

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^AT_EX packages required are:
 - graphicx
 - float
 - hyperref
 - booktabs
 - amsmath
 - units
 - cleverref
- To suppress these messages, call the model documentation with the keyword draft=False.

TESPy Version: 0.4.1 - dev
Commit: 69f00d6e@dev
CoolProp version: 6.4.0
Python version: 3.7.6 (default, Jan 8 2020, 20:23:39) [MSC v.1916 64 bit (AMD64)]

1 Connections in offdesign mode

1.1 Specified connection parameters

label	p in bar (1)	T in °C (2)	m in kg/s (3)
ambient air:out1_compressor:in1	1.000	20.000	-
economizer:out1_chimney:in1	1.020	-	-
cooling water backflow:out1_condenser:in2	5.000	15.000	-
condenser:out2_cooling water feedflow:in1	-	-	1213.429
district heating backflow:out1_district heating condenser:in2	10.000	50.000	-
district heating condenser:out2_district heating feedflow:in1	-	90.000	-

Table 1: Specified connection parameters

1.2 Equations applied

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

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

$$0 = \dot{m} - \dot{m}_{\text{spec}} \quad (3)$$

1.3 Specified fluids

label	Ar (4)	CH4 (5)	CO2 (6)	H2O (7)	N2 (8)	O2 (9)
ambient air:out1_compressor:in1	0.013	0.000	0.000	0.000	0.755	0.231
fuel source:out1_fuel compressor:in1	0.000	0.960	0.040	0.000	0.000	0.000
superheater:out2_ls sink:in1	0.000	0.000	0.000	1.000	0.000	0.000
cooling water backflow:out1_condenser:in2	0.000	0.000	0.000	1.000	0.000	0.000
district heating backflow:out1_district heating condenser:in2	0.000	0.000	0.000	1.000	0.000	0.000

Table 2: Specified fluids

1.4 Equations applied

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

$$0 = x_{\text{CH4}} - x_{\text{CH4,spec}} \quad (5)$$

$$0 = x_{\text{CO2}} - x_{\text{CO2,spec}} \quad (6)$$

$$0 = x_{\text{H2O}} - x_{\text{H2O,spec}} \quad (7)$$

$$0 = x_{\text{N2}} - x_{\text{N2,spec}} \quad (8)$$

$$0 = x_{\text{O2}} - x_{\text{O2,spec}} \quad (9)$$

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

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

1.7 Referenced values for pressure

label	reference	factor in -	delta in bar
fuel source:out1_fuel compressor:in1	ambient air:out1_compressor:in1	1	0
ls source:out1_steam turbine high pressure:in1	superheater:out2_ls sink:in1	1	0

Table 4: Referenced values for pressure

1.8 Equation applied

$$0 = \text{value} - \text{value}_{\text{ref}} \cdot \text{factor} + \text{delta} \quad (11)$$

1.9 Referenced values for enthalpy

label	reference	factor in -	delta in kJ/kg
ls source:out1_steam turbine high pressure:in1	superheater:out2_ls sink:in1	1	0

Table 5: Referenced values for enthalpy

1.10 Equation applied

$$0 = \text{value} - \text{value}_{\text{ref}} \cdot \text{factor} + \text{delta} \quad (12)$$

1.11 Referenced values for temperature

label	reference	factor in -	delta in °C
fuel source:out1_fuel compressor:in1	ambient air:out1_compressor:in1	1	0

Table 6: Referenced values for temperature

1.12 Equation applied

$$0 = \text{value} - \text{value}_{\text{ref}} \cdot \text{factor} + \text{delta} \quad (13)$$

2 Components in offdesign mode

2.1 Components of type Compressor

2.1.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \quad \forall i \in [1] \quad (14)$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \quad \forall fl \in \text{network fluids}, \forall i \in [1] \quad (15)$$

2.1.2 Inputs specified

label	eta_s_char (16)
compressor	True
fuel compressor	True

Table 7: Parameters of components of type Compressor

2.1.3 Equations applied

$$0 = (h_{\text{out}} - h_{\text{in}}) \cdot \eta_{s,\text{design}} \cdot f(X) - (h_{\text{out},s} - h_{\text{in}}) \quad (16)$$

