NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 7, JULY-2015

PARAMETER IDENTIFICATION AND MODELLING OF SEPARATELY EXCITED DC MOTOR

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ABSTRACT

DC Motors can be used in various applications and can be used in various sizes and rates as per the applications. In this paper we have focused on the physical parameters of DC motor. Modelling of any system is an important task in control applications because the electrical and mechanical components should be represented in mathematical form. Physical parameters are important in calculating the transfer function of DC motor. By using the physical parameters one can design the controller for controlling speed of the motor. A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems. The controller attempts to minimize the error by adjusting the process control inputs. The weighted sum of the proportionate, integrate, differentiate actions is used to adjust the process via a control element such as the position of a control valve, or the power supplied.

KEYWORDS*:*PID; DC Motor; Transfer function; Simulink.

INTRODUCTION

Identification of the physical parameters of any system plays an important role in choosing the controller parameters appropriately. These parameters are required to make sure that the system control satisfies the desired performance specifications. DC motors have been extensively used for constant speed applications, by using controlling techniques DC motors can be used in variable speed drives applications. Due to the versatile control characteristics of dc motors, these motors are extensively used in industries. DC drives are less complex and less expensive for most horsepower ratings. DC motors have a long tradition of use as adjustable speed machines. The main objective of this paper is to identify the physical parameters of DC motor for evaluating the transfer function. A separately excited DC motor rated 220V 19A 1500 rpm is considered and its parameters are determined to evaluate transfer function. The parameters are useful in design of PI controllers. Hence determination of mechanical parameters of motor and load by employing appropriate techniques is of utmost importance. The controller tuning is done taking into account mechanical parameters of motor as well as load in parameters. Accurate determination of physical parameters is important task. This also enhances the validation capacity of simulation.

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DC MOTOR MODEL

A. Separately Excited DC Motor

A DC motor consist of three main parts: a current carrying conductors called an armature; a circuit for magnetic field provided by magnets of poles; and a commutator. In order to build the DC motors transfer function its simplified mathematical model has been used. The current in the field coil and armature coil independent of one another. As a result these motor have excellent speed and torque control.

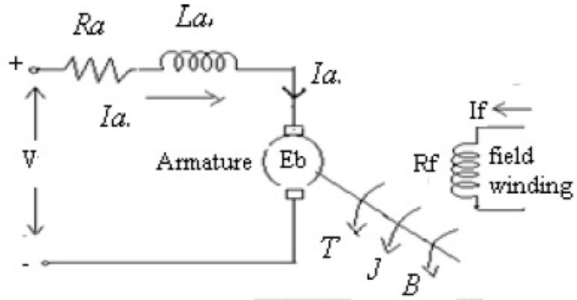


Figure 1: Separately Excited DC Motor

$$Va(t) = Ra.Ia(t) + La\ dIa/dt + Eb$$

$$Eb\ (t) = Kb.\ \omega(t)$$

$$Tm\ (t) = Kt.Ia(t)$$

The DC motor equations based on Newton's law combined with Kirchhoff's law:

$$J\frac{d\omega}{dt} + B\omega = K_t i_a - T_L$$

$$L_a\frac{di_a}{dt} + R_a i_a = V_a - K_b\omega_r$$

In the state-space form, the equations above can be expressed by choosing the rotational speed and electric current as the state variables and the voltage as an input. The output is chosen to be the rotational speed.

$$\frac{d}{dt}\begin{bmatrix}\omega_r\\ i_a\end{bmatrix} = \begin{bmatrix}-\frac{B}{J} & \frac{K}{J}\\ -\frac{K}{L_a} & -\frac{R_a}{L_a}\end{bmatrix}\begin{bmatrix}\omega_r\\ i_a\end{bmatrix} + \begin{bmatrix}0\\ \frac{1}{L_a}\end{bmatrix}V_a$$

$$\omega_r = \begin{bmatrix}1 & 0\end{bmatrix}\begin{bmatrix}\omega_r\\ i_a\end{bmatrix}$$

