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VECTOR CONTROL OF THREE-PHASE INDUCTION MOTOR USING ARTIFICIAL INTELLIGENT TECHNIQUE

Arunima Dey[1], Bhim Singh[2], Bharti Dwivedi[1] and Dinesh Chandra[3]
[1]Department of Electrical Engineering, Institute of Engineering and Technology, Sitapur Road, Lucknow, India
[2]Department of Electrical Engineering, IIT, Delhi, India
[3]Department of Electrical Engineering, MNNIT, Allahabad, India
E-Mail: arunimadey@gmail.com

ABSTRACT

The controllability of torque in an induction motor without any peak overshoot and less ripples with good transient and steady state responses form the main criteria in the designing of a controller. Though, PI controller is able to achieve these but with certain drawbacks. The gains can not be increased beyond certain limit so as to have an improved response. Moreover, it introduces non linearity into the system making it more complex for analysis. Also it deteriorates the controller performance. With the advent of artificial intelligent techniques, these drawbacks can be mitigated. One such technique is the use of Fuzzy Logic in the design of controller either independently or in hybrid with PI controller. This paper proposes a unique set of fuzzy logics for the speed controller design to be used in vector controlled three phase induction motor. The results obtained from the model using proposed Fuzzy Logic Controller and PI Controller are compared. It can be concluded that use of Fuzzy logic improves and smoothens out the ripples in the motor torque and stator currents. It also facilitates in limiting the magnitude of the torque and current values within the specified range in any kind of disturbance, either provided by the speed removal or by sudden application and removal of load torque. This has been verified through the simulation results of the model built completely in a MATLAB/SIMULINK environment.

Keywords: fuzzy inference system (FIS), fuzzy logic controller (FLC), membership function, vector control.

1. INTRODUCTION

The design of fuzzy logic as the name suggests is unique in itself [1-3]. Depending on the speed and torque performances requirement of the three-phase induction motor for various industrial application fuzzy controller with a unique inference system is designed. The performances of PI and fuzzy controller are compared in [4] but it has considered only 15 rules for designing. It is considered that more the rules, better is the performance of the controller. The same has been projected in [5, 6]. Abad *et al.,* in [5] have taken 49 rules for FLC and then compared the results with that of PI controller. [6] Has incorporated 21 rules and simulated the results. All the results obtained are for the step response of speed. Most of the papers have not included sudden changes in speed or load. The proposed FLC in this paper incorporates all the characteristics viz,

a) The starting of motor
b) Speed reversal
c) Load application
d) Load removal

The model of induction motor uses vector control and Space Vector Modulated (SVM) voltage source inverter (VSI). The simulated results thus obtained show improved transients and steady state torque and speed performances when compared with those of PI controller. The FLC is developed in MATLAB using Fuzzy logic toolbox.

2. VECTOR CONTROL OF INDUCTION MOTOR

Induction motor speed control methods are varied in number of which vector or field oriented control is the most widely accepted method. In vector control, the same performance characteristics are obtainable as is the case with a dc motor. This is achieved by decoupling the three-phase winding into two windings (90° apart) so as to facilitate independent control of torque and flux. A lot of literature is available in this regard. The model of the induction motor is a result of standard mathematical equations described in [7, 8]. The model incorporates the non-linear blocks of induction machine and inverter as used in real time mode. Figure-1 shows the complete model in which FLC has been introduced.

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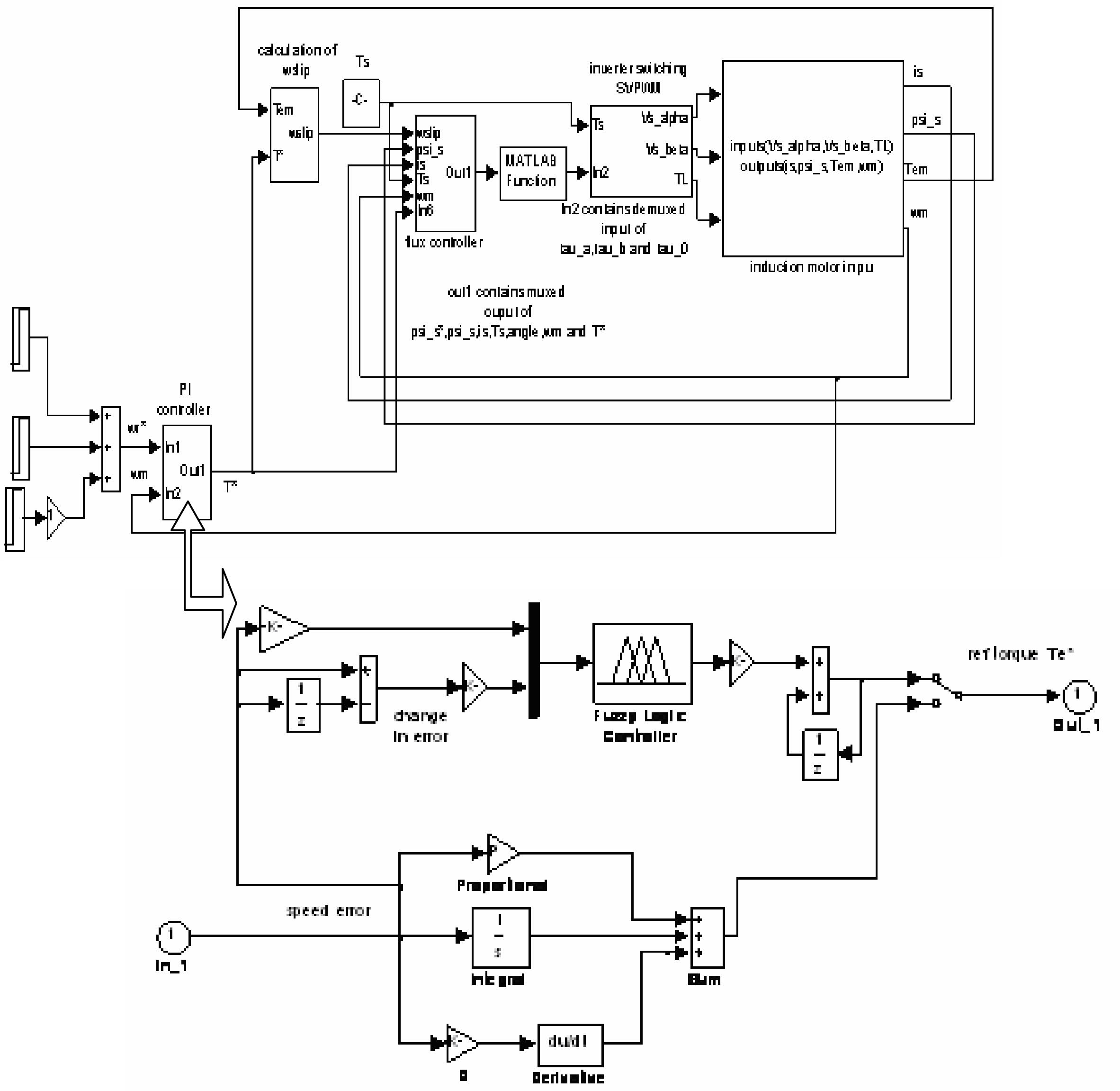

