A Grid Model Comparison Experiment: Insights from the discussion of differences in model formulation in the harmonization process

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Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Agenda

Modeling the grid 1.
Operations Research in grid modeling

Set-up of model comparison 2.
Challenges of setting up a framework

Insights 3.
Soft constraints: Parametrization of penalty terms // Cross border redispatch

Learnings 4.
Take-away messages from grid comparisons

Energy market modeling and loadflow calculation

Market result

Market model PowerFlex

- *Fundamental model for the European power sector with focus on DE*
- *Cost minimization over 8760 h (one year) with perfect foresight*
- *Reduced to LP*
- *Each country is connected to neighboring countries via interconnectors*

Regionalisation

Regionalisation

- *market results for the whole of Germany are distributed to the network nodes using suitable distribution keys.*

Grid topology

- *represented by PTDF-matrix*
- *thermal limits of each power line*

Load flow

Load flow optimization OptGrid

- *approximated DC load flows are optimized by*
  - *DC corridors*
  - *Redispatch*
  - *RES curtailment*
  - *DSM, Use of storage capacities*
- *Overloads cause penalty costs*
- *Different options come at different costs*

input data

RE generation
- hourly profiles
- wind, PV, run-of-river
- inflow for storage water and biogas
- variable costs

Thermal power plants
- power and efficiency
- CHP electricity and loss ratio
- variable costs

Demand
- hourly profiles of electricity and district heating

Storage / Flexibility
- batteries, pumped storage, load management
- power, efficiency, storage capacity
- variable costs

International electricity exchange
- coupling capacity
- residual demand

model

Target function
- cost minimization
- one year, perfect foresight, global optimum
- use of technologies according to marginal costs

Variables
- hourly generation of power and heating plants
- hourly usage of storage
- hourly load shifting of flexible consumers
- additional electricity demand from new consumers (PtX)

Restrictions
- hourly demand coverage
- power limits
- reservoir fill level

(Dis)investment decisions for pp, RES and storage
Grid restrictions

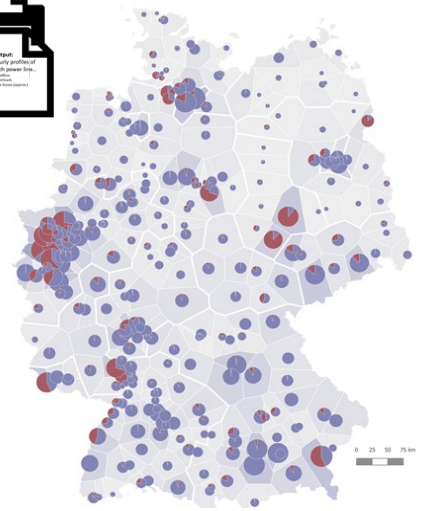
output

Optimal values of all variables:

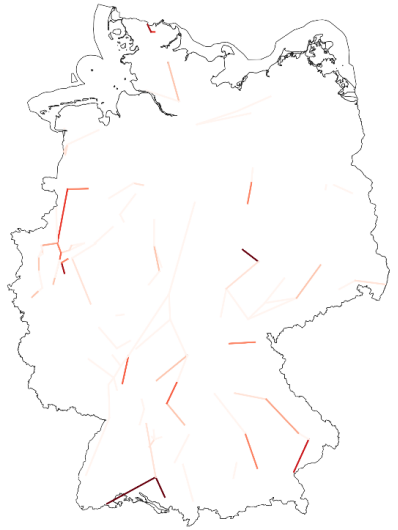
Hourly profiles
- generation profiles for electricity and district heating
- application profiles for storage and load management
- exchange profiles between countries
- price profiles for electricity and district heating

Derived indicators
- electricity and district heating mix
- CO2 emissions from electricity and district heating generation
- contribution margins and hours of use for power plants and storage facilities
- net import balances
- electricity prices

