Project Part 3

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1 Question 1

The 'jaggedy' data that is plotted for the air flow rate is due to the fact that the air flow rate into the boiler is 'noisy'. The air flow rate has disturbances which are associated with it, such as wind speed, air temperature and air pressure, to name a few. Noise can arise from measurement devices and electrical equipment however in this process, the most influencing factor associated with the noise is due to air currents. The air currents are constantly changing and thus result in a very noisy measurement. The noise results from a variable concentration of winds in a specific area. The air currents are caused due to a difference in pressure and temperature of the entering air, thus fixing the state of the air entering the boiler would eliminate the noise issue. A means to do this would be to preheat the inlet air to a uniform temperature, ensuring that the temperature of all the air into the reactor is of a uniform temperature, reasonable to operation of the boiler. This will reduce air currents and in turn reduce noise. A second way to eliminate the noise associated with the air flow rate would be to filter the measurement. Filtering the measured signal will remove the noise and smooth the data out. This method is used in Question 2. The measurement is filtered and noise is removed from the measurement using an exponentially weighted moving average filter with $\alpha = 0.01$.

2 Question 2

A comparison of the filtered and unfiltered data is shown in Figure 1 and Figure 1.

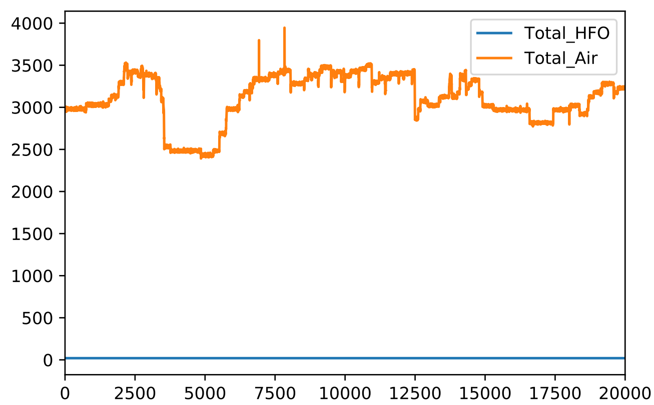

Figure 1: Unfiltered data.

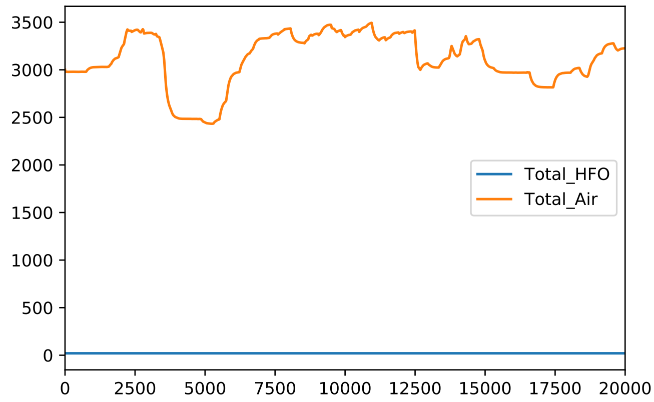

Figure 2: Filtered data.

3 Question 3

Figure 3 shows that the manipulated variable and the set point resulting plots are not the same. The reason for these plots not being identical is because the error value in the first 0.1 hours is not zero (for the case of PI and PID control) or held at a constant value (for the case of proportional only control). The difference between the steady state value for the composition and the composition set point, initially is extremely large and not constant. The manipulated variable therefore needs to be changed in order to reduce this error in attempt to achieve a reasonably small, constant error value. The proportional controller therefore acts in order to bring the manipulated variable closer to set point, away from the original calculated steady state value. The proportional only controller results in offset due to the means of the error calculation, satisfied control is achieved when the error is a steady constant value. The initial steady state value is $s = 0.1271$ and the set point value is $s = 0.1278$.

Additional to this is the responsibility of the controller bias. The bias attempts to prevent excessive initial responses by adding a steady state controller output value to the controller.

