

## NOVEL CONTROLLER FOR THREE PHASE INDUCTION MOTOR

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### **Abstract: -**

*Induction motor has many application in the industries due to its low maintenance and robustness. The speed control of induction motor is very important to obtain maximum torque and efficiency. This paper presents a method for improving the speed control of 3-phase induction motors (IM) using hybrid direct torque controller (DTC)/Fuzzy logic controller (FLC) techniques. A complete simulation of the conventional DTC and closed-loop for speed control of a 3-phase IM was tested using SimuLink. The speed control of the IM is done by using the conventional proportional integral (PI) controller and FLC. The proposed FLC has a nature of PI controller to determine the torque reference for the motor. The effect of variation of the speed reference trajectories on the dynamic response has been clearly tested for both conventional and FLC speed controllers. The simulation results showed a better dynamic performance of the induction motor when using the proposed DTC/FLC in comparison with a fixed PI controller. Also, the DTC/FLC has improved the speed control of the IM over a wide range of operating conditions.*

**Keywords: -** Induction motor, Fuzzy logic controller (FLC), direct torque control (DTC), PI controller.

## I. INTRODUCTION

The evolution from dc drives to various forms of *ac* drives has been motivated by the continuing need for simplicity and reliability. Although it is possible to achieve the *ac* motor's high level of speed control by the application of the trans-vector theory, the resulting controller becomes too complex to implement for a wide range of applications. An alternative to the trans-vector control is the direct torque control (DTC), which represented a step in mix improvement [2, 4]. The appearance of high -speed digital signal processor (DSP) and application specific integrated circuit (ASIC), DTC technology has become popular in ac motor drives [6-8]. DTC has its roots in field-oriented control and direct self-control [8-10]. Field-oriented control uses spatial vector theory to optimally control magnetic field orientation. Direct self-control theory is less well known. It was patented as a concept developed in Germany by Manfred Depenbrock and has been described in several published papers [10-12]. DTC has been developed, implemented and tested for three phase induction motor in many papers [14-16]. Most of researchers are concerned with the inner loop for a torque control without taking in consideration the overall loop for the speed regulation. Only a brief discussion was considered for the outer speed loop in [14]. Also, fuzzy logic has been used with DTC to improve the dynamic performance of the induction motors [18, 19]. This paper presents a method for improving the speed control of 3-phase induction motors (IM) using hybrid direct torque controller (DTC)/Fuzzy logic controller (FLC) techniques. A complete simulation of the conventional DTC and closed-loop for speed control of a 3- phase IM was tested using SimuLink. The speed control of the IM is done by using the conventional proportional integral (PI) controller and FLC. The proposed FLC has a nature of PI controller to determine the torque reference for the motor. The effect of variation of the speed reference trajectories on the dynamic response has been clearly tested for both conventional and FLC speed controllers. The main the objective of this paper is to compare a fuzzy logic controller with the PI controller. The simulation results showed a better dynamic performance of the induction motor when using the proposed DTC/FLC in comparison with a fixed DTC/PI controller. It has been shown that the DTC/FLC has improved the speed control of the IM over a wide range of operating conditions.

## II. DIRECT TORQUE CONTROL

Fig. 1 shows the basic functional blocks used to implement the DTC scheme. The core to the complete control has three key blocks that interact to provide the primary control required [14]; namely torque/flux comparators, optimal switching logic and adaptive motor model. The torque comparator and the flux comparator are both contained in the hysteresis control block. They compare the torque and flux references with their actual values, which are calculated using the adaptive motor model. The actual torque is controlled within differential hysteresis window, which has limited the switching frequencies of the power output devices within a range of 1.5 – 3.5 kHz. The optimal switching logic (OSL) selects the appropriate stator voltage vector that will satisfy both the torque status output and the flux status. As there are three independent limb, there will be eight different logic states, provides eight different voltages. In reality, there are only six non-zero stator voltage vectors and two zero-voltage vectors that the voltage-source inverter can produce [15] the outputs of the OSL are the switching position of the voltage-source inverter.

