Fuzzy logic based speed control of induction motor

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Abstract

Induction motors are designed to work for constant speed application, thus many industrial applications need wide range of speed control of induction motor. Fuzzy logic based speed controller for induction motor provides large range of speed control compared to conventional controllers. This paper presents the study of Fuzzy logic based speed controller for induction motor. Error signal and change of error signals are the two inputs to Fuzzy logic controller, which performs 49 if-then rules inference on that signals and generates control signals which are fed to inverters. Inverter output changes in accordance with change in speed of motor. The results obtained from this approach are compared with conventional controller like PI controllers.

Keywords: Induction motor, Fuzzy logic controller, Inverter

INTRODUCTION

Induction motors are becoming popular in industrial applications due to their low maintenance, robust construction, high starting torque and cost effectiveness. Induction motors are designed to have constant speed, but in some cases their speed needs to be controlled. Such cases are (1) when the induction motor is started with no-load; at the time of starting it draws more current from supply which is 6-7 times higher than the rated current. Since no load is connected to motor, it runs at very dangerous speed which may damage the motor. (2) In some situation the motor needs to drive the load whose speed may be greater than or less than the rated speed of induction motor. So in these situation instead of installing a new machine it is better to control the speed of existing machine.

The speed of induction motor can be controlled from stator side as well as from rotor side. These methods are implemented using controllers in industries. The most popular controller among all industries is PI controller, because they are easy to design and their low cost. The only problem associated with PI controller is that the design complexity increases with non-linearity of Induction motor. Hence non-conventional controller like Fuzzy logic controller can be used to overcome this problem.

FUZZY LOGIC CONTROL

After the discovery of fuzzy set theory by L. Zadeh in 1965, it has gained popularity in last 3 decades. In first few years, it was just a theoretical concept but in recent years engineers have started to use this approach in real word application. Fuzzy logic controllers follows the fuzzy set theory and it has three basic function blocks which are as follows…

Fuzzification: The Fuzzification module converts the crisp values of the control inputs into fuzzy values, so that they are compatible with the fuzzy set representation in the rule base.

Rule base: The rule base is essentially the control strategy of the system. It is usually obtained from expert knowledge or heuristics and expressed as a set of IF-THEN rules. The rules are based on the fuzzy inference concept and the antecedents and consequents are associated with linguistic variables.

Defuzzification: The mathematical procedure of converting fuzzy values into crisp values is known as 'Defuzzification'. There are four methods are available for Defuzzification. However, the choice of

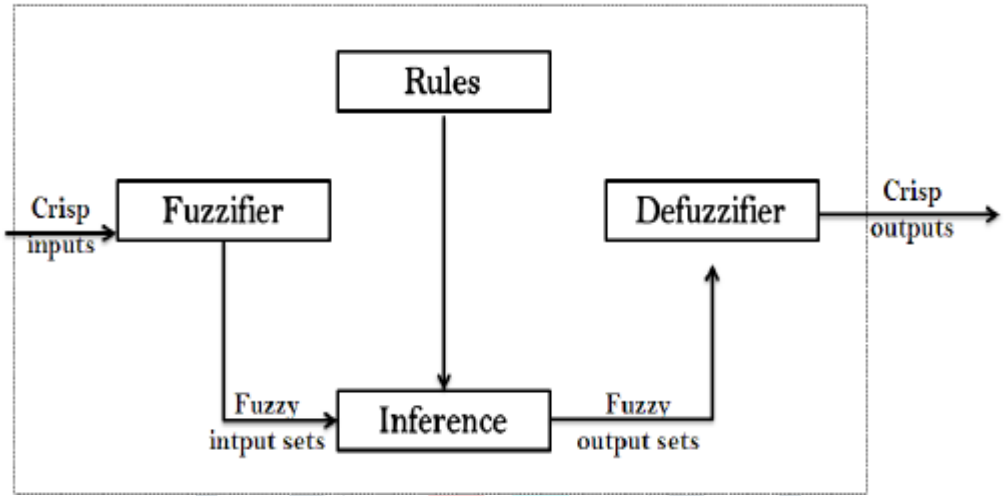

Figure 1: *Operation of Fuzzy logic controller*

Defuzzification depends upon the application and available processing power.

