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A DUAL FUZZY LOGIC CONTROL METHOD FOR DIRECT TORQUE CONTROL OF AN INDUCTION MOTOR

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Abstract: This paper presents a fuzzy logic hysteresis comparator-based Direct Torque Control (DTC) scheme of an Induction Motor (IM) under varying dynamic conditions. Here two fuzzy logic controllers are employed. One of the Fuzzy Logic Controller (FLC) is used to adjust the bandwidth of the torque hysteresis controller in order to reduce the torque and flux ripples and, hence, to improve motor dynamic response. The second fuzzy logic controller is employed in place of PI controller which regulates the speed. Output of this controller is the reference torque, and the inputs are error and change in error produced by comparing command speed with reference speed.

Keywords: Double fuzzy controller, Induction motor, Direct Torque Control (DTC).

I. INTRODUCTION

The advantages of Direct Torque Control (DTC) over its competitor field-oriented control (FOC) are well known. The DTC utilizes hysteresis band controllers for both stator flux-linkage and motor-developed torque controls. Unlike FOC, the DTC scheme does not need any coordinate transformation, pulse width modulation (PWM), and current regulators. The PWM stage takes almost ten times longer processing time than the DTC to respond to the actual change. The DTC uses flux and torque as primary control variables which are directly obtained from the motor itself. Therefore, there is no need for a separate voltage and frequency controllable PWM. This characteristic makes the DTC simpler and much faster in responding to load changes as compared to the FOC. The major problem in a DTC-based motor drive is the presence of ripples in the motor developed torque and stator flux. Generally, there are two main techniques to reduce the torque ripples. The first one is to use a multilevel inverter which will provide the more precise control of motor torque and flux. However, the cost and complexity of the controller increase proportionally. The other method is space vector modulation. Its drawback is that the switching frequency changes

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continuously. Advantages of intelligent controllers such as fuzzy logic, neural network, neuro-fuzzy, etc., are well known as their designs do not depend on accurate mathematical model of the system and they can handle nonlinearity of arbitrary complexity. Among different intelligent algorithms, fuzzy logic is the simplest, and it does not require intensive mathematical analysis.

Artificial intelligence-based controllers have been used by the researchers for the minimization of torque and stator flux ripples in DTC scheme-based induction motor (IM) drives.

II. DIRECT TORQUE CONTROL

A. Conventional DTC scheme

The basic characteristic of DTC is that the positions of the inverter switches are directly determined rather than indirectly, thus refraining from using a modulation technique like Pulse Width (PWM) or Space Vector (SVM) modulation. In the generic scheme, the control objective is to keep the motor's torque and the amplitude of the stator flux within pre-specified bounds. The inverter is triggered by hysteresis controllers to switch whenever these bounds are violated. The choice of the new switch positions is made using a pre-designed look-up table that has been derived using geometric insight in the problem and additional heuristics. The main reason that makes the design of the switching table difficult is the fact that the DTC drive constitutes a hybrid system, i.e. a system incorporating both continuous and discrete dynamics - in particular discrete-valued manipulated variables.

A PI controller is used for speed regulation. Speed is sensed from the induction motor using a shaft encoder and compared with reference, the generated error is processed by a PI controller whose output is corresponding reference torque. Here tuning of PI controller is also somewhat difficult because it relates to complex mathematical expressions, and also tuning is difficult in these type of controllers. Usage of PI controllers does not help in reduction of torque ripple. This is one of the main drawbacks in conventional DTC scheme. Since inverter switches are directly controlled without any modulation techniques, inverter is fed by variable switching frequency pulses which in turn lead to high torque ripples in classical DTC schemes. To overcome this problem intelligent control techniques such as ANN and fuzzy logic schemes are used.