## III. THE HYBRID PI /FUZZY LOGIC CONTROLLER

A 3 kW, 380 V, 50 Hz, 1420 rpm, 4 pole, and 3-phase induction motor was used. Other data and parameters were: Torque = 21 N.m, Motor moment of inertia  $J_m = 0.008 \text{ Kg m}^2$ , Load moment of inertia  $J_l = 0.084 \text{ Kg m}^2$ , stator resistance  $R_s = 2.15 \text{ } \Omega$ , rotor resistance  $R_r = 2.33 \text{ } \Omega$ , mutual inductance  $L_m = 202.5 \text{ mH}$ , stator leakage inductance  $L_{ss} = 7.5 \text{ mH}$ , rotor leakage inductance  $L_{rr} = 7.5 \text{ mH}$

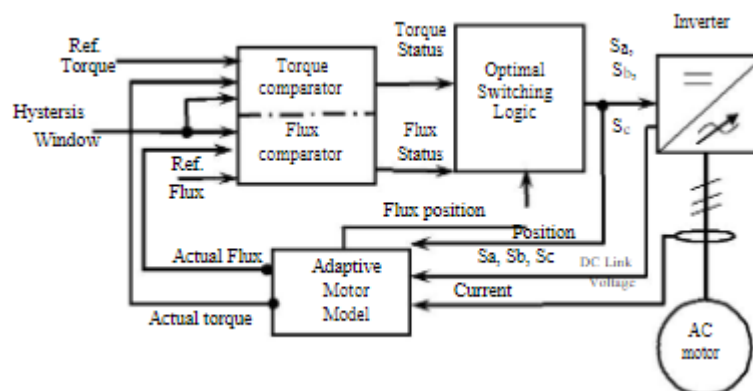


Fig. 1 The basic block diagram of the DTC

The simulations were carried out on the 3-phase induction motor (IM) driven by DTC and an outer loop that was switched for PI controller or fuzzy logic controller, to control the speed, as shown in Fig. 2.

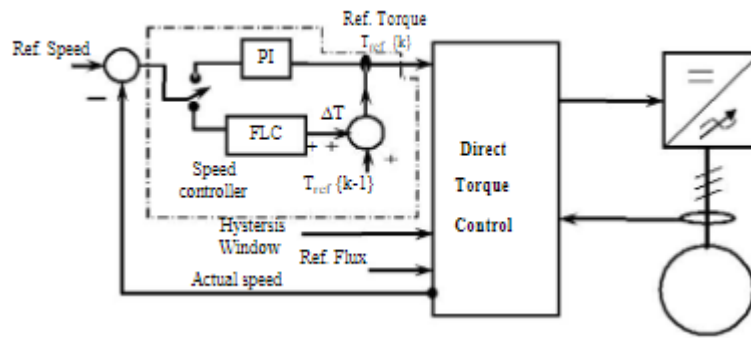


Fig. 2 DTC system with PI and FLC controller for speed loop

### A. DTC/PI CONTROLLER

The PI control was simulated for different values of proportional gain ( $K_p$ ), equal 0.5, 1.0 and 2 while the integral gain ( $K_i$ ) equals 0.1. The induction motor was tested during start-up and for a step change in the motor reference speed (Ref speed) of 500, 1500, and 750 rpm, respectively. Three tests were performed:

1. No-load without a current limiter: The results showed that the motor speed ( $\omega_m$ ) response, rise time and steady state error were improved as  $K_p$  was increased for positive step reference speed, while, the lowest value of  $K_p$  gave the best dynamic response for  $\omega_m$ .
2. No-load with a current limiter: Similar dynamic responses for the same operating conditions of the motor were performed except that the complete DTC scheme was equipped with a current limiter. The results depicted an improvement in the speed ( $\omega_m$ ) response, the rise time and the steady state speed error, for positive and negative step changes in the reference
3. Speed, when  $K_p$  was increased. There was an advantage in using the current limiter, which limited the
4. Torque reference to be  $\pm 40$  N.m.
5. 3. The simulation was done for same values of case 2 except that the motor was operating at full- load. The motor speed response was improved when  $K_p$  was increased, especially regarding the steady state
6. Error. Inally, the system was tested for other values of  $K_p$ , equals 5, 20, and 30 while  $K_i = 0.1$ . The results achieved for this case were similar to case 3.

