

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

Course: FM1220-1 Automatic Control

Date: 17.09.2021

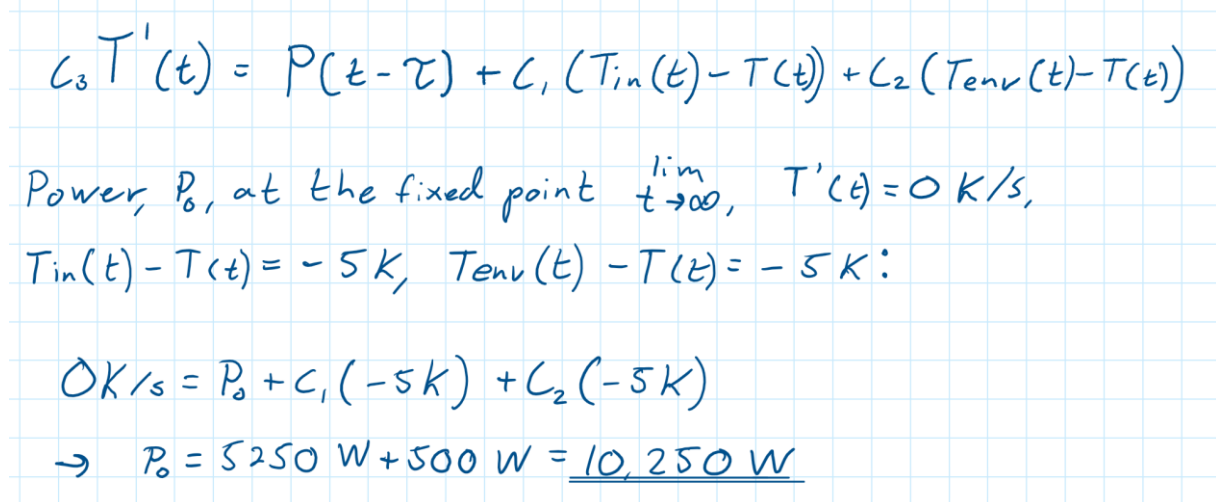
Family name	Given name and middle name(s)	Student number	Class	Group no.
Rådstoga	Lars Rikard	223786	IIA-IM	10
Jøndal	Anne	246081	IIA-IM	10
Breiland Teigen	Daniel	251282	IIA-IM	10
Pedersen	Krister	223788	IIA-IM	10

1. Calculation of the static operating point

Calculate from the model the constant power, P_0 , 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.



Handwritten derivation on a grid background:

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

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

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

$$0 \text{ K/s} = P_0 + C_1 (-5 \text{ K}) + C_2 (-5 \text{ K})$$

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

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, T_{in} , and T_{env} in one subplot, and P in another subplot.

Assume that the initial temperature is $T_{init} = 20 \text{ deg C}$. Run a simulation with $P = P_0$ 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.