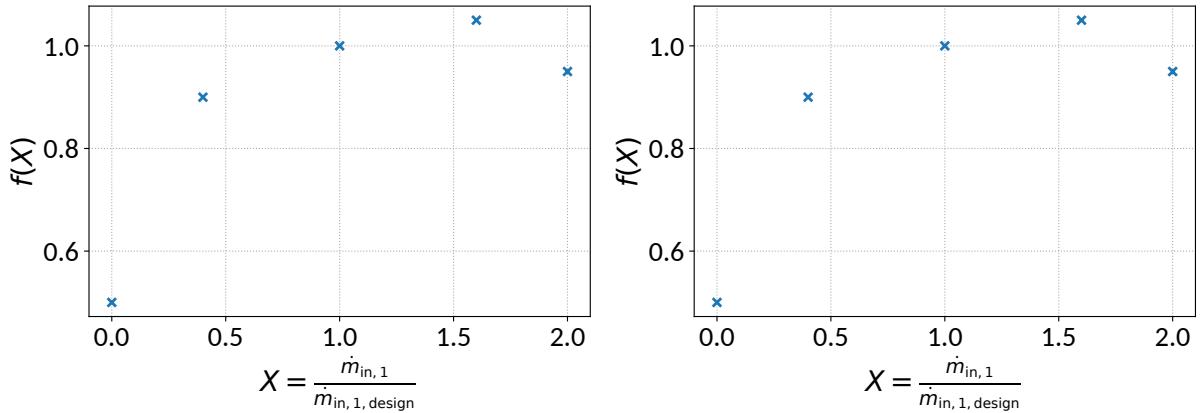


Figure 1: Characteristics of compressor (eq. 16)

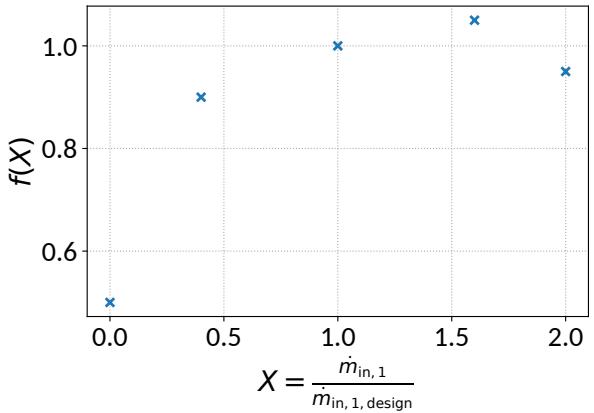


Figure 2: Characteristics of fuel compressor (eq. 16)

2.2 Components of type CombustionChamber

2.2.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},1} + \dot{m}_{\text{in},2} - \dot{m}_{\text{out},1} \quad (17)$$

$$\begin{aligned} 0 &= p_{\text{in},1} - p_{\text{out},1} \\ 0 &= p_{\text{in},1} - p_{\text{in},2} \end{aligned} \quad (18)$$

$$\begin{aligned} \Delta \dot{m}_{\text{fluid}} &= \dot{m}_{\text{in},1} \cdot x_{\text{fluid,in},1} + \dot{m}_{\text{in},2} \cdot x_{\text{fluid,in},2} - \dot{m}_{\text{out},1} \cdot x_{\text{fluid,out},1} \\ \dot{m}_{\text{fluid,m}} &= \frac{\dot{m}_{\text{in},1} \cdot x_{\text{fluid,in},1} + \dot{m}_{\text{in},2} \cdot x_{\text{fluid,in},2}}{M_{\text{fluid}}} \\ \dot{m}_{\text{H,m}} &= \dot{m}_{\text{CH4,m}} \cdot 4 \\ \dot{m}_{\text{C,m}} &= \dot{m}_{\text{CH4,m}} \cdot 1 \\ \dot{m}_{\text{O2,m,stoich}} &= \frac{\dot{m}_{\text{H,m}}}{4} + \dot{m}_{\text{C,m}} \end{aligned} \quad (19)$$

$$0 = \Delta \dot{m}_{\text{Ar}} \quad (20)$$

$$0 = \Delta \dot{m}_{\text{CH4}} - \dot{m}_{\text{CH4,m}} \cdot M_{\text{CH4}} \quad (21)$$

$$0 = \Delta \dot{m}_{\text{CO2}} + \dot{m}_{\text{C,m}} \cdot M_{\text{CO2}} \quad (22)$$

$$0 = \Delta \dot{m}_{\text{H2O}} + \frac{\dot{m}_{\text{H,m}}}{2} \cdot M_{\text{H2O}} \quad (23)$$

$$0 = \Delta \dot{m}_{\text{N2}} \quad (24)$$

$$0 = \Delta \dot{m}_{\text{O2}} - \dot{m}_{\text{O2,m,stoich}} \cdot M_{\text{O2}} \quad (25)$$

$$\begin{aligned} 0 &= \sum_i \dot{m}_{\text{in},i} \cdot (h_{\text{in},i} - h_{\text{in},i,\text{ref}}) - \dot{m}_{\text{out},1} \cdot (h_{\text{out},1} - h_{\text{out},1,\text{ref}}) \\ &\quad + LHV_{\text{fuel}} \cdot \left(\sum_i \dot{m}_{\text{in},i} \cdot x_{\text{fuel,in},i} - \dot{m}_{\text{out},1} \cdot x_{\text{fuel,out},1} \right) \end{aligned} \quad (26)$$

