

## Software Information

- Please check, whether your inputs, the equations applied and the characteristics are displayed correctly.
- You are welcome to send your feedback via <https://github.com/oemof/tespy/issues>.
- L<sup>A</sup>T<sub>E</sub>X packages required are:
  - graphicx
  - float
  - hyperref
  - booktabs
  - amsmath
  - units
  - cleveref
- To suppress these messages, call the model documentation with the keyword `draft=False`.

TESPy Version: 0.4.0 - dev  
Commit: d918f10d@feature/self\_documenting\_models  
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

$$0 = p - p_{\text{spec}} \quad (1)$$

$$0 = T(p, h) - T_{\text{spec}} \quad (2)$$

## 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

$$0 = x_{\text{Ar}} - x_{\text{Ar,spec}} \quad (3)$$

$$0 = x_{\text{CH4}} - x_{\text{CH4,spec}} \quad (4)$$

$$0 = x_{\text{CO2}} - x_{\text{CO2,spec}} \quad (5)$$

$$0 = x_{\text{H2O}} - x_{\text{H2O,spec}} \quad (6)$$

$$0 = x_{\text{N2}} - x_{\text{N2,spec}} \quad (7)$$

$$0 = x_{\text{O2}} - x_{\text{O2,spec}} \quad (8)$$

## 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

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

## 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

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

# 2 Components in offdesign mode

## 2.1 Components of type Compressor

### 2.1.1 Mandatory constraints

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

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

### 2.1.2 Inputs specified

label	eta_s_char (??)
compressor	True

Table 5: Parameters of components of type Compressor

### 2.1.3 Equations applied

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

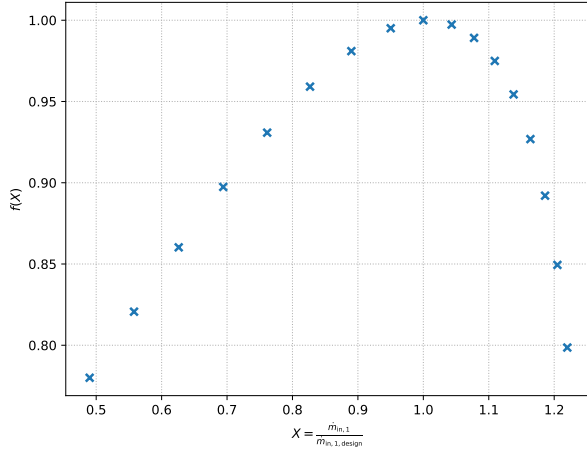


Figure 1: Characteristics of compressor (eq. ??)

## 2.2 Components of type CombustionChamber

### 2.2.1 Mandatory constraints

$$0 = \dot{m}_{in,1} + \dot{m}_{in,2} - \dot{m}_{out,1} \quad (14)$$

$$\begin{aligned} 0 &= p_{in,1} - p_{out,1} \\ 0 &= p_{in,1} - p_{in,2} \end{aligned} \quad (15)$$

$$\begin{aligned} \Delta \dot{m}_{fluid} &= \dot{m}_{in,1} \cdot x_{fluid,in,1} + \dot{m}_{in,2} \cdot x_{fluid,in,2} - \dot{m}_{out,1} \cdot x_{fluid,out,1} \\ \dot{m}_{fluid,m} &= \frac{\dot{m}_{in,1} \cdot x_{fluid,in,1} + \dot{m}_{in,2} \cdot x_{fluid,in,2}}{M_{fluid}} \end{aligned} \quad (16)$$

$$\dot{m}_{H,m} = \dot{m}_{CH_4,m} \cdot 4 \quad (17)$$

$$\dot{m}_{C,m} = \dot{m}_{CH_4,m} \cdot 1$$

$$\dot{m}_{O_2,m,stoich} = \frac{\dot{m}_{H,m}}{4} + \dot{m}_{C,m}$$

$$0 = \Delta \dot{m}_{Ar} \quad (18)$$

$$0 = \Delta \dot{m}_{CH_4} - \dot{m}_{CH_4,m} \cdot M_{CH_4} \quad (19)$$

$$0 = \Delta \dot{m}_{CO_2} + \dot{m}_{C,m} \cdot M_{CO_2} \quad (20)$$

$$0 = \Delta \dot{m}_{H_2O} + \frac{\dot{m}_{H,m}}{2} \cdot M_{H_2O} \quad (21)$$