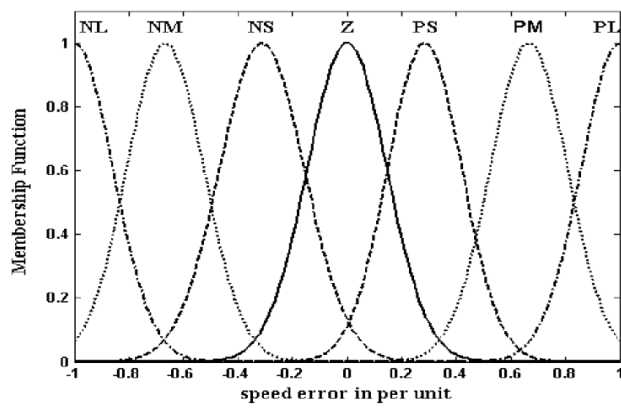
### B. DTC/FL CONTROLLER

The PI simulation results showed that the motor response, given the values of  $K_p$  changed according to the operating condition. This is the main drawback of the classical PI controller. The main the objective of this paper is to compare a fuzzy logic controller with the PI controller. The FLC uses a set of fuzzy rules representing a control decision mechanism to adjust the effect of certain system stimuli. Therefore, the aim of using FLC is to replace a skilled human operator with a fuzzy rules- based system. The fuzzy input vectors are the motor speed deviation  $\Delta\omega$  and the acceleration  $\Delta\dot{\omega}$ . The fuzzy set for inputs and output membership functions are shown in Fig. (3). Seven linguistic variables ( $LV$ ) are used for each input variables. These are PL (Positive Large), PM (Positive Medium), PS (Positive Small), Z (Zero), NS (Negative Small), NM (Negative Medium) and NL (Negative Large). The fuzzy output is the change in reference torque ( $\Delta T_{ref}\{k\}$ ) which is to be added to the previous value of reference torque ( $T_{ref}\{k-1\}$ ). The output fuzzy sets have the same linguistic variables used for input except T is added to indicate the fuzzy sets are used for torque. For example T-PL means Torque Positive Large. A look-up table, in which the relation between the input variables,  $\Delta\omega$  and  $\Delta\dot{\omega}$ , are defined and the output variable of the fuzzy logic controller was developed and used in the simulation. The look-up table is given in Table-1. The Maximum of Minimum method has been used to find the output fuzzy rules stage, as follows:

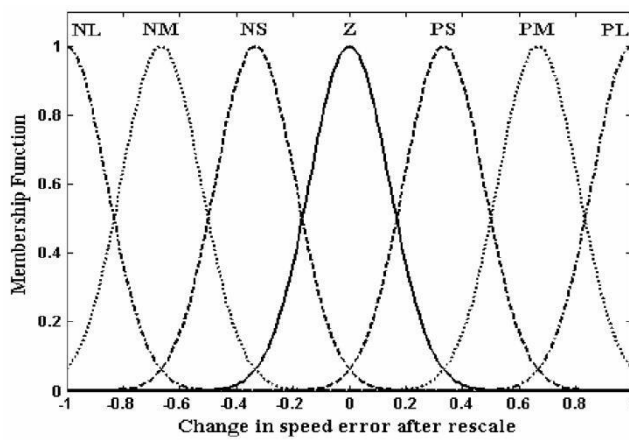
$$\Delta T\{k\} = \frac{\int y \cdot \alpha(y) \cdot \alpha_j}{\int \alpha(y) \cdot \alpha_j}$$

Table-1: Look-up Table which defines the relationship between input and output variable in a fuzzy set form.

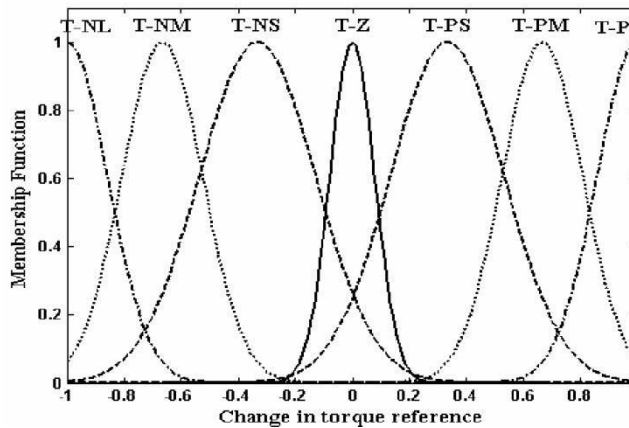
Speed Deviation ( $\Delta\omega$ )	Speed Deviation Chang ( $\Delta\dot{\omega}$ )						
	NL	NM	NS	Z	PS	PM	PL
NL	T-NL	T-NL	T-NL	T-NL	T-NM	T-NS	T-Z
NM	T-NL	T-NL	T-NL	T-NM	T-NS	T-NS	T-NS
NS	T-NL	T-NL	T-NM	T-NS	T-NS	T-NS	T-NS
Z	T-NM	T-NM	T-NS	T-Z	T-PS	T-PM	T-PL
PS	T-PM	T-PM	T-PM	T-PM	T-PM	T-PL	T-PL
PM	T-NS	T-Z	T-PS	T-PM	T-PL	T-PL	T-PL
PL	T-Z	T-PS	T-PM	T-PL	T-PL	T-PL	T-PL