Fuzzy Logic Controller in Matlab

MATLAB provides users with built in function of Fuzzy logic controller. It can be accessed by using the command "fuzzy" in command window. The fuzzy logic controller window consist of input block, output block and controller block as shown in the following figure 1. Designer may choose more than one input and more than one output at the same time. The input and output blocks consist of membership functions of the given system. The designer may choose from various membership functions depending upon his needs, however most commonly used membership functions are Triangular and Trapezoidal membership function. The rule base of the controller consist of number of

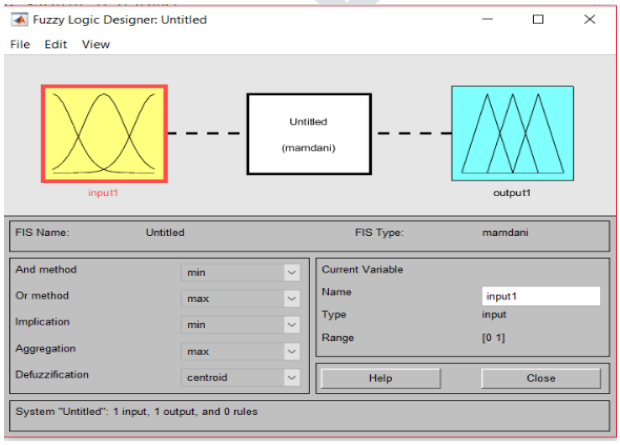

Figure 2: *Fuzzy Logic Controller in MATLAB*

IF-THEN rules, which are designed according to inputs and outputs of the system. The rules designed in controller are in linguistic form; hence, it is easy for any operator to understand.

Simulation for the Proposed Scheme

The speed control of induction motor using fuzzy logic controller can be simulated using MATLAB software. Whole simulation process can be divided into following blocks.

Fuzzy logic controller: Basic function of the fuzzy logic controller in this particular scheme is to generate current reference signals, which drives the inverter, and hence the input voltage to the motor can be changed according to speed of the motor. There are two inputs to the fuzzy logic controller. One is error in speed, which can be obtained by comparing the actual rotor speed with that of reference speed; another input is change in error. There are 7 membership functions for both speed error and change in speed error, hence total of 49 IF-THEN rules needs to be designed in controller block. The output table for the FLC is shown in table.

Table 1: *Output Table of FLC*

Δe \ e	**NL**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PL**
NL	NL	NL	NLM	NM	NMS	NS	ZE
NM	NL	NLM	NM	NMS	NS	ZE	PS
NS	NLM	NM	NMS	NS	ZE	PS	PMS
ZE	NM	NMS	NS	ZE	PS	PMS	PM
PS	NMS	NS	ZE	PS	PMS	PM	PLM
PM	NS	ZE	PS	PMS	PM	PLM	PL
PL	ZE	PS	PMS	PM	PLM	PL	PL

Driver circuit for inverter: The current reference generated by the fuzzy logic controller are converted from d-q to α-β quantities using inverse Park transformation. This driver circuit generates the GATE pulses, which drives the inverter switches.

Inverter circuit: It consist of six power electronic switches such as IGBT, MOSFET etc. connected in bridge form. The driver circuit governs the sequential switching of the power electronic switches. The output voltage of the inverter is fed to induction motor.

Induction motor: For the means of simplicity, the induction motor is modeled in mathematical form. The dynamic (mathematical) model of induction motor consist of electrical sub model and mechanical sub model. The dynamic model of induction motor is shown in following figure 3.

Whole control strategy for the speed control of induction motor can be simulated as shown in figure 4. The simulation results obtained by the fuzzy logic controller can be compared with conventional PI controller. Research says that overshoot problem arising in using PI controller for speed control of induction motor can be overcome by using Fuzzy logic controller.

