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COMPARATIVE STUDY AND ANALYSIS OF SPEED CONTROL OF THREE PHASE INDUCTION MOTOR USING CONVENTIONAL METHOD AND MACHINE LEARNING

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ABSTRACT

Induction motor is widely used in industrial applications like automotive industry. Automotive industry is very wide like rail, aerospace, shipping etc. Speed control of induction motor is very necessary because if any application requires to drive motor at required speed then it becomes compulsory to achieve speed and algorithm is necessary to implement in Microcontroller, DSP or FPGA or in any other controller. If speed is not controlled then motor may overheat or rotor may sleep when load is attached with motor shaft. The problem of wheel sleep is most common in rail industry when friction is reduced because of rainy season on rail roads. If overheating of motors occurs at that time speed also need to be reduces and this required speed should be achieved smoothly with in short time of seconds without any overshoot or delay. This paper deals with mathematical modelling of induction motor and control algorithms. Three different methods are implemented in simulation to prove the concept of control algorithm and it is widely used in industry.

KEYWORDS: *Control, PI, Fuzzy, Anfis, Induction motor, Mathematical Modelling*

INTRODUCTION

There are various methods for speed control of motors like PID, Fuzzy, Neural network, Genetic algorithms, Particle swarm optimization etc. But some of this methods requires equivalent transfer function by mathematical modelling for obtaining compensator to achieve best time domain parameters. Equivalent representation of mechanical or electrical system in equation form is called mathematical modeling. Before actual implementation it is always a good practice to do simulation and mathematical modelling to observe the behaviors of system. We can give different standard inputs to system and can observe behavior of system. If system works satisfactorily then we can further proceed for actual implementation. Step signal is one of the standard test signal. We have implemented it into our simulation. Ramp and parabolic is also standard test signals. Step signal is sudden shock kind of signal, Ramp is a linearly increasing signal and parabolic is exponential kind of signal. Induction motor is nonlinear and it is not possible to obtain transfer function and some methods like GA becomes tedious to implement. So, it is necessary to move at PID, Fuzzy and ANFIS for speed control application. Different authors have proposed different methods but this paper deals with implementation of all three methods in single paper.

A.Visioli, "Tuning of PID controllers with Fuzzy Logic", IEEE proceedings for Control Theory Applications, Volume 148, No.1, January 2001

A. Visioli in 2001 presented a comparison between different methods, based on fuzzy logic for tuning of PID controllers. He considered different control structures in which a fuzzy mechanism is adopted to improve the performance given by Ziegler-Nichols parameters. He taken different kind of six transfer functions and verified results from implemented algorithm.

Endra Joelianto, Deddy Candra Anura, "Transient Response Improvement of PID Controller using ANFIS-Hybrid Reference Control", 2nd International Conference on Instrumentation Control and Automation, 15-17 November 2011

This paper proposed an ANFIS based hybrid reference control to improve the transient response performance of the closed loop PID control system. The design steps consist of generating training data set, obtaining membership functions and number of membership functions and then ANFIS learning.

MATHEMATICAL MODELLING

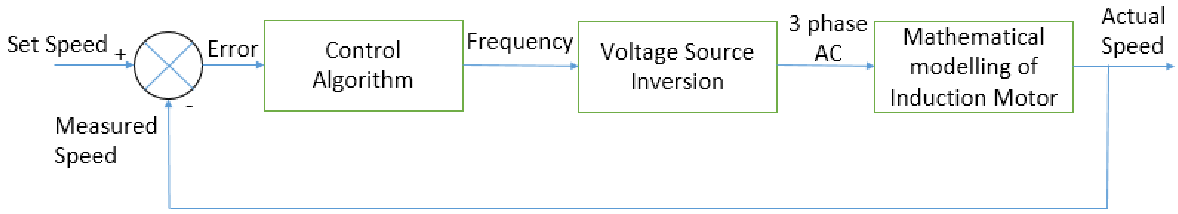

Figure 1. Implementation flow diagram

PI CONTROL ALGORITHM

Error e(t) = Set Speed – Measured Speed = N – N*

Frequency F = k_p e(t) + $k_i \int e(t)dt$

FUZZY CONTROL ALGORITHM

Triangular membership function

$$f(x,a,b,c) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{c-x}{c-b} & b \le x \le c \\ 0 & c \le x \end{cases}$$

