

Assignment 6 - Project Kårstø Statpipe Butane Splitter

TTK4210 - Advanced Control of Industrial Processes

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1 Identification and tuning of the controllers

In this chapter we will look at the tuning of the different controllers of the system. Firstly we will look at the secondary controllers, before we later move on to the higher level controllers. A summary of the different controller parameters can be found in Table 1.1.

Table 1.1: Summary of controller parameters in the plant

Controller	K_p	T_i	T_d
24_FC1005	1.18125	5	-
24_FC1015	0.2	5	-
24_FC1019	0.27225	5	-
24_LC1028	47.9	128	-
24_PC1024	17.5	2400	-

1.1 Tuning of secondary controllers

Firstly we want to tune the secondary controllers, which do not depend much on which control structure is used for composition control. The controllers this applies to is the flow controllers 24_FC1005, 24_FC1015 and 24_FC1019, the level controller 24_LC1028, and also the pressure controller 24_PC1024. These controllers all have fast dynamics compared to the composition control and primary level controllers.

1.1.a Tuning of 24_FC1019

Firstly we tune the controller 24_FC1019, which is a flow controller controlling the bottom flow B of N-butane. When trying to apply Skogestad IMC-tuning to a first order model, the results were poor as there are close to none time delay, as expected in a valve, which lead to this being a unprecise model. Ziegler-Nichols method, as described in [1], was then a natural choice, and with a critical gain of $K_{pk} = 0.605$ and integral time $T_i \rightarrow \infty$ we got the oscillations shown in Figure 1.1.1. By zooming into this we read the period of the oscillations as $T_k = 6$ s. This yields the gain and integral time $K_p = 0.27225$ and $T_i = 5$ s. With this tuning we get the response shown in Figure 1.1.2. This is a good response to a relatively large step reference change. Before the reference step the controller has an external set point, that is why the set point is changing

dynamically. When doing the step change, the controller settings was changed from external to internal set point, and then back to external for the second step.

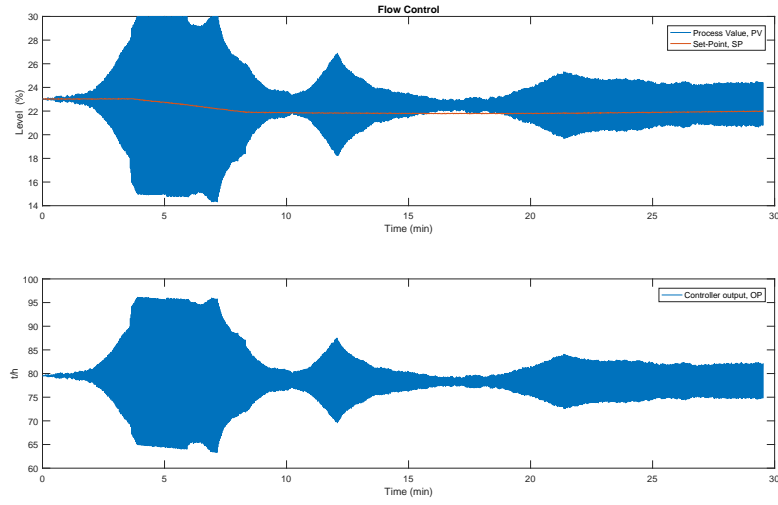


Figure 1.1.1: Oscillations of the flow controller 24_FC1019 with $K_{p_k} = 0.605$ from about 22 min

