Minimization of Torque Ripple of Induction Motors using Fuzzy Direct Torque Control

Sunita Chauhan
Associate Professor
National Inst. of Technology,
Kurukshetra, Haryana

Pretty Neelam Topno
M.Tech Control System
National Inst. of Technology,
Kurukshetra, Haryana

Dhaval R. Vyas
M.Tech Control System
National Inst. of Technology,
Kurukshetra, Haryana

ABSTRACT
Direct torque control (DTC) is a new method of induction motor control. The key issue of the DTC is the strategy of selecting proper stator voltage vectors to force stator flux and developed torque within a prescribed band. Due to the nature of hysteresis control adopted in DTC, there is no difference in control action between a larger torque error and a small one. It is better to divide the torque error into different intervals and give different control voltages for each of them. To deal with this issue a fuzzy controller has been introduced. But, because the number of rules is too high some problems arise and the speed of fuzzy reasoning will be affected. In this paper, a comparison between a new fuzzy direct-torque control (DTFC) with space vector modulation (SVM) is done. The principle and a tuning procedure of the fuzzy direct torque control scheme are discussed. The simulation results, which illustrate the performance of the proposed control scheme in comparison with the fuzzy hysteresis connected of DTC scheme are given.

Keywords
Induction machine, Direct torque control, Fuzzy logic, Space vector modulation.

1. INTRODUCTION
In applications of high-performance induction motor drives such as motion control, it is usually desirable that the motor can provide good dynamic torque response as it is obtained from dc motor drives. Many control schemes have been proposed for this goal. In recent years an innovative control method, called direct torque control has been introduced, due to its capability to produce fast torque control of the induction motor without to use many on-line computation as for vector control. Classical (DTC) uses two hysteresis controllers for stator flux and developed torque, respectively. The key issue of design of the DTC is the strategy used for selection of the proper stator voltage vectors to force stator flux and developed torque values to maintain into their prescribed bands. Usually, the hysteresis controller is a two-value ON-OFF controller, which has the same outputs both for the big torque errors as for the small torque errors. Therefore, big torque ripples are produced. In order to reduce the torque ripples, the torque errors have to be dividing into several intervals on which operate different control action. As the DTC control strategy is not based on mathematical analysis, it is not easy to give an apparent boundary to the division of torque error. Fuzzy control is a way for controlling a system without the need of knowing the plant mathematic model. In this paper, the fuzzy direct torque control associated with the space vector modulation technique is analyzed. The space vectors are generated by two fuzzy logic controllers. The first one is for flux control and the second one is for torque control. The uses of fuzzy controllers instead of PI controllers permit a faster response and more robustness. The use of SVM technique which provide a constant inverter switching frequency has as results small torque ripples and current distortion.

2. FUZZY DTC
In order to improve the DTC performances a complimentary use of fuzzy regulators is proposed. The two hysteresis controllers of classical DTC will be complimented with two fuzzy regulators as it is shown in figure.1

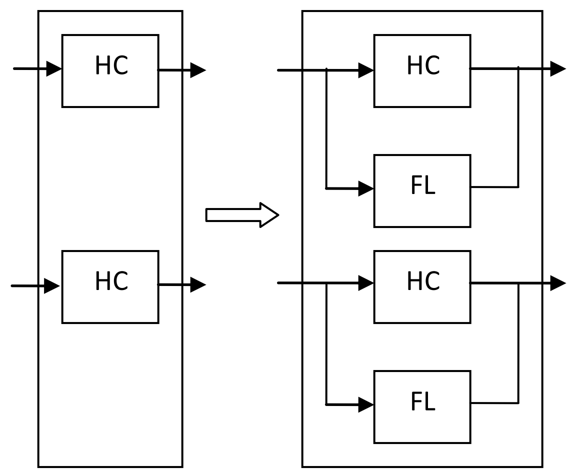


Fig. 1 The improvement of DTC performances by adding fuzzy controllers

It follows from the previous section that the controller adopting DTC strategy has the property of hysteresis, which only takes two value controls for the very big or small error of the torque. That means the control action will be the same in the whole error range. To get better control performance a fuzzy logic controller has been introduced to be a compliment to the hysteresis controller. The width of hysteresis cycle will be fuzzy variables: $b_{\o}$ for flux controller and b_T for torque controller. The fuzzy rules' sets are shown in Table 1. In Fig.2 it is shown the membership functions of input and output variables in Fig.3.

