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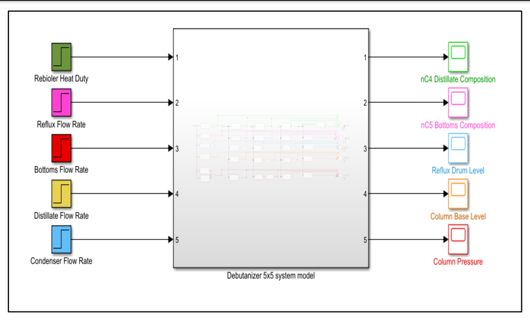
Analyzing the Performance of Various Control Strategies for a Debutanizer Column

Abstract

The debutanizer column process is critical for the gas and petroleum industries producing Liquified Petroleum Gas and light naphtha as its products. In MATLAB-SIMULINK, two control systems, feedback and IMC using PID controllers, were designed and tested for setpoint tracking and reduced IAE for a 5x5 modeled debutanizer column. The inputs in order are reboiler heat duty, reflux, bottoms, distillate, and condenser flow rates. The outputs in order are distillate and bottoms designs, reflux drum and column base levels, and column pressure.

Design and Implementation

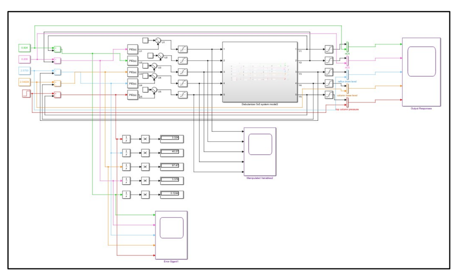
Open-loop testing: Step tests were performed for each input, and the outputs' final values reached were compared with the ones attained in the literature paper to validate the model. A scale factor was used to correct the transfer functions that approached different values with a high %error.



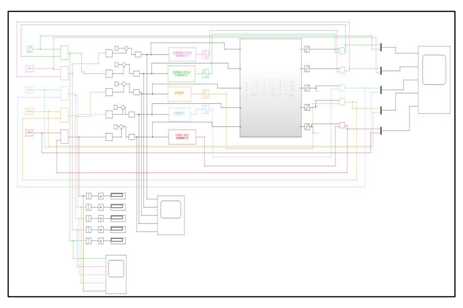
The figure displays the open-loop system. The subsystem incorporates the 25 transfer function model and its arrangement.

Control Configuration Selection: Based on RGA analysis conducted using the steady-state gain matrix and CN and NI considerations for singularity and stability, the final agreed configuration was: 1-2, 2-1, 3-4, 4-3, 5-5.

Control strategies model design: PID controllers were first tuned using the IMC tuning method. Then, constraints for the system were selected. Each control strategy was designed with and without constraints.



The figure displays the constrained feedback PID multiloop system.



The figure displays the constrained IMC system.

Conclusion

The aim of this project is successfully attained. Two control approaches, feedback, and IMC, were studied to handle the challenges of controlling the debutanizer column. It was concluded that both control designs struggled with the enforcement of input moves. Furthermore, IMC was more advantageous than the feedback system as it was faster and less fluctuating. Both systems were excellent in setpoint tracking in the two scenarios other than the constrained system.

