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Strategies of Speed Control of Induction Motor Drive

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Abstract—**The synthesis of the standard proportional integral regulator types is characterized by its sensitivity during parametric variations of controlled system controlled. So, to remedy this problem the adjustment techniques are developed. In this order, the work presented in this paper proposes the use of a fuzzy regulator for controlled the speed of a three-phase induction_machine.**

For this purpose, the model of the induction machine is presented as well as the structure of the fuzzy control adopted. Then, thanks to the numerical simulation under MatLab the performances during the variation of the rotor resistance are analyzed compared to the result with a PI controller.

Keywords— **Induction motor, FLC controller, PI controller, speed control, Performances, simulation.**

NOMENCLATURE

R_s:	stator resistance (Ω);
R_r:.	rotor resistance(Ω);
L_s:	stator inductance (H);
L_r:	rotor inductance (H);
L_m:	magnetizing inductance(H);
J:	motor inertia (Kg.m^2);
K_f:	viscous coefficient;
P:	number of pairs poles;
φ_s	stator flux (H);
φ_r	stator flux (H);
i_s:	stator current (A);
i_r:	rotor current (A);
T_l	load torque (N.m);
T_e	electromagnetic torque (N.m);
w_s	stator pulsation (rd/s)
w_r	rotor pulsation (rd/s)
w_{sl}	Slip frequency (rd/s);
s	Slip;
Ω_r	rotor speed (rd/s)
σ :	leake flux total coefficient;
θ_s :	stator angle

I. INTRODUCTION

In industry, variable speed electric drives are often used. He are generally equipped with electric machines such as squirrel induction machines because require the lower maintenance, smaller motor size, and improved reliability. But, there control is complex due highly non-linear and time-varying dynamics. So, the vector control strategy has solved the coupling problem in separation between the flux and electromagnetic torque but this control is sensitive to drive parameter variations and therefore the performance may deteriorate if conventional controllers are used [1]. So, the cage induction motor (IM) is most often used of variable speed.

Generally, the variable speed application requires the high performances. However, field oriented control of induction machines was introduced by Blaschke and Hasse which has better dynamic response. This method is one of the most popular drive machine due to its dynamic performance [2-4]. Most of the research on the drive design of the IM concentrated on the modern control design, such as Sliding Mode Control [5], Fuzzy Logic Control [6], Neural Networks Control [7], H_∞ Control [8], Neural-Fuzzy Control [9], etc. However, the rotor flux indirect vector control technique is most widely used [10]. The main objective of the FOC is to independently control the flux and the torque.

These two control methods are introduced and applied to an indirect field oriented induction motor. These controllers are evaluated under simulations for a variety of operating conditions of the drive system and the results demonstrate the ability of the proposed control structures to improve the performance and robustness of the drive system.

The organization of this paper is as follows. Section II develops the model of IM and introduces the field oriented control method applied for induction machine. Section III presents the synthesis of speed fuzzy logic controller. Section IV shows the simulation results and their discussion. Finally, section V presents the conclusion.

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II. SYSTEM DESCRIPTION AND CONTROL

The description of indirect field oriented control (IFOC) considered is show in Fig. 1 and the induction motor parameters are indicates in the Table I.

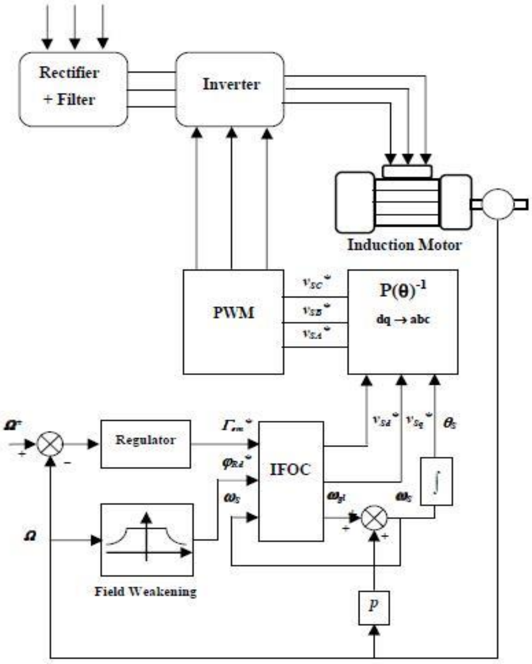


Fig. 1 Bloc diagram of Indirect Field Oriented Control

The induction motor model is defined by the electrical and mechanical equations [11]. The system can be represented by the state equation as following [12, 13]:

$$\dot{X} = AX + BU \tag{1}$$

$[X] = [i_{ds}\, i_{qs}\ \Phi_{dr}\ \Phi_{qr}]^T$ is the state vector, $[U] = [v_{ds}\, v_{qs}\,]^T$ is the control vector, A and B are the matrix defined by:

$$A = \begin{bmatrix} -\frac{1}{\sigma L_s}\left(R_s + \frac{1}{T_r}\frac{L_m^2}{L_r}\right) & \omega_s & \frac{1}{\sigma L_s}\left(\frac{L_m}{L_r}\right)\frac{1}{T_r} & \frac{1}{\sigma L_s}\left(\frac{L_m}{L_r}\right)\omega \\ -\omega_s & -\frac{1}{\sigma L_s}\left(R_s + \frac{1}{T_r}\frac{L_m^2}{L_r}\right) & -\frac{1}{\sigma L_s}\left(\frac{L_m}{L_r}\right)\omega & \frac{1}{\sigma L_s}\left(\frac{L_m}{L_r}\right)\frac{1}{T_r} \\ \frac{L_m}{T_r} & 0 & -\frac{1}{T_r} & \omega_s - \omega \\ 0 & \frac{L_m}{T_r} & -(\omega_s - \omega) & -\frac{1}{T_r} \end{bmatrix} \tag{2}$$

$$B = \begin{bmatrix} \frac{1}{\sigma L_s} & 0 \\ 0 & \frac{1}{\sigma L_s} \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \tag{3}$$

Where, $\sigma = 1 - \frac{L_m^2}{L_s L_r}$.

The electric model must be supplemented by the terms of the electromagnetic torque and speed, and describing the mechanical mode. The electromagnetic torque (T_e) can be written in several forms [14]:

$$T_e = K_t(\Phi_{dr} i_{qs} - \Phi_{rq} i_{ds}) \tag{4}$$

Where, $K_t = p\frac{3}{2}\frac{L_m}{L_r}$ is the torque constant with p is number of pairs poles .

The success of FOC is based on the proper division of stator current into two components: the torque component i_{qs_ref} and magnetizing flux component i_{ds_ref}. The IFOC method uses a slip equation for partitioning the stator current [15-17]:

$$\omega_{sl\_ref} = \frac{R_r}{L_r}\frac{i_{qs\_ref}}{i_{ds\_ref}} \tag{5}$$

With: $\omega_{sl\_ref} = \omega_s - \omega_r$

Where, R_r an L_r rotor resistance and inductance referred to stationary side respectively; ω_{sl_ref} : slip frequency; ω_s: synchronous speed; ω_r: rotor speed.

A block diagram of IFOC is shown in Fig. 2.

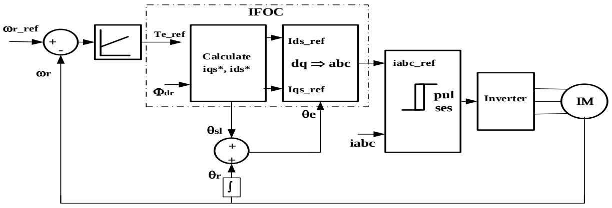


Fig . 2. Bloc schema of speed control

The classic Proportional and Integral (PI) controller is firstly calculated, by the method of location of poles. Considering the transfer function of the mechanical part of the machine:

$$\frac{\Omega(s)}{T_{em}(s)} = \frac{1}{k_f + J.S} \tag{6}$$

The structure speed control is show by Fig. 3.

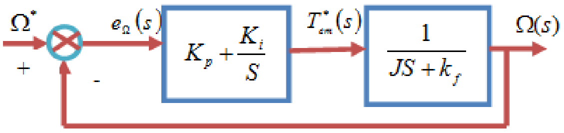


Fig. 3. IM speed control loop with PI

The transfert function is:

$$\frac{\Omega(s)}{\Omega^*(s)} = \frac{(K_p S + K_i)\left(\frac{1}{J}\right)}{P(s)} \tag{7}$$

