Speed Control of Induction Motor Using V/f Control Strategy

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Abstract: This paper presents a methodology for implementation of a rule-based fuzzy logic controller applied to a closed loop Volts/Hz induction motor speed control. The Induction motor is modeled using a dq axis theory. The designed Fuzzy Logic Controller's performance is weighed against with that of a PI controller[1]. For V/f speed control of the induction motor, a reference speed has been used and the control architecture includes some rules. These rules portray a nonchalant relationship between two inputs and an output, all of which are nothing but normalized voltages.

Index term: *Fuzzy logic, PI controller, Induction motor, membership function.*

I. INTRODUCTION

The constant *V/f* control is one of variable-speed control methods used for induction motor. The choice of the motor depends on the constraints imposed by the application: high torque, speed variation, speed control with respect to load variations, low cost in maintenance and simplicity of control etc. In the last few years, fuzzy logic has met a growing interest in many motor control applications due to its non- linearity's handling features and independence of the plant modeling.
The present work consists in the development and simulation of a controller for a closed loop speed control where the manipulated variable is the volts/Hz relation and, therefore, the slip value. For such applications, the proposed FLC is a suitable way to provide the necessary frequency variation command signal. The frequency command also generates the voltage command through a volts/Hz function generator, with the low frequency stator drop compensation. For simulation purposes, all values are normalized to per unit (pu). This paper will focus only on FLC techniques and the comparison with the classical PI controller. Conversely, the V/f control using fuzzy logic controller (FLC) overcomes disadvantages of Conventional PI controllers. FLCs have the ability to adapt with nonlinearity. Also the control performance is not much affected by plant parameter variations. FLCs are based on certain well defined linguistic rules; hence necessity of precise mathematical model of a real plant can be avoided.

II. BLOCK DIAGRAM OF SPEED CONTROL OF A INDUCION MOTOR

Architecture:The controller architecture includes some rules which describe the casual relationship between two normalized input voltages and an output one. Theseare:-Error (e),-Change-of-error (Δe), that is the derivative of speed error -Output, defined as the change-of-control ($\Delta\omega_{sl}$), that added to the motor speed (ωm) is the input ($\omega{*}e$) to the converter. These error inputs are processed by linguistic variables, which require to be defined by membership functions.
The Fuzzy Logic Controller is designed by using the FIS editor. The membership functions and the rules have to be designed by the programmer so as to achieve the desired results. The FIS program thus generated is to be fed to the FLC before proceeding with the simulation.

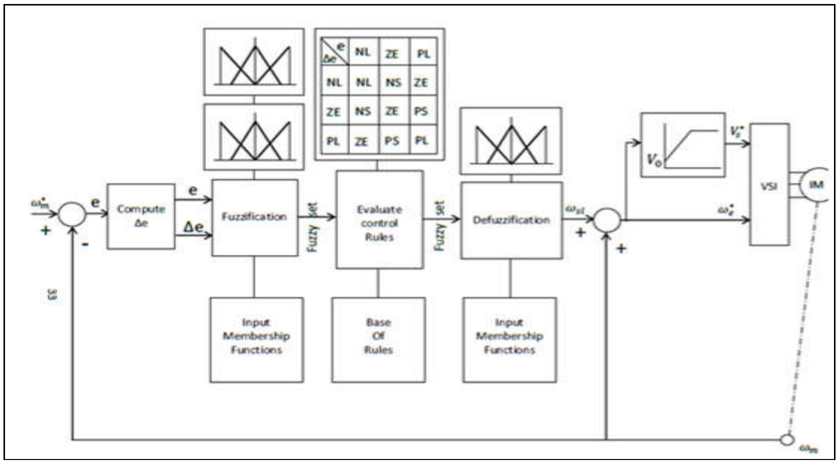

Figure 1: Block diagram of speed control of induction motor

III. IMPLEMENTATION OFFUZZY LOGICCONTROLLER

To obtain fuzzy based model of the motor, the training system derives information from two main sources:-
a. The static flux linkage curves of the motor, whichprovides important information about the electromagnetic characteristics of the motor.
b. The dynamic real time operating waveforms of the motor, which can include real-time operating effects, such as mutual coupling between phases, temperature variations, eddy currents and skin effects. During the training phase, each input-output data pair, which consists of a crisp numerical value of measured flux linkage, current, angle and voltage is used to generate the fuzzy rules.

