31765: Optimization in modern power systems

Lecture 8a: Review of Assignment 1

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Assignment 1 – Part A

Case 1	9'000	ED
Case 2	12'000	ED, active generator constraint
Case 3	12'000	NTC-based ED (transportation model)
Case 4	12'000	DC-OPF
Case 5	15'000	DC-OPF, active line constraint

- The assignment asked you to calculate for each case study the power dispatch and the total generation costs. It did not ask you to solve an ED and DC-OPF for each case study. Based on the characteristics of each case study, you had to decide if you will solve an ED, a DC-OPF, or make any modifications (see Case 3).
- The dual variables of the line flow inequality constraints are not the dual variables of the $0 \leq P_g \leq P_{g,max}$ constraint and they are not associated with a node. The line flow inequalities are the constraints that have to do with the *line limits*, i.e. $\frac{1}{x_{ij}}(\delta_i - \delta_j) \leq P^{max}_{\text{line}}$.
- The correct unit for the OPF and ED results is monetary units per hour. For example \$/h or EUR/h or DKK/h, and so on (see Lecture Notes, page 8).
- Do not forget to multiply your objective function with the baseMVA, if your P_G is in per unit. Otherwise, you will not get the correct objective function value and wrong LMPs!

Assignment 1 – Part A – Case Study 3

- Case 3: It is not a DC-OPF, since there are no reactances. It is not an ED, since it has line limits. It is the NTC-based calculations (NTC stands for Net Transfer Capacity), also called the transportation model. The Nordic Electricity Market (Nordpool) solves a version of this algorithm.
- You had to introduce 3 new optimization variables, representing the power flows: P_{12}, P_{13}, P_{23}.
- You had to replace the constraint $\sum P_{gen} = \sum P_{load}$ with:

$$\begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} P_{12} \\ P_{13} \\ P_{23} \end{bmatrix} = \begin{bmatrix} P_{G1} \\ P_{G2} \\ -P_{\text{load}} \end{bmatrix} \tag{1}$$

$$P_{13} \leq \frac{70}{S_{\text{base}}} \tag{2}$$

- Does this matrix remind you of something similar?

Assignment 1 – Part A

Quotes from your assignment reports:

- *"The results of DC-OPF and economic load dispatch are the same when there is no line congestion (study case 2,3 and 4 have same results)."*
- *"Line congestion in a network drives the total generation cost higher.""*
- *"When there is no congestion (with 70 percent load), the dual variables for the inequality constraints are all zero. However, with the full load there is one multiplier that is nonzero. [...] This multiplier corresponds to the constraint that is 'active', i.e. influencing the minimum of the objective function. We have also tested this by increasing the maximum of this line, which removed the congestion and lead to uniform nodal prices again.*

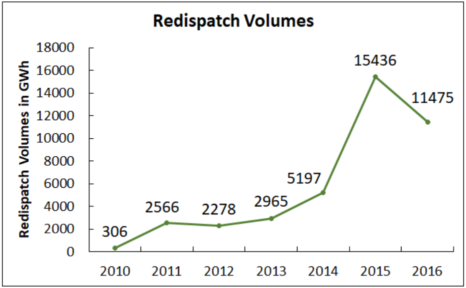
Assignment 1 – Part A

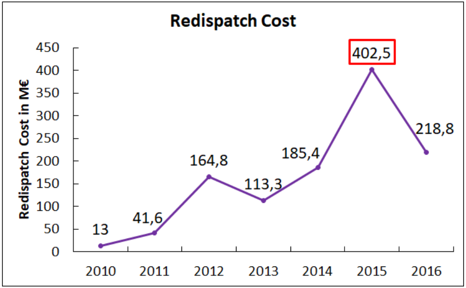
Main takeaway:

- Cost ED $\leq$ Cost OPF always (both for DC-OPF and AC-OPF)
- Cost ED $=$ Cost DC-OPF when there is no congestion (or more generally said, when all additional constraints considered in OPF are non-binding)

Cost of Redispatching

- In Germany, the power exchange solves an economic dispatch problem and determines how much different generators will produce. Then the operators solve AC power flows to determine if this generator dispatch leads to line overloadings and violation of other constraints[1] If yes, they perform redispatching. This leads always to higher costs than the Economic Dispatch.



