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Assignment 1 Optimal combinations of production plants - local energy planning (Date: 31.01.2014)

Assignment 1a

peak load operation time τ_{PL}

peak load: gas boiler

- 0.1 EUR/kWh operational cost ($= r_P$)
- 100 EUR/kW investition cost ($= f_P$)

base load: bio fuel boiler

- 0.05 EUR/kWh operational cost ($= r_B$)
- 300 EUR/kW investition cost ($= f_B$)

formulary

$$\tau_{PL} = \frac{f_B - f_P}{r_P - r_B} \tag{1}$$

calculation

$$\tau_{PL} = \frac{300 - 100}{0.1 - 0.05} = 4\,000h$$

maximum effect base load $\dot{Q}_{max,BL}$

formulary

$$\dot{Q}_{max,BL} = \dot{Q}_h(\tau_{PL}) \tag{2}$$

$$\dot{Q}_h = \dot{Q}_{h,min} + (\dot{Q}_{h,max} - \dot{Q}_{h,min}) \cdot [1 - \sqrt[3]{\frac{\tau}{\tau_0}} + (\frac{\tau}{\tau_0})^2 \cdot (1 - \sqrt{\frac{\tau}{\tau_0}})] \tag{3}$$

calculation

$$\dot{Q}_{max,BL} = \dot{Q}_h(4\,000h) = 5\,000kW + (60\,000kW - 5\,000kW) \cdot [1 - \sqrt[3]{\frac{4\,000h}{6\,500h}} + (\frac{4\,000h}{6\,500h})^2 \cdot (1 - \sqrt{\frac{4\,000h}{6\,500h}})]$$

$$\dot{Q}_{max,BL} = 17\,707.3kW$$

maximum effect peak load $\dot{Q}_{max,PL}$

formulary

$$\dot{Q}_{max,PL} = \dot{Q}_{h,max} - \dot{Q}_{max,BL}) \tag{4}$$

calculation

$$\dot{Q}_{max,PL} = 60\,000kW - 17\,707.3kW = 42\,292.7kW$$

Energy use

formulary

$$Q = \int \dot{Q} d\tau \tag{5}$$

$$Q_{PL} = \int_0^{\tau_{PL}} \dot{Q}_h d\tau - \dot{Q}_h(\tau_{PL}) \cdot \tau_{PL} \tag{6}$$

$$\int_0^{\tau_{PL}} \dot{Q}_h d\tau = \dot{Q}_{h,min} \cdot \tau|_0^{\tau_{PL}} + \Delta\dot{Q}_h \cdot [\tau|_0^{\tau_{PL}} - \frac{1}{\sqrt[3]{\tau_0}} \cdot \frac{\tau^{\frac{4}{3}}}{\frac{4}{3}}|_0^{\tau_{PL}} + \frac{1}{\tau_0^2} \cdot \frac{\tau^3}{3}|_0^{\tau_{PL}} - \frac{1}{\tau_0^{\frac{5}{2}}} \cdot \frac{\tau^{\frac{7}{2}}}{\frac{7}{2}}|_0^{\tau_{PL}}] \tag{7}$$

$$Q_{PL} = \int_0^{\tau_{PL}} \dot{Q}_h d\tau - \dot{Q}_h(\tau_{PL}) \cdot \tau_{PL} \tag{8}$$

$$Q_{BL} = \dot{Q}(\tau_{PL}) \cdot \tau_{PL} + \dot{Q}_{DHW}(\tau_{year} - \tau_{PL}) + \int_{\tau_{PL}}^{\tau_0} \dot{Q}_h d\tau \tag{9}$$

calculation

$$\int_0^{4000} \dot{Q}_h d\tau = 5\,000 \cdot 4\,000 + (60\,000 - 5\,000) \cdot [4\,000 - \frac{1}{\sqrt[3]{6500}} \cdot \frac{4\,000^{\frac{4}{3}}}{\frac{4}{3}} + \frac{1}{6\,500^2} \cdot \frac{4\,000^3}{3} - \frac{1}{6\,500^{\frac{5}{2}}} \cdot \frac{4\,000^{\frac{7}{2}}}{\frac{7}{2}}]$$

