Improving the Performance of BSG - 23 DC Motor by Applying LQR and LQT Methods.

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ABSTRACT

The use of DC motors is very extensive, especially in the context of control, so designing a suitable DC motor controller is very important. Automatic control systems have a crucial role in various needs of society or developed countries. Examples can be found in the control of spacecraft, missiles, aircraft control systems, satellites, and so on. In the industrial sector, control of production machines during the manufacturing process and regulations such as pressure, temperature, flow, friction, humidity, and others are very necessary. The importance of optimal control issues is increasing as the demand for efficient systems continues to grow. The concept of control system optimization involves balancing performance and technical specifications to create an optimal control system within physical limits. In dealing with an optimal control system, rules are needed to make decisions that can minimize deviations from its ideal behavior. One example of a commonly used control system is by using the LQR or Linear Quadratic Regulator method.

Keywords : *DC Motor, Control, LQR*

I.INTRODUCTION

Optimal control is a major focus of attention nowadays because there is a huge increase in the demand for high-performance systems[1][2]. The basic idea of control system optimization involves tradeoffs in the selection of performance indices and engineering to create an optimal control system within physical constraints[3][4]. In achieving an optimal control system, the goal is to find a rule for making decisions about the control of the system that can minimize the deviation from its ideal behavior[5].

In this report, the author discusses the LQR (Linear Quadratic Regulator) and LQT (Linear Quadratic Regulator) methods included in the curriculum of the "System Optimization" course in PPNS Automation Engineering. LQR is one of the optimal control methods for state space-based systems. The LQR controller has two parameters, namely the Q and R weight matrices. Meanwhile, LQT has two parameters, namely the Q and T weight matrices, which need to be determined to achieve optimal control actions according to expectations [6][7][8]. Implementations of the LQR and LQT methods include regulating the speed of induction motors, controlling the frequency of generator power plants, and even on quadcopter drones [9]. The combination of this LQR method with the discipline of system optimization is crucial to achieving the optimum point and reducing errors in a device, so that device performance can be adjusted according to desire [10][11].

In this lecture "System Optimization", the author discusses the application of LQR and

LQT methods on DC motors by involving datasheets[12][13]. Information from the datasheet will be entered into a MATLAB script, and then simulated using MATLAB Simulink software to observe the step response[14][15]. The DC motor used is the BSG-23 type, which is equipped with the values of moment of inertia, motor constant, damping ratio, resistance, and inductance[16][17].

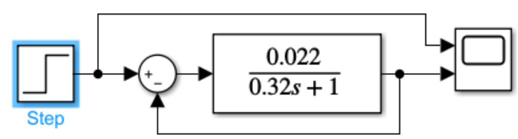
In this lecture "System Optimization", the author discusses the application of LQR and LQT methods on DC motors by involving datasheets[18][19]. Information from the datasheet will be entered into a MATLAB script, and then simulated using MATLAB Simulink software to observe the step response[20]. The DC motor used is the BSG-23 type, which is equipped with the values of moment of inertia, motor constant, damping ratio, resistance, and inductance.

II.METHODOLOGY

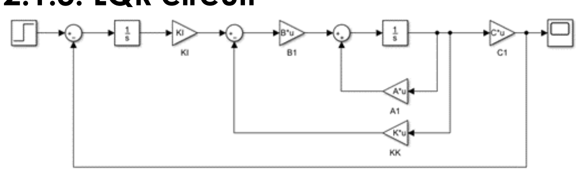
2.1 LQR (Linear Quadratic Regulator)

```
% LQR SYSTEM OPTIMIZATION ON DC MOTOR
clear;
clc;
% DC Motor Models
J = 69,900 ; b= 0.1 ; K= 0.022 ; R= 0.10 ; L = 0.000012 ;
% J = Momentum, b = Damping ratio, K = constant, R = resistance, L = Inductance
A = [-b/JK/J; -K/L -R/L];
B = [0;1/L];
C = [1 0]

AA = [ A zeros(2,1); -C 0];
BB = [B;0];
% Pole Placement
J = [-3 -4 -5];
K = acker(AA,BB,J);
KI = -K(3);
KK = [K(1) K(2)];
% LQR Matrix
Q = [1 0 0;
0 1 0;
0 0 1000];
R = [1] ;

K_lqr = lqr(AA,BB,Q,R)
KI2 = -K_lqr(3);
KK2 = [K_lqr(1) K_lqr(2)];
```