**a: Input fuzzy set (speed error in p.u.)**



**b: Input fuzzy set (change in speed error.)**



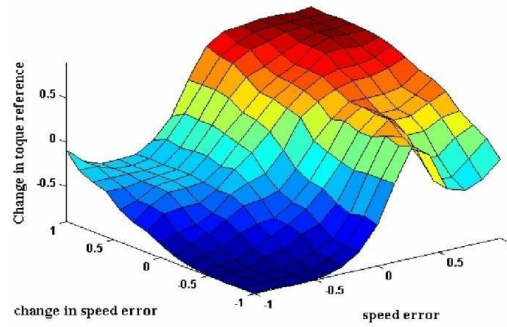
**C: Output fuzzy set**

**Fig. 3: Input and Output Fuzzy Memberships**

The FLC is implemented and simulated to determine the desired torque reference ( $T_{ref}$ ) for the system shown in Fig. (2). The FLC output is added to the previous torque reference  $T_{ref}\{k-1\}$  to calculate the present  $T_{ref}\{k\}$  by using the following equation:

$$T_{ref}\{k\} = T_{ref}\{k-1\} + \Delta T\{k\}$$

The Surface Viewer has a special capability that is very helpful in cases with two (or more) inputs and one output: This figure shows the output surface of the FLC of the system versus two inputs, as shown in Fig. 4.



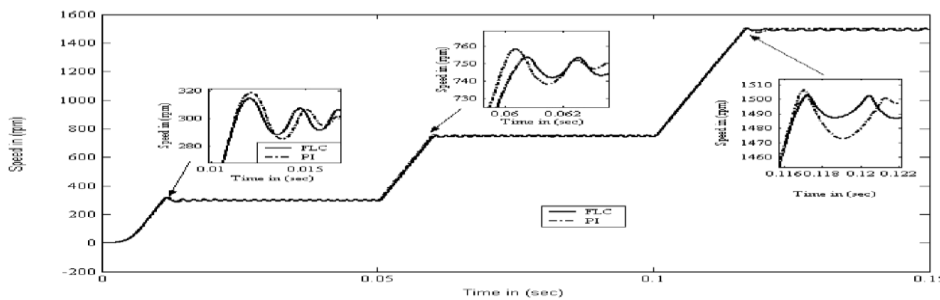
**Fig. 4: Output surface of FLC**

#### IV. SIMULATION RESULTS

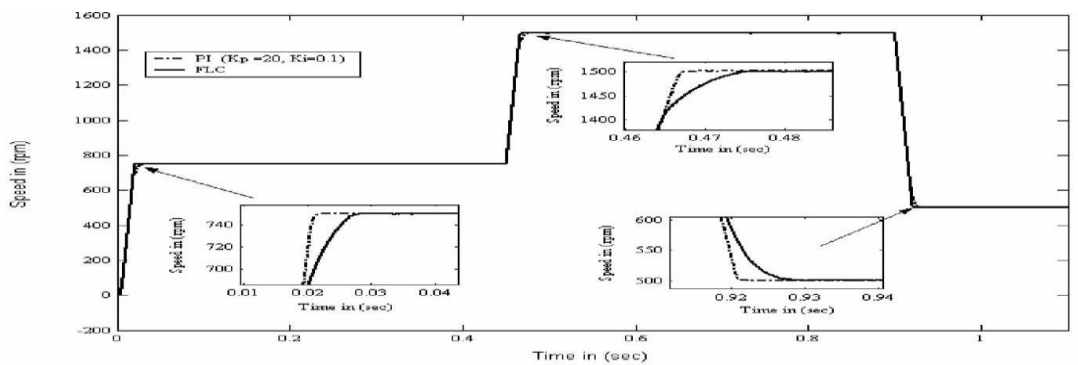
Different disturbances were simulated to test the performance of the motor using the DTC under PI and FL controllers. Fig. 5 shows a comparison of the dynamic response for the motor equipped without a current limiter and at no-load for  $\omega_{ref}$  equals 300, 750 and 1500 rpm. The proposed FLC for speed regulation gave better dynamic response, regarding the percentage overshoot and oscillations, compared with the conventional PI controller with  $K_p = 20$  and  $K_i = 0.1$ . Figures 6 and 7 give a comparison of the dynamic response for the motor when started with a current limiter against no-load and full-load, respectively, for  $\omega_{ref}$  equals 750, 1500 and 500 rpm. A better dynamic performance for the overall system was achieved, regarding steady state error and rise time, when using the proposed DTC/ FLC, especially at *full Load* condition.