Error e(t) = Set Speed – Measured Speed = N – N*

Error = [-100 100]

Change of Error = [-1000000 1000000]

Frequency = [-50 50]

Rules		Input 2						
		NB	NM	NS	ZE	PS	PM	PB
Input 1	NB	NB	NB	NB	NB	NM	NS	ZE
	NM	NB	NB	NB	NM	NS	ZE	PS
	NS	NB	NB	NM	NS	ZE	PS	PM
	ZE	NB	NS	NM	ZE	PS	PM	PB
	PS	NM	NS	ZE	PS	PM	PB	PB
	PM	NS	ZE	PS	PM	PB	PB	PB
	PB	ZE	PS	PM	PB	PB	PB	PB

Table 1. Fuzzy Rules

Rules: Input 1 AND Input 2 is Output

Defuzzification method: Centroid

There are various methods for defuzzification like weighted average, centre of gravity etc.

ANFIS ALGORITHM

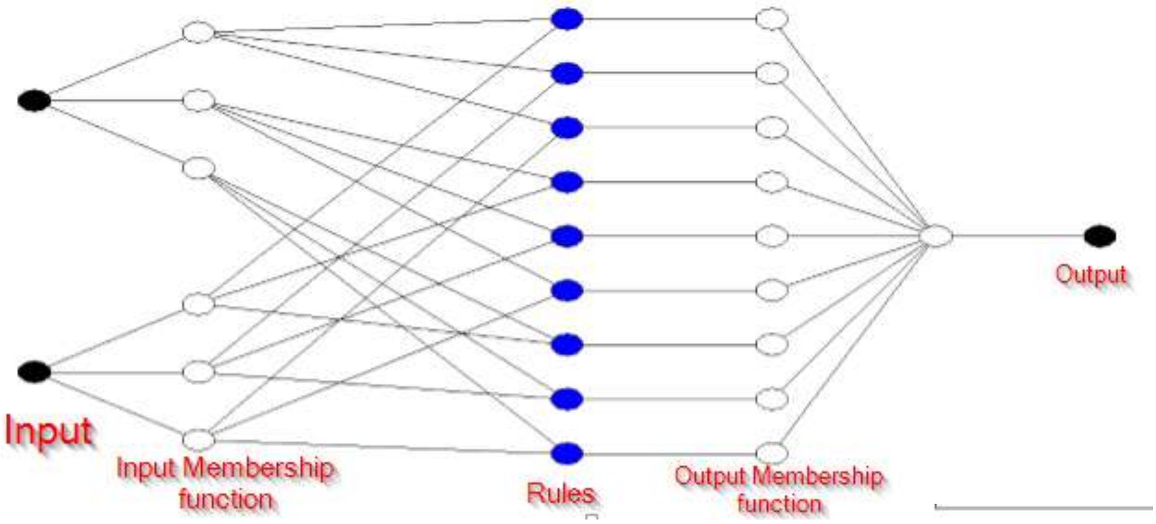

Figure 2. ANFIS Structure

It is using Hybrid optimization method with Three Input-1 and Three Input-2 triangular membership functions.

Output of all this control algorithms is frequency which controls PWM for voltage source inversion for DC to AC conversion.