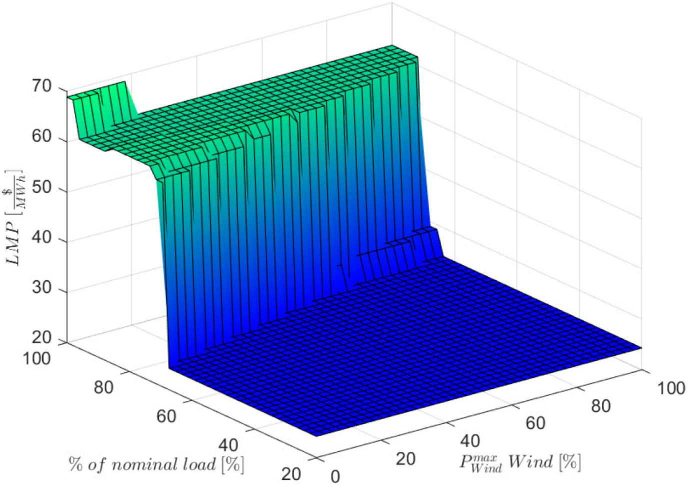


Source: Bundesnetzagentur

[1] Note: they just perform a series of AC power flows; an AC Optimal Power Flow would lead to similar, and ofter better, results in terms of costs.

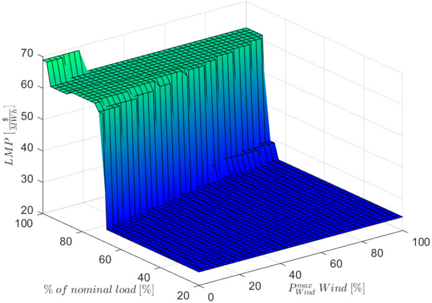
Assignment 1 – Part B

From your assignment reports:



Assignment 1 – Part B

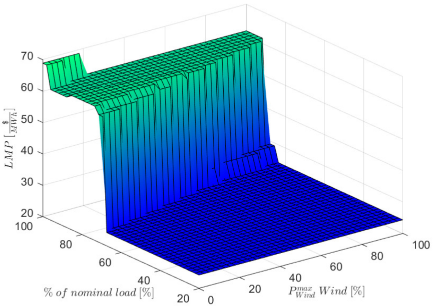
- The LMP "jumps", i.e. LMPs change in a non-smooth way
- That's the reason they are called "marginal prices". They are valid for a limited area around that specific operating point. If you move further away from that point, the price can change dramatically.



Assignment 1 – Part B

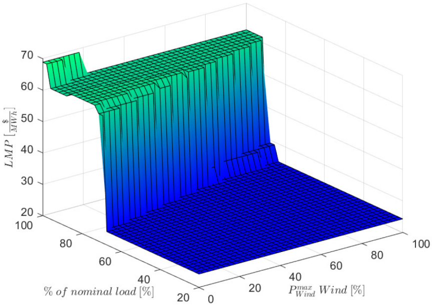
- When there is *no congestion*, the *DC-OPF* results is having the same LMPs over all nodes. This price is the system marginal price and is equal to the cost of the marginal generator. And equal to the price resulting from the economic dispatch.

- Attention: the AC-OPF will always result to different prices on different nodes. This is because the AC-OPF considers the losses in the line flows.



Assignment 1 – Part B

- Inequality LM:
  - If the constraint is binding, then LM $\neq 0$
  - If the constraint is non-binding, then LM$=0$
  - And, as we saw in the previous lecture, inequality LMs are always non-negative



Tips and Remarks

- The Lecture Notes can help!
- Max Page Limit was 3.5 pages. Please respect the page limit!
- The workload of each Assignment has been sized for a group of 3 persons. It follows that if in a group only one person (out of 3) is doing most of the work, the level of the work and the final report might not be at an equally good as other groups. *Each group member is graded individually, and their contribution to the assignments will be assessed during the exam.*