Software Information

- Please check, whether your inputs, the equations applied and the charactersitics are displayed correctly.
- You are welcome to send your feedback via `https://github.com/oemof/tespy/issues`.
- LaTeXpackages required are:
  - graphicx
  - float
  - hyperref
  - booktabs
  - amsmath
  - units
  - cleveref
- To supress these messages, call the model documentation with the keyword draft=False.

TESPy Version:	0.4.2 - dev
Commit:	72386f6c@dev
CoolProp version:	6.4.0
Python version:	3.8.0 (default, Oct 28 2019, 16:14:01) [GCC 8.3.0]

1 Connections in offdesign mode

1.1 Specified connection parameters

label	p in bar (1)	T in °C (2)
ambient air:out1_compressor:in1	1.000	20.000
combustion:out1_gas turbine:in1	-	1200.000
waste heat recovery:out1_chimney:in1	1.000	-
district heating backflow:out1_condenser:in2	5.000	60.000
waste heat recovery:out2_district heating feedflow:in1	-	90.000

Table 1: Specified connection parameters

1.2 Equations applied

$$0 = p - p_{\mathrm{spec}} \tag{1}$$

$$0 = T\left(p, h\right) - T_{\mathrm{spec}} \tag{2}$$

1.3 Specified fluids

label	Ar (3)	CH4 (4)	CO2 (5)	H2O (6)	N2 (7)	O2 (8)
ambient air:out1_compressor:in1	0.013	0.000	0.000	0.000	0.755	0.231
fuel source:out1_combustion:in2	0.000	0.960	0.040	0.000	0.000	0.000
superheater:out2_ls cycle closer:in1	0.000	0.000	0.000	1.000	0.000	0.000
district heating backflow:out1_condenser:in2	0.000	0.000	0.000	1.000	0.000	0.000

Table 2: Specified fluids

1.4 Equations applied

$$0 = x_{\mathrm{Ar}} - x_{\mathrm{Ar,spec}} \tag{3}$$

$$0 = x_{\mathrm{CH4}} - x_{\mathrm{CH4,spec}} \tag{4}$$

$$0 = x_{\mathrm{CO2}} - x_{\mathrm{CO2,spec}} \tag{5}$$

$$0 = x_{\mathrm{H2O}} - x_{\mathrm{H2O,spec}} \tag{6}$$

$$0 = x_{\mathrm{N2}} - x_{\mathrm{N2,spec}} \tag{7}$$

$$0 = x_{\mathrm{O2}} - x_{\mathrm{O2,spec}} \tag{8}$$

1.5 Referenced values for mass flow

label	reference	factor in -	delta in kg/s
evaporator:out2_drum:in2	drum:out2_superheater:in2	4	0

Table 3: Referenced values for mass flow

1.6 Equation applied

$$0 = \text{value} - \text{value}_{\text{ref}} \cdot \text{factor} + \text{delta} \tag{9}$$

1.7 Referenced values for temperature

label	reference	factor in -	delta in °C
fuel source:out1_combustion:in2	ambient air:out1_compressor:in1	1	0

Table 4: Referenced values for temperature

1.8 Equation applied

$$0 = \text{value} - \text{value}_{\text{ref}} \cdot \text{factor} + \text{delta} \tag{10}$$

2 User defined equations in offdesign mode

3 Components in offdesign mode

3.1 Components of type Compressor

3.1.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \; \forall i \in [1] \tag{11}$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \; \forall fl \in \text{network fluids}, \forall i \in [1] \tag{12}$$

3.1.2 Inputs specified

label	eta_s_char (13)
compressor	True

Table 5: Parameters of components of type Compressor

3.1.3 Equations applied

$$0 = (h_{\text{out}} - h_{\text{in}}) \cdot \eta_{\text{s,design}} \cdot f(X) - (h_{out,s} - h_{in}) \tag{13}$$

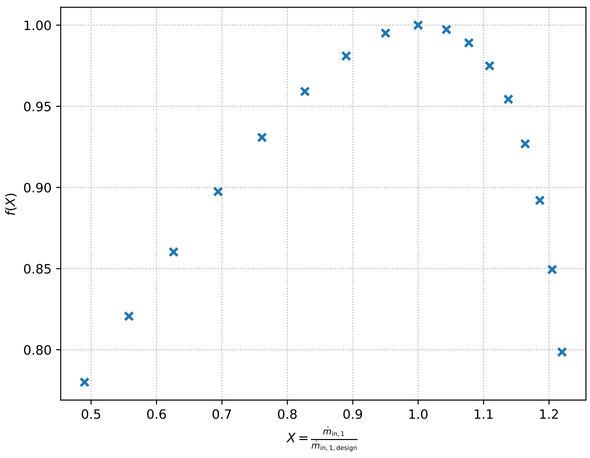

Figure 1: Characteristics of compressor (eq. 13)

