USN/TNM/EIK

Report for assignment: Programming a simulator of a control system in OpenModelica

Course: FM1220-1 Automatic Control

Date: 15.10.2021

Family name	Given name and middle name(s)	Student number	Class	Group no.
Rådstoga	Lars Rikard	223786	IIA-IM	10

1. Construct a simulator

Construct a simulator of the wood-chip tank (without a controller system) in OpenModelica. (Include a picture of the model block diagram in the report.)

Solution

A simulator, seen in Figure 1-1, for the wood-chip tank without a control system was constructed as part of lecture 4. The simulator is merely an implementation of the mathematical model (1.1) in OpenModelica.

$$h'(t) = \frac{K_s u(t-\tau) - \omega_{out}(t)}{\rho A} \tag{1.1}$$

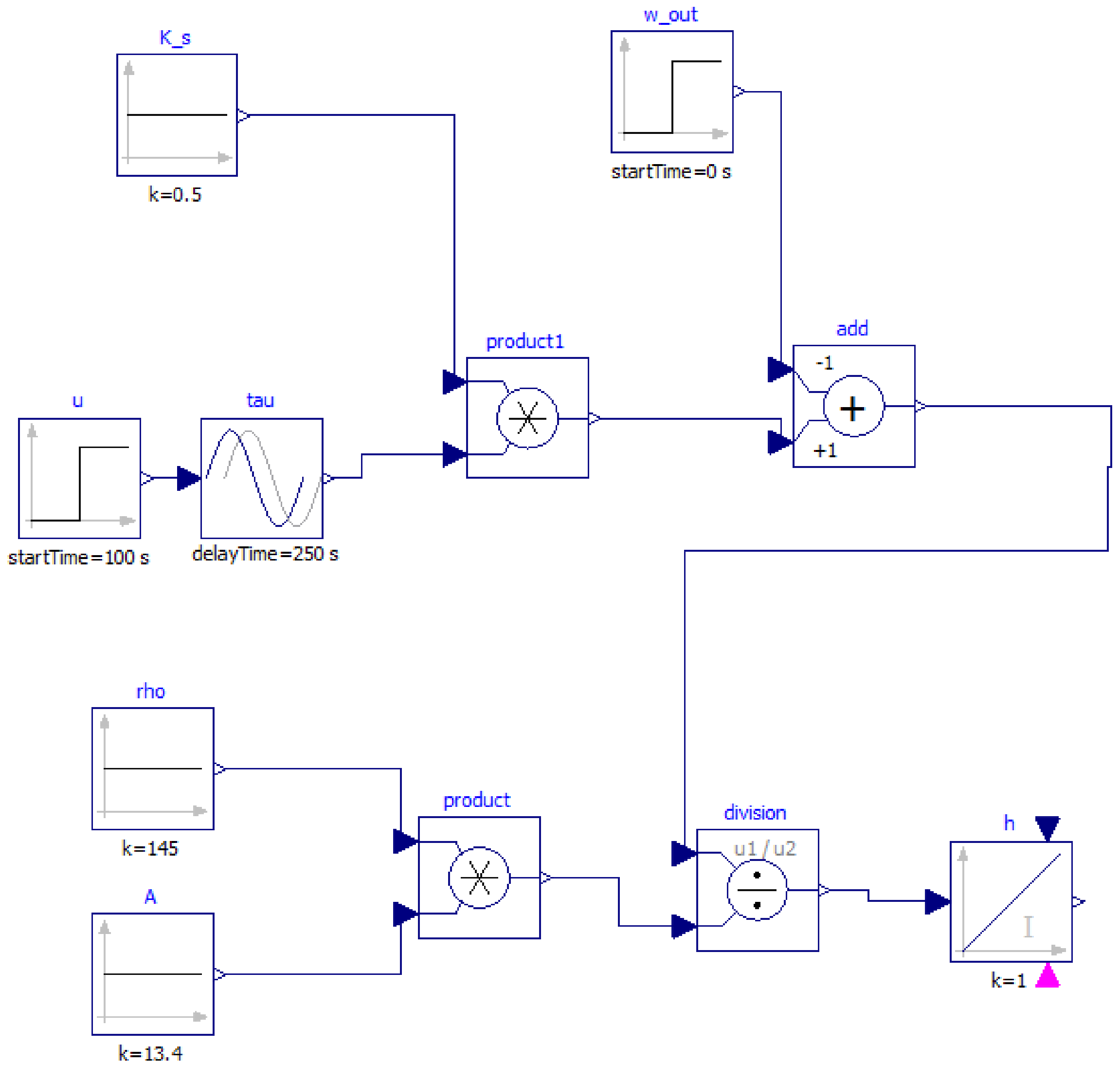

Figure 1-1 Simulation of the wood chip process without control

2. Demonstrate process dynamics

Demonstrate with a simulation that the process dynamics (i.e., the dynamics of the uncontrolled process) is qualitatively "integrator with time-delay". Which process component is due to the integrator, and which is due to the time delay?

Solution

The height in the tank is due to the integrator, but the integrator is also due to the input flow proportional to the time delayed control signal u. This is displayed in Figure 2-1 where the red line represents the level that is at first only affected by the integrator due to the outflow represented by the blue line. But is at time = 251s also affected by the time delayed inflow represented by the green line, resulting in a net change of level equal to zero. A control signal u = 50 is required for this result.