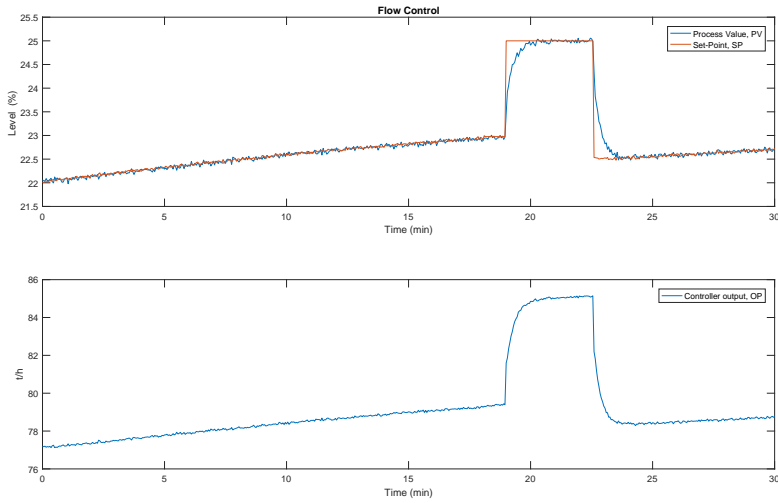


Figure 1.1.2: Response of 24_FC1019 tuned using Ziegler-Nichols method

1.1.b Tuning of 24_FC1005

We now tune the controller 24_FC1005, another flow controller, this one controlling D , the distillate flow of Iso-butane. Using the same method as in the tuning of 24_FC1019, we find the critical values $K_{pk} = 2.625$ and $T_k = 6$ s. This yields the parameters $K_p = 1.18125$ and $T_i = 5$ s. As we see in Figure 1.1.4, the we get a slow oscillation when switching back to external reference, but this is due to oscillations in the set point, and not the process value. We see that the process nicely follows the reference with high accuracy.

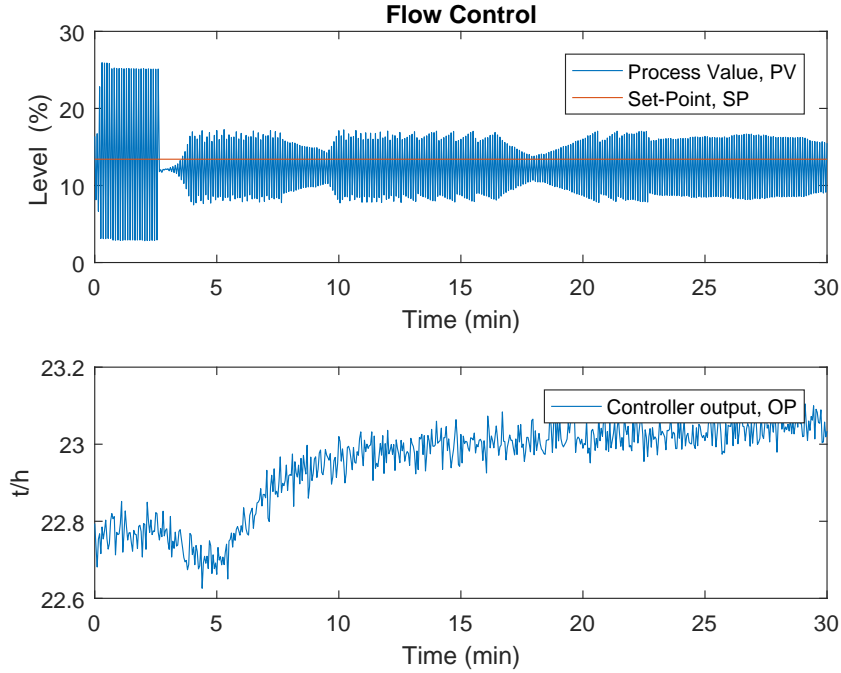


Figure 1.1.3: Oscillations of the flow controller 24_FC1005 with critical gain $K_{pk} = 2.625$ from about 23 min

1.1.c Tuning of 24_LC1028

Further we tune the level controller 24_LC1028 which controls the area for heat exchange in the bottom heat exchanger. This makes it indirectly control the bottom vapour flowrate V . Here we use the SIMC-method for tuning of PI(D)-controllers. Using this method we now need to take into account the internal scaling in the controller. By setting the integral time $T_i \rightarrow \infty$ we get a simple P-controller which we apply a step in the reference. By using the SIMC-tuning rules from [2] applied on a integrating step response we get

