Modelling and Analysis of Control Pairings of an Industrial Depropanizer Column

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Goals

The aim of this work is to analyse different control configurations (LV, LB, DV, LD and Ryskamp) and suggest an effective one for a depropanizer distillation column of the Slovnaft refinery. We design the mathematical model of the process in the gPROMS ModelBuilder environment to analyse the control performance of the configurations. In order to validate the obtained model, we simulate it in the desired operating conditions and compare the model response against historical plant data. Selected control structures are assessed in terms of the steady-state coupling (Relative Gain Array analysis) and dynamic response (disturbance rejection and set-point tracking).

Process Description

We study an operation of a distillation column, whose design specifications and feed composition are shown in Figs. 1 and 2.

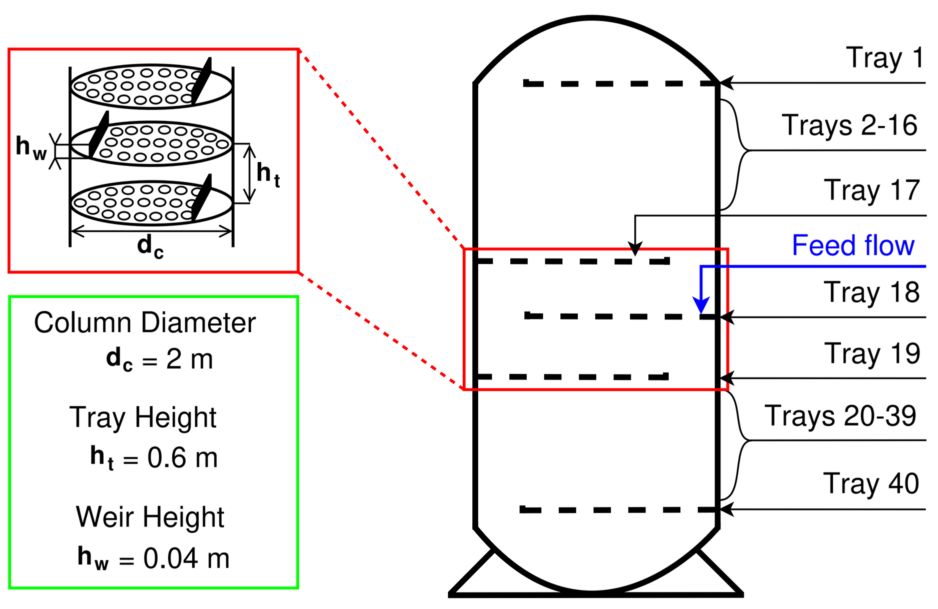
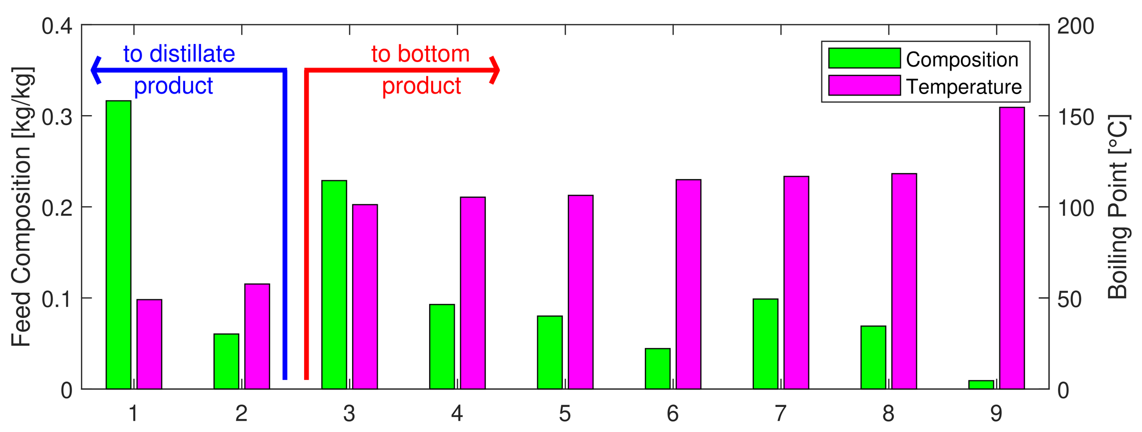


Fig. 1: Distillation column of the depropanizer.



