Global Journal of Researches in Engineering
Electrical and Electronics Engineering
Volume 13 Issue 17 Version 1.0 Year 2013
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Comparative Study on DC Motor Speed Control using Various Controllers

By K. Venkateswarlu & Dr. Ch. Chengaiah
Sri Venkateswara University, India

Abstract- Electrical machines like DC motors, brushless DC motors, permanent magnet DC motors are being controlled with power electronics converters. The control has become precise with invention of Micro Controllers and power devices like IGBT, Power MOSFET. In this paper the attempt is made to simulate a speed control of separately excited DC motor with PID and fuzzy controllers. The aim of development of this paper is towards providing efficient method to control speed of DC motor using analog Controller. With the availability of MATLAB/SIMULINK, Fuzzy Controller for comprehensive study of modeling analysis and speed control design methods has been demonstrated.

Keywords: DC motor, open loop, closed loop system, speed control, PID controller and fuzzy controller.

GJRE-F Classification : FOR Code: 090699

COMPARATIVESTUDYONDCMOTORSPEEDCONTROLUSINGVARIOUSCONTROLLERS

Comparative Study on DC Motor Speed Control using Various Controllers

K. Venkateswarlu [α] & Dr. Ch. Chengaiah [σ]

Abstract- Electrical machines like DC motors, brushless DC motors, permanent magnet DC motors are being controlled with power electronics converters. The control has become precise with invention of Micro Controllers and power devices like IGBT, Power MOSFET. In this paper the attempt is made to simulate a speed control of separately excited DC motor with PID and fuzzy controllers. The aim of development of this paper is towards providing efficient method to control speed of DC motor using analog Controller. With the availability of MATLAB/SIMULINK, Fuzzy Controller for comprehensive study of modeling analysis and speed control design methods has been demonstrated.

Keywords: DC motor, open loop, closed loop system, speed control, PID controller and fuzzy controller.

I. Introduction

The field of electrical energy will be divided into three areas: Electronics, Power and Control. Electronics basically deals with the study of semiconductor devices and circuits at lower power. Power involves generation, transmission and distribution of electrical energy. Modern manufacturing systems are automated machines that perform the required tasks. The electric motors are perhaps the most widely used energy converters in the modern machine tools and robots. These motors require automatic control of their main parameters such as speed, position, acceleration etc...

In this paper separately excited DC drive system is used, because of their simplicity, ease of applications such as reliability and favorable cost have long been a backbone of industrial applications and it will have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance.

Many varieties of control schemes such as proportional, integral, derivative, proportional integral (PI), PID, adaptive, and FLCs, have been developed for speed control of dc motors. The important aspect of the speed control of a dc motor is the armature voltage control method. By varying voltage to the armature of a dc motor, the speed of the motor can be varied. Speed of a DC motor can be controlled by PID controller also.

In this paper mainly concentrated on speed control of separately excited DC motor. the design of a mathematical model of the separately excited DC motor using MATLAB code has been done and SIMULINK model is used for studying the performance characteristics of dc motor and mainly concentrated on the design of PID controller and Fuzzy logic controller using MATLAB/ SIMULINK model.

Author α: PG Student SVUCE.
e-mail: k.venkateswarlu256@gmail.com
Author σ: Associate Professor SVUCE.

II. Mathematical Modeling of Separately Excited DC Motor

In order to build the DC motor's transfer function, its simplified mathematical model has been used. This model consists of differential equations for the electrical part, mechanical part and the interconnection between them. The electric circuit of the armature and the free body diagram of the rotor is shown in the Fig 1. and the physical parameters of the motor is shown in table1.

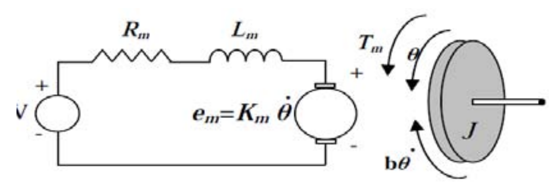

Figure 1 : The electric circuit of the armature and the free body diagram of the rotor for a DC motor

Table 1 : Physical parameters of the DC motor

J	Moment of Inertia of the Rotor(kg.m^2)	0.01
b	Damping ratio of the Mechanical System (Nms)	0.1
Km	Motor Constant (Nm/A)	0.01
Rm	Motor Electric Resistance(Ω)	1
Lm	Motor Electric Inductance(H)	0.5
V	Input Voltage(Volt)	6
&	Rotating Speed(r/s)	600

The motor torque, Tm, is related to the armature current (I), by a constant factor K_t. The back emf (e_m) is related to the rotational speed by the following equations.

$$T_m = K_t I \qquad (1)$$

$$e_m = K_e \dot{\theta} \qquad (2)$$

Assuming that, Kt(torque constant) =Ke(electromotive force constant) =Km (motor constant).

