



Comparative analysis of Conventional MSSMC and Fuzzy based MSSMC controller for Induction Motor

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Abstract: Induction motor is efficient motor than the other motor and widely used in Industries. Several advantages of IM are simple construction, easy installation and high robustness. Induction motor is used for the different applications and performance requires velocity control, position control and accuracy control in various loading condition. For better performance, precise control is required. Classical control methods like DTC, VC, SMC are used control of IM. Combine of Velocity and position control is known as Trapezoidal control command. Trapezoidal control command is suitable method for speed control of the Induction Motor. MS-SMC method is more suitable than the SMC method for the Trapezoidal control command of induction motor drive. From the recent years, numbers of works have been done on fuzzy logic and neural network based speed control techniques of IM.

Keywords: MSSMC, SMC, DTC, VC, FLC.

I. Introduction

Widely, IM have been universally used in the industry due to its merits like simple built, high robustness, reliable and good operation and more over relatively low cost. But the control and evaluation of behavior of induction motors are more complex than other drives. The main reasons for that is complexity like need of variable frequency, machine parameter variations and main problem found chattering in current and due to performance of the drives became poor. Hence, many researchers who had developed conventional control techniques like VC, DTC, PI, SMC and MS-SMC. Except MS-SMC, all the control techniques are used only for one segment either speed control or position control. Study of mathematical modeling and simulation modeling for MS-SMC is done by the researcher. But the available information about MS-SMC is only for speed control of SM and it is less IM is mostly used in industries. So, this review is very helpful to control of IM using conventional MS-SMC and propose smart controller using Fuzzy MS-SMC for better performances like reduce chattering effect, incremental motion control etc.

II. Objectives of work

The main research objectives of this research work are to do a simulation for conventional MS-SMC controller, smart controller using fuzzy with MS-SMC of IM and analyze its performance using simulation in MATLAB. Also, to enhance the performance of the system by employing a new control technique for IM and compare the performances of propose smart controller using fuzzy MS-SMC and conventional MS-SMC for IM.

III. Fuzzy logic based intelligent control

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem.

IV. To apply the traditional control theory, one must

- Know the model of the controlled system
- Know the objective function formulated in precise terms
- Able to solve the corresponding mathematical design problem.

Components of Fuzzy Logic systems

1. Fuzzification 2. Inference 3. Defuzzification

Implementation of Fuzzy Logic

1) Define the control objectives and criteria 2) Determine the input and output relationships and choose a minimum number of variables for input to the FL engine 3) Using the rule-based structure of FL, IF X AND Y THEN Z rules that define the desired system o/p response for given system i/p 4) Create FL MF that define the values of I/P or O/P terms used in the rules 5) Create the necessary pre- and post-processing FL routines if implementing in S/W 6) Test the system, evaluate the results, tune the rules and MF, and retest until satisfactory results are obtained.

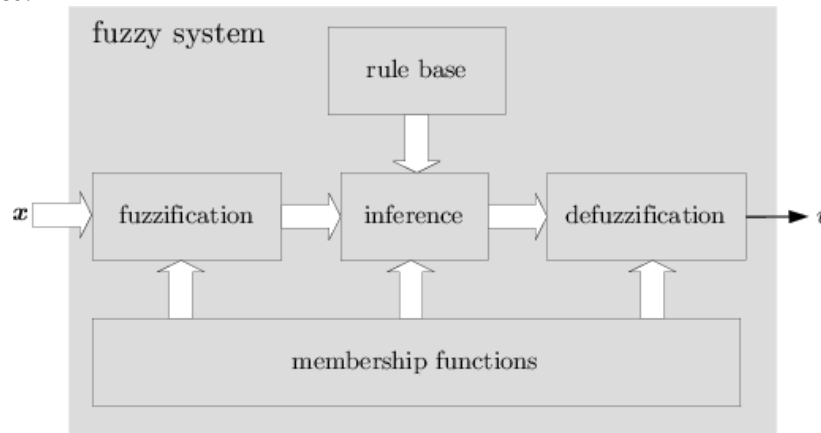


Fig. 1 Component of Fuzzy System

Here Position mode has been replaced by the fuzzy controller. The fuzzy logic position controller has 2 i/p:

1. The change of error is the difference between the actual speed and the reference speed.
2. The rate of change of speed is the derivative of the difference between the actual and the reference speed.

