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Field Current Speed Control of Direct Current Motor using Fuzzy Logic Technique

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Abstract

This paper describes a MATLAB/Simulink realization of the direct current (DC) motor speed control method by controlling the voltage applied to the field circuit of a separately excited DC motor in the constant power region. A comparison between armature voltage control method and the field current control method is presented. The simulation results obtained present the flexibility of the motors speed control. The field current control method settles faster than the armature voltage control method and has higher overshoot in all cases.

Keywords: MATLAB, DC motor, Speed, Armature, Field, Fuzzy Logic.

1. Introduction

Speed control means intentional change of the drive speed to a value required for performing the specific work process. Speed control is a different concept from speed regulation where there is natural change in speed due change in load on the shaft. Speed control is either done manually by the operator or by means of some automatic control device. One of the important features of DC motor is that its speed can be controlled with relative ease. We know that the expression of speed control of DC motor is given by equation 1.

$$\omega = \frac{V_a - I_a R_a}{K\emptyset} \quad (1)$$

Therefore speed (ω) of any type of DC motor – series, shunt, compound and separately excited can be controlled by changing the quantities on right hand side of the expression. So the speed can be varied by changing;

(i) Terminal voltage of the armature V_a
(ii) External resistance in armature circuit R_a
(iii) Flux per pole $\emptyset$.

The first two cases involve changes that affect the armature circuit and the third involves change in magnetic field. Therefore speed control of DC motor is classified as armature control methods and field control methods. The aim of this research is to control the speed of a separately excited DC motor using field voltage control method and the objective is to design and build an effective Fuzzy logic controller for the DC motor speed control over a wider range (0–2000 rpm).

Many authors have done so much work on DC motor speed control using different types of approaches depending on the application of the motor or purpose of the speed control technique. Some researchers used the convention control methods like the use of proportional-integral-derivative (PID) controller, proportional- integral (PI) controller or non-linear auto-regressive moving average (NARMA) controller (George, 2008). Others used the concept of fuzzy logic technique or the combination of fuzzy and artificial neural network (Neuro-Fuzzy), but mostly used armature voltage control method.

1.1 Field Control of Separately Excited DC Motor

This method requires a variable voltage supply for the field circuit which is separated from the main power supply to which the armature is connected. Such a variable supply can be obtained by an electronic rectifier. In this method, the voltage source supplying the field current is different from that which supplies the armature (Isaac and Victor, 2001). This method avoids the disadvantages of poor speed regulation and low efficiency as in armature control method. However, it is quite expensive. Therefore, this method of speed control is employed for large size motors where efficiency is of great importance (Waleed, 2005).

2. Concept of Fuzzy Logic Controller (FLC)

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. The operation of a FLC is based on qualitative knowledge about the system being controlled. Fuzzy logic, unlike the crispy logic in Boolean theory, deals with uncertain or imprecise situations. A variable in fuzzy logic has sets of values which are characterized by linguistic expressions, such as SMALL, MEDIUM, LARGE, etc.(Mendel, 1995). Figure 1 shows the internal structure of a fuzzy logic controller. Triangular membership distribution is used in the analysis and defuzzification is carried out by center of gravity method (Mendel, 1995). Generally, the number of rules in a fuzzy logic controller depends on the number of input and output variables and the number of membership functions (Zadeh, 1996). If all the premise terms are used in every rule and the rule is formed for each possible combination of premise elements, then the number of rules is defined as in equation (1)

$$N_r = \prod_{i=1}^{n} N_i \quad (2)$$

Where, N_r is the total number of rules, n is the number of input variables and N_i is the number of membership functions on each universe of discourse, (Passino and Yurkovich, 1997).

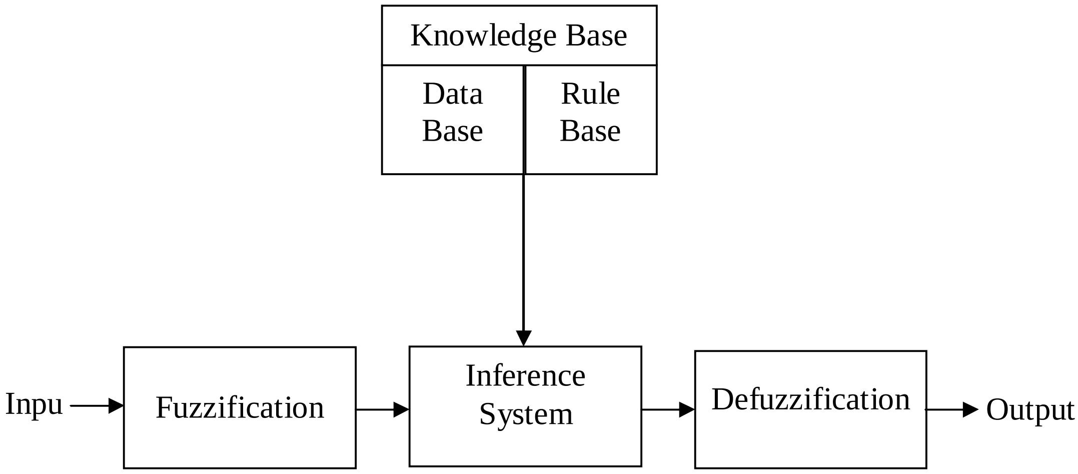

Figure 1: Structure of fuzzy logic controller.