#### V. CONCLUSIONS

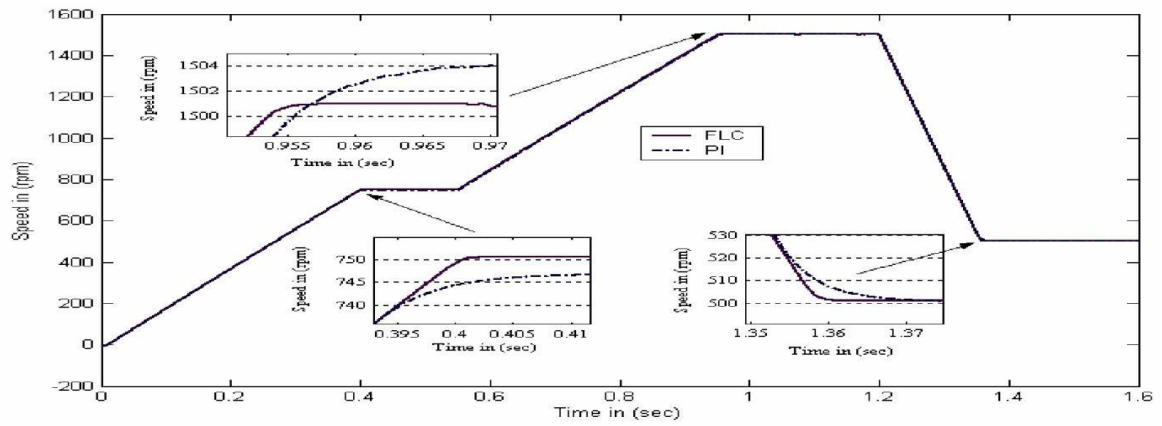
In this paper, a comparison was made for testing the speed control of a 3-phase induction motor using a hybrid PI/FLC DTC technique. The effect of variation of the operating point on the dynamic response has been tested for both conventional PI and fuzzy logic controllers. The simulation results showed better dynamic performance of the induction motor when using the DTC/FLC as compared with fixed PI controller. The DTC/FLC has improved the speed control of 3-ph IM over a wide range of operating conditions



**Fig. 5: Dynamic response for motor speed when the 3-ph. IM was equipped with DTC that has no current limiter at no-load using FLC and PI controller**

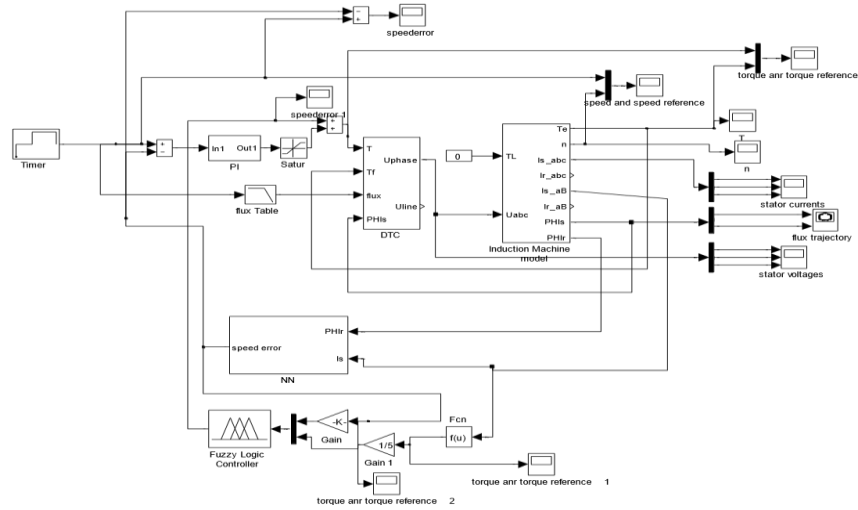


**Fig. 6: Dynamic response for motor speed when the 3-phase IM was equipped with DTC That has a current limiter at no-load using FLC and PI controller**

