Fuzzy based DTC control of Induction motor for Pumping Application

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***Abstract*— In this paper DTC based fuzzy logic control of voltage source inverter used for pumping application has been proposed. In order to improve the performance of the system the proposed fuzzy based DTC controller is used to reduce the losses of the system. The Mamdami input is designed with two input and one output and 49 rules are framed. The reason for choosing two inputs is one input is used for error and another input is used for change in error. The difference between the set-speed and actual speed is called error. The difference between the pre-set error and the previous error is the change in error. Each input is designed with 7 triangular membership functions.Through this paper the drawbacks of conventional DTC control, such as high torque ripple ratio are overcome with help of Fuzzy based DTC control. The performance conditions such as speed and change in speed and load torque is observed and simulation results are carried in MATLAB software.**

Keywords- Fuzzy logic controller, Induction motor drives, centrifugalpump, speed control,Mamdami input, Direct torque control

I. INTRODUCTION

In order to respond to the changes in the speed and torque good dynamic performance of the drive is mandatory. In comparison with many other control methods the direct torque control (DTC) provides the fast response and has many advantages but the main drawback is it has high torque ripple and the conventional DTC control with PI controller cannot obtain better response for the change in load torque and inertia moment in the load. In order to overcome this drawback, Fuzzy logic based speed controller of induction motor is proposed. The proposed topology has achieved great importance, becauseit doesn't require any mathematical models. Due to change in temperature during working condition a fuzzy logic controller is used to estimate the changes in stator resistance. In this way the fuzzy logic controller provides good dynamic performance of the machine and they are robust.

II. DESIGN AND DESCRIPTION OF FUZZY LOGIC CONTROLLER

A. Designing of input and output variables

In order to design a fuzzy logic controller first we have to clearly specify the input and output variables. Through fuzzy logic controller we can take several inputs, As of now we are taking two observed values. They are speed error$e\omega(k)$ and variation of speed with respect to time $ce\,\omega(k)$ are considered.

$$e\omega(k)=\acute{\omega}r(k)-\omega r(k) \qquad (1)$$

$$ce\omega(k)= e\omega(k)-e\omega(k-1) \quad (2)$$

Where$\acute{\omega}r$ (k) is the reference speed $\omega r(k)$ is the actual rotor speed and $e\omega(k-1)$ is the value of the error
The output variables are specified as the variation of command current and is integrated to get reference command current, (k) and is given by the equation

$$(k)= (k-1)+C\ (k) \qquad (3)$$

B. Fuzzification

The crisp variables $e\omega$ (k) and $ce\omega(k)$ are converted in to fuzzy variables $e\omega$ and $ce\omega$respectively. This process is called fuzzification.The membership functions are chosen to be in triangular shape. A suitable scaling factor is to be taken to bring the input and output variables to universe of discourse. The universe of discourse is chosen between the (-0.8 ,0.8).It consists of 7 fuzzy sets NL(negative small),NM(negative medium),NS(negative small), ZE(zero), PS(positive small),PM(positive medium),PL(positive large).The shape of the membership function is assumed to be asymmetrical in shape. The degree of membership is in the range 0 to 1.The input and output designed for fuzzy are shown below