1. Propylene
2. Propane
3. Isobutane
4. Isobutene
5. 1-Butene
6. N-Butane
7. Trans-2-Butene
8. Cis-2-Butene
9. Isopentane

Fig. 2: Feed composition and boiling points of components.

Process Flow Diagram

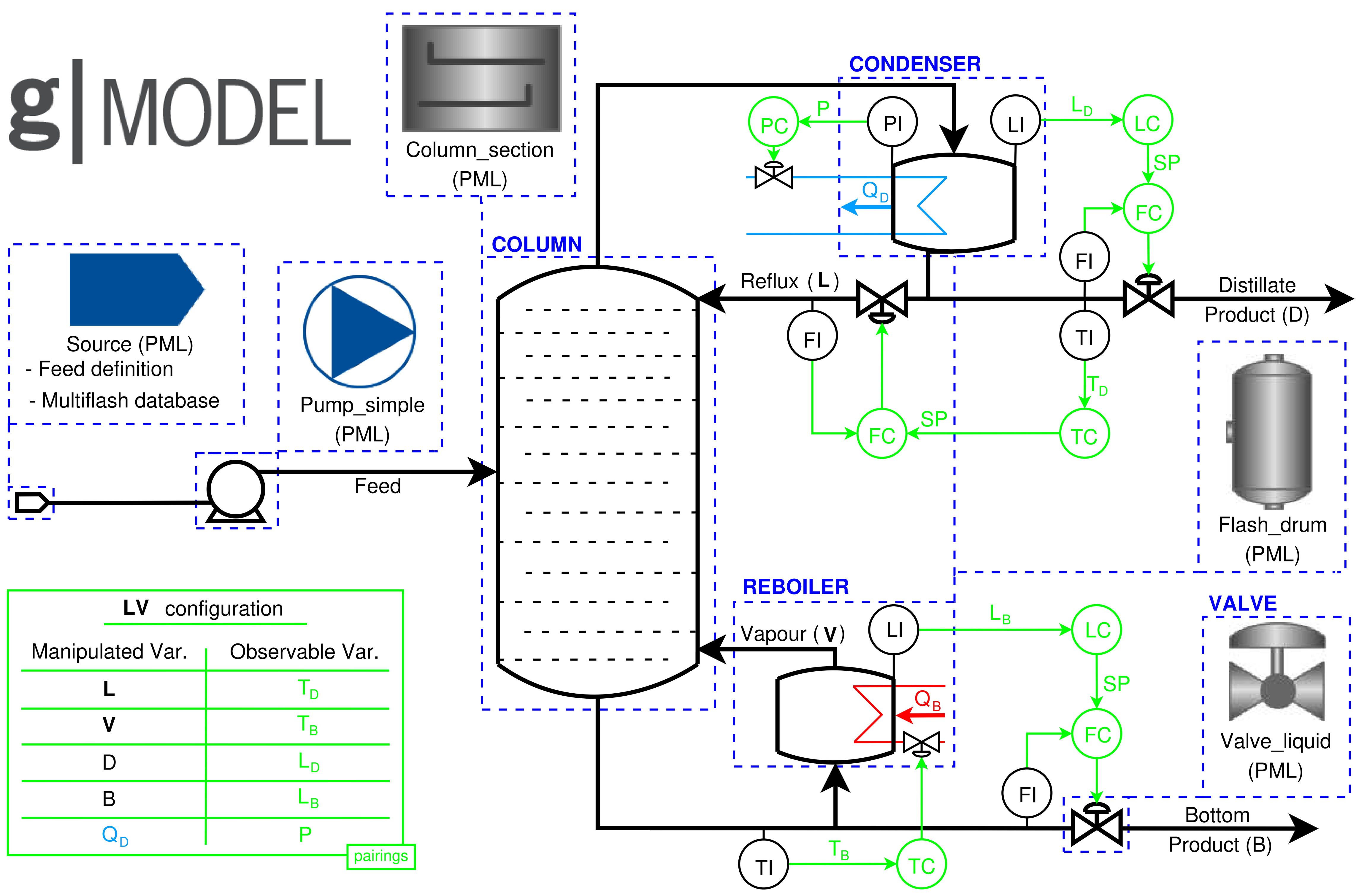


Fig. 3: The flow diagram of the column (LV configuration) with the utilized Process Model Library (PML) objects.