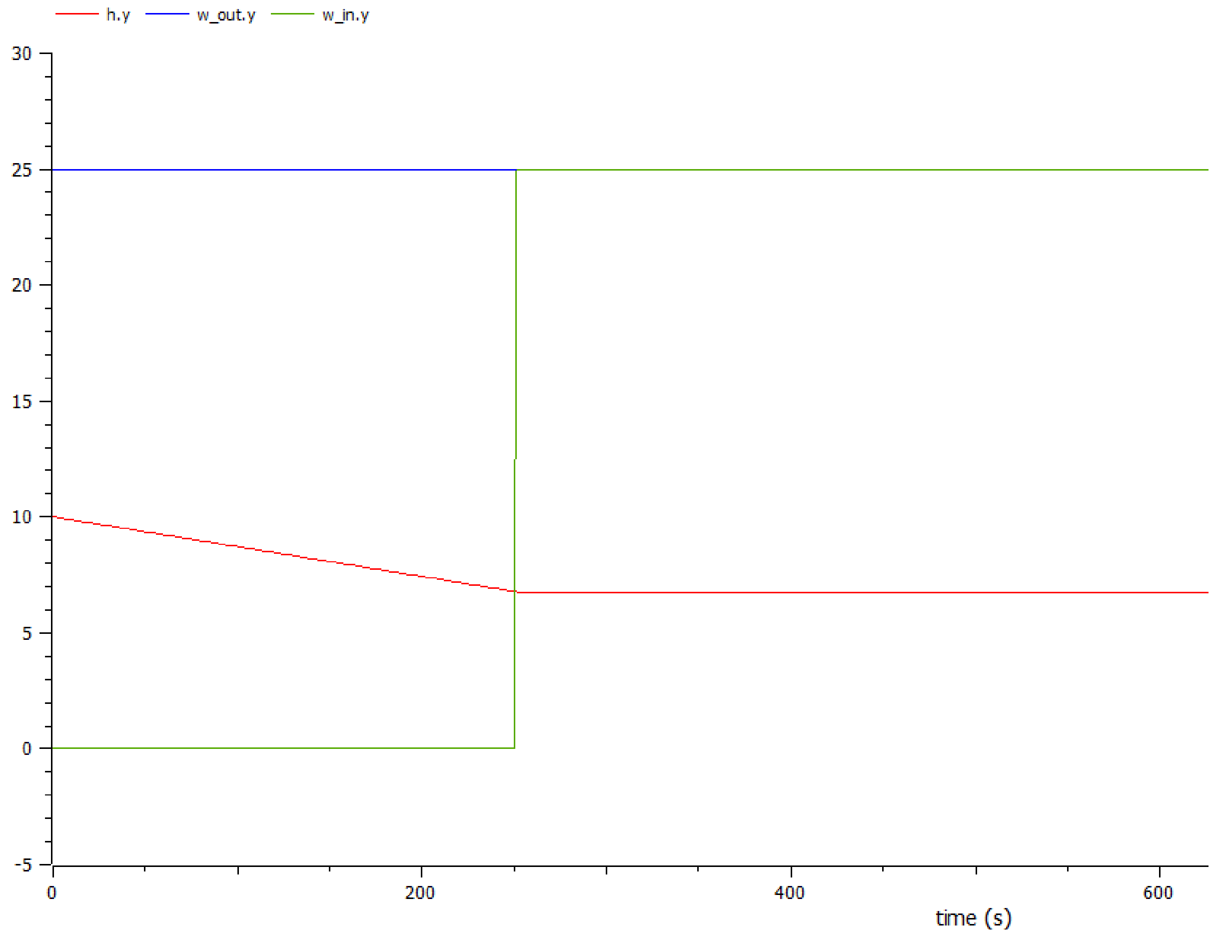

Figure 2-1 Integrator with time delay

3. Enhance the simulator with PI

Enhance the process simulator from Task 1 with a PI level controller. (Include a picture of the model block diagram in the report.) The level controller manipulates the control signal (u) in unit of %, and the controller receives hm as the level measurement signal. The level setpoint is 10 m.

Solution

The enhanced controller can be seen in Figure 3-1.

