EE211 – Assignment 2
Modelling, Linearisation and Simulation of a Coupled Tanks System

Objective

The main objective of the assignment is for the students to become familiar with the concepts of linearisation and simulation. A nonlinear system (coupled tanks with turbulent flow) will be linearised around its equilibrium point, and simulated in the region of the equilibrium point for various amplitude inputs. Comparisons will also be made with linear models determined off equilibrium, and a linear model for the coupled tanks determined under the assumption of laminar flow.

Group project individuality

Note that each group will analyse a coupled tank system of different geometric dimension, around different equilibrium input flowrates.

Software Requirements and Alternatives

In order to accommodate students that might not have access to a Matlab/Simulink license or even to a computer with sufficient specs, the assignment can be completed using the following three, all equally valid, alternative approaches:

1. A Matlab/Simulink environment. Support material provided: Coupled tanks simulink model.
2. Scilab, freely available for download at https://www.scilab.org/download/6.1.0. This will provide a completely open Matlab-like environment, including a nice alternative to the Simulink simulation tool called XCos. The syntax is similar to Matlab but there are some notable differences particularly for specifying dynamical systems and transfer functions. Support material provided: Coupled tanks XCos model and sample scripts for defining transfer functions in Scilab scripting language.
3. Pen, paper and calculator. As backup, the students can solve the assignment using the known math for calculating explicit solutions to linear dynamical systems. One aspect of the assignment that requires simulation of the non-linear system cannot be completed, but valid alternatives using known linear theory are proposed.

Procedure

1. Following the procedure in the lecture notes, develop a linearised model for the coupled tanks system given to your group (analytical model + numerical application).
2. Simulate the nonlinear system, using the parameters provided in the group allocation table, for a square-wave input flowrate (in addition to the equilibrium input), of period 60s and amplitude ($(1/10)F_{in}^{o}$, $(2/10)F_{in}^{o}$, $(3/10)F_{in}^{o}$). Matlab/Simulink and Scilab/Xcos simulation models are provided.

   Alternative for pen-and-paper: Ignore this question. Solve question 6
3. Develop a Simulink simulation of the linearised model of the coupled tanks system (based on the nonlinear one supplied). Simulate the linearised system for a square-wave input flowrate (in

addition to the equilibrium input), of period 60s and amplitude (X 2X, 3X). Be careful to add the equilibrium input and states to the deviation variables of the linearised model !

Alternative for pen-and-paper: Use a sine wave of period 60s instead of a square wave.

4. Compare the responses obtained from Steps 2 and 3. Comment on your results – at what point does the linearised model begin to become invalid?

   Alternative for pen-and-paper: Ignore this question. Solve question 6

5. Assuming laminar flow, identify a suitable linear model coefficient (k_1, k_2) that best approximates the nonlinear model. Is the equilibrium point, for the same equilibrium input, identical to the one obtained with the turbulent flow? Compare the response of this model (using the linear system simulation) to that of the linearised (turbulent flow) model, around the operating point of your choice. Comment on your results.

   Alternative for pen-and-paper: Ignore this question. Solve question 6

6. Only for pen-and-paper:

   Repeat Steps 1 and 3 for a range of operating points different from the equilibrium (Choose at least 4 additional operating points). Compare the responses of all these alternative linear representations of the non-linear system. Comment on the results: What are the differences between the models particularly in the regions around the chosen operating points ? Where does the response of each model look invalid ?

Bonus question: (Not required for 100% grade)

7. Linearise the system using a different equilibrium input flowrate (of your choice). Compare the poles (eigenvalues) of the various linearised systems. What do they tell about the speed of the response?