

A Review: Modelling of Brushed DC Motor and Various type of Control Methods

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Abstract

This Review Paper introducing the modeling of Brushed DC motor and different PID control techniques. A brushed DC motor is commutated an internally which is electric motor designed to be run by a direct current power supply. A Brushed motors were the first commercially important application for convert electric power to driving mechanical loads, and DC power distribution systems were used for more than 100 years to operate motors in commercial and industrial Applications. A conventional brushed DC Motor consist basically two parts, first one is the stationary body of the motor called the Stator and the other one is inner part which rotates producing the movement called the Rotor or “Armature” for DC motors. For the motion control of DC motor in almost applications, PID controller is used. The PID controllers have a long history in control engineering and they have been proven to be robust, simple and stable for many real world applications. Roughly, P action is related to the present error, I action is based on the past history of error, and D action is related to the future behavior of the error. From estimation point of view P, D, and I correspond to filtering, smoothing and prediction problems respectively. This control mode is combination of the Proportional, the Integral, and the Derivative mode. This is most powerful but complex controller mode. It provides accurate and stable control of the three controller mode. It is recommended in system where the load changes frequently. The Three-term, PID controllers are probably the most widely used industrial controller. An Even complex industrial control systems may comprises a control network whose main control building block is a PID control module. The three-term PID controller has had a long history of use and has survived the changes of technology from the analogue era in to the digital computer control system age quite satisfactorily. It was the first controller to be mass produced for the high- range volume market that existed in the process industries.

Keywords: Brushed DC motor, DC motor Modeling, P, I, D, PI, PD and PID controller

I. INTRODUCTION

A Brushed DC motors are an important machine in the most control systems such as electrical systems in trains, vehicles, homes, and process control system. It is well known that the mathematical model is very crucial in a control system design. For DC motor, there are many models which represent the machine behavior with a good accuracy. Although, the parameters of the model are also very important because the mathematical model can't provide a correct behavior without correct parameters in of the model. A brushed DC motor is internally commutated electric motors designed to be run from a direct current power source. Brushed motors were the first commercially important application of electric power to driving mechanical loads, and DC distribution systems were used for few eras to operate motors in commercial and industrial buildings.

PID control mode is combination of the Proportional, the Integral, and the Derivative mode. This is most powerful but complex controller mode. It provides accurate and stable control of the three controller mode. It is recommended in system where the load changes frequently. Three-term, PID controllers are most widely used industrial controller. In advance complex industrial control system may comprise a control network whose main control building block is a PID control module. The three-term PID controller has had a long history of use and has survived the changes of technology from the analogue era in to the digital computer control system age quite satisfactorily. It was the first controller to be mass produced for the high-volume in market that existed in the process industries. The PID control remains an important control tools due to three reasons: past record of success, simplicity in use and, wide availability. Also in the case where the complexity of the process demand a multi-loop or multivariable control solution, a network based on PID control building blocks is often used. In control system, different tuning methods have been proposed for PID controllers. Our purpose in this study is comparison of these tuning methods for single input and single output (SISO) systems using computer simulation. An Integral of the absolute value of the errors has been used as the criterion for comparison. These tuning methods have been implemented for first order, second and third order systems with dead time and for two cases of set point tracking and load rejection.

II. MODEL OF BRUSHED DC MOTOR

A conventional brushed DC Motor consist basically of two parts, the stationary body of the motor is known as the Stator and the inner part which is rotates and producing the movement called the Armature or "Rotor" for DC machines. A segmented copper sleeve, known as a commutator, resides on axle of a BDC motor. As the motor turns, carbon brushes (ride on the side of the commutator to provide supply voltage to the motor) little slide over the commutator, and coming in contact with different segments of the commutator. The segments which attached to different type of rotor windings, therefore, a dynamic magnetic field generated inside the motor when a voltage is applied across the brushes of the motor. Here given figure shows schematic diagram of Brushed DC motor.