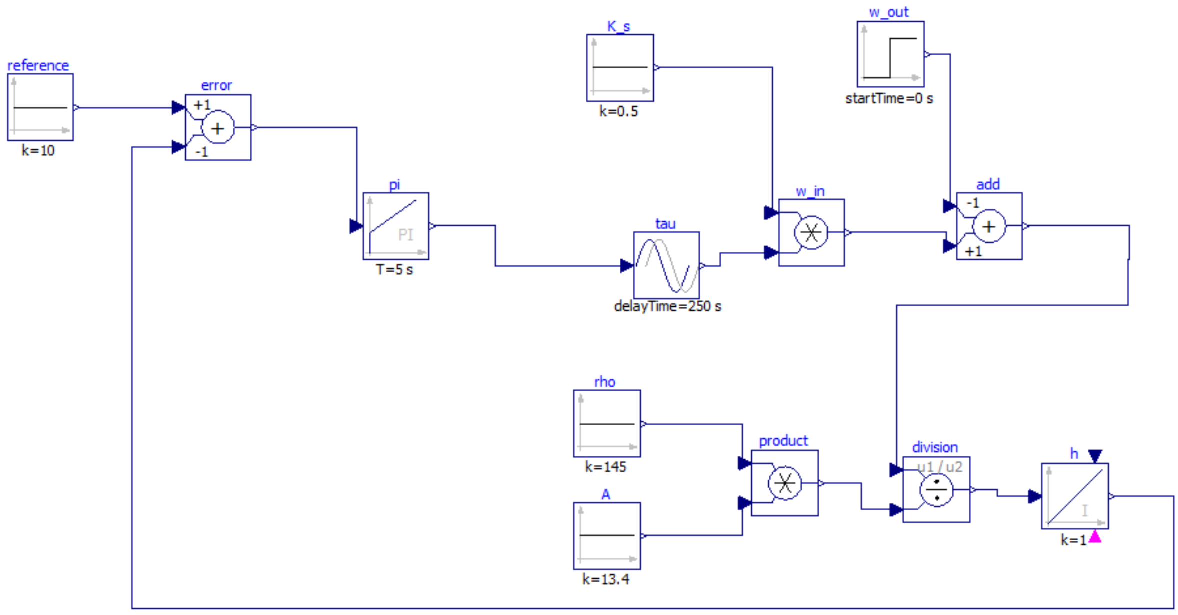

Figure 3-1 Simulator with PI controller.

4. Tune the PI with relaxed Ziegler-Nichols

Tune the PI controller using the Relaxed Ziegler-Nichols method. Verify with a simulation that the control system has ok stability with the tuned PI controller.

Solution

Part 1

The initial value for the height integrator is set to 10m, and the reference for the controller is initially set to 5 and increased to 10 after 100 seconds. Table 4-1 shows the PID controller values.

