Performance enhancement of Induction Motor Drive with comparative steady Using PID and F-PID Controller

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Abstract**:** *This paper presents the indirect vector controlled induction motor (IM) drive speed control scheme. PWM controlling scheme is based on Voltage source inverter type space vector pulse width modulation (SVPWM) and the Conventional-PID controller or Fuzzy-PID controller is employed in closed loop speed control. Decoupling of the stator current into torque and flux producing (d-q) current components model of an induction motor is involved in the indirect vector control. The torque component Iq current of an IM is developed by an intelligent based Fuzzy PID controller. Based on settling time and dynamic response the performance of Fuzzy Logic Controller is compared with that of the PID Controller to sudden load changes. It provides better control of motor torque with high dynamic performance. The simulated design is tested using various tool boxes in MATLAB. Simulation results of both the controllers are presented for comparison.*

Keywords: *Indirect Vector Control (IVC), Space Vector Pulse Width Modulation (SVPWM), PID Controller, Fuzzy Logic Controller (FLC).*

1. Introduction

In the modern time, the field oriented control of induction motor drive is normally used in high-performance drive system because of its benefits [1]. Most of the industries need adjustable speed drives. Even though many investigations have been carried out for decades for the efficient control of the speed of induction motors [2], since last two decades the progress of semiconductor technology has laid suitable spark that the static frequency converters can now be introduced at the acceptable cost.

The speed control of separately excited dc drives is simple because independent control of flux and torque can be brought about. Although, induction motors involve a coordinated control of stator current magnitude and the phase, making it a complex control. The rotor flux linkages can be resolved along with any frame of reference. For achieving this, the position of the flux linkages at every instant required. Then the control of the induction motor is very similar to that of separately excited dc motor [3] [4]. Therefore this control involves field coordinates; it is also called field oriented control [5]. The name vector control evolved requirement of the phase angle of the flux, a linkage in the control process gives the name vector control.

An advanced, computation intensive and possibly the best among all the PWM techniques for variable frequency drive application is The Space Vector Pulse Width Modulation (SVPWM) method [6]. It shows the feature of good dc-bus voltage utilization and low THD compared to other PWM methods. SVPWM is the best fit for digital implementation and can increase the obtainable maximum output voltage with maximum line voltage approaching 70.7% of the DC link voltage in the linear modulation range [7-9].

The conventional speed control methods have the following difficulties to achieve desired control, it depends on the accuracy of the mathematical model of the systems, and the expected performance is not met due to the load disturbance, classical linear control shows good performance only at one operating speed. Fuzzy logic is a technique to represent human-like thinking into a control system [9]. A fuzzy controller can be designed to emulate human deductive thinking, that is, the process people use to assume conclusions from what they know. The control of processes is applied through fuzzy linguistic descriptions [10-12].

In this paper, the speed control of SVPWM based Indirect Vector Controlled Induction Motor using Fuzzy PID control and the proposed design is tested by MAT LAB/Simulink. The second section of this paper covers Indirect Vector Control. Space Vector Pulse Width Modulation is covered in the third section of the paper. The fourth section deals with the Design of Fuzzy PID control. The results and discussions are covered in the fifth section. The conclusion OF this paper is in the last section.

2. Indirect Vector Control

The **Figure 1** is depicted indirect vector control method. As compared to the direct vector control method, it uses the indirect estimation of the slip speed and a feed forward method of control.

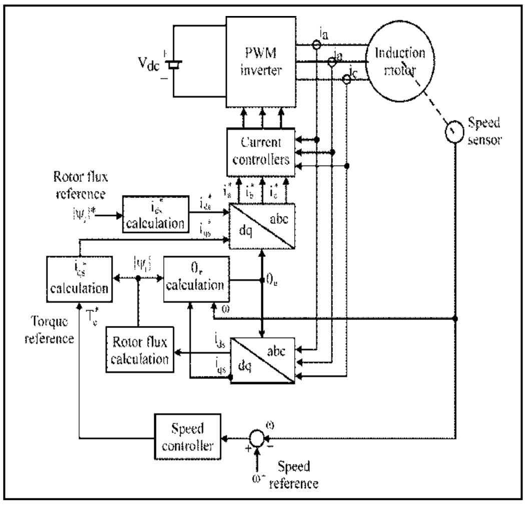


Figure 1: Indirect Estimation of the Speed

The speed error, with the help of a Conventional PID and/or Fuzzy PID intelligent controller, is converted into a torque controlling current component iqs*, of the stator current. To regulate the torque and the slip speed, the current component iqs* is used.

3. Space Vector Pulse Width Modulation

V_1, V_2, V_3, V_4, V_5, V_6 are six active vectors and V_0 and V_7 are labelled as two zero vectors. If these 8 voltage vectors are converted to 2 axes, it can be plotted as shown in **Figure 2** the tips of the 6 none zero vectors, when cornered form a regular hexagon with the two zero vectors lying at the origin.