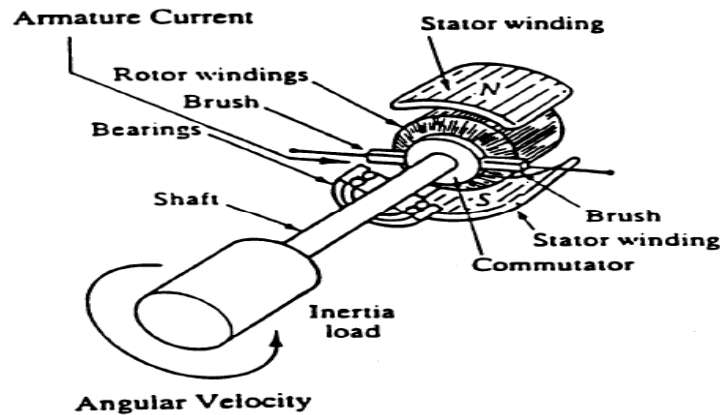


Fig. 1: Schematic of a Brushed DC motor

Since the brushes wear down and it is require replacement, brushless DC motors using power electronic devices have displaced brushed motors from many applications. In the above diagram to the right, it shows that commutator supplies electric current externally, also when electric current flows from the winding , magnetic field B producing force F which in-turn produces the torque which turns the DC Motor. A brushed DC motors working on the Flemings left hand rule. It is state that .when electric current passing through the coil ina magnetic field the magnetic force produce a torque which turns the armature of motor.

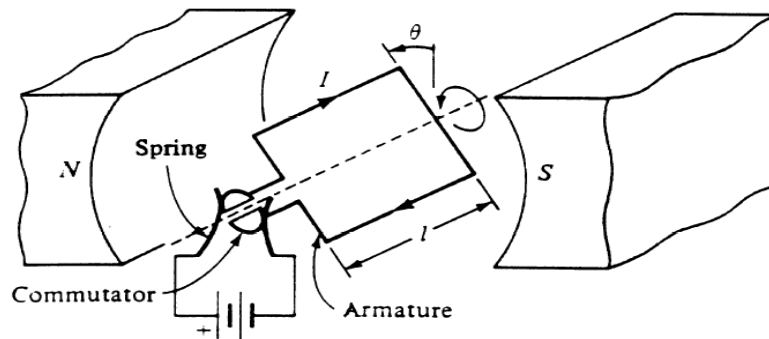


Fig. 2: Elements of Simple Brushed DC motor

III. MODELLING OF BRUSHED DC MOTOR

A common actuator in control systems is the DC motor. Here given the modeling of armature voltage control of DC motor and field current is constant. It directly provides rotary motion and, coupled with wheels or drums and cables, can provide transitional motion. The electric circuit of the armature and the free body diagram of the rotor are shown in the following figure:

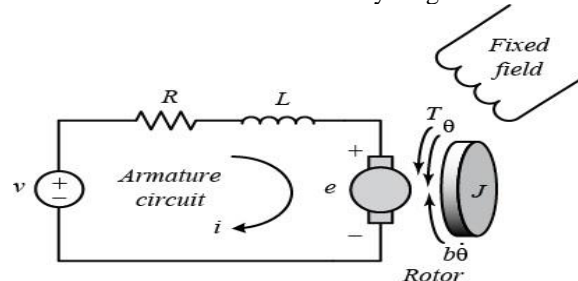


Fig. 3: DC Motor Equivalent Circuit

Applying KVL to circuit,

$$v = Ra * Ia * \frac{dia}{dt} + E \quad (1)$$

Since, field current is constant and flux will be constant,

Now, when armature is rotating an e.m.f is Induce,

$$E = \varphi * \omega \quad (2)$$

$$E = Kb * \omega \quad (3)$$

Here, ω = angular velocity

Kb = back e.m.f constant

Now, torque delivered by the motor will be the product of the armature current and flux,

$$T \propto \varphi * ia \quad (4)$$

$$T = K * ia \quad (5)$$

Here, K is the motor torque constant

The dynamic Torque equation with moment of inertia and co-efficient will be given as,

$$T = J * \frac{d^2\theta}{dt^2} + B * \frac{d\theta}{dt} \quad (6)$$

Now, taking Laplace of equation no.(1) , (4) , (5) , (6)

$$V(s) - E(s) = Ia(s) * (Ra + s * La) \quad (7)$$

$$E(s) = Kb * s * \theta(s) \quad (8)$$

$$T(s) = K * Ia(s) \quad (9)$$

$$T(s) = (s^2 * J + s * B) * \theta(s) \quad (10)$$

$$T(s) = (s * J + B) * s * \theta(s) \quad (11)$$

Here, the transfer function from the input voltage, $V(s)$, to the output angle, θ , directly follows:

$$\frac{\theta(s)}{V(s)} = \frac{K}{(Ra + s * La)(J * s + B)s + K * Kb * s} \quad (12)$$

