Induction Motor Speed Control Using Fuzzy Logic Controller

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Abstract*: This paper presents design & implementation of speed control using fuzzy logic for the speed control of single-phase induction motor. In recent years, the field oriented control of induction motor drive is widely used in high performance drive system. It is due to its unique characteristics like high efficiency, good power factor and extremely rugged .This scheme leads to be able to adjust the speed of the motor by control the frequency and amplitude of the stator voltage, the ratio of stator voltage to frequency should be kept constant.*

Keywords: Fuzzy logic control (FLC), Membership Function, PIC digital signal microcontroller Induction motor, *PWM (Pulse Width Modulation).*

1. Introduction

In recent years, speed control of induction motor drive is widely used in high performance drive system ,because of its advantages like high efficiency, very simple , extremely rugged, good power factor and it does not require starting motor. Induction motors are used in many applications such as HVAC, Industrial drives control, automotive control, etc... In recent years there has been a great demand in industry for adjustable speed drives [1].

There are different methods for controlling the speed of induction motor like PI controller, fuzzy controller etc. PI control methodology is commonly applied in constant *V/f* control strategy for induction motors. But in case of PI controller a mathematical model is described for controller design with conventional method.

Recently, Fuzzy logic control has found many applications in the past decade. Fuzzy Logic, deals with problems that have vagueness, uncertainty and use membership functions with values varying between 0 and 1[2]. This means that if the a reliable expert knowledge is not available or if the controlled system is too complex to derive the required decision rules, development of a fuzzy logic controller become time consuming and tedious or sometimes impossible. In the case that the expert knowledge is available, fine-tuning of the controller might be time consuming as well [3, 4].

2. Proposed Speed Control Method

The speed control of the induction motor is carried out by maintaining the voltage and frequency constant. Here driver circuit is used to drive the motor. The input to that circuit is come from the PWM inverter. According to the reference speed and current speed the Fuzzy logic controller will give the output to the PWM inverter.

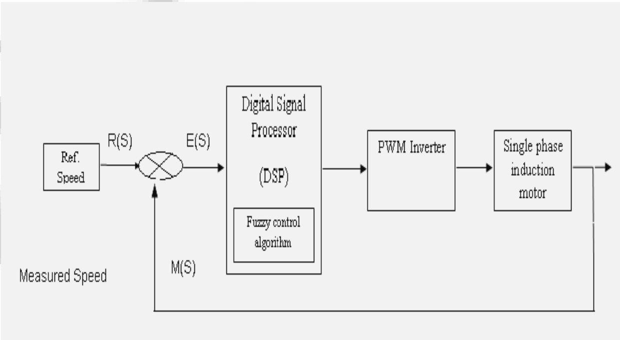

Figure 1: Proposed speed control method.

3. dSPIC 3010/11 Controller

The dsPIC30F is a High Performance Digital Signal Controllers with CPU module has a 16-bit (data) modified Harvard architecture with an enhanced Instruction set, including significant support for DSP. The instruction set includes many addressing modes and was designed for optimum C complier efficiency.

3.1 Features

1. High performance modified RISC CPU
2. 48 Kbytes on-chip Flash program space (16K Instruction words)
3. 2 Kb of on-chip data RAM and 1 Kb of nonvolatile data EEPROM
4. 4 MHz- 10 MHz oscillator input with PLL active (4x, 8x, 16 as)
5. 16 x 16- bit working register array
6. Timer module with programmable presale
7. 6-bit Capture input and 16- bit Compare/PWM output functions
8. 2 UART modules with FIFO Buffer
9. 6 PWM output channels
10. Analog-to-Digital Converter (A/D) with 4 S/H Inputs

3.2 I/O Port control registers

All I/O ports have three registers directly associated with the operation of the port, where x is a letter that denotes the particular I/O port. TRISx: Data Direction registers, PORTx: I/O Port registers, LATx: I/O Latch registers. Each I/O pin on the device has an associated bit in the TRIS, PORT and LAT Registers.

3.3 Timers

TMRx: 16-bit timer count register, PRx: 16-bit period register associated with the timer, TxCON: 16-bit control register associated with the timer. Some16-bit timers can be combined to form a 32-bit timer.

3.4 Input capture and output compare

The Input Capture module has multiple operating modes, which are selected via the ICxCON register. The dsPIC30F device may have up to eight output compare channels, designated OC1, OC2, OC3, etc., Each output compare channel can use one of two selectable time bases. The time base is selected using the OCTSEL bit (OCxCON<3>). Motor control PWM control registers: The control registers are PTOCN, PTMR, PTPER, PWMCON and PDC.

