Optimization of energy storage in buildings based on self-optimizing control

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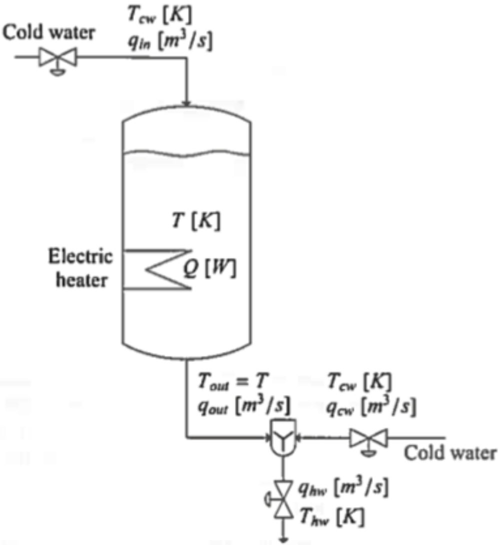
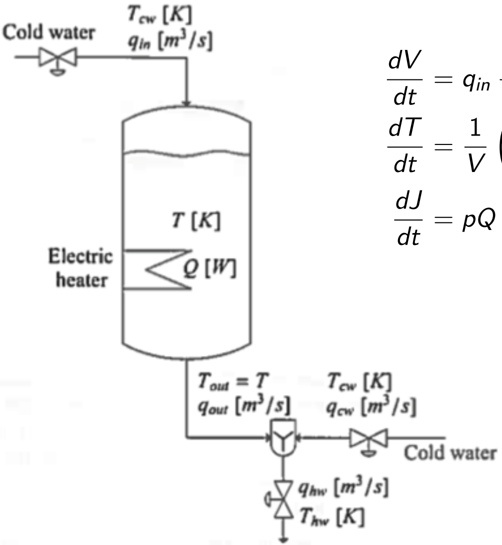
The system


Cold water
T_{cw} [K]
q_{in} [m^3/s]
T [K]
Electric heater
Q [W]
$T_{out} = T$
q_{out} [m^3/s]
T_{cw} [K]
q_{cw} [m^3/s]
Cold water
q_{hw} [m^3/s]
T_{hw} [K]

The system



$$\frac{dV}{dt} = q_{in} - q_{out}$$

$$\frac{dT}{dt} = \frac{1}{V}\left(q_{in}(T_{cw} - T) + \frac{Q - Q_{loss}}{\rho c_p}\right)$$

$$\frac{dJ}{dt} = pQ + p^* Q_{demand}$$

Goal

Find empirical rules for hot water tank heating by comparing with optimized solution of the system

Electricity market

- Prices vary with demand
- Demand depends on time of day, location, weather conditions and time of year
- The varying price means there are possible environmental and monetary savings to optimal operation

Possible advantages

How does this save us money?

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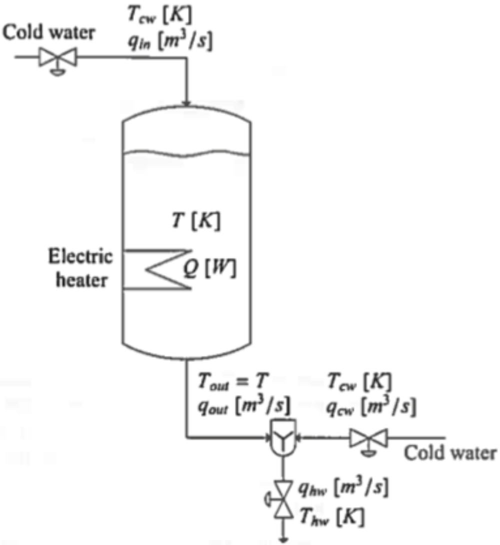
How does this make the world a better place?

- Renewable energy sources will be more profitable.
- Peak demand will decrease.

Milestones

- Model the system in Simulink and Matlab.
- Find optimal set points for the free variable, T_s.
- Compare different procedures with the optimal solution. Try to propose heuristic rules from these.

