University of
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USN/TNM/EIK

Report for assignment: Programming a simulator of a heated tank in Python

Course: FM1220-1 Automatic Control

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1. Calculation of the static operating point

Calculate from the model the constant power, P0, needed to bring the temperature to a constant value of 25 deg C.

Solution

The constant power required to bring the temperature to a constant value of 25 °C is 10,250W as shown in Figure 1-1.

$$C_3 T'(t) = P(t-\tau) + C_1\left(T_{in}(t) - T(t)\right) + C_2\left(T_{env}(t) - T(t)\right)$$

Power, P_0, at the fixed point $\lim_{t\to\infty}$, $T'(t) = 0\,K/s$,

$T_{in}(t) - T(t) = -5K$, $T_{env}(t) - T(t) = -5K$:

$$0K/s = P_0 + C_1(-5K) + C_2(-5K)$$

$$\rightarrow P_0 = 5250\,W + 500\,W = \underline{10{,}250\,W}$$

Figure 1-1 Calculation of the operating point.

2. Programming and simulation

Program a simulator of the tank heater in Python. The simulator must be implemented with "native" code in a For loop based on the Euler Forward discretization of the model (a built-in simulation function of Python should not be used). You can set the time-step to 1 s. The following variables should be plotted: T, Tin, and T_env in one subplot, and P in another subplot.
Assume that the initial temperature is T_init = 20 deg C. Run a simulation with P = P0 as calculated above. Is the static T the same as specified in task 1 above?

Solution

Yes, the static temperature, with the power calculated in task 1, gives the same temperature as the one used in the calculation: 25 °C. Parameters used are shown in (2.1) and plots showing the result can be seen in Figure 2-1.

```
time_step=1, start_time=0, stop_time=5000, power=10_250, time_delay=0
```
(2.1)

