Intelligence-enabled DC Motor Control Utilizing Integrated Field Current and Armature Voltage

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Abstract.

A DC machine should operate at exact as well as constant speed irrespective of changes while the machine starts. In this paper, for simulation of intelligent fuzzy logic approach to integrated control of a DC series motor applied in MATLAB/ Simulink environment. Intelligent FLCs were created to use integrated control of voltage across armature as well as current across the field in control of DC machine by variation of the voltage across the armature in the unchanged torque region also the current across the field in the unchanged range of control. Because intelligent fuzzy rules are created to be interdependent, two controllers would follow the same logics being activated concurrently, with the similar inputs but different results. The efficiency of the applied approaches is shown via bar graphs as controlling parameters of the motor at the instant of starting.

Keywords. DC Machine, Intelligent System, Fuzzy Logic.

1. Introduction

The usage of direct current (DC) machines has directly expanded as a result of the advancement and industrial uses of power electronics and Intelligent Controllers. This paper aims to apply an integrated control of voltage across the armature along with the current across the field windings approach for simulation of a DC series machine for speed control independently [1].

- Use of a individually activated, distinct armature voltage as well as field control technique in control of the speed of the DC machine.
- Designing and application of an efficient intelligent FLC for the regulation of speed of DC machine across a larger range (0–2400 rpm).

12. DC Machine Modelling

When a DC series motor is modelled, its electrical and mechanical dynamics are represented by mathematical formulas. This procedure aids in the creation of control methods for the motor as well as the analysis of its behaviour under varied operating situations [2].

A brief description of the modelling procedure is provided below:

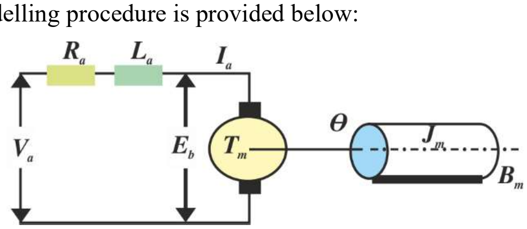

Figure 1. Equivalent Circuit of DC Machine

4.1. Transfer Function as per the Electrical and Mechanical Dynamics

The transfer function for the machine can be achieved in between the Voltage at input terminals $V(s)$ and speed response $\omega(s)$ by Laplace transform of the system equations:

$$\omega(s) = \frac{k_m}{(J_s+B)((L_a s+R_a+R_s)+k_e k_m)} \qquad (1)$$

13. Intelligent Controller

By the expert knowledge base a linguistic control approach is achieved as an Intelligent Fuzzy logic controller (FLC) for the proposed control strategy, which is transformed into an intelligent control approach [3]. The basis for an intelligent functioning is a fundamental comprehension of the system it is controlling. In contrast to Boolean theory's crispy logic, fuzzy logic handles ambiguous or imprecise circumstances. According to L. A. Zadeh, vagueness in the Crisp set consists logical parameters, detailed in form of linguistic terms as SMALL, MEDIUM, LARGE, etc [4].

The Equation 7 defines the number of rules if every concept is utilized in each logic and a logic is created to every conceivable set of concept components [5].

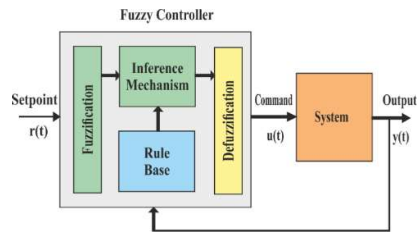

Figure 2. FLC Structure

$$N_r = \prod_{i=1}^{n} N_i \tag{2}$$

where N_i = degree of membership on every discourse space, n = input parameters, and N_r = total count of rules [6].

The connection is used to calculate the output value in the centre of gravity (COG).

$$u = \frac{\sum_i b_i A_i}{\sum_i A_i} \tag{3}$$

where b_i represents mean of the membership degree of corresponding rule and $A_i = \int u_i$ span of the membership degree u_i.

14. Applied Strategy

4.2. Integrated Field Current and Armature Voltage

A DC Series Motor's integrated armature along with field control allow the motor speed adjustment by adjusting both voltage across armature and field flux. Applications requiring precise control of both speed and torque use this technique, which offers a broad range of speed control [7].

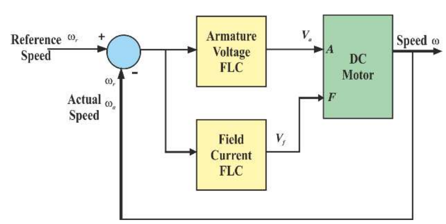

Figure 3. Integrated Filed Current and Armature Voltage Control

The connections between the two fuzzy logic controllers and the DC motor's armature and field windings are shown in Figure 3.

