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Fuzzy Based Closed Loop Operation of DC-DC Converter for Separately Excited Motor

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ABSTRACT:

The speed control of separately excited dc motor is carried out by varying the armature voltage for below rated speed and by varying field flux to achieve speed above the rated speed. This paper presents the speed control methodology by varying armature voltage using chopper by providing control signal to the switches. Speed can be controlled from below and up to rated speed .The firing circuit of chopper receives signal from controller and variable voltage is given to the armature of dc motor according to the desired speed .There are two controllers we are using here one is speed controller and other is current controller. Both controllers are fuzzy controllers in place of proportional -integral type .The reason behind using fuzzy type controller is it removes the delay and provide fast control. Now the simulation of model is done and analyzed in MATLAB (Simulink) under varying speed and torque condition.

I. INTRODUCTION

An electrical drive consists of electric motors, its power controller and energy transmitting shaft. In modern electric drive system power electronic converters are used as power controller. Electric drives are mainly of two types: DC drives and AC drives. The two types differ from each other in that the power supply in DC drives is provided by DC motor and power supply in AC drives is provided by AC motor. DC drives are widely used in applications requiring adjustable speed control, frequent starting, good speed regulation, braking and reversing. Some important applications are paper mills, rolling mills, mine winders, hoists, printing presses, machine tools, traction, textile mills, excavators and cranes. Fractional horsepower DC motors are widely used as servomotors for tracking and positioning. For industrial applications development of high performance motor drives are very essential. DC drives are less costly and less complex than AC drives.

DC motors are used extensively in adjustable speed drives and position control system. The speed of DC motors can be adjusted above or below rated speed. Their speed above rated speed are controlled by field flux control and speed below rated speed is controlled by armature voltage. DC motors are widely used in industry because of its low cost, less complex control structure and wide range of speed and torque.

There are various methods of speed control of DC drives – armature voltage control, field flux control and armature resistance control. For controlling the speed and current of DC motor, speed and current controllers are used. The main work of controller is to minimize the error and the error is calculated by comparing output value with the set point. This thesis mainly deals with controlling DC motor speed using Chopper as power converter and PI as speed and current controller.

II. SEPARATELY EXCITED DC MOTOR

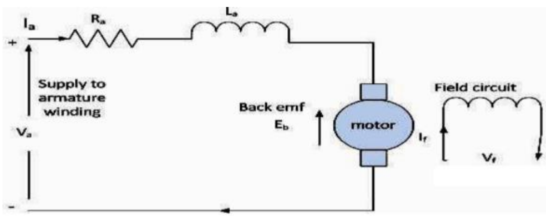

Fig.1.Circuit diagram of separately excited dc motor

Separately excited dc motor has field and armature winding with separate supply voltage. Field winding supplies field flux to armature. When DC voltage is applied to motor, current is fed to the armature winding through brushes and commutator. Since rotor is placed in magnetic field and it is carrying current also. So motor will develops a back emf and a torque to balance load torque at particular speed.

Mathematical analysis of separately Excited DC Motor

When a separately excited dc motor is excited by a field current of I_f and an armature current of I_a flows in the circuit, the motor develops a back EMF and a torque to balance the load torque at a particular speed. The field current I_f is independent of the armature current I_a. Each winding is supplied separately. Any change in the armature current has no effect on the field current. The is generally much I_f less than the I_a.

In the above figure suppose V_a is the armature voltage in volt, I_a is the armature current in ampere, E_g is the motor back emf in volt, L_a is the armature inductance in Henry, R_a is the armature resistance in ohm.

The armature equation is shown below:

$$V_a = E_g + I_a R_a + L_a \frac{dI_a}{dt} \quad (1)$$

Now the torque equation will be given by

$$T_d = J\frac{dw}{dt} + B_w + T_l \quad (2)$$

Equation for back emf of motor will be

$$E_g = K\,\Phi\,W \quad (3)$$

$$T_d = K\,\Phi\,I_a \quad (4)$$

$$w = (V_a - I_a R_a)/\,K\,\Phi \quad (5)$$

Now, from the above equation it is clear that speed of DC motor depends on applied voltage, armature current, armature resistance and field flux. So, there are three ways of controlling speed of DC motor – armature voltage control, armature resistance control and field flux control.

