Energy System Modelling
Karlsruhe Institute of Technology
Institute for Automation and Applied Informatics
Summer Term 2020

TUTORIAL V: INVESTMENT AND LARGE POWER SYSTEMS

Will be worked on in the exercise session on Friday, 26 June 2020.

PROBLEM V.1 (ANALYTICAL) – INVESTMENT IN GENERATORS AND TRANSMISSION LINES

Two generators are connected to the grid by a single transmission line (with no electrical demand on their side of the transmission line). A single company owns both the generators and the transmission line. Generator 1 has a linear cost curve $C_1(g_1) = 5g_1$ [€/h] and a capacity of 300 MW and Generator 2 has a linear cost curve $C_2(g_2) = 10g_2$ [€/h] and a capacity of 900 MW. The transmission line has a capacity K of 1000 MW. Suppose the demand in the grid is always high enough to absorb the generation from the two generators and that the market price of electricity π is never below 15 €/MWh and averages 20 €/MWh.

(a) Determine the full set of equations (objective function and constraints) for the generators to optimise their dispatch to maximise total economic welfare.

(b) What is the optimal dispatch?

(c) What are the values of the KKT multipliers for all the constraints in terms of π?

(d) A new turbo-boosting technology can increase the capacity of Generator 1 from 300 MW to 350 MW. At what annualised capital cost would it be efficient to invest in this new technology?

(e) A new high temperature conductor technology can increase the capacity of the transmission line by 200 MW. At what annualised capital cost would it be efficient to invest in this new technology?

PROBLEM V.2 (ANAL./PROG.) – DURATION CURVES AND GENERATION INVESTMENT

Let us suppose that demand is inelastic. The demand-duration curve is given by $D = 1000 - 1000z$, where $z \in [0, 1]$ represents the probability of time the load spends above a certain value. Suppose that there is a choice between coal and gas generation plants with a variable cost of 2 and 12 €/MWh, together with load-shedding at 1012€/MWh. The fixed costs of coal and gas generation are 15 and 10 €/MWh, respectively.

(a) Describe the concept of a screening curve and how it helps to determine generation investment, given a demand-duration curve.

(b) Plot the screening curve and find the intersections of the generation technologies.

(c) Compute the long-term equilibrium power plant investment (optimal mix of generation) using PyPSA.

(d) Plot the resulting price duration curve and the generation dispatch. Comment!

(e) Demonstrate that the zero-profit condition is fulfilled.

(f) While it can be shown that generators recover their cost in theory, name reasons why this might not be the case in reality.

PROBLEM V.3 (PROGRAMMING) – SYNTHETIC FUELS

Diesel can be produced via Fischer-Tropsch process from hydrogen and carbon dioxide. Assume, an constant electric demand and a constant traffic energy demand of each 1 MWh/day. The traffic demand can be satisfied by diesel cars.

(a) Why do we need to track the CO_2 emissions for this problem?

(b) Why can it be assumed, that using biomass to generate electricity is carbon neutral?

(c) What is the meaning of `e_cyclic` in the PyPSA syntax?

(d) Run an optimisation of the problem
   (i) Show that the total amount of carbon stays constant in every time step
   (ii) what are the optimal capacities of the different components?
   (iii) how are the storages used?

(e) How do the total system costs change if Carbon Capture and Storage (CCS) is as well allowed for biomass and OCGT?

(f) How do the total system costs change if the CO2 target for the atmosphere is negative?