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Comparative Analysis on ANN based Fuzzy and PI Controller based Speed Control of DC Motor

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Abstract: It concerns the study of intelligent control techniques and its application to speed control of DC motors fed by DC-DC converters, which can be implemented in an embedded system. The intelligent techniques include Fuzzy Logic Control (FLC) and Artificial Neural Network (ANN).

Implementation of closed loop control for power converters and drives requires efficient controllers and in turn requires high computation rate and so embedded system implementation is advantageous. The ease of design of intelligent controllers can be well understood only if the complexities in the conventional controller design are explained. Initially, conventional PT controller design based on the small signal model of the motor with buck type DC-to-DC power converter is designed. This controller implementation on a PC using data acquisition card is presented.

Then a fuzzy controller was designed with the embedded systems implementation in mind and the analysis of response of the motor speed is compared with conventional Proportional and Integration (P1) controller. Fuzzy controller gives a better performance compared to P1 controller. The simulated fuzzy controller was implemented experimentally in an 8051-based embedded system. A buck type DC-to-DC power converter fed DC drive was constructed and the fuzzy controller performance was studied experimentally. The entire system is found to be cost effective and has more advantages in terms of steady state error and rise time.

Keywords: DC Motor, PWM, ANN,Fuzzy logic, Speed Control, Astable Mode, Variable Speed Drive.

I. INTRODUCTION

The conventional methods that control electric motors in the past were very inefficient, expensive and gave very poor performance. In recent years, the demand for greater performance and precision in electric motors, combined with the development of better solid state electronic devices and cheap microprocessors has led to the creation of modern intelligent adjustable-speed drives using power converters.

The power electronic converter provides the interface between the power supply and the motor. The main advantage of using power converters is the savings.

Controller is a circuit responsible for controlling the motor output. This is accomplished by manipulating the operation of the power electronic converter. The closed loop control of motors is essential in many industrial applications. The evolution of power electronic converters and their control has generated new trends and potential in multidisciplinary directions. In this context, DC-DC power converter systems with motor load are more appropriate for modern intelligent control techniques, which are considered in this work.

The system designed has two loops with an inner ON/OFF current controller and an outer fuzzy speed controller. In outer speed control loop, the speed is fed back and is compared with set speed. After comparison, error signal and the change in error are calculated and are given as input to fuzzy controller. The fuzzy controller attempts to reduce the error to zero by changing the duty cycle of switching signal and thereby, the voltage fed to the armature of the separately excited motor to regulate the speed. The quadrant of operation is decided by comparing the reference speed and the actual speed of the motor. The Four-quadrant converter is designed to have switching frequency of more than 20 KHz. The use of high switching frequency reduces torque ripples on the motor 43 II Q2 D4 - ON D1,D4 - ON -G Q3Q2-ON D4,Q2 - ON III I Q1 Q4 - ON +Vdc D2,Q4 - ON Jo Idc -Vdc Q4 D2 - ON D3,D2 - ON Iv S shaft. Such a converter requires both current and voltage reversing capability to match rapidly changing speed references and to compensate for step load disturbances.

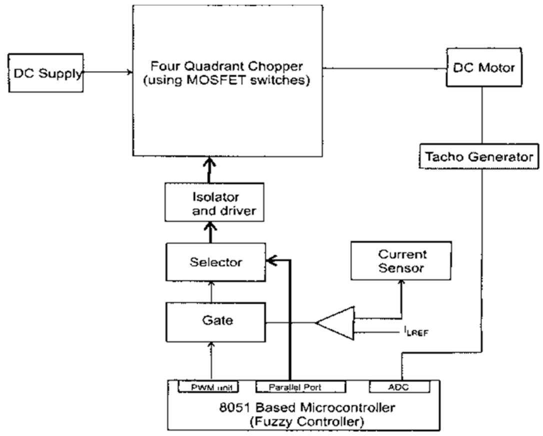

Fig-1. Block diagram of proposed model

II. METHODOLOGY

Neural networks and fuzzy set theory have been the object of intense study and application, especially in the last decade. Neural networks and fuzzy control were developed to deal with problems that were hard or impossible to solve using traditional techniques. Implementation of closed loop control for power converters and drives requires 1 efficient controller and in turn requires high computation rate. So embedded system implementation becomes essential

