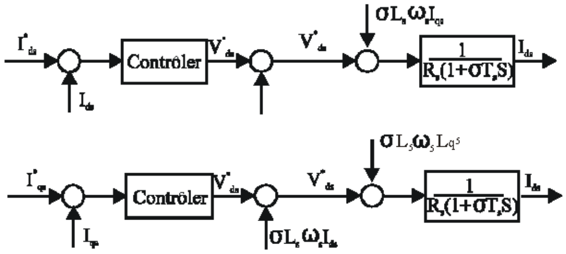

Fig. 2: Bloc of decoupling between the axes d and q

$$\phi_r = \phi_{dr}$$

$$V_{ds} = R_s I_{ds} + \sigma L_s \frac{dI_{ds}}{dt} + \frac{L_m}{L_r}\frac{d\phi_r}{dt} - \omega_s \sigma L_s I_{qs}$$

$$V_{qs} = R_s I_{qs} + \sigma L_s \frac{dI_{qs}}{dt} + \omega_s \frac{L_m}{L_r}\phi_r + \omega_s \sigma L_s I_{ds}$$

$$T_r \frac{d\phi_r}{dt} + \phi_r = L_m I_{ds}$$

$$\omega_r = \frac{L_m}{T_r \phi_r} I_{qs}$$

$$\theta_s = \int (\omega_r + \frac{L_m I^*_{qs}}{T_r \phi^*_r})$$

Where $T_r = L_r/R_r$
Concerning, the coupling it is illustrated by considering the equations of the asynchronous motor ordered by orientation of rotor flow and, supposing that its module only varies very slowly compared to I_{ds} and $_{IQs}$. They scribe then[6]:

$$V_{ds} = (R_s + S\sigma L_s) I_{ds} - \omega_s \sigma L_s I_{qs}$$

$$V_{qs} = (R_s + S\sigma L_s) I_{qs} + \omega_s \frac{L_m}{L_r}\phi_r + w_s \sigma L_s I_{ds}$$

$$\phi_r = \frac{L_m}{1 + T_r S} I_{ds}$$

$$\omega_r = \frac{L_m}{T_r \phi_r} I_{qs}$$

We note that, the terms correspond under the terms of coupling between the axes d and q.

$$\omega_s \sigma L_s I_{qs} \;, \omega_s \frac{L_m}{L_r}\phi_r \text{ and } \omega_s \sigma L_s I_{ds}$$

In This study, the method adopted to separate the control loops from axis d and q consists in adding identical tensions but of opposed signs as shows it Fig. 2 following.

FUZZY LOGIC CONTROLLER

In Fig. 3, the FLC is constituted by fore components fuzzification, rule base, inference mechanism and defuzzification. The fuzzification block is the interface between the fuzzy controller and the real world. It converts the real inputs to fuzzy sets. The interface mechanism uses the fuzzy sets inputs and the fuzzy rules in the rule base to produce a fuzzy consequence. The defuzzification block converts the fuzzy out put to a real one which can be applied to the controlled process[7].

The rule base is the principal component of the fuzzy controller, it indicates how the controller behaves to response to any input situation the rule base is constituted by Collection of N fuzzy If-Then rules. The input variables are the speed error $e_r(k)$ and the change in the speed error $\Delta_{er}(k)$, expressed by:

$$e_r(k) = \Omega_r(k) - \Omega(k)$$
$$\Delta_{er}(k) = e_r(k) - e_r(k-1).$$

The output variable is the torque command T(k).