3.2 Components of type CombustionChamber

3.2.1 Mandatory constraints

$$0 = \dot{m}_{\mathrm{in},1} + \dot{m}_{\mathrm{in},2} - \dot{m}_{\mathrm{out},1} \tag{14}$$

$$\begin{aligned} 0 =& p_{\mathrm{in},1} - p_{\mathrm{out},1} \\ 0 =& p_{\mathrm{in},1} - p_{\mathrm{in},2} \end{aligned} \tag{15}$$

$$\begin{aligned} \Delta\dot{m}_{\mathrm{fluid}} &= \dot{m}_{\mathrm{in},1} \cdot x_{\mathrm{fluid,in},1} + \dot{m}_{\mathrm{in},2} \cdot x_{\mathrm{fluid,in},2} - \dot{m}_{\mathrm{out},1} \cdot x_{\mathrm{fluid,out},1} \\ \dot{m}_{\mathrm{fluid,m}} &= \frac{\dot{m}_{\mathrm{in},1} \cdot x_{\mathrm{fluid,in},1} + \dot{m}_{\mathrm{in},2} \cdot x_{\mathrm{fluid,in},2}}{M_{\mathrm{fluid}}} \\ \dot{m}_{\mathrm{H,m}} &= \dot{m}_{\mathrm{CH4,m}} \cdot 4 \\ \dot{m}_{\mathrm{C,m}} &= \dot{m}_{\mathrm{CH4,m}} \cdot 1 \\ \dot{m}_{\mathrm{O2,m,stoich}} &= \frac{\dot{m}_{\mathrm{H,m}}}{4} + \dot{m}_{\mathrm{C,m}} \end{aligned} \tag{16}$$

$$0 = \Delta\dot{m}_{\mathrm{Ar}} \tag{17}$$

$$0 = \Delta\dot{m}_{\mathrm{CH4}} - \dot{m}_{\mathrm{CH4,m}} \cdot M_{\mathrm{CH4}} \tag{18}$$

$$0 = \Delta\dot{m}_{\mathrm{CO2}} + \dot{m}_{\mathrm{C,m}} \cdot M_{\mathrm{CO2}} \tag{19}$$

$$0 = \Delta\dot{m}_{\mathrm{H2O}} + \frac{\dot{m}_{\mathrm{H,m}}}{2} \cdot M_{\mathrm{H2O}} \tag{20}$$

$$0 = \Delta\dot{m}_{\mathrm{N2}} \tag{21}$$

$$0 = \Delta\dot{m}_{\mathrm{O2}} - \dot{m}_{\mathrm{O2,m,stoich}} \cdot M_{\mathrm{O2}} \tag{22}$$

$$0 = \sum_i \dot{m}_{\mathrm{in},i} \cdot \left(h_{\mathrm{in},i} - h_{\mathrm{in},i,\mathrm{ref}}\right) - \dot{m}_{\mathrm{out},1} \cdot \left(h_{\mathrm{out},1} - h_{\mathrm{out},1,\mathrm{ref}}\right)$$
$$+ LHV_{fuel} \cdot \left(\sum_i \dot{m}_{\mathrm{in},i} \cdot x_{fuel,\mathrm{in},i} - \dot{m}_{\mathrm{out},1} \cdot x_{fuel,\mathrm{out},1}\right) \tag{23}$$
$$\forall i \in \mathrm{inlets}$$
$$T_{\mathrm{ref}} = 298.15\,\mathrm{K}\; p_{\mathrm{ref}} = 10^5\,\mathrm{Pa}$$

3.3 Components of type Turbine

3.3.1 Mandatory constraints

$$0 = \dot{m}_{\mathrm{in},i} - \dot{m}_{\mathrm{out},i}\; \forall i \in [1] \tag{24}$$

$$0 = x_{fl,\mathrm{in},i} - x_{fl,\mathrm{out},i}\; \forall fl \in \mathrm{network\ fluids},\, \forall i \in [1] \tag{25}$$