The system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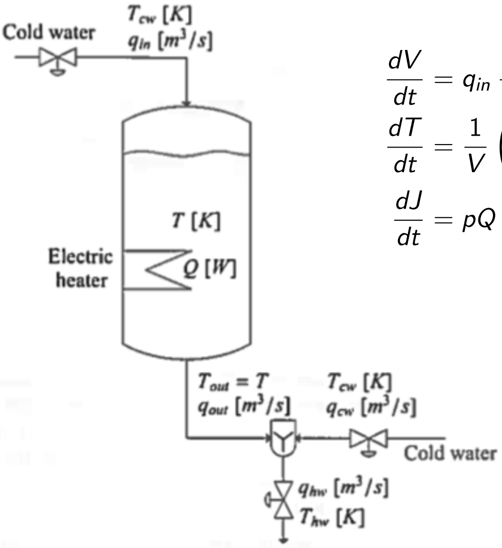

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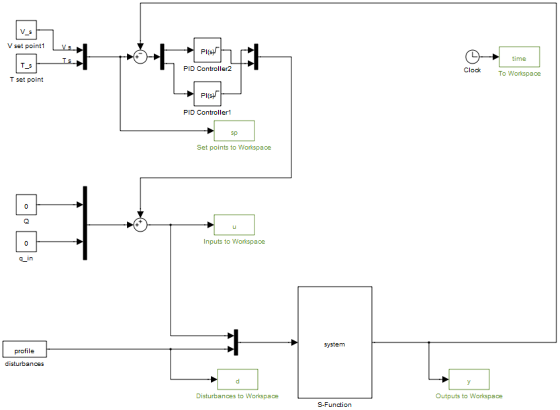
Simulink model



Volume set point

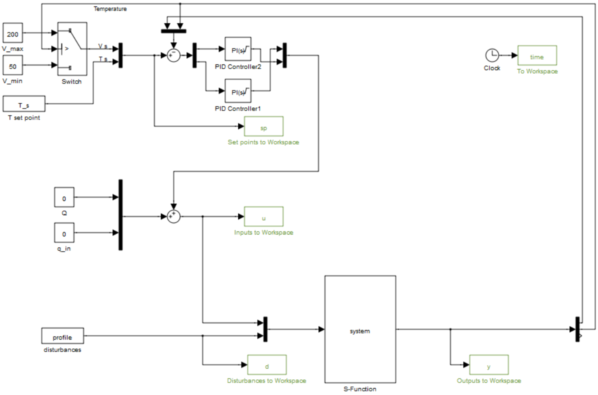
The volume set point for the tank should at optimal operation ensure this behavior:

1. Manipulate q_{in} to keep $V = V_{max}$ while $T > T_{hw,s}$
2. Set $q_{in} = 0$ while $T = T_{hw,s}$ and $V > V_{min}$
3. Manipulate q_{in} to keep $V = V_{min}$ while $T < T_{hw,s}$

Volume set point

- if $T \leq T_{hw,s}$: $V_s = V_{min}$
- else $V_s = V_{max}$

Simulink model with switch



Matlab input

Disturbances:

- The demand profile, q_{out} are generated in Matlab, using a script written by Vinicius.
- The price profile, p, are taken from Nordpols hourly database.
- The cold water temperature, T_{cw}, and the hot water set point, $T_{hw,s}$, are both assumed constant.

Optimized variable:

- Temperature set point, T_s.

Optimization

Our goal is to minimize the cost function J by changing the temperature set point.

Brute force optimization

Pros	**Cons**
Always finds correct solution	Inefficient
Reliable	Slow
Works for all problems	

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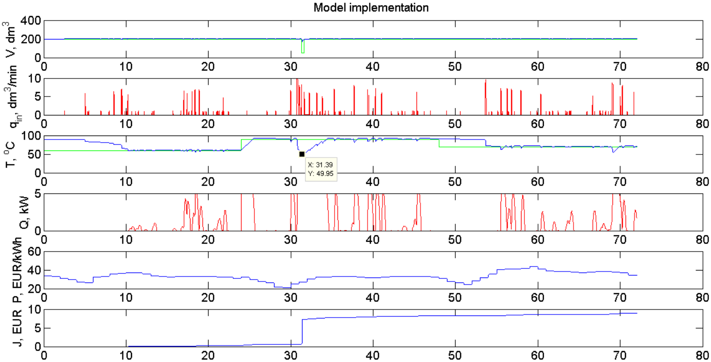
- With large sets of temperature set points. Brute force optimization does not calculate the solution within a reasonable time frame.
- Generating to large matrices containing temperature set points might cause Matlab to shut down.
- The main issue is that each simulation takes a long time

System behavior



Solution?

Use a method of optimization that does not require simulation.

Conclusions

- Both environmental and economical advantages to hot water energy storage.
- The optimal way of achieving this is not yet determined.