4. Fuzzy Logic Controller

The Fig. 2 shows block diagram of fuzzy logic controller (FLC). The inputs are most often hard or *crisp* measurements from some measuring equipment, rather than linguistic. A preprocessor, the first block in Fig. conditions the measurements before they enter the controller. The first block inside the controller is fuzzification, which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. The rules may use several variables both in the condition and the conclusion of the rules. The controllers can therefore be applied to both multi-input-multi-output (MIMO) problems and single-input-single-output (SISO) problems. The typical SISO problem is to regulate a control signal based on an error signal. The controller may actually need both the error, the change in error, and the accumulated error as inputs. Rule format: Basically a linguistic controller contains rules in the *if-then* format, but they can be presented in different formats.

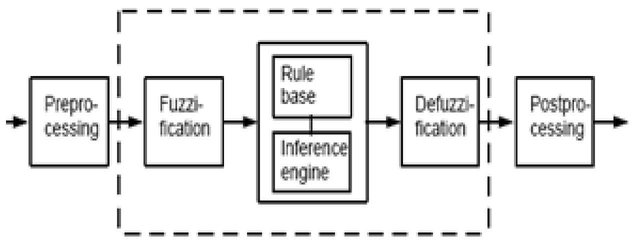

Figure 2: Block diagram of fuzzy controller.

In order to design a simplified fuzzy inference system for the *V/f* induction motor control, the triangular and symmetrical membership functions illustrated in Fig. 3 were used. All the linguistic variables of the fuzzy control system (speed error, speed error variation and frequency variation) were scaled into a common discourse universe with values between [-1, 1]. As a consequence, it was possible to map all the variables simultaneously with a unique set of membership functions.

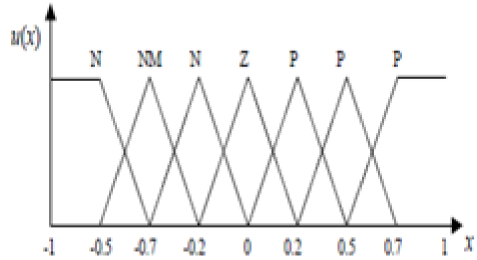

Figure 3: Membership function of fuzzy control system

The linguistic terms are described as follow: "NL" is "Negative and Large", "NM" is "Negative and Medium", "NS" is "Negative and Small", "ZZ" is "Zero", "PS" is "Positive and Small", "PM" is "Positive and Medium" and "PL" is "Positive and Large". The discourse universe of the "speed error" linguistic variable was designed for the [-200, 200] rpm interval. It was therefore normalized to [-1, 1] by dividing the speed error signal before the fuzzification process, as illustrated in Fig. 5. The "speed error variation" linguistic variable was adjusted to a discourse universe of [-150, 150] rpm, which was divided by 150 to take the signal into the [-1, 1] interval. In a similar way, the "frequency variation" output linguistic variable with a [-1, 1] Hz interval was multiplied by 3 to take it to the [-3, 3]

Fuzzy rules can be implemented based on expert knowledge of the control process, which is treated linguistically in an "if-then" structure. As a consequence, it dispenses with detailed or precise knowledge of the mathematical model that represents the control plant. The rules were based on the studies conducted in [14], whose first three fuzzy rules are represented as follows:

If (speed error is **NL**) **and** (speed error variation is **NL**)
Then (frequency variation is **NL**)
If (speed error is **NM**) **and** (speed error variation is **NL**)
Then (frequency variation is **NL**)
If (speed error is **PM**) **and** (speed error variation is **NL**)
Then (frequency variation is **NS**)

The knowledge database of all fuzzy rules is described in Table I.

TABLE I
FUZZY CONTROL SYSTEM RULE DATABASE

		Speed Error						
		NL	**NM**	**NS**	**ZZ**	**PS**	**PM**	**PL**
Speed Error Variation	**NL**	NL	NL	NL	NM	NM	NS	ZZ
	NM	NL	NM	NM	NS	NS	ZZ	PS
	NS	NM	NM	NS	NS	ZZ	PS	PS
	ZZ	NM	NS	NS	ZZ	PS	PS	PM
	PS	NS	NS	ZZ	PS	PS	PM	PM
	PM	NS	ZZ	PS	PS	PM	PM	PL
	PL	ZZ	PS	PM	PM	PL	PL	PL

5. Development of Simulink Model

The block model of the induction motor system with the controller was developed using the power system, power electronics, control system, signal processing toolboxes & from the basic functions available in the Simulink library in Matlab /Simulink. The entire system modeled in Simulink is a closed loop feedback control system consisting of controllers, samplers, comparators, feedback systems, the mux, de-mux, summers, adders, gain blocks, multipliers, clocks, sub-systems, integrators, state-space models, subsystems, the output sinks (scopes), the input sources, etc. The developed simulink model for the control of various parameters of the SCIM is shown in the Fig.