Figure-1. Vector control of a variable-frequency induction motor drive incorporating FLC.

3. DESIGN OF FUZZY LOGIC CONTROLLER

3.1 Fuzzy Inference System (FIS)

FIS consists of input block, output block and their respective membership functions. The rules are framed according to the requirement of the speed. More number of rules more accurate is the speed and torque performance. Figure-2 explains the design of fuzzy system.

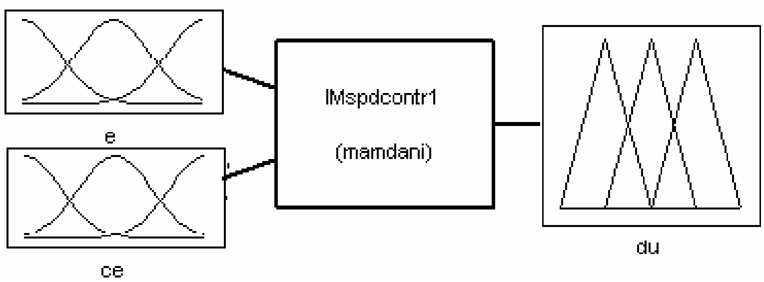

Figure-2. Design of fuzzy system in MATLAB environment.

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In this induction machine model, normalized values of two inputs in the form of speed error (e) and change in speed error (ce) and defuzzified value of torque command (du) as an output are considered. Basically, Fuzzy system includes three processes: a) Normalization b) Fuzzification and c) Defuzzification. The above figure shows the b) and c) processes. For defuzzification centroid method and for fuzzification mamdani method is used. The normalized membership functions with 7 in number for each and the 3-D surface view of the two inputs and output are shown in Figure-3

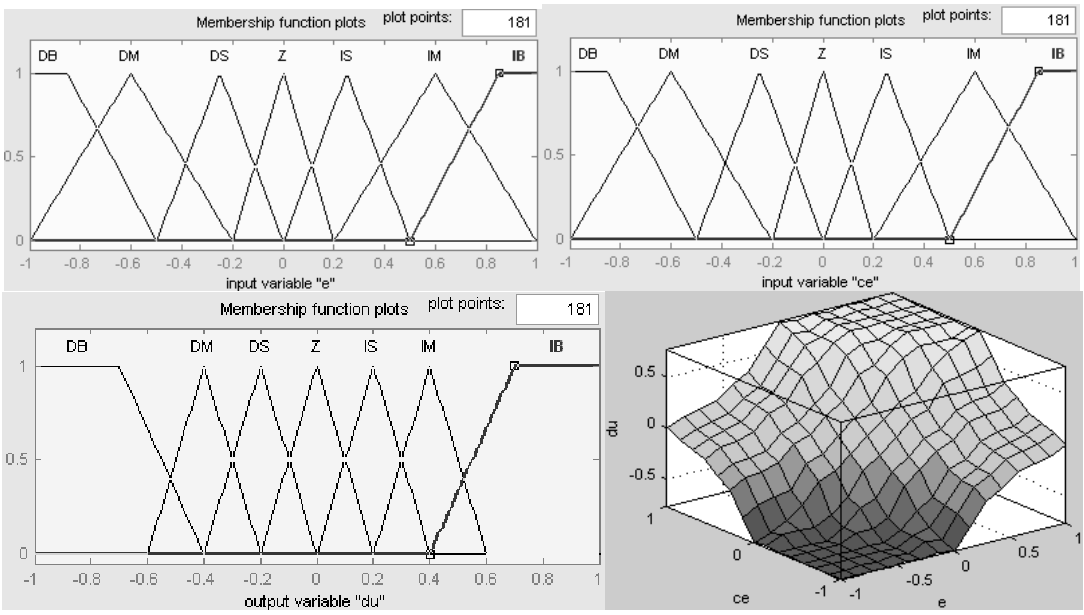

Figure-3. Normalized membership functions and 3-D surface view of the two inputs and output variables.