From Fig.1 and physical parameters of system mentioned above, the following equations can be written based on Newton's law combined with Kirchhoff's laws.

$$J\ddot{\theta} + b\dot{\theta} = K_m i - T_L \qquad (3)$$

$$L_m \frac{di}{dt} + R_m i = V - K_m \dot{\theta} \qquad (4)$$

Transfer Function Model of DC Motor

Using Laplace Transforms, the above equations can be expressed in terms of s-domain

$$s(Js+b)\dot{\theta}(s) = K_m I(s) - T_L(s) \qquad (5)$$

$$(L_m(s) + R_m) I(s) = V(s) - K_m s\theta(s) \qquad (6)$$

By eliminating I(s), the following open-loop transfer function can be obtained, where the rotational speed is the output and the voltage V is the input. When the motor is used as a component in a system, it is desired to describe it by the appropriate transfer function between the motor voltage and its speed. For this purpose assuming (load torque) $T_L = 0$ and (friction torque) $T_F = 0$, since neither affects the transfer function.

$$\left.\frac{\dot{\theta}(s)}{V(s)}\right|_{T_L(s)=0} = \frac{K_m}{(Js+b)(L_m s + R_m) + K_m^2} \qquad (7)$$

III. PID Controller

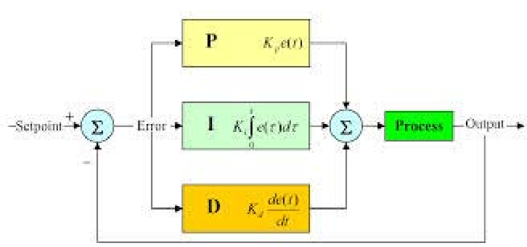

Figure 2 : PID Implementation

The PID control is most widely used in industrial applications. PID controller is implemented to control the speed of DC motor. The implementation of a PID controller is shown in fig (2). The error between the reference speed and the actual speed is given as input to a PID controller. The PID controller depending on the error changes its output, to control the process input such that the error is minimized. A detailed information about the theory and tuning of PID controllers is given in [1]. The Transfer function of a PID controller is given as,

$$c(s) = K_p\left(1 + \frac{1}{T_I * s} + T_D * s\right) \qquad (8)$$

The proportional control (K_p) is used so that the control signal u(t) responds to the error immediately. But the error is never reduced to zero and an offset error is inherently present. To remove the offset error the Integral control action (T_I) is used. To Derivative control (T_D) is used to damped out oscillations in the process response. Also, the presence of derivative control reduces the need of K_p being large to achieve stability.

By tuning the gains of the PID controller and producing the optimum response using trial and error method. With the help of MATLAB programming, the performance of separately excited DC motor with and without PID controller was obtained and results are tabulated in table2.

Table 2 : PID controller responses

response	Open loop (sec)	Closed loop (sec)	with PID controller (sec)
Rise Time	1.1362	1.0173	0.1195
Settling Time	2.0653	1.8476	16.0587
Settling Min	0.0901	0.0825	0.8841
Settling Max	0.0999	0.0908	1.0878
Overshoot	0	0	8.7813
Undershoot	0	0	0
Peak	0.0999	0.0908	1.0878
Peak Time	5.2388	4.6398	0.2337

Here a clear cut comparison is given for various values like rise time, dead time etc... in table 2. By employing this PID controller it can be seen that drastically reduced from 1.1362 in open loop to 0.1195 in closed loop system. Coming to peak time there is significant change from open loop to PID controlled system i.e. from 5.2388 seconds to 0.2337 but coming to settling time there is a drastic change from 2.0653 to 16.0857, this is not desirable. There is change in dead time i.e. improvement in dead time from 4 sec to 1 seconds in this system.

