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The road to the first best – Congestion management of electricity transmission in the CWE region

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Overview

For achieving a further integration of European electricity markets, an efficient utilization of transmission capacities is essential. This has lead stakeholders in the Central Western Europe region (CWE) to replace the hitherto existing congestion management which is based on net transfer capacities (NTC) by flow-based market coupling. The latter is expected to increase efficiency of cross-border transmission capacity utilization by shifting congestion management closer to the physical dispatch. A further step towards efficient congestion management would be the introduction of locational grid tariffs representing the impact of load (and possibly generation) on the cross-border capacities. Finally, a first best solution can be achieved by introducing a congestion management based on nodal pricing which makes all externalities explicitly visible to market participants and hence, provides incentives for optimal dispatch as well as investment decisions (Schweppe et al. (1988)). However, changing institutional frameworks to a first best congestion management might cause transaction costs which possibly counterbalance expected efficiency gains. In addition, large distributional effects might impede the implementation of congestion management mechanisms towards the first best.

Method

In this paper, we analyze the effects of introducing different congestion management mechanisms in the CWE region in a dynamic framework including dispatch as well as investment decisions with respect to generation and transmission capacity. The joint optimization of generation and transmission grids is particularly challenging due to Kirchhoff's circuit law according to which loop flows occur in inter-meshed AC networks. The resulting problem is a non-linear one and - as compared to alternative formulations - does not correspond to the classic transportation problem. Therefore, we apply a methodology presented in Hagspiel et al. (2014) to enable a simultaneous optimization of generation and transmission assets by coupling an electricity market model and a power flow model via Power Transfer Distribution Factors (PTDF) matrices. It has been shown by Hagspiel et al. (2014) that an iterative update of the PTDFs in the market model converges to the optimal result for generation and transmission assets with a consistent representation of power flows by means of PTDF matrices. It is noteworthy that in Hagspiel et al. (2014), the methodology has been demonstrated on a simple and stylized three node example, but also in a large-scale application of the European power system determining the optimal outcome under flow-based coupled national markets. We expand the model by accounting for different congestion management mechanisms and a higher spatial resolution for the CWE region. Specifically, we implement – besides nodal pricing - different congestion management mechanisms considering cross-border coordination of Transmission System Operators, various calculation methods for cross-border capacities, locational price components as well as different combinations of them. The model optimizes transmission and generation expansion as well as their dispatch simultaneously to achieve a cost-efficient electricity system under different congestion management regimes. In order to algorithmically represent these different regimes, but also to reduce calculation times, we implement a solution method based on a decomposition method for large-scale optimization problems.

Results

With the model developed we are able to determine the optimal system development under different congestion management regimes, including various costs components and social welfare. Hence, we are able to compare and order the different mechanisms with regard to efficiency gains. Specifically, we can benchmark different mechanisms to the first best outcome, namely nodal pricing, and analyze possible pathways leading to it. In addition, distributional as well as price effects (approximated by marginal costs of electricity supply) can be calculated from the model results. To capture the dynamic effects in the system, a horizon up to 2030 is considered. Furthermore, the calculated efficiency gains and distributional effects provide an estimation of the magnitude of transaction costs (caused e.g. by changing the congestion management mechanism or the negotiation of the distribution of efficiency gains) that would render a change of the congestion management mechanism beneficial. Overall, with our analysis we are able to determine the benefits as well as related costs of different congestion management mechanisms in the CWE region.

Conclusions

The substitution of NTC by flow based market coupling in the CWE region was a step towards a further integrated market associated with efficiency gains. However, as theory suggests, further efficiency gains can be achieved by shifting to a nodal pricing regime. In this paper we investigate and order different congestion management mechanisms according to their efficiency gains. Hence, we provide insights for policymakers of the CWE region regarding the choice of efficient congestion management mechanisms in the future. Academically, we contribute to the existing literature about congestion management mechanisms by applying a dynamic framework which extends the static approaches of e.g. Leuthold et al. (2008) or Neuhoff et al. (2011). Furthermore, the methodology of Hagspiel et al. (2014) is expanded by a novel approach to implement different congestion management mechanisms in power system models.

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