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°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 $U_A = 2$ MW/k, the heat transfer coefficient of building B is $U_B = 3$ MW/k, the ambient temperature is 5°C and the interior comfort temperature of the buildings must be 20°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 0.066, 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°C and the return temperature is T^R=40°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 $U_A = 2$ MW/k, the heat transfer coefficient of building B is $U_B = 3$ MW/k, the ambient temperature is 5°C and the interior comfort temperature of the buildings must be 20°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 optical 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$_{th}$.

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.