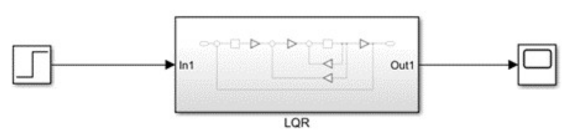
2.1.2. BSG-23 DC Motor Circuit 1st Order



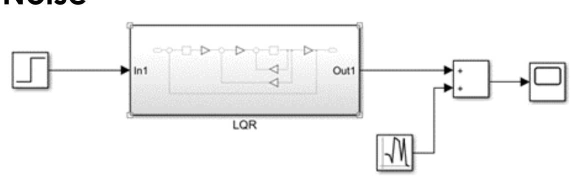
2.1.3. LQR circuit



2.1.4
LQR Subsystem Circuit without Noise



2.1.5 LQR Subsystem Circuit with Noise



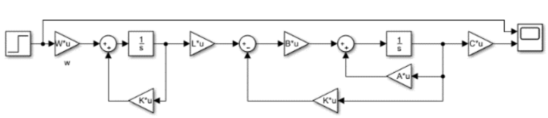
2.2 LQT (Linear Quadratic Tracking)

Linear Quadratic Tracking (LQT) is an optimal control method that aims to ensure that the system output follows the given reference as well as possible, taking into account a performance index. In order to use LQT, the system to be controlled must be linear. However, the characteristics of missiles are non-linear, so a linearization process is needed so that missiles can be controlled using the LQT method. In communication systems, noise refers to unwanted signals that are always present in a transmission system. The presence of noise can interfere with the quality of the desired signal and ultimately affect the reception process. and data delivery.

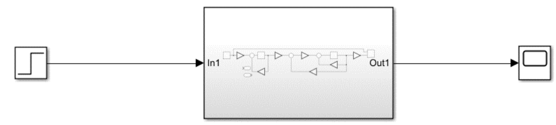
2.2.1 Matlab LQT Script Program

```
% LQR SYSTEM OPTIMIZATION ON DC MOTOR
clear;
clc;
% DC Motor Models
J = 69,900 ; b= 0.1 ; K= 0.022 ; R= 0.10 ; L = 0.000012 ;
% J = Momentum, b = Damping ratio, K = constant, R = resistance, L = Inductance
A = [-b/JK/J; -K/L -R/L];
B = [0;1/L];
C = [1 0]
Q=10; R=0.0000000001;
%0.00000000000001
W=C'*Q; %
[S,o,m,n]=care(A,B,C'*Q*C,R) %m=v(t) %S=P
K=inv(R)*B'*S %feedback Gain
ACL=(AB*K)'
L=inv(R)*B' %model following gain
```

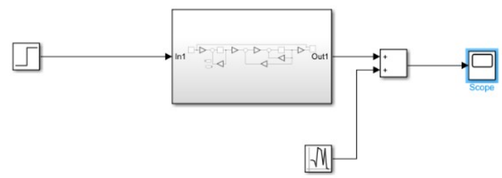
2.2.2 LQT circuit



2.2.3 Noise-free LQT Subsystem Circuit



2.2.4 LQT Subsystem Circuit with Noise



2.3 LQT (Linear Quadratic Regulator)

Specification

- Moment of inertia (J): 69,900kg.m2/s2
- Mechanical system damping (B): 0.1 Nms
- Motor Constant (K): 0.022 Nm/A
- Resistance (R): 0.10 ohm
- Inductance (L): 0.000012 H

2.3.1 First Order Modeling

General form of a first order ali function

$$G(s)=\frac{K}{\tau s+1}$$

Order 1 DC motor

Based on the DC motor data sheet, the first order equation is obtained:

Where$\tau = K . i\ sehingga$

$$K=\frac{\tau}{i}=\frac{0,32}{14,0}=0,022$$

First order equation of DC motor:

$$G(s)=\frac{0,022}{0,32\,s+1}$$

III.RESULTS & DISCUSSION

3.1 Simulation Results of BSG – 23 DC Motor Order 1

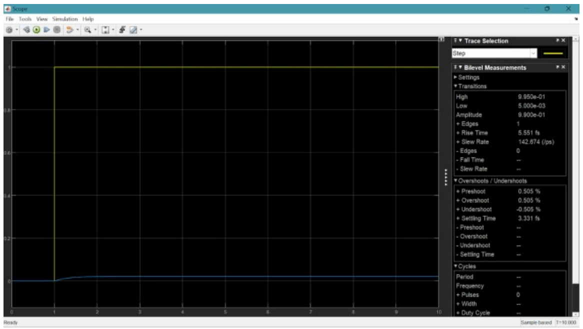


Figure 3.1 Step Response Display

Figure 3.1 shows the display of the DC motor BSG-23 step response. In the first-order SISO noise-free, a steady-state step response plot is obtained with an amplitude of 9.90 (n' does not reach the set point) with a rise time of 5.551 fs and the system experiences an overshoot and overshoot of 0.505%. %

3.2 ResultsNoise-free LQR Simulation

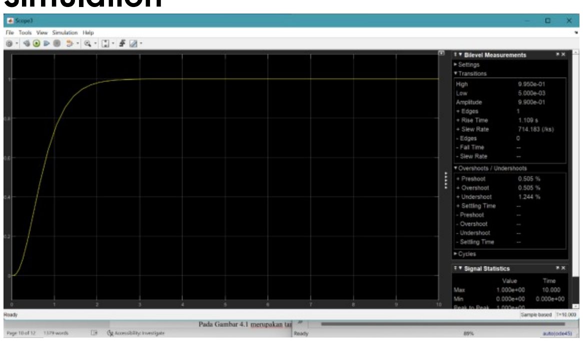


Figure 3. 2 LQR Step Response Display without Noise

Shown in Figure 3.2 is the step response of the BSG-23 DC motor with LQR control without noise. It can be observed that the step response of the BSG-23 DC motor with LQR control reaches an amplitude of about 0.99, which can be rounded to 1, indicating the achievement of the setpoint. Its rise time reaches a maximum value of about 1.109 seconds, while the overshoot and undershoot are quite small, each about 0.505%.

3.3 LQR simulation results with Noise

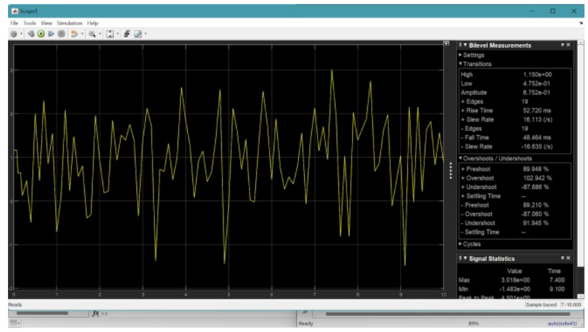


Figure 3.3 LQR Step Response Display with Noise

Figure 3.3 shows the step response of the BSG-23 DC motor with LQR control which is affected by the presence of noise. It can be seen that the step response of the BSG-23 DC motor with LQR control shows a graph fluctuation caused by the noise given. The system reaches an amplitude of around 6.75, indicating that the system has not reached the setpoint. The rise time reaches a maximum value of around 52,720 milliseconds, with an overshoot of 102,942% and an undershoot of around -87,686%.

3.4 ResultsNoise-free LQT Simulation

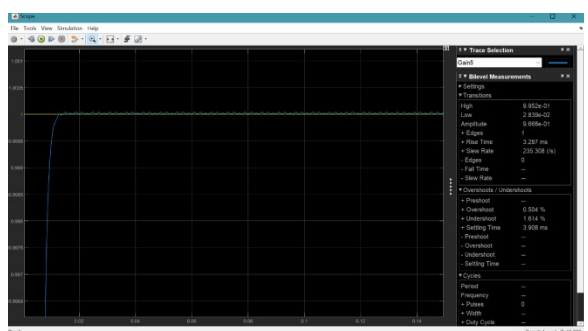


Figure 3.4 LQT Step Response Display without Noise

Figure 3.4 shows the step response of the BSG-23 DC motor with LQT control without any noise. It can be seen that the step response of the BSG-23 DC motor with LQT control reaches amplitude of about 9.66, which can be rounded to 1, indicating the achievement of the setpoint. The rise time reached a maximum value of about 3.387 milliseconds, with an overshoot of 0.504% and an undershoot of about 1.614%.

