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Analysis and Design of a Self-Tuned Neuro-Fuzzy Based IM Drives

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Abstract— **The main aim this paper is that it shows the dynamic response of speed with the design of the fuzzy logic controller to control the speed of motor for keeping the motor speed constant when load varies. Earlier FOC (field oriented control) of IM drive is widely used in high performance drive system. This is because of its unique characteristics like high efficiency, good pf and extremely rugged. This paper presents the speed control scheme of indirect vector controlled induction motor drive. Voltage source inverter type space vector pulse width modulation (SVPWM) is used for PWM controlling scheme. In this paper we will be using the Fuzzy and PI controller for controlling the torque component Iq current of an IM. The performances of the proposed FLC-based IM drive are investigated and compared to those obtained from the conventional proportional-integral (PI) controller based drive both simulated and experimentally at different dynamic operating conditions such as step change in command speed and load change. In this project we will be using neural network which is a combination of the fuzzy-logic and a 4-layer neural network i.e. it has the advantages of both FLCs and ANN. The vector control utilizes the PI controller or PID controller for error minimization and also for stable operation. Neuro-Fuzzy based controller also designed for vector control of induction motor but it uses trial or error tuning of the membership function, which is complex in practical implementation. In this project Neuro-fuzzy based induction motor drive is trained with back propagation algorithm which removes the Neuro-fuzzy trial and error complexity. The MATLAB software is used to simulate and compare the performances of PI control and Neuro-fuzzy controller for vector control of induction motor. The pros of the Neuro-fuzzy controller (FLCs) over the conventional controllers are :They are economically advantageous to develop A wider range of operating conditions can be covered using FLCs. They are easier to adapt in terms of natural tuning.**

Index Terms—**FOC, SVPWM, ANN, FLCs, PID.**

I. INTRODUCTION

As induction motors are widely used in industries because of its low cost, simple and robust construction. As the process control of every induction motors are very complex due to its non-linear nature and the parameter change with operating conditions. Conventionally PI or PID controllers can be used to drive motors. In this we will be considering a neuro-fuzzy controller (NFC) because of its limitations in both fuzzy logic control (FLC) and artificial neural network (ANN) controllers. A fuzzy controller is used for the speed control of the induction motor drive which has asymmetric membership functions which needs much more manual adjusting by trial and error method if optimized performance is in need. And also it is extremely very tough to create a serial of tuning data for ANN controllers that can handle all the operating modes.

The vector control techniques which is developed upon the field orientation principle decouples the flux and torque control in an IM.Controlling of IM drives is similar to that of a separately excited dc motor which maintains the general advantages of ac over dc motors, hence suitable for high-performance variable speed drive applications.With the advent of the recent power semiconductor technologies and various intelligent control algorithms, an effective control method based on vector control technology can be fully implemented in real time application. Because of these facilities, now a days vector controlled based high performance IM drives have occupied most of the positions that were previously stationed by dc motor drives.

Among various ac motors, IM occupies almost 90% of industrial drives due to its simple and robust construction, however the control of IM is complex due to its non-linear nature and the parameters change with operating conditions.

AIC could be the best candidate for IM control.These are much more advantageous as compared to the conventional PI, PID and their adaptive versions.The main advantages are that the designs of these controller do not depend on accurate system mathematical model and their performances are robust.

In this paper a Neuro-Fuzzy controller (NFC), as an AIC, is considered because of limitations of either fuzzy logic or neural network. A simple fuzzy controller implemented in the motor drive speed control has a narrow speed operation and needs much more manual adjusting by trial and error if high performance is id need. On the other hand, it is extremely tough to create a serial of training data for ANN that can handle all the operating modes.

Neuro-Fuzzy Controllers (NFCs), which overcome disadvantages of the fuzzy logic controllers and neural network controllers, have been utilized by the researchers for motor drive applications. Despite many advantages of NFCs, the industry has been still reluctant to apply these controllers for commercial drives due to high computational burden, but the cost is performance decreasing.