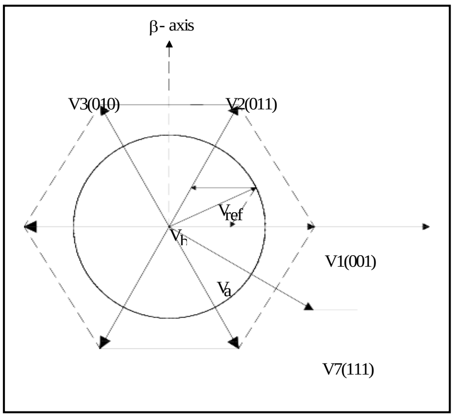


Figure 2: Space voltage vectors of a three-phase VSI

Table 1: Summary of inverter switching states

Name	A	B	C	V_{An}	V_{Bn}	V_{Cn}
V0	0	0	0	0	0	0
V1	1	0	0	2VDC/3	-VDC/3	-VDC/3
V2	1	1	0	VDC/3	VDC/3	-2VDC/3
V3	0	1	0	-VDC/3	2VDC/3	-VDC/3
V4	0	1	1	-2VDC/3	VDC/3	VDC/3
V5	0	0	1	-VDC/3	-VDC/3	2VDC/3
V6	1	0	1	VDC/3	-2VDC/3	VDC/3
V7	1	1	1	0	0	0

4. Design of Controller

4.1. Conventional PID Controller

The conventional PID controller is one of the most common (almost 90%) approaches for speed control in industrial electrical drives in general, because of its simplicity, and the clear relationship existing between its parameters and the system response specifications. A very common method to determine the Kp, Ki and Kd constants of this controller is the method of Ziegler-Nichols. The conventional PID controller block model is given in **Figure 3**.

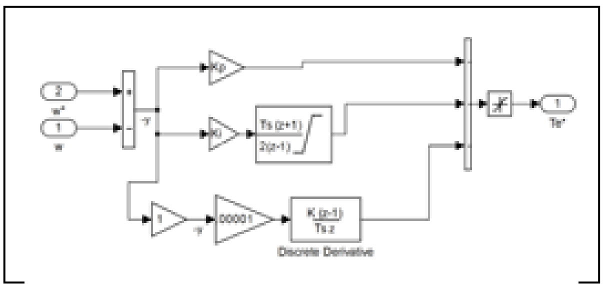


Figure 3: Conventional PID controller

The conventional PID controller for constant gain may perform well under some operating conditions but not at all, because the processes are in the general complex, time variant, with nonlinearity and model uncertainties.

4.2. Fuzzy PID Controllers

The first step is to find the degree of each data values in every membership region of its corresponding fuzzy domain to determine a fuzzy rule from each input-output data pair. Then value of variable is assigned to the region with the maximum degree.

After generating new rules from the input- output data pairs, a rule degree or truth is assigned to that rule, where these rule degrees are defined as the degree of confidence that the rule does, in fact, correlate to the function relating voltage and current to angle. For this developed method, a degree is assigned which is the product of the membership functions of each variable in its respective region.

Each training data set produces a corresponding fuzzy rule, is stored in the fuzzy rule base. Thus rules are generated, as each input- output data pair is processed. A fuzzy rule or knowledge base is in the form of two dimensional tables, which can be looked up by the fuzzy reasoning mechanism.

Speed error is calculated with the comparison between reference speed and speed signal feedback. Speed error and speed error changing are fuzzy controller inputs.

4.2.1 Membership Functions

The Fuzzy Logic Controller initially converts the crisp error and change in error variables into fuzzy variables and then are mapped into linguistic labels. Membership functions are associated with each label as shown in **Figure 4** and **5** which consists of two inputs and one output.

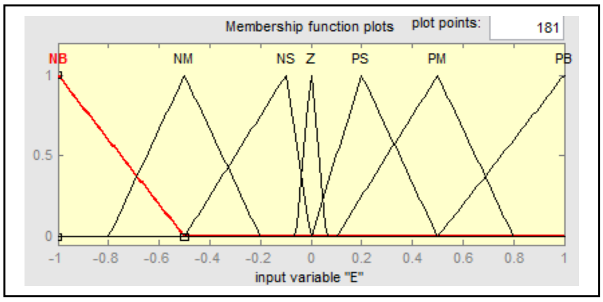


Figure 4: Speed error (e)

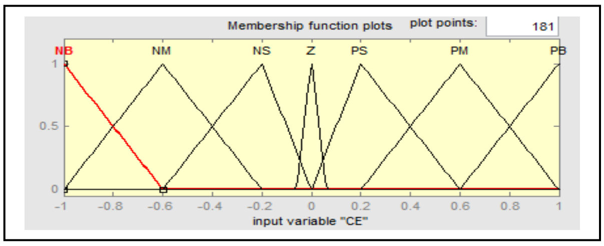


Figure 5: Change in speed error (ce) Output (u)

The linguistic labels are divided into seven groups. They are: nl-negative large, nm-Negative medium, ns- negative small, z-zero, ps-positive small, pm-positive medium, pl-positive large. Each of the inputs and the output contain membership functions with all these seven linguistics.

