

Comparison between PI & Fuzzy logic control of Induction Motor Drive

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Abstract— This paper compares the response of a induction machine with scalar speed PI controls and with Fuzzy logic controls. Fuzzy Logic Control is a part of intelligent control which contain hard and soft computing. The method uses a new linguistic rule table to adjust the motor control speed, and this FLC can achieve a good system performance of the IM scalar drive, and it is possible to implement a PI fuzzy logic controller instead the traditional PI controller. Hence, improvement can be achieved by the induction machine changing controls PI into Fuzzy.

Keywords— Fuzzy logic controller, PI controller, induction motor.

I. Introduction

In the last few years, fuzzy logic has met a growing interest in many motor control applications due to its non-linearities handling features and independence of the plant modeling. The fuzzy controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator[1][2]. The present work consists in the development and simulation of a controller for a closed loop speed control where the manipulated variable is the volts/Hz relation and, therefore, the slip value. For such applications, the proposed FLC is a suitable way to provide the necessary frequency varying command signal. The frequency command also generates the voltage command through a volts/Hz function generator, with the low frequency stator drop compensation. For simulation purposes, all values are normalized to per unit (pu). This paper will focus only on FLC techniques and the comparison with the classical PI controller.

II. CONTROL TECHNIQUE

Induction motor has several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives speed control has been described. However, for high dynamic performance industrial applications, their control remains a challenging problem because they exhibit significant non-linearity and many of the parameters, mainly the rotor resistance, vary with the operating conditions. a conventional controller such as a PID is unable to maintain satisfactory performance under these conditions. Recently, there has been observed an increasing interest in combining

artificial intelligent control tools with classical control techniques. In this paper both control methods (Classical PI

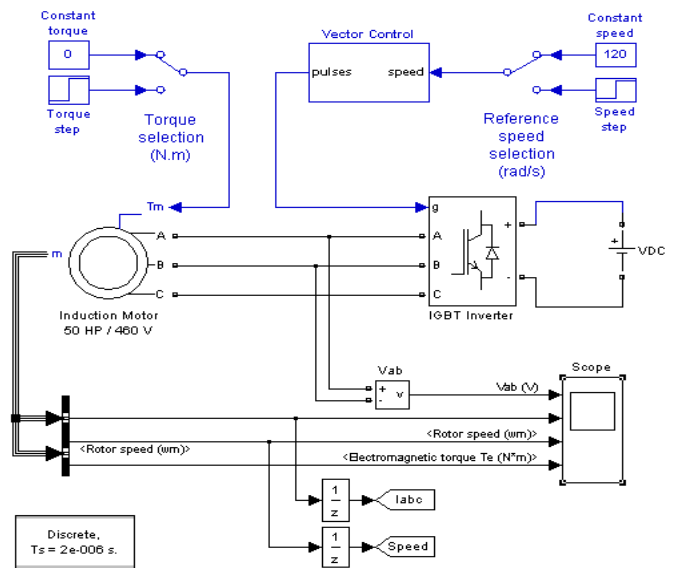


Fig. 1 simulink diagram of Vector Control of a Variable-Frequency Induction Motor Drive using PI controller.

controller and Fuzzy Control base) are introduced and applied to an indirect field oriented induction motor. In the first design approach a classical PI controller is introduced to apply to an induction motor in order to control its speed, as shown in figure 1. Its an simulink diagram of Vector Control of a Variable-Frequency Induction Motor Drive.

In the second design approach the basic fuzzy logic controller (FLC) is applied followed by the interpretation of linguistic IF-THEN rules as a set of controller structures that are switched according to the process states. Fuzzy logic has been implemented in this development of improved motor control because:

- 1) Fuzzy logic overcomes the mathematical difficulties of modeling highly non-linear systems.
- 2) Fuzzy logic responds in a more stable way to imprecise readings of feedback control parameters, such as the dc link current and voltage.

3) Fuzzy logic control mathematics and software are simple to develop and flexible for each modification. Figure 2 shows a typical FLC.