14.2 Implementation of a DC Motor Speed Control System Based on a intelligent FLC

The inputs to intelligent FLC are error in speed $E(t)$ and the error during change-in-speed $\Delta E(t)$. Equations four and five explain the inputs.

$$E(t) = \omega_b(t) - \omega_m(t) \tag{4}$$
$$\Delta E(t) = E(t) - E(t-1) \tag{5}$$

Here variation in error signal $\Delta E(t)$, base speed $\omega_b(t)$, motor speed $\omega_m(t)$, error signal $E(t)$, and previous error signal $E(t-1)$. Here, a Mamdani-type intelligent FLC with triangular membership functions was used. Accordingly, a set of 25 rules and five membership functions were selected [8].

14.3 Execution of Integrated FLC

Two distinct intelligent FLC were created to regulate voltage across armature and management of current across field in a integrated control approach [11]. The characteristics of the two controllers are comparable to those of the separate armature/field regulators. Different levels of speed were maintained below and over the nominal speed [9].

(i) Input and Response Membership Functions:

For Input 1 and 2: Large Negative →LN, Small Negative →SN, Zero →Z, Small Positive →SP, Large Positive →LP

For Response 1 and 2: Extremely Low →EL, Low →L, Average →A, High →H, Extremely High →EH

(ii) Rule Base: Here Fuzzy rules provide a proper modification in V_a and R_f by combining the impacts of E and ΔE. The standard 5x5 rule table is as follows:

E / ΔE	*LN*	*SN*	*Z*	*SP*	*LP*
LN	*EH*	*H*	*A*	*L*	*EL*
SN	*H*	*A*	*A*	*L*	*EL*
N	*A*	*A*	*A*	*A*	*A*
SP	*L*	*L*	*A*	*H*	*EH*
LP	*EL*	*L*	*A*	*H*	*EH*

Table.1 : Fuzzy Rules for V_a Control

E / ΔE	*LN*	*SN*	*Z*	*SP*	*LP*
LN	*EH*	*EH*	*H*	*A*	*L*
SN	*EH*	*H*	*A*	*L*	*EL*
Z	*H*	*A*	*A*	*A*	*H*
SP	*A*	*L*	*A*	*H*	*EH*
LP	*L*	*EL*	*A*	*H*	*EH*

Table.2: Fuzzy Rules for R_f Control

The matching rule basis for the speed controller as Armature Voltage and Field Resistance control is shown in Table 1 and Table 2 [12]. The fuzzy sets for variables Δe and e are shown in the left column and top row of the matrix, respectively, along with the membership function of the matrix's body [10].

15. Results

Here are the outcomes of simulated models at different speed bases. To adequately represent the transitory zones, the simulations were run at intervals of 0.6 seconds. MATLAB/Simulink environment is considered to simulate the prototypes of three distinct strategies for the controlling of speed discussed in this research. Some of them include the Integrated Armature and Field Regulation Strategy (IAFRS), the Field Current Regulation Strategy (FCRS), and the Armature Voltage Regulation Strategy (AVRS).The motor's varied speed responses at various desired base speed values are shown in Figures 4 and 5.

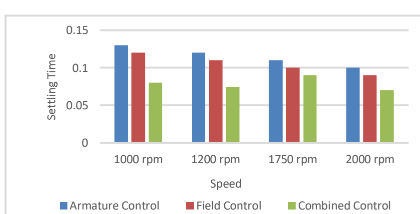

Figure 4. Comparison of settling times with Different Control Methods and different speeds

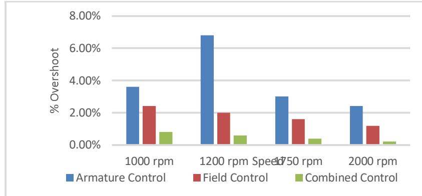

Figure 5. Comparison of Overshoot with Different Control Methods and Different Speeds

In this instance, the integrated regulation approach provides the fastest settling time and the least amount of overrun (0.8%). The motor's reactions at nominal speed shows as the controlling approach for field achieves the desired values more quickly in comparison of the integrated control strategy, although it has a larger overshoot.

16. Conclusion

Using MATLAB / Simulink's fuzzy logic controller technology, the speed of DC Machine has been effectively managed. Triangular membership functions were chosen because of their ease of use and computational efficiency. Only the integrated voltage across armature also current across the field regulation strategy can accurately describe the integrated outcomes of the armature and field feed stimulation to the machine, according to the outcomes, despite the fact that the field current control and armature voltage control strategies were equally precise and suitable. A broad variety of speed control considered to be accomplished by better to the integrated voltage across armature and current across the field regulation approach.

The independent AVRS and the FCRS have been compared to the CAFRS's performance. The findings show that, in terms of delay time T_d, rising time T_r, and settling time T_s, the armature voltage regulation strategy (AVRS) is more similar to the integrated armature and field regulation strategy (IAFRS). In all situations and with varying base speed values, the field current regulation strategy (FCRS) exhibits the largest overshoot.

These findings unequivocally demonstrate the fuzzy logic controller's capacity to choose the required output (voltage) in an acceptable manner in order to maintain the running of the machine at a fixed base parameter. Implementation time will be shortened by using the suggested FLC.

17. References

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