3.3.2 Inputs specified

label	eta_s_char (26)	cone (27)
gas turbine	True	True
steam turbine	True	True

Table 6: Parameters of components of type Turbine

3.3.3 Equations applied

$$0 = -\left(h_{\mathrm{out}} - h_{\mathrm{in}}\right) + \eta_{\mathrm{s,design}} \cdot f\left(X\right) \cdot \left(h_{\mathrm{out,s}} - h_{\mathrm{in}}\right) \tag{26}$$

$$0 = \frac{\dot{m}_{\mathrm{in,design}} \cdot p_{\mathrm{in}}}{p_{\mathrm{in,design}}} \cdot \sqrt{\frac{p_{\mathrm{in,design}} \cdot v_{\mathrm{in}}}{p_{\mathrm{in}} \cdot v_{\mathrm{in,design}}} \cdot \frac{1 - \left(\frac{p_{\mathrm{out}}}{p_{\mathrm{in}}}\right)^2}{1 - \left(\frac{p_{\mathrm{out,design}}}{p_{\mathrm{in,design}}}\right)^2}} - \dot{m}_{\mathrm{in}} \tag{27}$$

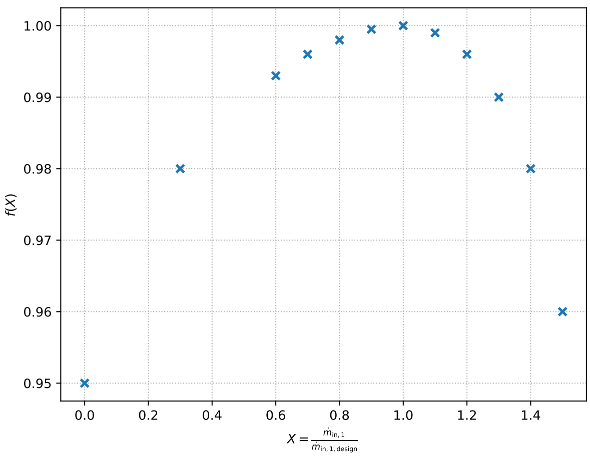

Figure 2: Characteristics of gas turbine (eq. 26)

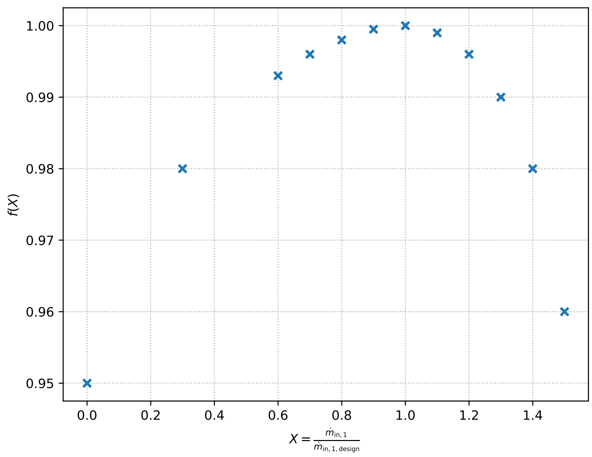

Figure 3: Characteristics of steam turbine (eq. 26)

3.4 Components of type HeatExchanger

3.4.1 Mandatory constraints

$$0 = \dot{m}_{\mathrm{in},i} - \dot{m}_{\mathrm{out},i} \; \forall i \in [1, 2] \tag{28}$$

$$0 = x_{fl,\mathrm{in},i} - x_{fl,\mathrm{out},i} \; \forall fl \in \text{network fluids}, \forall i \in [1, 2] \tag{29}$$

$$0 = \dot{m}_{\mathrm{in},1} \cdot (h_{\mathrm{out},1} - h_{\mathrm{in},1}) + \dot{m}_{\mathrm{in},2} \cdot (h_{\mathrm{out},2} - h_{\mathrm{in},2}) \tag{30}$$

3.4.2 Inputs specified

label	zeta1 (31)	zeta2 (32)	kA_char (33)
superheater	0.008	113727.177	True
evaporator	0.010	-	True
economizer	0.011	0.000	True
waste heat recovery	0.014	13.703	True