As above given transfer function we can find the speed and position of motor. For the modeling of DC motor Its physical parameters are required. The modeling of motor is very important for the control of motor.

IV. PID CONTROLLER

PID controllers are designed from 1890. PID controllers were subsequently developed in automatic ship steering. One of the earliest examples of a PID type controller was developed by Elmer Sperry in 1911, when the first published theoretical analysis of a three term controller was by Russian American engineer Nicolas Minorsky, (Minorsky 1922). Minorsky was designing automatic steering systems for the US Navy, and based his analysis on observations of a helmsman, noting the helmsman controlled the ship based not only on the current error, and also on past error as well as the rate of change current; this was then made mathematical by Minorsky. His goal was the stability, not a general control, which was simplified the problem significantly. While proportional control provides stability against the small disturbances, it was insufficient for dealing with a steady state disturbance, notably a stiff gale (due to the droop), which was required adding the integral term. Finally, the derivative term was added for improve stability and control. PID Controllers improve steady state accuracy by decreasing the steady state errors. As the steady state accuracy improves, also improves the stability. They help in reducing the offsets produced in system. Maximum an overshoot of the system can be controlled using PID controllers. They also help in reducing the noise signal produced in the systems. Slow response of the over damped system can be made faster with the help of PID controllers.

A. Proportional Control:

The Proportional control is denoted by the P-term in PID controller. It used when the controller action is to be proportional to the size of the process error signal $e(t)$.

The Time domain and Laplace domain representations for proportional control are given as:

$$\text{Time domain} \quad Uc(t) = kp * e(t) \quad (13)$$

$$\text{Laplace domain} \quad Uc(s) = kp * E(s) \quad (14)$$

Where, proportional gain is denoted by kp . And given figure shows block diagrams of proportional control.

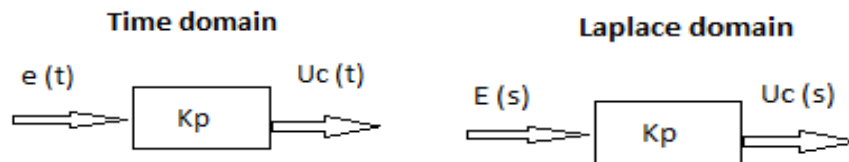


Fig. 4: Block diagrams of proportional terms.

B. Integral Control:

The Integral control is denoted by the I-term in PID controller and is used when it is required that the controller correct for any steady offset from a constant reference signal value. Integral control overcomes the shortcoming of proportional control by eliminating offset without the use of excessively large controller gain.

The Time and Laplace domain representations for integral control are given as

$$\text{Time domain} \quad uc(t) = Ki \int e(t) dt \quad (15)$$

$$\text{Laplace domain} \quad Uc(s) = \left[\frac{Ki}{s} \right] E(s) \quad (16)$$

Where, the integral controller term is denoted by K_i . The Time domain and Laplace domain block diagram is shown below.

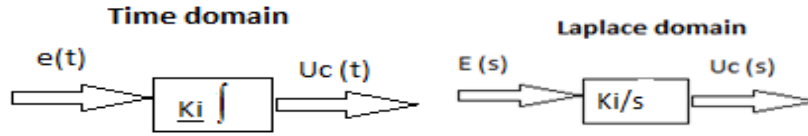


Fig. 5: Block diagram of Integral control

C. Derivative control

If the controller can use the rate of change of the error signal as an input, then this introduces an element of prediction into the control action. The Derivative control uses the rate of change of an error signal and is the D-term in PID controller.