TABLE. I Fuzzy Rules of torque and Flux Hysteresis Controller

e1 / e2	NL	NM	NS	ZE	PS	PM	PL
N	N	N	NS	ZE	PS	PS	P
ZE	N	N	NS	ZE	PS	PS	P
P	N	NS	NS	ZE	PS	P	P

PL: Positive Large, NL: Negative Large,

PM: Positive medium, NM: Negative medium,

PS: Positive small, NS: Negative small, ZE: Zero

P: Positive, N: Negative.

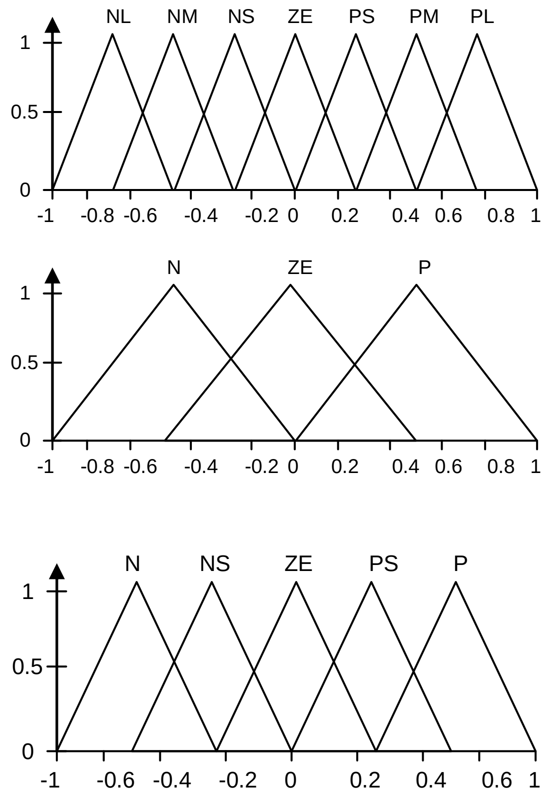


Fig. 2 input/output variables membership functions

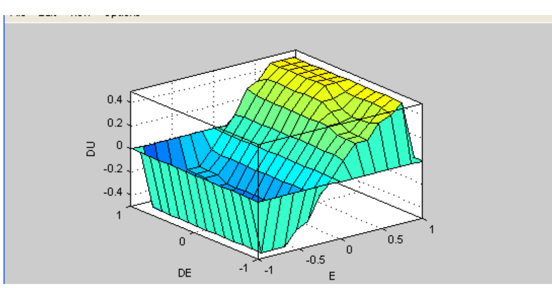


Fig. 3 Control surface

3. SPACE VECTOR MODULATION

The aim of SVM is to minimize harmonic distortion in the current by selecting the appropriate switching vectors and determining their corresponding dwelling width. As depicted in Fig.4 there are eight states available for voltage space vector according to eight switching positions of the inverter. SVM is based on time averaging techniques during sampling period *Ts*. If the reference vector *V*s ($V_{ref} = V1 + V2$), is located in sector I (Fig.4), then it is composed of voltage vector *V*1 and *V*2 and zero vectors *V*0 and *V*7:

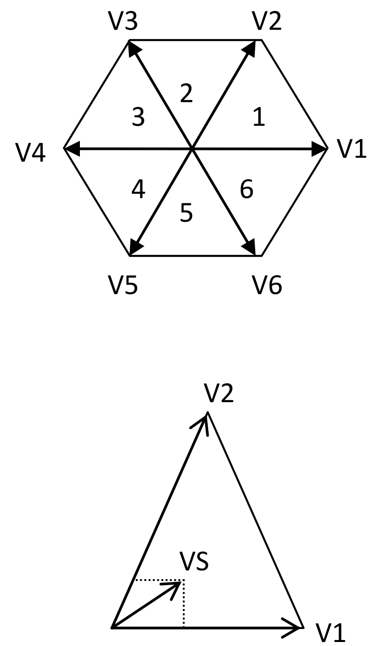


Fig. 4 Decomposition of voltage vector

All techniques SVM use to synthesize the reference Voltage standard the following equations

$T_0 = T_7 = 0.5(T_s - T_1 - T_2)$ (1)

$T_1 = 0.5Ts\ a\ \{\sin(\pi-\theta)\}/\{\sin(\pi/3)\}$ (2)

Several strategies SVM can be used for the piloting of the inverter only difference between these strategies is the choice of the null vector and the sequence of application of the vectors tension during the period of sampling.