Where

$$P(s) = s^2 + \frac{k_f + K_p}{J} + \frac{K_I}{J} = 0 \tag{8}$$

Imposing two (2) conjugated complex poles: $P_{1,2} = \alpha(1 \pm j)$, in closed loop, we deduce by identification:

$$S^2 + 2\alpha S + 2P^2 \tag{9}$$

So, $$K_p = 2\alpha J - k_f \tag{10}$$

And, $$K_i = 2\alpha^2 J \tag{11}$$

III. FUZZY LOGIC PRINCIPLE

In this section, we will illustrate the principles of fuzzy controllers, their design and their use in vector control of the IM. The principle of fuzzy logic controllers is based on the techniques of artificial intelligence whose theoretical foundations have been made by Zedeh [18]. The fuzzy logic controller operates in know ledge- based way, and it's know ledge relies on a set of linguistic if…then rules, like human operator. The block diagram of fuzzy logic control is mainly depicted in Fig. 4 [19].

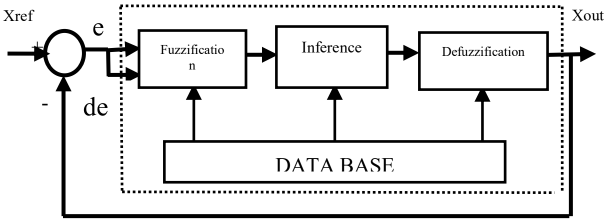


Fig. 4. The structure of a fuzzy logic

The FLC is made up of parameters such as rules base, data base, membership functions, input and output scaling factor (SF) [20-22].

In order to apply the vector control of IM, we define the error (e) and the derivative of the error (de) of the variable to be controlled:

$$\begin{cases} e_X(k) = X_{ref}(k) - X(k) \\ de_{X(K)} = e_X(k) - e_X(k-1) \end{cases} \tag{12}$$

Where x present, currents components ids, iqs, and speed w_r .

The definition of membership function, the controllers has too inputs (e(k) , de(k)) and a single output (S_x),(see Fig. 5, Fig. 6 and Fig. 7) . Otherwise the Fig. 8 and Fig. 9 shows respectively, the surface and rules.

