Lecture 10: Capacity and dispatch optimisation in a network

DTU Course 46770: Integrated Energy Grids

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Problem 10.1. We build on the models described in Problem sets 8 and 9:

Optimize the capacity and dispatch of solar PV, onshore wind, and Open Cycle Gas Turbine (OCGT) generators to supply the inelastic electricity demand throughout one year. To do this, take the time series for the wind and solar capacity factors for Portugal and Denmark in 2015 obtained from `https://zenodo.org/record/3253876#.XSiVOEdS8l0` and `https://zenodo.org/record/2613651#.X0kbhDVS-uV` (select the file 'pvoptimal.csv') and the electricity demand from `https://github.com/martavp/integrated-energy-grids/tree/main/integrated-energy-grids/Problems/data`.

Consider the annualized capital costs and marginal generation costs for the different technologies in the following table. The efficiency for the OCGT plant is 0.41.

Technology	Capital costs (EUR/MW/a)	Marginal costs (EUR/MWh)	CO_2 emissions (tCO_2/MWh$_{th}$)
Onshore Wind	101,644	0	0
Solar PV	51,346	0	0
OCGT	47,718	64.7	0.198

Table 1: Costs assumptions.

Now, however, we add Denmark as a second node and we connect Portugal and Denmark with an overhead HVAC line. Assume that the annualised capital cost of it is 42 EUR/MWkm/a.

For the subproblems, calculate the following:

- total system costs (in bn EUR)
- average electricity price (in EUR/MWh) and number/share of hours with zero prices.
- congestion rent
- utilisation of transmission lines (in % of capacity)
- total generation per technology (in TWh)
- total CO_2 emissions (in MtCO_2)

a) Set up a network with two nodes and connect them with an overhead AC line; keep the capacity at 0 GW and assume it cannot be extended.

b) Now assume the AC line connecting Portugal and Denmark has a capacity of 1 GW.

c) Now assume the AC line connecting Portugal and Denmark has a capacity of 10 GW.

d) Optimise the AC line capacity endogenously (assume its current capacity is 0 GW).

Problem 10.2. We build on Problem 10.1d), i.e. we optimise the capacity of the transmission line between Denmark and Portugal endogenously (starting at 0 GW). For (a)-(c) calculate the following:

- total system costs (in bn EUR)
- average electricity price (in EUR/MWh) and number/share of hours with zero prices.
- congestion rent
- utilisation of transmission lines (in % of capacity)
- total generation per technology (in TWh)
- CO_2 price (EUR/tCO_2)

a) Set up a network as in 10.1d) and add a CO2 constraint of 2.5 MtCO2/year.

b) The load distribution between Denmark and Portugal is approx. 1:1.5. Assume that both countries have national targets of 1 MtCO2/year and 1.5 MtCO2/year.

c) Assume the CO2 limits from b), but that the transmission capacities is limited to 1 GW (still endougenously optimised).

d) Change the global CO2 limit to 0.25, 0.5, 1, 1.5, 2 MtCO2/year, and plot the total system costs against the CO2 limit.