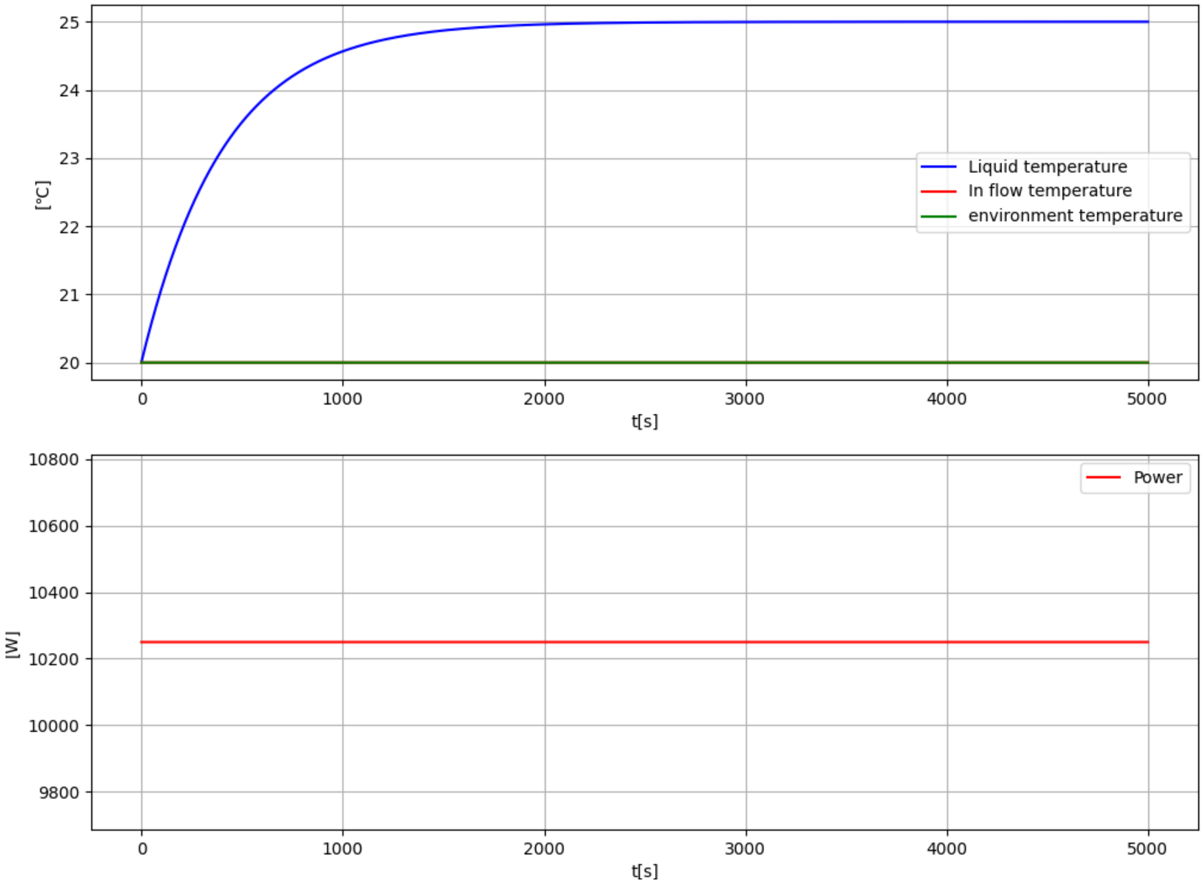

Figure 2-1 Plots showing liquid temperature moving towards a horizontal asymptote at 25°C.

3. Stability of the simulator

Demonstrate that the simulator becomes numerically inaccurate, and possibly unstable, if you select a (too) large simulator time step.

Solution

The simulator does indeed become unstable upon selecting large time steps. Figure 3-1 displays the result of simulations with the parameters in (3.1).

```
time_step=1, start_time=0, stop_time=5000, power=10_250, time_delay=0
```
(3.1)

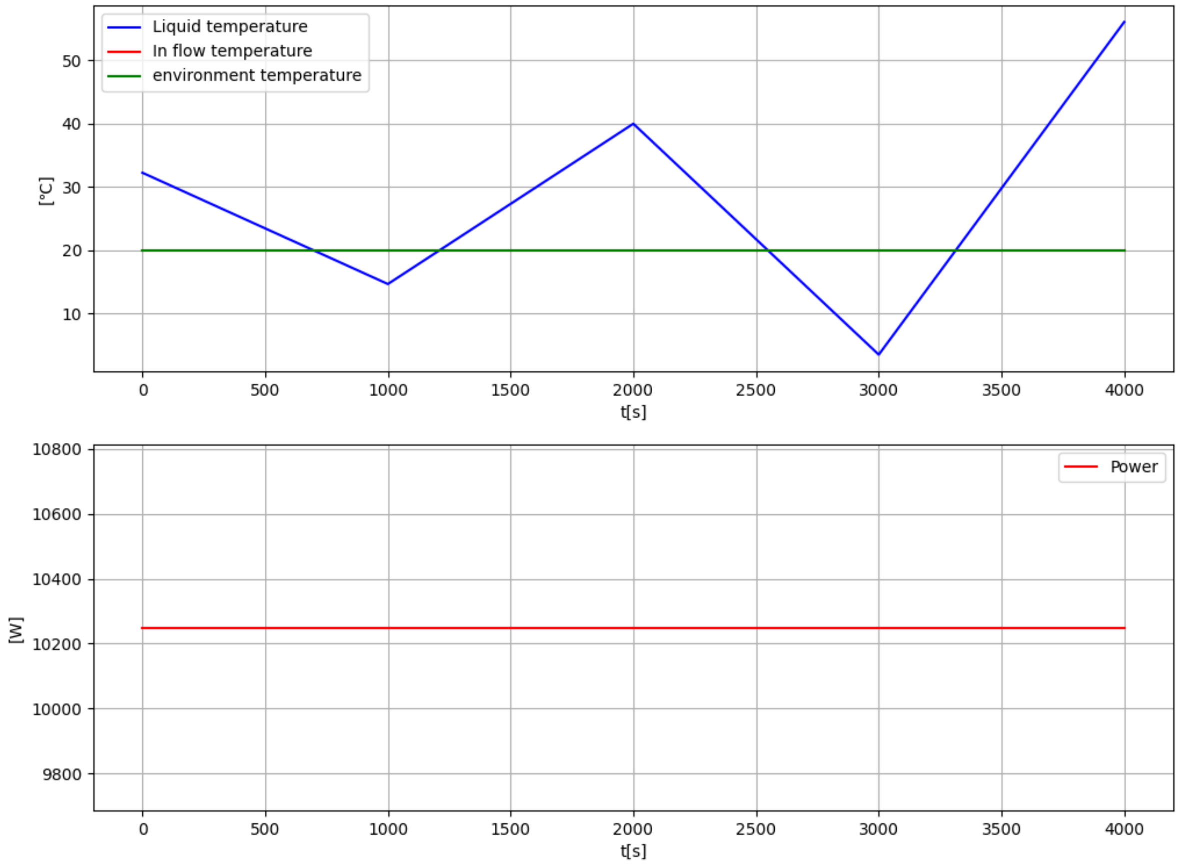

Figure 3-1 Plots showing unstable liquid temperature simulation.