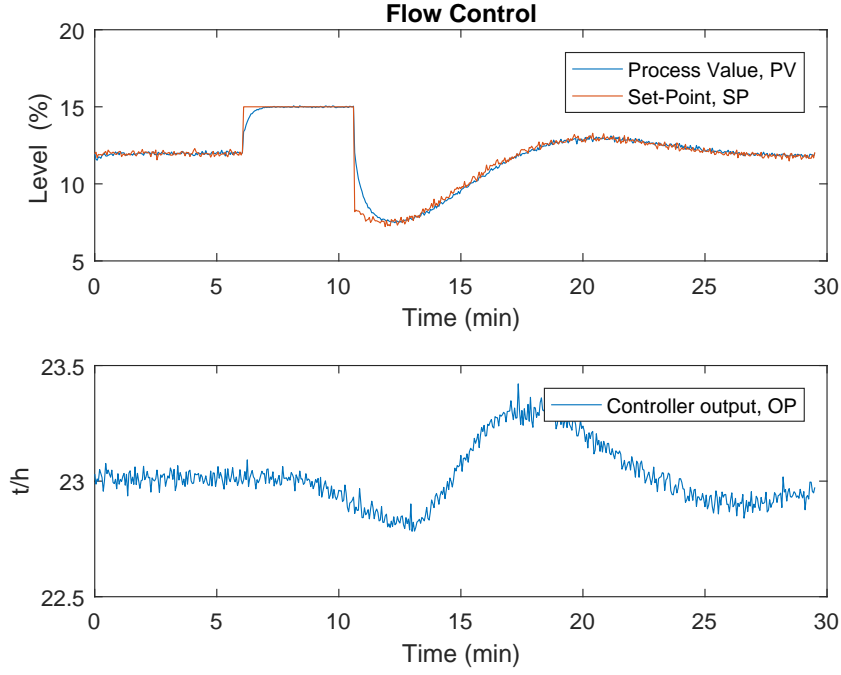


Figure 1.1.4: Response of FC_1005 tuned using Ziegler-Nichols method

$$\begin{aligned}
 k' &= \frac{\Delta y}{\Delta t \Delta u} \\
 K_c &= \frac{1}{k'} \frac{1}{\tau_c + \theta} \\
 T_i &= 4(\tau_c + \theta)
 \end{aligned} \tag{1.1.1}$$

where τ_c is chosen as 3θ to achieve robustness. Smaller τ_c improves preformance, but makes the system less robust, as described in [2]. By measuring on Figure 1.1.5 we get the observations

$$\begin{aligned}
 \Delta u &= 1 \\
 \Delta y &= -0.3413 \\
 \Delta t &= 462 \\
 \theta &= 8
 \end{aligned} \tag{1.1.2}$$

which again gives the results

$$\begin{aligned}
 K_c &= -42.3 \\
 T_i &= 128
 \end{aligned} \tag{1.1.3}$$

The scaling factor can be calculated as shown in (1.1.6), and when applying a step input with $\Delta y_{\text{ref}} = 2$, we get the immediate response $\Delta u_{\text{meas}} = -17.68$. $\Delta u_{\text{exp}} = K_p \Delta y_{\text{ref}} =$

20, which gives the scaling factor

$$G = \frac{u_{\text{exp}}}{u_{\text{meas}}} = -1.13 \quad (1.1.4)$$

which again gives the controller parameters

$$\begin{aligned} K_{p,\text{applied}} &= GK_c = 47.9 \\ T_i &= 128 \end{aligned} \quad (1.1.5)$$

This again leads to fairly good response, although the controller is maybe slightly aggressive. This is shown in Figure 1.1.6. The equations for the scaling parameter are given as

$$\begin{aligned} \Delta u_{\text{exp}} &= K_p \Delta y_{\text{ref}} \\ G &= \frac{\Delta u_{\text{exp}}}{\Delta u_{\text{meas}}} \\ \Rightarrow K_{p,\text{applied}} &= GK_p \end{aligned} \quad (1.1.6)$$

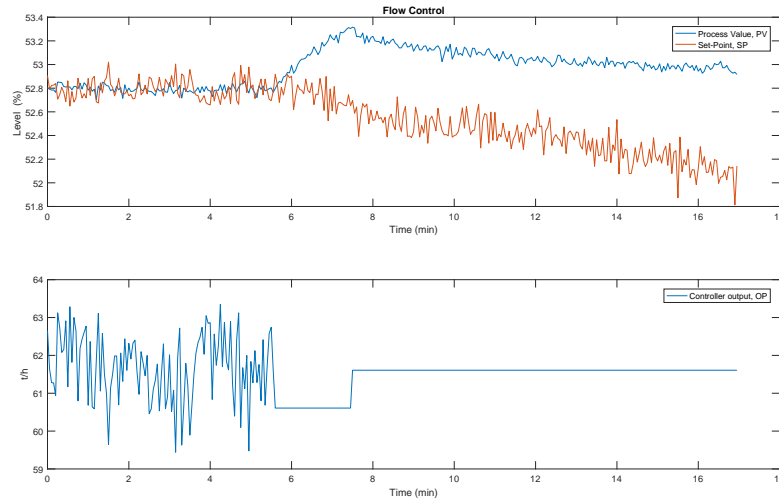


Figure 1.1.5: Output of 24_LC1028 with simple P-controller and applied step at $t \approx 7$ min

