1. Energy flow formulations

1.1. Energy flows in EP

$$SeS_{EP,j} = \frac{P_{EP}}{P_L} \quad (1)$$

$SeS_{EP,j}$ is the level of self-sufficiency of electricity procurement in case j. P_{EP} is the power procured from the grid. P_L is the demanded load.

1.2. Energy flows in RES

$$P_{PV,i,j} = P_{N,PV,j} * (G_i/G_{Ref}) * (1 - 0.0037 * (T_i + (0.00256 * G_i) - T_{Ref})) \quad (2)$$

$P_{PV,i,j}$ is the power of the PV plant in timeframe i in case j. $P_{N,PV,j}$ is the nominal power output of the photovoltaic plant. G_i is the solar irradiation in timeframe i. G_{Ref} is the solar radiation at reference conditions (1000 W/m^2). T_i is the ambient temperature in timeframe i. T_{Ref} is the temperature at reference conditions (25°C).

$$P_{WT,i,j} = P_{N,WT,j} * \upsilon_{WT,i} ** 3 * 0{,}5 * C_p * \rho_{Air} * R_{Rotor} ** 2 * \pi \quad (3)$$

$P_{N,WT,j}$is the nominal scaling factor of the wind turbines in case j. $\upsilon_{WT,i}$ is the wind speed in timeframe i. It is constrained as follows:

$$\upsilon_{WT,i} = \begin{cases} 0 \text{ for } \upsilon_{WT,i} < 3\ m/s \\ 0 \text{ for } \upsilon_{WT,i} > 26\ m/s \\ \text{else } \upsilon_{WT,i} \end{cases} \quad (4)$$

C_p is the coefficient of performance. ρ_{Air} is the air density. R_{Rotor} is the radius of the rotor. It is capped at 5 MW per turbine, matching the modeled wind turbines nominal power.

$$P_{Ef,i} = P_{L,i}/\eta_{Inv} \quad (5)$$

$P_{Ef,i}$ is the effective load. η_{Inv} is the efficiency of the inverter.

$$PD_i = P_{PV,i,j} + P_{WT,i,j} - P_{Ef,i} \quad (6)$$

PD_i is the power difference between the power output of PV and WT and the load $P_{Ef,i}$ in timeframe i.

$$B_{E,i,j} = \begin{cases} B_{E,i-1,j} + PD_i * RE_B \ for \ B_{E,i-1,j} + PD_i * RE_B > 0 \\ B_{M,j} \ for \ B_{E,i-1,j} + PD_i * RE_B > B_{M,j} \\ 0 \ for \ B_{E,i-1,j} + PD_i * RE_B \leq 0 \end{cases} \quad (7)$$

$$B_{Disc,i} = \begin{cases} 0\ for\ P_{PV,i} + P_{WT,i} = P_{Ef,i} \\ 0\ for\ B_{E,i} = 0 \\ PD_i * RE_B \end{cases} \quad (8)$$

$$B_{M,j} = B_{M,N,j} * SOCW \quad (9)$$

$B_{E,i,j}$ is the energy stored in the battery in timeframe i in case j. RE_B is the roundtrip efficiency of the battery. $B_{M,j}$ is the maximum battery capacity in case j. $B_{Disc,i,j}$ is the discharge power of the battery in timeframe i. $B_{M,N,j}$ is the nominal maximum battery capacity in case j. $SOCW$ is the allowed window of the state of charge.

$$P_{ES,i} = \begin{cases} 0\ for\ B_{E,i-1,j} + PD_i * RE_B \ll B_{M,j} \\ PD_i\ for\ B_{E,i-1,j} \geq B_{M,j} \\ PD_i - (B_{M,j} - B_{E,i-1,j})\ for\ B_{E,i-1,j} < B_{M,j} \end{cases} \quad (10)$$

$P_{ES,i}$ is the power sold in timeframe i.

$$SeS_{RES.i,j} = (B_{Disc,i,j} + P_{PV,i,j} + P_{WT,i,j}) / P_{Ef,i,j} \quad (11)$$

$SeS_{RES.i,j}$ is the share of the load that can be covered by the renewable energy system in timeframe i in case j.

$$SeS_{RES.j} = \sum_i^{i_{max}} SeS_{RES.i,j} / i_{max} \quad (12)$$

$SeS_{RES.j}$ is the amount of timeframes which are covered by the renewable energy system of all timeframes in case j. i_{max} is the total number of timeframes.

$$U_{i,j} = SeS_{RES.i,j} * P_{Ef,i} \quad (13)$$

$U_{i,j}$ is the used renewable energy in timeframe i in case j.

$$U_j = (\sum_i^{i_{max}} U_{i,j} + B_{E,i_{max},j}) / \sum_i^{i_{max}} P_{PV,i,j} + \sum_i^{i_{max}} P_{WT,i,j} \quad (14)$$

U_j is the ratio of the energy used compared to energy production in total in case j. $B_{L,i_{max},j}$ is the remaining electricity in the battery at the end of the investigation period in case j.