Table 4-1 Setup values for the PID

	K_p	T_i	T_d
Figure 4-1	25.0	99999.0	0
Figure 4-2	24.3	99999.0	0

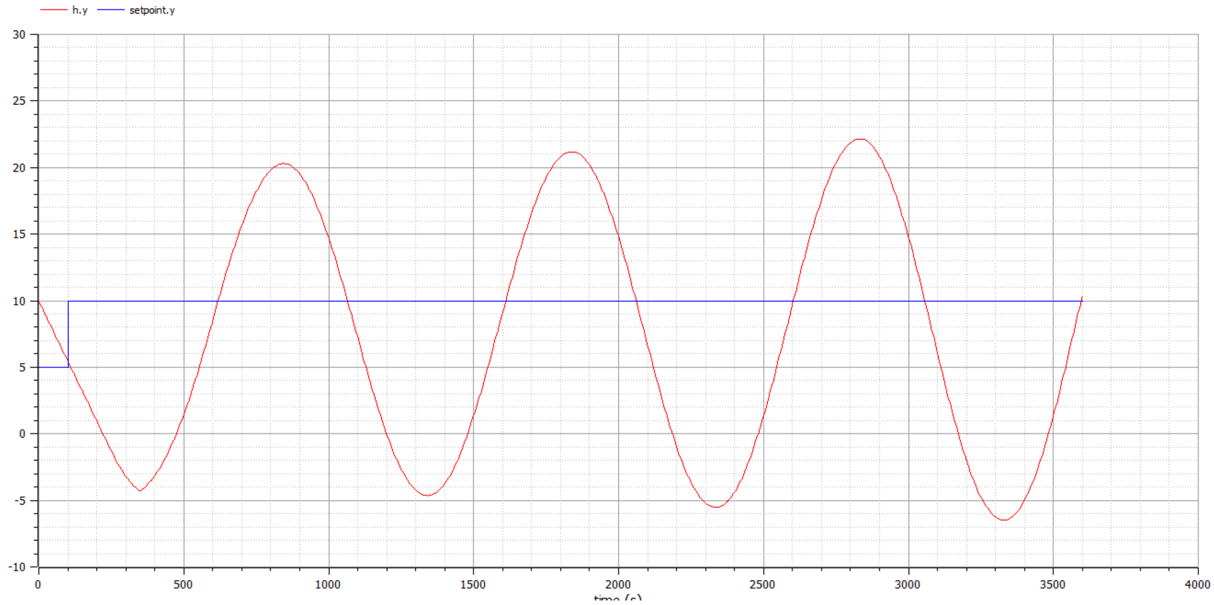

Figure 4-1 Observed unstability for the control loop at $K_p = 25$

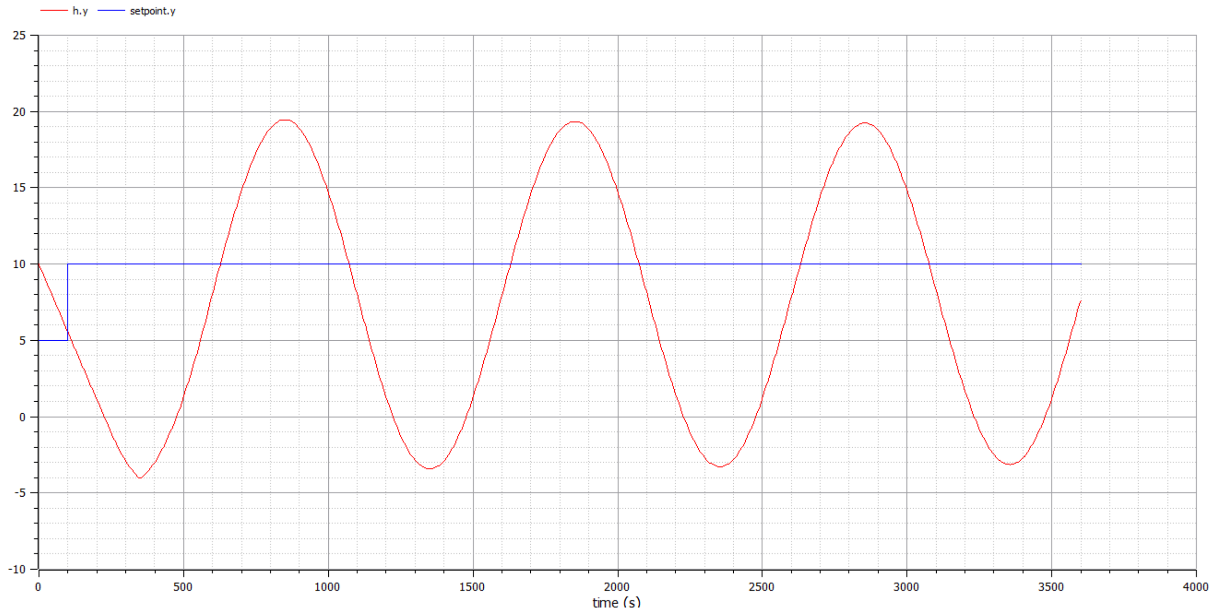

Figure 4-2 Observed marginal stability for the control loop at $K_p = 24.3$

Part 2

Using the excel sheet in Table 4-2 the Ziegler-Nichols control parameters are calculated