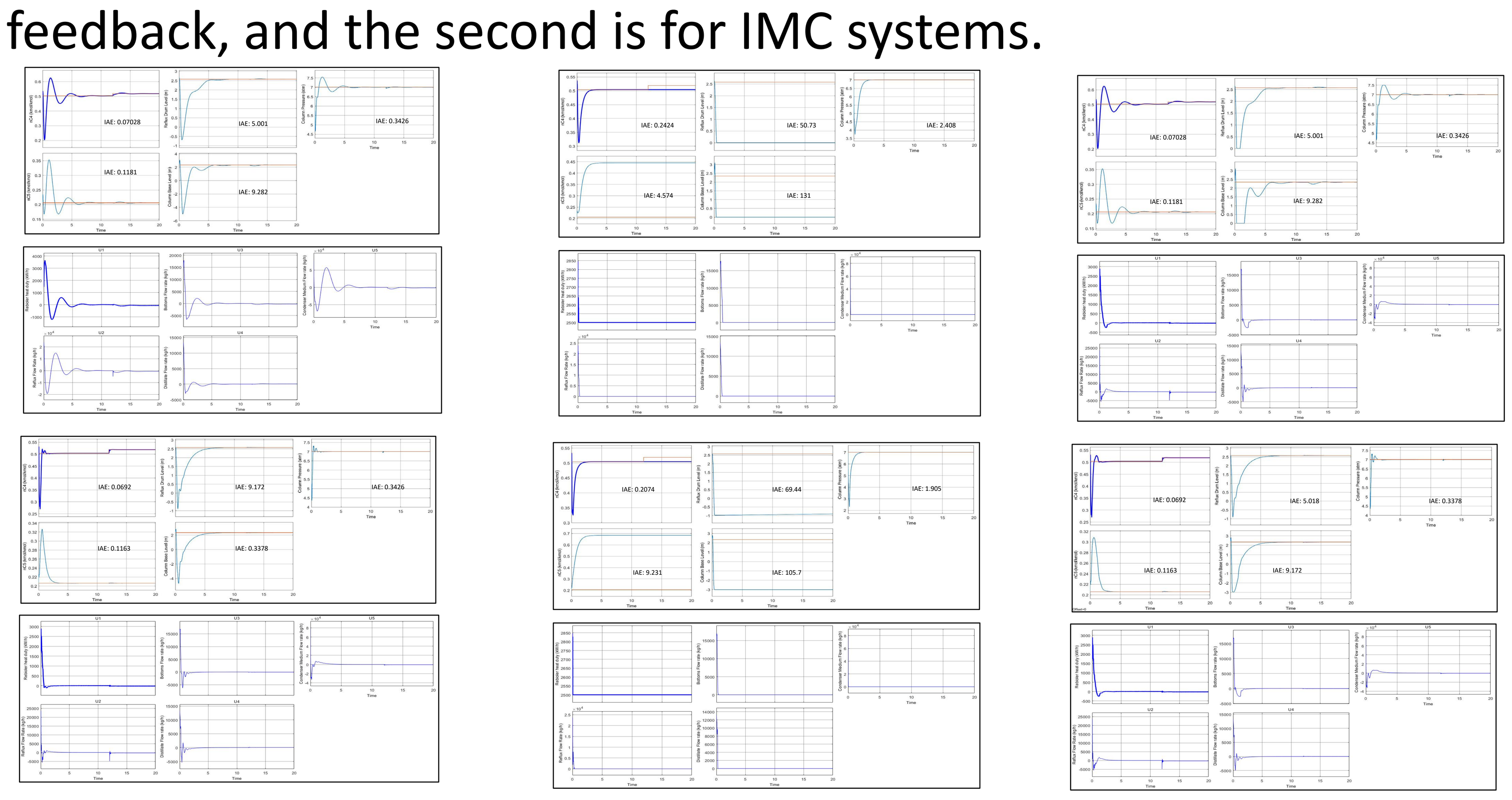
Objective and Motivation

This project is served to address the challenge of controlling the column due to its non-linearity nature, severe multivariable interactions, and enforced process constraints. The aims are as follows:

- Determine the transfer function model from a literature paper representing the debutanizer column process system.
- In MATLAB-Simulink, create the debutanizer unit simulation and apply the open-loop step test to evaluate the model.
- Utilize RGA analysis and specify the appropriate control configuration for the debutanizer column with the support of Condition Number (CN) and Niederlinski index (NI).
- Design feedback PID multiloops and IMC control strategies while tuning the PID controllers.
- Analyze all control strategies to optimize their performance and investigate the impact of input and output constraints.
- Examine the performances for the outcome responses for setpoint tracking. Plus, compare the IAE value.
- Select the best control strategy.

Results

A setpoint step-change was applied for each output one at a time while maintaining others at steady-state. The figures below display the outputs and inputs at distillate composition step change for unconstrained, constrained, and only output contained, respectively, as sample results: the first row is for feedback, and the second is for IMC systems.



The IMC control system was more rapid and less oscillatory than the feedback system in controlling the modeled debutanizer being designed with PID tuning settings for unconstrained cases and with output constrained only. Generally, the IAE results are better.

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