Heat and Cold Energy Demands of Buildings

Module 2.5
Substation and control

SHaKE – Sharing Heat and Knowledge on Energy Communities
Erasmus+ KA220-HED Cooperation Partnerships in HE
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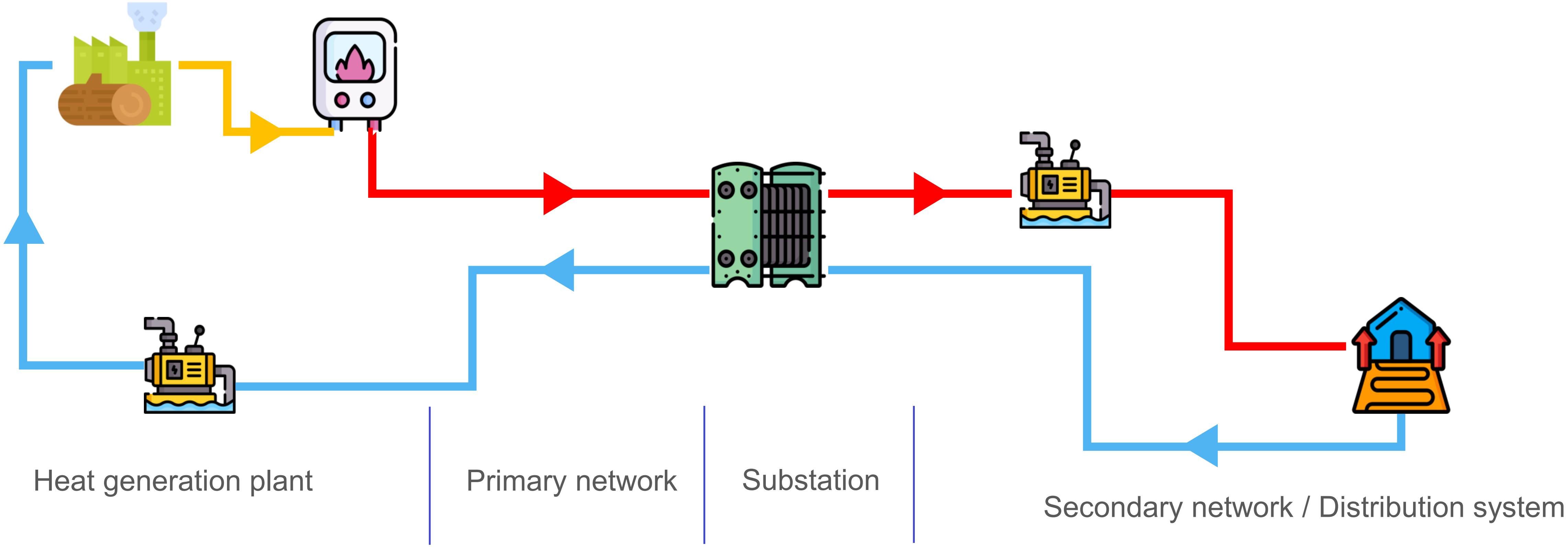
SHaKE
Sharing Knowledge on Energy Communities

1. Introduction

Once the consumption of the buildings is determined and the secondary network is sized, it is necessary to choose and size the substation



2. Substation components

The substation is the element at the interface between the primary and secondary networks. It enables the two sides of a heating network to be hydraulically separated. It is also the place where the energy use is calculated

A substation is composed of one or several:

Plate heat exchanger

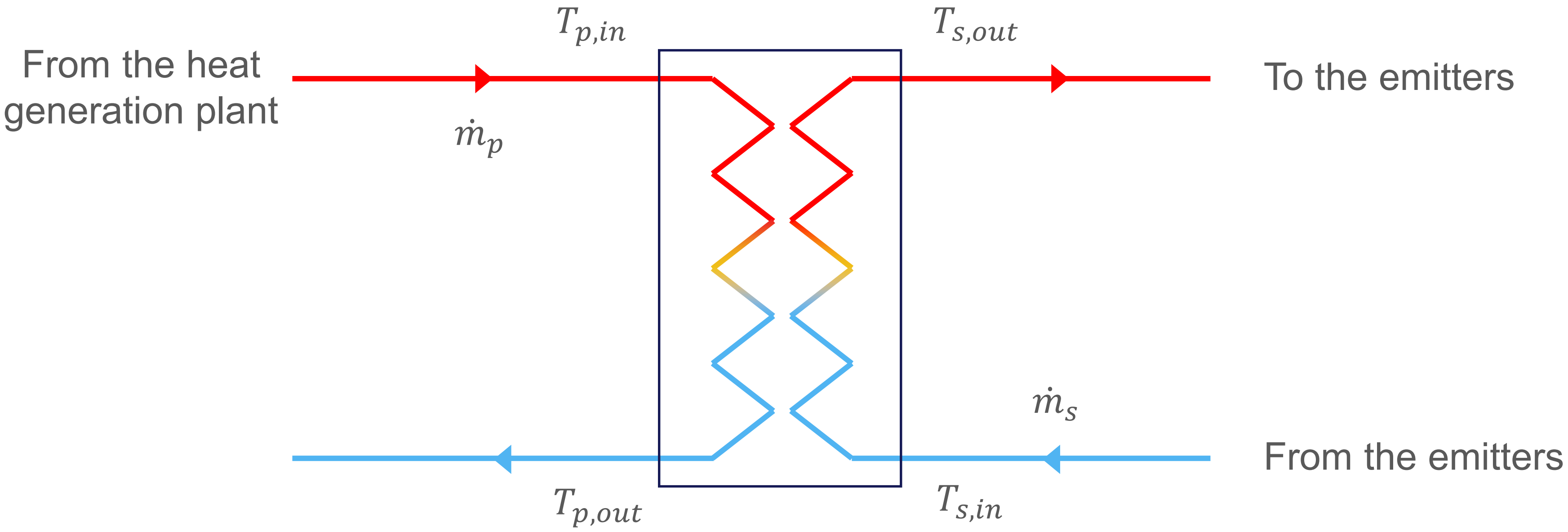
Control valve

Sensors & controller

Heat meters

2. Substation components

Plate heat exchanger



The plate heat exchanger is the most important element of the substation. It allows to separate and to enable the heat transfer between the primary and secondary side

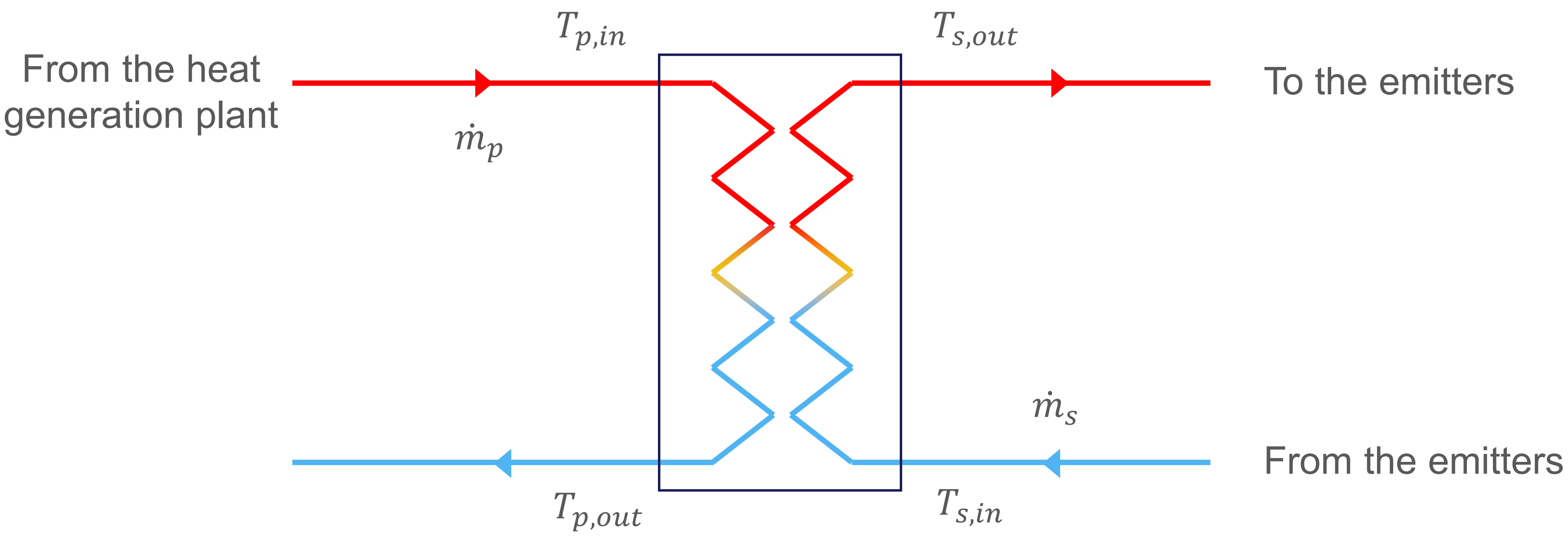
$$\dot{Q} = \dot{m}_s Cp\left(T_{s,out} - T_{s,in}\right)$$

$$\dot{Q} = \dot{m}_p Cp\left(T_{p,in} - T_{p,out}\right)$$

$$E = \frac{\dot{Q}}{\min\left(\dot{m}_p Cp;\ \dot{m}_s Cp\right)\left(T_{p,in} - T_{s,in}\right)}$$