$$0 = \Delta \dot{m}_{N_2} \quad (22)$$

$$0 = \Delta \dot{m}_{O_2} - \dot{m}_{O_2,m,stoich} \cdot M_{O_2}$$

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

## 2.3 Components of type Turbine

### 2.3.1 Mandatory constraints

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

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

### 2.3.2 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

### 2.3.3 Equations applied

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

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

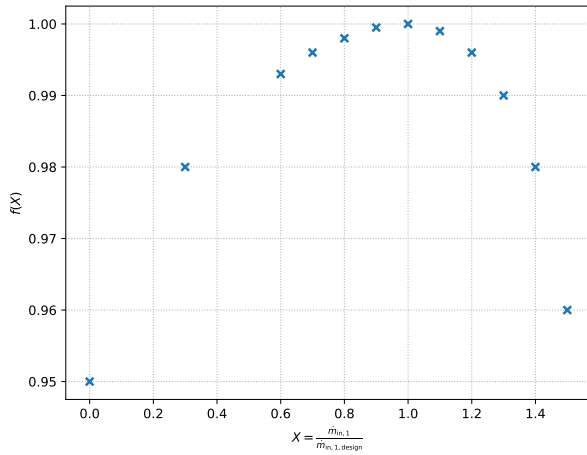


Figure 2: Characteristics of gas turbine (eq. 26)

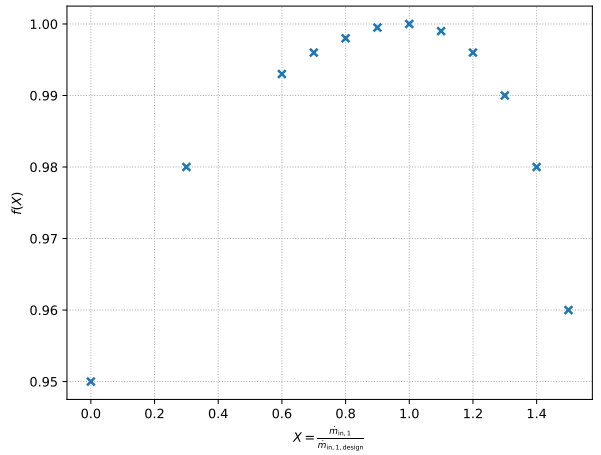


Figure 3: Characteristics of steam turbine (eq. 26)

## 2.4 Components of type HeatExchanger

### 2.4.1 Mandatory constraints

$$0 = \dot{m}_{in,i} - \dot{m}_{out,i} \quad \forall i \in [1, 2] \quad (28)$$

$$0 = x_{fl,in,i} - x_{fl,out,i} \quad \forall fl \in \text{network fluids}, \forall i \in [1, 2] \quad (29)$$

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

### 2.4.2 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

### 2.4.3 Equations applied

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

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

$$0 = \dot{m}_{in,1} \cdot (h_{out,1} - h_{in,1}) + kA_{\text{design}} \cdot f_{kA} \cdot \frac{T_{out,1} - T_{in,2} - T_{in,1} + T_{out,2}}{\ln \frac{T_{out,1} - T_{in,2}}{T_{in,1} - T_{out,2}}} \quad (33)$$

$$f_{kA} = \frac{2}{\frac{1}{f(X_1)} + \frac{1}{f(X_2)}}$$

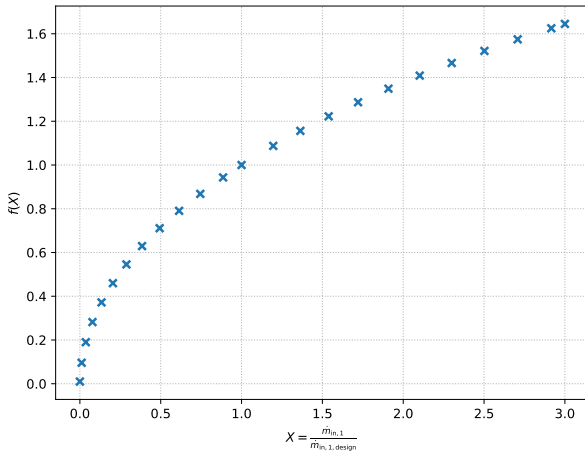


Figure 4: Characteristics of superheater (eq. 33)