B. Identification of parameters

Parameters of the DC motor such as armature resistance, armature inductance, back emf constant, moment of inertia of motor, torque constant, friction coefficient of the motor have to

be estimated properly so that controller parameters can be properly tuned and the desired response can be achieved from the control system.
where,
Va is the armature voltage. (In volt)
Eb is back emf the motor (In volt)
Ia is the armature current (In ampere)
Ra is the armature resistance (In ohm)
La is the armature inductance (In Henry)
Tm is the mechanical torque developed (In Nm)
Jm is moment of inertia (In kg/m²)
Bm is friction coefficient of the motor (In Nm/ (rad/sec))
K_T is torque constant
Kb is back emf constant (V/rad/s)
ω is angular velocity (In rad/sec)

K_T, Kb, Ra and La do not vary with load and hence these values are determined using conventional method. However, J and B vary with respect to load. Hence, their variations will have an effect on the dynamics of the system. The transfer function of the armature controlled DC motor is derived experimentally by calculating all the values of above mentioned parameters.
The transfer function of the armature controlled DC motor is of the form

$$\frac{\omega(s)}{V(s)} = \frac{K}{(J(s) + Bm)(La(s) + Ra) + K^2}$$

We know that
ω = (V a -I R)/Ka ϕ
Where, ϕ = Field flux per pole
Ka = Armature constant = PZ / 2πa
Where, P = No. of pole.

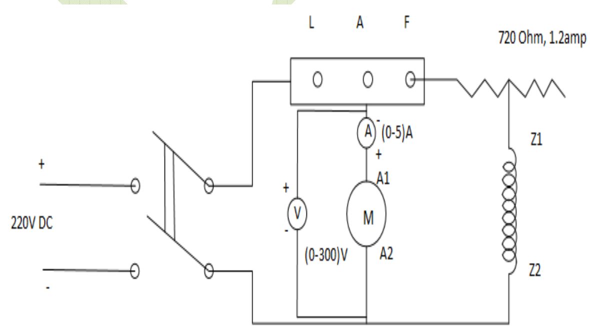


Figure 2: Experimental Setup

C. Experimental Results

Measurement of Armature Resistance (Ra): Armature Resistance is obtained directly by usual method.

Ra =1.7 Ω .

Measurement of Armature Inductance (La):
The AC voltage applied across the armature of DC motor is varied by adjusting the variac and the corresponding current values are tabulated. The impedance is first measured with the relationship between current (I), voltage(V) and impedance(Z). The inductive reactance is calculated from the following relationship

$$X_L = \sqrt{Z^2 - \mathrm{R}ac^2}$$

The armature inductance (La) is calculated from its relationship with the inductive reactance(X_L)

$$L_a = \frac{X_L}{2\pi f}$$

Measurement of Armature inductance

Voltage	Current	Z
2	0.37	5.40
3	0.52	5.76
4	0.69	5.79
5	0.83	6.02

Table1. Armature Inductance

The armature inductance is found out to be 0.0163 H.

Measurement of Back emf constant (Kb):
The DC motor is made to run in the rated speed (N) by varying the motor field current. When the motor has reached its rated speed(N)the single pole single throw switch connected across the ammeter connected to the armature is closed. Now the values of the current(Ia) and voltage(V) is noted down. The value of back emf constant (Kb) is calculated from the equation given below.

$$X_L = \frac{V - I_a R_a}{2\pi N/60}$$

The value of back emf constant (Kb) is evaluated as Kb=1.3908

Measurement of Inertia constant (J):
The DC motor is first made to run at the rated speed of 1500 rpm by varying the field and armature rheostat. When the motor has reached its rated speed the supply to the motor is disconnected and the time taken for the speed to fall from 1500 rpm (N_1) to 1000 rpm (N_2) is noted. This no load and loaded condition are given below. The values obtained are as

Without load:
Time for speed to fall from 1500rpm to 1000rpm without load, t_1=32(s)
V_1 and I_1 at 1500 rpm are 220 V and 0.9 A respectively.

V_2 and I_2 at 1000 rpm are 105 V and 0.32 A respectively.