2. Substation components

Plate heat exchanger



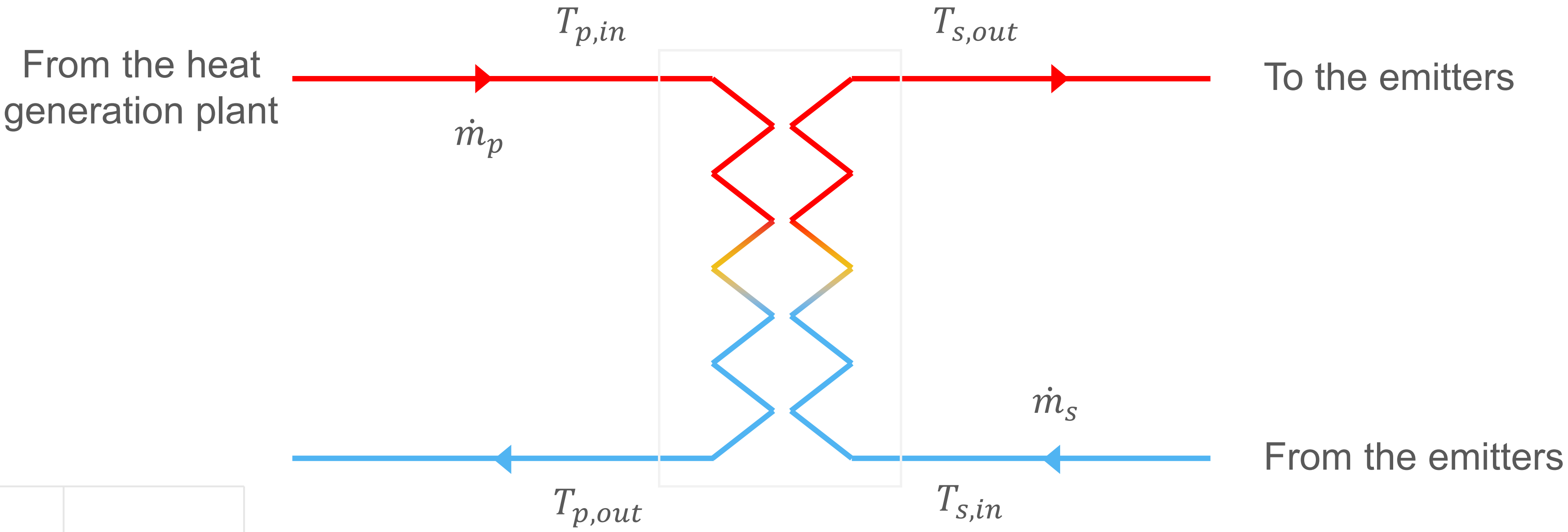
To ensure the best DHN performance the primary return temperature must be as low as possible. Hence, the pinch of the HEX must be the lowest possible

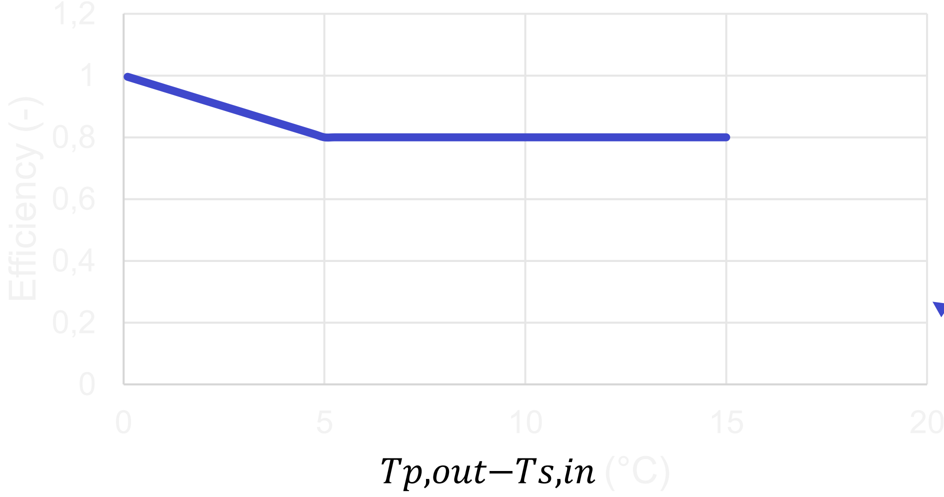
We want $Pinch = \Delta T_{min} = T_{p,out} - T_{s,in} < 1°C$

If $T_{p,in} - T_{s,out} > 1\,°C \rightarrow \dot{m}_p < \dot{m}_s \;\; for\ P = cst$

2. Substation components

Plate heat exchanger



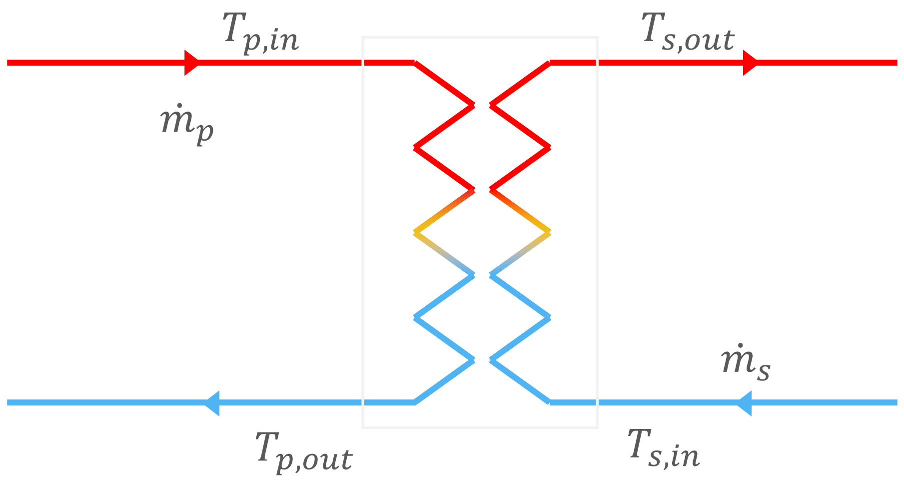


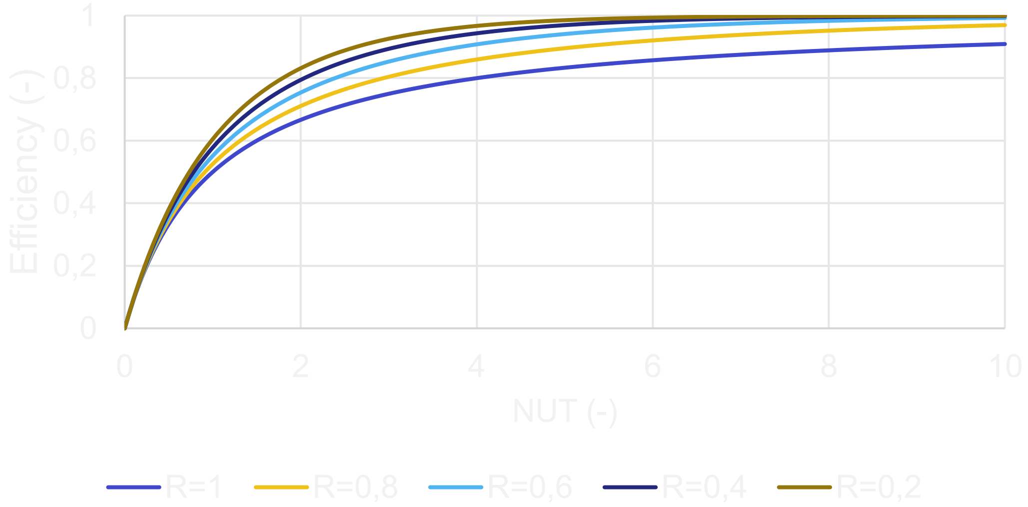
We want $\dot{m}_p < \dot{m}_s$ to have the pinch at the primary outlet

And we want $Pinch = \Delta T_{min} = T_{p,out} - T_{s,in} < 1°C$

For $T_{p,in} = 85°C, T_{s,out} = 80°C, T_{s,in} = 60°C, \dot{Q} = cst, \dot{m}_s = \text{cst}$

2. Substation components





$$\dot{Q} = UA\,\Delta TLM = UA\,\frac{T_a - T_b}{\ln(T_a/T_b)}$$

$$T_a = \max\left(T_{p,in} - T_{s,out}; T_{p,out} - T_{s,in}\right)$$

$$T_b = \min\left(T_{p,in} - T_{s,out}; T_{p,out} - T_{s,in}\right)$$

$$R = \frac{\min\left(Cp\,\dot{m}_p\,;Cp\,\dot{m}_s\right)}{\max\left(Cp\,\dot{m}_p\,;Cp\,\dot{m}_s\right)} \qquad NUT = \frac{UA}{\min\left(Cp\,\dot{m}_p\,;Cp\,\dot{m}_s\right)}$$

$$E = \frac{1 - \exp((R-1)NUT)}{1 - \mathrm{R}\exp((R-1)NUT}$$

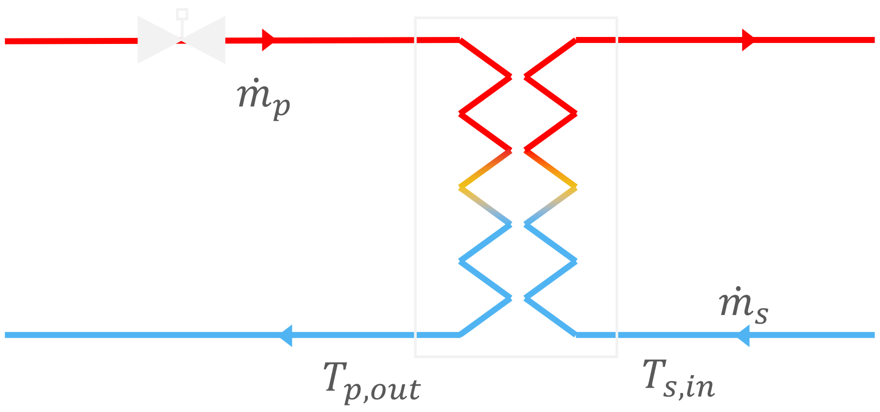
For a counterflow HEX

Increasing the HEX area at constant NUT, lower the pinch and so increase the HEX and DHN efficiency. But the more the HEX is large the more it costs