Fuzzy Logic Controller Design

The fuzzy logic controller has been designed using the Fuzzy Logic GUI (Graphical User Interface) provided in Matlab. For this purpose, we make use of the modified model. As shown above we have the three FIS variables: Error, Change in Error and the output. For each of the following we define the ranges from the data obtained and then we use the triangular MF and have four such MF for each FIS variable.

Membership Functions

First we have divided the “error” i/p into 4 MF whose range are selected in such a way that they overlap each other. The MFs are: NB = Negative Big, NP = Negative Small, ZE = Zero, PS = Positive Small, PB = Positive Big

The name of the MF and their range are given as follows:

- Error: MF1: NB | MF2: NS | MF3: ZE | MF4: PS | MF5: PB

The GUI for the same is shown below fig. 3

- Change in Error: MF1: NB | MF2: NS | MF3: ZE | MF4: PS | MF5: PB

The GUI for the same is shown below fig 4.

- Output: MF1: NB | MF2: NS | MF3: ZE | MF4: PS | MF5: PB

The GUI for the same is shown below fig 5.

Rules for the fuzzy system

For getting a satisfactory o/p we define certain rules depending upon the system. For example,

IF “x” is “a” and IF “y” is “b” THEN “z” is “c”

For 5 MF a maximum of 25 rules can be defined. For our system, we have defined 4 MF as well as well 5 MF. Greater the number of MF greater will be the accuracy. They are as follows:

The table 1 shows the fuzzy rules for speed control using 5 MF each for error, change in error and output.

The IM drive system is simulated with MS-SMC using FLC in the mechanical subsystem. MSSMC using FLC are tested for variation in parameter and load torque disturbance. The proposed system has more robust during variation in different loading conditions.

Design and simulation

The control object is to rotate the rotor 6π rad in 2s following the trapezoidal speed command profile with $\alpha_{d1}=43.1\text{rad/s}^2$, $\omega_d=10.78\text{rad/s}$, $\alpha_{d2}=-43.1\text{rad/s}^2$, $t_1=0.25$ s, $t_2=1.75$ s and $t_3=2$ s. The control gains α_i and β_i of the MSSMC are set as $\alpha_1=15$, $\beta_1=10$, $\alpha_2=12$, $\beta_2=10$, $\alpha_3=15$, $\beta_3=10$, $\alpha_4=300$, $\beta_4=200$ & $T_0=12$. Since the system dynamics in the conventional sliding mode $s_4 = x_2 + cx_1 = 0$ converge at a rate of e^{-ct} , $c=10$ are set to have a settling time of 0.4 s. The model used in Simulink to study the response of MSSMC using fuzzy logic control technique is shown below.