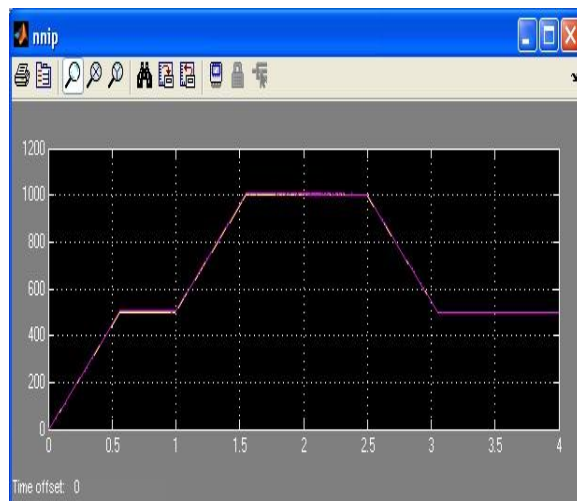


**Fig. 7: Dynamic response for motor speed when the 3-phase IM was equipped with DTC that has a current limiter at full load using FLC and PI controller**

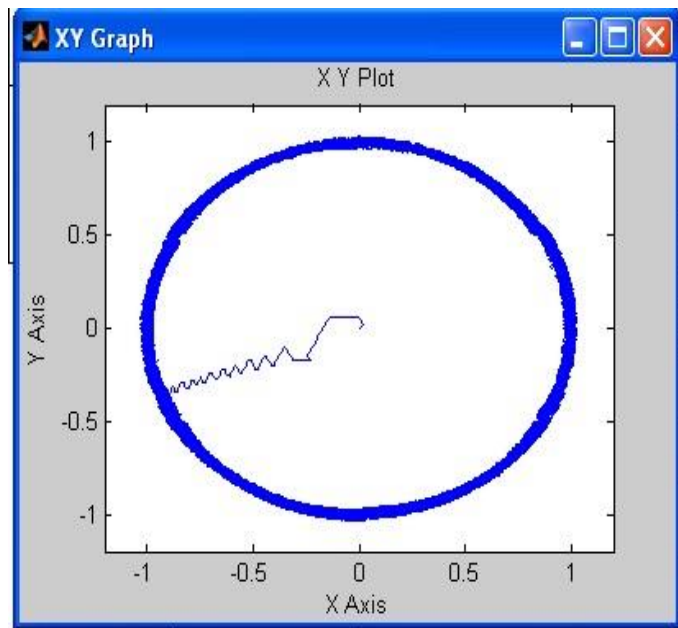
**Simulink Ckt & Result**



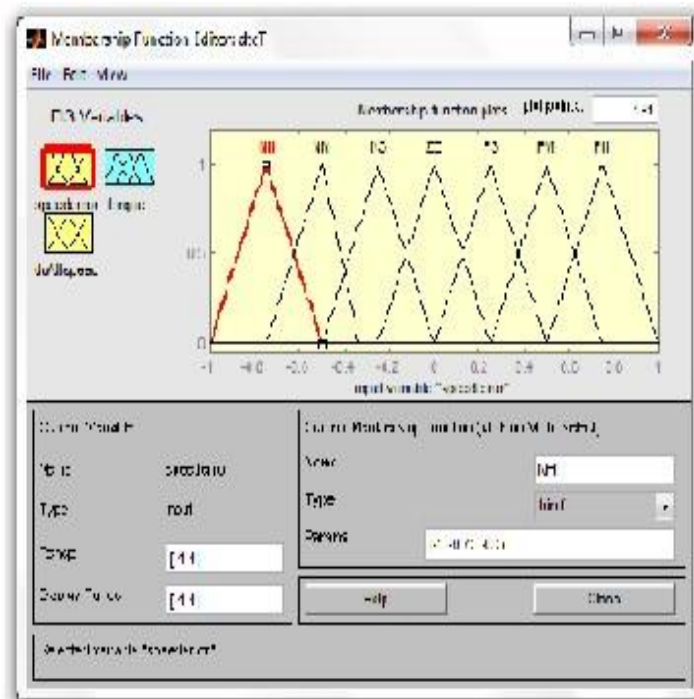
**DTC Fuzzy Circuit**



**Rotor Speed**



**Stator Flux Trajectory**



**MS File**

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