$\forall i \in \text{inlets}$

$$T_{\text{ref}} = 298.15 \text{ K } p_{\text{ref}} = 10^5 \text{ Pa}$$

2.2.2 Inputs specified

label	lamb (27)
combustion	2.500

Table 8: Parameters of components of type CombustionChamber

2.2.3 Equations applied

$$\begin{aligned} 0 &= \frac{\dot{m}_{\text{fuel,m}}}{\dot{m}_{\text{O2,m}} \cdot (n_{\text{C,fuel}} + 0.25 \cdot n_{\text{H,fuel}})} - \lambda \\ \dot{m}_{\text{fluid,m}} &= \frac{x_{\text{fluid}} \cdot \dot{m}}{M_{\text{fluid}}} \end{aligned} \quad (27)$$

2.3 Components of type Turbine

2.3.1 Mandatory constraints

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

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

2.3.2 Inputs specified

label	eta_s_char (30)	cone (31)
gas turbine	True	True
steam turbine high pressure	True	True
steam turbine low pressure	True	True

Table 9: Parameters of components of type Turbine

2.3.3 Equations applied

$$0 = -(h_{\text{out}} - h_{\text{in}}) + \eta_{s,\text{design}} \cdot f(X) \cdot (h_{\text{out},s} - h_{\text{in}}) \quad (30)$$

$$0 = \frac{\dot{m}_{\text{in,design}} \cdot p_{\text{in}}}{p_{\text{in,design}}} \cdot \sqrt{\frac{p_{\text{in,design}} \cdot v_{\text{in}}}{p_{\text{in}} \cdot v_{\text{in,design}}} \cdot \frac{1 - \left(\frac{p_{\text{out}}}{p_{\text{in}}}\right)^2}{1 - \left(\frac{p_{\text{out,design}}}{p_{\text{in,design}}}\right)^2} - \dot{m}_{\text{in}}} \quad (31)$$

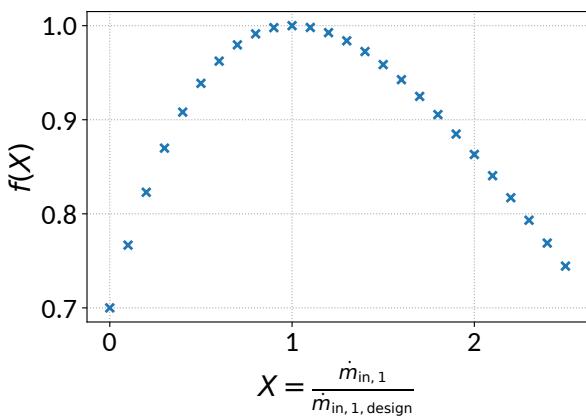


Figure 3: Characteristics of gas turbine (eq. 30)

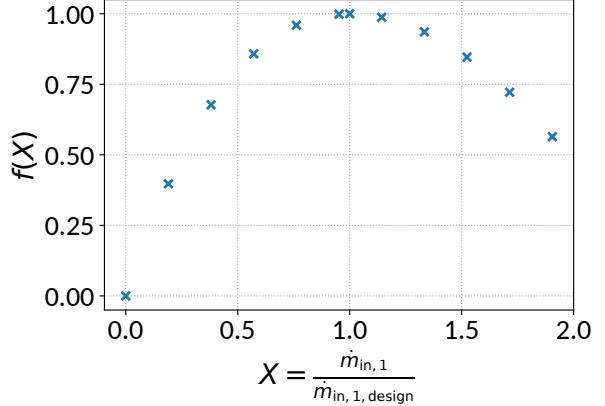


Figure 4: Characteristics of steam turbine high pressure (eq. 30)

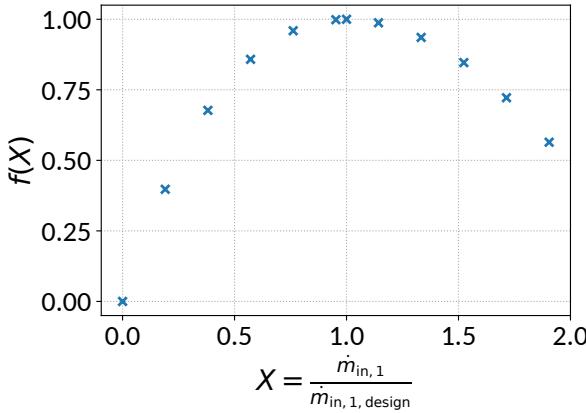


Figure 5: Characteristics of steam turbine low pressure (eq. 30)