4. Time delay

Set the time step to 1 sec. Include a time delay of 60 sec in P. Verify with a simulation that the time delay has been implemented correctly.

Solution

For this exercise a smaller stop time was selected to exaggerate the time delay. The parameters shown in (4.1) was used and the resulting plot can be seen in Figure 4-1.

```
time_step=1, start_time=0, stop_time=500, power=10_250, time_delay=60
```
(4.1)

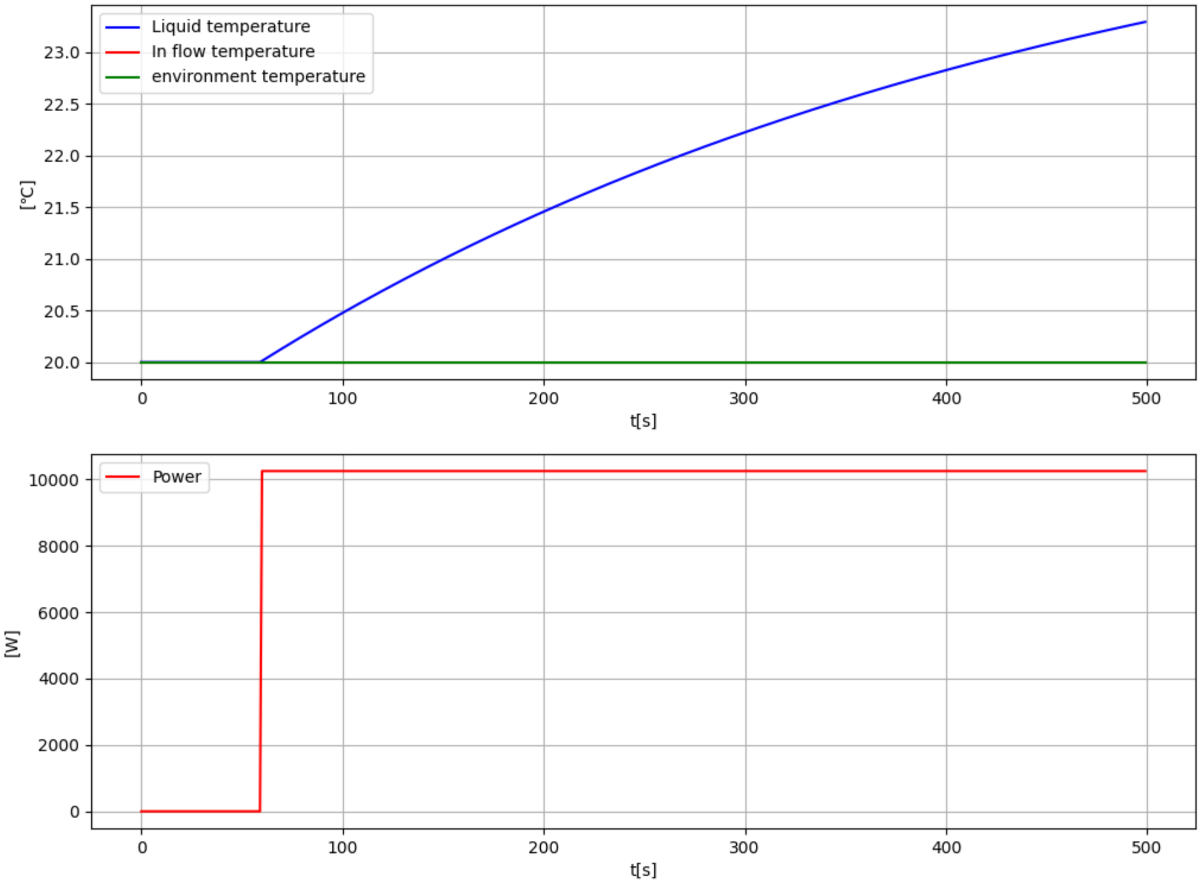

Figure 4-1 Simulation with time delay.