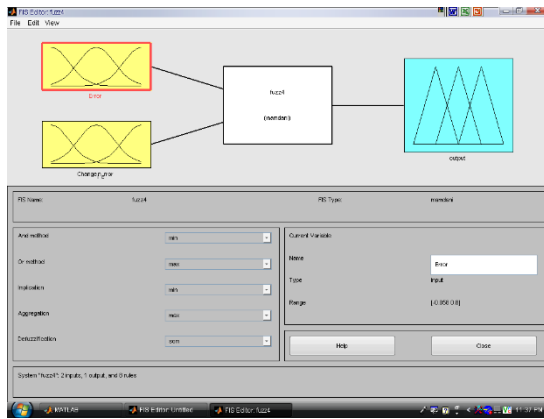


Fig. 2 Graphical User Interface for the fuzzy Logic Controller

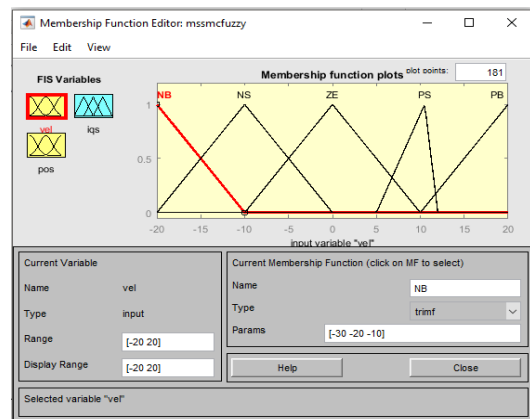


Fig. 3 Fuzzy Logic Input 1

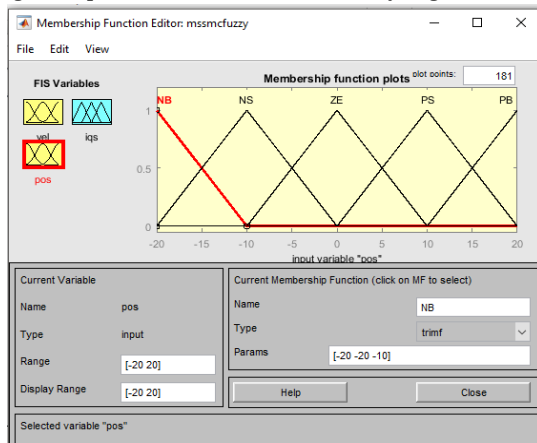


Fig. 4 Fuzzy Logic Input 2

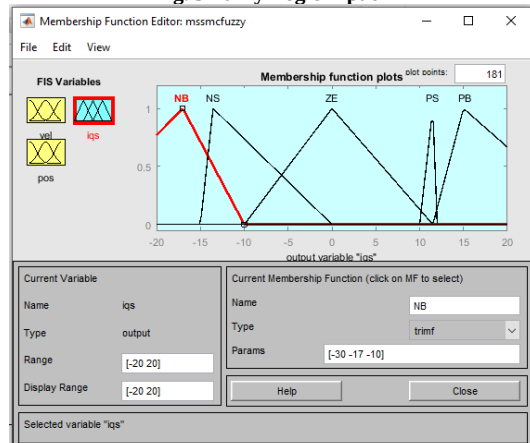


Fig. 5 Fuzzy Logic Output

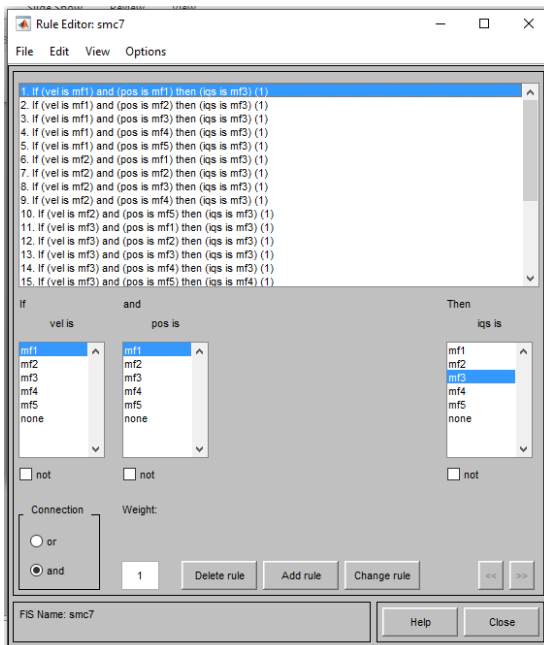


Fig. 6 Rules for Fuzzy System

Table 1: Membership Functions

Vel Pos	NB	NS	ZE	PS	PB
NB	NB	NB	NB	ZE	PS
NS	NS	ZE	NS	ZE	PS
ZE	NS	NS	ZE	PS	PB
PS	NB	NB	PS	ZE	PB
PB	NB	NB	PB	PS	PB

V. Software development and result discussion

To investigate the effectiveness of the proposed controller, three cases with parameter variations in load torque disturbances are considered. The following cases are tested in the simulation for convention MS-SMC and FLC based MS-SMC:

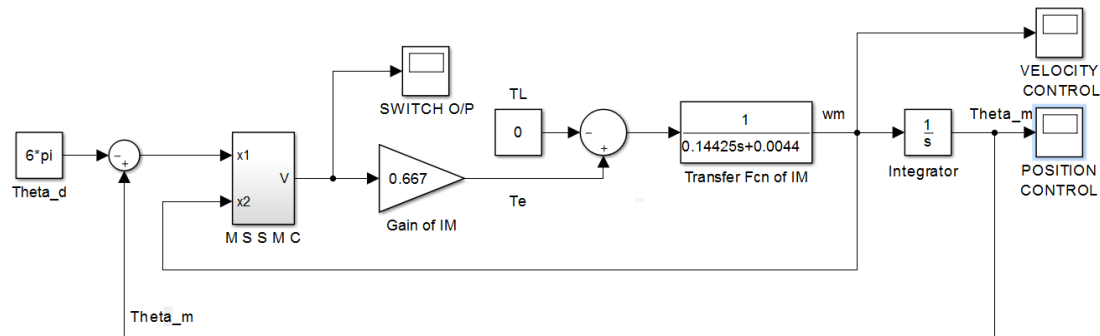


Fig. 7 Simulation model of multi-segment sliding mode control

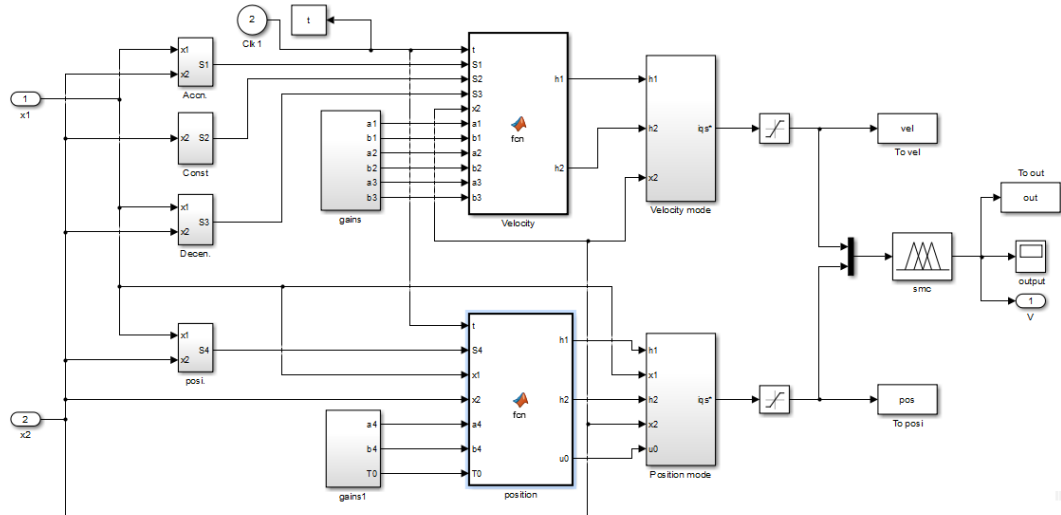


Fig. 8 Simulation model of MSSMC using fuzzy logic control

Case 1: $J_m = J_m B_m = B_m T_l = 0$ N for velocity (speed) control

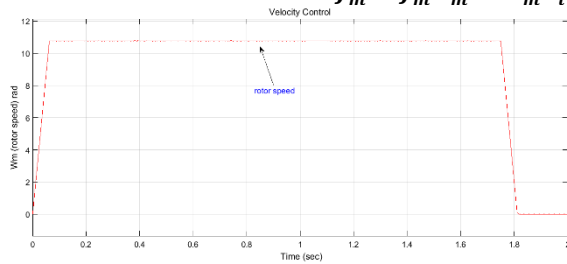


Fig. 9 Velocity Control with conventional MSSMC for case-2

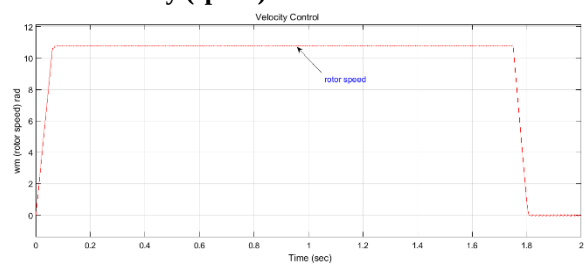


Fig. 10 Velocity Control with fuzzy based MSSMC control for case-2

Case 1: $J_m = J_m B_m = B_m T_l = 0$ N for acceleration (position) control

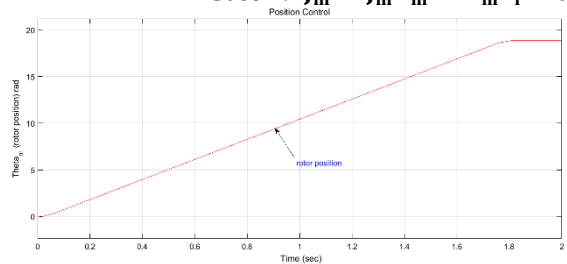


Fig. 11 Position Control with conventional MSSMC for case-2

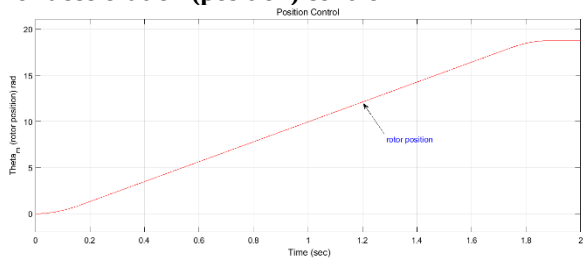


Fig. 12 Position Control with fuzzy based MSSMC for case-2

Case 2: $J_m = J_m B_m = B_m T_l = 7.5$ Nm for Velocity (speed) control

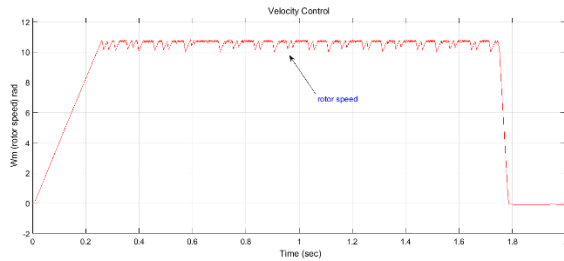


Fig. 13 Velocity Control with conventional MSSMC for case-3