Model Validation

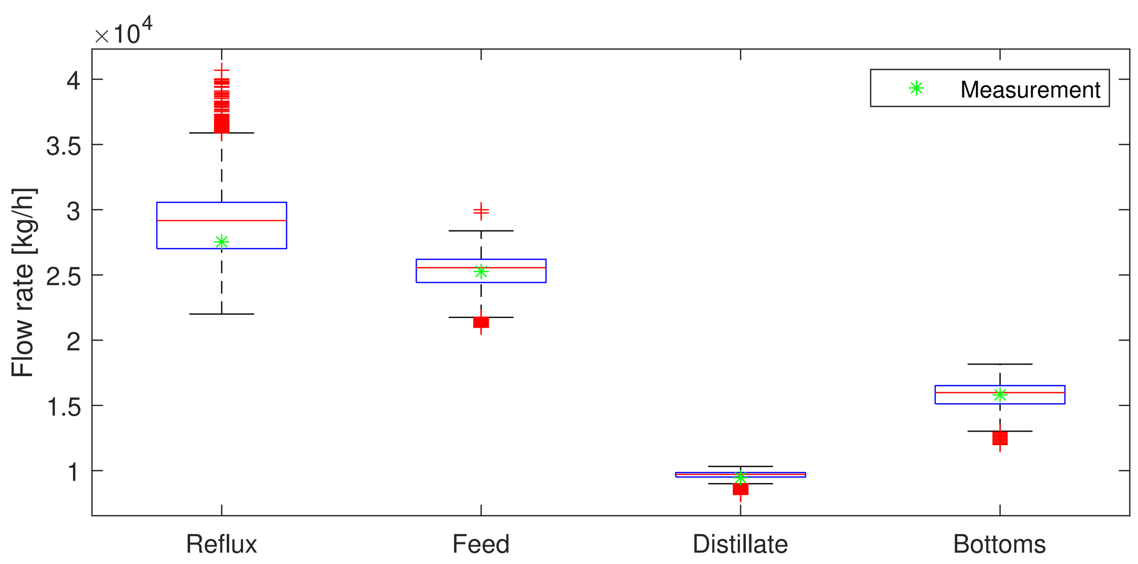


Fig. 4: Model validation results for process flows.

Historical plant data (half-year of production)

- Temperatures (2,776 data points)
  - *sensors*: tray 10, tray 37, bottom and distillate
- Flow rates (2,776 data points)
  - *sensors*: feed, distillate, bottom and reflux
- Composition (40 data points)
  - *laboratory analysis*: feed, distillate and bottom
- Pressure (2,776 data points)

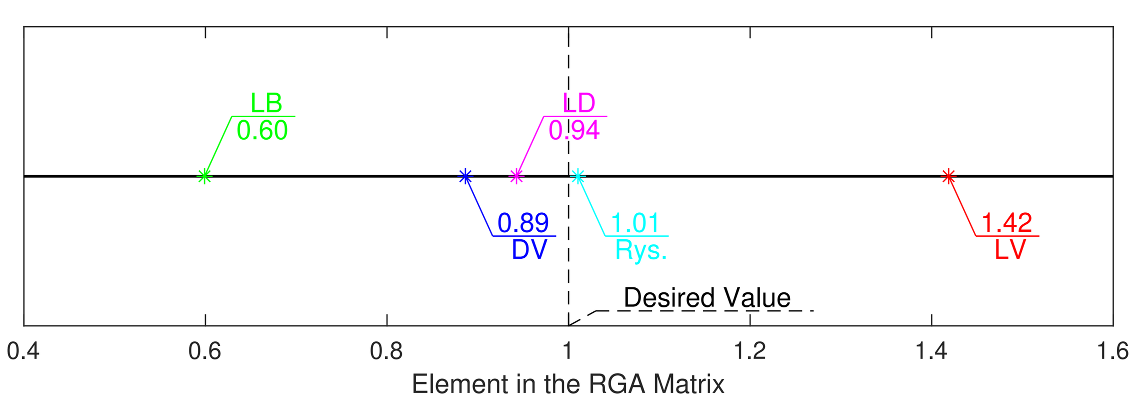


Fig. 5: The results of the RGA analysis.