Table 7: Parameters of components of type HeatExchanger

3.4.3 Equations applied

$$0 = \begin{cases} p_{\mathrm{in},1} - p_{\mathrm{out},1} & |\dot{m}_{\mathrm{in},1}| < 0.0001\,\mathrm{kg/s} \\ \frac{\zeta}{D^4} - \frac{(p_{\mathrm{in},1} - p_{\mathrm{out},1}) \cdot \pi^2}{8 \cdot \dot{m}_{\mathrm{in},1} \cdot |\dot{m}_{\mathrm{in},1}| \cdot \frac{v_{\mathrm{in},1} + v_{\mathrm{out},1}}{2}} & |\dot{m}_{\mathrm{in},1}| \geq 0.0001\,\mathrm{kg/s} \end{cases} \tag{31}$$

$$0 = \begin{cases} p_{\mathrm{in},2} - p_{\mathrm{out},2} & |\dot{m}_{\mathrm{in},2}| < 0.0001\,\mathrm{kg/s} \\ \frac{\zeta}{D^4} - \frac{(p_{\mathrm{in},2} - p_{\mathrm{out},2}) \cdot \pi^2}{8 \cdot \dot{m}_{\mathrm{in},2} \cdot |\dot{m}_{\mathrm{in},2}| \cdot \frac{v_{\mathrm{in},2} + v_{\mathrm{out},2}}{2}} & |\dot{m}_{\mathrm{in},2}| \geq 0.0001\,\mathrm{kg/s} \end{cases} \tag{32}$$

$$\begin{aligned} 0 =& \dot{m}_{\mathrm{in},1} \cdot (h_{\mathrm{out},1} - h_{\mathrm{in},1}) \\ &+ kA_{\mathrm{design}} \cdot f_{\mathrm{kA}} \cdot \frac{T_{\mathrm{out},1} - T_{\mathrm{in},2} - T_{\mathrm{in},1} + T_{\mathrm{out},2}}{\ln \frac{T_{\mathrm{out},1} - T_{\mathrm{in},2}}{T_{\mathrm{in},1} - T_{\mathrm{out},2}}} \\ f_{\mathrm{kA}} =& \frac{2}{\frac{1}{f(X_1)} + \frac{1}{f(X_2)}} \end{aligned} \tag{33}$$

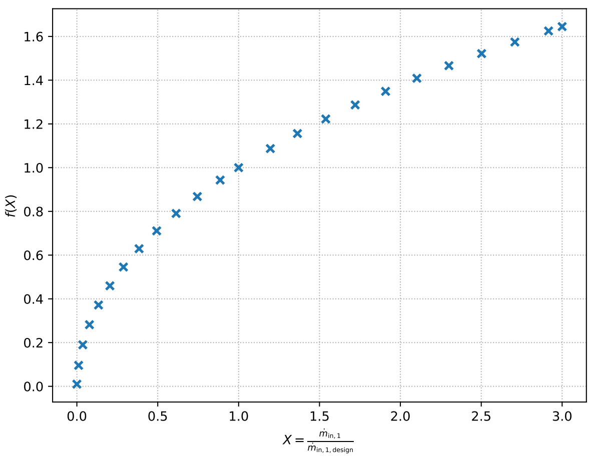

Figure 4: Characteristics of superheater (eq. 33)

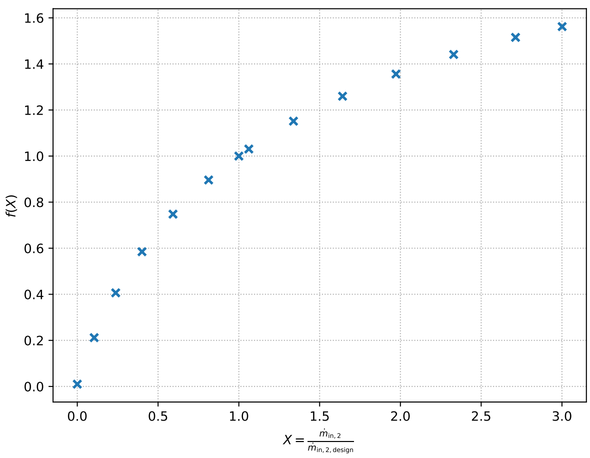

Figure 5: Characteristics of superheater (eq. 33)