In centre of gravity (COG) method, the output value is computed using the relation (Passino and Yurkovich, 1997);

$$u = \frac{\sum_i b_i A_i}{\sum_i A_i} \quad (3)$$

Where, $A_i = \int u_i$ is the area under the membership function u_i and b_i is the centre of membership function of the consequent i^{th} rule.

3. Methodology

Field current speed control method is generally used when the motor has to be operated above its rated speed. To understand the operation of field control, assume that the DC motor is running at a constant speed (Sanjeev and Vivek, 2010). If the field current is reduced by reducing the voltage across the field winding, the flux density will be reduced. This will reduce the back emf instantaneously and will cause armature current to increase resulting in the motor speed increasing. Consequently, the back emf will increase and a new equilibrium will be established at a higher speed. With field control one can achieve as high a speed as five times the rated speed (Mustapha, 2005).

In the field current control method, as shown in Figure 2, the armature windings are being supplied with a rated constant dc source (A+ and A-) and the field voltage, V_f is varied so as to vary the motor's speed.

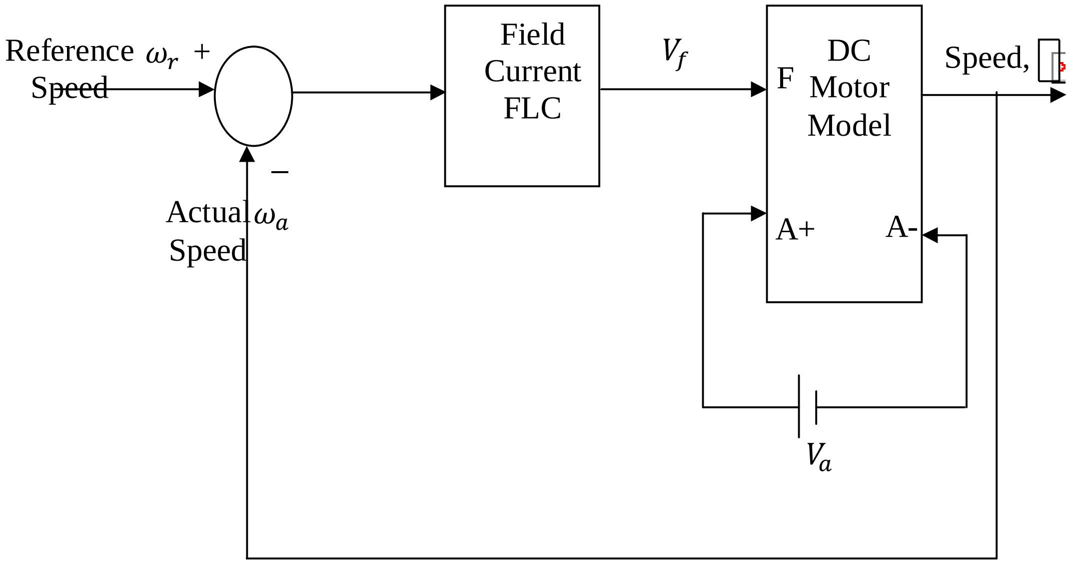

Figure 2: Field control method.

3.1 Field Current Control Method FLC Design

A fuzzy logic controller was designed for the field control method, with a field voltage rating of 300V. The speed range used for the error speed and the change in error was the rated speed of 1750 revolutions per minute (rpm).

Field control method is implemented in Matlab as shown in Figure 3. In this case the armature windings are held constant with the rated armature voltage of 240V. The field is then connected to the fuzzy logic controller via the controlled voltage source. The outputs are then taken to Matlab m-file (To workspace) for further analysis and computations.

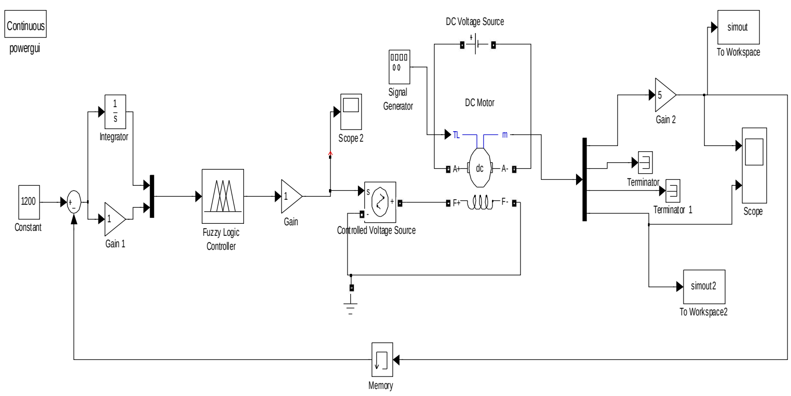

Figure 3: Simulink model of field control method.