2. Substation components

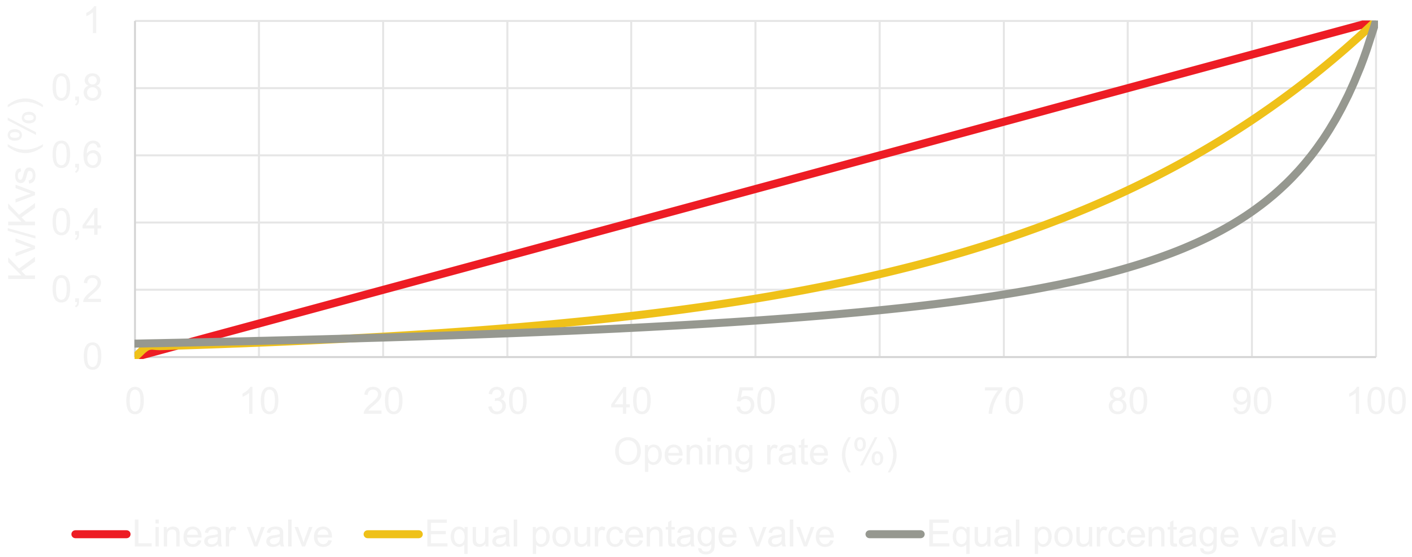
Control valve

From the heat generation plant



To the emitters

From the emitters

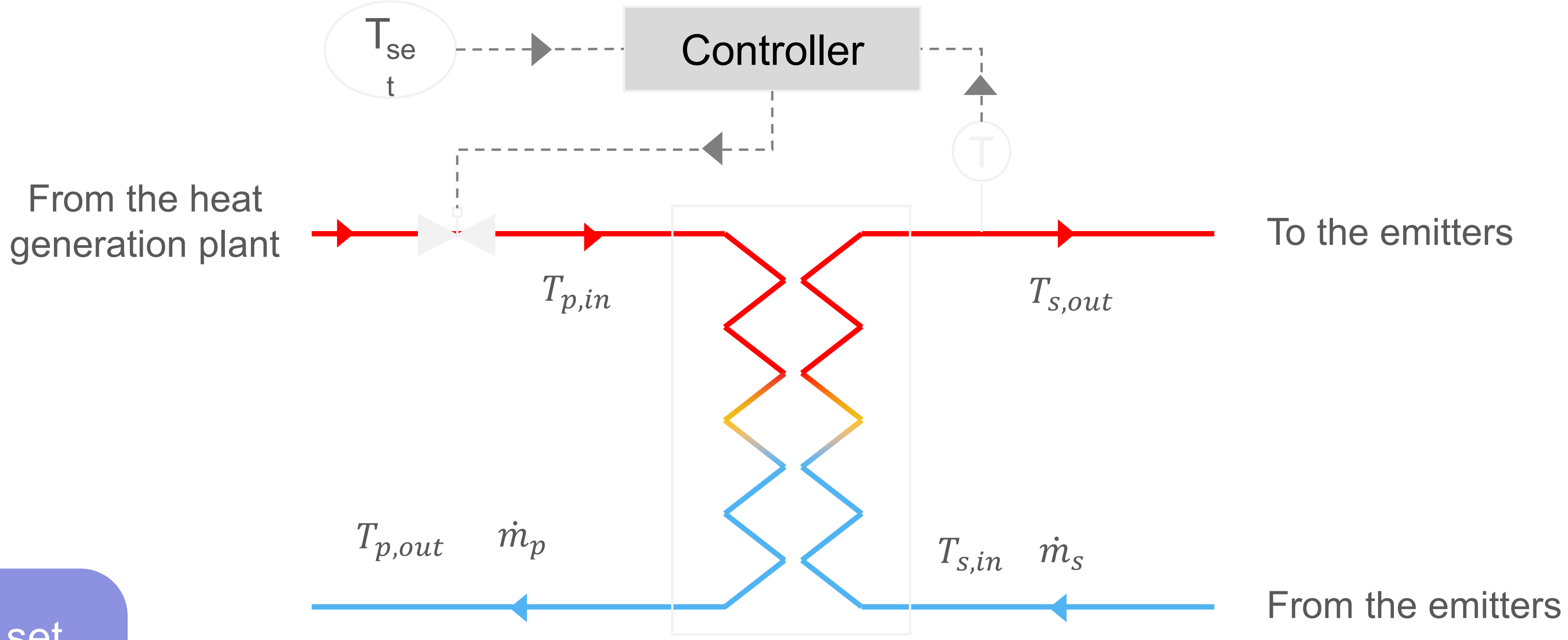


The control valve allows to control the mass flow rate through the primary side. It must be coupled with a sensor and a controller

2. Substation components

Sensors & controller

The controller compares the set point temperature to the measured one and sends an opening signal to the valve



$$T_{set} = a\,T_{ext} + b \qquad a = \frac{T_{emitters,max} - T_{ext,unheated+}}{T_{ext,min} - T_{ext,unheated}}$$

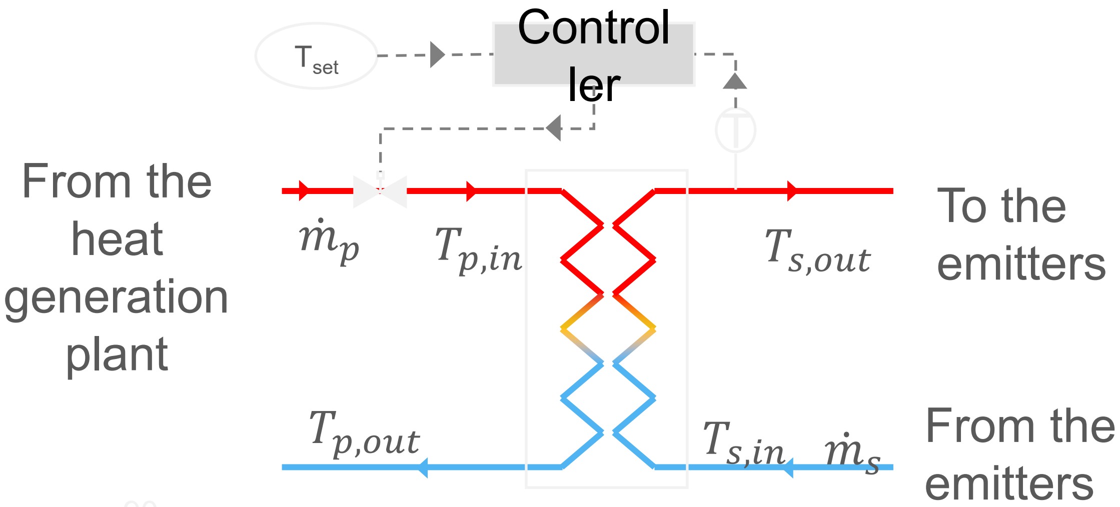
$$For \quad T_{ext} = T_{ext,min} \Longrightarrow T_{set} = T_{emitters,max}$$

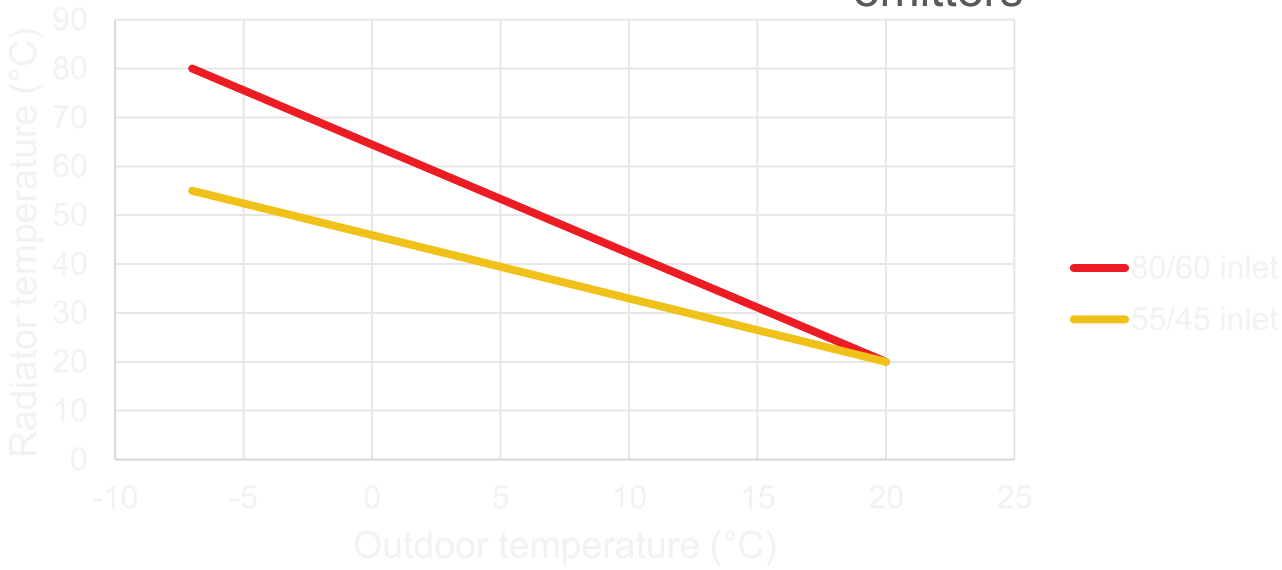
$$For \quad T_{ext} = T_{ext,unheated} \Longrightarrow T_{set} = T_{ext,unheated+}$$