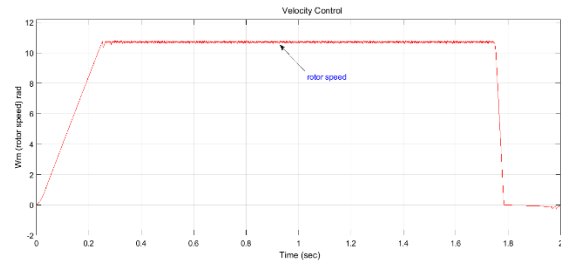


Fig. 14 Velocity Control with fuzzy based MSSMC for case-3

Case 3: $J_m = J_m B_m = B_m T_l = 7.5 \text{ Nm}$ for acceleration (position) control

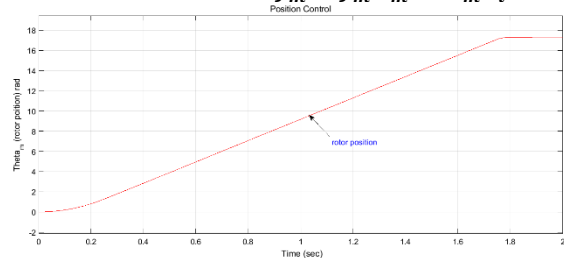


Fig. 15 Position Control with conventional MSSMC for case-3

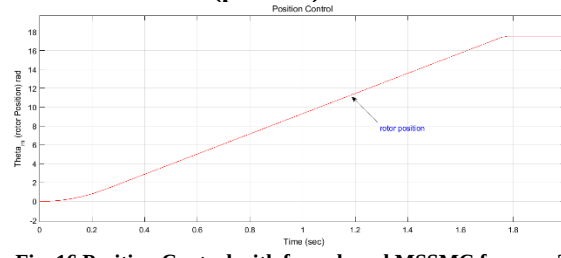


Fig. 16 Position Control with fuzzy based MSSMC for case-3

VI. Conclusion

Finally, after completion of the work we have studied the incremental motion control of IM in various loading conditions. Our focus is to develop FLC for MSSMC for IM and overcome the problems finding in conventional MSSMC technique like in various loading condition chattering is occurred and hence, it degrade the performance of IM. FLC is very convenient method than the other because of it attains human intelligence by utilizing linguistic variables than numerical ones. Its main advantage is to overcome mathematical computations.

