

# Lecture 7: Heat networks

DTU Course 46770: Integrated Energy Grids

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**Problem 7.1.** A district heating system is used to transport heat generated using a heat pump to two distant buildings. The pipeline diameter is 0.5 m, the water velocity is 2 m/s, the supply temperature  $T^S$  is variable through the network and the return temperature is  $T^R=40^\circ\text{C}$ . Assume the mass flow to be constant and that the heat losses in the pipelines due to dissipation to the ambient can be neglected.

The heat transfer coefficient of building A is  $U_A = 2 \text{ MW/k}$ , the heat transfer coefficient of building B is  $U_B = 3 \text{ MW/k}$ , the ambient temperature is  $5^\circ\text{C}$  and the interior comfort temperature of the buildings must be  $20^\circ\text{C}$ .

- a) Calculate the rate of heat extracted in every building.
- b) Calculate the input and output temperatures at the heat exchanger that serves every building.
- c) Calculate the supply temperature required for the water flow supplied by the heat pump.
- d) Assuming that the electricity demand required for pumping the water is proportional to the cubic mass flow with a proportionality constant of  $0.06 \text{ W s}^3 \text{ kg}^{-3}$ , calculate its relative size compared to the thermal power supplied by the district heating system.

**Problem 7.2.** A district heating system is used to transport heat generated using a heat pump to two distant buildings. The pipeline diameter is 0.5 m, the supply temperature is  $T^S=80^\circ\text{C}$  and the return temperature is  $T^R=40^\circ\text{C}$ . Assume the mass flow to be constant and that the heat losses in the pipelines due to dissipation to the ambient can be neglected.

The heat transfer coefficient of building A is  $U_A = 2 \text{ MW/k}$ , the heat transfer coefficient of building B is  $U_B = 3 \text{ MW/k}$ , the ambient temperature is  $5^\circ\text{C}$  and the interior comfort temperature of the buildings must be  $20^\circ\text{C}$ .

Calculate the mass flow needed at the heat exchanger that serves every building, assuming that the input and output temperature correspond to  $T^S$  and  $T^R$ .

**Problem 7.3.** Assume that we have three locations (1,2,3) with an electric bus and a heating bus. The electricity loads are  $[0, 10, 20]$  MWh and the heating loads are  $[30, 20, 10]$  MWh. The electric buses are connected with transmission lines in a ring and there is a gas power generator at node 1 with an efficiency of 0.3 and a marginal cost of 50 EUR/MWh. At each location the electric and heating buses are connected using heat pumps with a coefficient of performance (COP) of 3; heat can also be supplied to every heat bus with a gas boiler with an efficiency of 0.9 and a marginal cost of 20 EUR/MWh.

- a) Calculate the optimal heat generation by every component and the optimal power flowing through the lines.
- b) Repeat (a) assuming that the marginal cost of heat pumps is 10 EUR/MWh

**Problem 7.4.** In this problem, we will model a node that contains an electricity, a gas and a heat bus. There is a demand of 50 MWh of electricity and 40 MWh of heat. Electricity can be produced using an Open Cycle Gas Turbine (OCGT) with an efficiency of 0.35 or using a Combined Heat and Power (CHP) unit. Heat can be produced with the CHP unit or with a gas boiler. The OCGT, gas boiler and CHP unit have a marginal cost due to the fuel cost of 20 EUR/MWh<sub>th</sub>.

- a) In this section, we assume that the CHP has a fixed efficiency of 0.3 when producing electricity and 0.3 when producing heat. Model the OCGT and gas boiler, using a link and the CHP unit using and multilink element in PyPSA. Add a gas store to the gas bus that represents an unlimited supply of gas. Optimize the system and calculate which technologies are supplying the electricity and heat demand.
- b) In this section, we assume that the CHP unit can be operated either in condensing mode or in back-pressure mode. In practice, this means the feasible space for operating the CHP unit is determined by the iso-fuel lines (with constant  $c_v=0.15$ ) and the back-pressure line (with constant  $c_m=0.75$ ). Optimize the system and calculate which technologies are supplying the electricity and heat demand.