3.5 ResultsLQT Simulation with Noise

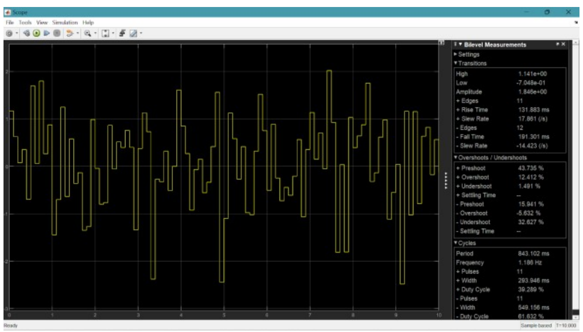


Figure 3.5 LQT Step Response Display with Noise

Figure 3.5 shows the step response of the BSG-23 DC motor with LQR control affected by noise. It can be seen that the step response of the BSG-23 DC motor with LQR control shows a graph fluctuation caused by the noise given. The system reaches an amplitude of about 1.84, indicating that the system has not reached the setpoint. Its rise time reaches a maximum value of about 131.883 milliseconds, with an overshoot of 12.412% and an undershoot of about 32.627%.

No	System model	Amplitude	Rise time	Overshoot	Undershoot
1	LQR without Noise	0.99	1.109 s	0.505 %	0.505%
2	LQR with Noise	6.75	52,720 ms	102.942%	-87.686 %
3	LQT without Noise	9.66	3.387 ms	0.504 %	1.614%
4	LQT with Noise	1.84	131.883ms	12.412%	32.627 %

IV.CONCLUSION

To formulate a mathematical model of a 1st order DC motor and identify the variables required for LQR, a DC motor datasheet is required that includes the values of moment of inertia, motor constant, damping ratio, resistance, and inductance. By performing calculations for 1st order mathematical modeling, the transfer function G(s) = 0.022/(0.32s + 1) is obtained. In addition, by running the MATLAB script for LQR and LQT, the values of variables such as A, B, C, K_lqr, and so on are obtained which appear in the workspace.

The step response results of the BSG-23 DC motor of order 1 produce a stable step response graph with an amplitude of about

0.124, which means reaching a setpoint of about 1. Its rise time reaches 5.551 seconds, with the system experiencing an overshoot of about 0.501% and an undershoot of about 1.985%. Meanwhile, the step response of the LQR DC motor BSG-23 reaches an amplitude of about 0.99, which can be rounded to 1, indicating the achievement of the setpoint. Its rise time reaches a maximum value of about 1.109 seconds, with a fairly small overshoot and undershoot, each around 0.505%. For the step response of the LQT system, the results are more optimal than the LQR, reaching an amplitude of about 0.99, which is rounded to 1, indicating the achievement of the setpoint. The rise time is more optimal than the rise time of the LQR step response without noise, which is around 1,109 milliseconds, with an overshoot of around 0.5% and an undershoot of around 0.5%.

From the results of the step response of the two systems, it can be compared and concluded that the BSG-23 DC motor system with the application of LQR produces more optimal performance compared to the BSG-23 DC motor with order 1. By using LQR, the step response of the BSG-23 DC motor can reach the setpoint, show a stable graph, have a fast rise time, and overshoot and undershoot with small values. However, the step response produced by the LQT system shows more optimal performance than the two previous systems.

V.CLOSING

1.Awards

research, especially those who funded your research. Include individuals who have helped you with your study: Advisors, Financial Supporters, or perhaps other supporters such as Proofreaders, Typists, and Suppliers who may have provided materials.

The researcher realizes that without the support of various parties, the compilation of this community service journal will never be realized. So on this occasion the researcher would like to express many thanks to the various parties who have participated. (This point can be adjusted again by adding words or including the party who wants to be appreciated)

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