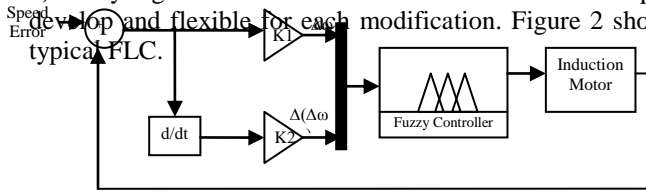


Fig.2 Fuzzy Logic Controller

A. Vector Control Drive

The method of torque control in ac machines is called either vector control or, alternatively field orientation. Vector control refers to the manipulation of terminal currents, flux linkages and voltages to affect the motor torque while field orientation refers to the manipulation of the field quantities within the motor itself. A complete vector controlled induction motor signal diagram is shown in figure 3. The feedback speed control loop generates the active or torque current i_{qs}^* . The vector rotator receives the torque and excitation current commands i_{qs}^* and i_{ds}^* from one of the two positions of a switch: the transient position (1) or the steady state position (2). The fuzzy controller becomes effective at Steady state condition; i.e., when the speed loop error, $d\omega_r$, approaches zero. A disadvantage of this control mode is that the transient response becomes sluggish. For any change in load torque or speed command, fast transient response capability of the drive can be restored by establishing the rated flux.

B. Fuzzy Logic Controller

The fuzzy controller is basically an input/output static non-linear mapping, the controller action can be written in the form

$$K_1 E + K_2 CE = DU \tag{1}$$

Where K_1 and K_2 are non-linear coefficients or gain factors, E and CE are error and change in error respectively, DU is output [6]. Including the summation process above equation can be written as

$$\int DU = \int K_1 E dt + \int K_2 CE dt \tag{2}$$

or

$$U = K_1 \int E dt + K_2 E \tag{3}$$

which is a fuzzy P-I controller with non-linear gain factors. Input variables require be normalized which range of membership functions specify them, in figure (2) normalization factors have shown with K_1 and K_2 . Suitable normalization has direct influence in algorithm optimality and faster response. Figure (4),(5)&(6) shows normalized membership functions for input and output variables. Fuzzy logic controller operation is basis on control expression of table I.

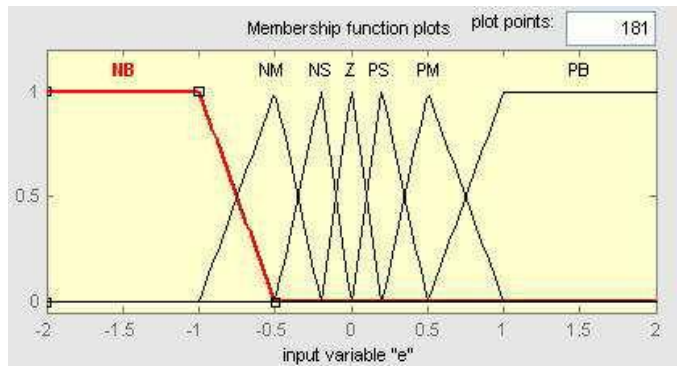


Fig. 4 Input (e) Membership functions

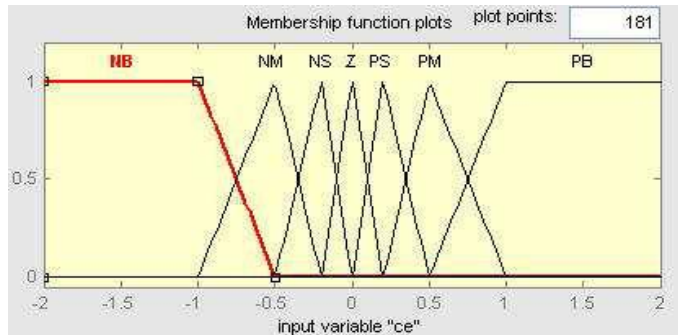


Fig. 5 Input (ce) Membership functions

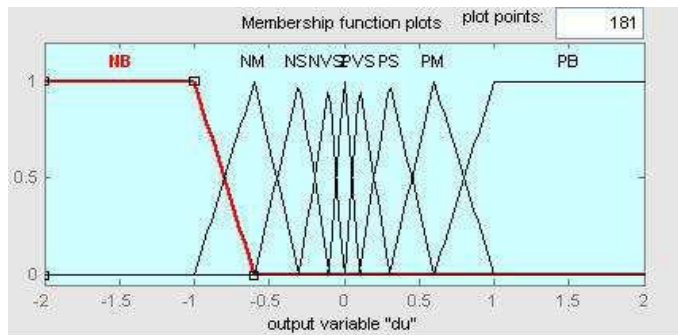


Fig 6. Output (du) Membership functions

C. Fuzzy Set & Rule Formation

A simple control rule can be written in fuzzy logic as:
If error (E) is zero (ZE) and change in error (CE) is negative small (NS), then output (DU) is negative small (NVS).