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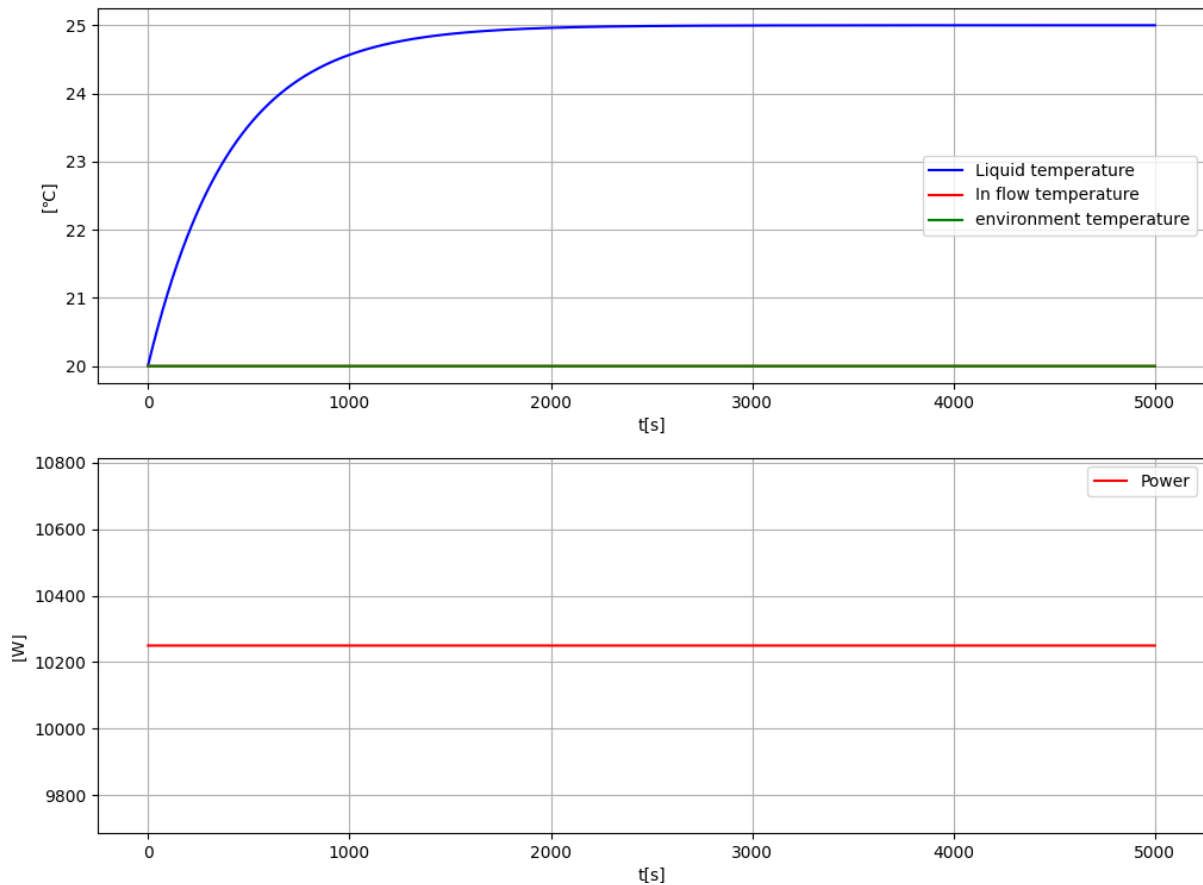


Figure 2-1 Plots showing liquid temperature moving towards a horizontal asymptote at 25°C.

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).

$$\text{time_step}=1, \text{ start_time}=0, \text{ stop_time}=5000, \text{ power}=10_250, \text{ time_delay}=0 \quad (3.1)$$