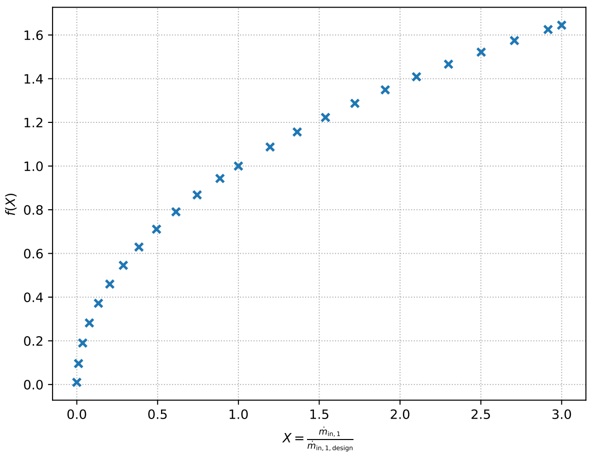

Figure 6: Characteristics of evaporator (eq. 33)

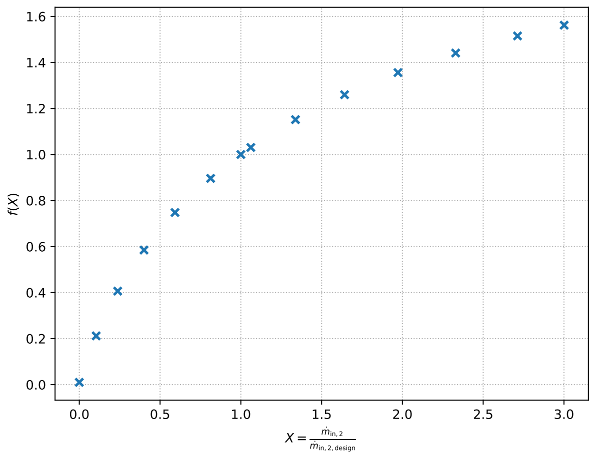

Figure 7: Characteristics of evaporator (eq. 33)

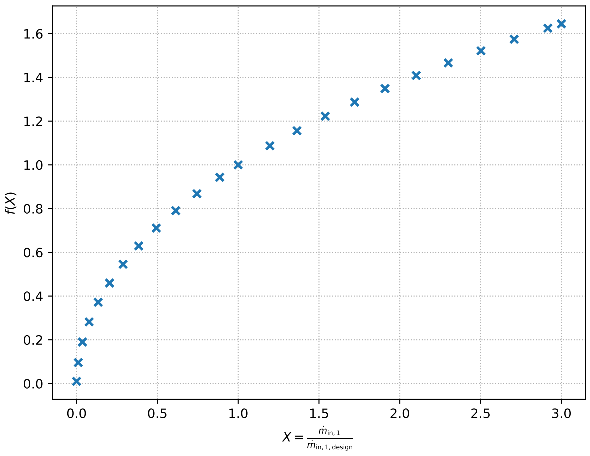

Figure 8: Characteristics of economizer (eq. 33)

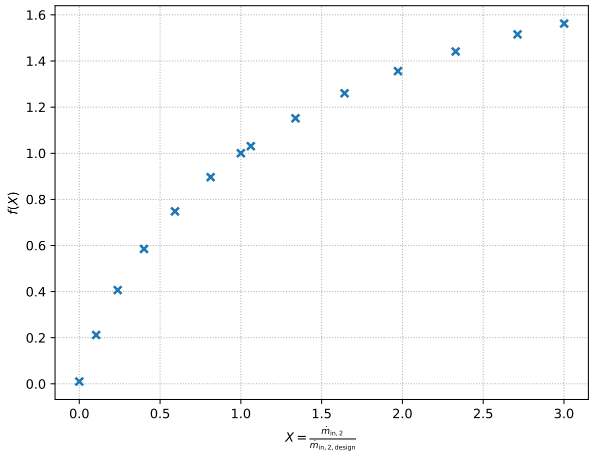

Figure 9: Characteristics of economizer (eq. 33)

