Flow-Based Market Coupling and Bidding Zone Delimitation: Key Ingredients for an Efficient Capacity Allocation in a Zonal System

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Abstract— The European energy market is based on the zonal system. This implies that only exchanges between the bidding zones are subject to an allocation mechanism. The key question in bidding zone delimitation is which exchanges need to be subject to an allocation mechanism, and which exchanges can be left outside the allocation mechanism. In the recent years, tremendous progress has been made by CWE and CEE TSOs to develop the flow-based (FB) capacity calculation methodology. The resulting FB capacity constraints represent the TSO’s constraints in the allocation mechanism. With a flow-based approach, a true competition between all relevant exchanges for the scarce capacity can be established. As such, bidding zone delimitation and FB capacity calculation and allocation are two key ingredients that are at hand to establish an efficient allocation mechanism for the European integrated electricity market.

Index Terms—Capacity Calculation, Capacity Allocation, Flow-Based Market Coupling, Bidding Zone Delimitation, Zonal System

I. INTRODUCTION

In Central Western Europe (CWE) - a region consisting of the Netherlands, Belgium, France, Luxembourg, and Germany - a single price coupling was launched successfully as of November 9, 2010. At the origin of this market coupling (MC) process lies a coordinated ATC capacity calculation method that was designed and implemented by the CWE TSOs. For several years now, the CWE TSOs have been working on the ‘next-step’ coordinated capacity calculation method, the ‘flow-based methodology’ (FB). The methodology has evolved from the theoretical stage by extensive experimentation, and is now ‘operationalized’. This means that the implementation of a flow-based market coupling (FBMC) in CWE, as a next (r)evolutionary step in the European market integration, is now envisaged.

Next to the transition from an explicit capacity allocation scheme to an implicit one (such as price coupling), the transition from an ATC to a FB capacity calculation is another major step in the European market integration, where according to the experimental studies in CWE significant welfare gains can be achieved. Indeed, the experimental results in CWE showed that with FB constraints instead of ATC constraints, the Day-Ahead market welfare could have increased to 90% of what could have been reached with infinite capacities [1].

Flow-based market coupling provides an efficient allocation mechanism in which all exchanges (i.e. exchanges of electricity from surplus to shortage areas) that are subject to the allocation mechanism compete with one another for the use of the scarce capacity. This has been reflected in the proposed European network code on capacity allocation and congestion management where the flow-based methodology is mentioned to be the preferred capacity calculation approach.

Exchanges that are subject to the allocation mechanism are all competing for the scarce capacity made available within the allocation mechanism. Exchanges that are outside the allocation mechanism are all exchanges of which the impact is taken into account before the allocation mechanism itself, i.e. exchanges that receive a ‘priority access’ and that are exempted from the competition element within the allocation mechanism. Thus, the key question in bidding zone delimitation is which exchanges need to be subject to an allocation mechanism, and which exchanges can be left outside the allocation mechanism.

In this paper it will be elaborated upon that

- only with a flow-based approach, a true competition between all relevant exchanges for the scarce capacity can be established,
- bidding zone delimitation defines which exchanges are subject to the allocation mechanism,

and that with a combination of these two, key ingredients are at hand to establish an efficient allocation mechanism for the European integrated electricity market.
II. (UN)ALLOCATED FLOWS AND BIDDING ZONE DELIMITATION

The European energy market is based on the zonal system. The zones (bidding areas) correspond in most of the cases to national borders (before the liberalisation generation, grid and supply were organized mainly on a national basis by integrated companies) and consequently vary largely in size. The Nordic market is an exception to that, as well as the Italian one; they have multiple bidding areas within national borders. The zones in the Nordic market, at the time of writing this paper, are illustrated in Figure 1.

Bidding zone delimitation is one way to manage congestions in the transmission network. Three systems may be distinguished in this respect [2]:

- the uniform system, where no exchanges are subject to an allocation mechanism;
- the nodal system, where exchanges between all nodes are subject to an allocation mechanism;
- the zonal system, where only exchanges between zones are subject to an allocation mechanism.