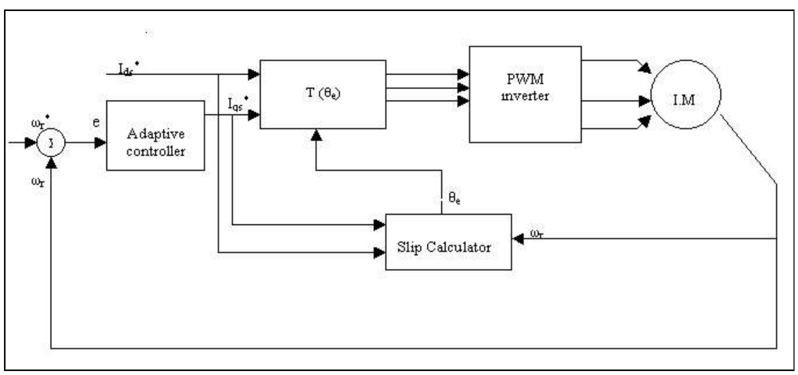

Figure 2: Block Diagram of Field Oriented Control system

Fuzzy logic: In the last few years, fuzzy logic has met a growing interest in many motor control applications due to its non-linearities handling features and independence of the plant modeling. The fuzzy controller (FLC) operates in a knowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator Fig.1 shows a scalar IM control structure with fuzzy knowledge based controller (FKBC). The FLC includes four major blocks: one that computes the error into two input variables, a fuzzification block, an inference mechanism, and the last step is defuzzification. The speed reference control is ω_m.

Knowledge Base Proposed: Fig 2 shows the triangle-shaped membership functions of error (e) and change-of-error (Δe).The fuzzy sets are designated by the labels: NL(negative large), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PL (positive large).

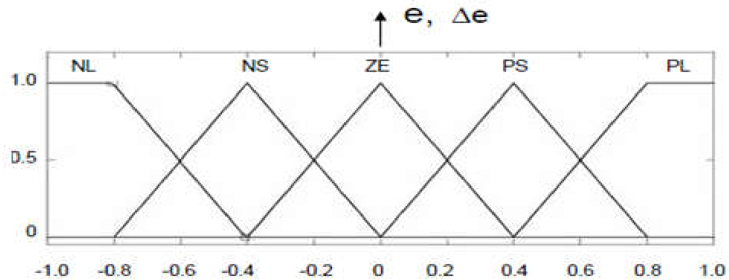

Figure 3: Triangular membership functions for input variables e and Δe

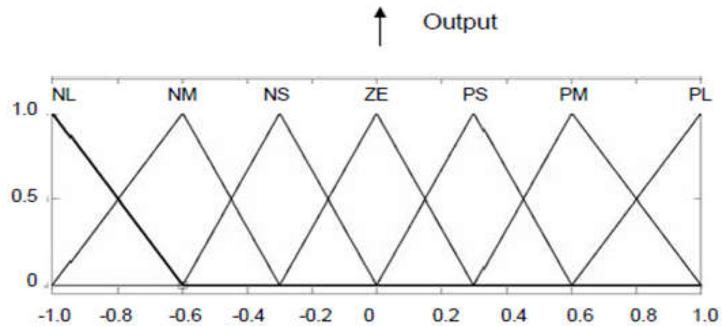

Figure 4: Triangular membership functions for output variable

Fig. 3 shows the proposed membershipfunctions for output variable and the control rules.The inference strategy used in this system is the Mamdani algorithm, and the center-of-area/gravity method [3] is used as the defuzzification strategy.

Δe \ e	NL	NS	ZE	PS	PL
NL	NL	NL	NM	NS	ZE
NS	NL	NM	NS	ZE	PS
ZE	NM	NS	ZE	PS	PM
PS	NS	ZE	PS	PM	PL
PL	ZE	PS	PM	PL	PL

Table 1: Linguistic Variable

According to the equation giving a PI-like FKBC is The fuzzy if-then statements are symbolicallyexpressed with the formIf e is (…) and Δe is (…) then ωsl is (…)The output control is, thenωe =ωm + ωsl ∗(2). The command signal is obtained from twenty-fiverules witch all have the same weight of one, asshown in appendix.To tune the fuzzy control, it is possible to change thetwo values kp and ki (ec.1).Fig. 4 shows the control surface extracted from theMatlab® fuzzy logic toolbox surface viewer, when kp and ki =1.