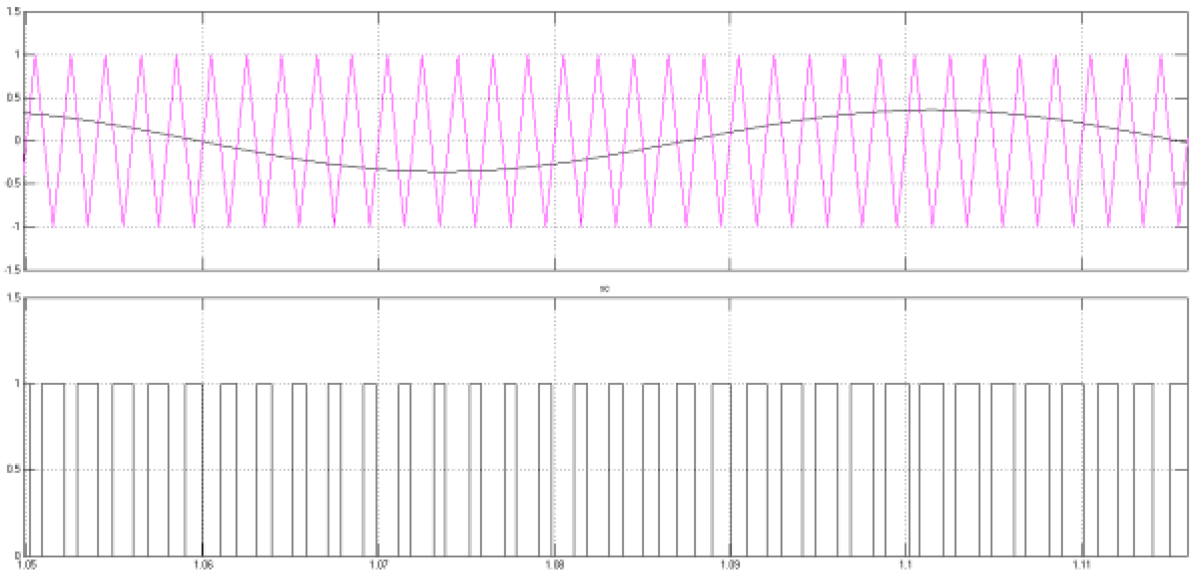

Figure 3. Frequency control using PI, Fuzzy and ANFIS and PWM Generation

VOLTAGE SOURCE INVERSION

Three phase voltage for induction motor is given by this equation:

$V_a = 2\sqrt{\frac{2}{3}}\frac{V_{dc}}{3}\left(2 * u(1) - u(2) - u(3)\right)$

$V_b = 2\sqrt{\frac{2}{3}}\frac{V_{dc}}{3}(-u(1) - 2 * u(2) - u(3))$

$V_c = 2\sqrt{\frac{2}{3}}\frac{V_{dc}}{3}(-u(1) - u(2) - 2 * u(3))$

u(1) = U(2)*sin(U(1))

u(2) = U(2)*sin(U(1) – 2*($\frac{\pi}{3}$))

u(3) = U(2)*sin(U(1) + 2*($\frac{\pi}{3}$))

U(1) = 2*π*F = Theta

U(2) = $\frac{2*\pi*F}{2*\pi*50}$ = Signal

MATHEMATICAL MODELLING OF INDUCTION MOTOR

$$\begin{bmatrix} V_{ds} \\ V_{qs} \\ - \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & \frac{\sqrt{3}}{3} & -\frac{\sqrt{3}}{3} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

$I_{ds} = (\frac{1}{(L_s - \frac{Lm^2}{L_r})})(\psi_{ds} - (\frac{L_m}{L_r})\psi_{dr})$

$I_{qs} = (\frac{1}{(L_s - \frac{Lm^2}{L_r})})(\psi_{qs} - (\frac{L_m}{L_r})\psi_{qr})$

$$\begin{bmatrix} I_{sa} \\ I_{sb} \\ I_{sc} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & 0 \\ -0.5 & -\frac{\sqrt{3}}{2} \\ -0.5 & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{ds} \\ I_{qs} \end{bmatrix}$$

$I_{dr} = (\frac{1}{(L_r - \frac{Lm^2}{L_s})})(\psi_{dr} - (\frac{L_m}{L_s})\psi_{ds})$

$I_{qr} = (\frac{1}{(L_r - \frac{Lm^2}{L_s})})(\psi_{qr} - (\frac{L_m}{L_s})\psi_{qs})$

$$\begin{bmatrix} I_{ra} \\ I_{rb} \\ I_{rc} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & 0 \\ -0.5 & -\frac{\sqrt{3}}{2} \\ 0.5 & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{dr} \\ I_{qr} \end{bmatrix}$$

$$T_e = (\psi_{ds} I_{qs} - \psi_{qs} I_{ds})\frac{3P}{4}$$

$$N^* = \frac{30}{\pi}(w_e)$$

MOTOR PARAMETERS	
Stator Resistance Rs(Ohms)	10.1
Stator Inductance Ls(Henry)	(15.81+245.8954)/(2*pi*50)
Rotor Resistance Rr(Ohms)	9.8546
Rotor Inductance Lr(Henry)	(15.81+245.8954)/(2*pi*50)
Mutual Inductance Lm(Henry)	(245.8954)/(2*pi*50)
Rotor Inertia J (Kg-m^2)	0.0088
Number of Poles P	4