The control of the speed is done by the FLC taking into consideration following rules given in Table-1.

Table-1. Control expression of FLC.

e \ ce	**DB**	**DM**	**DS**	**Z**	**IS**	**IM**	**IB**
DB	DB	DB	DB	DB	DM	DS	Z
DM	DB	DB	DB	DM	DS	Z	IS
DS	DB	DB	DM	DS	Z	IS	IM
Z	DB	DM	DS	Z	IS	IM	IB
IS	DM	DS	Z	IS	IM	IB	IB
IM	DS	Z	IS	IM	IB	IB	IB
IB	Z	IS	IM	IB	IB	IB	IB

4. RESULTS AND DISCUSSIONS

4.1 Starting

Figures 4a and 4b show the starting characteristic using FLC and PI controller respectively. Since the motor is started on no load, the currents of the stator gradually picks up the values to full magnitude with reduced frequency as soon as the motor starts running, the speed attained by it is the ref. speed and full frequency of the currents are obtained. The electromechanical torque becomes zero, as the load torque is zero. The net flux both at stator and rotor remains constant.

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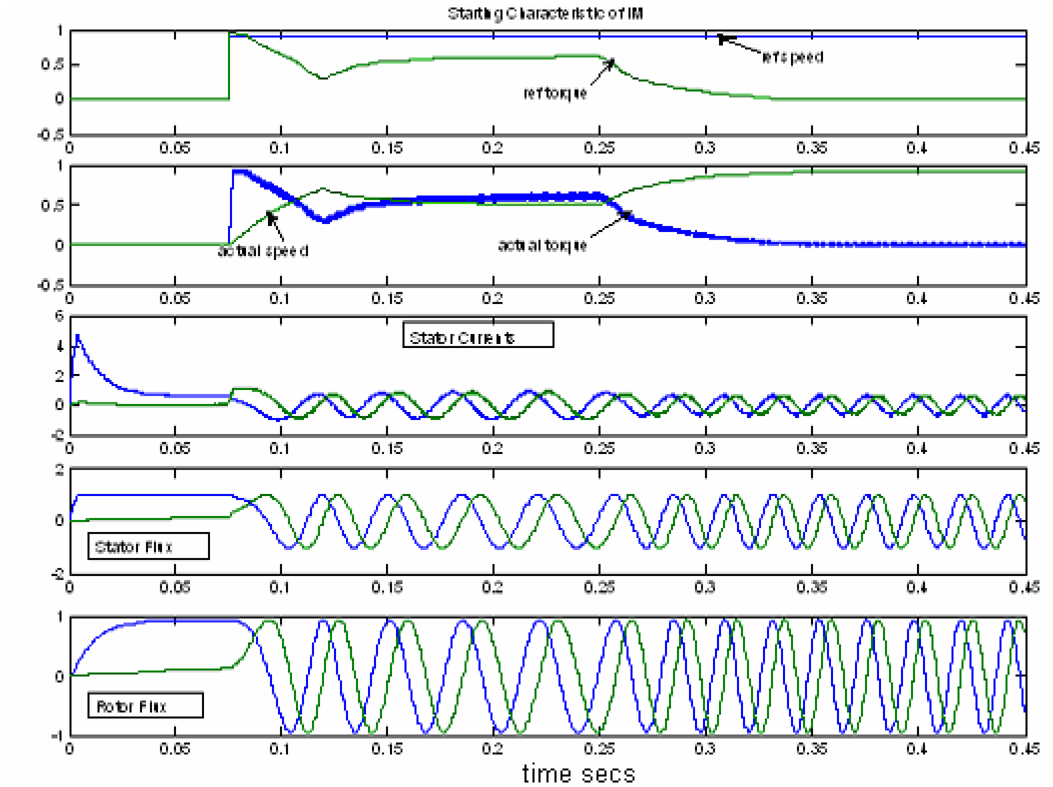

Figure-4a. Output through FLC.