for P, PI and PID control. Simulating in PI mode with these parameters give decent stability as seen in figures: Figure 4-3 and Figure 4-4.

Table 4-2 Control parameters using Ziegler-Nichols

Kpu:	24,3
Pu:	1000

	Kp	Ti	Td
P	12,15	∞	0
PI	10,935	833,3333	0
PID	14,58	500	125

Pi controlled

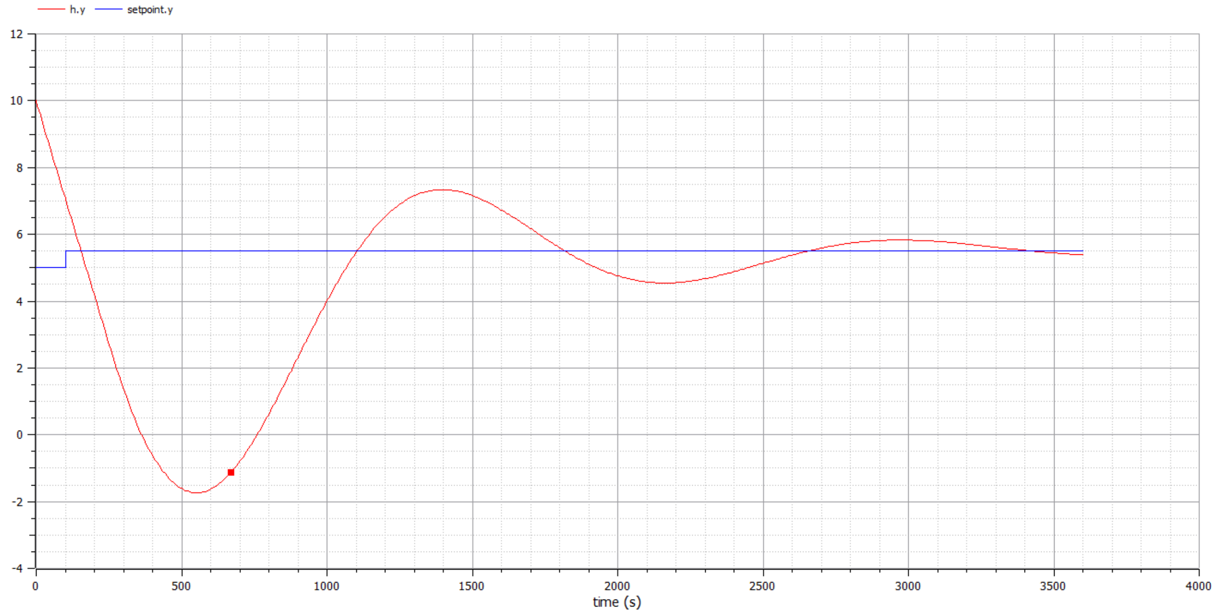

Figure 4-3 Simulation with Ziegler-Nichols tuned PI controlled, setpoint jump from 5 to 5.5 meters