In this work, designing have been done the simulation of smart controller using FLC for MSSMC with the help of MATLAB. After the simulation of fuzzy based MSSMC for IM in MATLAB/SIMULINK, we have studied that fuzzy based smart controller give the better result (reduced chattering) for MSSMC for IM in various loading conditions. But main drawback of FLC is seen that it took more execution time for given task compared to conventional MSSMC method for IM.

VII. References

- [1] Abdelkrim Benchaib, Ahmed Rashid, "real-time sliding-mode observer and control of an induction motor", Institute Of Electrical And Electronics Engineers Trans. on Industrial Elect.vol.46, No.1, Feb, 2002.
- [2] Barrero F., A. Gonziilez, A. Torralba, E. GalvBn and L.G Franquelo, "Speed Control of Induction Motors Using a Novel Fuzzy-Sliding Mode Structure", IEEE Conf. paper, pp. 1073-1078
- [3] F. J. Lin, W. D. Chou and Huang, "Adaptive sliding mode controller based on real-time genetic algorithm for induction motor servo drive", IEE Proc.Electr. Power Appl. vol. 150, No. 1, Jan 2003.
- [4] Faa Jeng Lin, Rong Jong Wai, "Adaptive fuzzy neural network control for IM spindle motor drive," IEEE Trans. Energy Conversion, Vol. 17, No. 4, Dec. 2002, pp. 507-513.
- [5] Faiz J., Sharifian M.B.B., "Optimal design of three-phase Induction Motors and their comparison with a typical industrial motor," Computers and Electrical Engineering, vol. 27, no. 2, 2001, pp. 133-144.
- [6] Guorong Liu and Xizheng Zhang, "Robust Sliding-mode Control for Induction Motor Drive with RBF Neural Network Based Rotor Speed Estimation", Institute Of Electrical And Electronics Engineers transactions on neural networks, Vol. 15, no. 3, 2006.
- [7] J. Rivera Dominguez, C. Mora-Soto, S. Ortega-Cisneros, J. J. Raygoza Panduro, and A. V. Loukianov, "Copper and core loss minimization for induction motors using high-order sliding-mode control," IEEE Trans. Ind. Electron., vol. 59, no. 7, pp. 2877–2889, Jul. 2012.
- [8] K. K. Shyu and C. K. Lai, "Incremental Motion Control of Synchronous Reluctance Motor via Multi-Segment Sliding Mode Control Method", IEEE Trans. Control System Technology, (accepted), 2001.
- [9] Kou-Cheng Hsu, Hsin Han Chiang, Guan Hua Huang, Tsu Tian Lee, "Enhanced Fuzzy Sliding Mode Control to Motion Controller of Linear Induction Motor Drives" Institute Of Electrical And Electronics Engineers, 2014.
- [10] M. H. Park, K.S. Kim, "Chattering Reduction in the Position Control of Induction Motor Using the Sliding Mode", IEEE Trans. Power Electron., vol. 6, no. 3, pp. 317-325, 1991.
- [11] Mr. Hardik A.Shah, Mrs. Ami T.Patel, "Controller Design via Sliding Mode Control Approach of Induction Motor - A Survey". Institute Of Electrical And Electronics Engineers, 2014.
- [12] S.M-Mahmoud, L.Chrif Alaoui, V.Van Assche, D.Pinchon, J M Castelain & P. Bussy, "Sliding mode control based on field orientation for an induction motor" IEE Proc.-Electr. Power Appl. vol. 150, No. 3, May 2005.