Performance Enhancement of an Induction Machine – A New Idea with Computer Based Fuzzy Logic Theory

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Abstract

The development of inverters providing variable voltage, variable frequency sources have widened their applicability in controlling speed / torque of a. c. motors over a wide range. Conventional armature voltage control, slip energy recovery schemes and rotor resistance control are being replaced by static converters. The proposed work, a six step inverter is used as static converter. The main theme is to choose a particular switching state based on fuzzy logic theory in order to get required torque and performance enhancement (PE). Fuzzy logic theory is recently widely emphasized in process control applications and among, the designing of inverter fed induction motor switching state evoked as interest which utilizes Matlab software package.

Keywords: *Fuzzy Logic Theory, Fuzzy Logic Controller, Arbitrary Reference Frame, Fuzzy Rules, Switching State, Torque Control, Expert System, Knowledge based system and performance enhancement (PE).*

1.0 Introduction

Now days, Induction motors have become widely used popular drive in which full torque capability and avoiding of saturation of the motor is furnished by the variable frequency operation accomplished with constant flux. It is achieved by the applied voltage is varied as function of frequency that obtained with inverters.

During the past several years, Fuzzy Logic Controller has emerged as one of the most effective and practical tool for design of control systems. The use of a Fuzzy Logic Controller significantly modifies the approach to automatic control problems. A conventional controller adjust the system control parameters based up on differential equations, while Fuzzy Logic Controller adjust same Parameters by Fuzzy rule based expert system, a logical model of the practical system variations.

Y. F. Li and C.C Lau [1] developed Fuzzy algorithms for microcomputer based servo controller. Gilberto C.D. Soza and Bimal K. Bose [2] applied a fuzzy logic to a speed control system that uses a phase controlled bridge converter and a separately excited DC Motor. B.Cakir, A.B. Yildiz, N.Abut and N.Inanc [3] are proposed new control method of a separately excited DC traction motor using fuzzy logic. Silverio Bolognami and Mauro Ziglioho [4] designed a Fuzzy Logic Controller for a switched reluctance motor.

In the proposed, Fuzzy Logic Controller, a Fuzzy Logic approach is applied corresponding to error in flux and torque. The noted problems of the conventional controllers like sluggish response during starting and under changes of torque command are minimized in the proposed method with enhancement in the performance of an Induction motor.

2.0 Design of Fuzzy Logic Control for Inverter fed Induction Motor

Simulation of the induction motor in d-q axis reference frame is done, the stator flux and stator torque [5, 6] are determined using equations 2.1, 2.2 and 2.3. The procedure [7] is explained in the flow chart given in Fig (1).

Expression for flux linkages:

$$\begin{bmatrix} \lambda_{ds} \\ \lambda_{qs} \\ \lambda_{dr} \\ \lambda_{qr} \end{bmatrix} = \begin{bmatrix} L_S & 0 & M & 0 \\ 0 & L_S & 0 & M \\ M & 0 & L_r & 0 \\ 0 & M & 0 & L_r \end{bmatrix} \begin{bmatrix} I_{ds} \\ I_{qs} \\ I_{dr} \\ I_{qr} \end{bmatrix} \quad (2.1)$$

Stator Flux: $\lambda s = [(\lambda ds)^2 + (\lambda qs)^2]^{1/2}$ (2.2)

Expression for Torque: $T = (3/2) (P/2) (\lambda ds\ Iqs - \lambda qs\ Ids)$ (2.3)

Where, λds, λqs = Stator d-q axis fluxes , Ls = Stator Inductance, Ids,Iqs = Stator d-q axis currents Lr = Rotor Inductance, λdr and λqr = Rotor d-q axis fluxes, M = Mutual Inductance, Idr, Iqr = Rotor d-q axis currents, T = Torque, P = Number of poles, λs = Stator flux.