With load:
Time for speed to fall from 1500rpm to 1000rpm with load, t_2=9(s)
V_1 and I_1 at 1500 rpm are 220 V and 5 A respectively.
V_2 and I_2 at 1000 rpm are 124 V and 0.25 A respectively
The inertia constant is evaluated from the following expression:

$$J = VavIav\left(\frac{t_1 t_2}{t_1 - t_2}\right)\frac{1}{N_{av}}\left(\frac{60}{2\pi}\right)^2\frac{1}{\Delta N}$$

Where, Vav =$(V_1+V_2)/2$ =172V
Nav= $(N_1+N_2)/2$ = 1250 rpm
N = N_1-N_2 = 500 rpm
Iav = $(I_1+I_2)/2$ = 2.625 A

By substituting the values in equation, the value of inertia constant (J) is calculated as 0.8247 kg/m2.

Friction Coefficient Of Motor:
K_T.Ia = B. ω
B = 0.0079 Nm/(rad/sec)

The transfer function of armature controlled DC motor can be evaluated as follows.

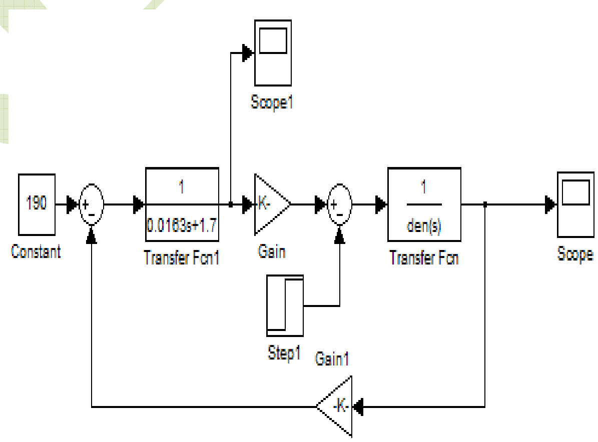
$$\frac{\omega(s)}{V(s)} = \frac{K}{(J(s)+Bm)(La(s)+Ra)+K^2}$$

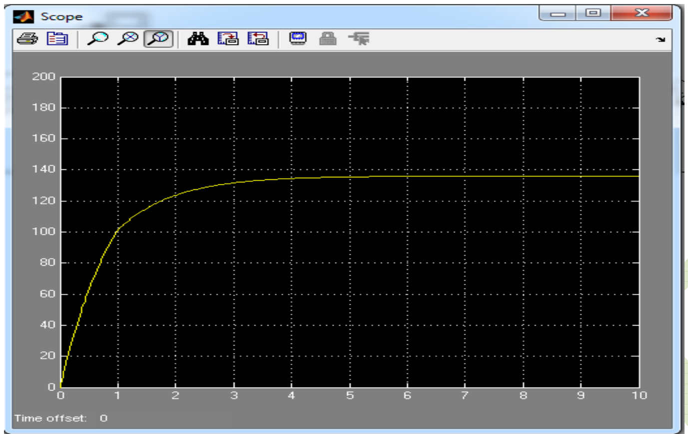
ω / V= 1.3908/[(0.0163s + 1.7) (0.8247s + 0.0079) + 1.9343]

From transfer function of DC motor we can conclude that it is a second order system.

SIMULINK MODEL

The above transfer function can be represented in Simulink model as:





The above simulation results shows ω =136 i.e., the speed of the motor is1298 rpm at 190V. The Speed Control of DC Motor using Armature Voltage Control is performed, and from that experiment for 190 V the speed of the motor is found out to be 1280 rpm. The table below shows the values of speed obtained from simulation and by Armature Voltage Control method. So from table below it is clear that the simulated result and experimental result are matching.

Voltage(V)	**Speed(RPM) (Simulated)**	**Speed(RMP) (Armature Voltage Control)**
200	1375	1335
190	1298	1280
180	1241	1254
160	1098	1121
140	907	972

Table 2. Observations comparison for different armature voltages

The above transfer function can be used to control the speed of DC motor. PID controller can be used to achieve the desired speed of motor.