We have used seven fundamental linguistic variables NB, NM, NS, ZE, PS, PM, PB respectively negative big, negative medium, negative small, zero, positive small, positive medium, positive big. The membership functions of the linguistic variables of the error speed and the change of error speed are the same and are not symmetrical in order to improve the response near the reference speed. The control rules are presented in table1 and are formulated as follows[7]:

if $e_r(k)$ is A_i. and $\Delta_{er}(k)$ is
Bi then T(k) is Ci where, $i = i....N$

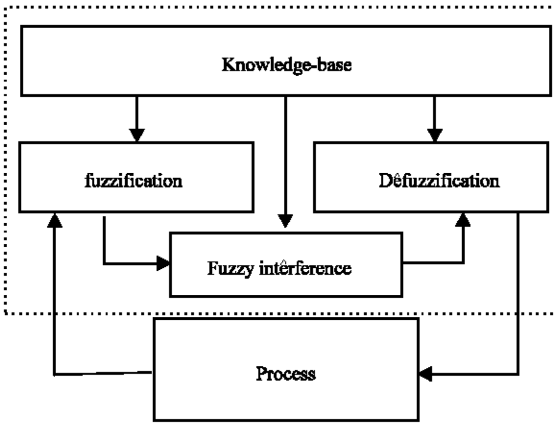

Fig. 3: Fuzzy system

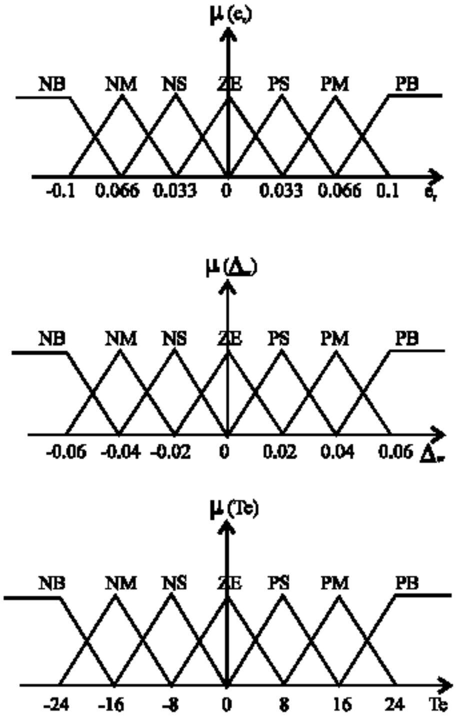

Fig. 4: Membership functions

ce/e	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NM	NM	NS	ZE	ZE	ZE
NM	NB	NM	NM	ZE	ZE	ZE	ZE
NS	NB	NS	NS	ZE	ZE	ZE	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	ZE	ZE	ZE	PS	PS	PB
PM	ZE	ZE	ZE	PS	PM	PM	PB
PB	ZE	ZE	ZE	PS	PM	PM	PB

Fig. 5: Matrix of inference

In Fig. 4 the error of the speed is normalised in a universe of discourse of all variables have been normalised in the [-0.1+0.1] interval and Change in error used the variables in the [-0.06, +0.0.6] interval._The universe of the out put variable torque is [-24+24] interval.

A description of inferences is illustrated with the Fig. 5.

RESULTS

After simulation study, performance of the proposed control method has verified. Performance specifications can be met by adjusting the normalizing gains of the fuzzy

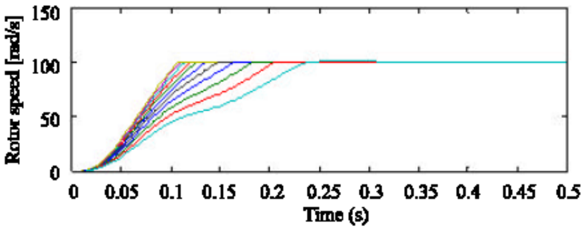

Fig. 6a: Simulation traces of PI controller with change of the rotor resistance and no application of the resistant torque

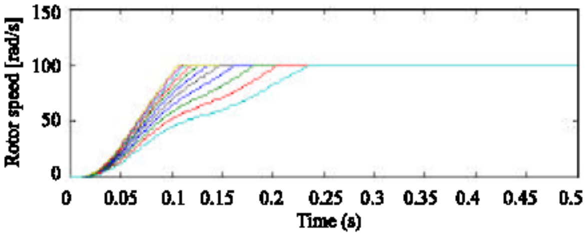

Fig. 6b: Simulation traces of fuzzy controller with change of the rotor resistance and no application of the resistant torque