In the recent years, scientists and researchers have acquired significant development on various sorts of control theories and methods. Among these control technologies, intelligent control methods, which are generally regarded as the aggregation of fuzzy logic control, neural network control, genetic algorithm and expert system, have exhibited

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particular superiorities. The Fuzzy logic controller (FLC) method can be utilized in systems that have vagueness or uncertainity. Membership functions with the values between 0 & 1 are used in FLC to deal with the control puzzle, such as nonlinearity, load disturbances, and parameter disturbances.

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth (truth values between “completely true” and “completely false”). It was introduced by Dr. Loft Zadeh of UC/Berkeley in 1960’s as a mean to model the uncertainity of natural language, but only recently its use has spread over a large range of engineering applications. Fuzzy logic techniques attempts to simulate human thought processes,even in technical control problems, reducing engineering time and costs.

Fuzzy controls supports non-linear design techniques that are now being exploited in motor control applications. Examples include the ability to vary gain over a range of the inputs in order to not saturate the control capability.Matlab/Simulink was used as a simulation tool. Matlab is an integrated technical computing environment that combines numeric computation, advanced graphics visualization, and a high level programming language. Simulink is build on the top of Matlab and is an interactive environment for modelling analysing and simulating a wide variety of dynamic systems.

This paper presents a novel speed control scheme of the IM drive based on a newly developed FC. A complete simulation model for the indirect field oriented control of IM incorporating the proposed self-tuned NFC is developed in Matlab/Simulink. The performances of the proposed self-tuned NFC-based IM drive is investigated at different operating conditions both in simulation and in experiment. In order to prove the superiority of the proposed NFC, the performances of the proposed controller are also compared to those obtained by a conventional proportional-integral (PI) and FLC controller. The proposed NFC based IM drive is found to be more robust as compared to the conventional PI and FLC controller.

II. METHODOLOGY :

The portion is to control the speed of an IM. To control the speed of an IM we will be implementing the NFC (neuro-fuzzy controller). In this we will be comparing the reference speed with the actual speed of the motor then it is fed to the error calculator where the error is calculated then it is multiplied with the integral constant then it is fed to the ANFIS based neuro-fuzzy logic controller. From there we need to calculate real and reactive current using torque and the flux. Real and reactive current are fed to the vector rotator where the current is converted from 2-ph to 3-ph current. It is done so as to get the proper efficiency as each wave will have 120 deg phase shift as it will provide a smooth waveform showing 100% efficiency. Then the 3-ph current is fed to the hysteresis current controller where the 3-ph current gets converted into pulses. These pulses are needed for the sinusoidal pulse generation in the spwm inverter.

BLOCK DIAGRAM:

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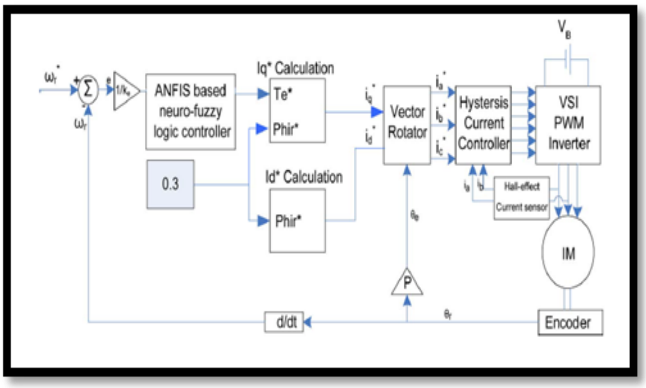


Fig: BLOCK DIAGRAM OF THE NFC BASED SPEED CONTROL IM DRIVE

Next starts the main portion of the speed control of the induction motor. Where the DC supply is given to the inverter where DC to AC conversion occurs then the AC supply is fed the induction motor. The IM what we are using is a asynchronous AC IM. Speed of the IM is sensed by the speed sensor called ENCODER. This sensed speed is the actual speed and the speed fed manually will be the reference speed which is compared to calculate the speed error then the process is continued as explained earlier.