III. MODELLING OF DC MOTOR FOR DRIVE SYSTEM

An electrical DC drive is a combination of controller, converter and DC motor. Here we will use chopper as a converter. The basic principle behind DC motor speed control is that the output speed of DC motor can be varied by controlling armature voltage keeping field voltage constant for speed below and up to rated speed. The output speed is compared with the reference speed and error signal is then fed to speed controller. If there is a difference in the reference speed and the feedback speed, Controller output will vary. The output of the speed controller is the control voltage Eg that controls the operation duty cycle of converter. The converter output gives the required voltage V to bring motor speed back to the desired speed. The Reference speed is provided through a potential divider because it is linearly related to the speed of the DC motor. Now the output speed of motor is measured by Tacho-generator. The tacho voltage we will get from the tacho generator contains ripple and it will not be perfectly dc. So, we require a filter with a gain to bring Tacho output back to controller level.

The basic block diagram for DC motor speed control is show below:

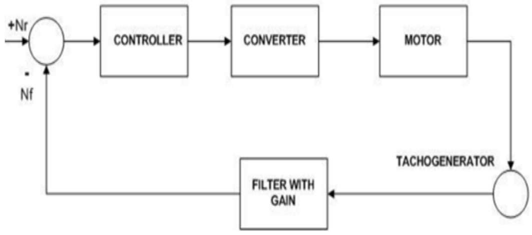

Fig.2.Closed loop model for speed control of dc motor

The controller used in a closed loop model of DC motor provides a very easy and common technique of keeping motor speed at any desired set-point speed under changing load conditions. This controller can also be used to keep the speed at the set-point value when the set-point is ramping up or down at a defined rate. In this closed loop speed controller, a voltage signal is obtained from the Tacho-generator attached to the rotor which is proportional to the motor speed is fed back to the input where signal is subtracted from the set-point speed to produce an error signal. This error signal is then fed to controller to make the motor run at the desired set-point speed. If the error speed is negative, this means the motor is running slow so that the controller output should be increased and vice-versa.

There are different types of controller available and its selection is also an important work. Some of the controllers which are most widely used are – proportional controller, on– off controller, integral controller, derivative controller and PID controller. In proportional controller error speed is proportional to the measured output. This controller has the limited use and can never force the motor to run exactly at the set point speed. Therefore an improvement is required for correction in the output. In PI controller, the proportional term does the job of fast correction and the integral term takes finite time to act and makes the steady state error zero. In derivative approach further refinement is done. This controller will allow the rate of change of error speed to apply an additional correction to the output drive. It can be used to give a very fast response to sudden changes in motor speed. In simple PID controllers it becomes very difficult to generate a derivative term in the output that has any significant effect on speed of motor. It can be deployed to reduce the rapid speed oscillation caused by high proportional gain. Therefore, in many controllers, it is not used. The derivative action causes the noise (random error) in the main signal to be amplified and reflected in the controller output. Hence the most suitable controller for speed control is PI type controller. In this paper it is replaced by fuzzy controller for better speed control of motor.

IV. INTRODUCTION TO FUZZY LOGIC CONTROLLER

A new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzy fication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