4. Results and Discussion

Results of simulations done at various speed references are hereby presented. Matlab/Simulink software was used to run the simulation model for the field voltage control method done at 0.6 seconds time intervals to enable the transient regions to be properly captured. The reference speed levels of the motor chosen were 1750 rpm (rated speed) and 2000 rpm (above rated speed). The separately excited DC motor used has the following parameters: 5hp, V_a=240V, V_f=300V and R_a=2.581Ω.

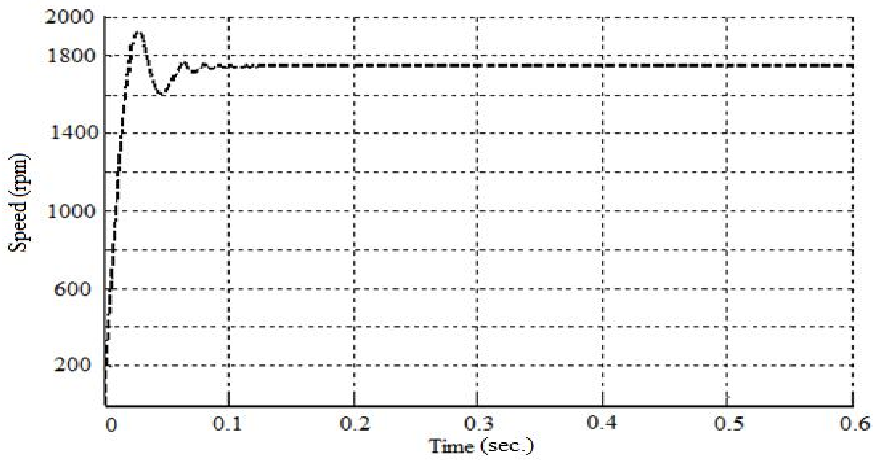

Figure 4: Field control method at rated speed (1750 rpm).

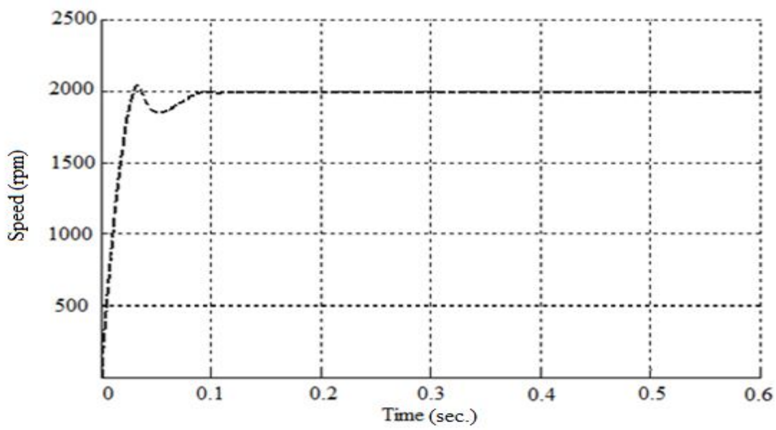

Figure 5: Field control method at above rated speed (2000 rpm).

Figures 4 and 5 shows the transient response of the motor at its rated speed of 1750 rpm and at 2000 rpm, a reference value slightly above the motors rated speed. It can be seen that the speed response settles faster after 0.128 seconds for 1750 rpm and 0.116 seconds for 2000 rpm, having overshoot of 10.1% and 2.1% respectively. See table 1 for other response characteristics.

Table 1: Speed response characteristics.

Reference Speed	Delay Time, Td (sec.)	Rise Time, Tr (sec.)	Peak Time, Tp (sec.)	Settling Time,Ts (sec.)	Overshoot, Mp (%)
1750 rpm	0.008	0.017	0.027	0.128	10.1
2000 rpm	0.010	0.023	0.033	0.116	2.1

5. Conclusion

Field control method of DC motor speed control used in this research was found to be accurate in controlling the speed of the separately excited DC motor, as shown by the transient speed responses of the motor obtained. Therefore the speed of the separately excited DC motor has been efficiently controlled using field current control method at the rated speed of 1750 rpm and 2000 rpm and the fuzzy logic controller designed was found to be effective, covering a wide range of speed (0-2000 rpm). In view of the above, it can be concluded that the aim and objective of the research have been achieved.

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