Methodology

Configuration	L	V	D	B
LV	T_D	T_B	L_D	L_B
LB	T_D	L_B	L_D	T_B
DV	L_D	T_B	T_D	L_B
LD	T_B	L_D	T_D	L_B
Ryskamp	R	L_B	L_D	T_B

Tab. 1: Pairings of variables (R - reflux ratio).

1. *Relative gain array (RGA)* - comparison of different steady state sets of variables

$$\lambda_{11} = \frac{1}{1 - \frac{g_{12}g_{21}}{g_{11}g_{22}}} \quad \text{where} \quad g_{ij} \approx \frac{\Delta y_i}{\Delta u_j} \tag{1}$$

2. *Disturbance Rejection Control*
3. *Set Point Tracking*

Used PI controllers are tuned to give a similar performance.

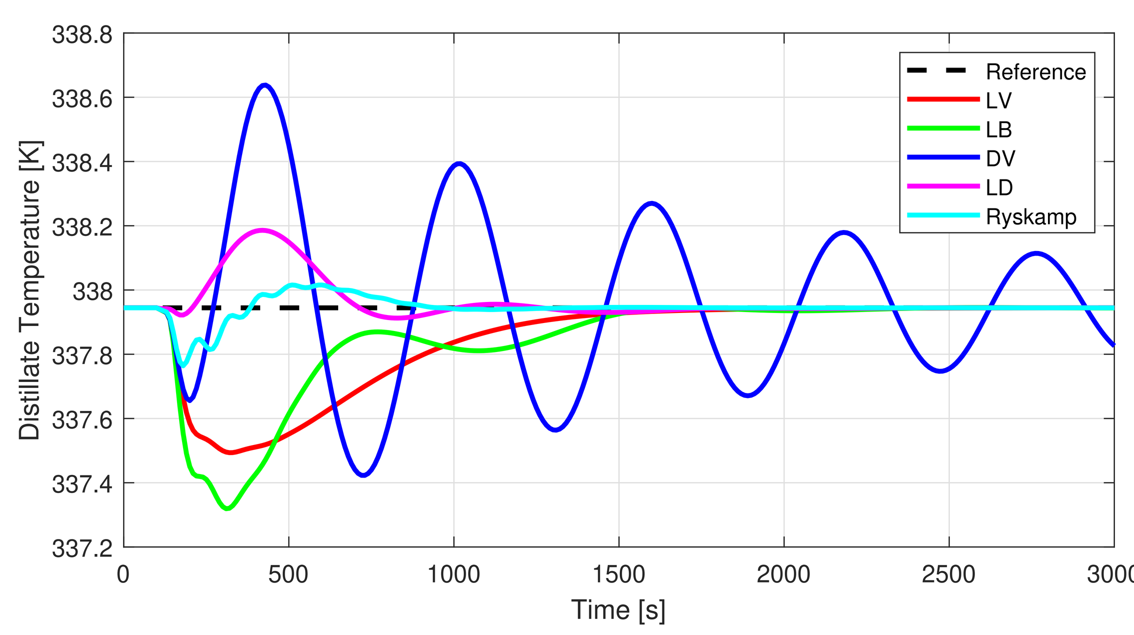


Fig. 6: Disturbance rejection control (-10 % of feed flow).

Results

The results from both steady-state and dynamic analysis are shown in Figs. 5–7. The Ryskamp configuration gives the best control performance and therefore we consider this configuration for the best option for control of the depropanizer.