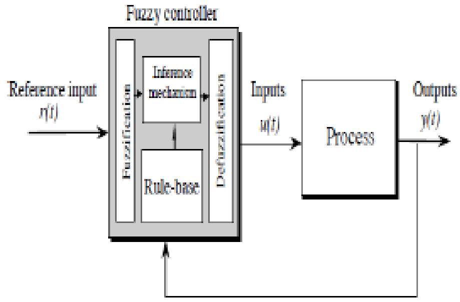

Fig.3. General structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

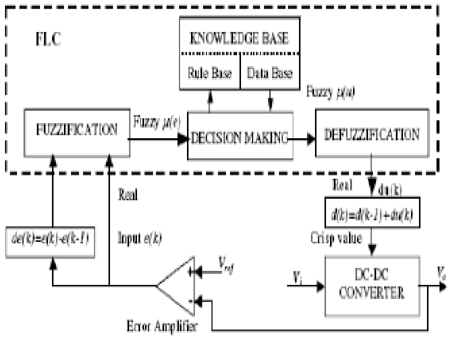

Fig.4. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

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A. Fuzzy Logic Membership Functions:

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

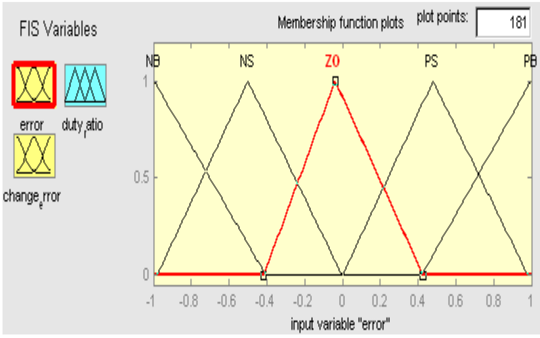

Fig. 5.The Membership Function plots of error

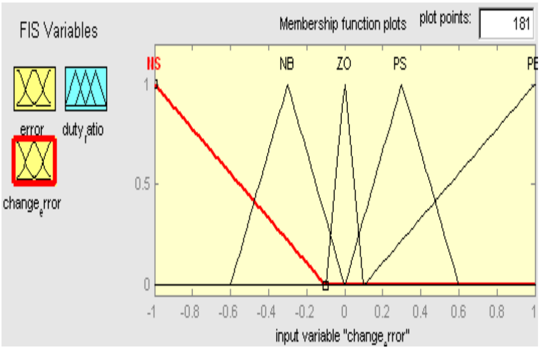

Fig.6. The Membership Function plots of change error

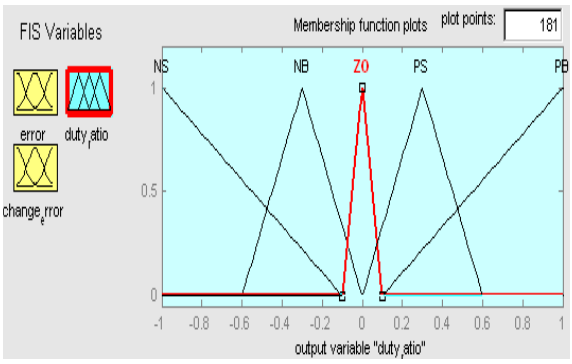

Fig.7. The Membership Function plots of duty ratio

B. Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table II

Table rules for error and change of error

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

V. MATLAB/SIMULINK RESULTS

Case 1: proposed system with PI controller

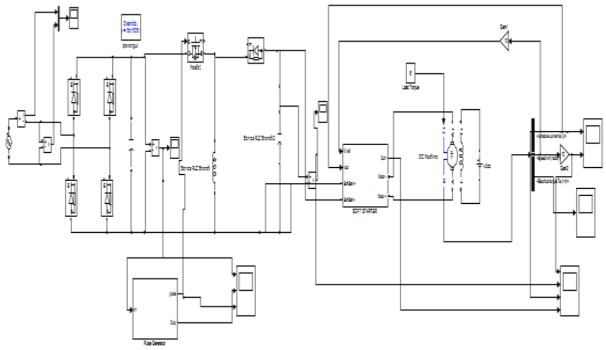

Fig.8.Simulink circuit for proposed system with PI controller

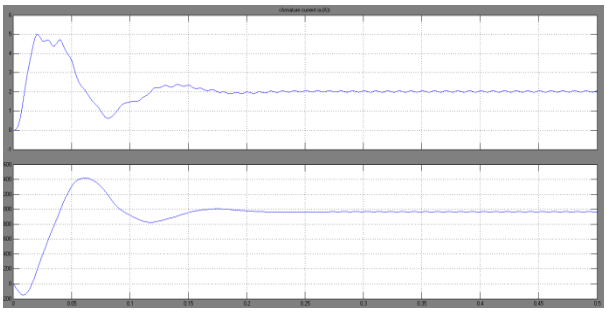

Fig.9.Simulation result for stator current and speed of the motor