$T_1V_S = T_1V_1+T_2V_2$ (3)

$T_1=0.5T_S\ a\ \{\sin(\theta)\}/\{\sin(\pi/3)\}$ (4)

Where:

*T*1 and *T*2 are the active pulse times of voltage vectors *V1* and *V*2.

$a = V_S/(\sqrt{0.667}V_{dc})$

Vdc : d-c link voltage. *T*0, *T*7 are a null vector times. The Fig.5. shows the direct torque control scheme for ac motor drives (DTC) with fuzzy hysteresis and space vector modulation.

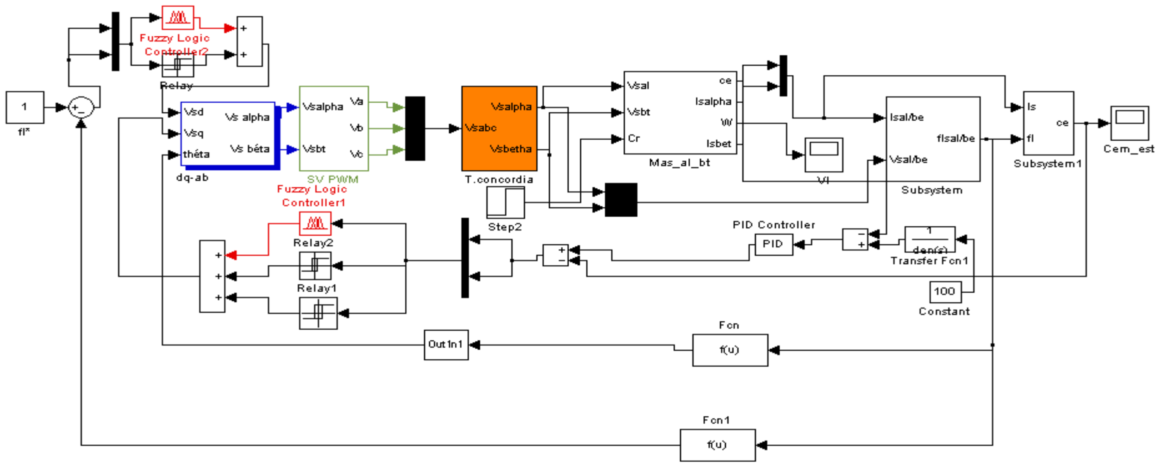


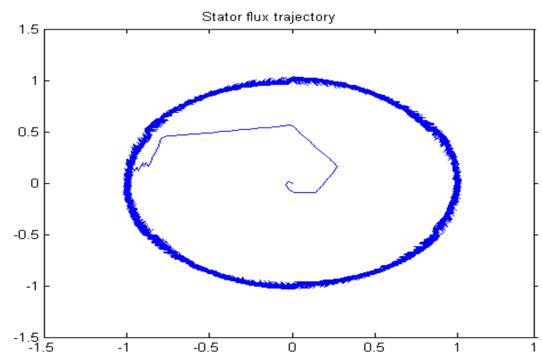
Fig. 5 A direct torque control scheme for IM motor drives (DTC) with fuzzy hysteresis and space vector modulation

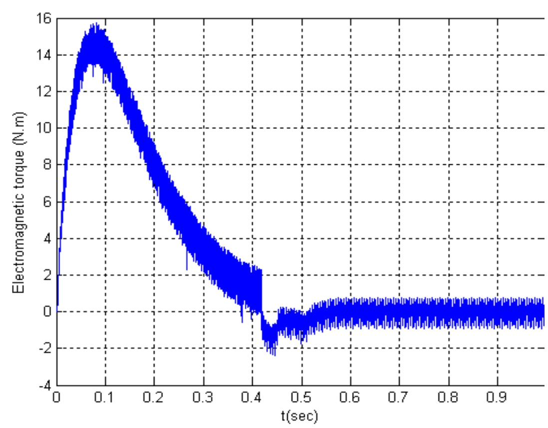
Fig 3 shows 3-dimensional surface of the I/O membership function used in Fuzzy Logic System.