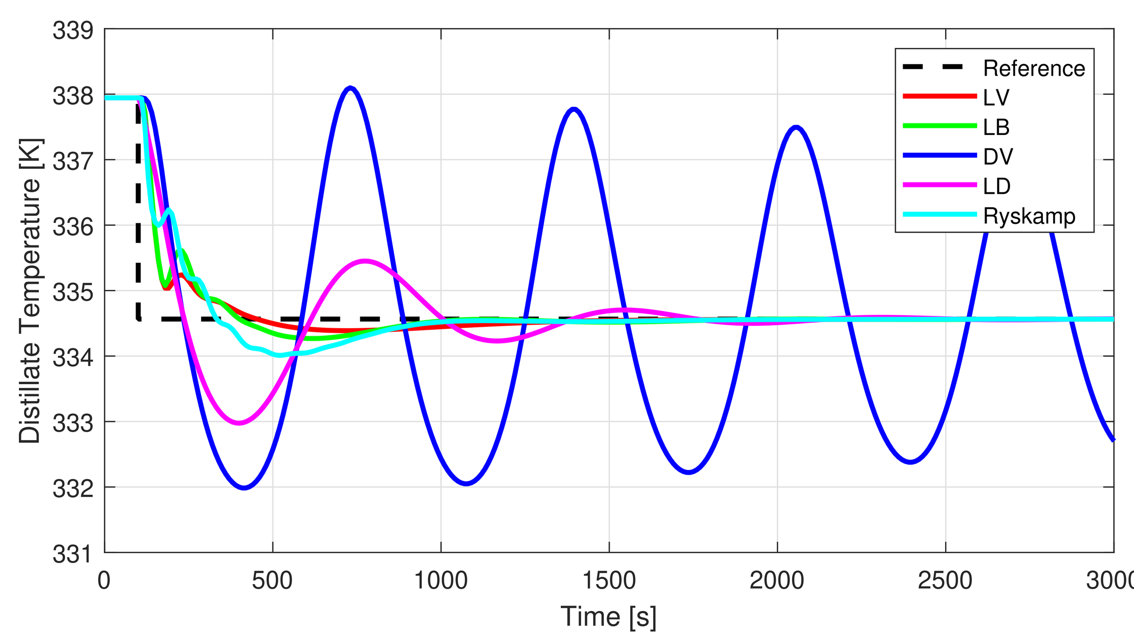


Fig. 7a: Set-point tracking (-1 % of T_D).

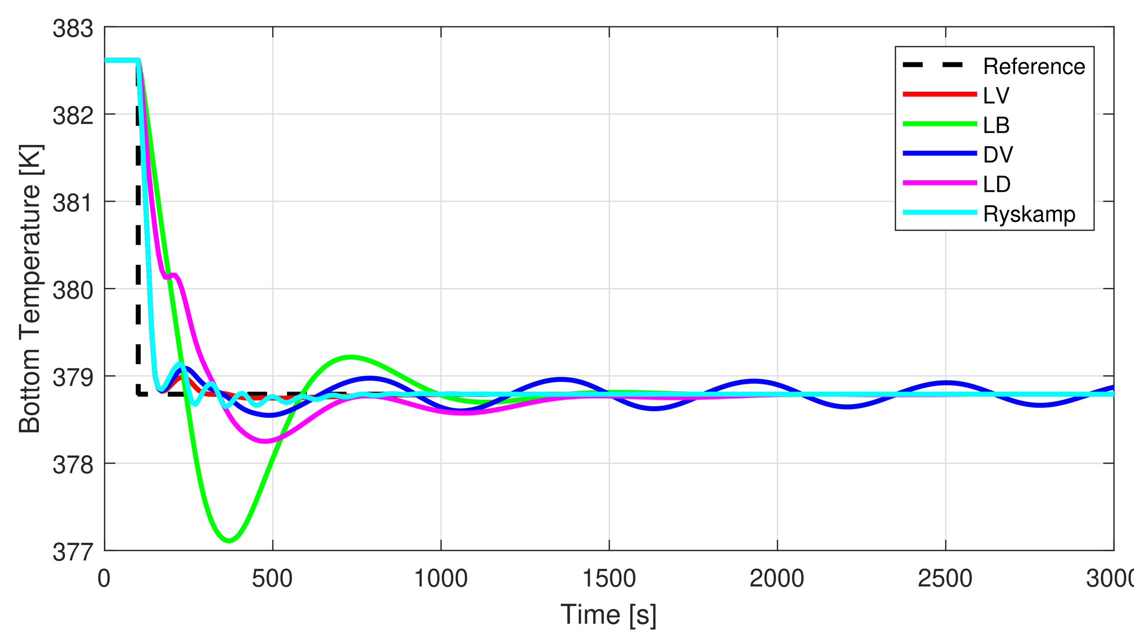


Fig. 7b: Set-point tracking (-1 % of T_B).

Conclusions

In this contribution, we studied LV, LB, DV, LD and Ryskamp configuration for control of the depropanizer distillation column. In order to analyse the control performance of the configurations, we designed the mathematical model of the process in the gPROMS ModelBuilder environment. The model was subsequently validated by the comparison of the model response (for the desired operating conditions) and historical plant data. In order to identify the best control configuration, we carried out the RGA analysis and tested the plant response in simulation for disturbance rejection control and for set-point tracking.

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