2.4 Components of type HeatExchanger

2.4.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \quad \forall i \in [1, 2] \quad (32)$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \quad \forall fl \in \text{network fluids}, \forall i \in [1, 2] \quad (33)$$

$$0 = \dot{m}_{\text{in},1} \cdot (h_{\text{out},1} - h_{\text{in},1}) + \dot{m}_{\text{in},2} \cdot (h_{\text{out},2} - h_{\text{in},2}) \quad (34)$$

2.4.2 Inputs specified

label	zeta1 (35)	zeta2 (36)	kA_char (37)
superheater	0.009	9405.952	True
evaporator	0.011	-	True
economizer	0.015	0.000	True

Table 10: Parameters of components of type HeatExchanger

2.4.3 Equations applied

$$0 = \begin{cases} p_{in,1} - p_{out,1} & |\dot{m}_{in,1}| < 0.0001 \text{ kg/s} \\ \frac{\zeta}{D^4} - \frac{(p_{in,1} - p_{out,1}) \cdot \pi^2}{8 \cdot \dot{m}_{in,1} \cdot |\dot{m}_{in,1}| \cdot \frac{v_{in,1} + v_{out,1}}{2}} & |\dot{m}_{in,1}| \geq 0.0001 \text{ kg/s} \end{cases} \quad (35)$$

$$0 = \begin{cases} p_{in,2} - p_{out,2} & |\dot{m}_{in,2}| < 0.0001 \text{ kg/s} \\ \frac{\zeta}{D^4} - \frac{(p_{in,2} - p_{out,2}) \cdot \pi^2}{8 \cdot \dot{m}_{in,2} \cdot |\dot{m}_{in,2}| \cdot \frac{v_{in,2} + v_{out,2}}{2}} & |\dot{m}_{in,2}| \geq 0.0001 \text{ kg/s} \end{cases} \quad (36)$$

$$\begin{aligned} 0 = & \dot{m}_{in,1} \cdot (h_{out,1} - h_{in,1}) \\ & + kA_{\text{design}} \cdot f_{kA} \cdot \frac{T_{out,1} - T_{in,2} - T_{in,1} + T_{out,2}}{\ln \frac{T_{out,1} - T_{in,2}}{T_{in,1} - T_{out,2}}} \end{aligned} \quad (37)$$

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

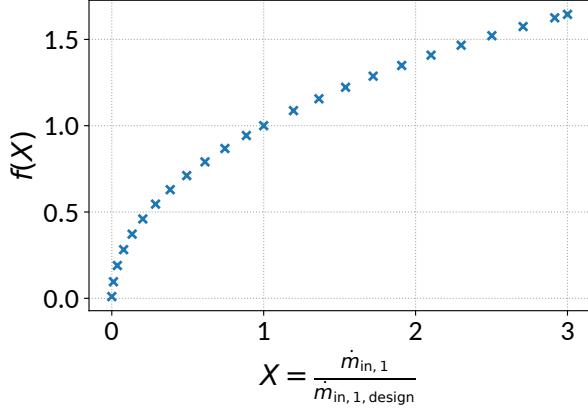


Figure 6: Characteristics of superheater (eq. 37)

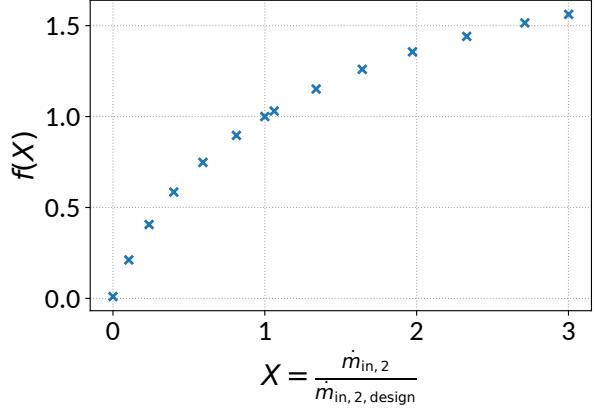


Figure 7: Characteristics of superheater (eq. 37)

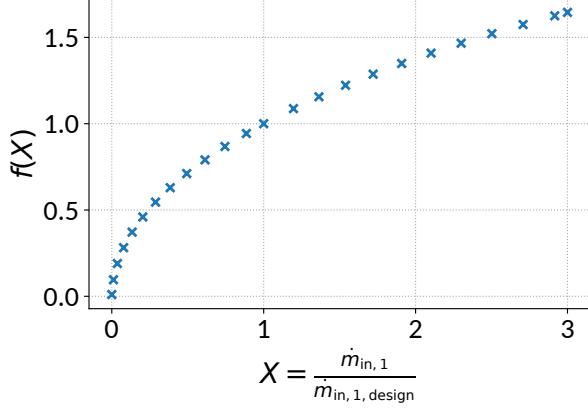


Figure 8: Characteristics of evaporator (eq. 37)