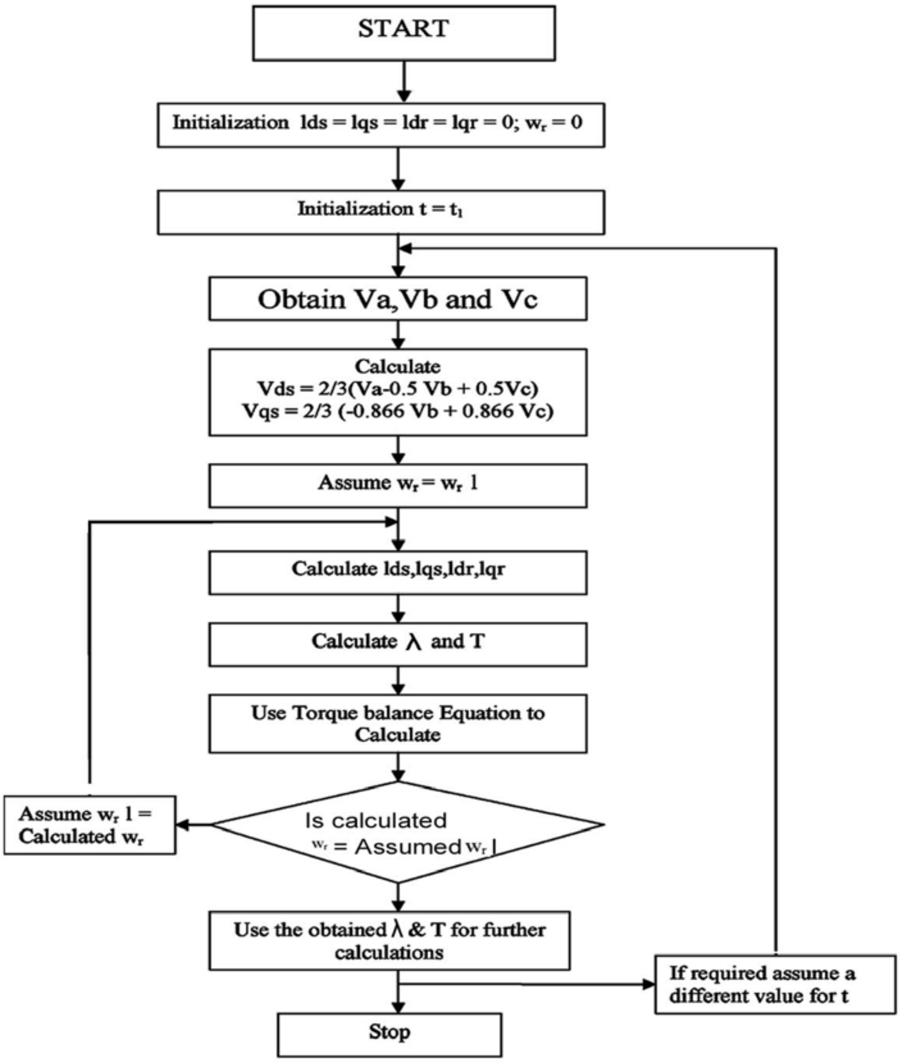

Fig.(1) Flow chart for simulation for Induction Motor

These values are used to calculate the state variables for Fuzzy logic controller [8]. The general Fuzzy logic controller is as shown in Fig. (2).

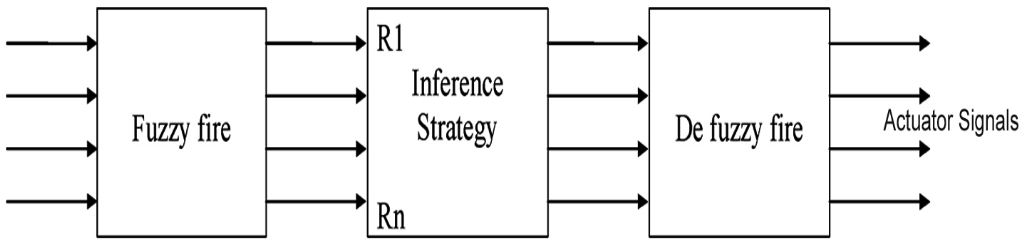

Fig (2)Fuzzy Logic Controller

2.1 Fuzzy State and Control Variables

Fuzzy Logic controller is designed to have two state variables and one control variable for achieving constant torque and flux control. Each variable is divided into fuzzy segments. The number of fuzzy segments in each variable is chosen to have maximum control with minimum number of rules.

The first state variable is the difference between the command state flux λ_{sref} and the estimated stator flux λ_{scal} is given by.

Error in stator flux $E_{\lambda} = \lambda_{sref} - \lambda_{scal}$ (2.4)

The second state variable is the difference between command electric torque T_{ref} and the estimated electric torque T_{cal} is given by

Error in torque $E_T = T_{ref} -- T_{cal}$ (2.5)

In order to generate membership function for the fuzzy state variables, inductive reasoning method is used.

2.2 Member Ship Function Generation using Inductive Reasoning Method

The Inductive reasoning method [9] generates the membership function based on data provided. To subdivide the data set into the membership function, fuzzy thresholds are established. First threshold line, with an entropy minimization screening method is used to start segmentation process and then data set partitioned in to fuzzy sets.