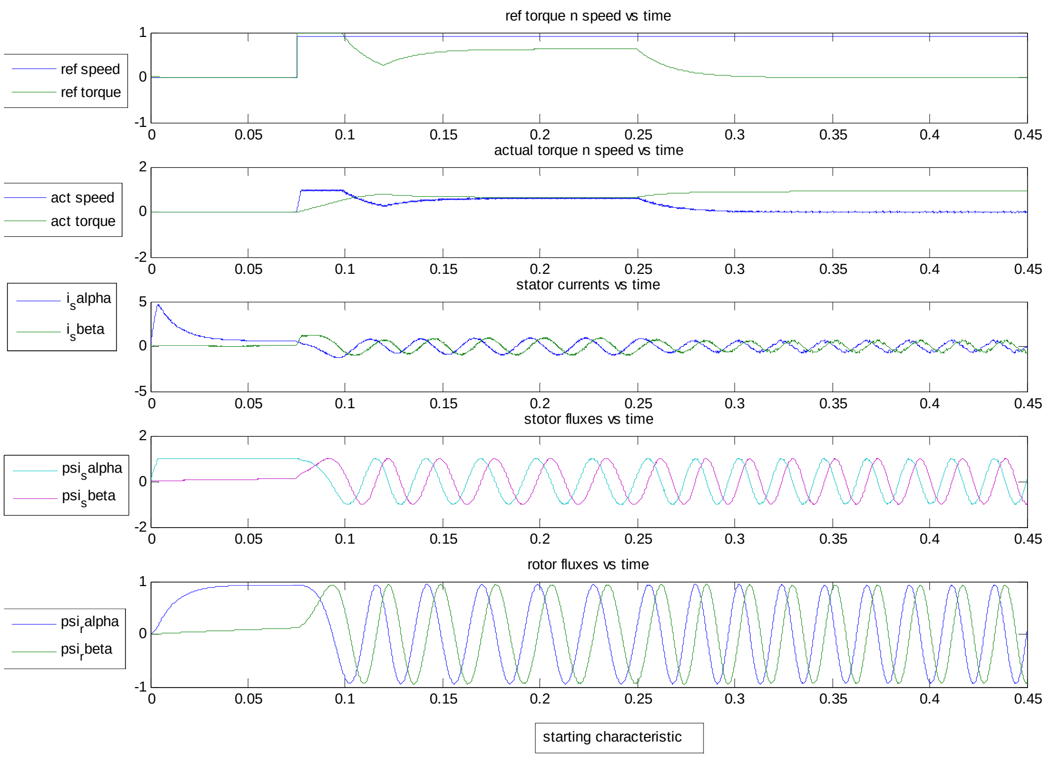

Figure-4b. Output through PI controller.

4.2 Speed reversal

Figures 4c and 4d show the speed reversal characteristic using FLC and PI controller respectively, when the reference speed is reversed at 0.30 seconds, the actual speed follows it and tries to attain the reference value at the minimum possible time. The torque Tem also reduces drastically only to attain its reference value in the minimum time. The current waveforms show a sharp

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increase in the magnitude with low frequency at the reversal of speed. The rotor and stator fluxes also have their frequency reduced for reversal speed. The implementation of FLC drastically improves the torque and current performance characteristics of the motor especially during speed reversal. The peak-over shoot in case of torque and current magnitude is very less and restricted within limit using FLC unlike PI output.

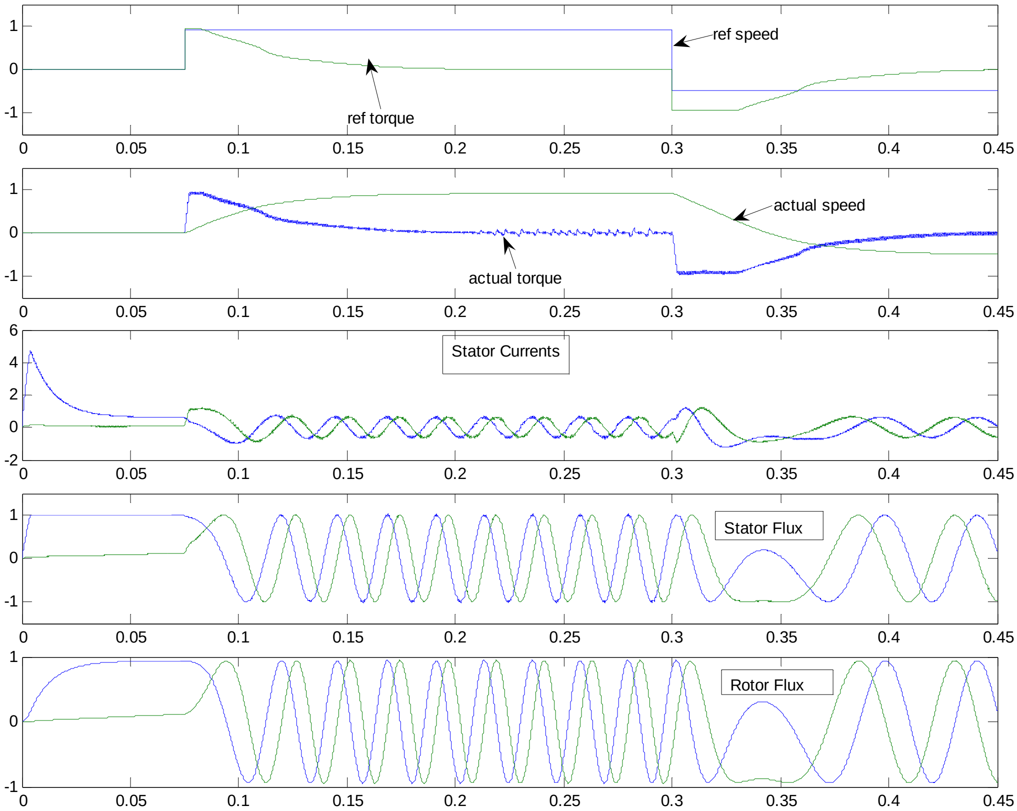
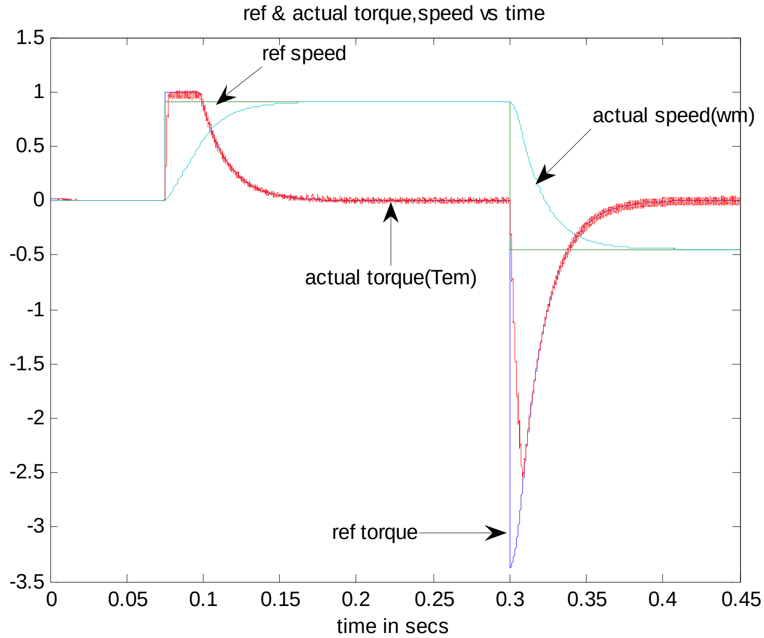