It is important to note that this behaviour of the MV and SP plots not being identical will be evident regardless of the controller type as perfect control is physically unrealisable. Other forms of control include PI and PID. PI and PID controllers, in contrast to P controllers, eliminate offset as the control aims to achive an error value of zero. A PI controller will exhibit overshoot in the response, however, the integral error that is calculated will result in the response reaching the set point with zero offset. PID controllers contain derivative action. Derivative action is responsible for predicting future behaviour of the response and thus the behaviour of the error signal. The PID controller

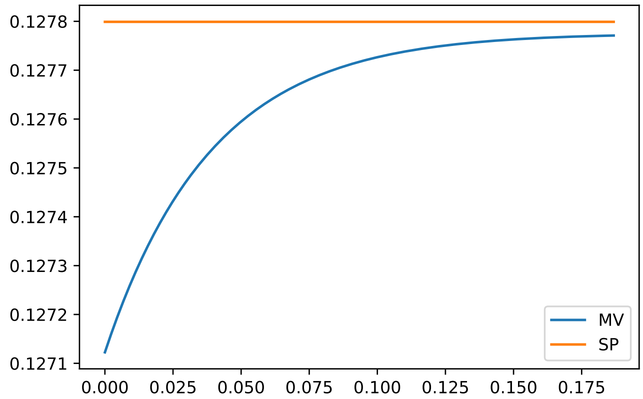

Figure 3: The result of the composition response for the first 0.1 hours.

will therefore exhibit less overshoot than the PI controller as the derivative term will assist the integral term in reducing the error.

4 Question 4

When fitting the first order plus dead time model to the response of a set point change in the black liquor, Figure 4 shows the fitted response to the composition (manipulated variable). Figure 6 shows that the black liquor under went a set point change from 100kg/hr to 130kg/hr at a time of 5 minutes. The original response for the composition is shown in Figure 5. When doing the fitting, the curve fit function was used. The curve fit requires initial guess values for the parameters being estimated, these values where estimated using the original plots, shown in Figure 6 and Figure 5. Table 1 shows the numeric value of the parameters estimated for the set point change of the black liquor flow rate specified above.

Table 1: FOPDT model parameters fitted in Figure 4

K	τ	θ(hours)	Y_O
0.1168	0.68	0.0797	0.1271

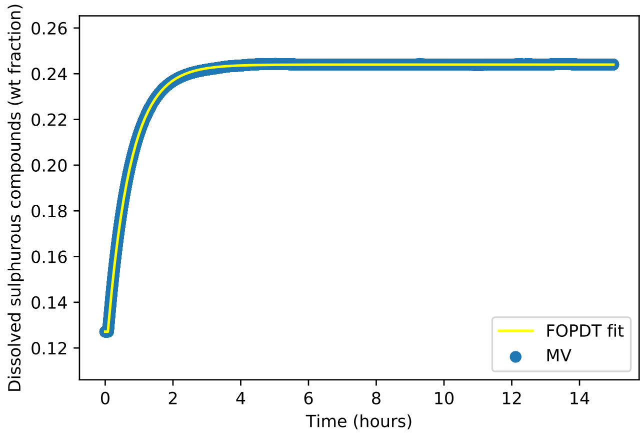

Figure 4: The fitted parameters plotted against the original manipulated variable.

5 Question 5

The PI controller is able to track set points much better than P only control. The code that I implemented for the PI controller that I implemented took very long to run. However the basic principle is that the $BL = bias + kc * (error_list[i] + (1/I) * integral)$ where the integral is the previous error value added to the current error value multiplied by dt. The code can be followed in the ipynb file attached to this submission. In general PI control gives better control with overshoot and zero offset.

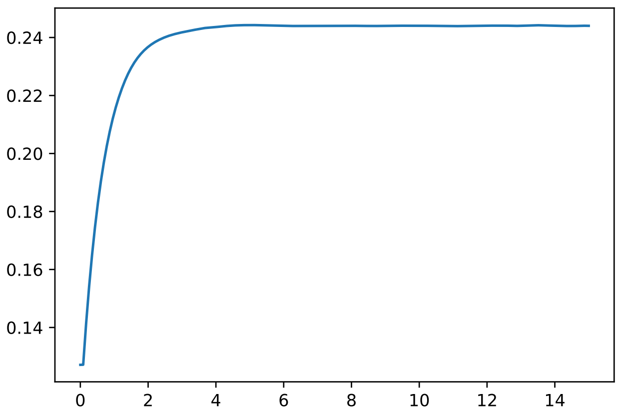

Figure 5: The original response to the BL set point change.