The time and Laplace domain representations for derivative control are given as:

$$\text{Time domain} \quad uc(t) = Kd * \left[\frac{de}{dt} \right] \quad (17)$$

$$\text{Laplace domain} \quad Uc(s) = [Kd * s] E(s) \quad (18)$$

Where the derivative control gain is denoted KD . This particular form is termed pure derivative control, for which the block diagram representations are shown in Figure.

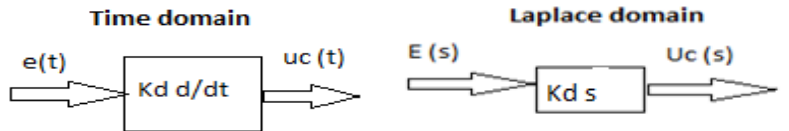


Fig. 6: Block diagram of Derivative control

To use derivative controller more care is to be needed than when using proportional or an integral control. For example. In the most real time applications a pure derivative control term cannot be implemented due to possible measurement noise amplification and a modified term has to be used instead of it. However. Derivative control has useful to design features and is an essential element of some real-world control applications: (for example, tachogenerator feedback in the d.c. motor control is a form of derivative control).

D. Proportional and Integral Controller:

As the name suggests it is a combination of the proportional and an integral controller the output (it's also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have,

$$Uc(t) = Ki \int e(t) dt + Kp e(t) \quad (19)$$

Where K_i and k_p proportional constant and integral constant respectively.

E. Proportional and Derivative Controller:

As the name suggests it is a combination of proportional and a derivative controller the output (also called the actuating signal) is equal to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to summation of proportional of error and differentiation of the error signal, writing this mathematically we have,

$$Uc(t) = Kd \frac{de(t)}{dt} + Kp * e(t) \quad (20)$$

Where K_d and k_p proportional constant and derivative constant respectively.

F. PID controller:

The Three-term or PID controllers are probably the mostly used industrial controller. Even though complex industrial control systems may comprise a control network whose main control building block is a PID control module? The three-term PID controller has had a long history of use and which survived the changes of technology from the analogue era into the digital computer control system age quite satisfactorily. It was the first (only) controller to be mass produced for the high-volume market that existed in the process industries. This control mode is combination of the Proportional, the Integral, and the

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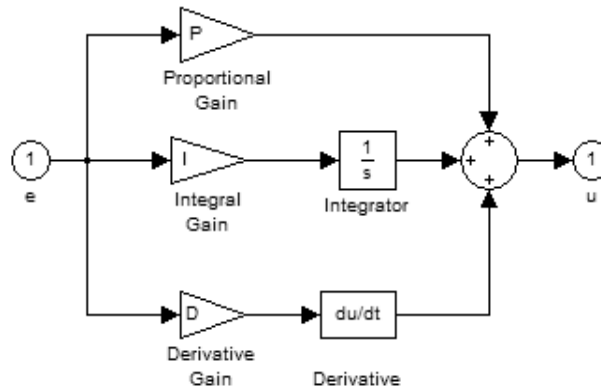


Fig. 7: Typical model of PID controller

This type of neuro-controller is meaningful from a viewpoint of application because PID controllers are so widely used today. The equation of a PID controller is given by:

$$u = K_p * e + K_i \int e * dt + K_d * \frac{de}{dt} \quad (19)$$

Where K_p is proportional, K_i is integral, and K_d is derivative gain of the controller.

V. CONCLUSION

According to this review paper we concluded that DC motor modeling is easier than other AC and DC motors. The modeling of DC motor is most important for analysis of position and speed of motor. In any type of application the modeling of motor is necessary. According to research work, for tracking of output we have to use controller. For the steady state and transient analysis of any type of control system PID controller is more important and inexpensive. So, the PID controller is more useful and familiar controller in control system.