2. Substation components

Sensors & controller

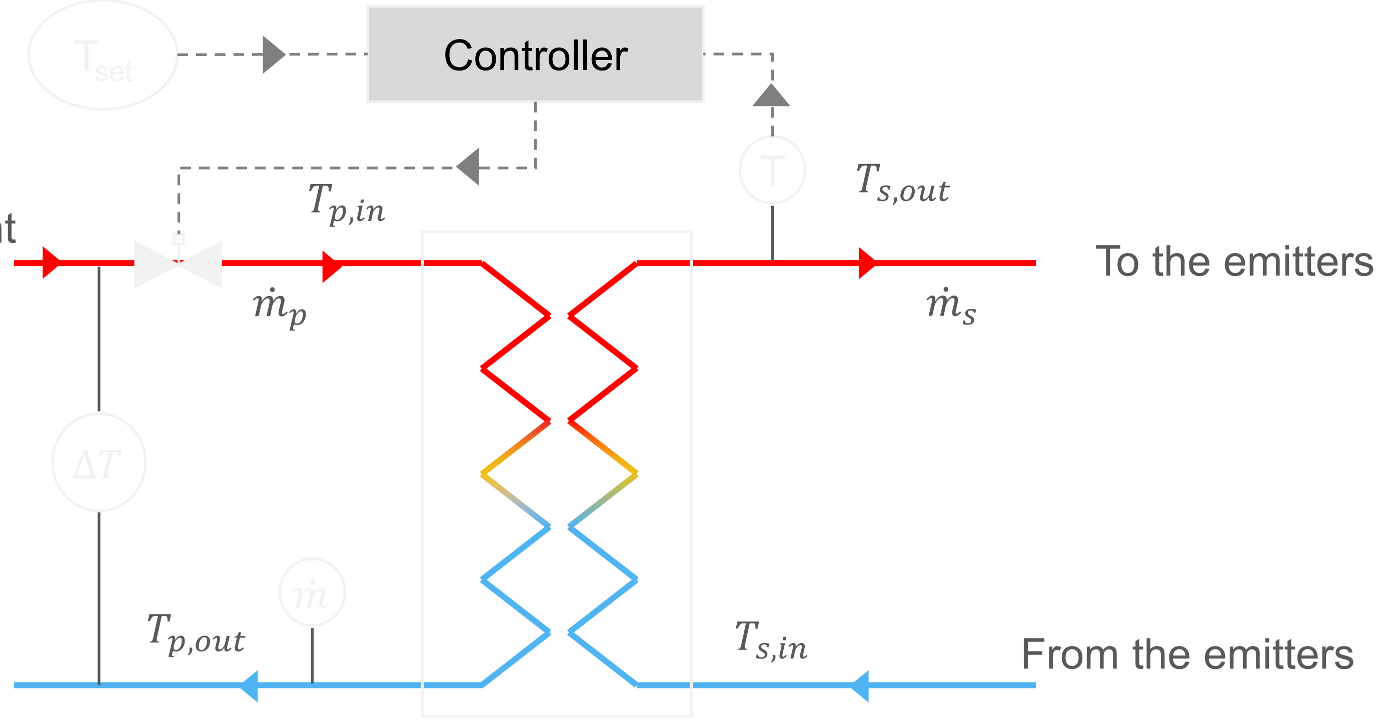
The controller compares the set point temperature to the measured one and sends an opening signal to the valve





2. Substation components

Heat meters



The heat meter measures the supply and return temperatures and the flow rate at the primary side to calculate the energy consumed by the SST