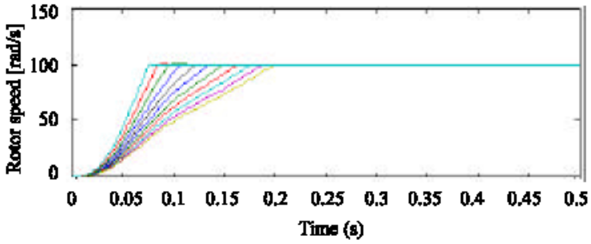

Fig. 6c: Simulation traces of PI controller with change of the moment inertial and no application of the resistant torque

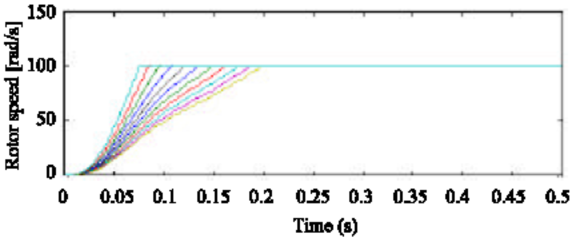

Fig. 6d: Simulation traces of fuzzy controller with change of the moment inertial and no application of the resistant torque

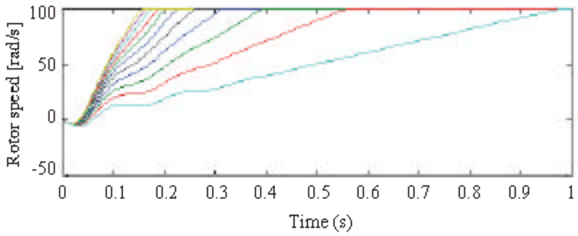

Fig. 7a: Simulation traces of PI controller with change of the rotor resistance and application of the resistant torque

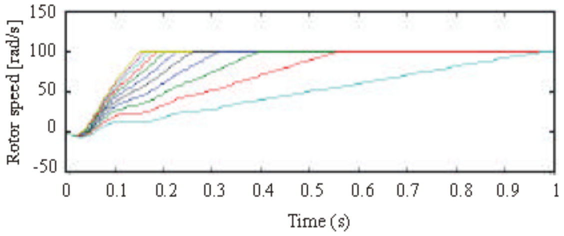

Fig. 7b: Simulation traces of fuzzy controller with change of the rotor resistance and application of the resistant torque

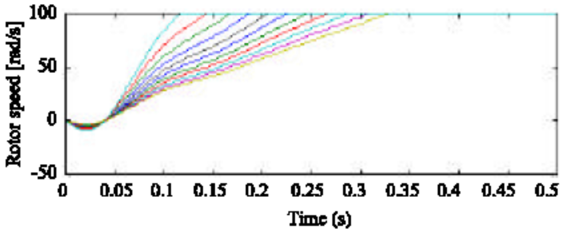

Fig. 7c: Simulation traces of PI controller with change of the moment inertial and application of the resistant torque

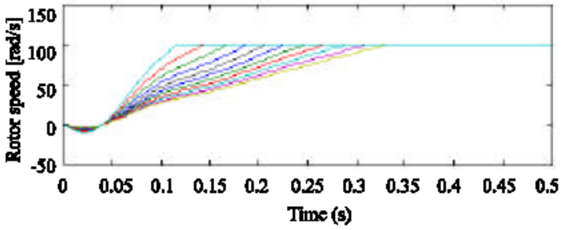

Fig. 7d: Simulation traces of fuzzy controller with change of the moment inertial and application of the resistant torque

logic controller, with considerations of the limiting the torque and the flux of the rotor machine, so in Fig. 6 and 7, the control of variable speed is assured bay fuzzy logic controller and PI Controller, show simulation with change of the rotor resistance moment inertial for several values and application of The perturbation, in remark that speed remains stable in the value of Reference 100 rad/s, what