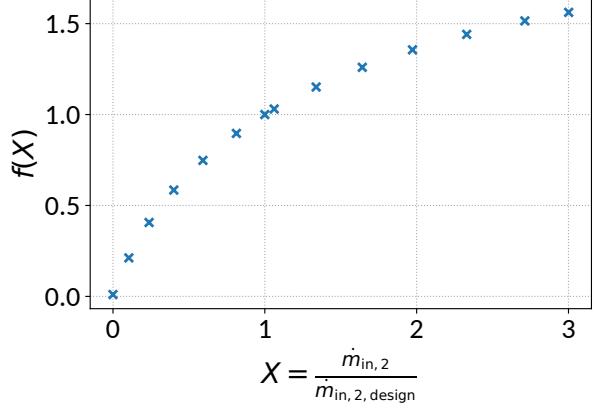


Figure 9: Characteristics of evaporator (eq. 37)

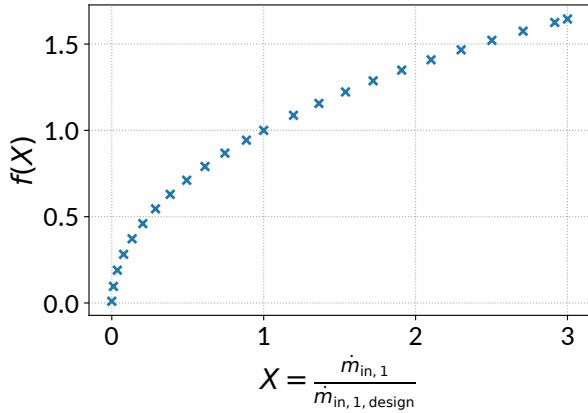


Figure 10: Characteristics of economizer (eq. 37)

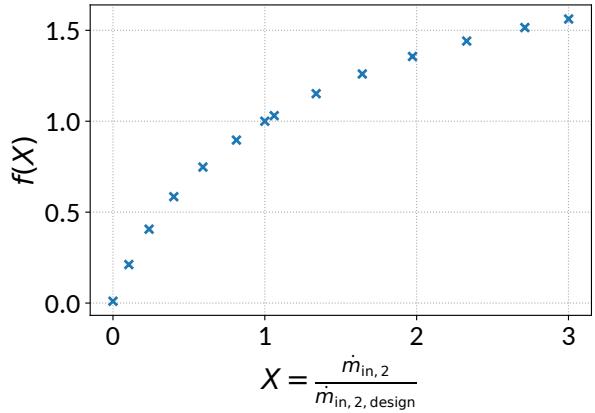


Figure 11: Characteristics of economizer (eq. 37)

2.5 Components of type Drum

2.5.1 Mandatory constraints

$$0 = \sum \dot{m}_{in,i} - \sum \dot{m}_{out,j} \quad \forall i \in \text{inlets}, \forall j \in \text{outlets} \quad (38)$$

$$0 = x_{fl,in,1} - x_{fl,out,j} \quad \forall fl \in \text{network fluids}, \forall j \in \text{outlets} \quad (39)$$

$$0 = \sum_i (\dot{m}_{in,i} \cdot h_{in,i}) - \sum_j (\dot{m}_{out,j} \cdot h_{out,j}) \quad \forall i \in \text{inlets} \quad \forall j \in \text{outlets} \quad (40)$$

$$\begin{aligned} 0 &= p_{in,1} - p_{in,i} \quad \forall i \in \text{inlets} \setminus \{1\} \\ 0 &= p_{in,1} - p_{out,j} \quad \forall j \in \text{outlets} \end{aligned} \quad (41)$$

$$\begin{aligned} 0 &= h_{out,1} - h(p_{out,1}, x=0) \\ 0 &= h_{out,2} - h(p_{out,2}, x=1) \end{aligned} \quad (42)$$

2.6 Components of type Splitter

2.6.1 Mandatory constraints

$$0 = \sum \dot{m}_{\text{in},i} - \sum \dot{m}_{\text{out},j} \quad \forall i \in \text{inlets}, \forall j \in \text{outlets} \quad (43)$$

$$0 = x_{fl,\text{in}} - x_{fl,\text{out},j} \quad \forall fl \in \text{network fluids}, \forall j \in \text{outlets} \quad (44)$$

$$0 = h_{in} - h_{\text{out},j} \quad \forall j \in \text{outlets} \quad (45)$$

$$\begin{aligned} 0 &= p_{\text{in},1} - p_{\text{in},i} \quad \forall i \in \text{inlets} \setminus \{1\} \\ 0 &= p_{\text{in},1} - p_{\text{out},j} \quad \forall j \in \text{outlets} \end{aligned} \quad (46)$$