In fig 5 fuzzy logic controller generate a vector for flux control. Further various transformation have been performed to obtain stator voltages ($V_{s\alpha}$ & $V_{s\beta}$) and stator current ($I_{s\alpha}$ & $I_{s\beta}$) also desired flux $f_{I\alpha/\beta}$ is obtained. In inner most closed loop two feedback are taken first feedback generate space vector for torque control and second feedback gives value of theta. Outer most feedback loop is provided to obtain the difference between reference and feedback.

4. SIMULATION RESULT

To study the performance of the fuzzy logic controller with direct torque control strategy, the simulation of the system was conducted by using MATLAB /SIMULINK and fuzzy logic tools. In the case of combined control strategy, where the hysteresis regulators are associated with fuzzy regulators and space vector modulation. The comparative results obtained by simulation for an induction motor are given in figures (6-7). The torque pulsations in the case of fuzzy DTC with space vector modulation are smaller than in the case of classical DTC with fuzzy hysteresis in (figure.6), but the stator current is bigger. The figures which are presented show the dynamics of the flux and the torque of the induction motor. The trajectory of stator flux has a reduction of the ripples (figure.7), and trajectory of stator flux is circular. Fast torque response and good establishment time, and this while the comparators hysteresis is complimented by fuzzy regulators in (Figure.6). The results of simulation obtained shown well the performances of the combined fuzzy- hysteresis direct torque control of the induction motor. In the case of space vector modulation as we can see from figure. 7 the torque ripples are reduced. These results are obtained in spite of using larger sampling period for the DTFC. The simulation results given in Fig. 7 show a good tracking of electromagnetic torque using DTFC -SVM and prove that this technique allows a good dynamic performance similar to the basic DTC schemes. Moreover, it can be noted that the effects due to the crossing of sector boundaries, typical of basic DTC schemes, are avoided using the DTFC-hysteresis scheme.





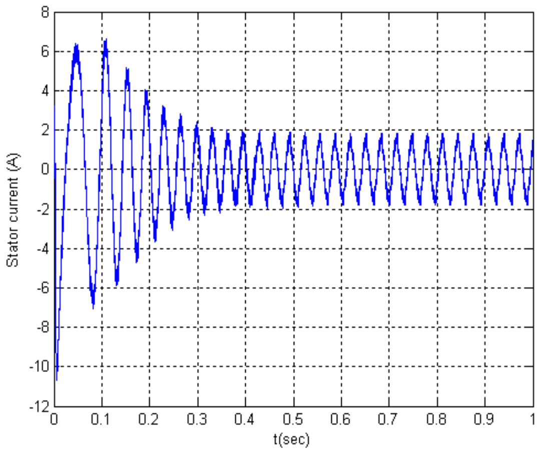
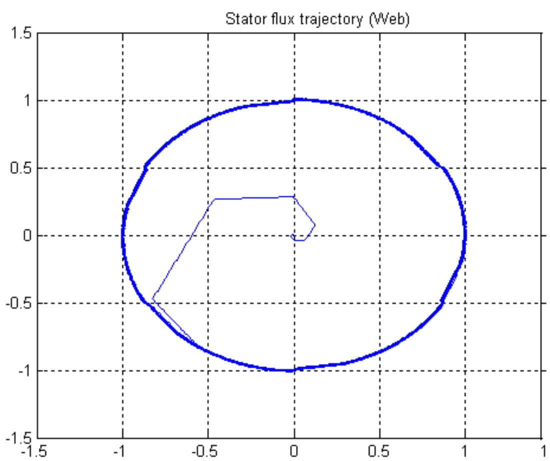
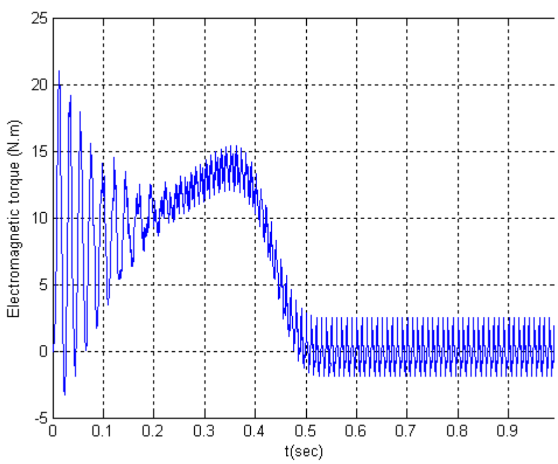