1.1.d Tuning of PC_1024

When applying a step on the input of the pressure controller PC_1024 we get the output response shown in Figure 1.1.7. When then applying the SIMC method to this output response, we see that we do not have a proper first order model with delay or a clean integrating response with delay, we instead treat the time from the step until the

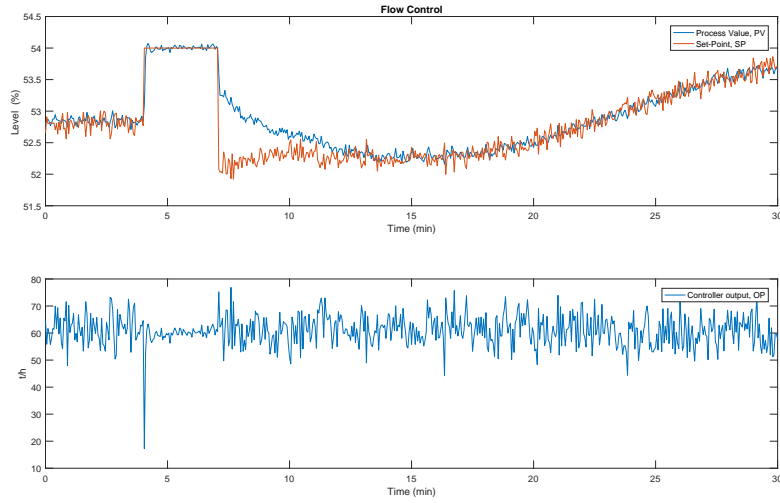


Figure 1.1.6: Output of 24_LC1028 tuned using SIMC and PID-scaling

integration starts properly as the time delay θ . We also calculate the internal gain as in (1.1.6) and obtain the parameters $G = -1.62$, $\delta u = 0.3$, $\delta t = 900$, $\delta y = -0.021$ and $\theta = 300$. Using the rules from (1.1.1) and choosing $\tau_c = \theta$ for faster control we get the controller parameters

$$\begin{aligned} K_p &= GK_c = 17.5 \\ T_i &= 4(\tau_c + \theta) = 2400 \end{aligned} \tag{1.1.7}$$

This integral time seems quite large, but when looking at the response of the PC_1024 after tuning the parameters, shown in Figure 1.1.8, we see that the controller response is fairly good, and keeps the pressure well within acceptable deviations.

1.1.e Tuning of 24_FC1015

When it came to the controller 24_FC1015, I came to the conclusion that all responses were unstable when trying to use the classic tuning methods. I therefore went back to the even more classic method of trial and error. By tweaking K_p and T_i within reasonable limits we hit a set of parameters, $K_p = 0.2$ and $T_i = 5$, which gave fairly good response. This is shown in Figure 1.1.9. We see that the process value follows the reference pretty good.

1.2 Tuning and identification of level controllers

We now move on to the identification and tuning of the level controllers 24_LC1015 and 24_LC1016. These controllers