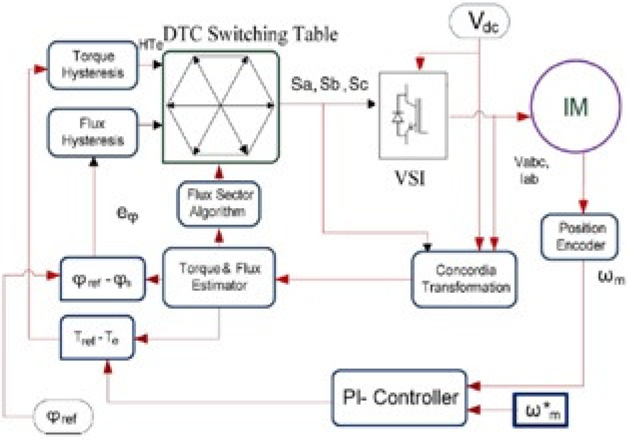


Fig.1 Classical DTC scheme

III. PROPOSED SYSTEM

The proposed controller is a hybrid controller with a fuzzy proportional-integral controller and a proportional term (FPI+P) and fuzzy controller for hysteresis bandwidth variation. The full controller structure is shown in figure 2.

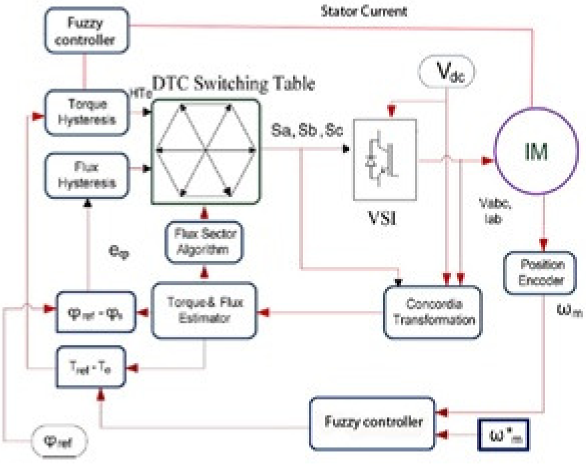


Fig.2 Fuzzy system for speed regulation

A. *Fuzzy Controller for speed regulation*

The proportional gain makes the fast corrections when a sudden change occurs in the input. To eliminate the stationary error an integral action is necessary, so a fuzzy PI is included in the controller. If the error is large and the controller tries to obtain a larger output value than the limits, the integral action will remain in pause until the correction level drops below the saturation level. So, as the error becomes smaller the integral action gains importance as does the proportional action of the fuzzy PI controller.

$$E_2=GE.e,\ CE2=GCE.ce,\ CU2=GCU.cu2 \qquad (1)$$

Where, *GE,GCE* and *GCU* are the scaling factors of the error, change of error and output, used to tuning the response of the controller . $E2$ (error) and $CE2$ (change of error) are the inputs of the fuzzy controller, and $cu2$ (control action) is its output.