Table 2. Three Phase Induction Motor Parameters

RESULT ANALYSIS

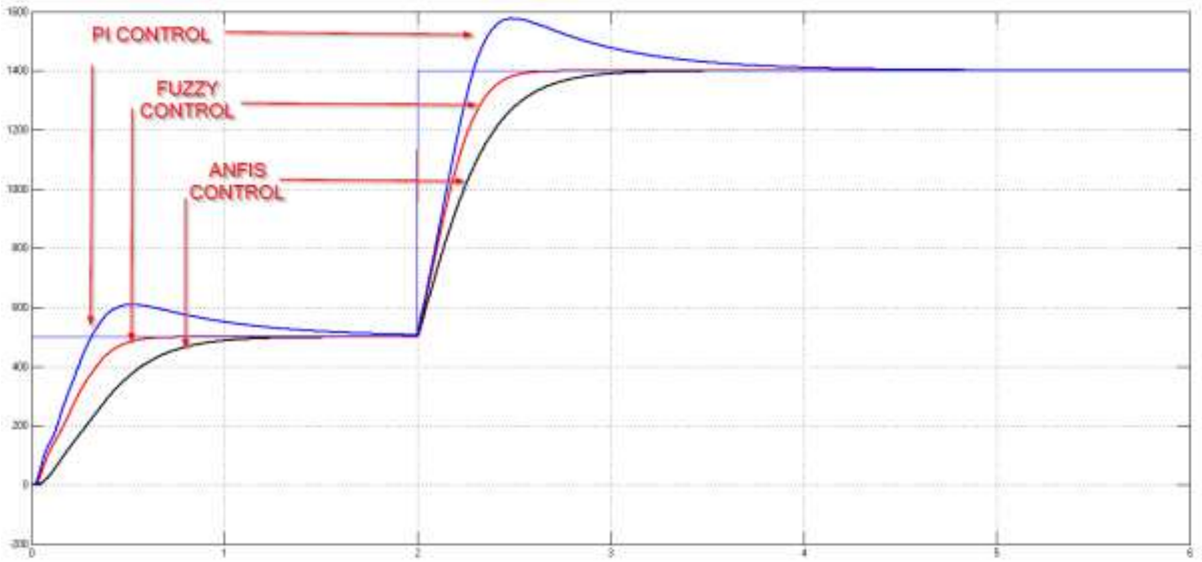

Figure 4. Comparative Results

Table below shows the comparison of achieved best parameters with classical tuning and machine learning method.

Tuning Algorithm	Speed	Time domain Parameters			Speed Change after sometime	Time domain Parameters		
		Rise time	Settling time	Peak Overshoot		Rise time	Settling time	Peak Overshoot
PID	**500**	0.27	1.8	20	**1400**	2.2	5	19.5
Fuzzy	**500**	0.41	0.57	0.1	**1400**	2.3	2.5	0
ANFIS	**500**	0.72	1.02	0	**1400**	2.6	2.9	0

Table 3. Result table of Time Domain Parameters

CONCLUSION

From the above implementation it can be concluded that ANFIS and Fuzzy method gives best results for speed control of induction motor compared to conventional method of PID tuning. ANFIS method gives least peak overshoot and rise time is also fast but takes more settling time.

ANFIS method also have various algorithms and in current simulation we have used hybrid method. It can further improved by using another method like back propagation.

Fuzzy system also have different kind of membership functions. In this paper we have used triangular membership function. By using Gaussian, trapezoidal and other membership functions we can achieve different results and can compare. In this paper we have used trial and error method for PID tuning because transfer function is not available, else one can use Integral absolute error, Integral square error, Integral time absolute error, Integral time square error methods.

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