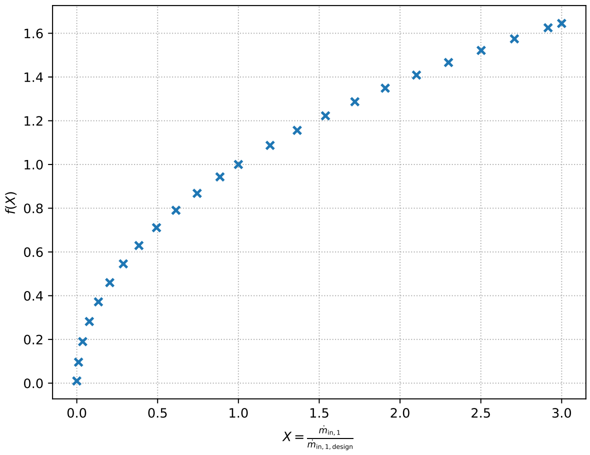

Figure 10: Characteristics of waste heat recovery (eq. 33)

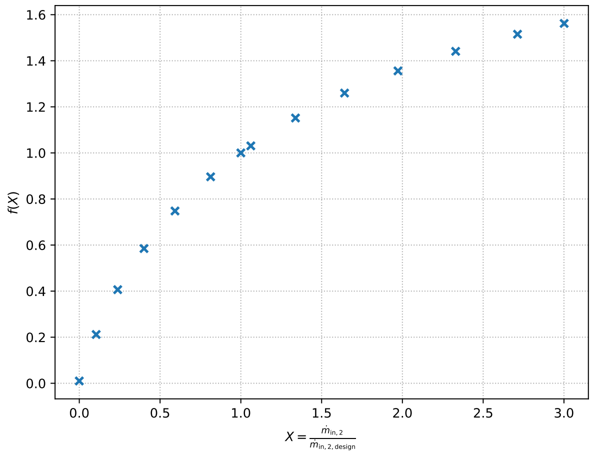

Figure 11: Characteristics of waste heat recovery (eq. 33)

3.5 Components of type Drum

3.5.1 Mandatory constraints

$$0 = \sum \dot{m}_{\text{in},i} - \sum \dot{m}_{\text{out},j} \; \forall i \in \text{inlets}, \forall j \in \text{outlets} \tag{34}$$

$$0 = x_{fl,\text{in},1} - x_{fl,\text{out},j} \; \forall fl \in \text{network fluids}, \; \forall j \in \text{outlets} \tag{35}$$

$$0 = \sum_i \left(\dot{m}_{\text{in},i} \cdot h_{\text{in},i}\right) - \sum_j \left(\dot{m}_{\text{out},j} \cdot h_{\text{out},j}\right) \; \forall i \in \text{inlets} \; \forall j \in \text{outlets} \tag{36}$$

$$\begin{aligned} 0 = p_{\text{in},1} - p_{\text{in},i} \; \forall i \in \text{inlets} \setminus \{1\} \\ 0 = p_{\text{in},1} - p_{\text{out},j} \; \forall j \in \text{outlets} \end{aligned} \tag{37}$$

$$\begin{aligned} 0 =& h_{\text{out},1} - h\left(p_{\text{out},1}, x = 0\right) \\ 0 =& h_{\text{out},2} - h\left(p_{\text{out},2}, x = 1\right) \end{aligned} \tag{38}$$

3.6 Components of type CycleCloser

3.6.1 Mandatory constraints

$$0 = p_{\text{in},i} - p_{\text{out},i} \; \forall i \in [1] \tag{39}$$

$$0 = h_{\text{in},i} - h_{\text{out},i} \; \forall i \in [1] \tag{40}$$

3.7 Components of type Condenser

3.7.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \; \forall i \in [1, 2] \tag{41}$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \; \forall fl \in \text{network fluids}, \; \forall i \in [1, 2] \tag{42}$$

$$0 = \dot{m}_{\text{in},1} \cdot \left(h_{\text{out},1} - h_{\text{in},1}\right) + \dot{m}_{\text{in},2} \cdot \left(h_{\text{out},2} - h_{\text{in},2}\right) \tag{43}$$

3.7.2 Inputs specified

label	pr1 (44)	zeta2 (45)	kA_char (46)	subcooling (47)
condenser	0.990	14.111	True	True