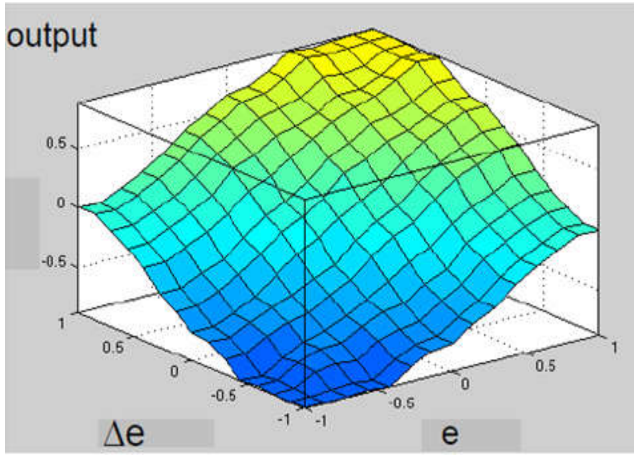

Figure 5: Three-dimensional plot of control surface

IV. IM DYNAMIC MODEL

The induction motor is modeled with Matlab/Simulink® program running under three phase sinusoidal symmetrical excitation and is at vectorized form in conformity with state vector formulation [8].

Ω_0 = base freq.; ω_m = rotor frame freq.;ω_k =dq frame freq.; ω_s = synchronous frame freq.; (rad/sec)
λ_s=stator flux, λ_r=rotor flux (pu)
R_s ; R_r =stator and rotor resistance (pu)
V_s ; v_r =stator and rotor voltage (pu)
I_s ; i_r =stator and rotor current (pu)
L_s ; L_r = stator and rotor inductance (pu)
L_m = magnetizing inductance (pu)
L_{sl} = stator leakage inductance (pu)
L_{rl} = rotor leakage inductance (pu)
T_e = electromagnetic torque (pu)
T_l = load torque (pu)
B_m = viscous friction coefficient. (pu)
d, q=direct and quadrature axis
p=number of poles

ELECTRICAL SYSTEM EQUATION:

$$\bar{v}_s = R_s \, \bar{i}_s + \frac{1}{\omega_0}\left(\frac{d\bar{\lambda}_s}{dt}\right) + \omega_k \, M_{(pi/2)} \, \bar{\lambda}_s$$

$$\bar{v}_r = R_r \, \bar{i}_r + \frac{1}{\omega_0}\left(\frac{d\bar{\lambda}_r}{dt}\right) + (\omega_k - \omega_m) M_{(pi/2)} \, \bar{\lambda}_r \qquad (3)$$

FLUX LINKAGE EQUATION:

SIMULATION RESULTS

On d axis:

$$\bar{\lambda}_{sd} = L_s\, \bar{i}_{sd} + L_m\, \bar{i}_{rd}$$

$$\bar{\lambda}_{rd} = L_m\, \bar{i}_{sd} + L_r\, \bar{i}_{rd}$$

where

$$L_s = L_m + L_{sl}$$

$$L_r = L_m + L_{rl}$$

On q axis:

$$\bar{\lambda}_{sq} = L_s\, \bar{i}_{sq} + L_m\, \bar{i}_{rq}$$

$$\bar{\lambda}_{qr} = L_m\, \bar{i}_{qs} + L_r\, \bar{i}_{qr}$$

V. SIMULATION

The Induction Motor has been modeled in chapter 2, section 2.5. The very equations mentionedthere can be used to build the Induction Motor model in SIMULINK shows blockdiagram of the induction motor with three inputs namely, input voltage (v_s), speed of inductionmotor (ω_m) and speed of the *dq* frame (ω_k). Torque and current are taken as outputs.

The block diagram of scalar control of induction motor using fuzzy logic controller and PI controller designed in MATLAB/SIMULINK®. The parameters that have been used to describe the electrical and electromechanical systems are shown in Fig. 9. These parameters are expressed in per unit (pu).