Norm EN 1434

$$Q = \int_0^V \rho Cp\, \Delta T\, dV$$

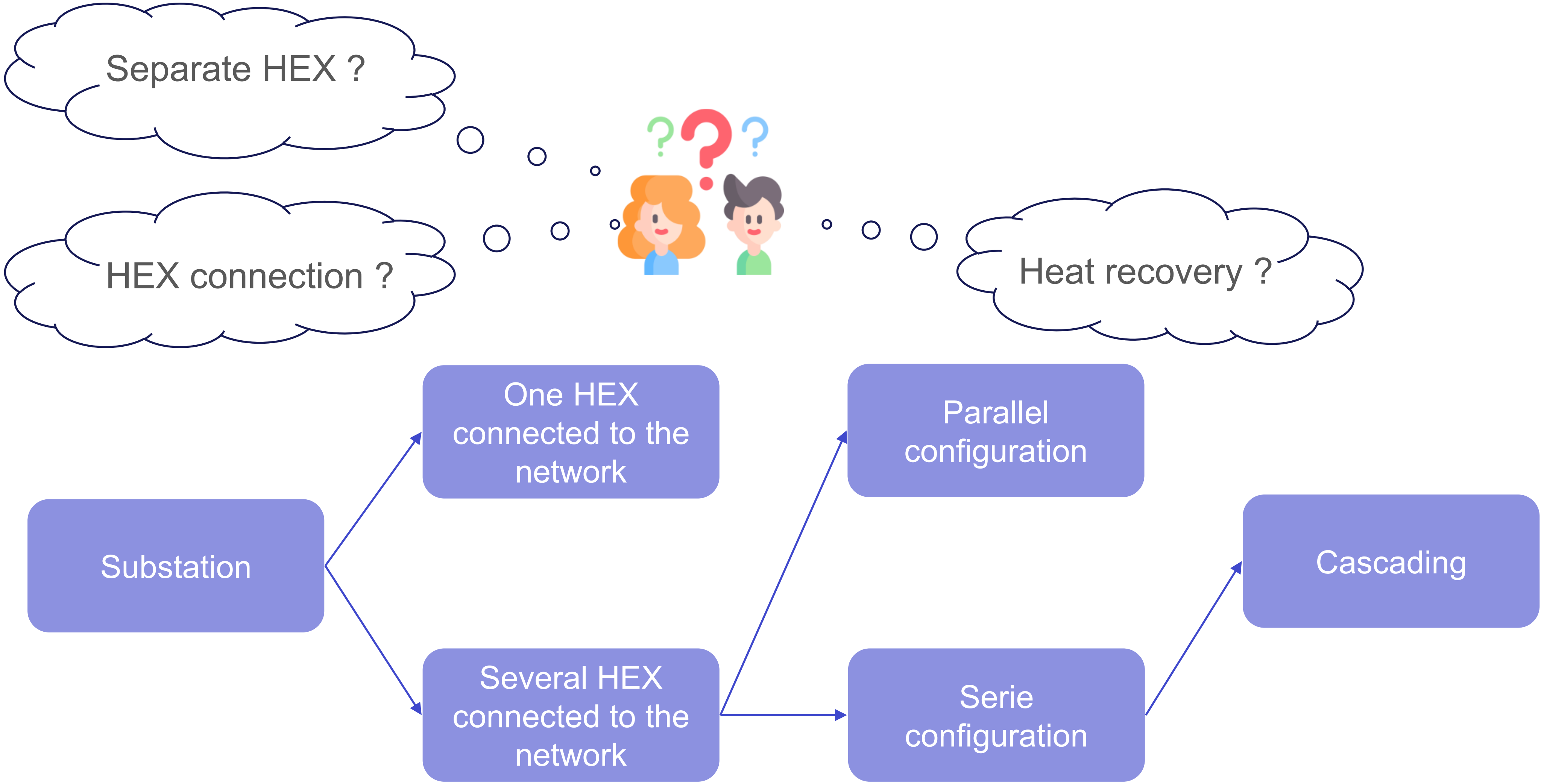
Uncertainty on flow rate

$$E_f = \pm\left(2 + 0{,}02\,\frac{q_{max}}{q}\right)$$

$$E_t = \pm\left(0{,}5 + 3\,\frac{\Delta T_{min}}{\Delta T}\right)$$

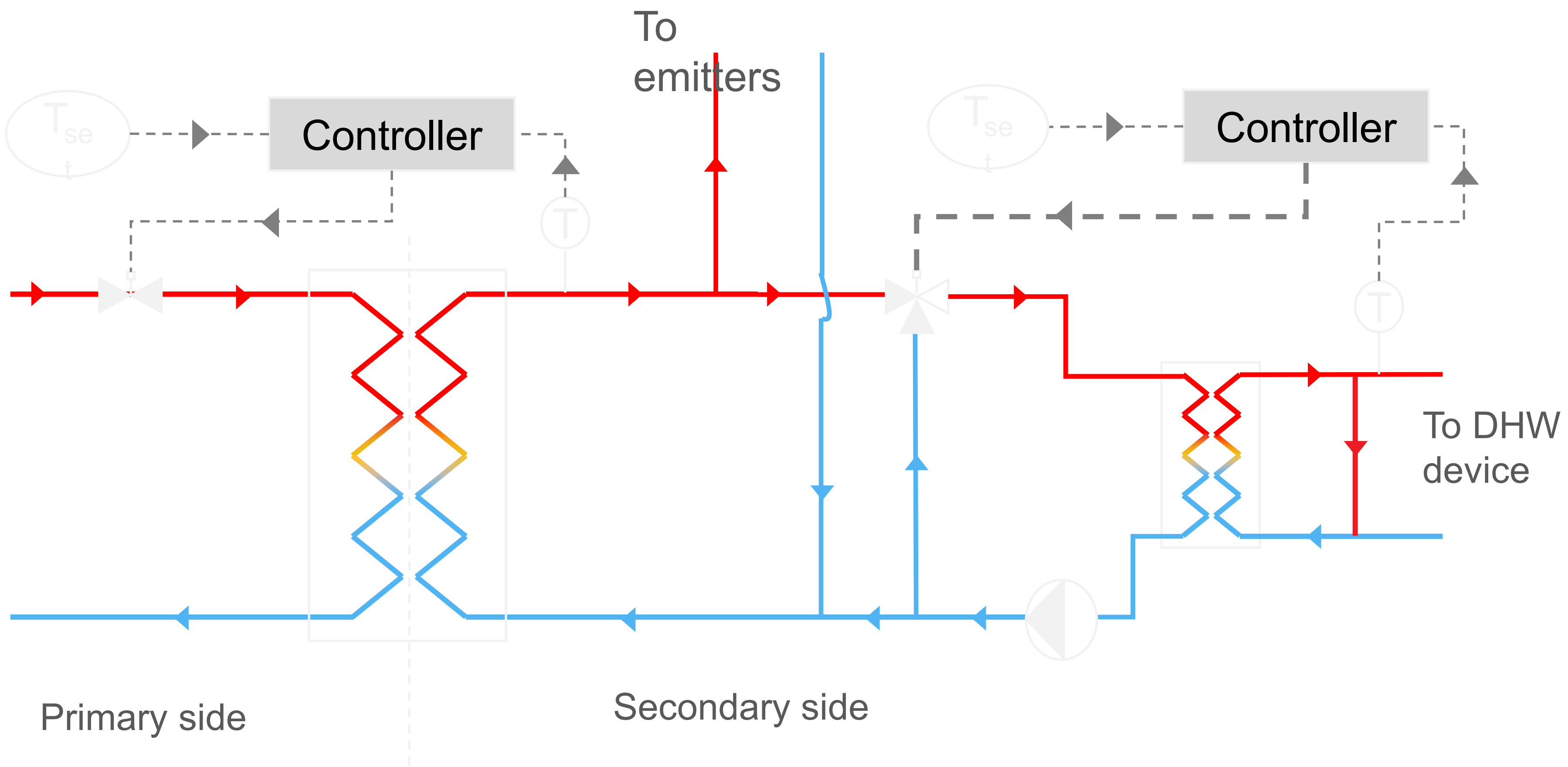
Uncertainty on temperature difference

2. Substation components

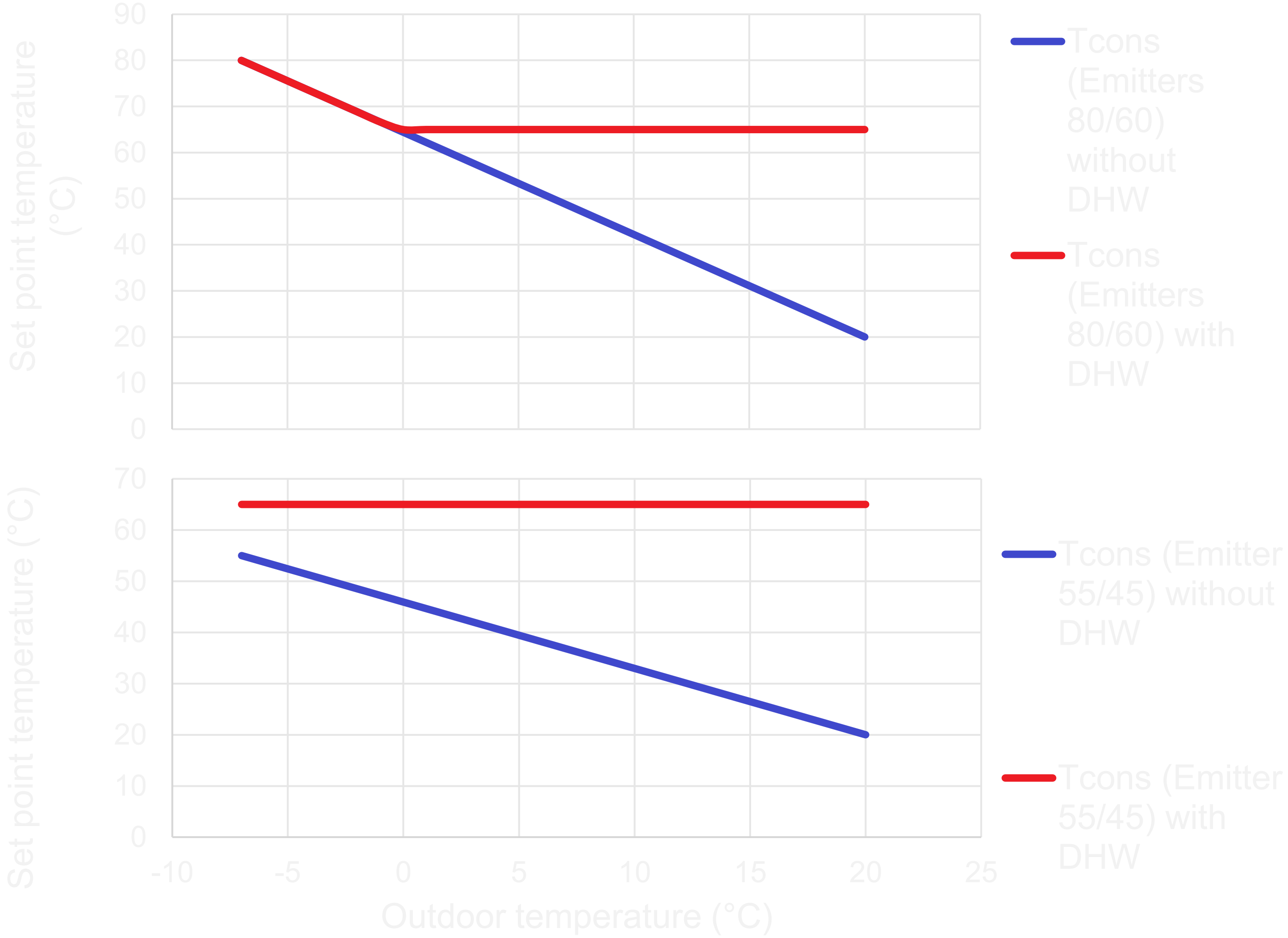


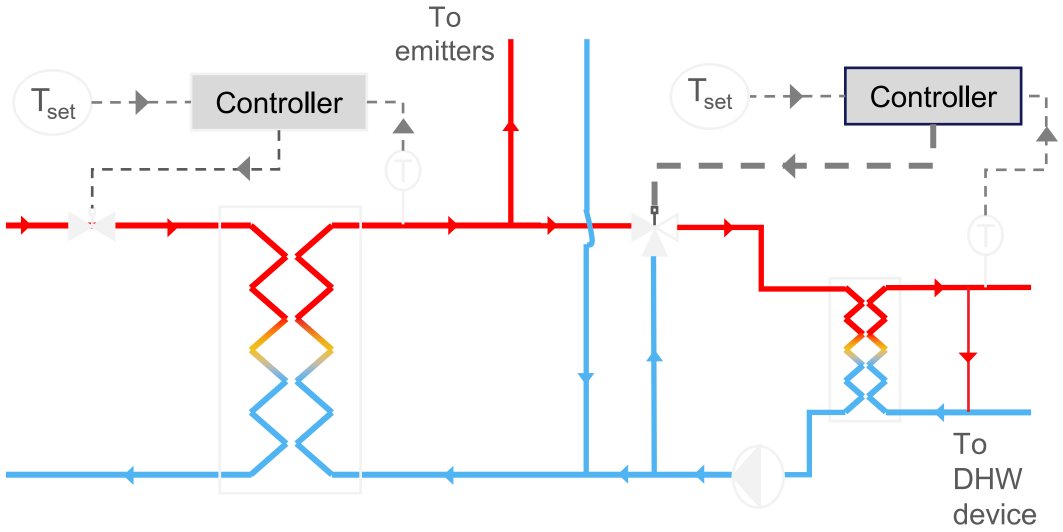
2. Substation components

One heat exchanger configuration



2. Substation components



