

Model Documentation of the Distillation Column

1 Nomenclature

1.1 Nomenclature for Model Equations

K_{R1}, T_{N1}	parameters of the first PI controller
K_{R2}, T_{N2}	parameters of the second PI controller
K_1, K_2, K_3, K_4, T_1	parameters of the model, equilibrium point
x_S	filling level
x_T	temperature on the bottom
z_{ii}	malfunctions for $i = 1, 2$
fb_i	feedback for $i = 1, 2$
w	supply of heat steam, equivalent to M_H

1.2 Signal Flowchart

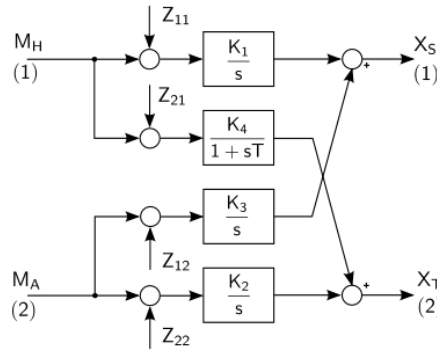


Figure 1: Signal Flowchart

2 Model Equations

State Vector and Input Vector:

$$\begin{aligned} \underline{x} &= (x_S \ x_T)^T & &= (x_1 \ x_2)^T \\ \underline{u} &= (fb_1 \ fb_2 \ w \ z_{11} \ z_{21} \ z_{12} \ z_{22}) & &= (u_1 \ u_2 \ u_3 \ u_4 \ u_5 \ u_6 \ u_7)^T \end{aligned}$$

Transfer Functions:

$$G_{R_{11}} = K_{R1} \left(1 + \frac{1}{sT_{N1}} \right) \quad (1a)$$

$$G_{R_{22}} = K_{R2} \left(1 + \frac{1}{sT_{N1}} \right) \quad (1b)$$

$$G_{P_{11}} = \frac{K_1}{s} \quad (1c)$$

$$G_{P_{12}} = \frac{K_4}{1 + sT} \quad (1d)$$

$$G_{P_{21}} = \frac{K_3}{s} \quad (1e)$$

$$G_{P_{22}} = \frac{K_2}{s} \quad (1f)$$

Parameters: K_{R1} , T_{N1} , K_{R2} , T_{N2} , T_1 , K_1 , K_2 , K_3 , K_4
Outputs: x_1 , x_2

2.1 Exemplary parameter values

Symbol	Value
K_{R1}	1.7
T_{N1}	1.29
K_{R2}	0.57
T_{N2}	1.29
T_1	1
K_1	0.4
K_2	1.2
K_3	-0.8
K_4	-0.2

3 Derivation and Explanation

A rough analysis of the column behavior leads to the following approaches for the four subtransfer functions:

$$\frac{X_S}{M_H} = \frac{K_1}{s}; \quad \frac{X_T}{M_A} = \frac{K_2}{s}; \quad \frac{X_S}{M_A} = \frac{K_3}{s}; \quad \frac{X_T}{M_H} = \frac{K_4}{1 + sT}.$$

M_H is standing for the supply of the heat steam and M_A represents the drain of the product. The system model is based on the signal flowchart.

4 Simulation

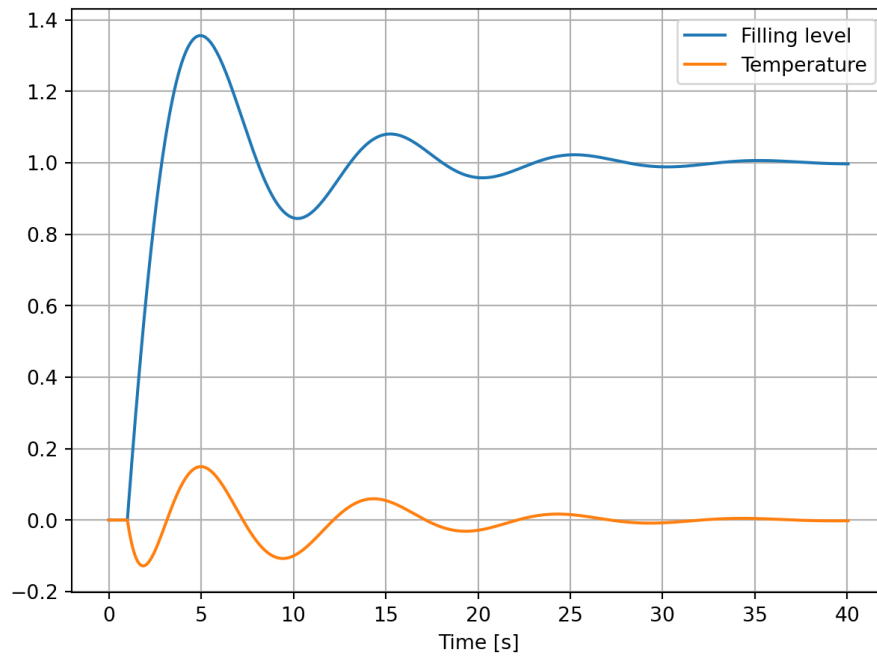


Figure 2: Simulation of the distillation column.

References

- [1] Institut für Regelungs- und Steuerungstheorie TU Dresden: *Regelungstechnikpraktikum, Praktikumsanleitung*, published in OPAL April 2022.
(not publicly accessible)
- [2] Knoll, Carsten: *Example2 : linear system consisting of various blocks*, Python Script published 2019.
<https://github.com/TUD-RST/pyblocksim/blob/master/examples/example2.py>