2. Cost formulations

2.1. Cost formulations in EP

$$c_{tot,EP,j} = \sum_{i}^{i_{max}} P_{EP,i,j} * L_P * c_{EP} \tag{15}$$

$c_{tot,EP}$ is the total cost of electricity procurement in case j. L_P is the lifetime of the plant. c_{EP} is the cost for electricity procurement.

2.2. Cost formulations in RES

$$c_{Cap,PV,j} = P_{N,PV,j} * c_{Capex,PV} \tag{16}$$

$c_{Cap,PV,j}$ is the capital expenditure of the PV plant in case j. $c_{Capex,PV}$ is the cost factor for capital expenditures regarding PV plants.

$$c_{Op,PV,j} = P_{N,PV,j} * c_{Opex,PV} * L_{PV} \tag{17}$$

$c_{Op,PV,j}$ is the operational expenditure of the PV plant in case j. $c_{Capex,PV}$ is the cost factor for operational expenditures regarding PV plants. L_{PV} is the lifetime of the PV plant.

$$c_{Cap,WT,j} = P_{N,WT,j} * c_{Capex,WT} \tag{18}$$

$c_{Cap,WT,j}$ is the capital expenditure of the wind turbines in case j. $c_{Capex,WT}$ is the cost factor for capital expenditures regarding wind turbines.

$$c_{Op,WT,j} = P_{N,WT,j} * c_{Opex,WT} * L_{WT} \tag{19}$$

$c_{Op,WT,j}$ is the operational expenditure of the wind turbines in case j. $c_{Capex,WT}$ is the cost factor for operational expenditures regarding wind turbines. L_{WT} is the lifetime of the wind turbines.

$$c_{Cap,B,j} = B_{M,j} * c_{Capex,B} \tag{20}$$

$c_{Cap,B,j}$ is the capital expenditure of the battery in case j. $c_{Capex,B}$ is the cost factor for capital expenditures regarding the battery.

$$c_{Op,B,j} = B_{M,j} * (c_{Rep,B} * z_{B,j} * L_P / z_{max,B} + B_{M,j} * c_{Opex,B} * L_P) \tag{21}$$

$c_{Op,B,j}$ is the operational expenditure of the battery system in case j. $c_{Rep,B}$ are the costs for the replacement of batteries. $z_{B,j}$ is the theoretical cycles the batteries needed in case j. $z_{max,B}$ is the number of cycles that the battery will last without a significant loss of capacity. $c_{Opex,B}$ is the cost factor for operational expenditures for the battery system. L_P is the lifetime of the plant.

$$c_{Cap,Inv,j} = P_{N,Inv,j} * c_{Capex,Inv} * L_{Inv}/L_P \quad (22)$$

$c_{Cap,PV,j}$ is the capital expenditure of the inverter in case j. $P_{N,Inv,j}$ is the maximum nominal power the inverter can handle in case j. This is set equal to the maximum power which is transferred through the system at any given timeframe. $c_{Capex,Inv}$ is the capital cost factor of the inverter. L_{Inv} is the lifetime of the inverter.

$$c_{tot,RES,j} = c_{Cap,PV,j} + c_{Op,PV,j} + c_{Cap,WT,j} + c_{Op,WT,j} + c_{Cap,B,j} + c_{Op,B,j} + c_{Cap,Inv,j} \quad (23)$$

$c_{tot,RES,j}$ is the total cost of the RES in case j.

$$c_{tot,ES,j} = \sum_i^{i_{max}} P_{ES,i} * L_P * c_{ES,i} \quad (24)$$

$c_{ES,i}$ is the market price for electricity sales in timeframe i. $c_{tot,ES,j}$ is the total revenue of electricity sales in case j.

$$c_{tot,RES+EP,j} = c_{tot,RES,j} + (1 - SeS_{RES,j}) * P_{Ef} * L_P * c_{EP} - c_{tot,ES,j} \quad (25)$$

$c_{tot,RES+EP,j}$ is the cost of the RES with electricity procurement in times when the RES cannot cover the energy demand and energy sales when the RES produces surplus energy.