Figure 4c. FLC output showing speed reversal at t = 0.3 seconds.



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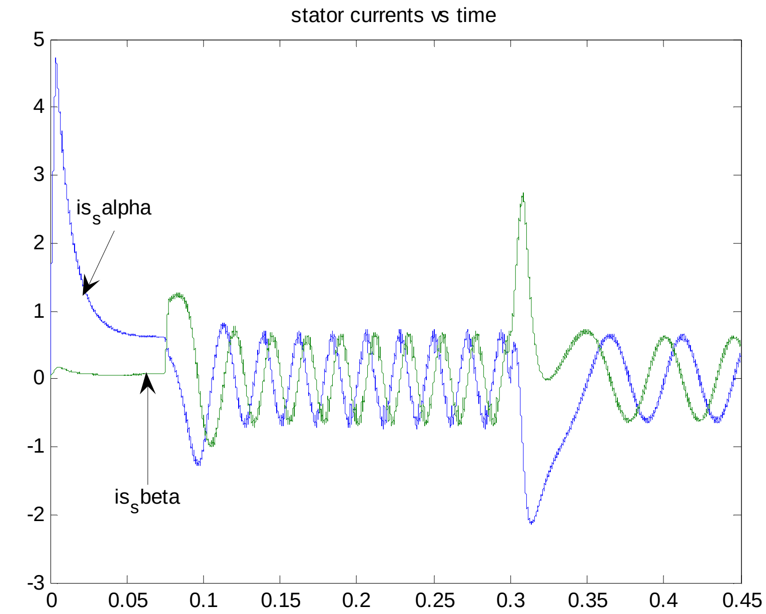

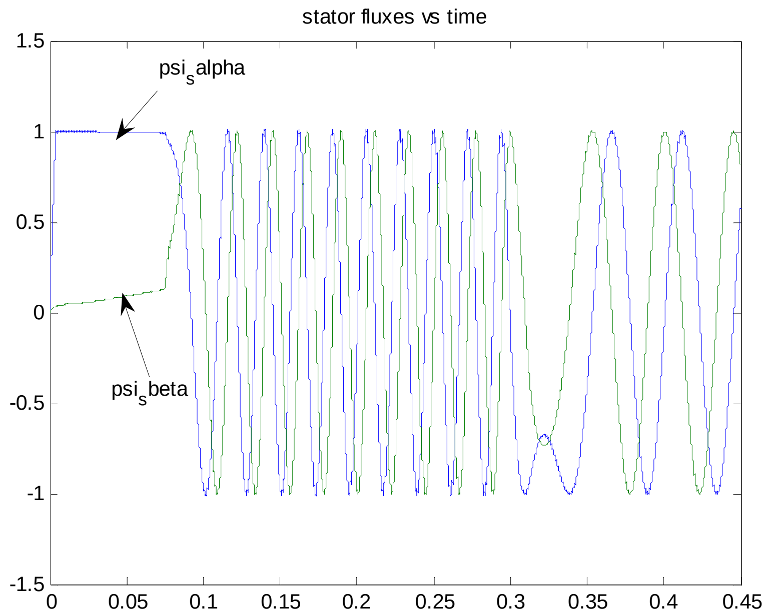

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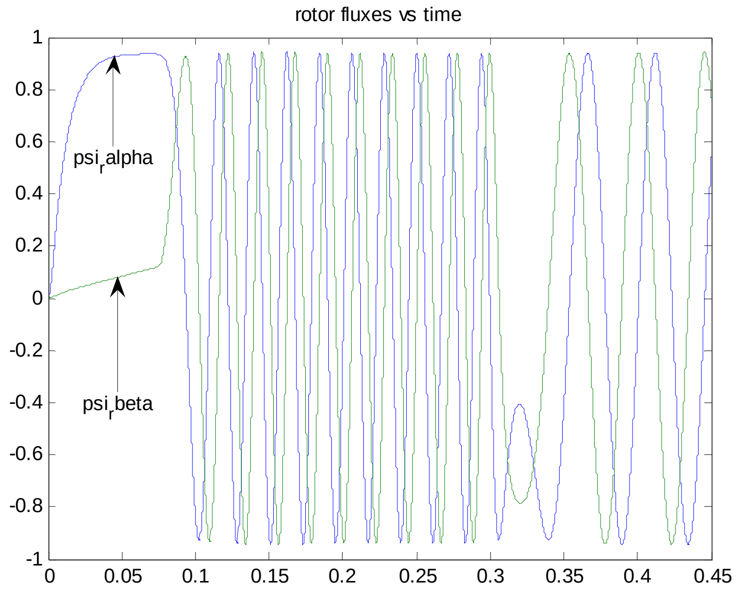

Figure-4d. PI controller output showing speed reversal at t = 0.3 seconds.