Fig.6 response of trajectory of flux, electromagnetic torque and stator current for scheme of simulation results of fuzzy-hysteresis regulators connected





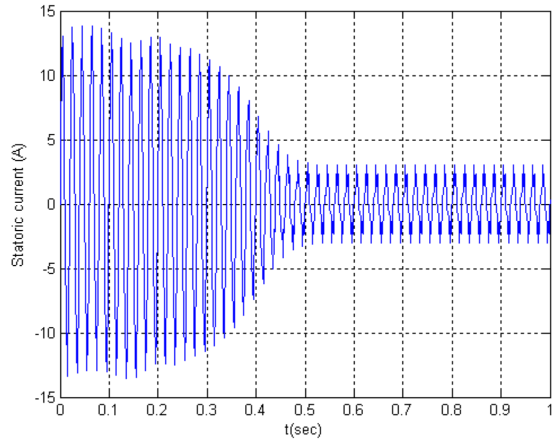


Fig. 7 response of trajectory of flux, electromagnetic torque and stator current for scheme of DTC- fuzzy hysteresis with SVM

5. CONCLUSION

In this paper, a fuzzy direct torque control with space vector modulation is analyzed in comparison to fuzzy hysteresis connected of DTC. The results obtained by numerical simulation are given. In short, the advantages of proposed fuzzy direct torque control using space vector modulation technique in comparison with a fuzzy hysteresis of DTC are the following:

– Reduced torque and flux distortion
– Constant switching frequency thanks to apply SVM
– Fast torque response because of the use of fuzzy controller
– Lower sampling time
– No problems during Low-speed operation
– No current and torque distortion caused by sector changes

INDUCTION MOTOR PARAMETRS
Power rating 4 kW
Stator voltage 220/380 V
Stator resistance 10 Ω
Stator leakage inductance 0.6550 H
Rotor resistance 6.3 Ω
Rotor leakage inductance 0.6520 H
Mutual inductance 0.612 H
Inertia 0.03kg.m2
Number of poles 2
TORQUE RATING 25 N.M

6. ACKNOWLEDGMENTS

We are very much thankful to Mr. Saket Dubey, Senior Engg, LANCO Power Plant and Mr.Kamlesh Dewangan, Engineer, NTPC, Sipat for giving us valuable guidance in this paper.

7. REFERENCES

[1] Casadei, D., serra, G., Tani, A, «Performance analysis of a DTC control scheme for induction motor in the low speed range», in proceeding of EPE, (1997), p.3.700-3.704, Trondheim.

[2] Depenbrok. M, «Direct self-control (DSC) of inverter fed induction machine», In: IEEE Trans. On PE (1988), Vol. PE-3, No4, October 1988, p 420-429.

[3] A. Cataliotti, G. Poma: "A Fuzzy approach for easy and robust control of an induction motor". EPE 97, pp 2.421-2.425, 1997.

[4] J. R G Schonfield,"Direct torque control-DTC", ABB Industrial Systems Ltd.

[5] Ned Gulley, J.-S. Roger Jang: Fuzzy Logic Toolbox for Use With Matlab". The Math Works inc, Natick, Mass, 1996.

[6] H.Buhler: Réglage par Logique floue. Presses polytechniques et universitaires Romande, 1994.

[7] Sayeed Mir, Malik E. Elbuluk, Donald S. Zinger: PI and fuzzy Estimators for Tuning the Stator Resistance in Direct Torque Control of Induction Machines. IEEE Trans. On Power Electronics, Vol. 13, No. 2, pp. 279-287, March 1998.