The universe of discourse of flux error fuzzy state variable is divided into three over lapping fuzzy sets positive flux error P, Zero flux error ZE and negative flux error N.This is shown in Fig.(3).

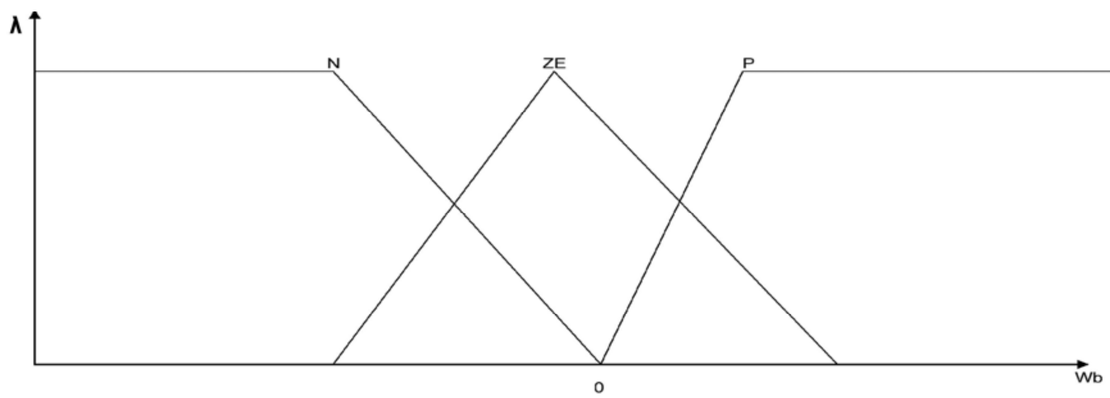

Fig (3) Membership distribution for FLUX

To make, the torque variations small, the universe of discourse of torque error is divided into five overlapping fuzzy sets likely Positive large error PL, Positive small error PS, zero error Z, negative small error NS, and negative large error NL. This is shown in Fig .(4).

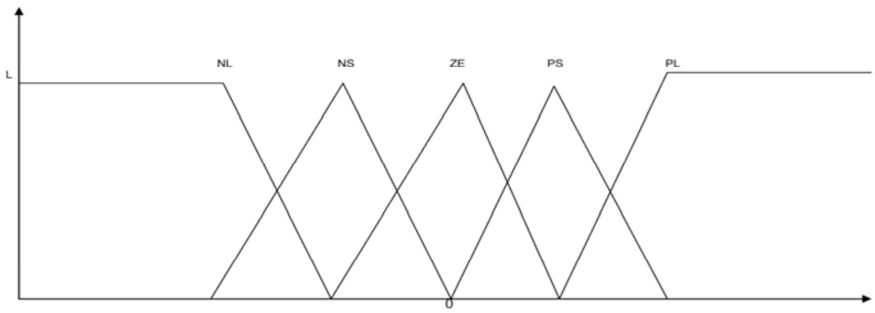

Fig (4) Membership distribution for TORQUE

2.3 Fuzzy Rules for Self Control

Each control rule can be described using the state variables E_λ and E_T the control variable n. The i th rule Ri can be written as,

Ri: if E_λ is Ai, and E_T is Bi then n is Ni

Where Ai, Bi and Ni represent the fuzzy segments. The control rules[10] are formulated using the vector diagram for direct self-control as shown in Fig. (5).

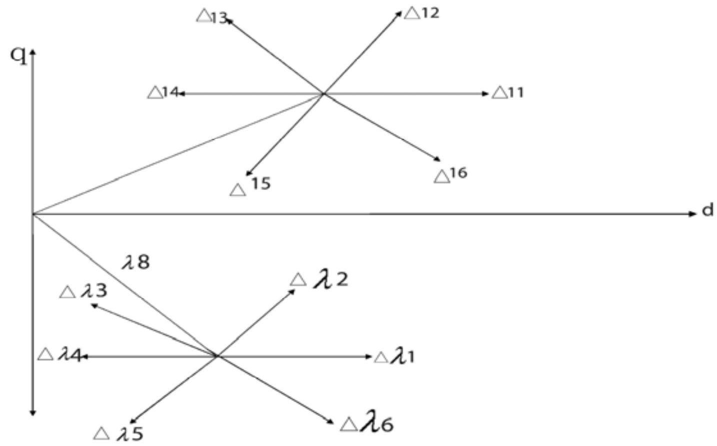

Fig (5) Vector diagram used for switching state Selection

From the vector diagram, states 5, 6, and 1 increases the flux while states 2, 3 and 4 decreases it. Similarly states 6, 1 and 2 increases the torque which states 3, 4 and 5 decreases it. For a large increase in flux and a small increase in torque, state 6 is selected. For a small increase in flux and a large increase in torque, state 1 is selected. For a small decrease in flux and a small increase in Torque, state 2 is selected. For a large decrease in flux and a small decrease in torque, state 4 is selected. For a small decrease in flux and a large decrease in torque state 5 is selected. For a small decrease in torque and constant flux, state 0 is selected. All these rules are formulated in table- 1 of membership matrix table for flux (Quantized Level).