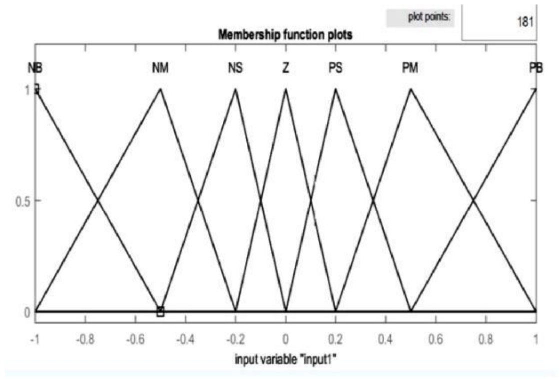

Figure 1. Input for speed error

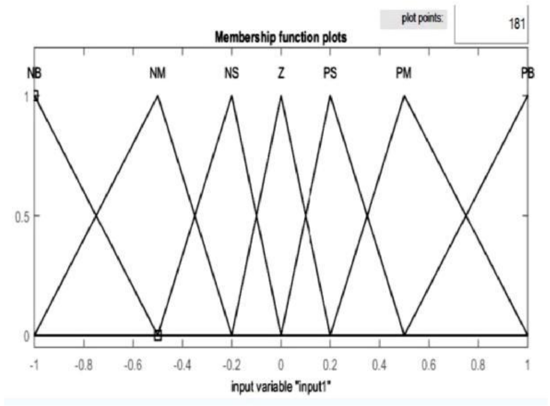

Figure 2. Input for change in speed error

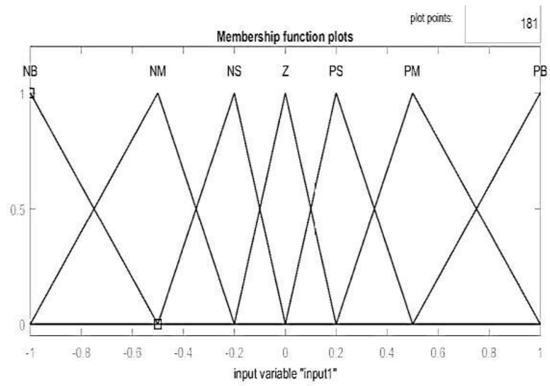

Figure 3. Output for change in command current

C. Knowledge base stage

In this stage the rules which govern the relationship between input and output are framed using IF -THEN statements. It consists of 49 rules. This rules are designed the rules are designed by the control engineer on the basis of the experience

TABLE I. FUZZY CONTROL RULE

c	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NS	NB	ZE	PM	PS	PM
PS	NS	NB	ZE	NM	PM	PB	PS
PM	NB	ZE	PM	PS	PM	PB	PB
PB	ZE	PM	PS	PS	PB	PB	PB

D. Defuzzification

During defuzzification the centroid of each membership function is first evaluated and the final output is obtained by taking the average of the individual centroids and also by the degree of membership function. The above design of the fuzzy logic controller is implemented with the help of DTC control and the block diagram is as shown below.

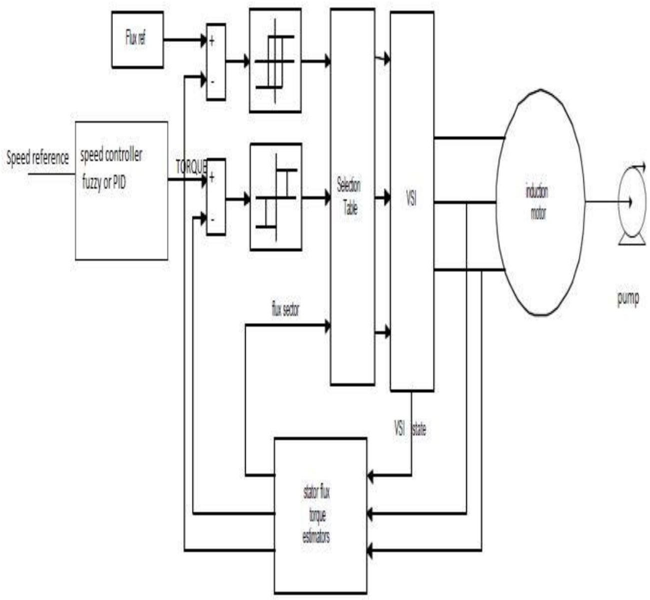

Figure 4. Block diagram of fuzzy logic base DTC control of induction motor

III. DIRECT TORQUE CONTROL

The direct torque control consists of two loops corresponding to the magnitude of stator flux and torque. Thereference values of the torque and flux are calculated and are compared with the actual values. The error produced is fed to hysteresisblocks. The inputs for the look up table consists of the error in the stator flux and torque. The error in the stator flux and torque are restricted to their hysteresisbands. The torque in the hysteresis band is effected by the switching frequency and the flux affects the stator current distortion. The above figure shows locus of the stator flux with the help of discontinuous line the locus is divided into six vectors. The states that are not considered in torque are $V_{k,}V_{k+3}$..The reason is that depending on the flux position of the stator, They can either increase or decrease by 30 degrees depending on the stator flux position