❖ MOTOR DYNAMICS AND CONTROL STRUCTURE

IM Dynamics

The mathematical model of a three-phase Y-connected squirrel-cage IM in a de-qe synchronously rotating reference frame is described in (1)-(4), shown at the bottom. Where vdse-vqse are the d, q-axis stator voltages, idse and iqse are the d, q-axis stator currents, Rs and Rr are the self-inductances of the stator and rotor resistances per phase, and Ls and Lr are the self- inductances of the of the stator and rotor, respectively; Lm is the mutual or magnetizing inductance; We is the speed of the rotating magnetic field; Wr is the rotor speed; P is the number of poles; p is the differential operator (d/dt); Te is the developed electromagnetic torque; Tl is the load torque; Jm is the rotor inertia; Bm is the rotor damping coefficient; and thethar is the rotor position. The motor parameters are given below:

$$\begin{bmatrix} v_{qs}^e \\ v_{ds}^e \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + pL_s & \omega_e L_s & pL_m & \omega_e L_m \\ -\omega_e L_s & R_s + pL_s & -\omega_e L_m & pL_m \\ pL_m & (\omega_e - \omega_r)L_m & R_r + pL_r & (\omega_e - \omega_r)L_r \\ -(\omega_e - \omega_r)L_m & pL_m & (\omega_e - \omega_r)L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{qs}^e \\ i_{ds}^e \\ i_{qr}^e \\ i_{dr}^e \end{bmatrix}$$

$$T_e = J_m \frac{d\omega_r}{dt} + B_m \omega_r + T_L$$

$$T_e = \frac{3}{2}\frac{P}{2} L_m \left(i_{qs}^e i_{dr}^e - i_{ds}^e i_{qr}^e \right)$$

$$\frac{d\theta_r}{dt} = \omega_r$$

CONTROL STRUCTURE :

The key feature of the field oriented control is to keep the magnetizing current at a constant rated value by setting iqs=0. Thus, the torque producing current component iqs can be adjusted according to the torque demand. With this , the mathematical formulation can be:

$$\omega_{sl} = \frac{R_r}{L_r} \frac{i^e_{qs}}{i^e_{ds}}$$

$$i^e_{ds} = \frac{\lambda^e_{dr}}{L_r}$$

$$T_e = \frac{3}{2} \frac{P}{2} \frac{L_m}{L_r} \lambda^e_{dr} i^e_{qs}$$

where ωsl is the slip speed and λe dr is the d-axis rotor flux linkage. Equations are used to simulate the whole drive system. The schematic diagram of the proposed NFC-based indirect FOC of IM . The basic configuration of the drive system consists of an IM fed by a current-controlled voltage source inverter (VSI). The normalized speed error Δω% is processed by the NFC to generate the reference torque T∗ e (n). The command current i∗ q(n) is calculated as follows:

$$i^*_q(n) = T^*_e(n) \frac{2}{3} \frac{2}{P} \frac{L_r}{L_m} \frac{1}{\lambda^*_{dr}}.$$

Currents i*q and i* d are transformed into i* a, i*b, and i*c by Inverse Park's transformation. The phase command currents i*a, i*b, and i* c are then compared with the corresponding actual currents ia, ib, and ic to generate pulsewidth modulation (PWM) logic signals, which are used to trigger the power semiconductor switches of the three-phase inverter. The inverter produces the actual voltages to run the motor.