REFERENCES

- [1] Abdulrahman A. A.Emhemed , Rosbi Bin Mamat "Modelling and Simulation for Industrial DC Motor Using Intelligent Control" international journal Symposium on Robotics and Intelligent Sensors 2012 .
- [2] Hsiao-Ping Wang "Design of Fast Fuzzy Controller and its Application on Position Control of DC Motor" IEEE international conference of CECNet 2011.
- [3] Prof. Behzad Behnam , Masoud Mansouryar "Modeling and Simulation of a DC Motor Control System with Digital PID Controller and Encoder in FPGA Using Xilinx System Generator", 2011 2nd IEEE International Conference on Instrumentation Control and Automation.
- [4] Gohiya C.S, S.S.Sadistap, S.A.Akbar, B.A.Botre "Design and Development of Digital PID Controller for DC Motor Drive System Using Embedded Platform for Mobile Robot" 2013 3rd IEEE International Advance Computing Conference (IACC).
- [5] Wae-Gyeong Shin and Soo-Hong Leelan "Analysis of the main factors on the wear of brushes for automotive small brush-type DC motor" , Journal of Mechanical Science and Technology 24 (2010).
- [6] A.Kiruthika, A.Albert Rajan, P.Rajalakshmi "Mathematical modelling and Speed control of a Sensored Brushless DC motor using Intelligent controller" 2013 IEEE International Conference on Emerging Trends in Computing, Communication and Nanotechnology (ICECCN 2013).
- [7] Astrom K J and T Hagglund, Automatic tuning of PID controllers, Instrument Society of America, 1998.
- [8] Syed Hasan Saeed, "Automatic control system" Integral university lucknow and Professional Publishing Ltd, dehli, august 2002.
- [9] M.Maria Louis, elements of electrical engineering PHI learning publisher fifth edition, 2013.
- [10] J.S.katre "elements of electrical engineering" tech max publications pune 2013-14.
- [11] Parikh P. A., Sheth S. and Parikh T. 'Positional Analysis of a DC brushed Encoder Motor using Ziegler-Nichols Algorithm' CAD/CAM, Robotics and Factories of the Future. Springer India 2016.
- [12] Parikh. P. A., Joshi. K. D. and Sheth. S." Color Guided Vehicle – An Intelligent Material Handling Mechatronic System" Proceedings of the 1st International and 16th National Conference on Machines and Mechanisms (iNaCoMM2013), IIT Roorkee, India 2013.
- [13] Parikh P. A., Shah H. B. and Sheth S. "A Mechatronics design of a line tracker robot using Ziegler Nichols control technique for P, PI and PID controllers" International Mechanical Engineering Congress (IMEC-2014) .
- [14] P. Parikh, Dr. H. B. Shah and S. Sheth." Development of a multi-channel wireless data acquisition System for swarm robots - A Mechatronic Approach using Arduino UNO and MATLAB "International Journal of Engineering Development and Research (IJEDR) 2014.
- [15] Patel T., Sheth S. and Patel P. "Design of Semi-automatic Hydraulic Blanking Machine using PLC" National Conference on Innovative & Emerging Technologies (NCIET- 2015).
- [16] S. Sheth, R. Kher, R. Shah, P. Dudhat, and P. Jani. "Automatic Sorting System using Machine Vision" Multi-Disciplinary International Symposium on Control, Automation & Robotics 2010.
- [17] Sheth S., Patel Kavitha H. and Patel H. "Design of Automatic Fuel Filling system using a mechatronics approach " CAD/CAM, Robotics and Factories of the Future. Springer India 2013.
- [18] H. Gangadia, S. Sheth and P. Chauhan." Design and modeling of special Purpose Equipment for shell-diaphragm welding in conveyer pulley" Procedia Technology, Elsevier 2014 .
- [19] B. M. Y. Nouri. "Modeling and control of mobile robot. Proceedings of the First International Conference on Modelling, Simulation and Applied Optimization, Sharjah", U.A.E 2005.

- [20] Copeland B. R..”The Design of PID Controllers using Ziegler Nichols Tuning” 2008.
- [21] B. R. Gajjar and S. Sheth. “Design and Automation in Back Plug Press Fitting Process of Ball Pen Assembly“ Applied Mechanics and Materials 2014 .
- [22] B. R. Gajjar and S. Sheth. “Investigation of Automation Strategy and Its effect on Assembly Cost: A Case Study on Ball Pen Assembly Line “International Journal of Current Engineering and Technolog 2014.
- [23] Ian C., Control system design, Lecture on 14, Feb-2004.