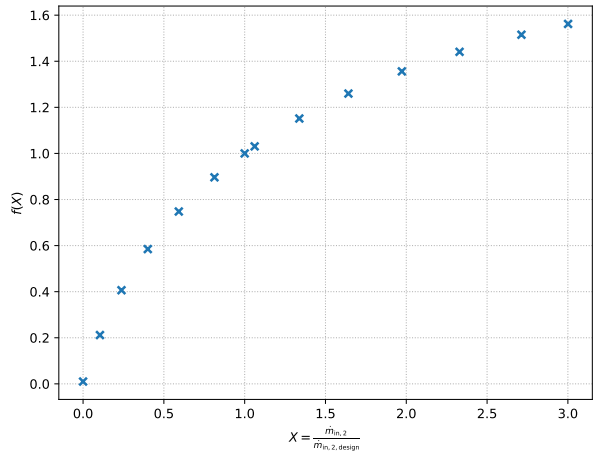


Figure 5: Characteristics of superheater (eq. 33)

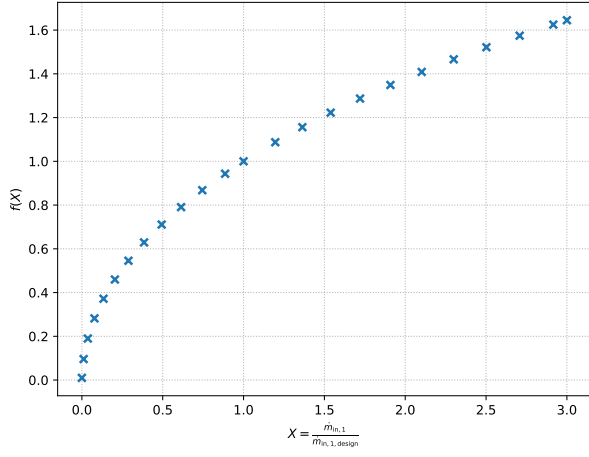


Figure 6: Characteristics of evaporator (eq. 33)

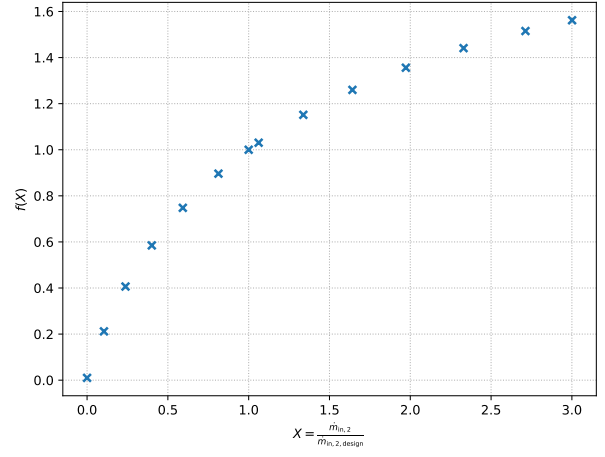


Figure 7: Characteristics of evaporator (eq. 33)

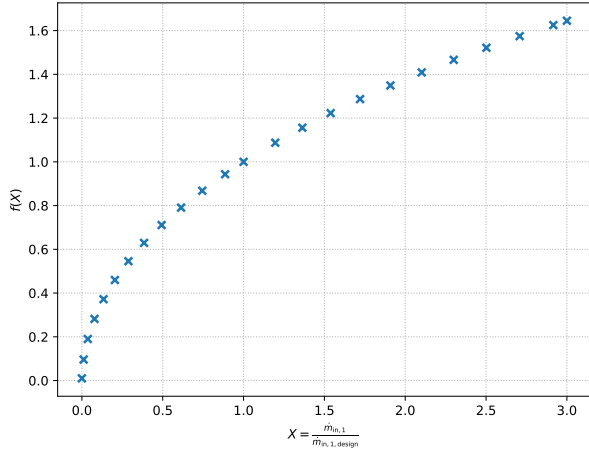


Figure 8: Characteristics of economizer (eq. 33)