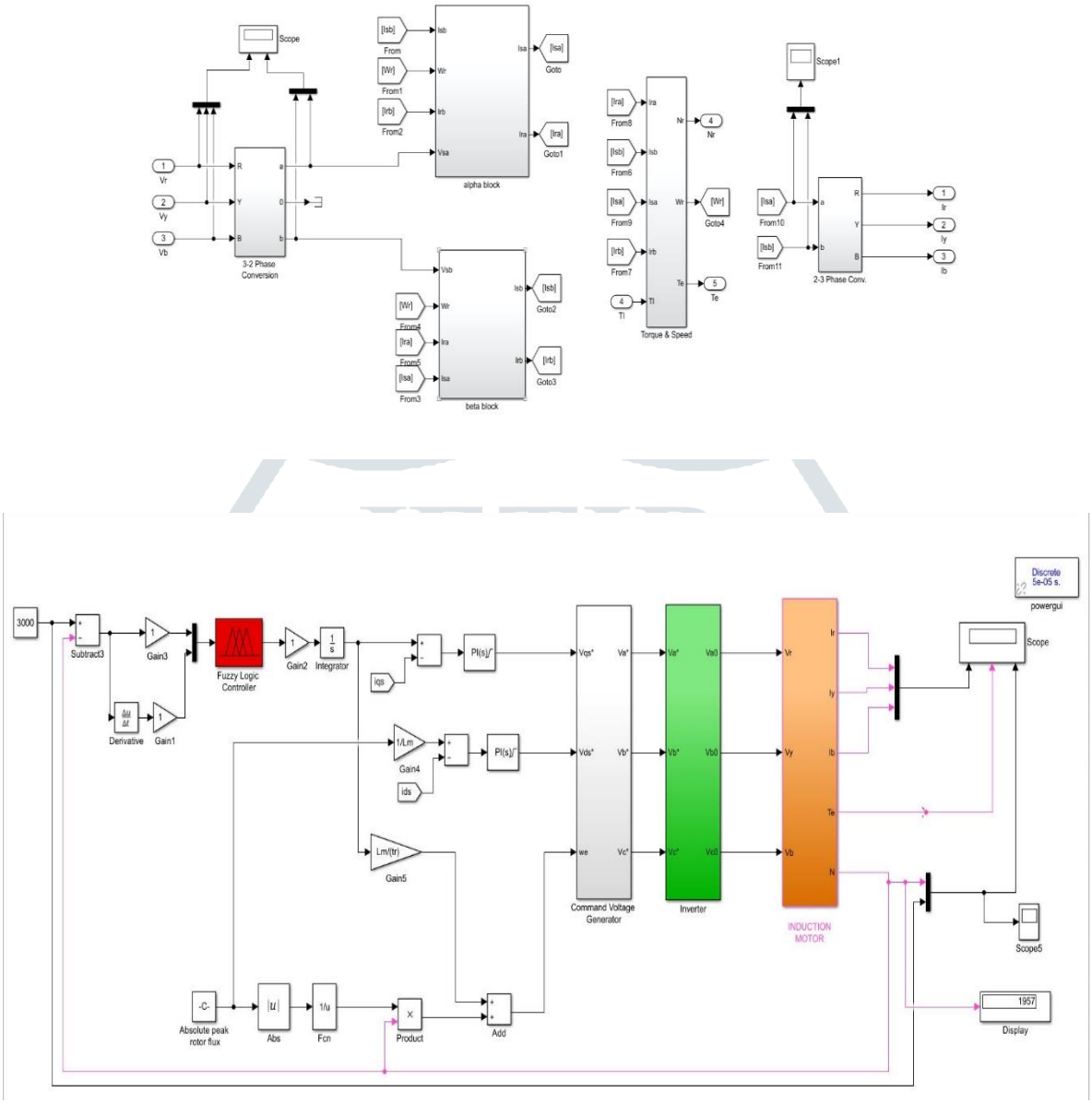

Figure 4: *Simulation Diagram in MATLAB*

Figure 3: *Dynamic Model of Induction Motor*

The dynamic (mathematical) model of induction motor is designed with following parameters.

Table 2: *Parameters of Induction Motor*

Parameter	**Value**
Stator resistance (R_s)	0.435
Rotor resistance (R_r)	0.816
Stator inductance	0.0424
Rotor inductance	0.0417
Stator leakage inductance	0.002
Rotor leakage inductance	0.002
Mutual inductance	0.041
Inertia	0.089
Number of poles	4

