Homework 1 (100 points)

ENERGY 295 - Electrochemical Energy Storage Systems: Modeling and Estimation

Fall Quarter 2021

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Due September 30th, 2021 at 11 AM (Electronic pdf copy in CANVAS and hard-copy to the TA)

Problem 1 (30 points)

Consider a dynamic system represented by the following ordinary differential equation:

$$\frac{d^3x(t)}{dt^3} + 8\frac{d^2x(t)}{dt^2} + 30\frac{dx(t)}{dt} + 3x^4(t) = \frac{3}{5}u(t)$$

1. Is the system linear or nonlinear? Why?
2. Write a space-state model for the system.
3. Use the state-space model to find the equilibrium point, x_e, when the input is $u_e = 25$;
4. Obtain the linearized state-space model of the system around this equilibrium point.
5. Write the transfer function of the linearized model around x_e,u_e.

   Note 1: ***lsim*** command in MATLAB simulates the time response of a dynamic system to arbitrary inputs (use "help lsim" in MATLAB prompt to learn the syntax and read the detailed description of this command).

6. Use the ***lsim*** command in MATLAB to simulate the response of the linearized system to a step change in the input of the value $\delta u = 10$ over a time horizon of 25 seconds.

   Note 2: To simulate the nonlinear system, "**ODE23**" or "**ODE45**" commands in MATLAB can be used.

7. Simulate the nonlinear state-space equation for the same step increase in input ($u = uo + \delta u = uo + 10$) over a time horizon of 25 seconds
8. Compare and comment the two solutions.
9. Is the linearized system stable?

Problem 2 (10 points)

Find the DC gain of the signal corresponding to

$$\frac{Y(s)}{U(s)} = G(s) = \frac{3}{s(s-2)}$$

Problem 3 (40 points)

Design a closed-loop observer for the system

$$\frac{d^2x(t)}{dt^2} + \frac{dx(t)}{dt} + x(t) - u(t) = 0$$

The initial value of the system is $(0,0)$ and input $u(t)$ is a step input of magnitude 2. Assume that the value of $x(t)$ is available via a sensor. Let the incorrect initial value of the observer be $(-2,-1)$.

Problem 4 (20 points)

The Battery Test Manual for Electric Vehicles, (https://inldigitallibrary.inl.gov/sites/sti/sti/6492291.pdf), is based on technical targets for commercial viability established for energy storage development projects aimed at meeting system level Department of Energy (DOE) goals for electric vehicles (EVs). The specific procedures defined in this manual support the performance and life characterization of advanced battery devices under development for EVs. After reading the manual, answer the following questions:

1. How can test-induced degradation mechanisms be minimized?
2. What is the recommended resting time after each charge (or discharge) prior to further testing?
3. Define the Battery Size Factor (BSF).
4. What are the only two tests that are defined in terms of requested current as opposed to requested power?