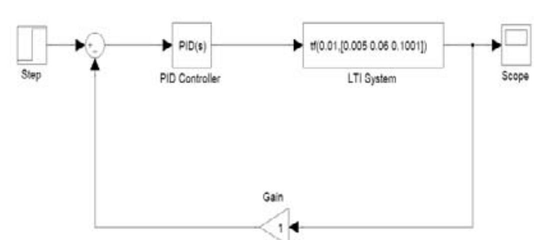

Figure 3 : Simulink model of PID controller

Global Journal of Researches in Engineering (F) Volume XIII Issue XVII Version I Year 2013

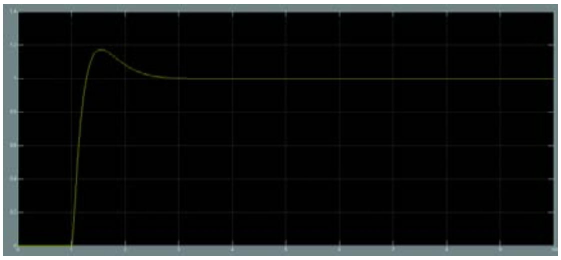

Figure 4 : Response of PID controller

IV. Fuzzy Controller

Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human's knowledge about how to control a system without requiring a mathematical model. The approach of the basic structure of the fuzzy logic controller system is illustrated in Fig 5.

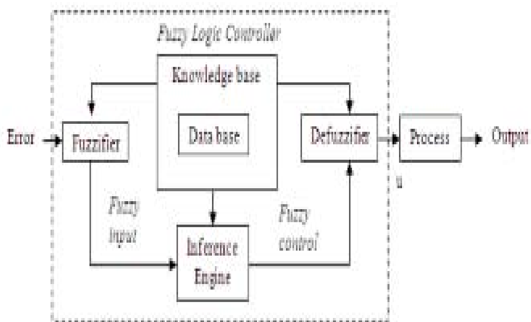

Figure 5 : Structure of Fuzzy Logic Controller

Basically, the Fuzzy Logic controller consists of four basic components: fuzzification, a knowledge base, inference engine, and a defuzzification interface. Each component affects the effectiveness of the fuzzy controller and the behavior of the controlled system. In the fuzzification interface, a measurement of inputs and a transformation, which converts input data into suitable linguistic variables, are performed which mimic human decision making. The results obtained by fuzzy logic depend on fuzzy inference rules and fuzzy implication operators. The knowledge base provides necessary information for linguistic control rules and the information for fuzzification and defuzzification. In the defuzzification interface, an actual control action is obtained from the results of fuzzy inference engine.

Input and outputs are non-fuzzy values and the basic configuration of FLC is featured in Fig6. In the system presented in this study, Mamdani type of fuzzy logic is used for speed controller. Inputs for Fuzzy Logic controller are the speed error (e) and change of speed error. Speed error is calculated with comparison between reference speed, ω ref and the actual speed, ω act.

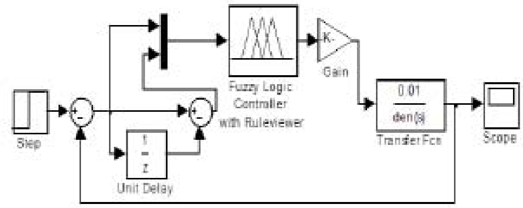

Figure 6 : Simulink model for FUZZY controller

Fuzzy Rule Matrix

The control rules that relate the fuzzy output to the fuzzy inputs which are derived from general knowledge of the system behavior is shown in table 3. Some of the control rules are developed using trial and error method.

Table 3 : Rule Matrix Table

de \ e	NB	N	Z	P	PB
NB	NVB	NB	N	NS	Z
N	NB	N	NS	Z	PS
Z	N	NS	Z	PS	P
P	NS	Z	PS	P	PB
PB	Z	PS	P	PB	PVB

To illustrate the control of motor by the fuzzy rule matrix, 5valid rules from the rule matrix table are identified for Zero & Positive small of error and change in error.

