Simulation dynamischer Systeme

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June 27, 2017

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Coursework

Please finish the exercises below and hand them in as coursework. The following requirements need to be addressed:

- Please use the tools mentioned in the exercises
- Start with a small introduction (1/2 page) explaining the problem, create a graph to illustrate the set-up.
- Comment inside your code and explain the selected solution
- Plot and show the results all graphs need to be fully labelled
- Discuss the results
- Discuss possible shortfalls and limitations of your solution
- The report should not exceed more then five pages
- You need to credit (reference) all sources of information, if you got assistance from a colleague, please refer to her/him as well, e.g. make clear which contribution comes from which person.

For a complex scientific equipment, we need to understand and therefore, create a model of a glass-tube-based heating system. It consist of a tubular glass-tube. Heat is supplied to the tube at an adjustable rate q, e.g., by means of a heating coil. The tube loses energy (heat) to the surroundings at a rate proportional to the surface area times the difference between the tube and the ambient temperature. Finally the rate of change of the tube energy is proportional to the rate of change of its temperature. Thus, there is a energy balance between heat generated by the coil heater and heat loses to the ambient surrounding.

$$
\begin{aligned}
m \cdot c_p \frac{dT}{dt} &= Q && (1)\\
Q &= q_{in} - q_{out} && (2)\\
q_{in} &= q && (3)\\
q_{out} &= h_s \cdot A_s (T - T_a) && (4)
\end{aligned}
$$

where m is the mass of the glastube, c_p is the heat capacity of the glass, A_s is the exterior surface area, h_s is the heat transfer coefficient (to the ambient) and T_a is the ambient temperature.

- Heating Element: Maximum power (q_{max}) = 2kW.
- Quartz Tube:
  - Inner radius =0.1m,
  - Thickness = 0.01m,
  - Outer radius[1] = 0.2 m,
  - length = 1 m,
  - density = 2500 $\mathrm{kg/m^3}$,
  - $\mathrm{c_p} = 1078\,\mathrm{J/Kg\,K}$
  - $h_s = 5\,W/m^2\,K$

[1] including insulation, for the computation of heat loss area

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Exercise 1: System-Identification

The file ’measurement_data.csv’ contains measurement results of a step response.
Use the above model and make a fit to determine the model parameters for the mass m and the surface area A_s
Do those fit with the theoretical (given) values? Please discuss the results.

Exercise 2: Use python to analyse the system

For the above system, characterise with the help of python the system.

- Which temperature can be reached for a maximum power of up to 2 kW
- Is the system linear?
- How does an unit step response look like?
- What is the characteristic of the model?

Show the output of the system for:

- Start from 0 and apply $u = 1 \cdot 10^3 \cdot sin(2\pi f\, t)$, f = 1 mHz, t=0-350min s, dt=0.5 s with an offset of $1 \cdot 10^3$
- From a constant u= 1 kW apply a step-function to u= 2 kW at t=30min min, show about t=300 min, dt=0.5s
- Start from 0 apply a constant signal of u = 1 kW with additional random noise in the range of $\pm 0.5\, kW$ for for t=0-250 min, dt=0.5s

Explain and discuss the results

For the sinusoidal input function, vary the frequency f and find the frequency for which the output amplitude is just half a DC input signal DC with max. amplitude (2 kW). Try to solve this problem programmatic.

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Exercise 3: Controller

Both controllers could be implemented time discrete or time continuous or both. Make assumptions where needed.

- Create a simple P-controller and tune the controller in a way that the simulation proofs to be a valid system (all intermediate states should be checked, stability, etc.).
- Create a more advanced PI-controller and tune it to be stable and realistic (e.g. check the controller output P_{max} should be not more then 2 kW).

Summary

Please summarise your findings.

What is the limitation of your model?

How could the model be improved?

What are your observations for the simulations? How could the controllers be improved?

Do you like Python?