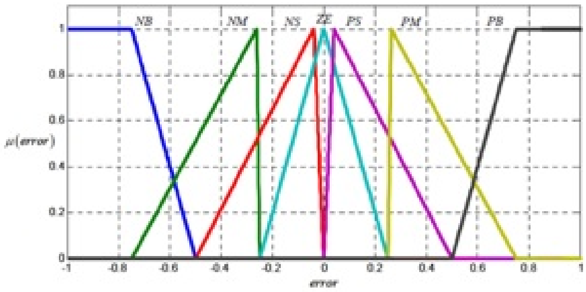


Fig.3 Fuzzy function for error

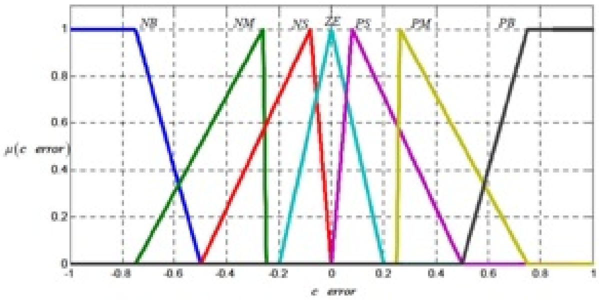


Fig.4 Fuzzy function for change in error

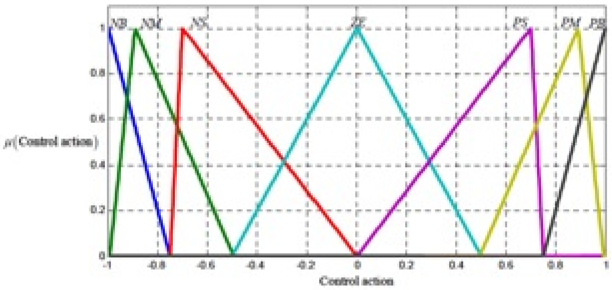
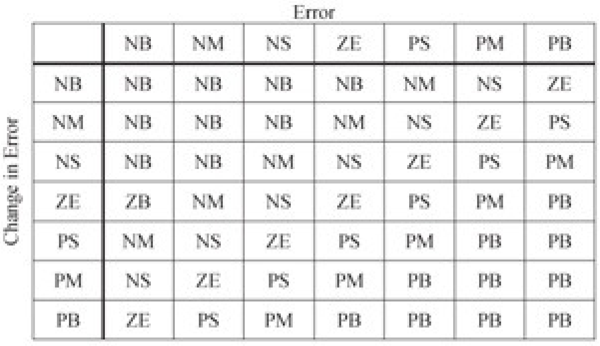


Fig.5 Fuzzy function for output

Table. I: Rule base for the fuzzy controller



Change in Error	Error						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	ZB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

B. Fuzzy controller for hysteresis bandwidth adjustment

In this work, a Mamdani-type FLC is developed to adapt the torque hysteresis band in order to reduce the ripples in the motor-developed torque. In conventional DTC technique, the amplitude of the torque hysteresis band is fixed. However, in this proposed scheme, the FLC controls the upper and lower limits of the torque hysteresis band on the basis of its feedback inputs. The FLC is used as a nonlinear function approximation producing a suitable change in the bandwidth of the torque hysteresis controller in order to keep the torque ripples minimum. There are five membership functions for one input ($dT\ e$) and three membership functions for another input (dIs). Automatically, there will be fifteen rules. For the inputs, normally triangular/trapezoidal membership functions in order to reduce the computational burden. However, Gaussian membership functions are chosen for the output so that the hysteresis bandwidth will be changed smoothly. The motor estimated torque variation ($dT\ e$) and stator current variation (dIs) over a sampling period are chosen as inputs to the FLC which can be defined by the following equations:

$$dT_e = T_e[n] - T_e[n\text{-}1] \tag{2}$$

$$dI_s = I_s[n] - I_s[n\text{-}1] \tag{3}$$

Where $Te[n]$ and $Te\ [n - 1]$ present the present and previous samples of motor-estimated torque, respectively. Combining the equations leads to the conclusion that reducing the motor torque ripples directly reduces the motor speed ripples as well. The output of the FLC is the change in torque hysteresis bandwidth "ΔHBT." The updated upper and lower bandwidths of the torque hysteresis controller are obtained.

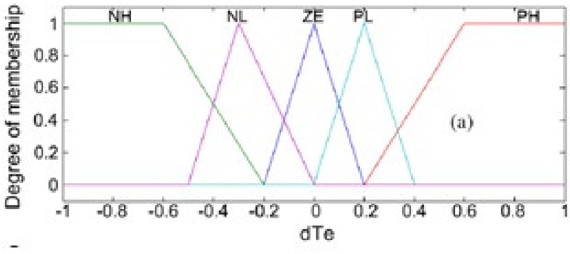


Fig.6 Fuzzy function for change in torque

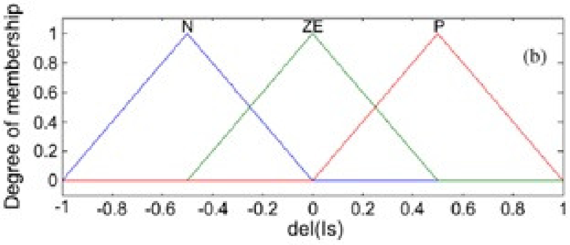


Fig.7 Fuzzy function for change in stator current

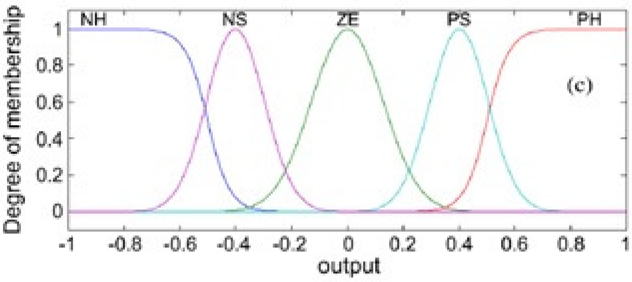


Fig.8 Fuzzy function for output

Table. II Rule base for the fuzzy controller

		CHANGE IN TORQUE				
		NH	**NL**	**ZE**	**PL**	**PH**
CHANGE IN Is	**N**	NH	NH	ZE	PS	PH
	ZE	NH	NH	ZE	PH	PH
	P	NH	NS	ZE	PH	PH