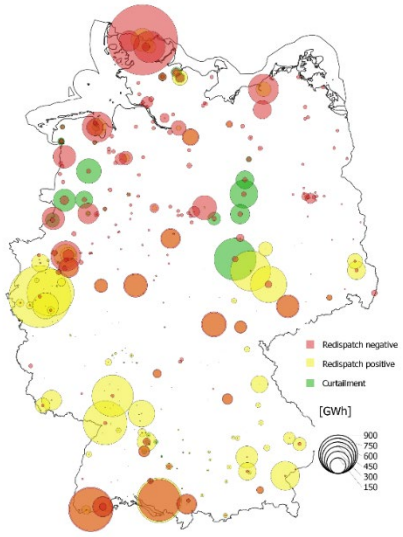
Resulting installed capacity (invest)
Line loads (grid)
Grid extension decisions (grid)



Regionalisation of demand to the nodes



congestions before redispatch



redispatch by extension

MODEX Net

2-stage energy market and redispatch modeling

Zonal balance

$$min \sum_{p,t} G(p,t) * cost(p) \quad (1.0)$$

$$s.t. \sum_{p} G(p,t) = \sum_{n} dem(n,t) \quad (1.1)$$

$$pmax(p) * avail(p,t) \geq G(p,t) \quad (1.2)$$

g_da
= fixed dispatch

Redispatch based on load flows

$$min \sum_{p,t} \left(RDup(p,t) + RDdown(p,t)\right) * rdcost + \sum_{v,t} OL(v,t) * olcost \quad (2.0)$$

$$s.t. \sum_{p,n} \left(g\_da(p,t) + RDup(p,t) - RDdown(p,t)\right) - dem(n,t) = NetI(n,t) \quad (2.1)$$

$$RDup(p,t) \leq \left(pmax(p) * avail(p,t)\right) - g\_da(p,t) \quad (2.2)$$

$$RDdown(p,t) \leq g\_da(p,t) \quad (2.3)$$

$$OL(v,t) \geq FLOW(t,v) - cap_v \ *(1\text{-}tau) \quad (2.4)$$

$$OL(v,t) \geq -FLOW(t,v) - cap_v \ *(1\text{-}tau) \quad (2.5)$$

Market model — **Redispatch model**

Note: All upper-case letters are endogenous variables, lower-case letters parametric model input, only a selection of formulas

MODEX Net

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Structured harmonization

Characteristic	input data	regionalization	model formulation
RES profiles	Agreement on a weather year		
Power plants	Technical parameterization and aggregation of power plants could not be harmonized		
Grid topology	Differences in network topology could not be harmonized		
RES infeed	Many harmonizations can be realized, but some input data cannot be harmonized	Distribution methods could not be harmonized, but compared	
Demand		Learn more about the comparison of different regionalizations in the next presentation by Oriol Raventos	
Load Flow			decision of AC or DC loadflow could not be harmonized
Solvability			usage of hard or soft constraints could not be harmonized
Cross border redispatch			Model formulations of cross border redispatch could not be harmonized*
Time-coupling			no consideration of time-coupling
PST / FACTS / DLR			no consideration of PST* / FACTS / DLR*
Security (n-1)			consideration of outages by deduction of line capacity to 70%*

* Sensitivities for comparison were done.