Table 8: Parameters of components of type Condenser

3.7.3 Equations applied

$$0 = p_{\text{in},1} \cdot pr1 - p_{\text{out},1} \tag{44}$$

$$0 = \begin{cases} p_{\text{in},2} - p_{\text{out},2} & |\dot{m}_{\text{in},2}| < 0.0001 \, ^{\text{kg}}/_{\text{s}} \\ \frac{\zeta}{D^4} - \frac{(p_{\text{in},2} - p_{\text{out},2}) \cdot \pi^2}{8 \cdot \dot{m}_{\text{in},2} \cdot |\dot{m}_{\text{in},2}| \cdot \frac{v_{\text{in},2} + v_{\text{out},2}}{2}} & |\dot{m}_{\text{in},2}| \geq 0.0001 \, ^{\text{kg}}/_{\text{s}} \end{cases} \tag{45}$$

$$0 = \dot{m}_{\text{in},1} \cdot (h_{\text{out},1} - h_{\text{in},1}) + kA_{\text{design}} \cdot f_{\text{kA}} \cdot \frac{T_{\text{out},1} - T_{\text{in},2} - T_{\text{sat}}(p_{\text{in},1}) + T_{\text{out},2}}{\ln \frac{T_{\text{out},1} - T_{\text{in},2}}{T_{\text{sat}}(p_{\text{in},1}) - T_{\text{out},2}}}$$

$$f_{\text{kA}} = \frac{2}{\frac{1}{f(X_2)} + \frac{1}{f(X_2)}} \tag{46}$$

$$0 = h_{\text{out},1} - h\left(p_{\text{out},1}, x = 0\right) \tag{47}$$

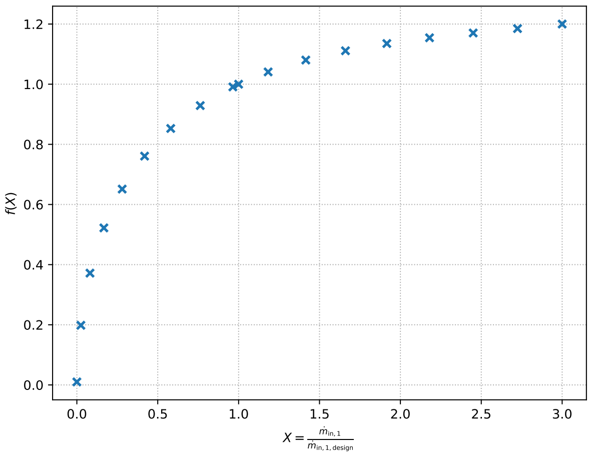

Figure 12: Characteristics of condenser (eq. 46)

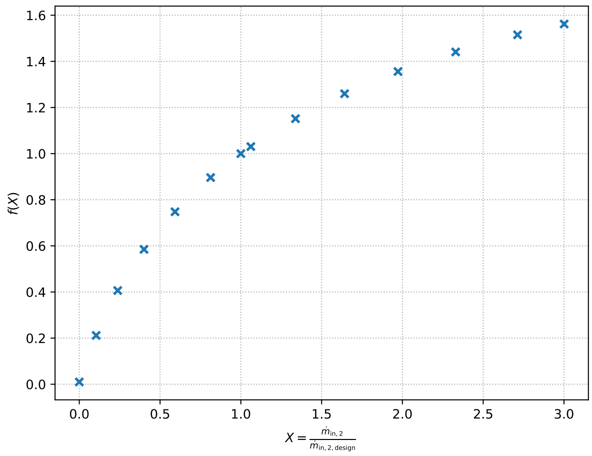

Figure 13: Characteristics of condenser (eq. 46)

3.8 Components of type Pump

3.8.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \; \forall i \in [1] \tag{48}$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \; \forall fl \in \text{network fluids}, \forall i \in [1] \tag{49}$$

3.8.2 Inputs specified

label	eta_s_char (50)
feed water pump	True

Table 9: Parameters of components of type Pump

3.8.3 Equations applied

$$0 = (h_{\text{out}} - h_{\text{in}}) \cdot \eta_{\text{s,design}} \cdot f(X) - (h_{out,s} - h_{in}) \tag{50}$$

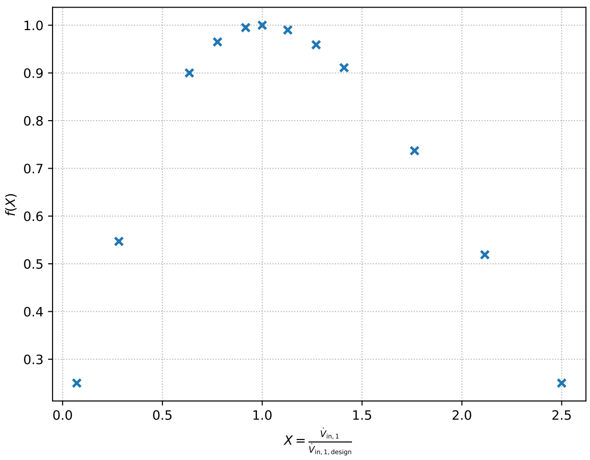

Figure 14: Characteristics of feed water pump (eq. 50)