4.3 Load application and load removal

Load application

When the load is suddenly applied at t = 0.12 seconds, the Tem i.e. actual torque which was following the reference torque earlier, now jumps to the value of load torque and settles to a magnitude of nearly 0.65. Since, torque and speed are related to each other, so the actual speed ω_m too decreases when the load is applied.

The nature of the stator currents have to face the effect of application of load and thus increases in magnitude at 0.12 seconds to meet out the sudden load demand. The stator and rotor fluxes remain unaffected by the load application.

Load removal

After the application of load torque at t = 0.12 seconds, the effect of load removal is considered on the various parameters of the motor. When the load is suddenly removed at t = 0.35secs, the Tem reduces drastically and attains its settled value finally. The speed follows the inverse law of torque Tem and hence ω_m increases to settle down to its reference value. The magnitudes of stator currents face the consequences of load removal by decreasing. The stator flux and rotor fluxes still remain unaffected.

The waveforms are shown in Figures 4e and 4f using FLC and PI controller, respectively. From the waveforms it is inferred that the constancy of flux is maintained under any load condition.

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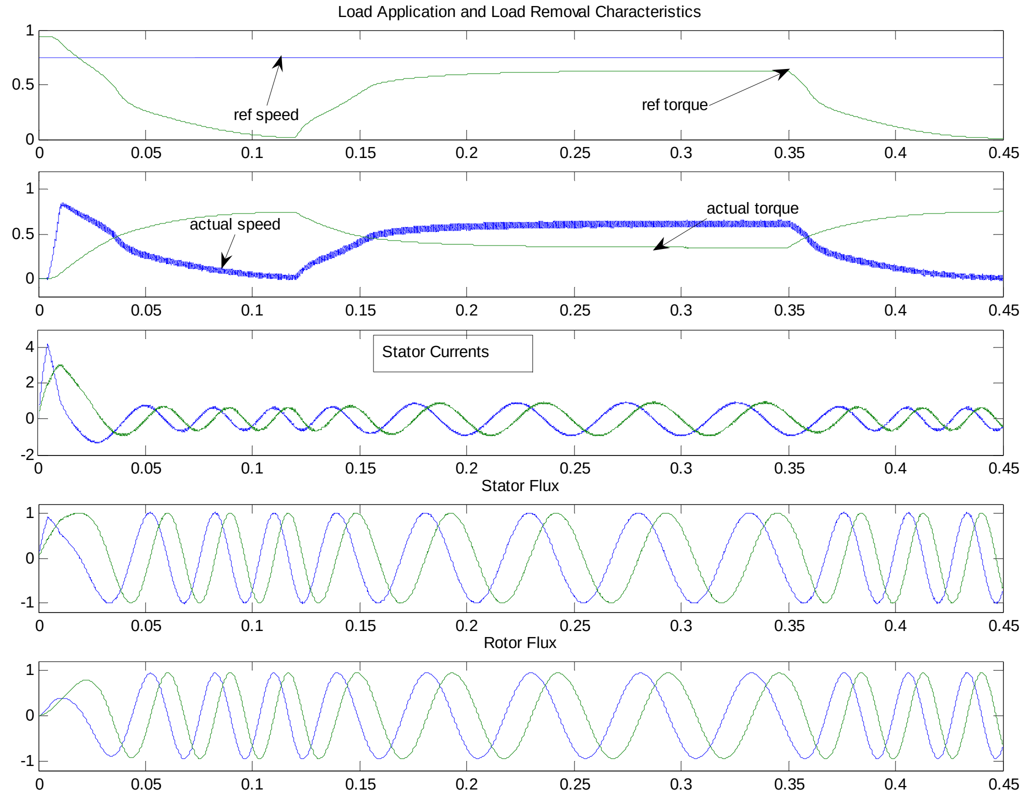
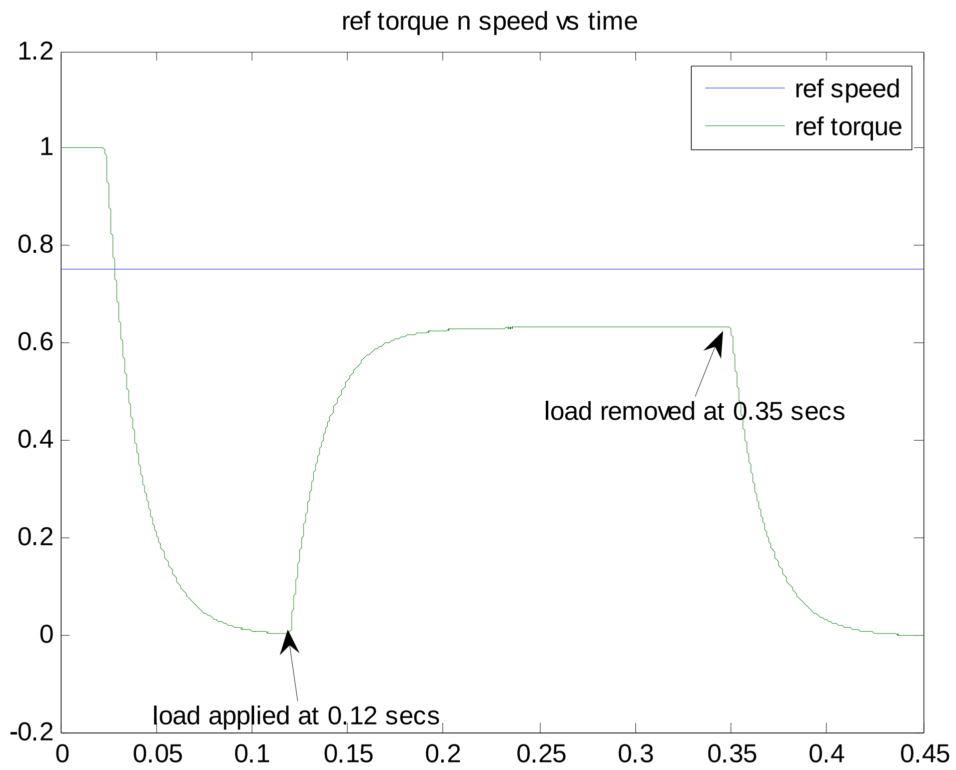


