Assignment 3: Non –linear systems

Introduction

In this assignment we will look in to non-linear components that are common in the handling units. It is the heater and the valve. The heater has a non-linear thermal characteristic (see Figure 1); it is a typical exponential function. In order to compensate for the more or less know non-linearity in the heater, a valve with complementary characteristics (logarithmic) is used. (Compare with Chapter 17 "To Compensate Exactly for Nonlinearities"). However, the valve suffers from valve authority effect and thus the compensation will not be perfect.

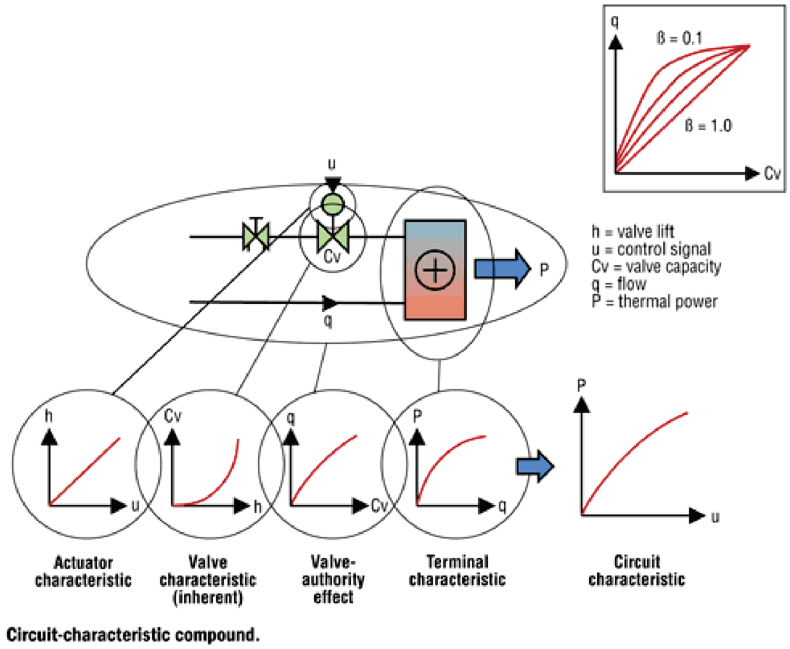

Figure 1: Nonlinearities in the heat regulatory unit.

Valve authority effect

When opening a valve, the area of the valve opening increases and thereby also the flow. But the flow depends not only on the area; it also depends on the pressure drop across the valve. However, the pressure drop depends on how much the valve is open; thus, a non-linear function arises. When the valve is closed the total pressure drop is over the valve. When the valve opens, the pressure decreases across the valve. From a control engineering perspective, it would be best that this decrease was minimal because it gives a more linear system. However, it is not advisable to have high pressure drops across all valves. The valve authority, *A*, is described as

$$A = \frac{\Delta P_{valve}}{\Delta P_s} ,$$

where

ΔP_{valve} is the pressure drop across the valve

ΔP_s is the pressure before the valve

The flow rate for different values of *A* is shown in Figure 2.

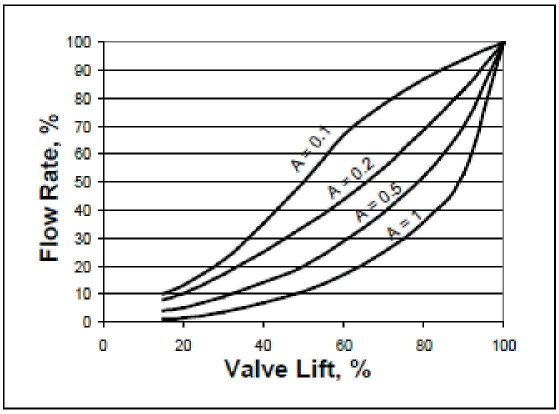

Figure 2: Effects on the flow rate due to different valve authorities. *A=1* is the ideal case.

Combined with the heater the total nonlinearity from the control signal to the output power can be described as in Figure. The rights most figure show the output power as function of the valve lift.

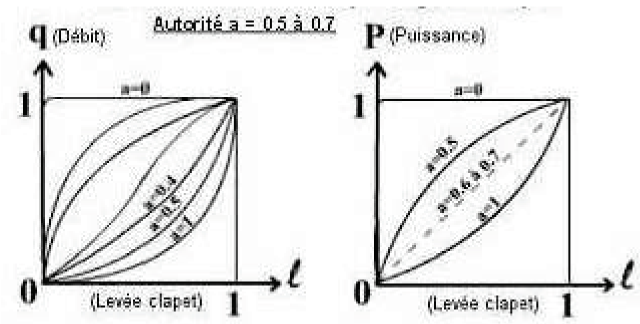

Figure 3: Effects on the output power due to different valve authorities.

Task

In this assignment we will use a valve to control a system

$$G(s) = \frac{1}{(s^2 + s + 1)(s + 3)}.$$

The valve is considered to be static and it has a gain K_{vs} (called "valve coefficient"). Thus the overall dynamic system is given by

$$G(s) = \frac{k_{vs}}{(s^2 + s + 1)(s + 3)}.$$

You task will be to study different values of K_{vs}. The valves are sold in fixed sizes: … 1, 1.6, 2.5, 4.0, 6.3, 10, 16, …

Circle criteria

In this task you shall use the circle criteria to find the maximum valve we can use. We do not know the exact nonlinearity, but we know that it is limited by the two blue curves in the figure below.

First, ignore saturation in the valve and find the maximum size of valve.

Secondly, include saturation and find the maximum valve.

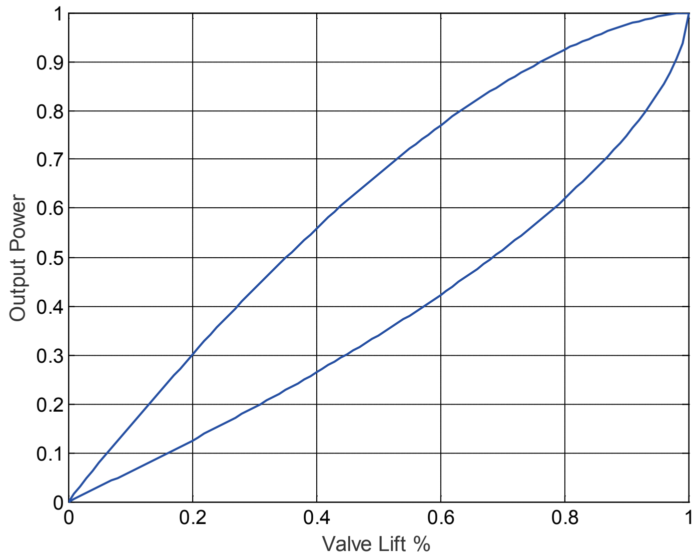

Figure 4: The exact nonlinearity is not known, but we know that is limited to the area between the two curves.

Hint: If you would like to add a circle in the Nyquist plot. The following Matlab code can be used:

```
hold on;
fi=(-1:0.1:1)*pi;
x=-m+r*exp(1i*fi);          % m is the center of the circle and r is the radius
plot(x);
hold off;
```

Describing function

Replace the continuous valve with a shut-off valve and a relay control. Use descriptive function to find the maximum valve coefficient that keeps the magnitude of the oscillation below 0.5.

Report

Hand in a written report on how you solved the problem. It should contain a short
(i) background/introduction, (ii) method, (iii) results with plots and diagrams,
(iv) conclusion/discussion. Place your Matlab-script as an appendix. Put your name and the name of your file on the front page. Hand in the report by using Blackboard