IV SIMULATION RESULTS

A. Simulation results

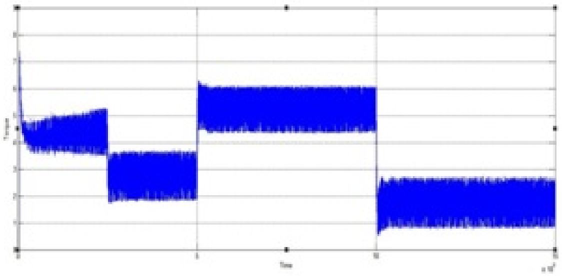


Fig.9 Classical DTC with step change in load from 2Nm to 5Nm back to 1.5Nm

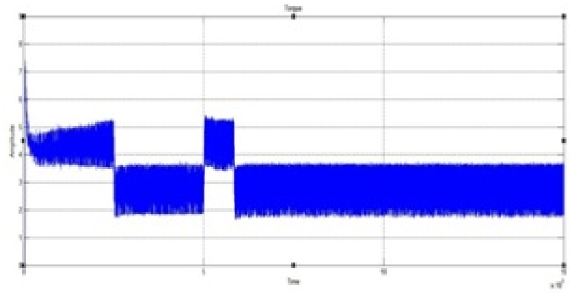


Fig.10 Classical DTC with speed change from 600RPM to 800RPM

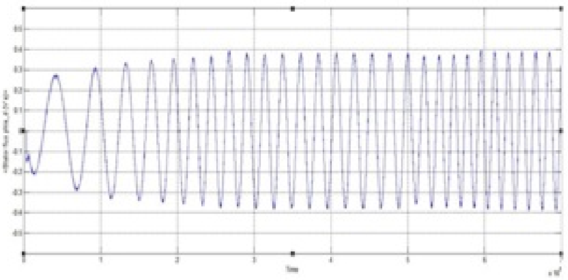


Fig.11 Classical DTC flux

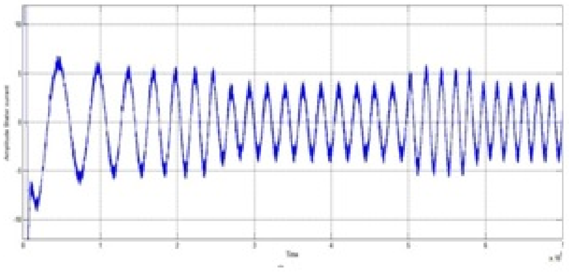


Fig.12 Classical DTC stator current

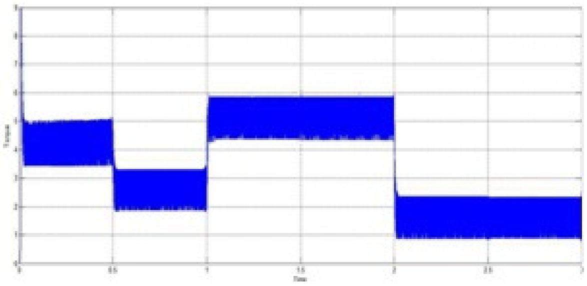


Fig.13 DTC with two fuzzy controllers with load change from 2Nm to 5 Nm to 1.5Nm

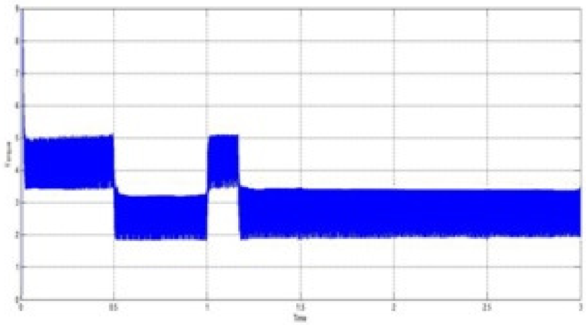


Fig.14 DTC with two fuzzy controllers with speed change from 600 RPM to 800 RPM

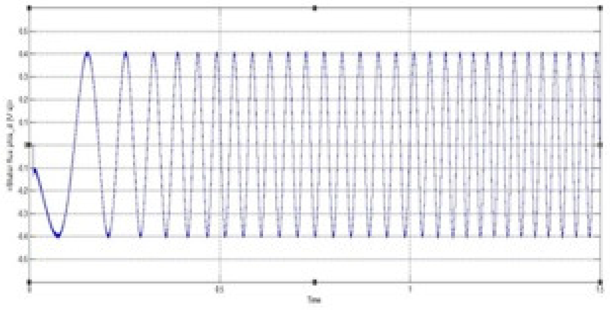


Fig.15 Flux in DTC with two fuzzy controllers

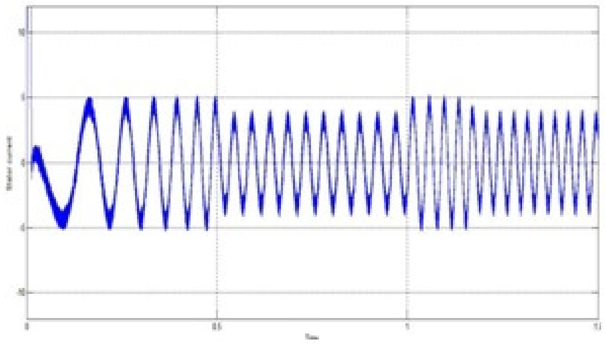


Fig.16 Stator current in DTC with two fuzzy controllers

V. INFERENCE AND CONCLUSION

Simulation is done under various test conditions in MATLAB/SIMULINK. Results are observed in the two schemes of DTC which shows that scheme which employs two fuzzy controllers yields better output with low torque ripples. Ripples are minimum in stator current in scheme which employs two fuzzy controllers. It can be inferred from the above results that DTC with two fuzzy controllers yields a better output. Better results are obtained by proper tuning of the fuzzy logic controllers.

Motor parameters: R_s=1.405, R_r=1.395, L_s=0.005839, L_r=0.005839, L_m=0.172. J=0.0131, B=0.005839, Pole pairs=2.