2.7 Components of type Condenser

2.7.1 Mandatory constraints

$$0 = \dot{m}_{\text{in},i} - \dot{m}_{\text{out},i} \quad \forall i \in [1, 2] \quad (47)$$

$$0 = x_{fl,\text{in},i} - x_{fl,\text{out},i} \quad \forall fl \in \text{network fluids}, \forall i \in [1, 2] \quad (48)$$

$$0 = \dot{m}_{\text{in},1} \cdot (h_{\text{out},1} - h_{\text{in},1}) + \dot{m}_{\text{in},2} \cdot (h_{\text{out},2} - h_{\text{in},2}) \quad (49)$$

2.7.2 Inputs specified

label	pr1 (50)	zeta2 (51)	kA_char (52)	subcooling (53)
district heating condenser	0.990	120.302	True	True
condenser	0.990	8.358	True	True

Table 11: Parameters of components of type Condenser

2.7.3 Equations applied

$$0 = p_{\text{in},1} \cdot pr1 - p_{\text{out},1} \quad (50)$$

$$0 = \begin{cases} p_{\text{in},2} - p_{\text{out},2} & |\dot{m}_{\text{in},2}| < 0.0001 \text{ kg/s} \\ \frac{\zeta}{D^4} - \frac{(p_{\text{in},2} - p_{\text{out},2}) \cdot \pi^2}{8 \cdot \dot{m}_{\text{in},2} \cdot |\dot{m}_{\text{in},2}| \cdot \frac{v_{\text{in},2} + v_{\text{out},2}}{2}} & |\dot{m}_{\text{in},2}| \geq 0.0001 \text{ kg/s} \end{cases} \quad (51)$$

$$\begin{aligned} 0 &= \dot{m}_{\text{in},1} \cdot (h_{\text{out},1} - h_{\text{in},1}) \\ &\quad + kA_{\text{design}} \cdot f_{\text{kA}} \cdot \frac{T_{\text{out},1} - T_{\text{in},2} - T_{\text{sat}}(p_{\text{in},1}) + T_{\text{out},2}}{\ln \frac{T_{\text{out},1} - T_{\text{in},2}}{T_{\text{sat}}(p_{\text{in},1}) - T_{\text{out},2}}} \end{aligned} \quad (52)$$

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

$$0 = h_{\text{out},1} - h(p_{\text{out},1}, x = 0) \quad (53)$$

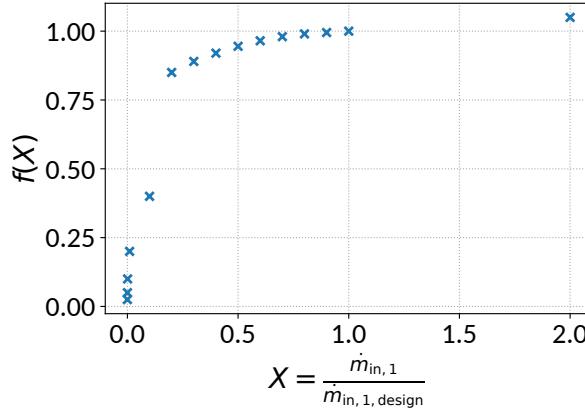


Figure 12: Characteristics of district heating con-
denser (eq. 52)

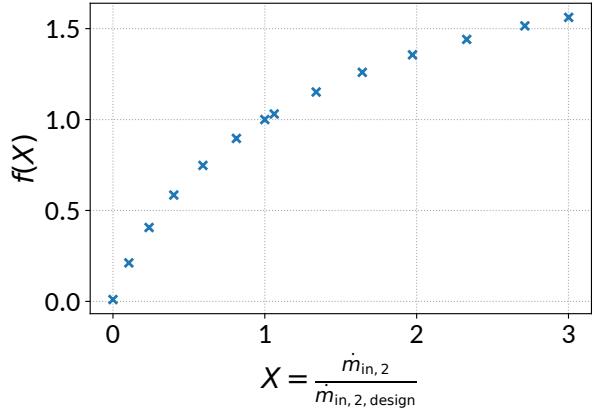


Figure 13: Characteristics of district heating con-
denser (eq. 52)