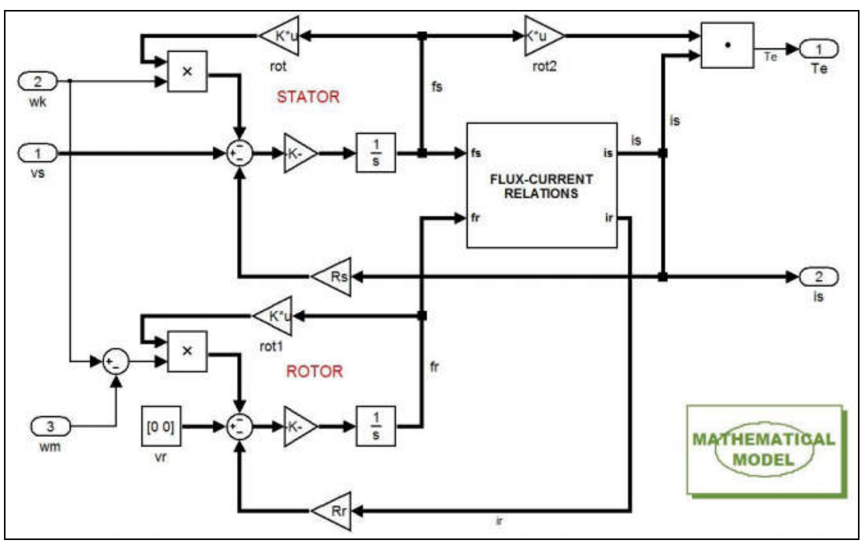

Figure 6:Space vector model of Induction motor

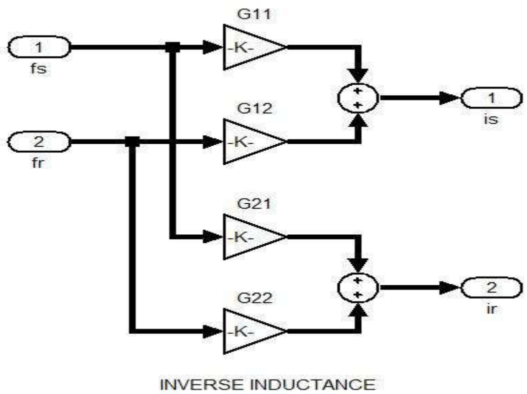

Figure 7: Simulink model for flux-current relation

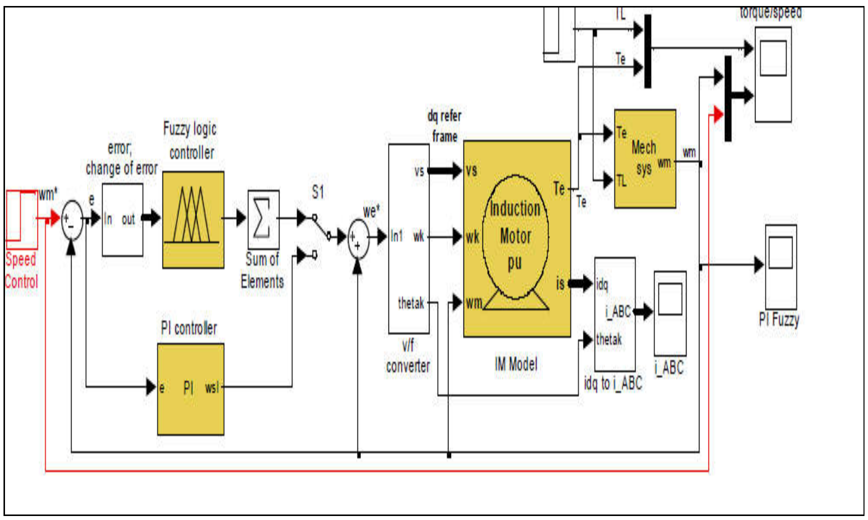

Figure 8: Scalar control of induction motor using fuzzy logic controller and pi controller

Parameter	Quantity
Stator Resistance	0.025 pu
Rotor Resistance	0.015 pu
Stator Leakage Inductance	0.10 pu
Rotor Leakage Inductance	0.01 pu
Magnetizing Inductance	3.0 pu
Base Frequency	2*π*50 rad/s
Number of Poles	2
Moment of Inertia	0.6 pu
Viscous Friction Coefficient	1e-5 pu
Proportional Constant	0.6
Integral Constant	5.6
Saturation Limit	0.03

Figure 9:The parameters for the PI controller used for comparison with the Fuzzy Logic Controller are

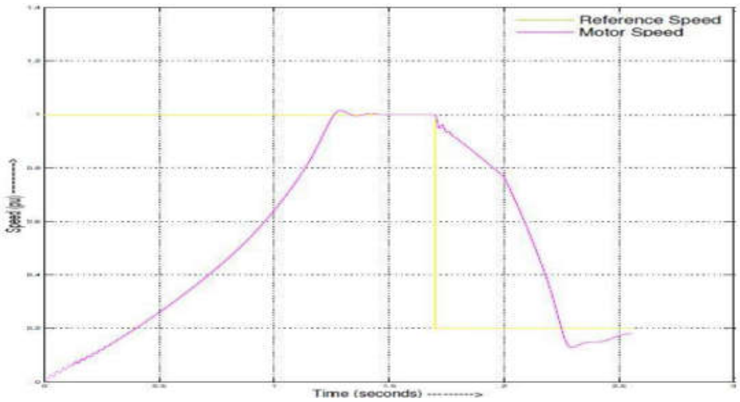

Figure 10: Speed versus Time Plot with Reference Speed (ω^*_m) varying from 1 to 0.2 using Fuzzy Logic Controller