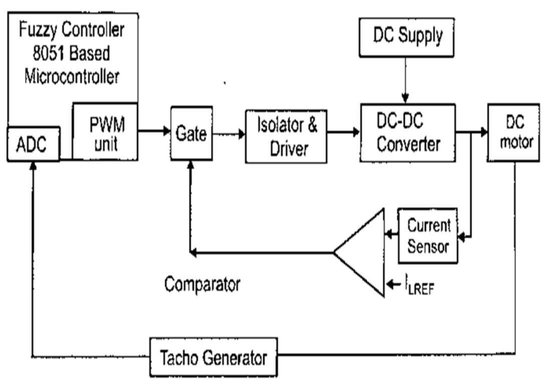

Fig. Fuzzy logic Controller for DC motor

Table 1. Comparative analysis for steady state error of ANN based Fuzzy and PI Controller

Speed	Load	PI	Fuzzy	ANN trained with Fuzzy controller data	ANN trained with PI controller data
60% of rated value	0% of rated torque	1.2	0.55	0.44	0.29
	100% of rated torque	1.0	0.75	0.6	0.56
100% of rated value	0% of rated torque	2.0	1.67	1.0	0.05
	100% of rated torque	8.7	1.86	1.0	0.625

Table 2. Comparative analysis for Rise time of ANN based Fuzzy and PI Controller

Speed	Load	PI	Fuzzy	ANN trained with Fuzzy controller data	ANN trained with PI controller data
60% of rated value	0% of rated torque	1.057	0.8313	0.83	0.814
	100% of rated torque	11.4	5.45	4.89	4.6
100% of rated value	0% of rated torque	1.9	1.417	1.42	1.417
	100% of rated torque	23.5	10.5	9.95	9.95

III. EXPERIMENTAL IMPLEMENTATION

The designed controllers were implemented using Cygnal 8051 based processor (C805 1 F005) and programming it. A buck converter was built and the controllers were 93 tested on the 220V DC motor. A tacho-generator was used to sense the speed and to feedback the speed signal. A LEM make current sensor LTS25NP is used to sense the armature current and it is compared with the reference current using a comparator. The AND gate is used to allow the PWM waveform when the actual current is less than the reference current. This PWM waveform is then level amplified and fed to the DC -DC power converter through an isolator and driver chip. The Buck converter output is used as supply to the armature of the DC motor, whose speed is to be controlled. The tacho generator connected to the motor shaft gives a DC voltage proportional to the speed and this DC voltage is fed to the ADC available in the micro-controller. The Figures 6.7 to 6.9 show the experimental graph of response of DC motor for a step change in reference speed applied to a prototype motor. Figure 6.7 shows the response of the Conventional PT controller. While Figures 6.8 shows the response of the Fuzzy controller, Figure 6.9 shows the response of the ANN controller trained using P1 controller data. These results confirm the simulation results that the ANN controller reduces the rise time in the response.

IV. RESULTS

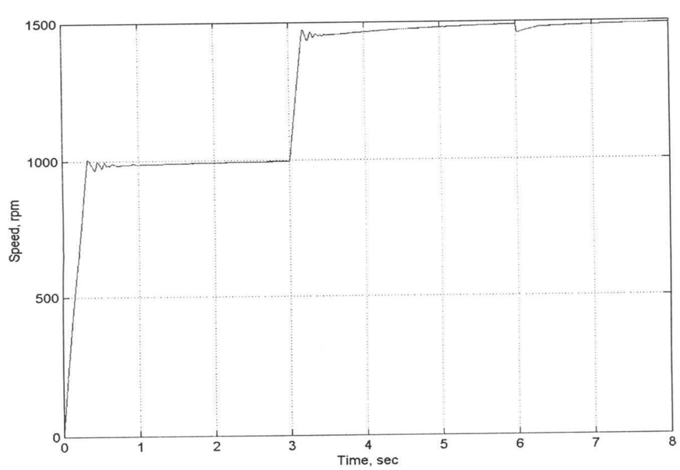

Fig. Simulated Speed variation for the step change in reference speed 1000 rpm to 1500 rpm and for change in load torque from zero to rated value at t=6 secs with PI controller

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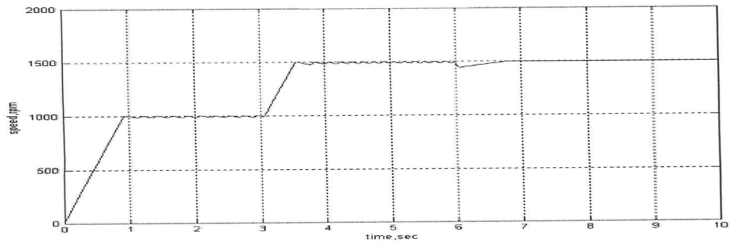

Fig. Simulated Speed variation for the step change in reference speed 1000 rpm to 1500 rpm and for change in load torque from zero to rated value at t=6 secs with Fuzzy controller

V. CONCLUSION

The study of Fuzzy and ANN control techniques and its application to control the speed of separately exc motors has been taken up in this thesis. The DC motor drive system uses Buck type DC-DC converters and microcontroller based embedded system for intelligent control algorithm implementation. Initially, the conventional controller design starting from mathematical modeling of the DC motor and the related power electronic converters were discussed. Instead of the general time averaged model, the small signal model was developed and based on the small signal model; the conventional P1 controller was designed. The small signal model is advantageous as it takes care of the dynamics of the system under study.