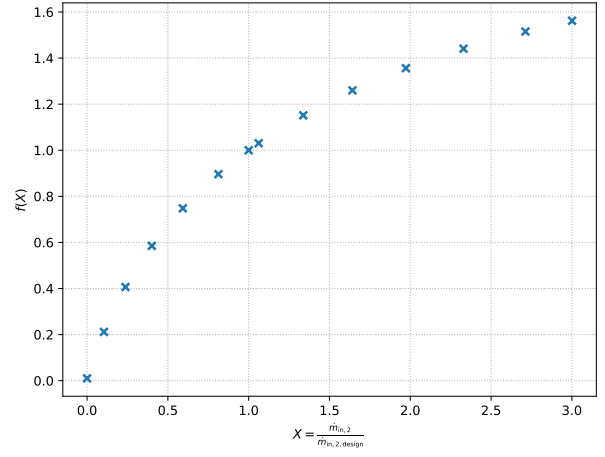


Figure 9: Characteristics of economizer (eq. 33)

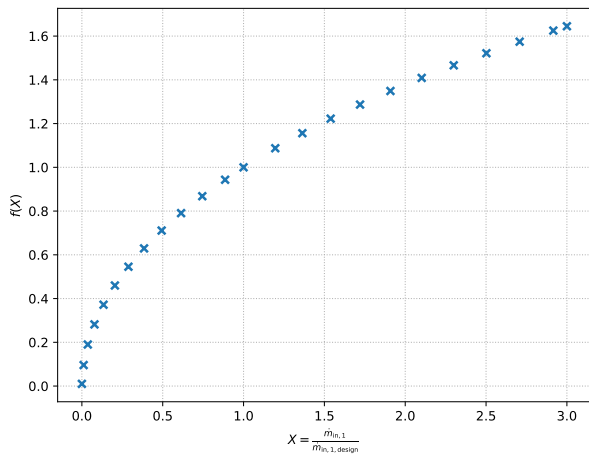


Figure 10: Characteristics of waste heat recovery (eq. 33)

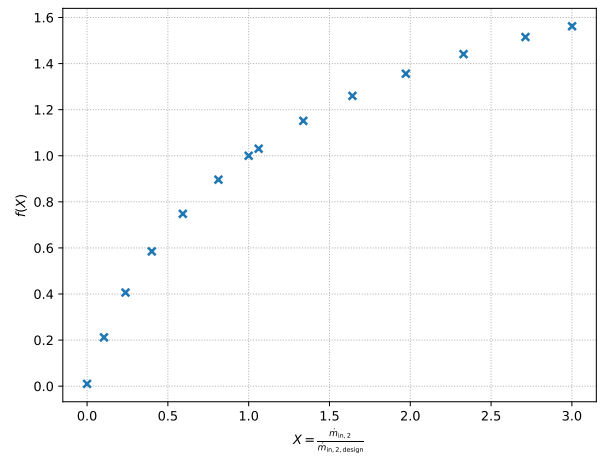


Figure 11: Characteristics of waste heat recovery (eq. 33)

## 2.5 Components of type Drum

### 2.5.1 Mandatory constraints

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

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

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

$$\begin{aligned} 0 &= p_{\text{in},1} - p_{\text{in},i} \quad \forall i \in \text{inlets} \setminus \{1\} \\ 0 &= p_{\text{in},1} - p_{\text{out},j} \quad \forall j \in \text{outlets} \end{aligned} \quad (37)$$

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

## 2.6 Components of type CycleCloser

### 2.6.1 Mandatory constraints

$$0 = p_{\text{in},i} - p_{\text{out},i} \quad \forall i \in [1] \quad (39)$$

$$0 = h_{\text{in},i} - h_{\text{out},i} \quad \forall i \in [1] \quad (40)$$

## 2.7 Components of type Condenser

### 2.7.1 Mandatory constraints

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

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

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

### 2.7.2 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

### 2.7.3 Equations applied

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

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



$$\begin{aligned}
0 &= \dot{m}_{in,1} \cdot (h_{out,1} - h_{in,1}) \\
&\quad + kA_{design} \cdot f_{kA} \cdot \frac{T_{out,1} - T_{in,2} - T_{sat}(p_{in,1}) + T_{out,2}}{\ln \frac{T_{out,1} - T_{in,2}}{T_{sat}(p_{in,1}) - T_{out,2}}} \\
f_{kA} &= \frac{2}{\frac{1}{f(X_2)} + \frac{1}{f(X_2)}}
\end{aligned} \tag{46}$$