$$\int_0^{4000} \dot{Q}_h d\tau = 108\,752\,075 kWh$$

$$Q_{PL} = 108\,752\,075 kWh - 17\,707.3 kW \cdot 4\,000 h = 37\,922\,875 kWh$$

$$Q_{BL} = 17\,707.3 \cdot 4\,000 + 5\,000 \cdot (8\,760 - 4\,000) + 5\,000 \cdot (6\,500 - 4\,000) + 55\,000[(6\,500 - 4\,000) -$$
$$\frac{1}{\sqrt[3]{6\,500}} \cdot \frac{6\,500^{\frac{4}{3}} - 4\,000^{\frac{4}{3}}}{\frac{4}{3}} + \frac{1}{6\,500^2} \cdot \frac{6\,500^3 - 4\,000^3}{3} - \frac{1}{6\,500^{\frac{5}{2}}} \cdot \frac{6\,500^{\frac{7}{2}} - 4\,000^{\frac{7}{2}}}{\frac{7}{2}}]$$

$$Q_{BL} = 132\,775\,935 kWh$$

total annual cost

formulary

$$C = c_{gas} \cdot Q_{PL} + c_{bio} \cdot Q_{BL} \tag{10}$$

calculation

$$C = 37\,922\,875 kWh \cdot 0.1^{EUR}/_{kWh} + 132\,775\,935 kWh \cdot 0.05^{EUR}/_{kWh}$$

$$C = 10\,431\,085 EUR$$

Assignment 1b

peak load operation time τ_{PL}

peak load: gas boiler

- 0.1 EUR/kWh operational cost ($= r_P$)
- 130 EUR/kW investition cost ($= f_P$)

base load: waste combustion boiler

- -0.08 EUR/kWh operational cost ($= r_B$)
- 1300 EUR/kW investition cost ($= f_B$)

$$\tau_{PL} = \frac{1300 - 130}{0.1 + 0.08} = 6\,500h$$

maximum effect base load $\dot{Q}_{max,BL}$

$$\dot{Q}_{max,BL} = \dot{Q}_h(6\,500h) = 5\,000kW + (60\,000kW - 5\,000kW) \cdot [1 - \sqrt[3]{\frac{6\,500h}{6\,500h}} + (\frac{6\,500h}{6\,500h})^2 \cdot (1 - \sqrt{\frac{6\,500h}{6\,500h}})]$$

$$\dot{Q}_{max,BL} = 5\,000kW$$

maximum effect peak load $\dot{Q}_{max,PL}$

$$\dot{Q}_{max,PL} = 60\,000kW - 5\,000kW = 55\,000kW$$

Energy use

$$\int_0^{6500} \dot{Q}_h d\tau = 5\,000 \cdot 6\,500 + 55\,000 \cdot [6\,500 - \frac{1}{\sqrt[3]{6500}} \cdot \frac{6\,500^{\frac{4}{3}}}{\frac{4}{3}} + \frac{1}{6\,500^2} \cdot \frac{6\,500^3}{3} - \frac{1}{6\,500^{\frac{5}{2}}} \cdot \frac{6\,500^{\frac{7}{2}}}{\frac{7}{2}}]$$

$$\int_0^{6500} \dot{Q}_h d\tau = 138\,898\,809kWh$$

$$Q_{PL} = 138\,898\,809kWh - 5\,000kW \cdot 6\,500h = 106\,398\,809kWh$$

$$Q_{BL} = 5\,000 \cdot 6\,500 + (8\,760 - 6\,500) \cdot 5\,000 + \int_{6500}^{6500} ...$$

$$Q_{BL} = 43\,000\,000kWh$$

total annual cost

formulary

$$C = c_{gas} \cdot Q_{PL} + c_{waste} \cdot Q_{BL} \tag{11}$$

calculation

$$C = 138\,898\,809kWh \cdot 0.1^{EUR}/_{kWh} + 43\,800\,000kWh \cdot (-0.08^{EUR}/_{kWh})$$

$$C = 10\,385\,881EUR$$

Assignment 1c