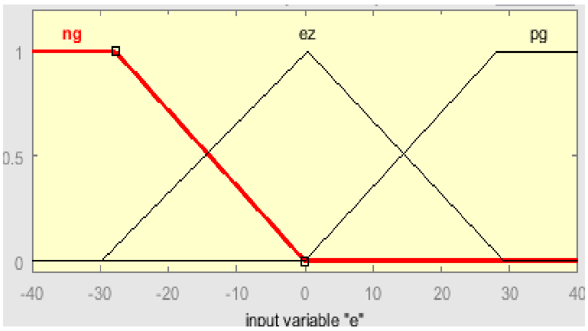


Fig. 5. Inputs membership function of "*e" and* of "*de"*

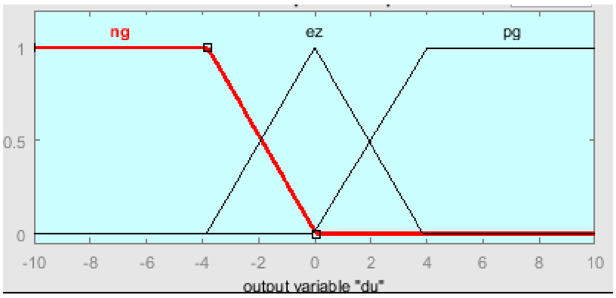


Fig. 6. Output membership function of "*du"*

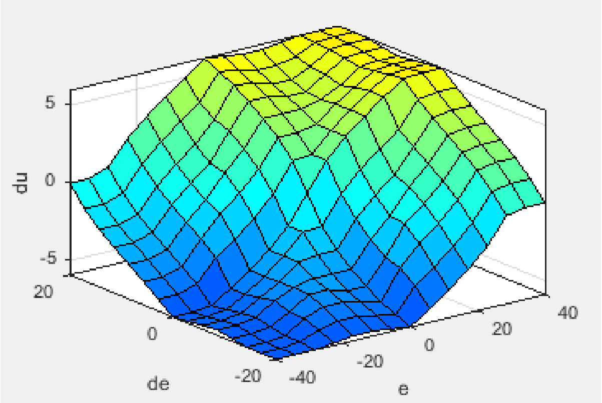


Fig. 7. Surface of FLController

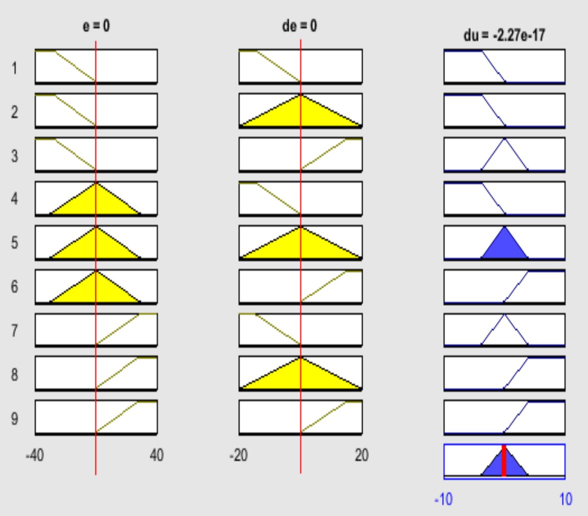
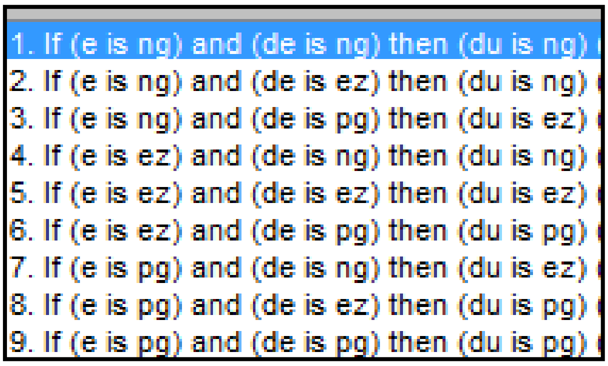


Fig. 8. Rules of FLC

TABLE II: Rules tables



1. If (e is ng) and (de is ng) then (du is ng)
2. If (e is ng) and (de is ez) then (du is ng)
3. If (e is ng) and (de is pg) then (du is ez)
4. If (e is ez) and (de is ng) then (du is ng)
5. If (e is ez) and (de is ez) then (du is ez)
6. If (e is ez) and (de is pg) then (du is pg)
7. If (e is pg) and (de is ng) then (du is ez)
8. If (e is pg) and (de is ez) then (du is pg)
9. If (e is pg) and (de is pg) then (du is pg)

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The number of linguistic value are characterizes by the symbols likewise: ng: negative big, ez: zero equal; pg: positive big.

The development of the basic rules of the controller is interpreted by the rules of the form (If…..Then).The fuzzy rules that defined the output of the controllers according to inputs. Where Table 2 present two linguistics variables of inputs "e" and its variation "de" and the output variable « du ».

TABLE I: Rules tables

de / e	ng	ez	pg
ng	ng	ng	ez
ez		ez	
pg	ez	pg	pg

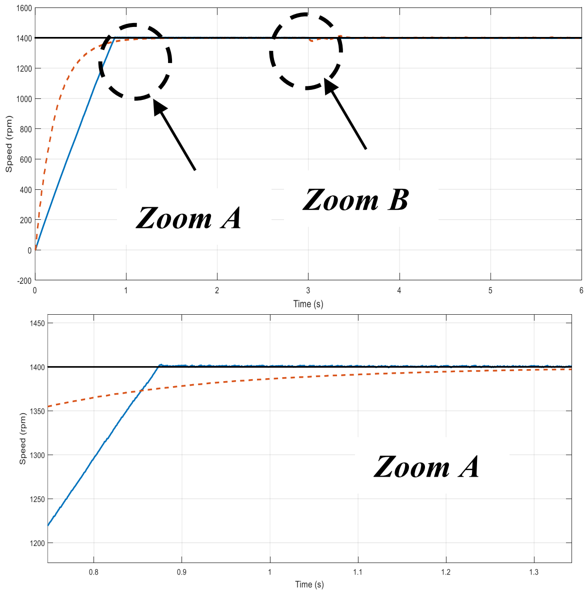
IV. SIMULATION RESULTS

Validation of this study was done by comparison and performance analysis engine magnitudes.

The parameters motor are: R_s=0.435Ω; R_r= 0.316 Ω; L_s=2 mH; L_r=2 mH; L_m=9.3 mH; J=0.089 Kg.m^2; K_f=0.0002 Kg.m/s and p=2.