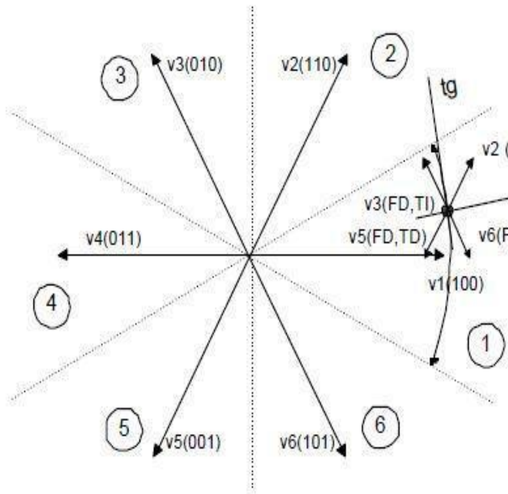

Figure 5. Voltage vectors of different possible switching states.FD: flux decrease, TD: torque decrease, FI: flux increase,TI:Torque increase

IV. Simulation Circuit

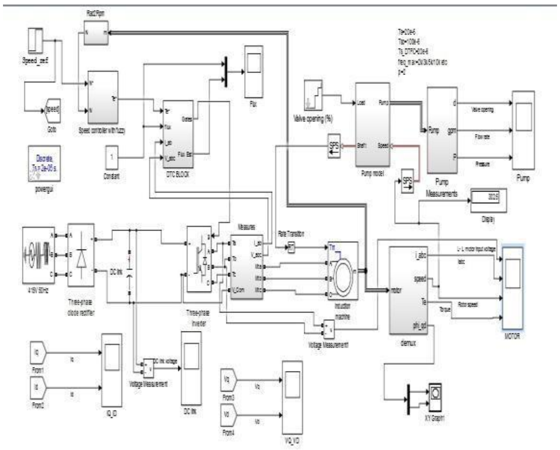

Figure 6. Simulation circuit of Fuzzy based DTC control of the Induction motor for pumping application

V. SIMULATION AND RESULTS

The proposed fuzzy based DTC model is developed for a 3hp Induction motor and with the input voltage of 540v to a VSI.The parameters of the Induction motor is as shown below:

TABLE II. Values and parameters of an Induction motor drive

Parameters	Nominal Values
Stator Resistance(Rs)	0.435Ω
Rotor Resistance(Rr)	0.816Ω
Mutual Inductance(Lm)	69.1e-3H
Stator Inductance(Ls)	2e-3H
Rotor Inductance(Lr)	2e-3H
Inertia(J)	0.089Kg.
Frequency(F)	50Hz
Phase Voltage(V)	460v

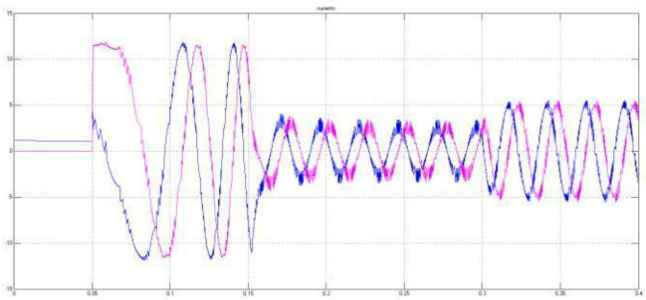

Figure 7. Comparison of DTC and DTC with Fuzzy logic control Current waveform of DTC control

