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

2 Model Equations

State Vector and Input Vector:

$$\underline{x} = (x_S \ x_T)^T = (x_1 \ x_2)^T$$

$$\underline{u} = (fb_1 \ fb_2 \ w \ z_{11} \ z_{21} \ z_{12} \ z_{22}) = (u_1 \ u_2 \ u_3 \ u_4 \ u_5 \ u_6 \ u_7)^T$$

Transfer Functions:

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

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

$$G_{P_{11}} = \frac{K_1}{s} \tag{1c}$$

$$G_{P_{12}} = \frac{K_4}{1 + sT} \tag{1d}$$

$$G_{P_{21}} = \frac{K_3}{s} \tag{1e}$$

$$G_{P_{22}} = \frac{K_2}{s} \tag{1f}$$

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:

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

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 following signal flowchart.

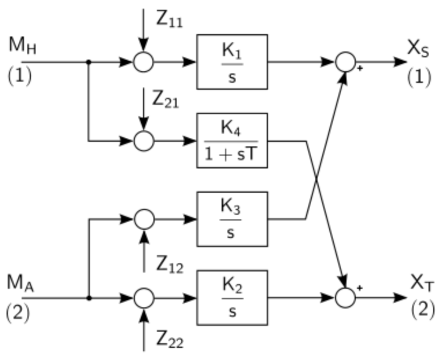

Figure 1: Signal flowchart

4 Simulation

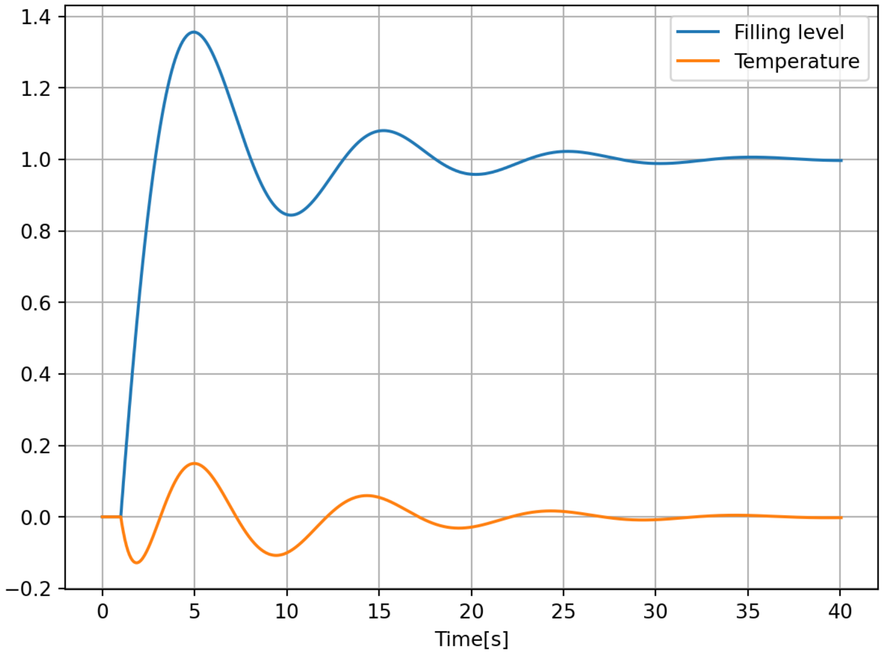

Figure 2: Simulation of the ground of a distillation column.

References

[1] Institut für Regelungs- und Steuerungstheorie TU Dresden: *Regelungstechnikpratikum, Praktikumsanleitung*, published in OPAL April 2022.