For this purpose, Two cases of operating are considered: the case where the motor parameters are nominal and the case where the rotor resistance changes. For a reference speed of 1400 rpm, Figure 9 shows the velocity speeds when the rotor resistance is nominal. The essential parts are represented by the zooms A and B. Fig. 10 and Fig. 11 show the superposition of speed responses, respectively, for the case where PI and FLC are used.

It is clear that for PI Controller performance degrades during the application of the load at the moment 3 seconds (loops of speed control); that is, the speed does not follow its reference. On the other hand, when using the controller FLC, the speed correctly follows its reference despite the load (see zoom C). Thus, the performance for FLC is much better.



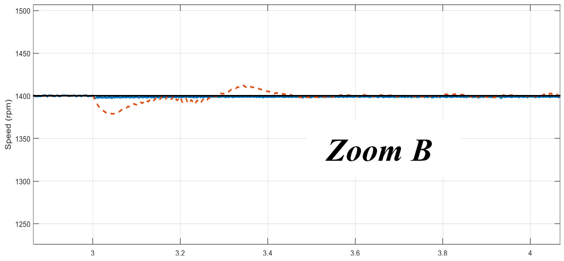


Fig. 9. Speeds with PI and FLC controllers

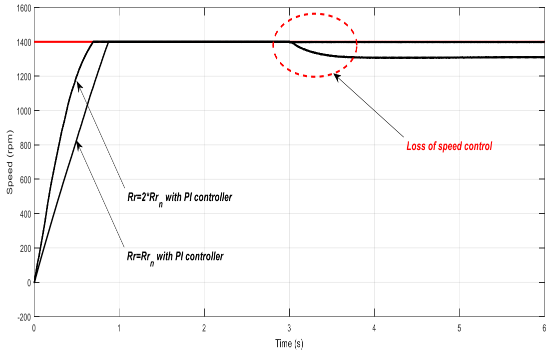


Fig. 10. Speeds with PI and Rr variation

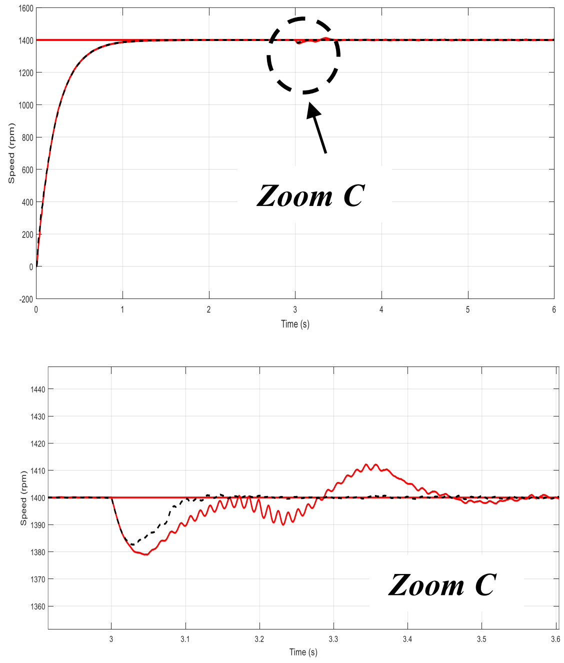


Fig. 11. Speeds with FLC and Rr variation

V. CONCLUSIONS

In this paper, the fuzzy field-oriented control of a induction motor has presented. Different regimes of operation are studied. The case of the variation of , rotor resistance was considered to evaluate the performance of the fuzzy approach. The simulation results have shown that the fuzzy logic controller has very good dynamic performances. Additionally, the robustness tests have shown that FFOC was insensitive to parameters variation. This returns to the fact that the fuzzy logic controller synthesis was realized without taking account of the machine model.

REFERENCES

[1] M. Bayindir, H. Can, Z. H. Akpolat, M. Özdemir, & E. Akin, “Application of reaching law approach to the position control of a vector controlled induction motor drive.“ Electrical Engineering, 87, 207–215. (2005).

[2] Shah Faisal. M , Paliwal. S, ”Speed Control of Three Phase Squirrel Cage Induction Motor Using Fuzzy Logic Controller", Int. Journal of Engineering Research and Application", ISSN : 2248-9622, Vol. 8, Issue5 (Part -IV) May 2018, pp 03-07.

[3] [3] Hamidreza Pairodin Nabi, Pooya Dadashi, Abbas Sloulaie,” A novel structure for vector control of symmetrical six-phase induction machines with three current sensors, ETASR, Engineering Technology & Applied Science Research, Vol 1, N° 2, pp 23-29, 2011.