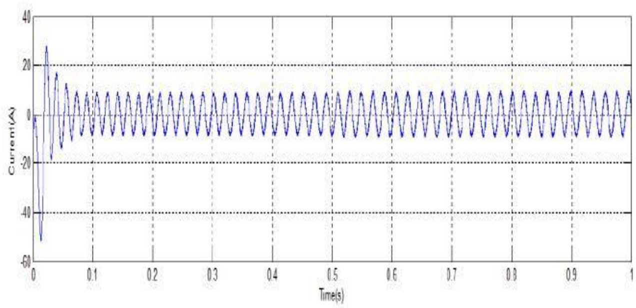

Figure 8. Current waveform of DTC with Fuzzy logic control

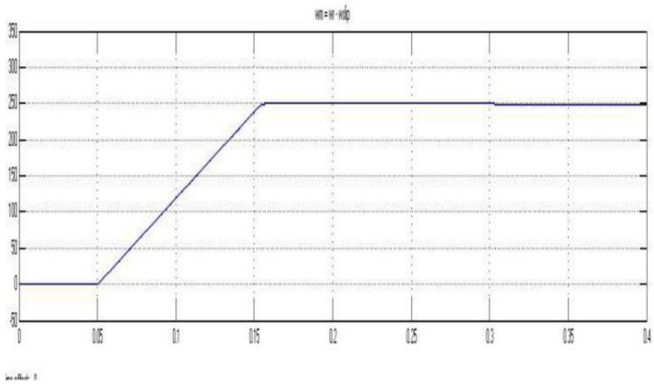

Figure 9. Speed waveform of DTC control

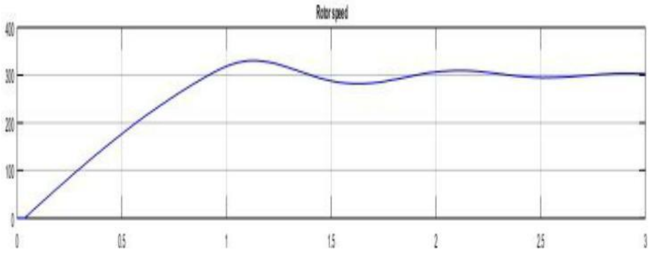

Figure 10. Speed waveform of DTC with Fuzzy logic controller

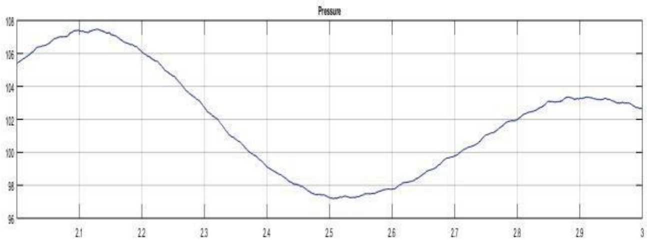

Figure 11. Pressure

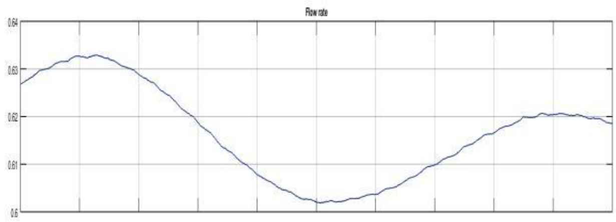

Figure 12. Flow rate

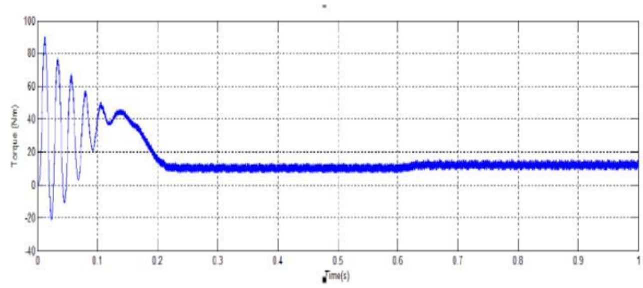

Figure 13. Torque waveform of DTC with fuzzy control

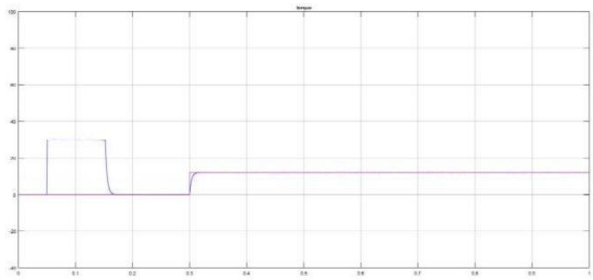

Figure 14. Torque waveform of DTC

VI. CONCLUSION

In this paper fuzzy logic based DTC control is proposed and simulation studies are carried out in MATLAB. It has been observed that the ripples in the stator fluxand in electromagnetic torque are reducing by using fuzzy logic controller. The fuzzy logic controller helps in reducing the stator flux. The conventional DTC is sluggish in response during starting up conditions.The errors due to the change in torque and flux are not distinguished by using DTC control. Thesedrawbacks are overcomed with the help of Fuzzy based DTC controller.

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