III. SIMULATION:

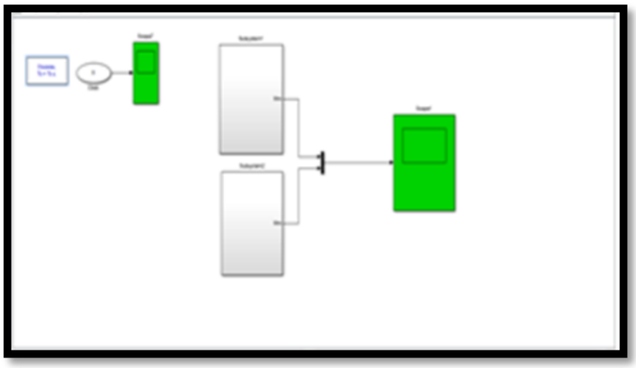


FIG 1: subsystem 1 (fuzzy controller) subsystem 2 (PI controller)

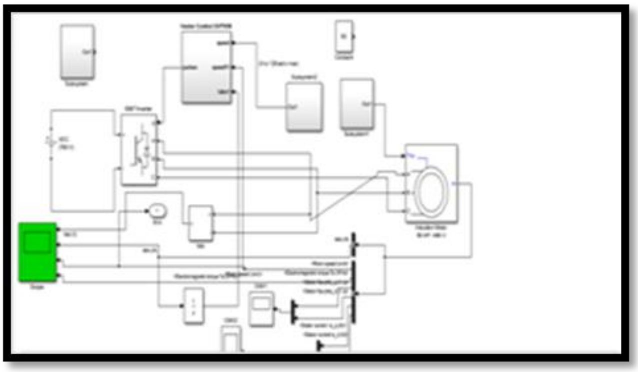


FIG 2: subsystem 1 (fuzzy controller)

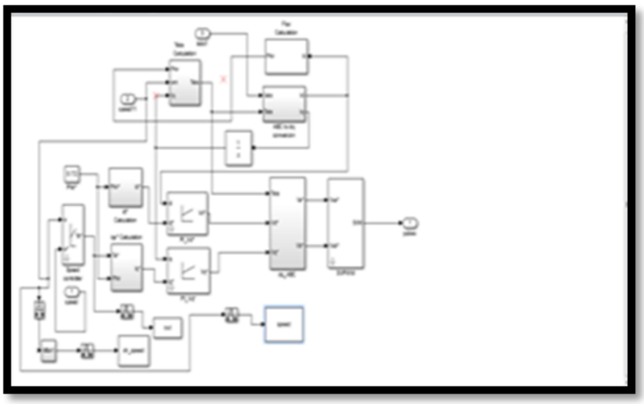


FIG 3: SUBSYSTEM 1 (block inside fuzzy controller)

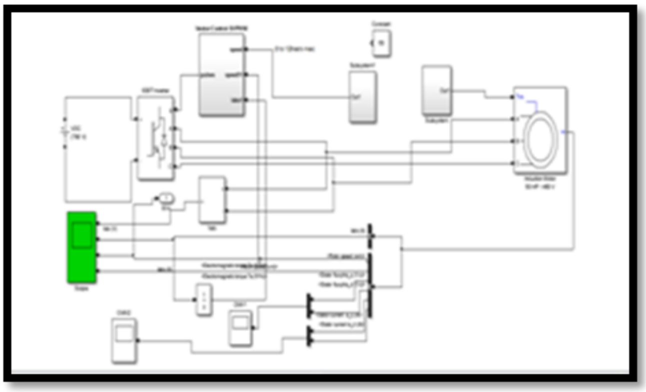


FIG 4: SUBSYSTEM 2 (PI controller)

