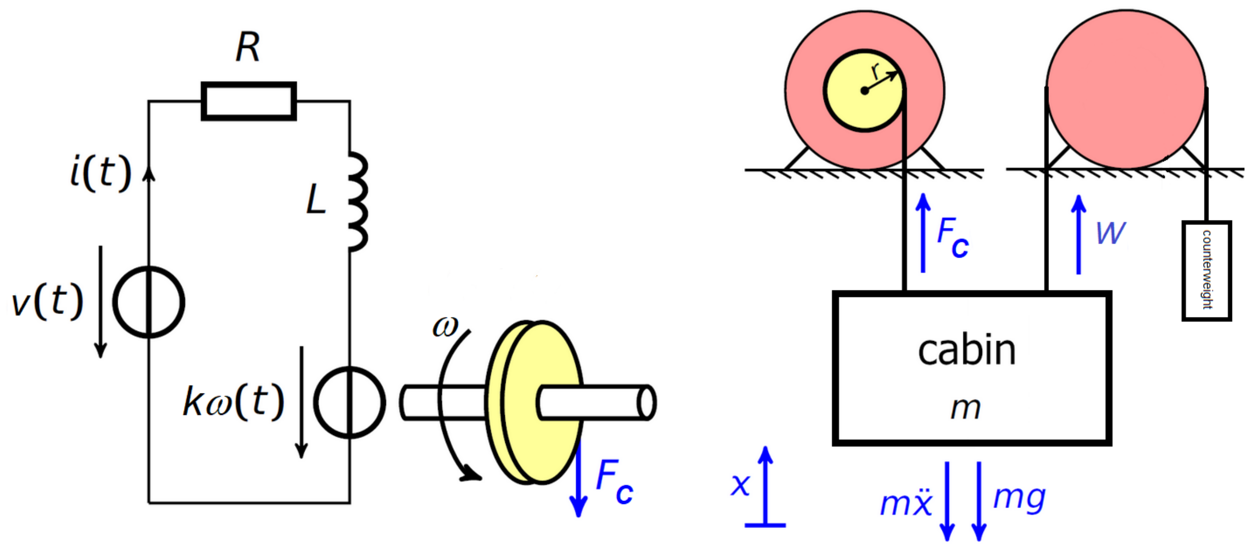
AEM 591/ECE 593/ME 591 Project 1

Elevator Simulation in Python

This project is intended to introduce some of the tools in Python for use in the analysis of dynamical systems. For this project, consider the following dynamical system of an elevator



which has the following governing equations.

For the electromechanical dynamics, one has following two equations:

$$\begin{aligned} F_c(t)r(t) &= ki(t) + I_m\dot{\omega}(t) \\ v(t) &= R(t)i(t) + L\frac{di(t)}{dt} + k\omega(t) \end{aligned} \tag{1}$$

where F_c is the force on the cabin exerted by the cable, r is the radius of the elevator cable from the center of the motor, k is the motor characteristic, i is the current, I_m is the moment of inertia of the motor, ω is the rotational speed in radians, v is the applied voltage, R is the resistance of the coil winding, and L is the inductance of the motor. Note that in this model, the moment generated by the motor is $ki(t)$ and the electromotive force is equal to $k\omega(t)$.

For the cabin dynamics, one has

$$F_c(t) = m\ddot{x}(t) + mg - W \tag{2}$$

where m is the mass of the cabin, $\vec{x}$ is the position of the cabin, g is the acceleration due to gravity, and W is the mass of the counterweight.

Furthermore, the radius of the cable from the motor center varies as a function of the cabin position by the change in the circumference due to the thickness of the cable, δ_c. This can be modeled by

$$\dot{r}(t) = \frac{\delta_c \dot{x}(t)}{2\pi r} \tag{3}$$

In addition, the resistance varies with time as the motor heats up. This can be modeled by

$$R(t) = R_0 + \delta_R(1 - e^{\frac{-t}{\tau_R}}) \tag{4}$$

Note that the heat radiated by the motor is equivalent to the power, Ri^2.

For this project, assume that

1. I_m = 700 Nm and does not vary significantly with r
2. k = 100 Nm/A
3. L = 0.4 H
4. m = 500 kg
5. g = 9.81 m/s^2
6. W = 300 kg
7. r_0 = 3 m
8. δ_c = 0.05 m
9. R_0 = 5 Ω
10. δ_R = 5Ω
11. τ_R = 3 s

For this project, perform the following

1. Derive a state-space formulation using x, $\dot{x}$, i, and r as the states, $v(t)$ as the input, and x and $\dot{x}$ as the outputs.
2. Linearize the state-space system about equilibrium at $x = 0$, 15, and 30 m for a value of $R = 10\Omega$ which occurs as $t \to \infty$. Analyze the controllability, observability, and stability.
3. Simulate the nonlinear system with doublet commands on $\dot{v}$, both up and down, for initial conditions close and far from the linearized states, but including t. Use input values which keep the elevator velocity reasonable.
4. Simulate the linearized system with doublet commands on $\dot{v}$, both up and down, for initial conditions close to the linearized states. Use input values which keep the elevator velocity reasonable.
5. Write a few paragraphs summarizing the results of these simulations and any analysis. Make sure to compare the linear simulations to the nonlinear.