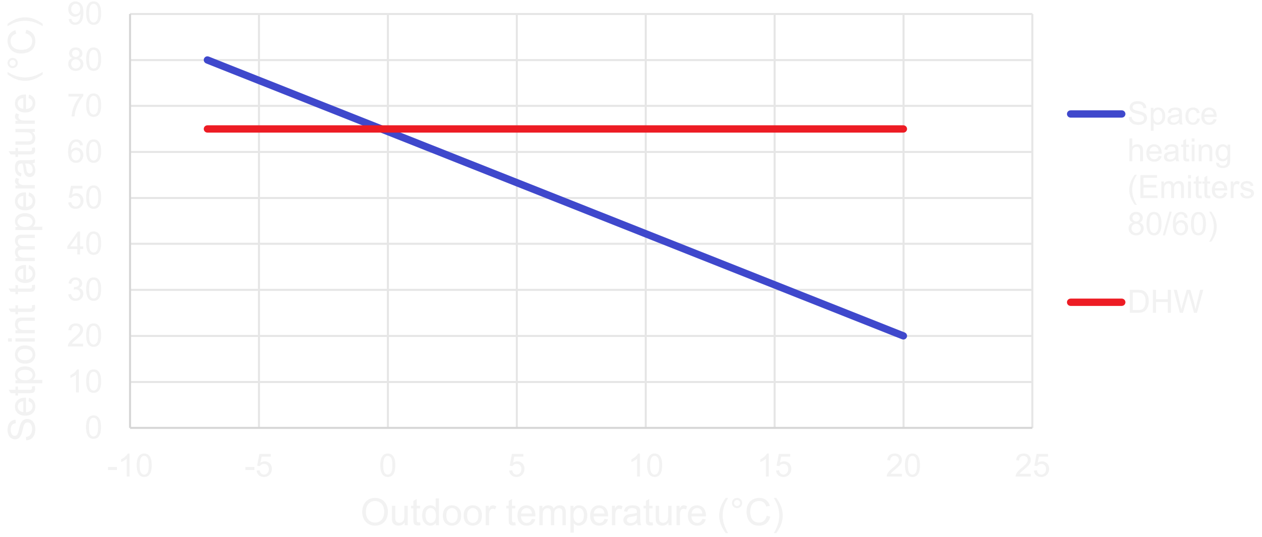


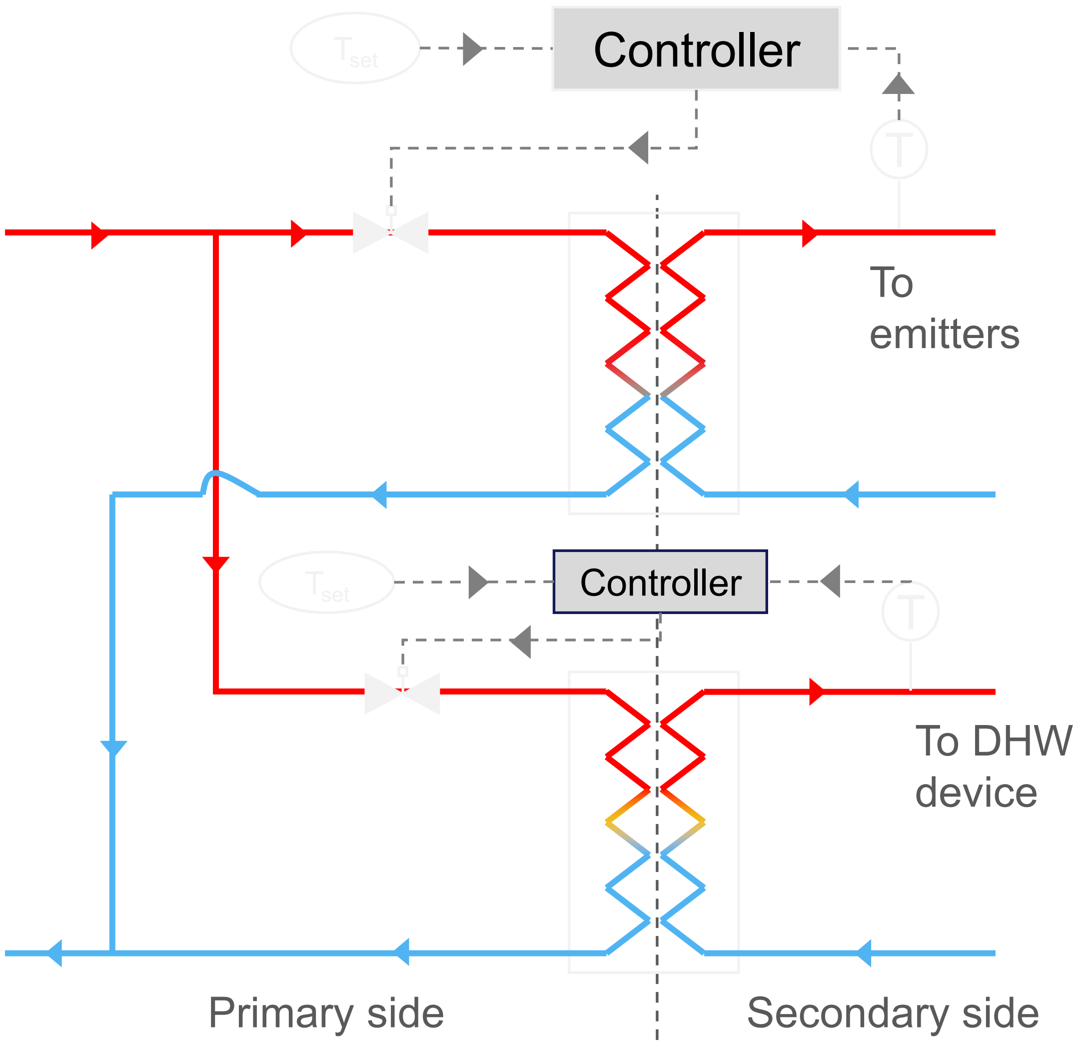
- Only one HEX connected directly to the networks
- Set point temperature must be superior to 60°C to supply DHW
- Secondary supply and return temperatures are high

2. Substation components

Parallel configuration

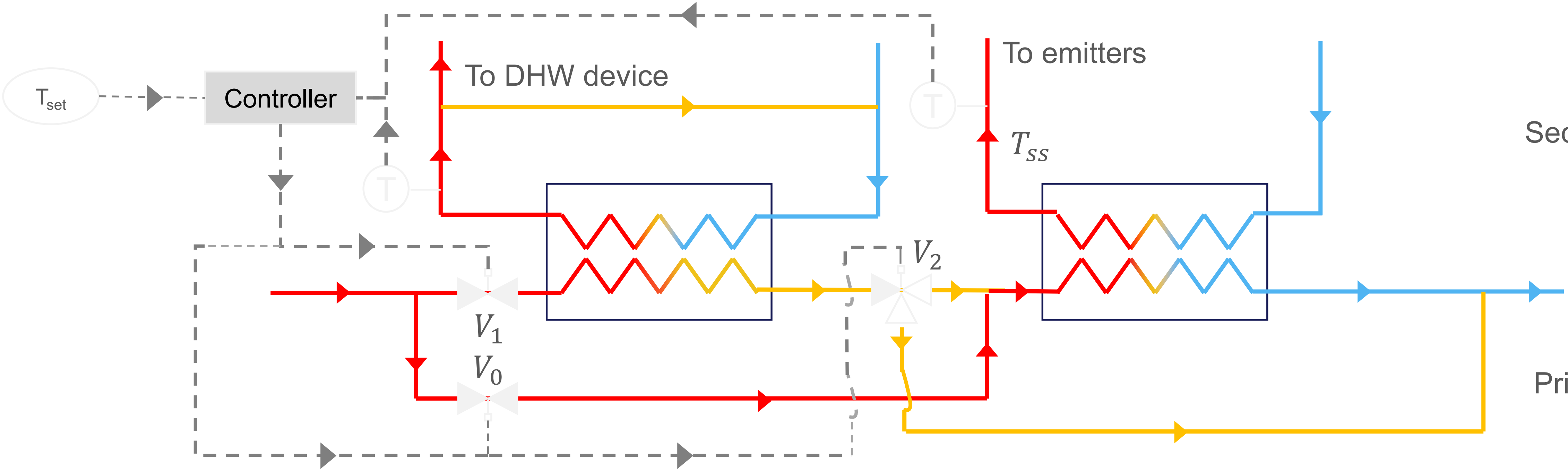
- Two HEX connected directly to the networks, one for the space heating and one for the DHW
- Set point temperature must be superior to 60°C to supply DHW
- Simple control and installation