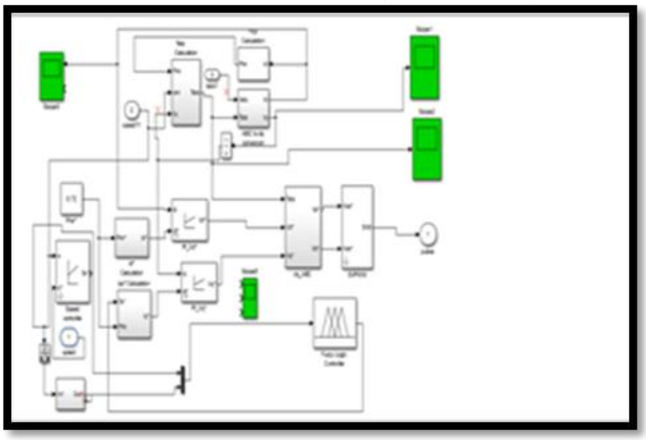
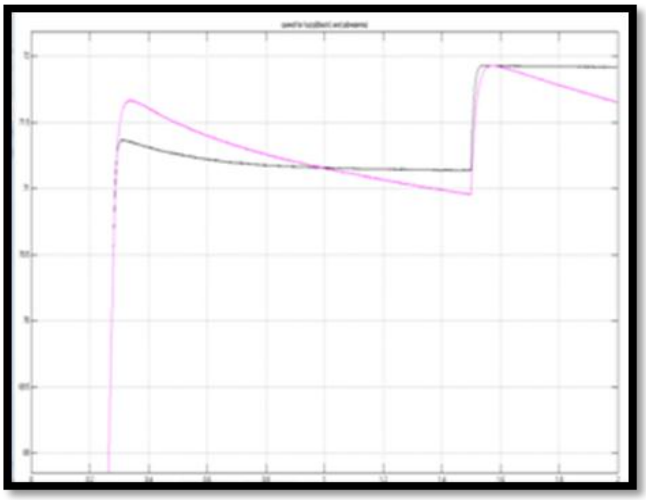


FIG 5: SUBSYSTEM 2 (inside PI controller block)

IV. RESULTS AND DISCUSSIONS:



A. Simulation Results

The performance of the proposed simplified NFC-based IM drive is investigated in simulation using Matlab/Simulink at different operating conditions shows the simulated starting performances of the drive at full load with the proposed NFC, conventional two-input NFC, and PI controllers, respectively. It is clearly seen from these figures that the performance of the proposed simplified low computational NFC is similar to that of the conventional NFC and, at the same time, it is superior to that of the conventional PI controller in terms of overshoot and settling time. Fig shows the zoom-in view of the speed responses of the drive system with a step increase in the load from zero to rated level for the three controllers. It is found that the proposed simplified NFC can handle the load disturbance with lesser dip in speed as compared to both conventional NFC and PI controller. The variation of rotor resistance is a crucial issue for IM drive performance. So, in order to test the performance of the drive with parameter variations, the performance of the drive is tested for all three controllers with doubled rotor resistance, and the corresponding speed responses are the speed responses of the drive system first with a step decrease in command speed from 180 to 150 rad/s, and then, a step increase in command speed from 150 to 180 rad/s using the proposed NFC, conventional NFC, and PI controller, respectively. In this test, the proposed NFC exhibits a little larger undershoot than the PI controller but no overshoot and less settling time. It is found that the performance of the proposed simplified NFC is almost similar to that of the conventional NFC and, at the same time, it is superior to that of the conventional PI controller as the PI controller takes longer time to reach the steady state. Based upon tests, it is evident that the proposed NFC does not decrease system performance significantly as compared to the conventional two-input NFC In addition, the simplified NFC provides superior performance as compared to the conventional PI controller.

V. CONCLUSIONS:

On the basis of the above outcomes, the following observations were made:

i. On increasing the motor inductance (either rotor or stator), the transients lasted for longer period i.e., the machine took longer time to achieve its steady state speed, current and torque. Also the start was a bit jerky.

ii. On increasing the rotor resistance, there was no effect on the steady state time but the machine started with lesser jerks, i.e., the fluctuations in the transient period were reduced. Also the maximum torque occurred at a lower speed.

iii. On increasing the stator resistance, the steady state time increased as well as the machine started with more jerks. Thus the stator resistance must be kept as low as possible.

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