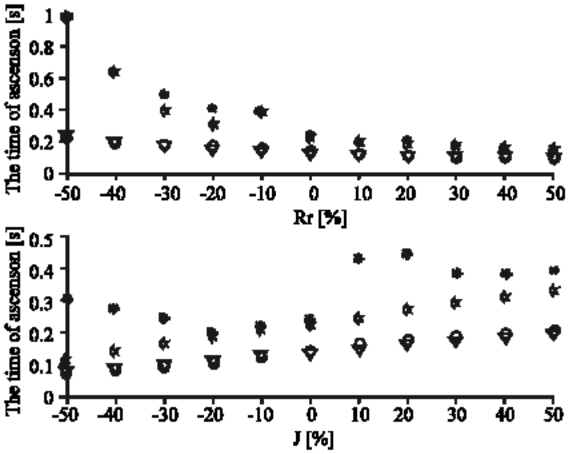

Fig. 8a: The time of ascension of the speed with PI and fuzzy controller in chage of the rotor resistance and moment inertial

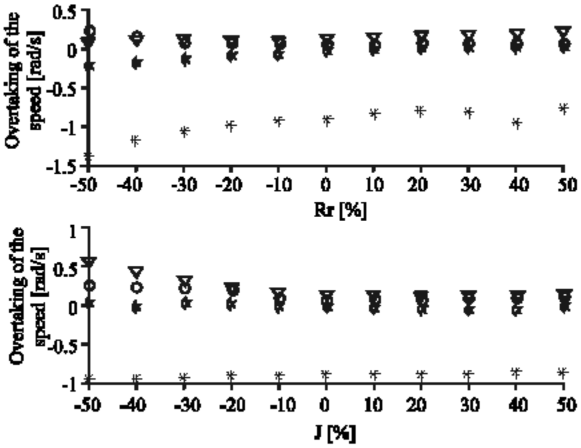

Fig. 8b: Overtaking of the speed with PI and fuzzy controller in change of the rotor resistance and moment inertial

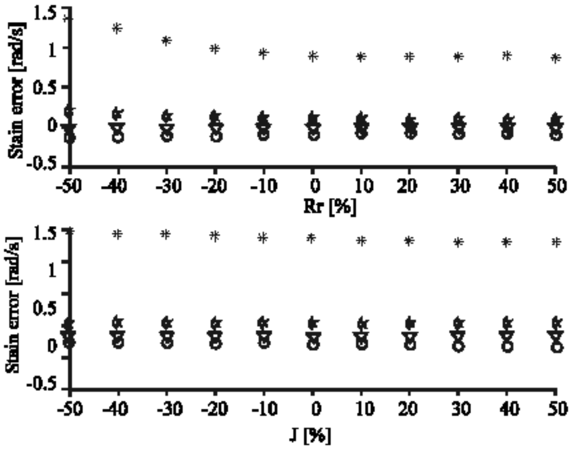

Fig. 8c: Static Error of the speed with PI and fuzzy controller in change of the rotor resistance and moment inertial

shows the robustness of the fuzzy controller live has screw the exteriors perturbation.

Then Fig. 8 shows simulation with change the value of the rotor résistance and the moment inertial for several values and application of the perturbation, in remark that the speed attain its value optimal and is stabilized has this value, The time of ascension and the overtaking of the speed and static error has minimized bay fuzzy logic controller. Dank can about it say that the fuzzy controller is robust with the variations of the moment inertial and rotor resistance of the machine.

We also took into account the indics of following qualities time of assembled and the time of response T_r.

CONCLUSION

This study has presented a comprehensive review of the control of induction motor. A field oriented controller is present high-performance. In this technique, AC machine is similar in DC machine. In this study, principles and use fullness of fuzzy logic and PI controller have been illustrated, particularity through applications for the intelligent control of a complex variable speed drive system. Advantages of fuzzy control are that its parameter insensitive, provides fast convergence and accepts noisy and inaccurate signals. System performance, both in study state and dynamic conditions, was found to be excellent.

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