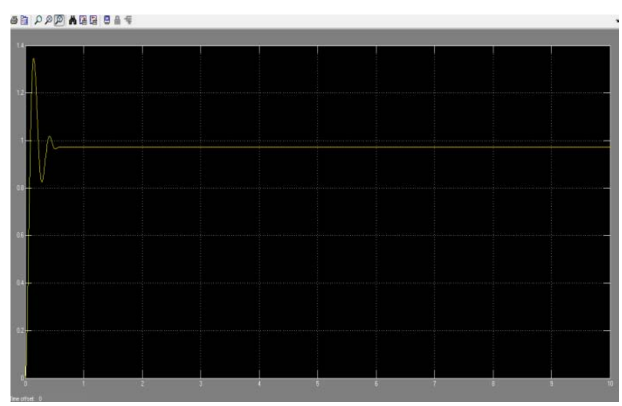

Figure 7 : Response with FUZZY controller

Global Journal of Researches in Engineering (F) Volume XIII Issue XVII Version I Year 2013

Table 4 : Comparison of results

Open Loop (sec)	Closed Loop(sec)	PID (sec)	FUZZY (sec)
Rise Time: 1.1362	Rise Time: 1.017	Rise time: 0.1195	Rise time: 0.2
Settling Time: 2.0653	Settling Time:1.847	Settling time: 16.0587	Settling time: 0.6
Peak: 0.0999	Peak: 0.090	Dead time: 1	Dead time: 0
Peak Time: 5.2388	PeakTime: 4.6398		

All these shows a great change in the performance of the system. However there is peak overshoot and steady state error .This steady state error can be removed by increasing the gain and peak overshoot automatically will reduce as load is employed on the system. Hence these will not pose any problem on system performance. The above Simulink results are tabulated in Table 4.

From fig7 there is no dead time in the system i.e. dead time is 0. Hence we have reached one of our aim .there is a considerable decrease in rise time which is in the order of 0.2sec. This shows how fastly the system is responding. system has reached its steady state before 0.6 seconds, all these shows a great change in the performance of the system.

V. Conclusions

Speed response characteristics of separately excited dc motor were obtained by mathematical model using MATLAB coding and SIMULINK model. The response is found to be not satisfactory i.e. response doesn't satisfy the desired design requirements like rise time, settling time, peak value, steady state error and dead time etc. There exists a dead time of 1 sec which is a major drawback to the system by conventional method.

To overcome the above drawback we employed PID controller design, by proper tuning of K_P, K_I and K_D to improved the characteristics like steady state error. But the above designed system failed to reduce the dead time of the system. Hence in order to reduce the dead time modern technique like FUZZY controller was employed.

FUZZY controller is proposed to replace conventional PID controller to improve the system characteristics. The corresponding step response is very smooth and ripples free. The rule base adopted is of MAMDANI type and its rule viewer is presented.

References Références Referencias

1. Dr. Jamal A. Mohammed, Modeling, Analysis and Speed Control Design Methods of a DC Motor ,Eng. & Tech. Journal ,vol .29, no.1,2011
2. I.J.Nagrath and M.Gopal, Control Systems Engineering, (Wiley Eastern Limited).
3. S. Ayasun and C. O. Nwankpa, DC Motor Speed Control Methods Using MATLAB/Simulink and Their Integration into Undergraoutputate Electric Machinery Courses, IEEE Trans Eoutputc, March, (2007), 347-354.
4. S. Othman, "Proportional Integral and Derivative Control of Brushless DC Motor," European Journal of Scientific Research, Vol. 35 No. 2 (2009), pp. 198-203.
5. Allaoua, B. Gasbaoui and B. Mebarki, "Setting Up PID DC Motor Speed Control Alteration Parameters Using Particle Swarm Optimization Strategy", Leonardo Electronic Journal of Practices and Technologies, Issue 14, Jan.-June 2009, pp. 19-32.
6. M. H. Rashid, Power Electronics, Circuits Devices and Applications, 2nd Edition, Prentice- Hall International, Inc., New Jersey, 1993.
7. W. P. Aung," Analysis on Modeling and Simulink of DC Motor and its Driving System Used for Wheeled Mobile Robot", World Academy of Science, Engineering and Technology 32, 2007, pp.299- 306.
8. B. Kuo, Automatic Control Systems, Prentice-Hall, Englewood, Cliffs.NJ, 1995.
9. N. S. Nise, Control Systems Engineering (3 rd Edition), John Wiley and Sons Inc., New York, 2000.
10. A. Klee, Development of a Motor Speed Control System Using MATLAB and Simulink, Implemented with a Digital Signal Processor, MSc. Thesis, Orlando, Florida, 2005.

Global Journal of Researches in Engineering (F) Volume XIII Issue XVII Version I Year 2013

Global Journals Inc. (US) Guidelines Handbook 2013

www.GlobalJournals.org