Laboratory 4
Control of a distillation column

1 Introduction

This fourth laboratory deals with the control of a distillation column. This laboratory is virtual, i.e. you will have to use a simulator running on Matlab and Simulink. Ideally the fourth lab is scheduled to be completed from the end of the S9 to the end of S12. As for the other labs, the workload is calibrated for a team of two students, although the complete understanding of the lab has to be individual.

In this document, the brief simulator overview (section 2) is presented first, and the instructions regarding the experiments to conduct come then from the section 3.

As a reminder, the knowledge of the documents titled ***Notice générale pour les labos et les TPs*** and ***LINMA1510_Fiches_20190506*** is a **prerequisite for doing the laboratories**.

2 Simulator overview

For this laboratory, download the `Labo4_Student.zip` file from the page of the course on *Moodle* and extract it. Run MATLAB and place its current directory on the extracted folder. Open the Simulink diagram `Labo4_students.slx` (as shown on the figure 1) and run it.

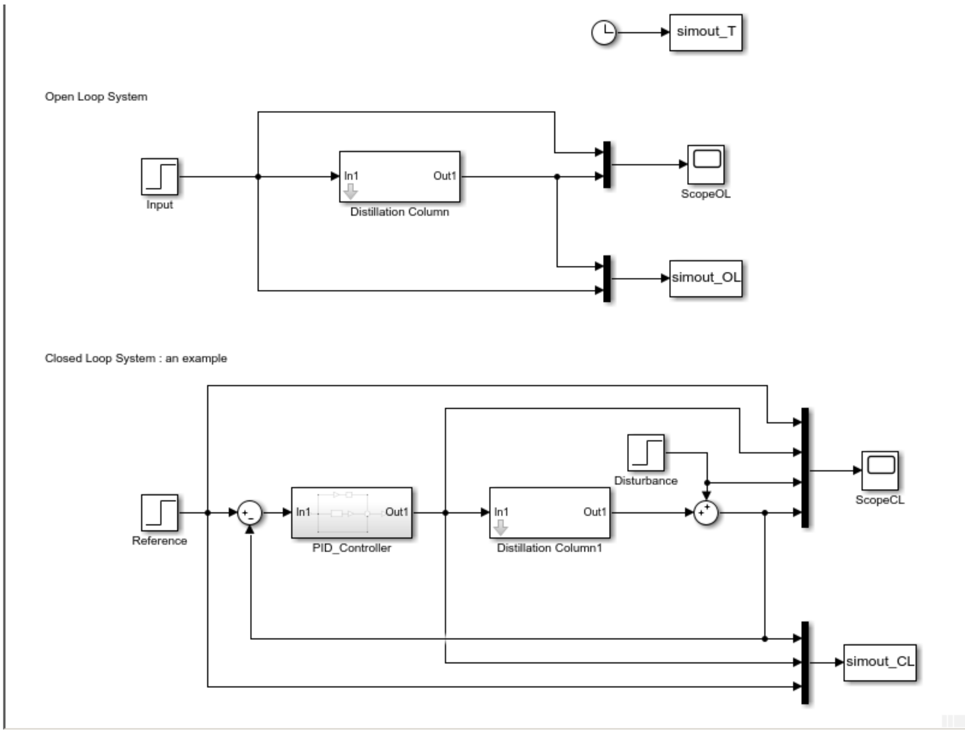

Figure 1: Overview of the lab diagram on Simulink

The code used to simulate the distillation column should ideally be hidden for the students (it is not to avoid problems caused by different OS run by the students). Ideally, perform this project without looking at the model of the distillation column.

The students can see the results of the simulation by double-clicking on the *Scope* blocks of the diagram, but the data are also forwarded to the workspace of MATLAB via the *ToWorkspace* blocks. As an example there is a script named `Labo4_Analysis_students.m` to ease the first analysis for the future work...

3 First experiment: ITAE criterion

Open Simulink and run some test in open loop to characterize the system (stability, order, minimum/non-minimum phase, gain, delay, settling time).

Model the system as a first order transfer function with a delay.

According to the document *Fiche 22: Régulation optimale - Critère ITAE*, apply the method to design a PI and then a PID controller.

Program a new diagram on Simulink with these controllers and compare their performance.

4 Second experiment: Ziegler-Nichols

4.1 Open-Loop: temporal study

Based on the open loop step response, calculate coefficients a and τ.

According to the document *Fiche 23: Méthode de Ziegler-Nichols*, apply the method to design a P, a PI and a PID controller.

Program a new diagram on Simulink with these controllers and compare their performances (and don't forget to study the disturbance rejection).

4.2 Closed-Loop: frequency study

Program a new diagram on Simulink to apply the frequency method of Ziegler-Nichols. Increase the proportional controller gain from 0 to its final value $K_p = K_u$, at which its closed loop output is a stable and consistent periodic signal. Then calculate coefficients K_u and T_u, the oscillation period (see *Fiche 23: Méthode de Ziegler-Nichols*).

According to the document mentioned above, apply the method to design a P, PI and a PID.

Program a new diagram on Simulink with these controllers and compare their performance (and don't forget to study the disturbance rejection).

5 Third experiment: match requirements specifications

Design a P, a PI or a PID to match the requirements specification listed below:

- Closed loop stability;
- Null static error on a step response;
- Settling time (5%) on a step response $\leq 8,5$ s;
- Disturbance rejection on a step response similar to the settling time;
- Robustness margins : $\phi_m \geq 70^o; G_m \geq 8dB$.

6 Assessment preparation

For the lab assessment, it is necessary to perform the test with the software `Lab_4_2021_eval_vX.exe` (that will be available after the Easter holidays). This software requires the student's FGS number, asks randomly selected questions and returns a numerical key. This **personal key is needed for the individual lab assessment**.

Moreover, to be better prepared for this assessment at the end of the course, you are advised to understand and prepare responses to the following statements:

1. Be able to provide a (synthetic) digest of your experiences performed during this lab;

2. Be able to present, illustrate and comment the method you selected to design the controller and show that it matches the requirements (in 5).

3. Be able to present, illustrate and comment the results to show that your last controller matches the specifications (in 5).