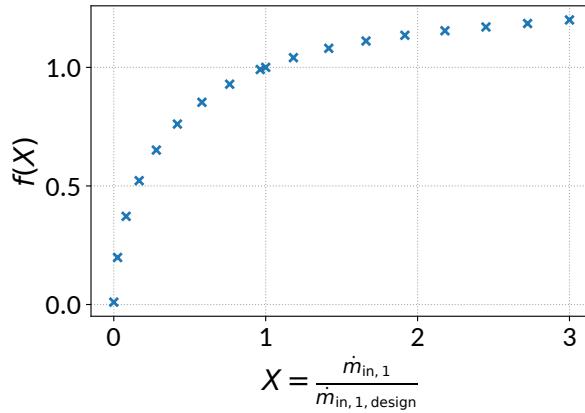


Figure 14: Characteristics of condenser (eq. 52)

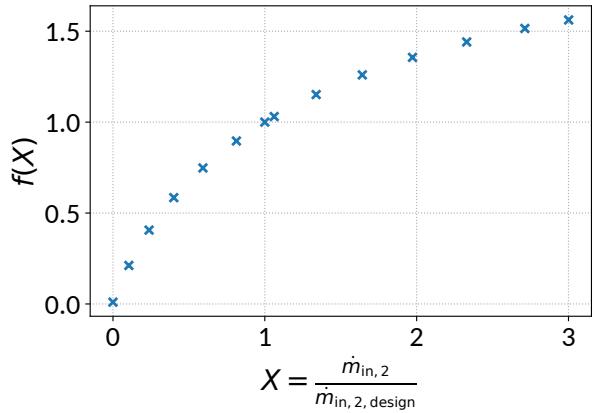


Figure 15: Characteristics of condenser (eq. 52)

2.8 Components of type Pump

2.8.1 Mandatory constraints

$$0 = \dot{m}_{in,i} - \dot{m}_{out,i} \quad \forall i \in [1] \quad (54)$$

$$0 = x_{fl,in,i} - x_{fl,out,i} \quad \forall fl \in \text{network fluids}, \forall i \in [1] \quad (55)$$

2.8.2 Inputs specified

label	eta_s_char (56)
feed water pump 1	True
feed water pump 2	True

Table 12: Parameters of components of type Pump

2.8.3 Equations applied

$$0 = (h_{out} - h_{in}) \cdot \eta_{s,design} \cdot f(X) - (h_{out,s} - h_{in}) \quad (56)$$

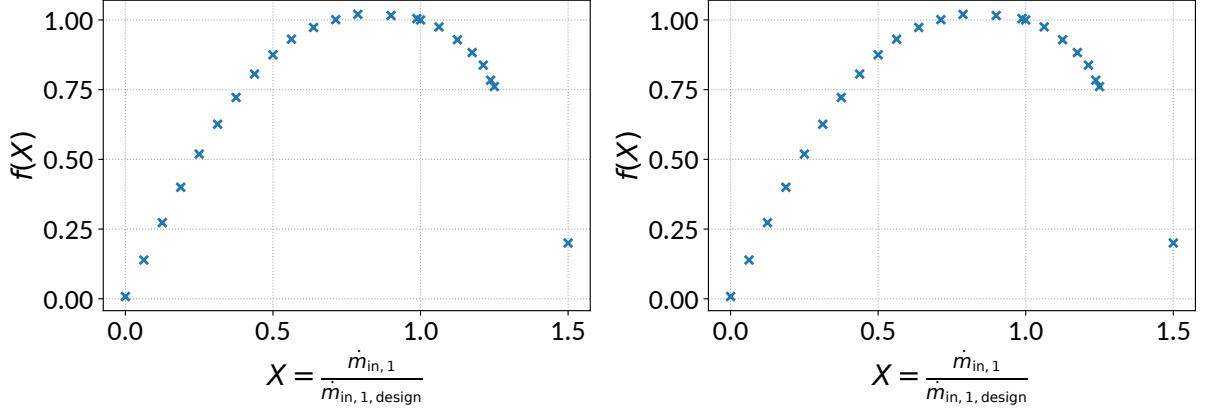


Figure 16: Characteristics of feed water pump 1 (eq. Figure 17: Characteristics of feed water pump 2 (eq. 56)
56)

2.9 Components of type Merge

2.9.1 Mandatory constraints

$$0 = \sum \dot{m}_{in,i} - \sum \dot{m}_{out,j} \quad \forall i \in \text{inlets}, \forall j \in \text{outlets} \quad (57)$$

$$0 = \sum_i \dot{m}_{in,i} \cdot x_{fl,in,i} - \dot{m}_{out} \cdot x_{fl,out} \quad \forall fl \in \text{network fluids}, \forall i \in \text{inlets} \quad (58)$$

$$0 = \sum_i (\dot{m}_{in,i} \cdot h_{in,i}) - \dot{m}_{out} \cdot h_{out} \quad \forall i \in \text{inlets} \quad (59)$$

$$\begin{aligned} 0 &= p_{in,1} - p_{in,i} \quad \forall i \in \text{inlets} \setminus \{1\} \\ 0 &= p_{in,1} - p_{out,j} \quad \forall j \in \text{outlets} \end{aligned} \quad (60)$$