PID CONTROLLER

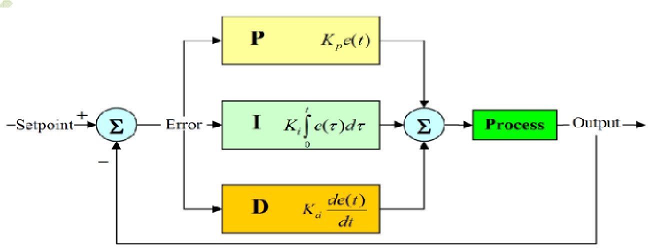


Figure 3: PID controller block diagram

PID controllers typically use control loop feedback in industrial and control systems applications. The controller first computes a value of error as the difference between a measured process variable and preferred set-point. It then tries to minimize the error by increasing or decreasing the control inputs to the process, so that process variable moves closer to the set point. This method is most useful when a mathematical model of the process or control is too complicated or unknown. To increase performance, for example to increase the responsiveness of the system, PID parameters must be adjusted according to the specific application.

One of the advantages of PID is that for many processes there are straight forward correlations between the process responses and the use and tuning of the three terms (P, I, and D) in the controller. There are two steps in designing a PID system. First, engineer must choose the structure of the PID controller, for example P, PI, or PID. Second, numerical values for the PID parameters must be chosen in order to tune the controller. These three parameters for the PID algorithm are the proportional, integral, and derivative constants. The proportional constant decides the reaction based on the current error, the integral constant determines the reaction according to the total of recent errors, and the derivative constant determines the reaction using the rate at which the errors have been changing. These three actions are then used to adjust the process through control element such as the position of a valve. In simple terms, P depends on the current error, I depend on the sum of past errors, and D predicts future errors based on current rate of change of errors.

A. Implementation of PID Control

As suggested earlier, to implement a PID control, engineer must first choose the structure of the PID controller. Secondly, engineer must choose numerical values for the PID coefficients to tune the controller.

B. Tuning of PID Controller

The second part of setting up a PID controller is to tune or choose numerical values for the PID parameters. PID controllers are tuned in terms of their P, I, and D terms. Tuning the control gains can result in the following improvement of responses:

Proportional gain (Kp):
Larger proportional gain typically means faster response, since the larger the error, The larger the proportional term compensation. However, an excessively large Proportional gain may result in process instability and oscillation.

Integral gain (Ki):
Larger integral gain implies steady-state errors are eliminated faster. However, the trade-off may be a larger overshoot, since any negative error integrated during transient response must be integrated away by positive error before steady state can be reached.

Derivative gain (Kd):
Larger derivative gain decreases overshoot but slow down transient response and may lead to instability due to signal noise amplification in the differentiation of the error.

The mathematical model of DC motor is to be known to determine the response of motor for typical values of Kp, Kd, Ki.

CONCLUSION

Parameter identification of DC Motor is most essential factor in modelling of motor. Proper controlling can be achieved by using the transfer function of DC motor. The simulated results and experimental results shows that the derived transfer function is accurate.

REFERENCES

1. Li, Y. and Ang, K.H. and Chong, G.C.Y. (2006) "*PID control system analysis and design*". *IEEE Control Systems Magazine 26(1):pp. 32-41.*

2. Sandeep M. Chaudhari, *"Implementation of Ziegler Nichhol's Technique for Tuning of PI Mode Temperature Controller", NCACCN.*

3. Nikhileshwar P. Adhikari, Milan Choubey and Richa Singh, Department of Electrical Engineering, Gyan Ganga College of Technology, Jabalpur, (MP), "*DC Motor Control Using Ziegler Nichols and Genetic Algorithm Technique", International Journal of Electrical, Electronics andComputer Engineering 1(1): 33-36(2012)*

4. S.M.Girirajkumar, Atal.A.Kumar, N.Anantharaman "*Speed Control of a Real Time D.C. Shunt Motor Using SA Based Tuning of a PID Controller*".

5. I.J.Nagrath and Gopal, Control System Engineering.