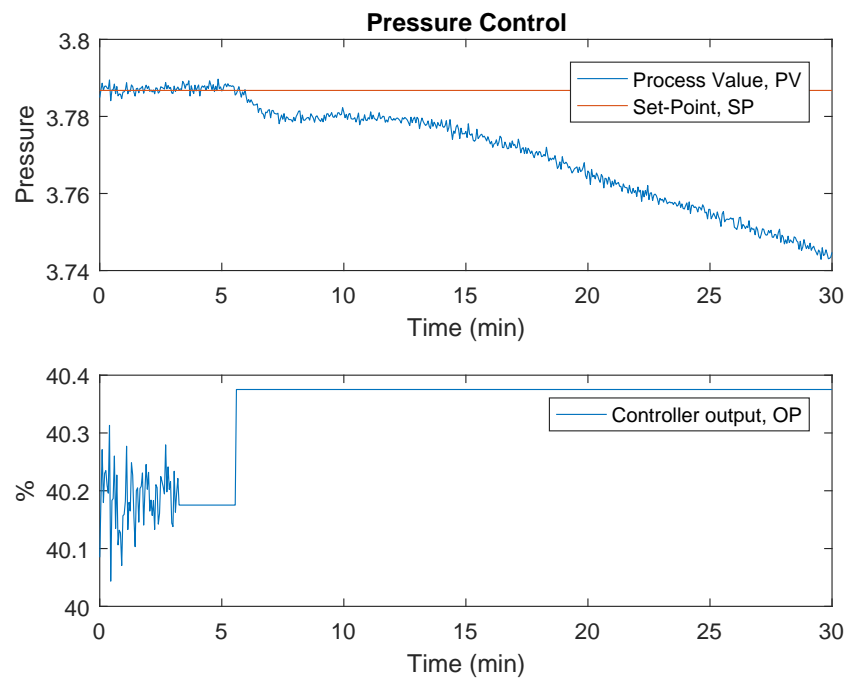


Figure 1.1.7: Response of the controller PC_1024 when applying a step on input

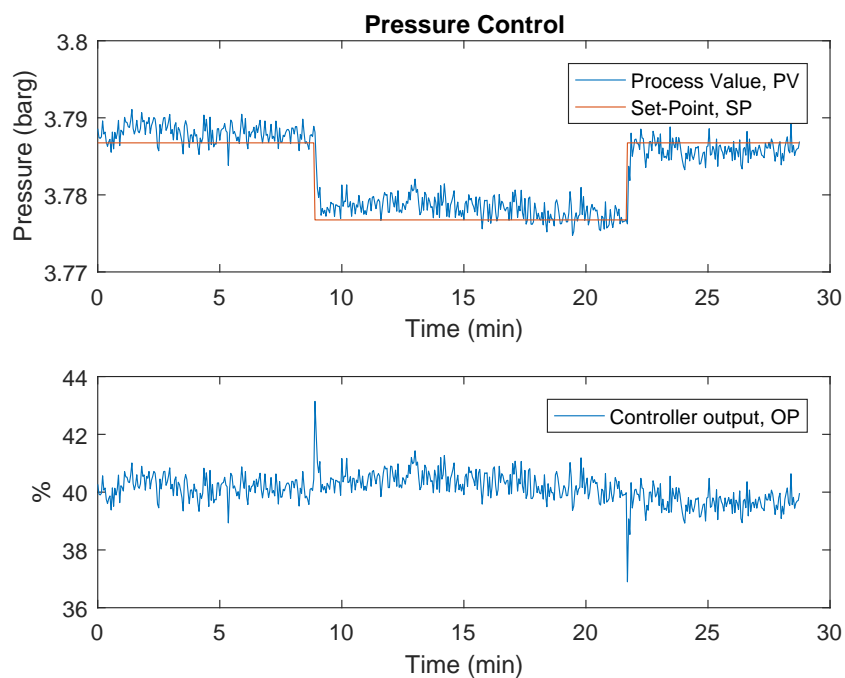


Figure 1.1.8: Response of the pressure controller PC_1024 after tuning and applying a step in the reference value

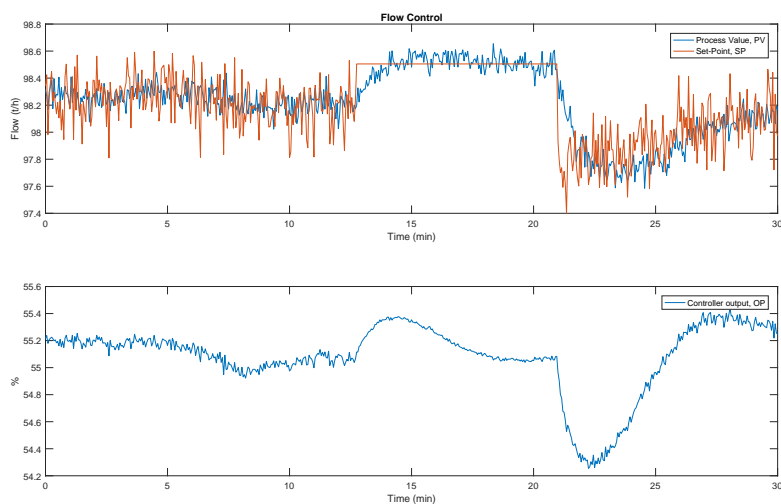


Figure 1.1.9: Response of the controller 24_FC1015 after tuning using trial and error

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