[*THE COST OF MISSING REGIONAL INVESTMENT INCENTIVES IN ZONAL ELECTRICITY MARKETS – CASE STUDY FOR THE GERMAN ELECTRICITY SYSTEM IN A EUROPEAN CONTEXT*]

[Ulrike Pfefferer, University of Technology Nuremberg, +4991192741622, ulrike.pfefferer@utn.de]
[Jonas Egerer, University of Technology Nuremberg, jonas.egerer@utn.de]
[Veronika Grimm, University of Technology Nuremberg, veronika.grimm@utn.de]
[Lukas M. Lang, University of Technology Nuremberg, lukas.lang@utn.de]

Motivation and research question

The European electricity market is organized into bidding zones which are mainly in line with national borders. In this zonal pricing mechanism regional and temporal supply and demand scarcities are neglected. Due to the uniform price at the day-ahead spot market, efficient and system-serving market incentives regarding production quantities and investment in generation capacities within bidding zones cannot be ensured [1]. Interzonal transmission constraints are not reflected in the spot market, leading to infeasible market outcomes in many hours of the year which requires congestion management. In recent years, significant increases in costs and volumes to solve transmission constraints were observed and further increases are expected in the future [2], [3], [4].
Consequently, investors do not receive a regional price signal for their, from a system perspective, optimal location choice regarding potential investments in renewable energy sources, fossil or renewable gas capacities or various flexibility options. This may not only lead to inefficient investment choices regarding the location within the bidding zone but also to an inefficient technology mix.

Methods

Our analysis focuses on the German bidding zone integrated into the European electricity market and is based on a multi-level electricity market model [5],[6].

Level 1: Zonal spot market generation quantities and investments in generation capacities
Under the assumption of perfect competition, private firms decide about their profit-maximizing production quantities as well as their long-term investments in generation capacities. Trading between bidding zones is optimized by considering inter-zonal trading constraints.

Due to the lack of missing regional scarcity signals within the German bidding zone assumptions regarding the distribution of newly built capacities are implemented.

Level 2: Cost-based congestion management for the German bidding zone
Based on level 1 market results and the needed assumptions for investments, necessary re-dispatch quantities to solve transmission network congestion at minimum costs within the core region Germany are determined.

These sequentially solved optimization problems are depicted in level 1 with a concave-quadratic objective function and as a linear optimization problem in level 2. To further discuss and evaluate the system-efficient location choice of newly built generation capacities within the German bidding zone, these results are compared to a nodal pricing system for the German spot market (11-nodes) and to a modeling approach that integrates the location choice into the cost-minimizing problem of level 2. All optimization approaches are implemented in GAMS.

The data basis is an aggregated zonal representation of the European electricity market and an aggregated 11-node network within the German bidding zone. The target year for our scenario-based analysis is 2030, which captures uncertainties regarding the future development of the German electricity demand and the CO_2-emission price. In addition, an early German coal exit for the year 2030 is considered as sensitivity.

Results

The preliminary results show that from a system-optimal perspective and despite an early coal phase-out in Germany in 2030, additional investment in generation capacity is required, particularly in southern Germany. This is mainly characterized by regions with a lack of generation combined with high electricity demand and limited transmission network capacities. In northern Germany, on the other hand, investments in flexibilization of demand,

e.g. electrolysis capacities, are more advantageous. It is expected that transmission network congestion and redispatch costs will decrease as those investments are taken place in regions with either a shortage or surplus of electricity generation.
However, due to the lack of regional incentives or regional price signals within the uniform bidding zone, it is questionable whether this system-optimal distribution can be achieved. In case of inefficient placement of investments and an inefficient technology-mix, the results may show that additional investments in flexibility options are inevitable.

Conclusions

Our analysis highlights possible inefficiencies of neglecting regional investment incentives within the current zonal pricing meachnism in the European electricity market, particularly for the German bidding zone. In context of the ongoing energy transition, which is characterized by the further expansion of renewable energy sources, the planned coal phase-out in Germany as well as the necessity for transmission network expansion, the question of system-optimal choice of locations for investments in additional generation capacities is expected to become increasingly critical. Furthermore, the system-efficient integration of flexibility options, including electrolyzers, storage technologies or various demand-side-mangement options are essential to secure energy supply during the transition phase. Failing to account for regional disparities in supply, demand and transmission network constraints in the allocation of future generation capacities and flexibility measures risks exacerbating out-of-market costs, such as those associated with congestion management and redispatching, thereby undermining the economic and operational efficiency of the energy system.

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