[4] [4] M.A. Denai, S.A. Attia, "Fuzzy and neural control of an induction motor", International Journal Applied math computer, Vol. 12, N°2, pp 221-233, 2002.

[5] Rai .T , Debre P, "Generalized Modeling Model Of three phase Induction Motor", IEEE, 2016.

[6] B. Kumar, M, Yogesh, K. Chauhan, and V. Shrivastava, “ Efficacy of Different Rule Based Fuzzy Logic Controllers for Induction Motor Drive,“ International Journal of Machine Learning and Computing, Vol. 2, No. 2, April 2012

[7] M. Zerikat and S. Chekroun, “Adaptation Learning Speed Control for a High-Performance Induction Motor using Neural Networks, “World Academy of Science, Engineering and Technology 21 2008, Vol, 14, No. 7, pp. 293-298.

[8] Jyoti yadav,” Speed Control of Induction Motor using Fuzzy Logic Approach”, IJSTE - International Journal of Science Technology & Engineering | Volume 3 | Issue 01 | July 2016 ISSN (online): 2349-784X .

[9] Ramesh, P.; Sharmeela, C. "FLC Based Closed Loop Control of MLI Fed Induction Motor Drive", Journal of Computational and Theoretical Nano science, Volume 14, Number 3, March 2017, pp. 1259-1264(6) . https://doi.org/10.1166/jctn.2017.6440

[10] F. J. Lin and C. H. Lin, “A Permanent-magnet Synchronous Motor Servo Drive Using Self-constructing Fuzzy Neural Network Controller,” IEEE Transactions on Energy Conversion, Vol. 19, No. 1, pp. 66-72 (2004).

[11] Teena P, Mahajan P, "Speed Control Of Induction Motor Using Fuzzy Logic Controller Using DSPIC30f2010" International Journal Of Electrical, Electronics And Data Communication, ISSN: 2320-2084 Volume-4, Issue-10, Oct.-2016.

[12] P.S. Phutane , S.R. Karpe , "Performance of a 4- switch, 3-phase inverter fed induction motor (IM) drive system", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 2, Issue 3, March 2013.

[13] J. Chatelain , “Machine électriques”, tome I, Edition Dunod 1983, ISBN 2-04-015620-8.

[14] Rosendo Peña Eguiluz, “Commande algorithmique d’un système mono-onduleur bimachine asynchrone destiné à la traction ferroviaire”, These Doctorat De l'INPT Toulouse 2002.

[15] Trzynadlowski A.M. (1994): The Field Orientation Principle in Control of Induction Motors. — Dordrecht: Kluwer.

[16] M. Malinowski, "Sensorless Control Strategies for Three - Phase PWM Rectifiers", Ph.D. Thesis, Warsaw University of Technology, Warsaw, Poland – 2001.

[17] Bimal K. Bose "An Adaptive Hysteresis-Band Current Control Technique of a Voltage-Fed PWM Inverter for Machine Drive System, " IEEE Transaction on Industrial Electronics, Vol.37, No.5, October 1990.

[18] Shaija P Ja, A. E. Daniel, "An Intelligent Speed Controller Design for Indirect Vector Controlled Induction Motor Drive System", Procedia Technology 25 (2016) 801 – 807.

[19] L.A. Zadeh, “The role of fuzzy logic in the management of uncertainty in expert systems,” Fuzzy Sets and Systems, vol 11, no 1–3, pp. 197-198, 1983.

[20] A. Aissaoui, M. Abid, H. Abid, A. Tahour and A. Zeblah, “A fuzzy logic controller for synchronous machine,” Journal of Electrical Engineering, vol. 58, no. 5, pp. 285-290, 2007.

[21] Jagadish H. Pujar and S. F. Kodad, “Robust sensorless speed control of induction motor with dtfc and fuzzy speed regulator,” International Journal of Electrical and Electronics Engineering 5:1 2011.

[22] L. Cammarata and L. Yliniemi, “Development of a self-tuning fuzzy logic controller for a rotary dryer,” Report A of University of Oulu, Department of Process Engineering, no. 1, December 1999.

[23] R. K. Mudi and N. R. Pa1, “A robust self-tuning scheme for PI- and PD-type fuzzy controllers,” IEEE Trans, Fuzzy Systems, vol. 7, pp. 1-16, February 1999.