Table – 1
Membership Matrix Table for Flux: Quantized Level

Linguistic sets	-0.005	-0.004	-0.003	-0.002	-0.001	0.000	0.001	0.002	0.003	0.004	0.005
P	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.400	0.800	1.000	1.000
Z	0.000	0.000	0.200	0.600	0.900	1.000	0.900	0.600	0.200	0.000	0.000
N	1.000	1.000	0.800	0.400	0.100	0.000	0.000	0.000	0.000	0.000	0.000

Table – 2 A
Membership Matrix Table for Flux for Torque

Linguistic sets	-5	-4	-3	-2	-1	0	1	2	3	4	5
PL	0	0	0	0	0	0	0	0.5	1	1	1
PS	0	0	0	0	0	0	1	0.5	0	0	0
ZE	0	0	0	0	0	1	0	0	0	0	0
NS	0	0	0	0.5	1	0	0	0	0	0	0
NL	1	1	1	0.5	0	0	0	0	0	0	0

Table – 2B
Fuzzy Rules of Control

E_T/E_R	P	Z	N
PL	1	2	2
PS	1	2	3
ZE	0	0	0
NS	6	0	4
NL	6	5	5

After developing the control, it is required to develop a membership matrix as given in table – 2A that includes both the state variables. The table-1 for E λ (Error in Flux) consists three sets P, Z, N. The table-2B for ET (Error in Torque) consists five sets PL, PS, ZE, NS, and NL. The designed fuzzy logic controller for Induction motor [11] considered in Fig. (6).

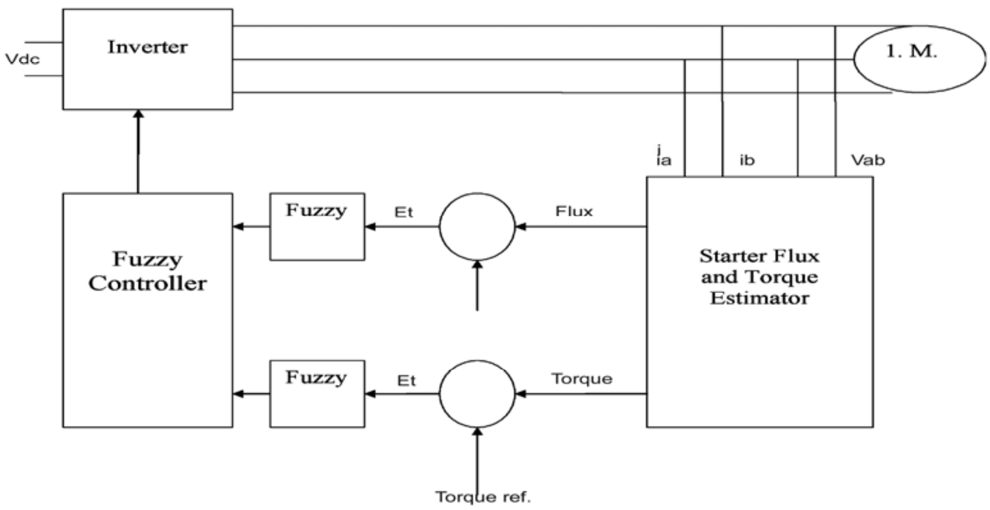

Fig (6) Designed Fuzzy Logic Controller for Induction Machine

3.0 Results

A 10 KW, 4 pole, 400Volts Induction motor data is being used for the simulation. The command torque and command flux are 14.31 N-m and 0.952 wb, respectively. For any variation in the torque and flux, the corresponding inverter switching state is obtained. This inverter switching state brings the motor torque and flux to the desired level.

4.0 Conclusions

In order to improve the operational performance of the induction motor, FUZZY Logic Theory may be used. An induction machine operated with a conventional controller shows sluggish response during starting and under changes of torque command. It is being proposed that the problems of current conventional controller may be more significantly minimized by using computer based fuzzy logic theory.

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