Optimal allocation of transmission capacity between reserve procurement and electricity spot market

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Overview

Current developments, such as grwoing shares of intermittent generation from RES, increase the need for flexibility and challenge the reliability of the electric power system. Balancing markets provide TSOs, being responsible for system reliability, with flexible resources. In contrast to other electricity markets that experience an advanced integration among European countries along with improved interconnection infrastructure, the balancing market lags behind in terms of integration. Balancing markets are predominantly nationally organised. However, in the light of increasing needs for flexibility to efficiently integrate ever growing shares of RES generation, the integration of balancing markets is envisaged as a logical next step. It is currently in the focus of regulatory authorities (European Commission 2017) and there exists a number of cross-border initiatives.

Balancing markets comprise the procurement of reserve capacity and the activation of balancing energy. Several levels of balancing market integration can be differentiated. First, imbalance netting avoids the activation of counter-acting measures and consequently reduces operational activation costs. Second, the exchange of reserves enables to procure reserve capacity in other countries. This bears the potential to reduce procurement costs by efficiently utilising heterogenous resources across borders thus realising spatial arbitrage. Finally, reserve sharing allows for joint dimensioning of reserve requirements of associated countries and, in addition to spatial arbitrage, further reduces procurement cost in response to lower overall reserve requirements resulting from spatial smoothening of imbalances. While the first level can be applied after spot market clearing, the latter two options require transmission capacity to be reserved for potential associated cross-border flows in case of (cross-border) activation. The share of transmission capacity reserved for this purpose is unavailable for trading electricity in the other markets and – if scarce – incurs opportunity costs for the use in alternative markets. Moreover, reserve procurement and electricity spot markets are interrelated because generation operators act in both markets.

The objective of this work is to investigate the interrelation between aforementioned markets from a cross-border perspective. For this purpose, an analytical model of interrelated reserve procurement and spot markets in a two-country setting is developed. For given demand levels in the spot market and given national reserve requirements reserve procurement and day-ahead market clearing are jointly optimised under the constraint of limited cross-border transmission capacity. Thereby, the optimal allocation of transmission capacity to these markets is derived.

Besides qualitative analyses discussing design options (Doorman, van der Veen 2013; van der Veen, Hakvoort 2016; Neuhoff, Richstein 2016) and articles that are based on numerical modelling of the described and associated questions (Delikaraoglou et al. 2015; Farahmand, Doorman 2012; Gebrekiros, Doorman; Gebrekiros et al. 2015; Lorenz, Gerbaulet 2014; van den Bergh et al. 2017), there are also some analytical approaches. The interrelation between the markets has been investigated by Just, Weber (2008), while Baldursson et al. (2016a) derive the welfare optimal reserve requirement from the equilibrium on spot and reserve markets. Finally, Baldursson et al. (2016b) develop a stylised model to derive welfare benefits from balancing market integration. While the latter approach does not consider the interrelation between reserve and spot market, the two aforementioned works are limited to single-country frameworks. This work combines both aspects in one model.

Methods

The model takes the relation on the supply side of reserve and spot market as a starting point where bidding into the reserve market is characterised by opportunity costs based on the spot market. Two countries each with a reserve and spot market are interconnected by a given transmission capacity that can be used in either market.

The allocation of transmission capacity between these markets can be assessed as being efficient when its marginal values on either market equalise. The setting is formulated as a constrained optimisation problem maximising the welfare gain from the use of transmission capacity in both markets. The share of transmission capacity allocated to either market is the decision variable.

Results

The optimal allocation of transmission capacity between reserve procurement and electricity spot market is expected to depend on several factors and mutual relations. The dependence can be investigated by the help of comparative statics of the derived optimum. To start with, it is expected to depend on the heterogeneity of generation resources in the two countries which are relevant for defining the supply curves in all markets. Furthermore, the relation of demand levels in the two markets as well as the relation of demand levels of the two countries is expected to influence the decision on transmission capacity allocation. Finally, overall transmission capacity is crucial. If not being scarce, the question of optimal allocation between alternative useages in different markets does not arise. However, if scarce, the optimal shares to be used in either market may depend on absolute capacity, or more specifically on transmission capacity in relation to overall system size, e.g. determined by aggregated demand (both on spot and reserve market).

Conclusions

The approach develops an integrated analytical model capable of depicting the interrelations between spot and reserve markets as well as the useage of cross-border transmission capacity which is novel in literature. The optimal transmission capacity allocation between the markets concerned is derived and investigated with respect to key market and system characteristics. The analysis will notably show to what extent and under which conditions it is beneficial from a social welfare perspective to define a share of transmission capacity exclusively dedicated to the cross-border delivery of reserves. This provides a basis both for further numerical investigations and regulatory advice.

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