2. Substation components

Serie configuration

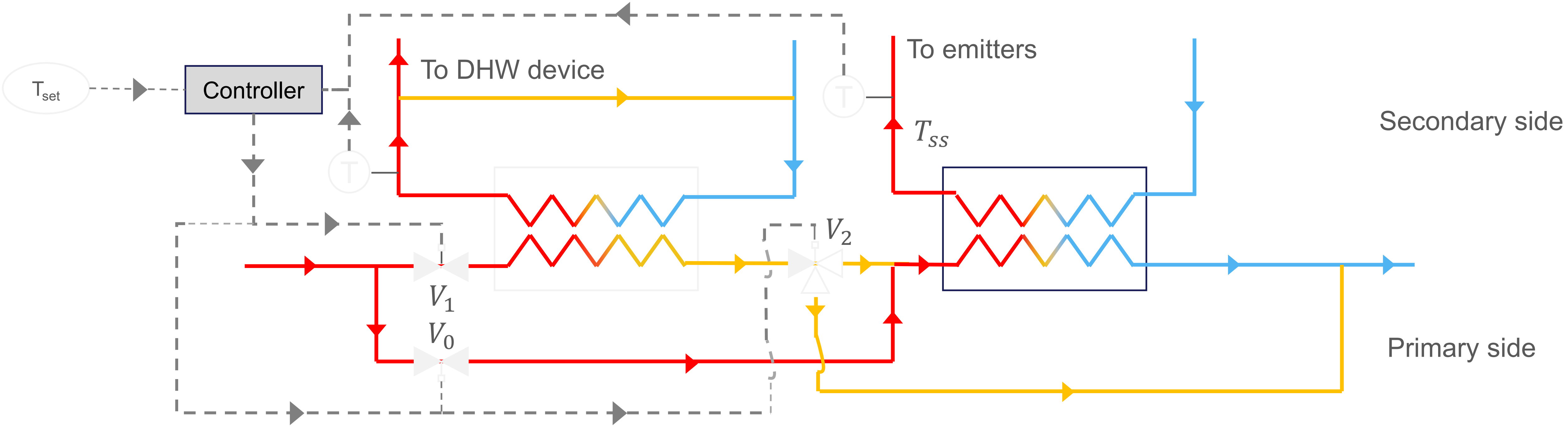


$If\ T_{ss} < T_{ss,set}\ firstly\ V_2\ opens\ and\ after\ V_0\ opens$

$If\ T_{ss} > T_{ss,set}\ firstly\ V_0\ closed\ and\ after\ V_2\ closed$

2. Substation components

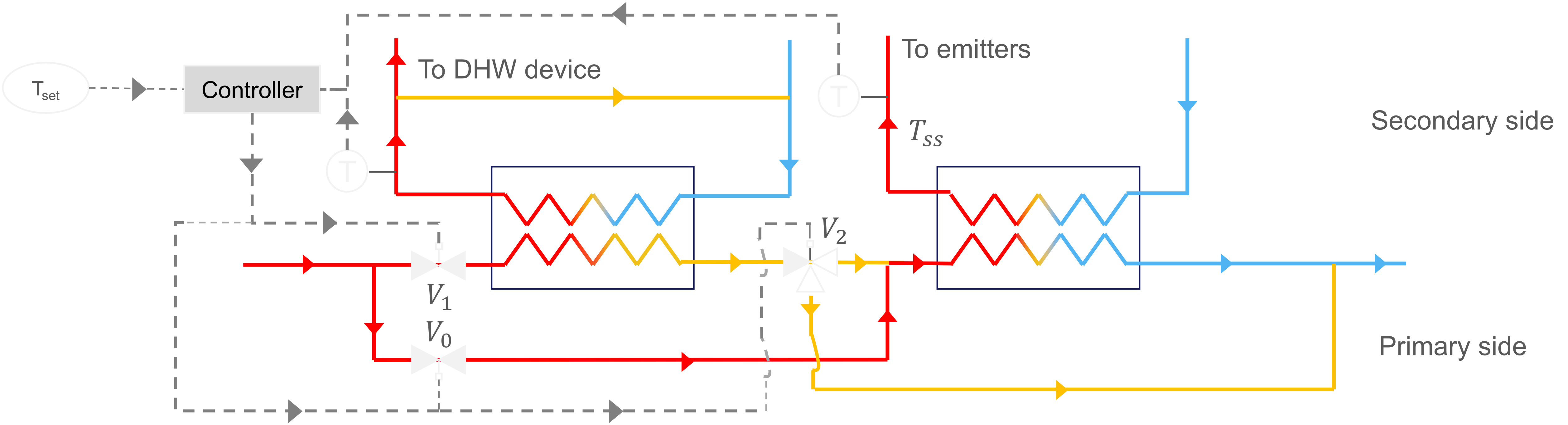
Serie configuration



$If\ T_{ss} < T_{ss,set}\ firstly\ V_2\ opens\ and\ after\ V_0\ opens$ $If\ T_{ss} > T_{ss,set}\ firstly\ V_0\ closed\ and\ after\ V_2\ closed$

2. Substation components

Serie configuration



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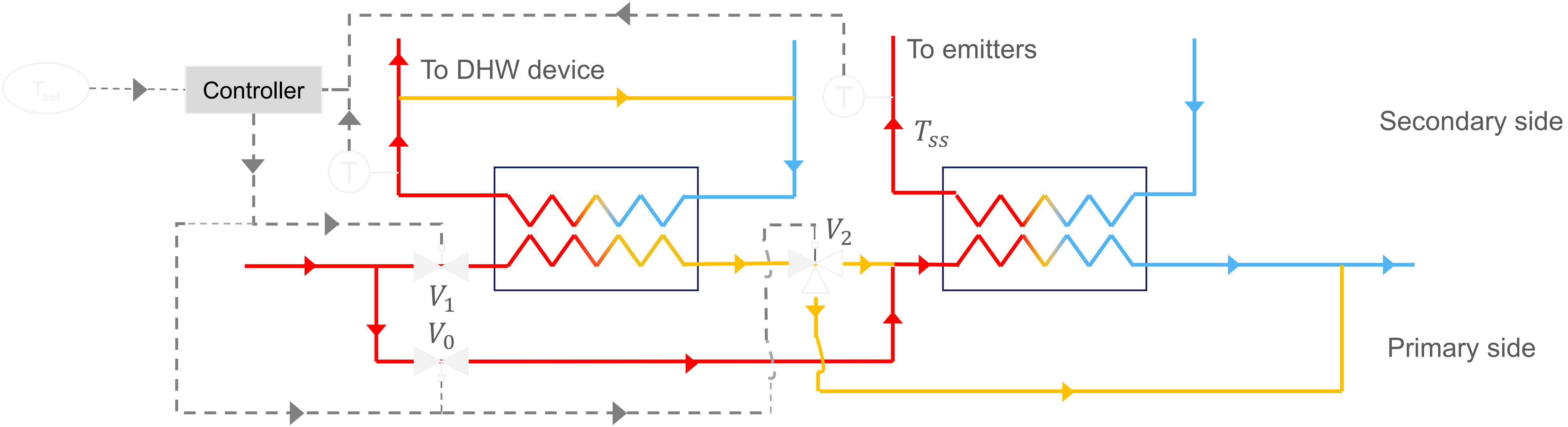
2. Substation components

Serie configuration

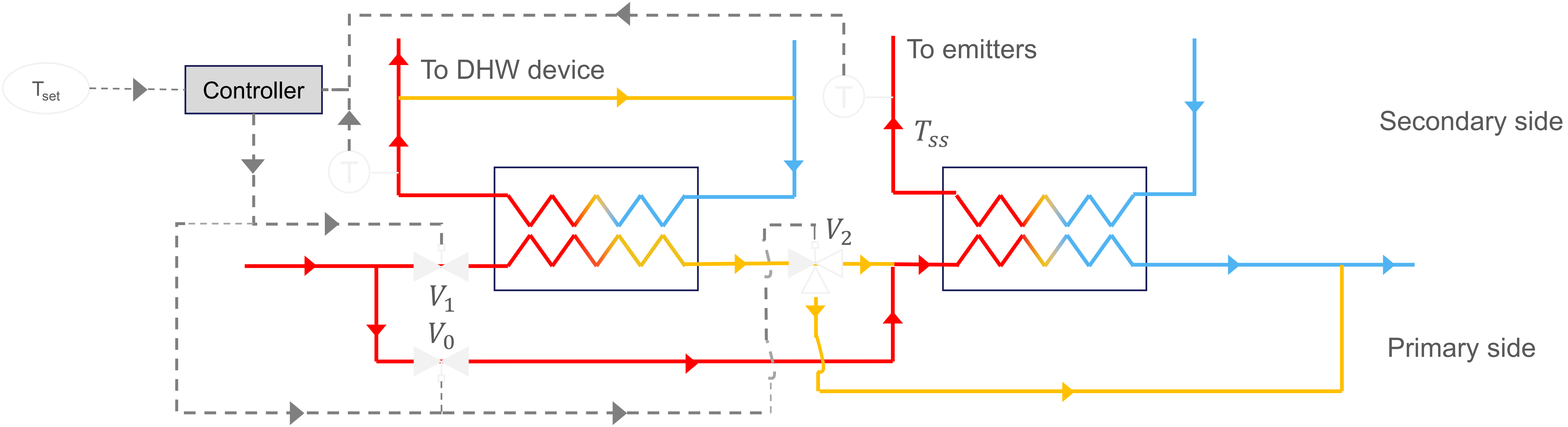


$If\ \ T_{ss} < \ T_{ss,set}\ \ firstly\ \ V_2\ \ opens\ \ and\ \ after\ \ V_0\ opens$

$If\ \ T_{ss}\ >\ T_{ss,set}\ \ firstly\ \ V_0\ \ closed\ \ and\ \ after\ V_2\ closed$

2. Substation components

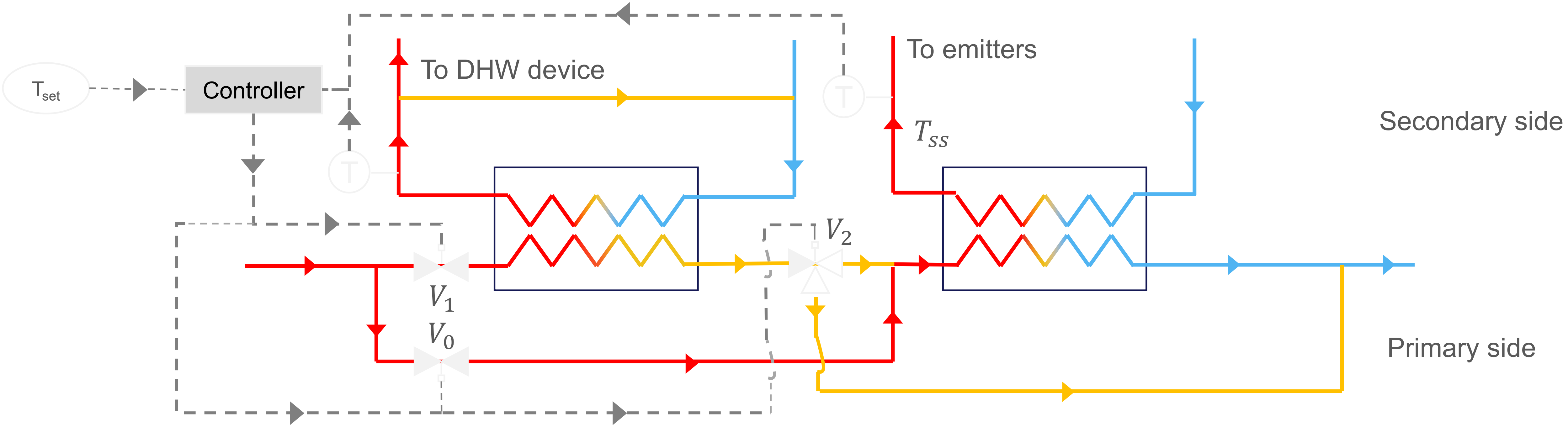
Serie configuration



If there is only a space heating demand → V_1 *is fully closed* $\Longrightarrow$ V_0 *opens*