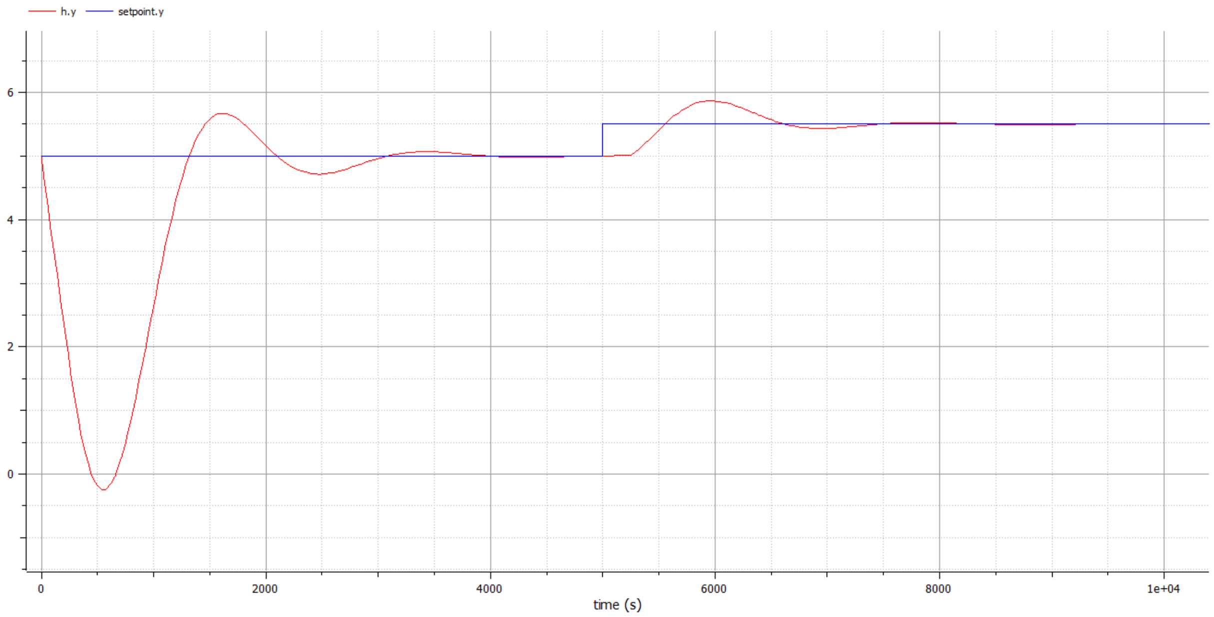

Figure 4-4 Simulation over a longer period

5. Find maximum control error

Assume that the process disturbance (wood chip outflow) changes as step from 1500 to 2000 kg/min. Find from a simulation what is the maximum control error due to this disturbance change. Also find from a simulation what is the steady state control error.

Solution

It looks like the maximum control error due to the disturbance is about 6.98 meters as shown in Figure 5-1. Though the steady state error seems to converge to 0 as seen in Figure 5-2.