Figure-4e. Output Using FLC for load application and load removal characteristics.



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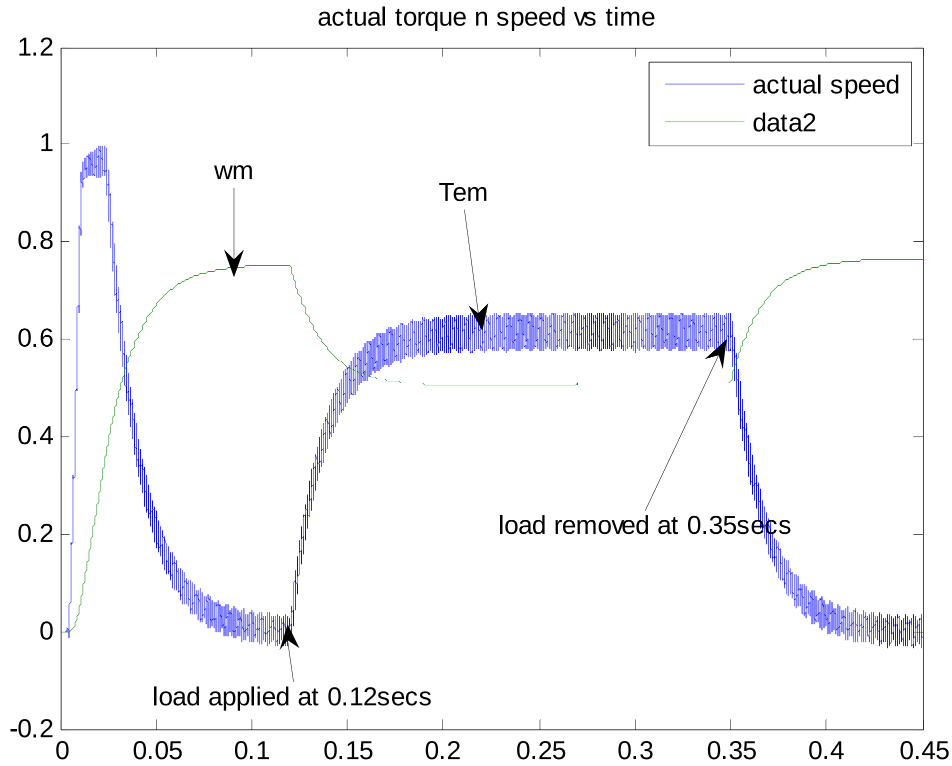