4.2.2 Knowledge Rule Base

The mapping of the fuzzy inputs into the required output is derived with the help of a rule base as given in **Table 2.**

Table 2: Rule base of fuzzy speed control

e\ce	NB	NM	NS	Z	PS	PM	PB
NB	NVB	NVB	NB	NM	NS	PS	Z
NM	NVB	NB	NM	NS	PS	Z	NS
NS	NB	NM	NS	NS	Z	NS	PS
Z	NM	NS	NS	Z	PS	PS	PM
PS	NS	NS	Z	PS	PS	PM	PB
PM	NS	Z	NS	PS	PM	PB	PVB
PB	Z	PS	PS	PM	PB	PVB	PVB

5. Result Analysis

For evaluation of implemented drive, different responses of a drive are presented. Starting response of for 120 rps reference speed with conventional PID and fuzzy PID Response has drawn for 0.25 second that motor speed is according to rps. It is concluded that FLC-based system is superior to conventional PID-based drive system in all aspects: rise time, settling time and overshoot and % of error.

5.1 RESPONSE OF PROPOSED SYSTEM FOR DIFFERENT INPUT CONDITIONS

5.1.1 Response of proposed system when reference speed is 120 rad/sec at 0 N-m torque

For this case reference speed set to 120 rad/sec and torque is set to 0 Nm, for both Fuzzy PID controller model and PID controller model. Model is simulated for 3sec and simulation plots for this case given below.

From the below Fig. 5.6(a) we can see that F-PID controller shows very good dynamic speed response. It is also seen that speed response is very fast and go to steady state without any overshoot. Rise time and steadying time is very small.

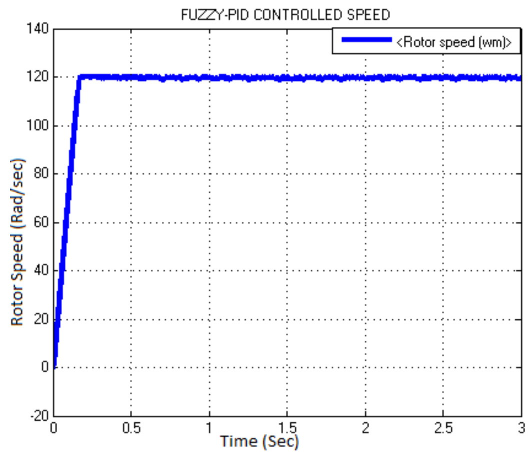
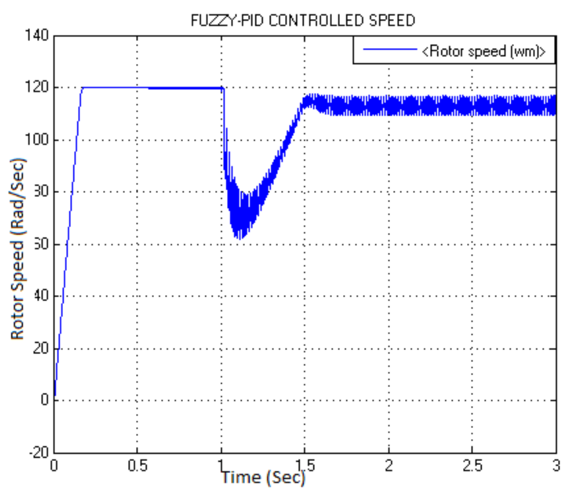


Figure 5.6: Response from F-PID controller:
(a) Rotor speed response

5.1.2 Response of proposed system when reference speed is 120 rad/sec and torque changed from 0 N-m to 7 N-m at 1.0 sec

For this case reference speed set to 120 rad/sec and torque is changed from 0 N-m to 7 N-m at 1.0 sec for both Fuzzy PID controller model and PID controller model. Model is simulated for 3 sec and simulation plots for this case are given below.



(a)

Figure 5.7: Response from F-PID controller: (a) Rotor speed response

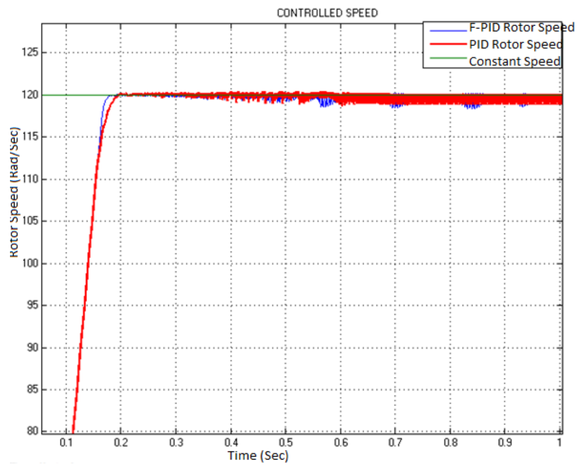


Figure 5.8: Comparison of response from fuzzy logic controller and PID controller:

(a) Rotor speed comparison

6. Conclusions

In this paper, the concept of fuzzy logic has been presented and the SVM-based indirect vector controlled induction motor drive is simulated using both PID and Fuzzy PID controller in the hybrid model. The results of both controllers under the dynamics conditions are compared and analyzed. The simulation result supports the FLC, settles quickly and has better performance than when PID controller.

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