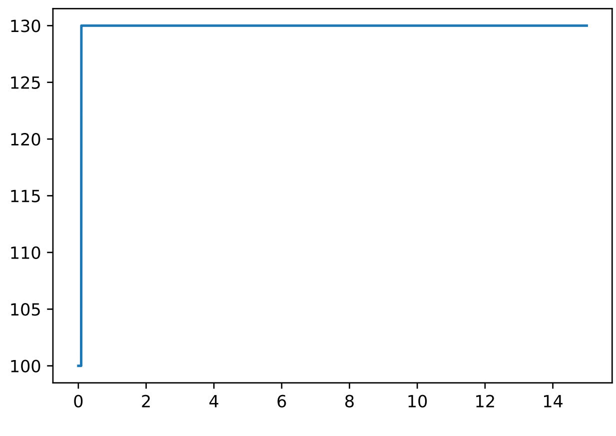

Figure 6: The set point change in the BL flow rate.

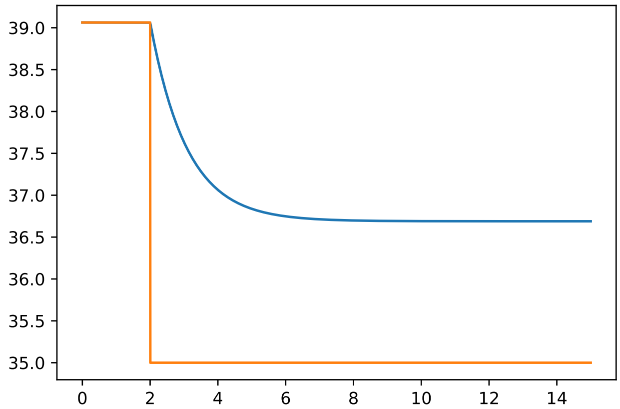

Figure 7: The result of the height response using PI control.

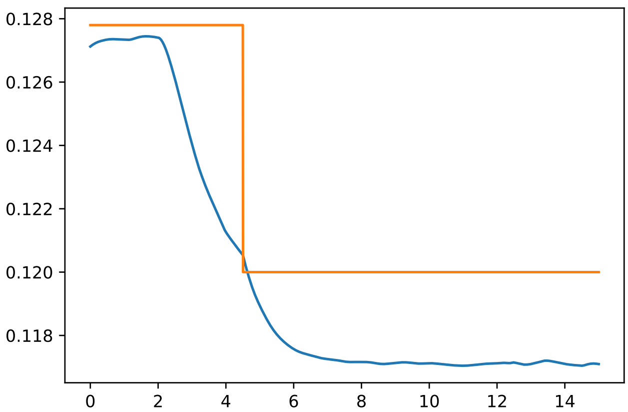

Figure 8: The result of the composition response for PI control.

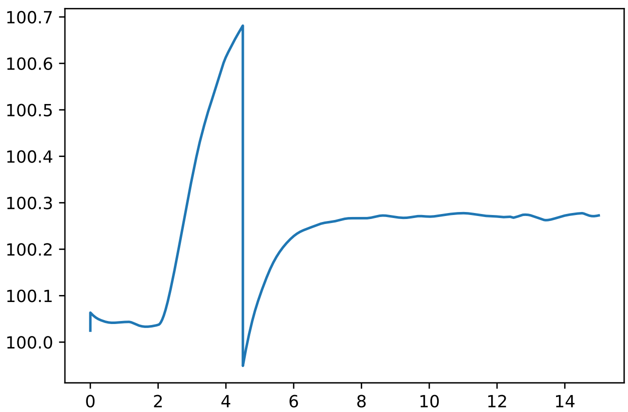

Figure 9: The result of the black liquor response for PI control.