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

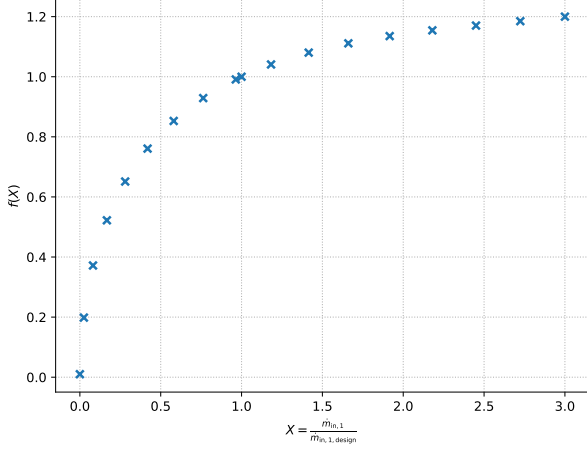


Figure 12: Characteristics of condenser (eq. 46)

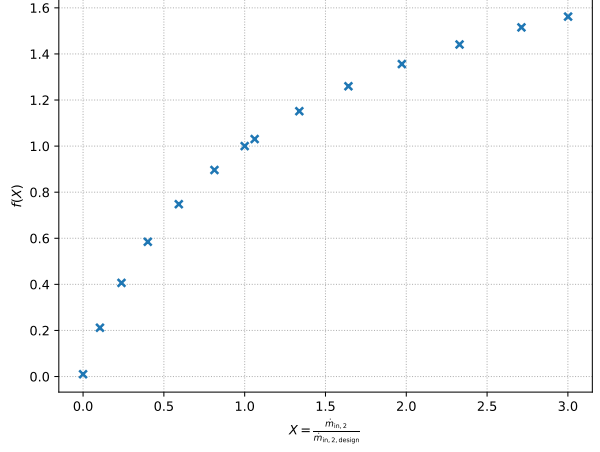


Figure 13: Characteristics of condenser (eq. 46)

## 2.8 Components of type Pump

### 2.8.1 Mandatory constraints

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

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

### 2.8.2 Inputs specified

label	eta_s_char (50)
feed water pump	True

Table 9: Parameters of components of type Pump

### 2.8.3 Equations applied

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

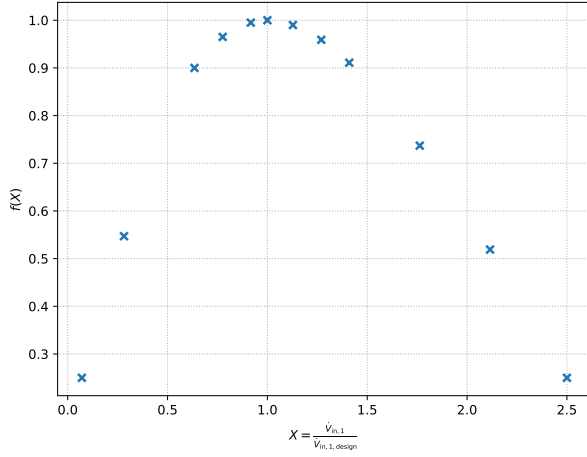


Figure 14: Characteristics of feed water pump (eq. 50)

### 3 Busses in offdesign mode

#### 3.1 Bus “power output”

Specified total value of energy flow:  $\dot{E}_{bus} = -111560045.018 \text{ W}$

$$0 = \dot{E}_{bus} - \sum_i \dot{E}_{bus,i} \quad (51)$$

label	$\dot{E}_{comp}$	$\dot{E}_{bus}$	$\eta$
gas turbine	$\dot{m}_{in} \cdot (h_{out} - h_{in})$	$\dot{E}_{comp} \cdot \eta$	1.000
compressor	$\dot{m}_{in} \cdot (h_{out} - h_{in})$	$\dot{E}_{comp} \cdot \eta$	1.000
steam turbine	$\dot{m}_{in} \cdot (h_{out} - h_{in})$	$\dot{E}_{comp} \cdot \eta$	1.000
feed water pump	$\dot{m}_{in} \cdot (h_{out} - h_{in})$	$\dot{E}_{comp} \cdot \eta$	1.000

Table 10: power output

#### 3.2 Bus “heat output”

This bus is used for postprocessing only.

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

Table 11: heat output

#### 3.3 Bus “heat input”

This bus is used for postprocessing only.

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

Table 12: heat input