ZE= Zero NB = Negative Big NM = Negative Medium
NS = Negative Small NVS = Negative Very Small PVS = Positive very small PS = Positive Small PM = Positive Medium PB = Positive Big

Table.1 Rules for FL Controller

CE \ E	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NVS	ZE	PS	PM
ZE	NM	NS	NVS	ZE	PVS	PS	PM
PS	NM	NS	ZE	PVS	PS	PM	PB
PM	NS	ZE	PS	PS	PM	PB	PB
PB	ZE	PS	PM	PM	PB	PB	PB

Next figure shows 3-dimensional surface of the I/O membership function used in Fuzzy Logic System

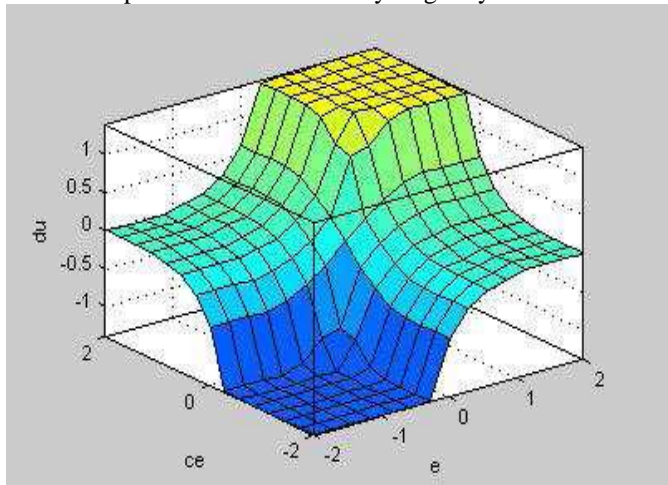


Fig. 7. Three-dimensional plot of control surface.

III. Simulation RESULTS

In this paper two case studies have been studied. In Both simulations, it is used simulink and powersym toolboxes of MATLAB software. In the first case study, a 50 HP induction motor is started and controlled by a PID controller. 3 phase voltages and currents are measured and plotted in the first 3 seconds of its action. Also acceleration curve and output torque are investigated. All graphs are shown in figure 9. In the second case, the same motor is started and controlled by a Fuzzy Logic Based controller as shown in figure 8. Its a simulink diagram of Fuzzy Vector Control of a Variable-Frequency Induction Motor Drive The results are shown in figure 10. As it is shown the outputs are improved regarding to magnitude of starting currents and also time response of acceleration. For example amplitude of current with a classic PI controller is about 500 A during startup while with fuzzy logic controller this value reduced to 200 A.

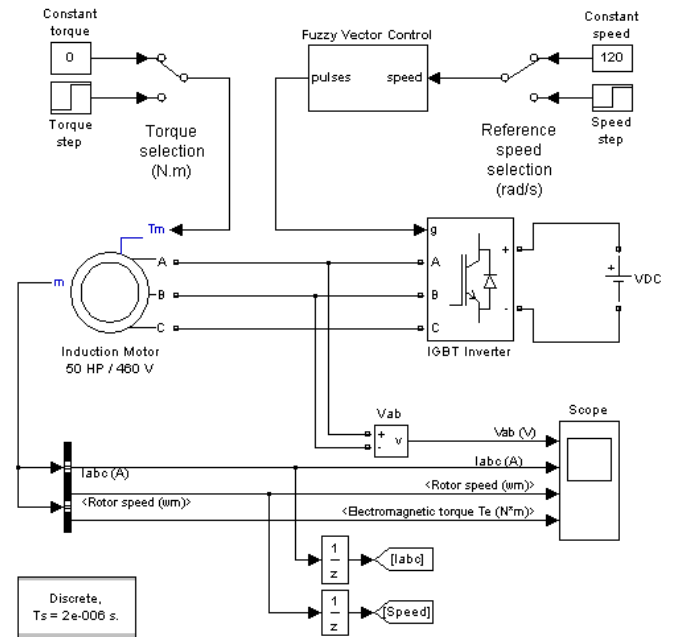


Fig. 8 simulink diagram of Fuzzy Vector Control of a Variable-Frequency Induction Motor Drive using Fuzzy Logic controller.