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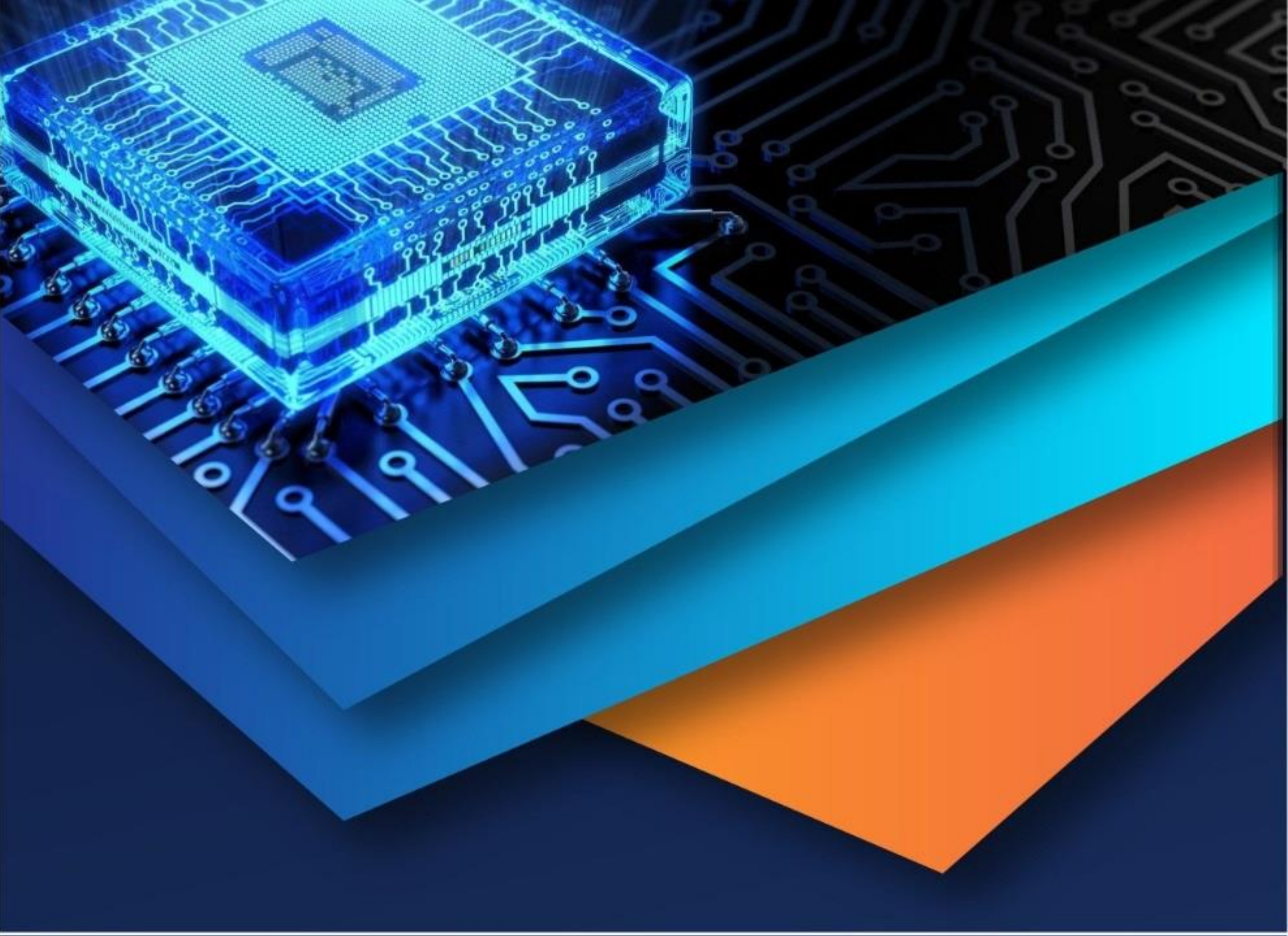

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