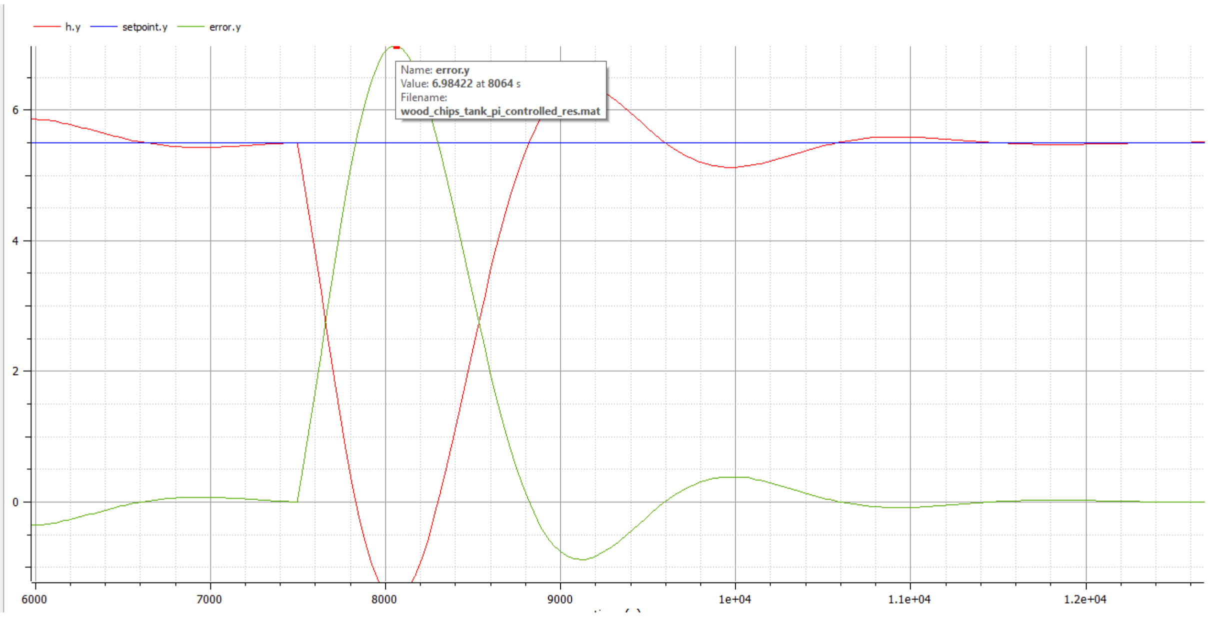

Figure 5-1 Error after output flow disturbance change.

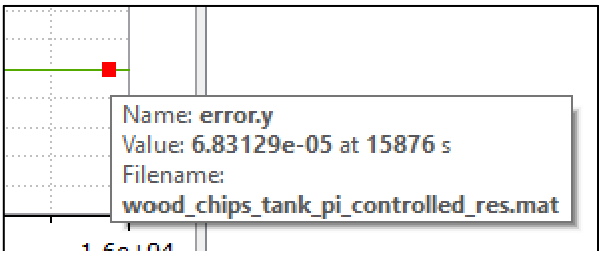

Figure 5-2 steady state error.

6. Replace the PI controller with P

As in Task 5, but now use a P controller (with the same gain as in the PI control). Which controller do you recommend here - P control or PI controller?

Solution

For the P controller the error can never be driven to zero and thus the PI controller would be highly recommended here. This can be seen in the simulation shown in Figure 6-1.

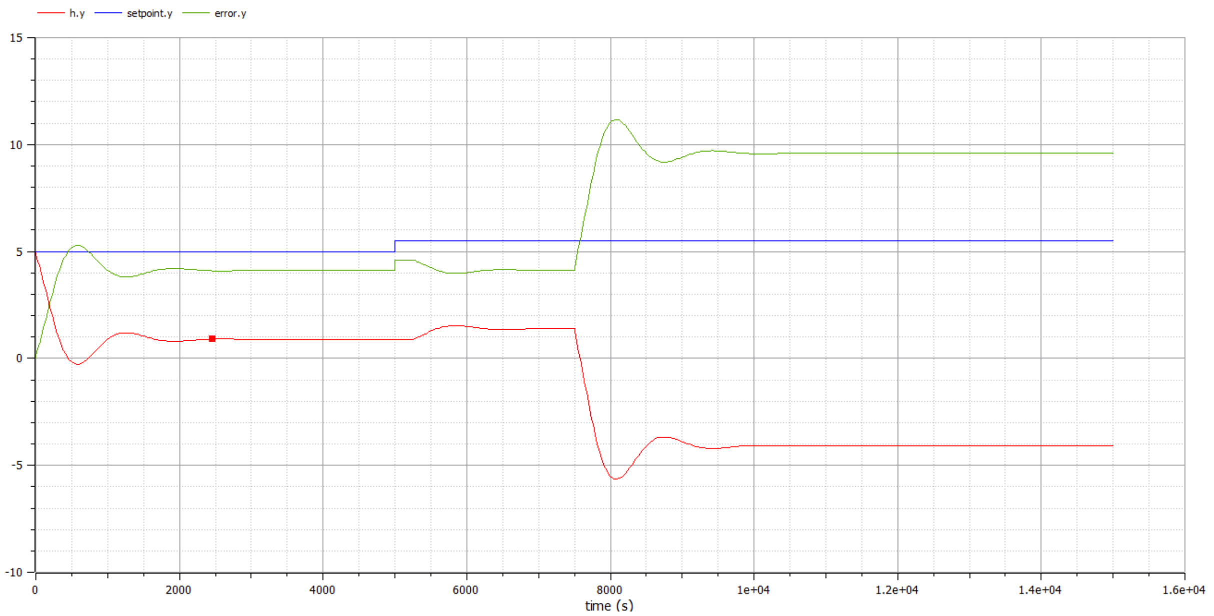

Figure 6-1 Steady state error with P controller