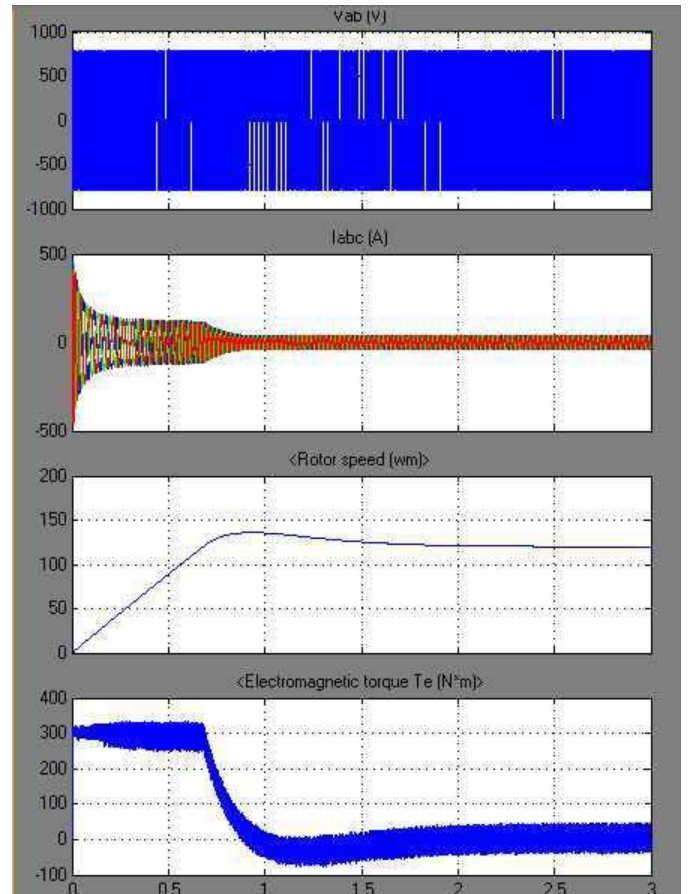


Fig 9. Output Variable of a classic controlled induction Motor from Top to Bottom: Voltage, Current, Rotor Speed, Output Torque

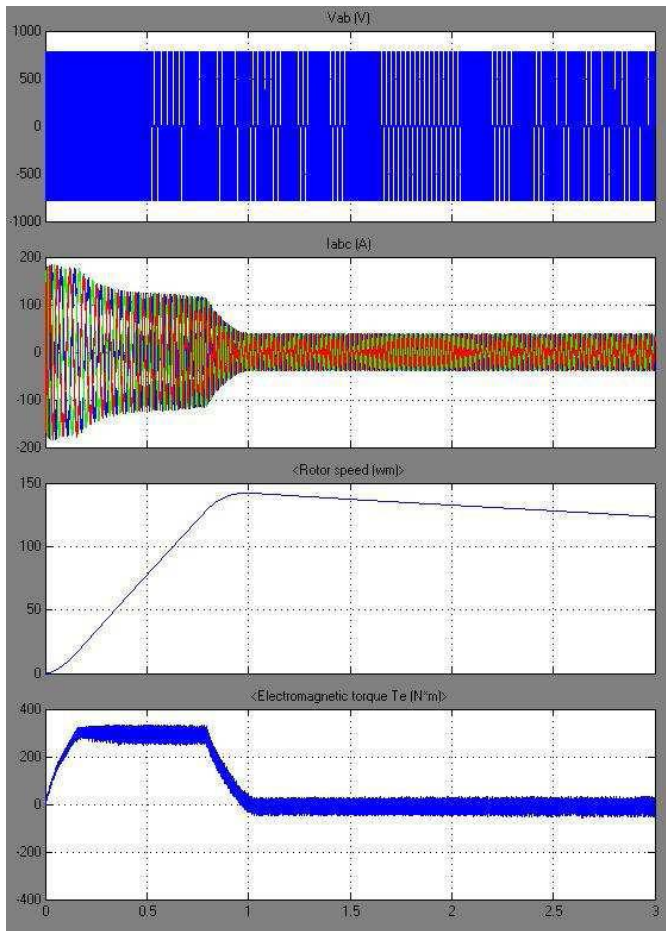


Fig 10. Output Variable of fuzzy controlled induction motor from top to bottom: Voltage,Current,Rotor speed,Output Torque

iv. Conclusions

Fuzzy logic controller can be used for controlling the speed of electrical motor without requiring mathematical model of the system. By this way, efficiency, performance and reliability of drives increases. For test of performance of an electrical motor drive, with fuzzy logic controller was implemented. It does not require to accurate motor and drive model. Induction motor drive was implemented with suitable speed regulation. Steady state error in speed control is acceptable and there is not any overshoot. Result of speed driver show that design and implementation are suitable.

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