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2 examples

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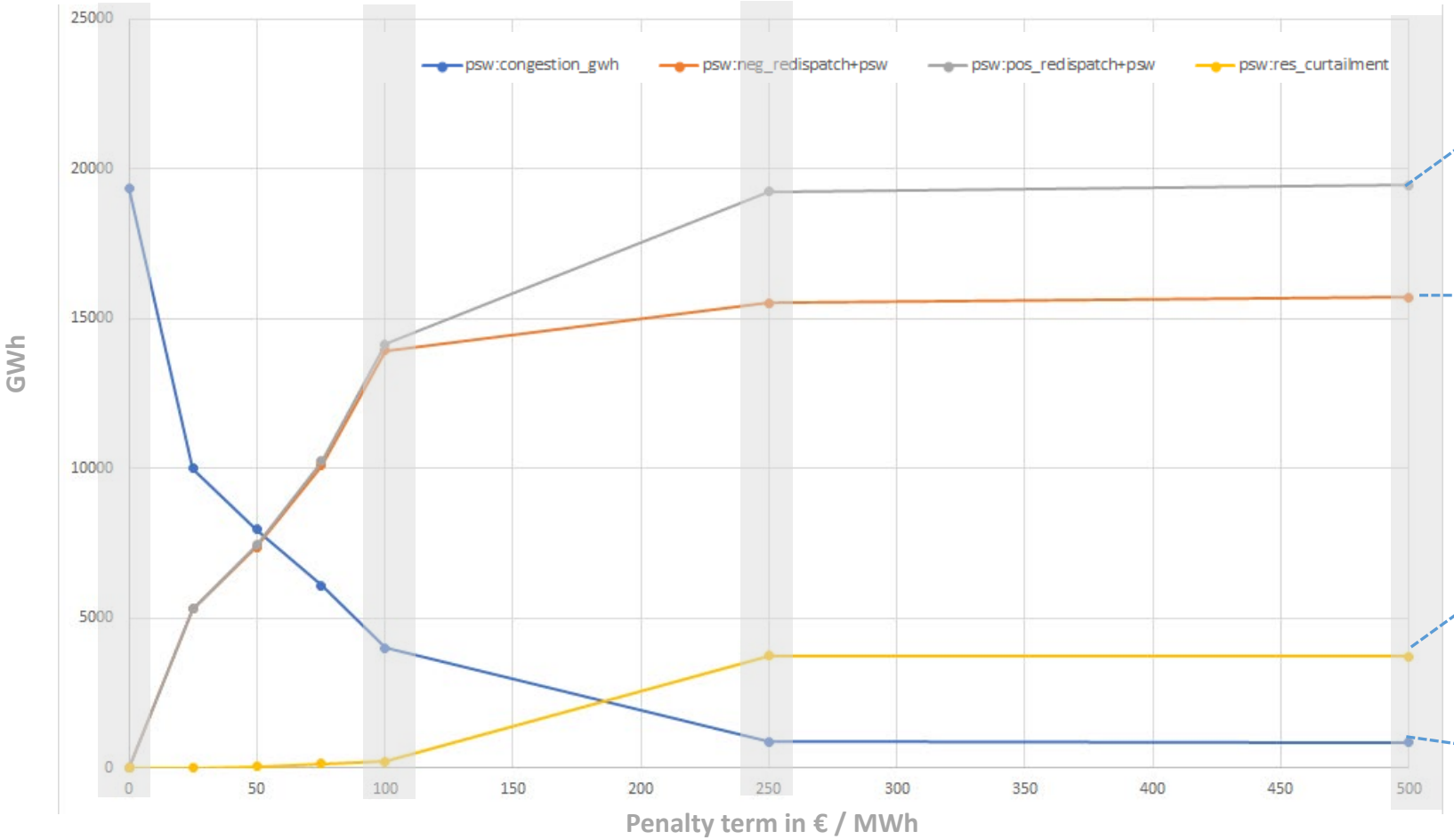
Solvability: hard constraints versus soft constraints

- **Öko-Institut** has switched from modeling with hard constraints on maximum line capacity to soft constraints for the following reasons:
  - **Solvability**: High risk of infeasibilities
    - Data errors in grid topology
    - Errors in regionalization procedures
  - **Quality of the results**: If feasible, the result could be highly inefficient, as large amounts of redispatch are used to relieve a minor congestion
  - **Reality check**: In reality, the TSOs do not resolve every bottleneck in the grid either
- Modelling option for handling model infeasibilities / avoiding very inefficient solutions: introducing so-called soft constraints
  - Soft-constraints impute slack variables to critical constraints ensuring solvability.
  - Slack variables are associated with high penalty costs to avoid their intensive use
  - If applied to the lines, the remaining line overloads can be checked for acceptability
- **New modelling challenge:** Parameterization of the penalty term, as the resulting redispatch strongly depends on it
- **Solution:** Sensitivity analyses

Soft constraints on line overloads: parametrization of penalty terms

Development of congestionwork, redispatch and RES curtailment depending on penalty costs of overloads



- At penalty costs of 0 €/MWh, no redispatch takes place
- Penalty costs between >0 – 100 €/MWh show that congestionwork can be efficiently decreased by redispatch
- Penalty costs between 100 - 250 €/MWh cause less efficient redispatch measures to be taken
- Penalty costs >250€/MWh do not further reduce the remaining congestion, nor does redispatch increase.