2.10 Components of type Valve

2.10.1 Mandatory constraints

$$0 = \dot{m}_{in,i} - \dot{m}_{out,i} \quad \forall i \in [1] \quad (61)$$

$$0 = x_{fl,in,i} - x_{fl,out,i} \quad \forall fl \in \text{network fluids}, \forall i \in [1] \quad (62)$$

$$0 = h_{in,i} - h_{out,i} \quad \forall i \in [1] \quad (63)$$

3 Busses in offdesign mode

3.1 Bus “power output”

This bus is used for postprocessing only.

label	\dot{E}_{comp}	\dot{E}_{bus}	η
gas turbine	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	$f(X) (18)$
compressor	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	1.000
fuel compressor	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\frac{\dot{E}_{\text{comp}}}{\eta}$	$f(X) (19)$
steam turbine high pressure	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	$f(X) (18)$
feed water pump 1	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\frac{\dot{E}_{\text{comp}}}{\eta}$	$f(X) (19)$
steam turbine low pressure	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	$f(X) (18)$
feed water pump 2	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\frac{\dot{E}_{\text{comp}}}{\eta}$	$f(X) (19)$

Table 13: power output

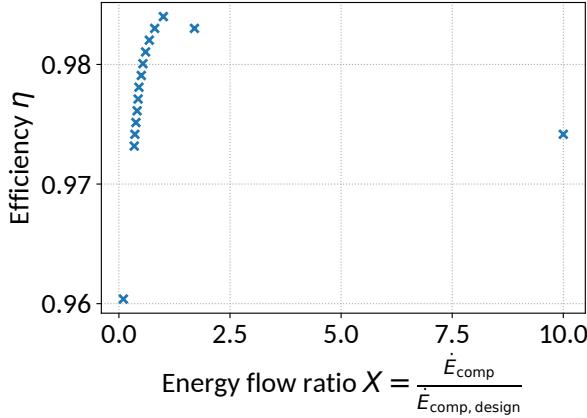


Figure 18: Bus efficiency characteristic

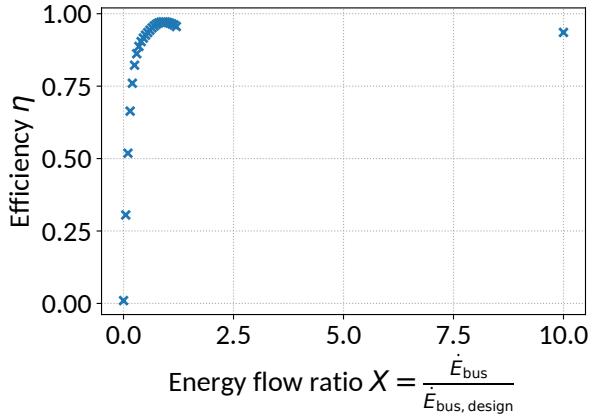


Figure 19: Bus efficiency characteristic

3.2 Bus “gas turbine power output”

Specified total value of energy flow: $\dot{E}_{\text{bus}} = -105822222.941 \text{ W}$

$$0 = \dot{E}_{\text{bus}} - \sum_i \dot{E}_{\text{bus},i} \quad (64)$$

label	\dot{E}_{comp}	\dot{E}_{bus}	η
gas turbine	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	1.000
compressor	$\dot{m}_{\text{in}} \cdot (h_{\text{out}} - h_{\text{in}})$	$\dot{E}_{\text{comp}} \cdot \eta$	1.000

Table 14: gas turbine power output

3.3 Bus “heat output”

Specified total value of energy flow: $\dot{E}_{\text{bus}} = -10000000.000 \text{ W}$

$$0 = \dot{E}_{\text{bus}} - \sum_i \dot{E}_{\text{bus},i} \quad (65)$$

label	\dot{E}_{comp}	\dot{E}_{bus}	η
district heating condenser	$\dot{m}_{\text{in},1} \cdot (h_{\text{out},1} - h_{\text{in},1})$	$\dot{E}_{\text{comp}} \cdot \eta$	1.000

Table 15: heat output

3.4 Bus “heat cond”

This bus is used for postprocessing only.

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

Table 16: heat cond

3.5 Bus “heat input”

This bus is used for postprocessing only.

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

Table 17: heat input