Quantifying the benfits of cross-border reserves in current and future European electricity systems

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Overview

With an increasing share of intermittent renewable energy, the need for reserves to deal with forecast errors increases. To reduce operational costs, cross-border reserves are an effective measure, while maintaining an adequate system [1,2]. This paper investigates the benefits of cross-border procurement and sizing of balancing capacity. To allocate reserves from other zones, it is crucial to take into account network constraints during procurement to ensure that these reserves can be made available in real-time [3]. A new method is presented to implicitly consider network constraints during the joint-clearing of the day-ahead energy and the balancing capacity market.

Methods

For our analysis, we compare three levels of coordination between neighbouring countries. An overview is given in Table 1. For all three cases, we use a joint market clearing of the Energy and the Balancing Capacity market. Case A corresponds roughly to the current situation in Europe, where each country has to self-provide its reserve requirements. During activation, exchange of balancing energy is permitted Case B is the next step towards coordination, allowing for cross-border procurement of balancing capacity. During the joint clearing of both markets, network constraints are efficiently taken into account. Case C corresponds to the highest level of coordination, where reserve sharing is allowed. In contrast to the other cases, a regional reserve requirement is imposed, corresponding to a joint sizing of reserves.

Table 1:

	Case A	**Case B**	**Case C**
Activation	Coordinated	Coordinated	Coordinated
Procurement	Uncoordinated	Coordinated	Coordinated
Sizing	Uncoordinated	Uncoordinated	Coordinated

We refrain from giving a detailed explanation of the UC model, but rather point out the main differences between the three considered scenarios. Also, the different types of reserves are simplified for one category of upward reserves. As stated before, the main challenge is to adequately account for the availability of cross-border capacity and the reserve requirement itself. The representation in the model is described in the following. For the unccordinated case, equation (1) ensures the provision of reserves, taking only reserve capacity within the zone into account. The flows on transmission lines are only constraint by electricity in- and exports (equation (2)).

Table 2: Uncoordinated procurement

$$\sum_{i:i\in I(z)\ AND\ i\in I} r^{+}_{i,t} \geq R^{+}_{z,t} \quad \forall\, z \in Z, t \in T \tag{1}$$

$$\underline{F_{z,z'}} \leq f_{z,z',t} \leq \overline{F_{z,z'}}\ \forall\, (z,z') \in ZZ', t \in T \tag{2}$$

In Case B, the reserve requirement remains the same, but can now be satisfied by the reserve capacity within the zone plus the amount of exchanged reserve from other zones. Thus equation (1) is replaced by equation (3). While the capacity constraint for electricity exchange remains active, an additional constraint reflects the required cross-zonal capacity for the exchanged reserve capacity (equation (4)).

Table 3: Coordinated procurement

$$\sum_{i:i\in I(z)\ AND\ i\in I} r_{i,t}^{+} + \sum_{z':(z',z)\in ZZ'} r_{z',z,t}^{+,exch} \geq R_{z,t}^{+} + \sum_{z':(z,z')\in ZZ'} r_{z,z',t}^{+,exch} \quad \forall z \in Z, t \in T$$	(3)
$$\underline{F_{z,z'}} \leq f_{z,z',t} + r_{z,z',t}^{+exch} \leq \overline{F_{z,z'}} \quad \forall (z,z') \in ZZ', t \in T$$	(4)

The fully coordinated Case C reflects the decreased reserve requirement on a regional level, due to spatial smoothing effects. Hence, we also introduce a regional reserve requirement (5). We reformulate the zonal reserve requirement (6) and incorporate additional network constraints taking into account reserve sharing mechanisms (7).

Table 4: Coordinated sharing

$$\sum_{z\in Z(r)} \sum_{i:i\in I(z)\ AND\ i\in I^{s}} r_{i,t}^{+} \geq R_{r,t}^{+} \quad \forall r \in R, t \in T$$	(5)
$$\sum_{i:i\in I(z)\ AND\ i\in I} r_{i,t}^{+} + \sum_{z':(z',z)\in ZZ'} r_{z',z,t}^{+,exch} + \sum_{z'\neq z:z'\in Z(r)} \sum_{i\in I(z)} r_{z',z,t}^{+,sh} \geq R_{z,t}^{+} + \sum_{z':(z,z')\in ZZ'(z)} r_{z,z',t}^{+,exch} \quad \forall z \in Z, t \in T$$	(6)
$$\underline{F_{z,z'}} \leq f_{z,z',t} + r_{z,z',t}^{+,exch} + r_{z,z',t}^{+,sh} \leq \overline{F_{z,z'}} \quad \forall (z,z') \in ZZ', t \in T$$	(7)

Results

To analyse the effects of the exchange and sharing of Balancing Capacity (BC) on the powerplant portfolio, the described metholodgy has been applied to a 2030 case study for Central Western Europe. The results indicate that both, the exchange and the sharing of BC can improve the day-ahead scheduling due to the relaxation of the must-run conditions linked to spinning reserve provision. For the sharing of BC, the overall reserve requirements are reduced due to the joint-sizing exercise, resulting in further relaxationa of the technical constraints. The results for the sharing case further suggest that the total amount of high flexibility capacity could be reduced, specifically when combined with alternative balancing capacity sources, e.g. demand responds.

Conclusions

The presented paper outlines a framework to incorporate different methods of coordination in terms of balancing capacity. Thus, we will be able to show the potential benefit of cross-border coorperation with regard to reserve producrement and sizing. We take a novel approach to also incorporate network constraints for joint reserve sizing, by efficiently allocating transmission capacity to both the electricity and the reserve market.

References

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