- Results are highly sensitive on parametrization
- Decision: overloads were penalized with 250€/MWh

Franziska Flachsbarth, Christina Wolff, Jonas Mehlem, Hannes Hobbie

Sensitivity analysis on cross border redispatch

- Öko-Institute started redispatch optimization without the option of cross border redispatch
- **Problem**: Grid bottlenecks near borders can sometimes be resolved only very inefficiently by national measures
- **Reality check**:
  - TSOs first carry out national congestion management without considering congestions on lines in border regions
  - The remaining congestions can be treated more efficient with cross border redispatch
  - The TSOs of different countries conclude bilateral agreements with each other on certain redispatch volumes

→ Complexity of the modeling leads to several alternatives:

Blacklisting: no limits on blacklisted lines	Use of dummy power plants; higher price for their use	Aggregated modeling of cross-border redispatch; higher price for their use	Detailed modeling of cross-border redispatch; higher price for their use

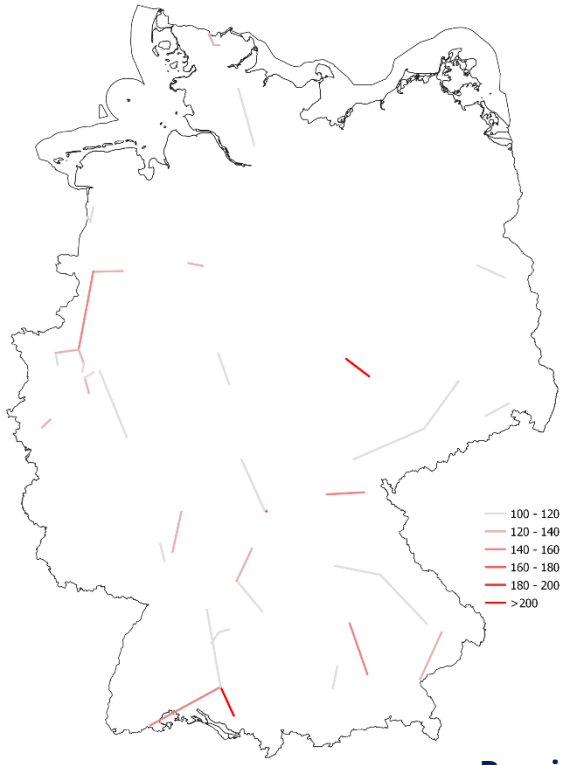
→ Öko-Institut ran a sensitivity analysis comparing blacklisting and aggregated modeling of cross-border redispatch

Sensitivity analysis on cross border redispatch

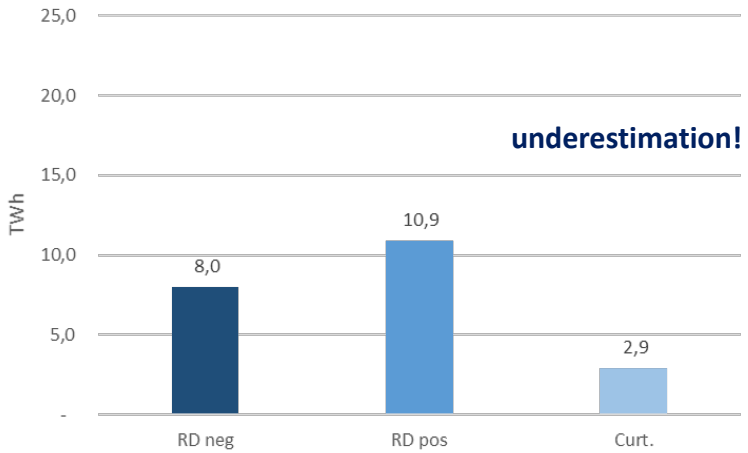
Without cross border redispatch it was not possible to remove all bottlenecks:

- Remaining bottlenecks mainly affect lines in border regions
- Remaining congestionwork: 5.6 TWh

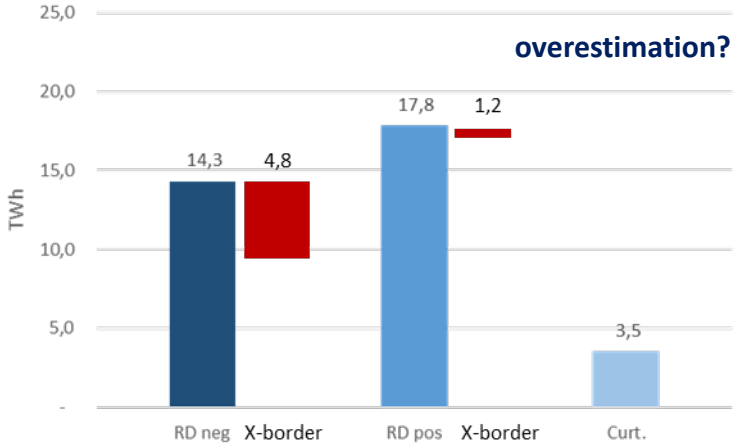
→ Blacklisting of overloaded lines in border regions



Scenario 2030: no x border redispatch

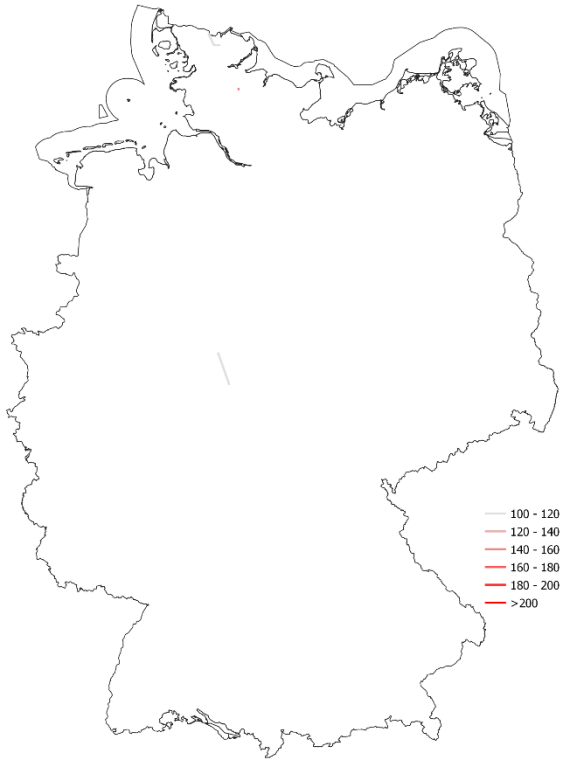


Scenario 2030: enabling x border redispatch



Enabling cross border redispatch at higher costs, almost all congestions disappear:

- Cross border redispatch is used, esp. negative redispatch in the north
- Germany-wide redispatch also increases
- Remaining congestionwork: 0.02 TWh



Reminder: Be aware of parametrization of 2 penalty terms (overloads, cross border redispatch)!

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Key Learnings

1. Differences in modeling methods remained even after harmonization: Be aware of model differences!

2. Inconsistencies in results can be better attributed to specific modeling methods if an institution performs a sensitivity analysis.

3. The parameterization of penalty terms is very sensitive.

Be sure to apply them carefully.

4. Each model has improved through knowledge sharing and collaborative interpretation of results.

For further information…

… get in touch:

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… discuss in our breakout session

… take a look at our publication:

Impact of model parametrization and formulation on the explorative power of electricity network congestion management models

Insights from a grid model comparison experiment

You can find it here:
https://www.econstor.eu/handle/10419/240928