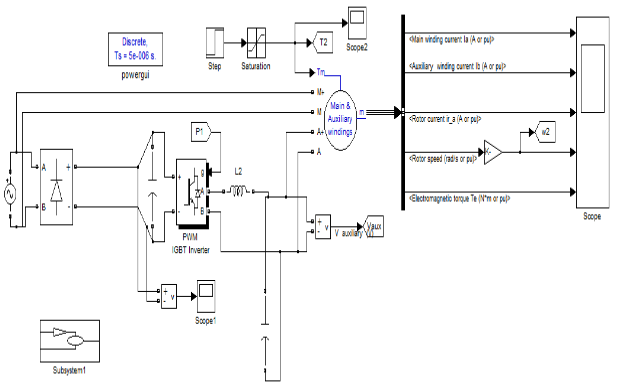

Figure 4: Simulink model of IM speed control using fuzzy logic

6. Hardware Results & Discussions

Figure 5 shows the setup of the hardware for speed control. Here the PWM is designed for the pulse control. Output of inverter is given to the PWM. The PWM o/p is pass to the driver circuit which drives the motor.

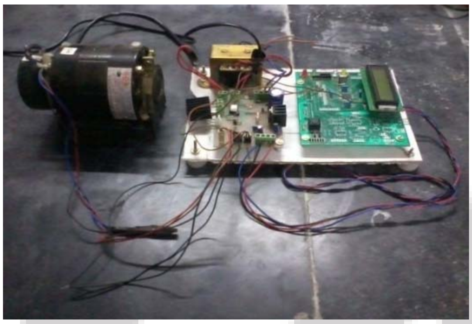

Figure 5: Hardware Setup

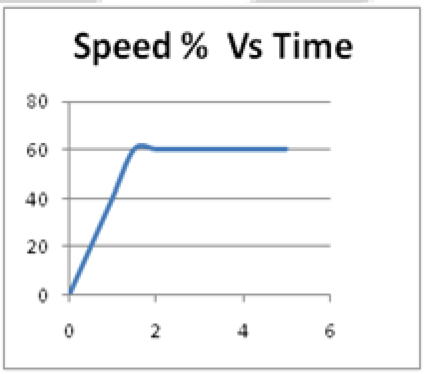

Figure 6: Hardware result

In above figure according to the error & change in error the required speed will achieved.

7. Simulation Results & Discussions

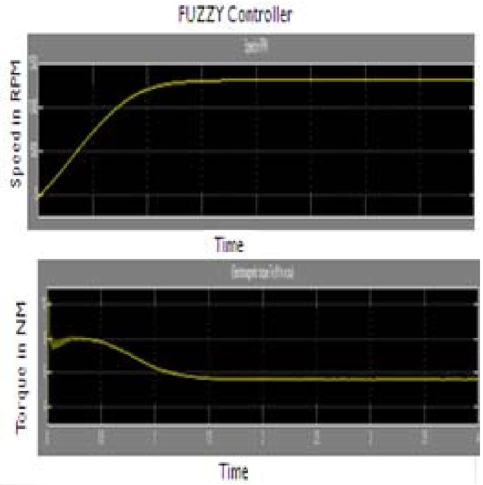

Figure 7: Simulation results

Simulink model with the controller for the speed control of IM is developed in Matlab 7 as shown in the Fig.7. Note that the fuzzy coordinated consists of 3 basic blocks viz., fuzzification, inference, and the de-fuzzification blocks A set of 49 fuzzy rules are written and called in the form of a file in the developed Simulink model. The response curves of torque and speed time are observed on the respective scopes & are shown in the Figs. 5 – 9 respectively after importing the scope data into the workspace and plotting them.

The 1st graph shows speed of induction motor vs. time. Here the speed will increase & it will reach to the rated speed after some time. The 2nd graph shows Torque vs. time output. From the graph we get that using fuzzy logic we get constant torque rapidely.

8. Conclusions

A systematic approach of achieving robust speed control of an induction motor drive by means of fuzzy control strategy has been investigated in this paper. Simulink models were developed in Matlab 7 with the fuzzy controllers for the speed control of IM. The control strategy was also developed by writing a set of 49 fuzzy rules The main advantage of designing the fuzzy coordination scheme to control the speed of the IM is to increase the dynamic performance & provide good stabilization. Simulations were run in Matlab 7 & the results were observed on the corresponding scopes. Graphs of speed, torque etc. vs. time was observed.

The output takes less time to stabilize, which can be observed from the simulation results. The developed control strategy is not only simple, reliable, and may be easy to implement in real time applications, but also cost-effective as when this control scheme is implemented in real time, the size of the controller will become very small. Collectively, these results show that the fuzzy controller provides faster settling times, has very good dynamic response & good stabilization.

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