4 Busses in offdesign mode

4.1 Bus "power output"

Specified total value of energy flow: $\dot{E}_{\text{bus}} = -100000000.000\,\text{W}$

$$0 = \dot{E}_{\text{bus}} - \sum_i \dot{E}_{\text{bus},i} \tag{51}$$

label	$\dot{E}_{\text{comp}}$	$\dot{E}_{\text{bus}}$	η
gas turbine	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	$f(X)$ (15)
compressor	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\frac{\dot{E}_{\text{comp}}}{\eta}$	$f(X)$ (16)
steam turbine	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	$f(X)$ (15)
feed water pump	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\frac{\dot{E}_{\text{comp}}}{\eta}$	$f(X)$ (16)

Table 10: power output

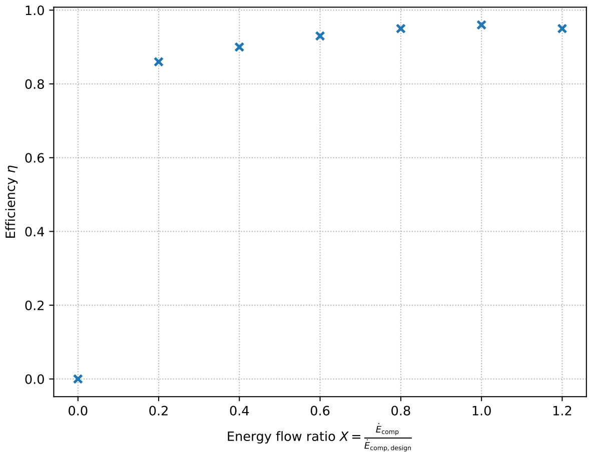

Figure 15: Bus efficiency characteristic

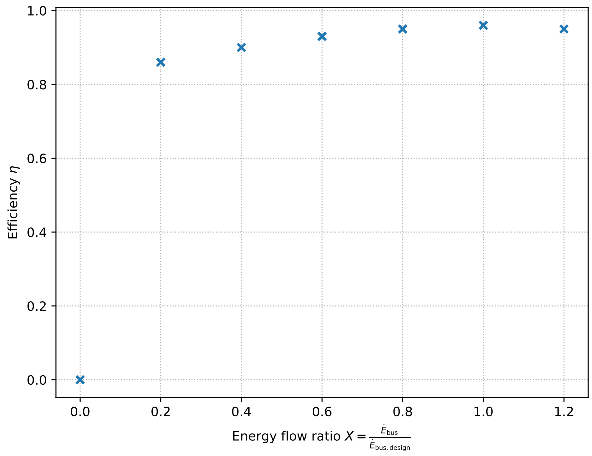

Figure 16: Bus efficiency characteristic

4.2 Bus "heat output"

This bus is used for postprocessing only.

label	$\dot{E}_{\mathrm{comp}}$	$\dot{E}_{\mathrm{bus}}$	η
condenser	$\dot{m}_{\mathrm{in},1} \cdot (h_{\mathrm{out},1} - h_{\mathrm{in},1})$	$\dot{E}_{\mathrm{comp}} \cdot \eta$	1.000
waste heat recovery	$\dot{m}_{\mathrm{in},1} \cdot (h_{\mathrm{out},1} - h_{\mathrm{in},1})$	$\dot{E}_{\mathrm{comp}} \cdot \eta$	1.000

Table 11: heat output

4.3 Bus "heat input"

This bus is used for postprocessing only.

label	$\dot{E}_{\mathrm{comp}}$	$\dot{E}_{\mathrm{bus}}$	η
combustion	$LHV_{\mathrm{fuel}} \cdot \left[\sum_i \left(\dot{m}_{\mathrm{in},i} \cdot x_{\mathrm{fuel,in},i}\right) - \dot{m}_{\mathrm{out},1} \cdot x_{\mathrm{fuel,out},1}\right]$	$\dot{E}_{\mathrm{comp}} \cdot \eta$	1.000

Table 12: heat input