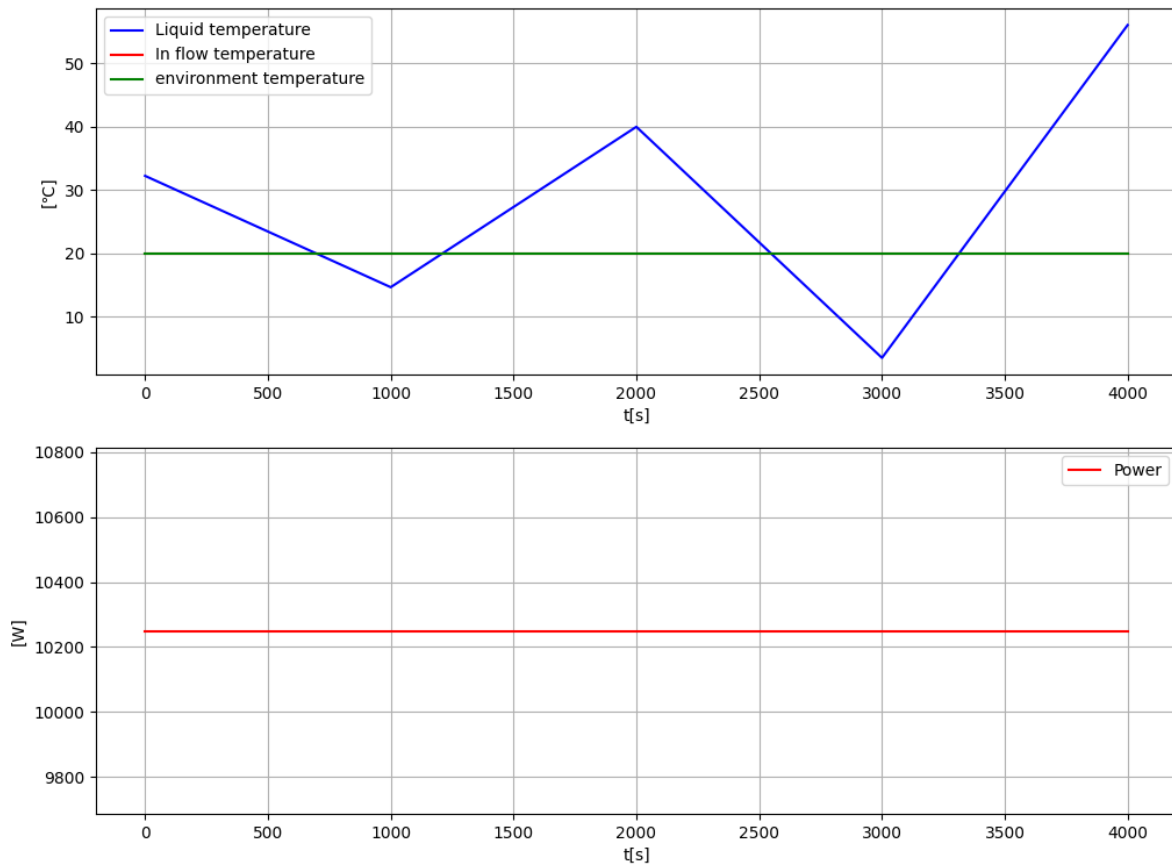


Figure 3-1 Plots showing unstable liquid temperature simulation.

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)

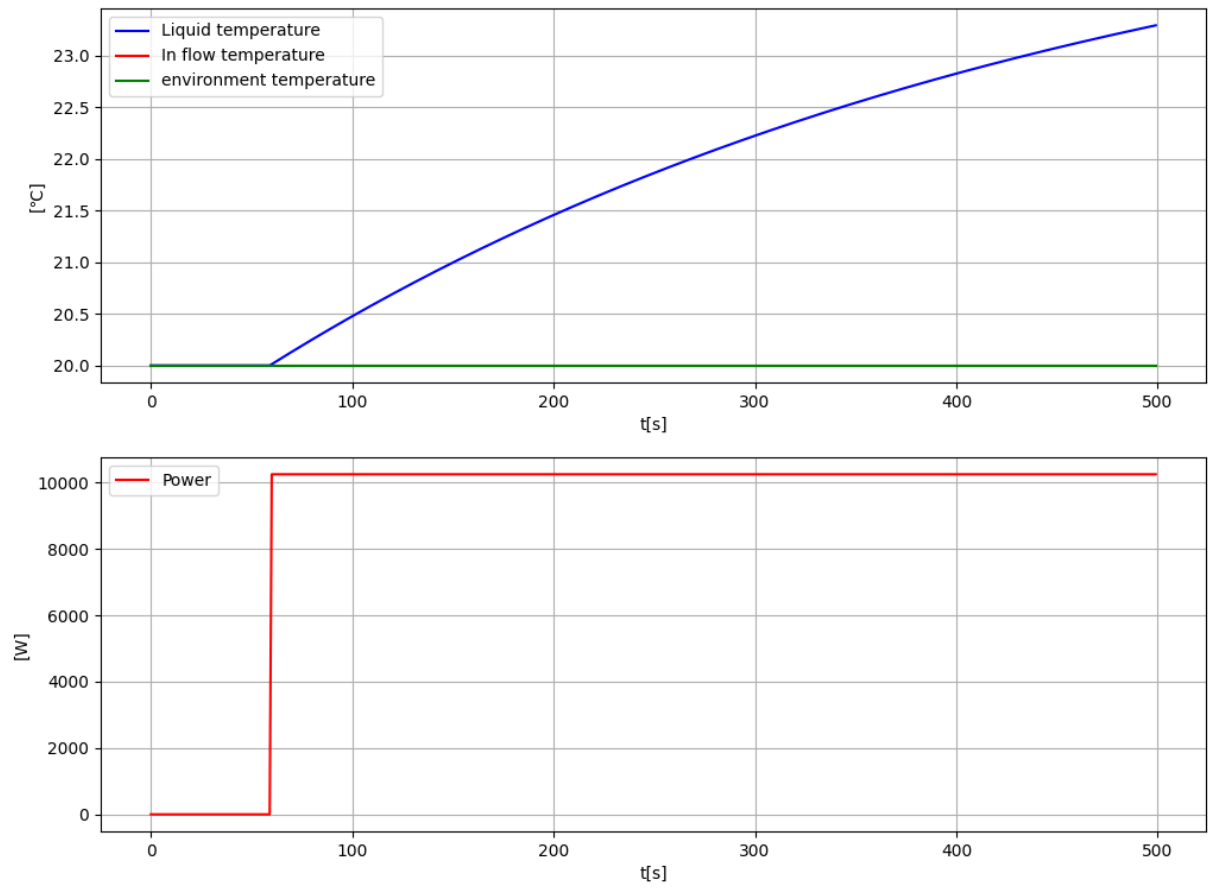


Figure 4-1 Simulation with time delay.