2. Substation components

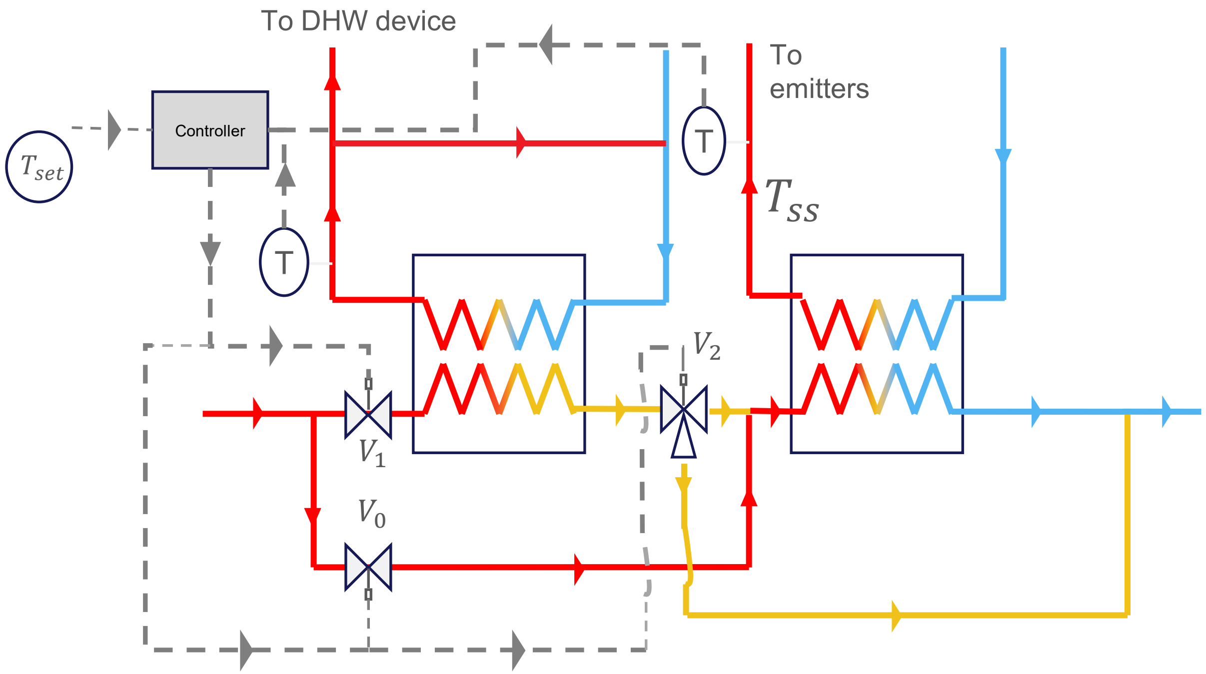
Serie configuration



If there is only a DHW demand → V_0 & V_2 $is\ fully\ closed \implies V_1\ opens$

2. Substation components

Serie configuration

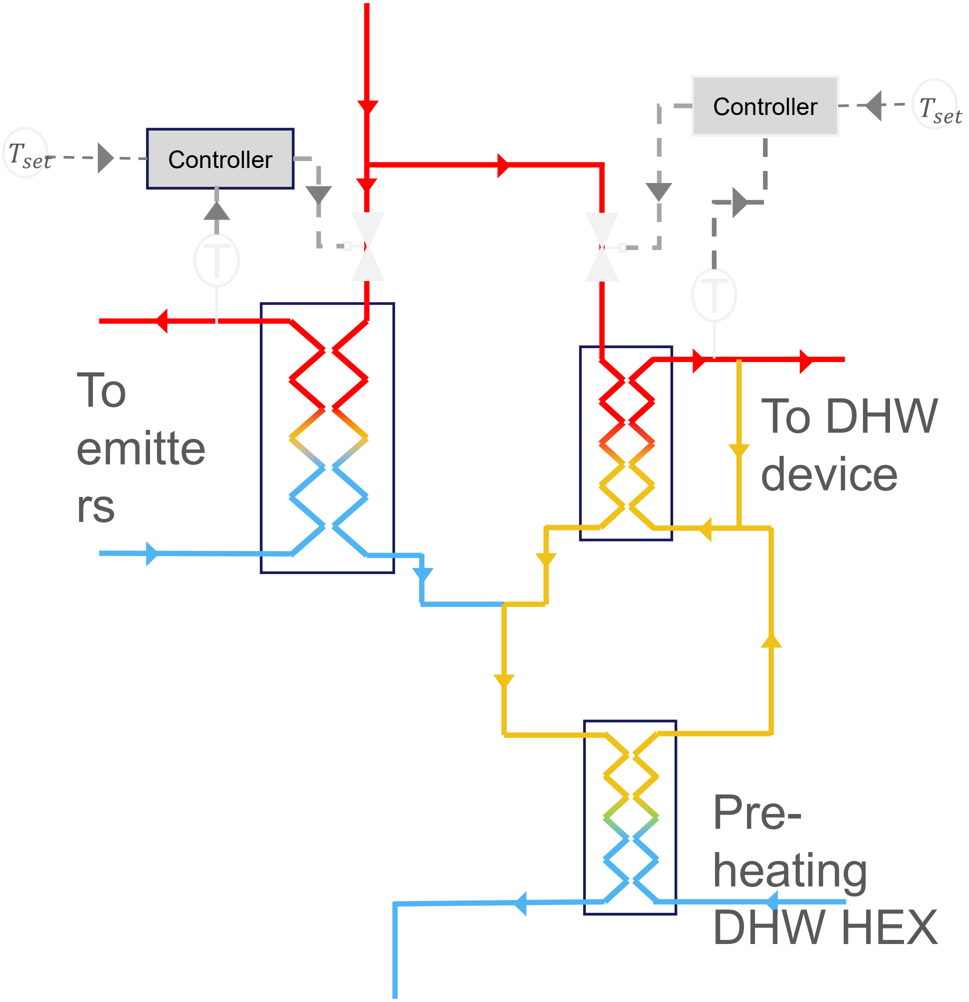


- Two HEX connected directly to the network, one for the space heating and one for the DHW
- Set point temperature must be superior to 60°C to supply DHW
- More complex control
- Not common, mostly used when space heating emitters operate at low temperature (ie 55/45 or less)

2. Substation components

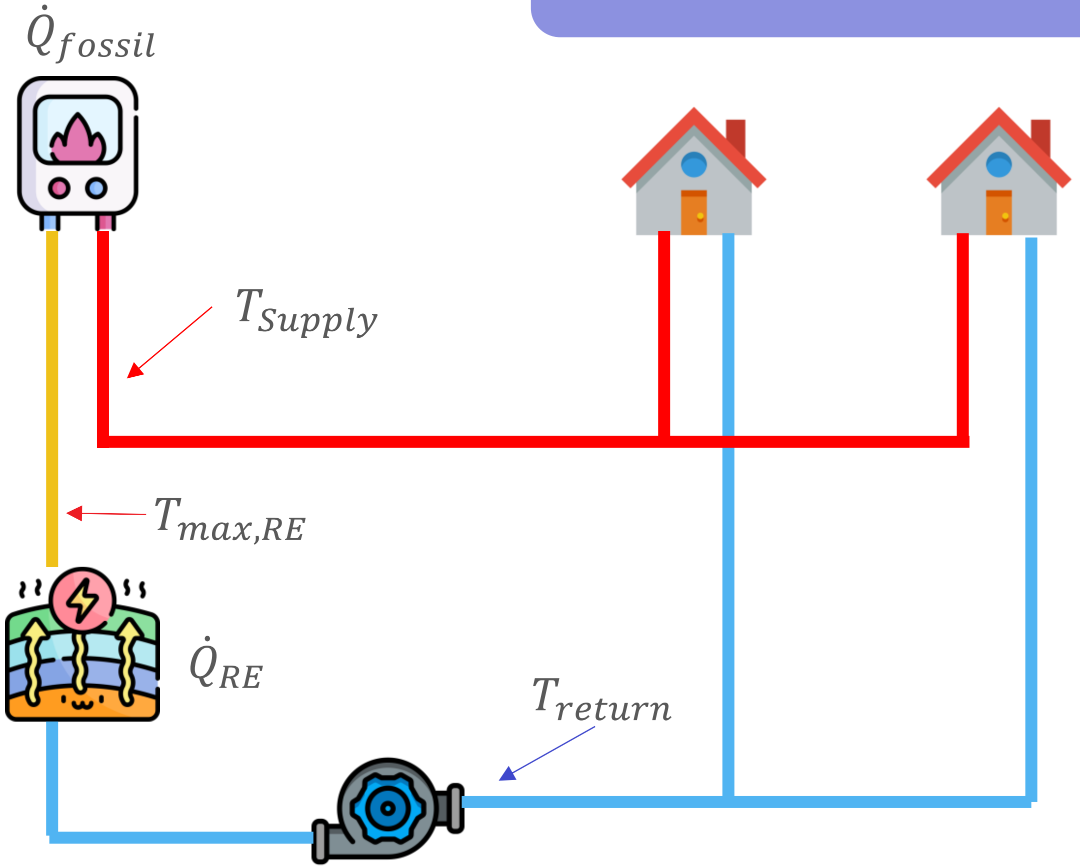
2-stage configuration

- Two HEX connected directly to the supply networks, one for the space heating and one for the DHW
- A third HEX for the preheating of the DHW using the primary return of the space heating and DHW HEX
- Set point temperature must be superior to 60°C to supply DHW
- Easy control
- More efficient than the parallel configuration but more expensive.
- Parallel configuration is often preferred



3. Conclusion

What is the objective of the different configurations?



Reducing the return temperature

$$\dot{Q} = \dot{Q}_{fossil} + \dot{Q}_{RE}$$

$$\dot{Q} = \dot{m}\, Cp\left(T_{Supply} - T_{max,RE} + T_{max,RE} - T_{return}\right)$$

This also allows to:

- Reducing the thermal losses through the pipes
- Reducing the pump consumption
- Increasing the RE heat production from low temperature energy sources

3. Conclusion

What is the objective of the different configurations?

Reducing the return temperature

$$\dot{Q} = \dot{Q}_{fossil} + \dot{Q}_{RE}$$

$$\dot{Q} = \dot{m}\, Cp\, (T_{Supply} - T_{max,RE} + T_{max,RE} - T_{return})$$

	Performanc e	Price	Complexit y
1 HEX	--	+	0
Parallel	+	+	+
Serie	-	-	--
Cascading (2 stage)	++	--	-

This also allows to:

- Reducing the thermal losses through the pipes
- Reducing the pump consumption
- Increasing the RE heat production from low temperature energy sources

Thank you!

Module 2.5 - Substation and control

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https://www.shakeproject-dhc.eu/

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