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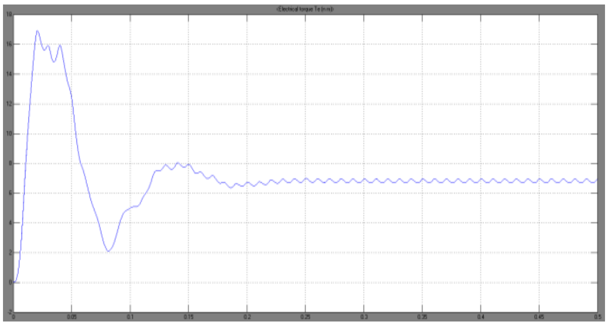

Fig.10.Simulation result for electromagnetic torque of the motor

Case 2: proposed system with fuzzy controller

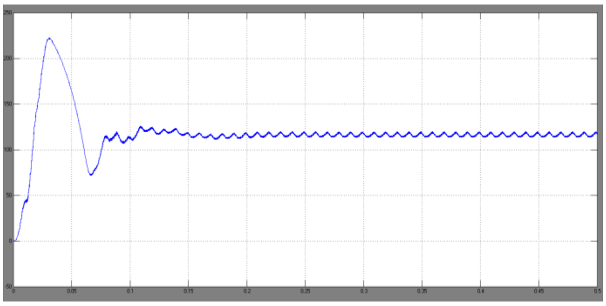

Fig.11.Simulation result for input voltage

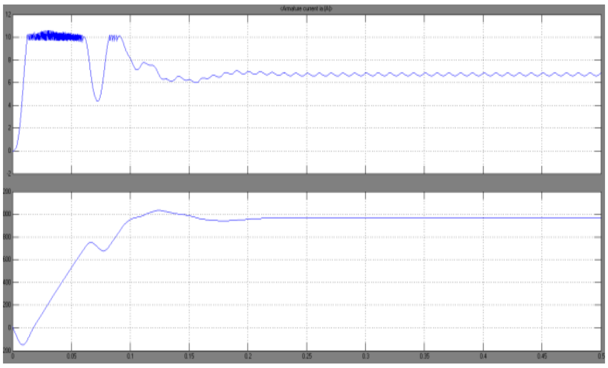

Fig.12.Simulatuon result for armature current and speed of the dc motor

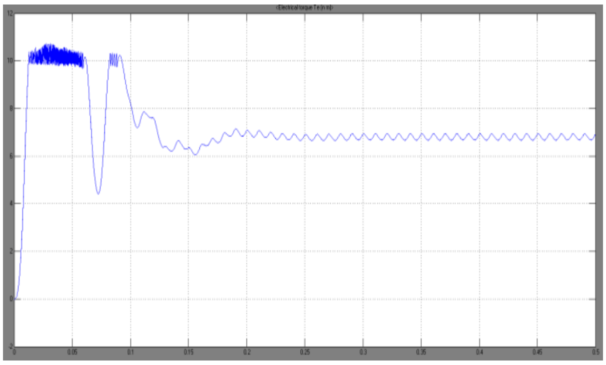

Fig.13.Simulation result for electromagnetic torque of motor

VI. CONCLUSIONS

In this paper, Fuzzy based Controller of separately excited DC motor has been presented. Fuzzy controller has been used to control the speed of the motor. The error between the model reference output and motor speed output is used as trajectory function to adapting the primes part and the consequence part of the fuzzy network so that the error goes toward zero. From simulation results, It is found that the proposed system is robust in that it eliminates the load disturbances considerably.

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