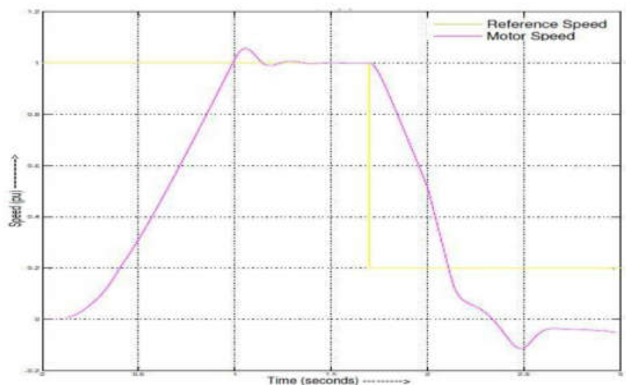

Figure 11: Speed versus Time Plot with Reference Speed (ω^*_m) varying from 1 to 0.2 pu using PI Controller

VI. RESULT

The block diagram is simulated and the plots for speed, and torque using both Fuzzy Logic Controller and PI Controller were observed. These have been compared above with the help of graph. The Speed versus Time plot is shown with reference speed varying from 1 to 0.2pu for Fuzzy Logic Controller and PI Controller respectively.

VII. CONCLUSION

The Fuzzy Logic Controller used in this simulation has some drawbacks along with advantage. But these disadvantages, viz. (i) achievement of only near to exact reference speed after change in reference speed and (ii) high rise time, can be reduced by refining the membership functions. In this simulation we have taken hybrid of trapezoidal and triangular membership functions for the inputs and triangular membership functions for the output. We can choose Gaussian membership functions for refining the control. Also the membership functions near the zero region can be made narrower and those towards the outside can be made comparatively wider. The tuning of the control will be taken up as the next step for the project.

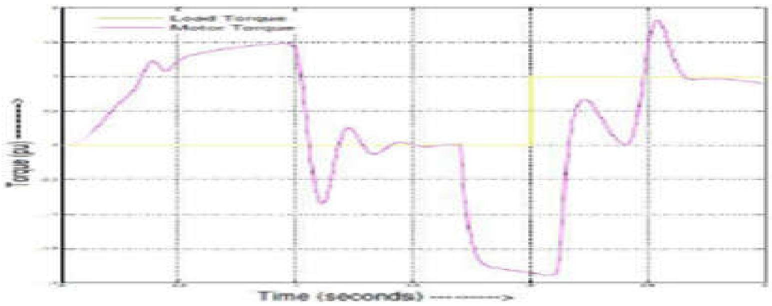

Figure 12: Torque versus Time Plot with varying from 1 to 0.6 pu using FLC & PI controller respectively

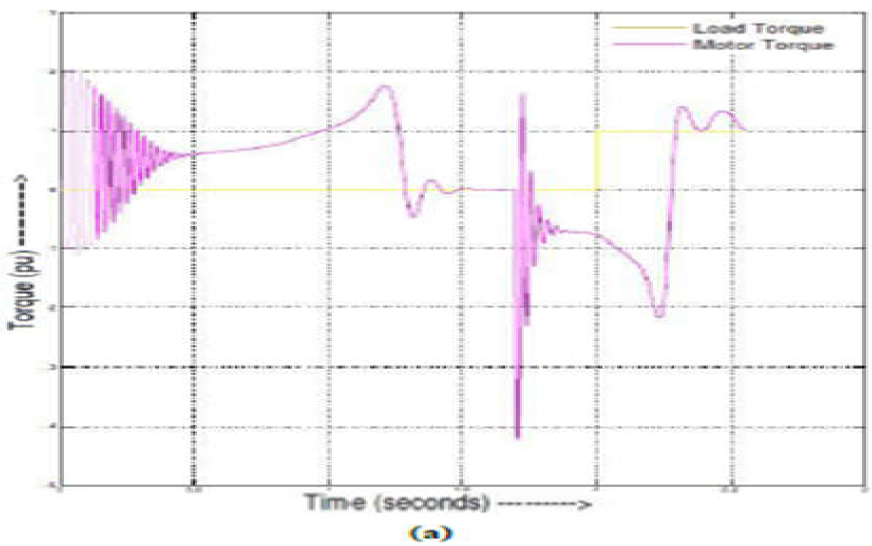

Figure 13:Torque versus Time Plot with varying from 1 to 0.6 pu using FLC & PI controller respectively

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