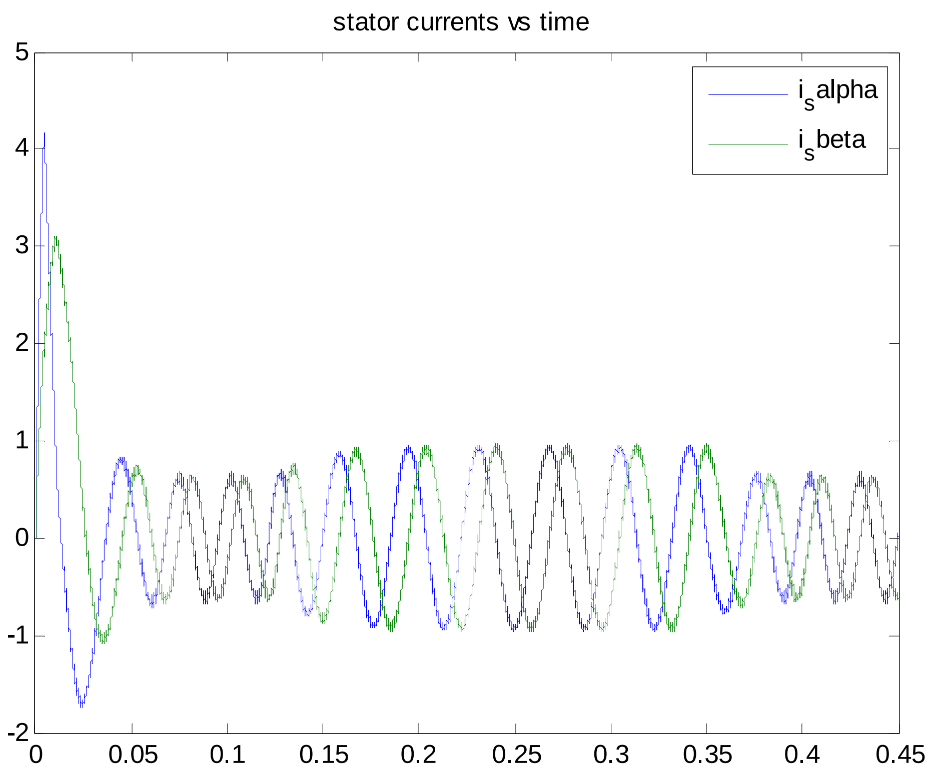

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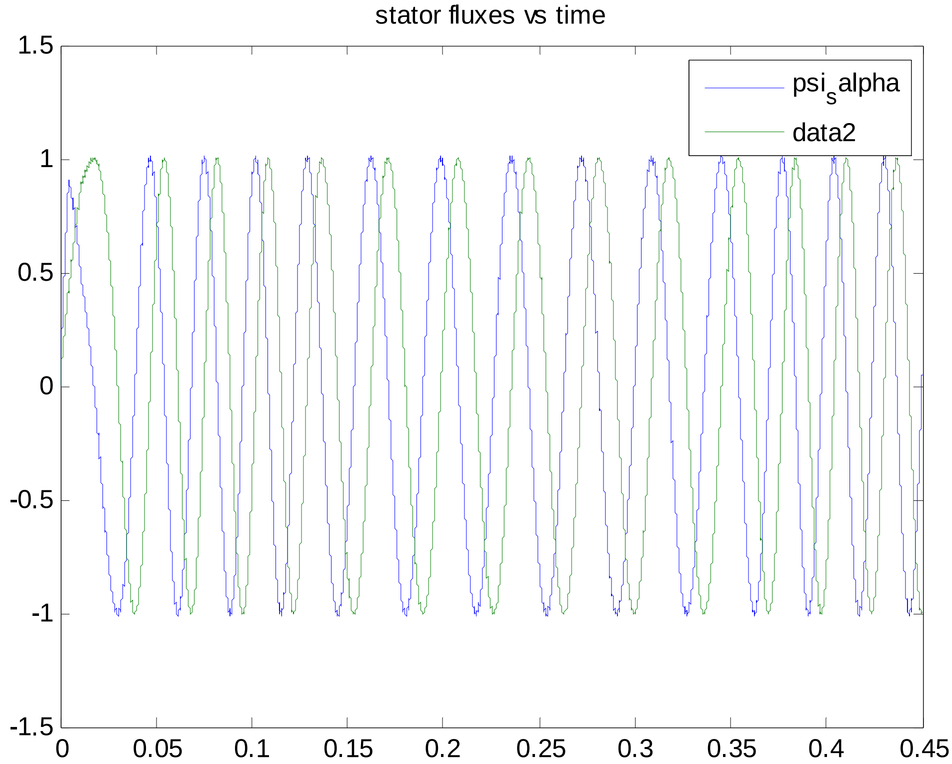

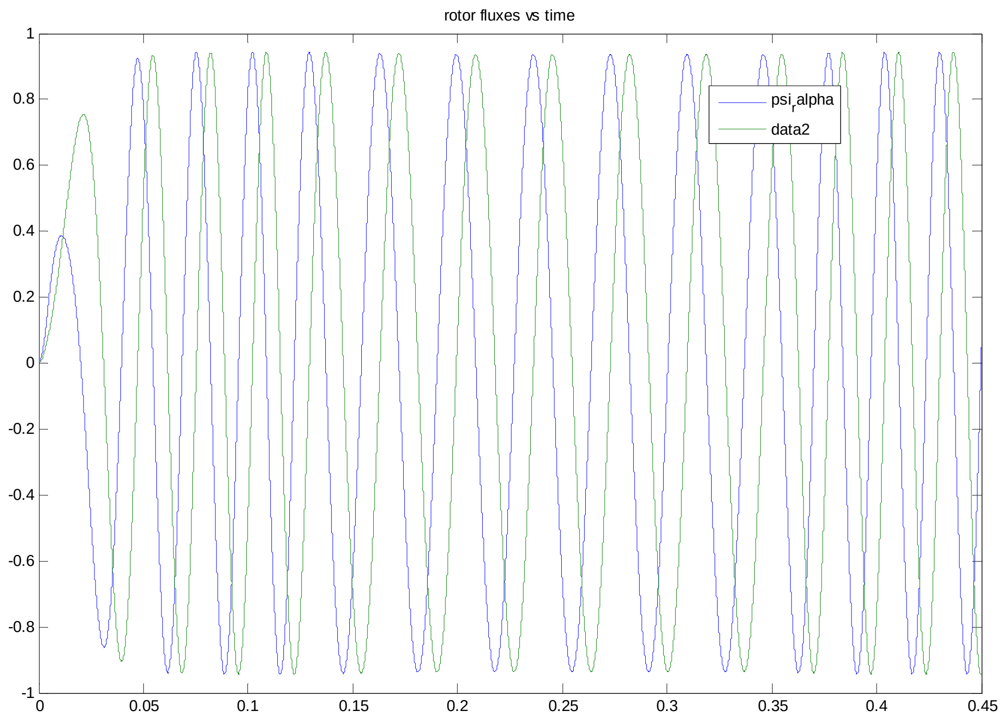

Figure- 4f. PI Controller output for load application and load removal characteristics.

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5. CONCLUSIONS

The results obtained from the model using Fuzzy Logic Controller and PI Controller is compared. It can be concluded that use of Fuzzy logic improves and smoothens out the ripples in the motor torque and stator currents. It also facilitates in limiting the magnitude of the torque and current values within the specified range in any kind of disturbance, either provided by the speed removal, sudden application and removal of load torque. The responses obtained using PI controller are achieved by having very large values of gains of k_p and k_i which in practical applications are not feasible as large gains of the controller have repercussions like increase in cost and size.

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