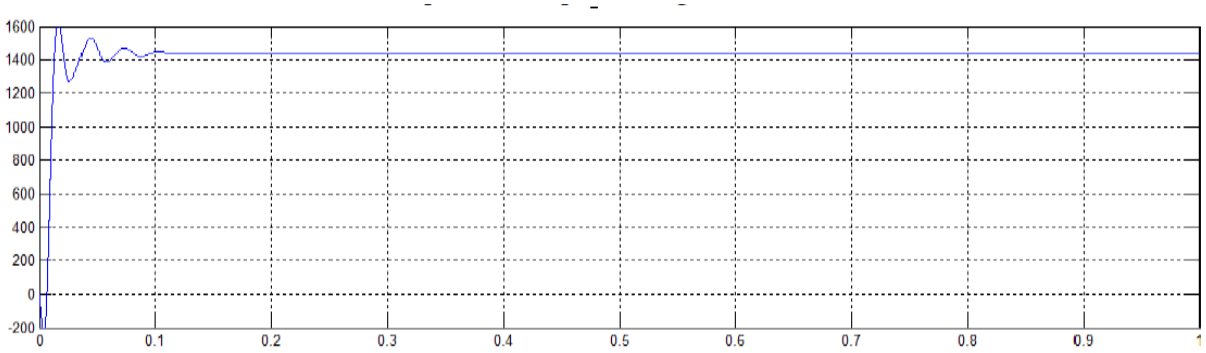

Figure 5: *Speed Response with FLC*

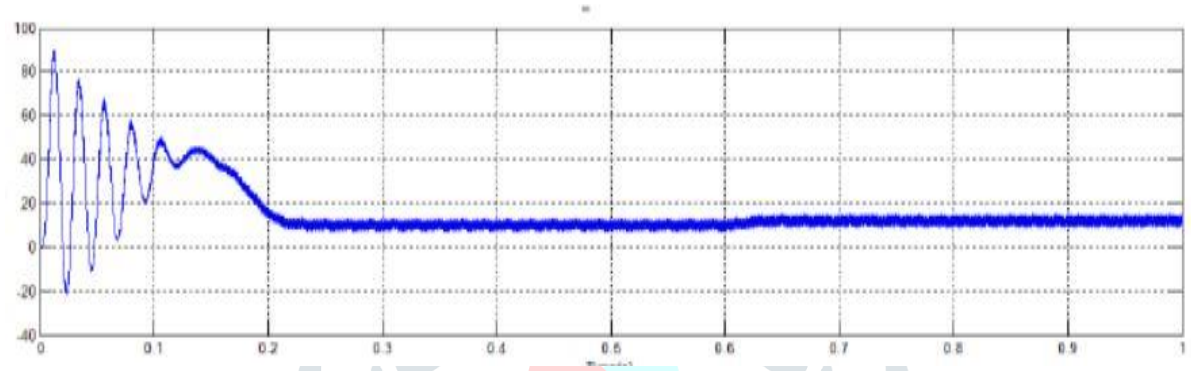

Figure 6*: Torque Response*

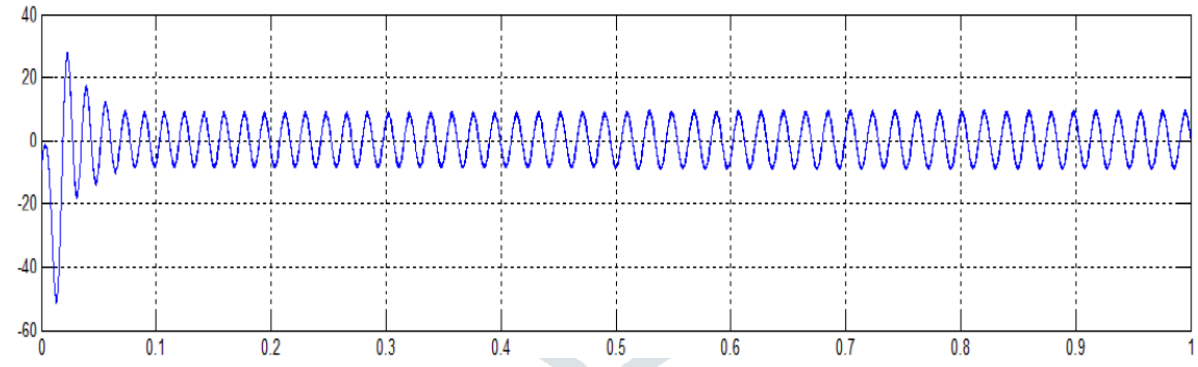

Figure 7: *Motor Current*

Simulation Results:

Hardware implementation

The whole system can be implemented using PIC microcontroller. The fuzzy logic rules can be embedded on the microcontroller and thus we can achieve desired pulses for inverter in accordance to change in speed. Complete block diagram for the proposed scheme is shown in the following figure.

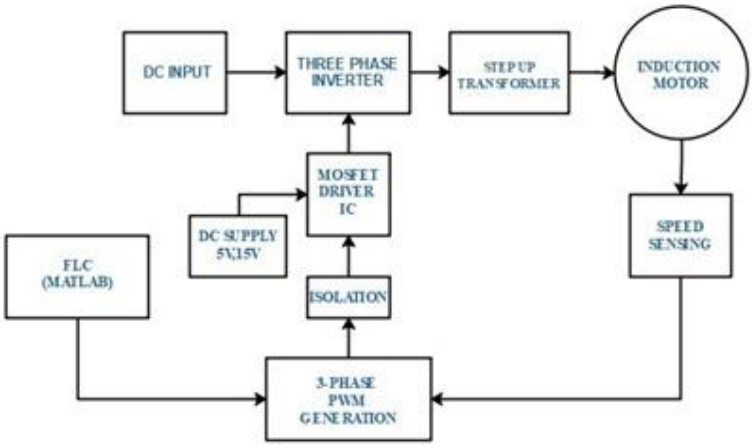

Figure 8: *Block Diagram for Hardware Implementation*

CONCLUSION

Fuzzy logic approach can be used to implement human thought process in real world application. Fuzzy logic controllers are easy to design and they provide wide range of control for linear and non-linear systems. The fuzzy logic controller used for speed control of induction motor removes the overshoot problems and gives better results compared to PI controller for the same system. In early years the fuzzy logic was just a theoretical concept, but now it is possible to implement these controllers to work in real word applications.

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