REFERENCES

[1] I. Takahashi and T. Nouguchi, “A new quick response and high efficiency control strategy for an induction motor,” *IEEE Trans. Ind. Appl.*, vol. IA- 22, no. 5, pp. 820–827, Sep. 1986.

[2] L. Tang, L. Zhong, M. F. Rahman, and Y. Hu, “A novel direct torque control for interior permanent-magnet synchronous machine drive with low ripple in torque and flux-a speed-sensor less approach,” *IEEE Trans. Ind. Appl.*, vol. 39, no. 6, pp. 1748–1756, Sep./Oct. 2003.

[3] S. Kouro, R. Bernal, H. Miranda, C. A. Silva, and J. Rodriguez, “High-performance torque and flux control for multilevel inverter fed induction motors,” *IEEE Trans. Power Electron.*, vol. 22, no. 6, pp. 2116–2123, Nov. 2007.

[4] D. Casadei and T. Angelo, “Implementation of a Direct Torque Control Algorithm for Induction motors based on Discrete Space Vector Modulation,” *IEEE Trans. Power Electron.*, vol. 15, no. 4, pp. 769–777, July 2000.

[5] C.T. Lin and C. S. G. Lee, *Neural Fuzzy Systems: A Neuro-Fuzzy Synergism to Intelligent Systems*. Upper Saddle River, NJ: Prentice-Hall, 1996.

[6] Y.S. Lai and J.-C. Lin, “New hybrid fuzzy controller for Direct Torque Control Induction Motor Drives,” *IEEE Trans. Power Electron.*, vol. 18, no. 5, pp. 1211–1219, Sep. 2003.

[7] L. Youb and A. Craciunescu, “Direct torque control of Induction motors with Fuzzy Minimization Torque Ripple,” in *Proc. WESCO*, 2009, vol.2,pp.713–717.