Exchanges that are subject to the allocation mechanism are all competing for the scarce capacity made available within the allocation mechanism. Exchanges that are outside the allocation mechanism are all exchanges of which the impact is taken into account before the allocation mechanism itself, i.e. exchanges that receive a ‘priority access’ and that are exempted from the competition element within the allocation mechanism. Thus, the key question in bidding zone delimitation is which exchanges need to be subject to an allocation mechanism, and which exchanges can be left outside the allocation mechanism.

The grid interconnects the sources and the sinks in the system; the flows fan out in accordance to Kirchoff’s laws. A geographical concentration of sources and sinks can have a strong impact on the flows as is illustrated in Figure 2. The flows represented by the white arrows are often labeled ‘transit flows’ if the source and the sink are in two different bidding zones, and referred to as ‘loop flows’ when the source and the sink are within the same bidding zone.

A transit flow can be either an allocated or an unallocated flow:

- A transit flow is an unallocated flow when the exchange, causing the transit flow, is not subject to the same cross-border allocation mechanism as the zone facing the transit flow
- A transit flow is an allocated flow when the exchange, causing the transit flow, is subject to the same cross-border allocation mechanism as the zone facing the transit flow
A loop flow is by definition an unallocated flow, as the source and the sink are located within the same bidding zone and the intrazonal exchange is not subject to an allocation mechanism.

An overview of allocated and unallocated exchanges, and their resulting flows is given in Figure 3. All unallocated flows need to be, and are, taken into account in the capacity calculation stage. Indeed, the unallocated flows receive a priority access to the grid and are exempted from the competition element within the allocation mechanism. As such their (forecasted) impact needs to be taken into account when assessing the ‘free capacity’ in the grid, that can be released to the market without endangering the grid.

As schematically indicated in Figure 3, intrazonal exchanges can be made subject to the allocation mechanism by means of bidding zone delimitation: a market splitting will make the former intrazonal exchange subject to the allocation mechanism. The same holds the other way around: exchanges can be withdrawn from the allocation mechanism by merging two (or more) bidding zones into one. Interzonal exchanges that are not subject to a regional allocation mechanism could be made subject to it by extending the scope of that regional allocation mechanism.

III. Flow-based market coupling

Flow-based capacity calculation was already elaborated upon in an ETSO paper in 2001 [3], whereas flow-based market coupling (FBMC) was described in a joint ETSO – Europex paper in 2004 [4].

The flow-based methodology was developed further in both the CWE (Central Western Europe) region [5], [6] and the CEE (Central Eastern Europe) region. Although both regions went their own way in developing the FB methodology, the principles are very similar. Today, in CEE, the developments have come to a standstill, whereas in CWE the FBMC is currently being implemented [6].

In the September 2012 version of the Network Code on Capacity Allocation and Congestion Management, it mentions [7]: There are two permissible approaches when calculating cross zonal capacity: Flow based or coordinated net transmission capacity based. The flow based approach is preferred over the coordinated net transmission capacity approach for day ahead and intraday capacity calculation where interdependencies of cross zonal capacity between bidding zones is high. Flow based should only be introduced after market participants have been consulted and given sufficient preparation time to allow for a smooth transition. The coordinated net transmission capacity approach may be applied in regions where interdependencies between cross zonal capacity are low and the added value of the flow based method cannot be proven.

FB capacity calculation is a coordinated capacity calculation mechanism that is currently being implemented for the Day-Ahead (DA) timeframe only. Although it is foreseen that FB will be implemented for the Intraday timeframe as well, the focus in this paper is on the DA.

At day D-2 the TSO’s capacity calculation starts, in order to provide the necessary input, i.e. the grid constraints that the
TSOs need to impose in order to safeguard the grid in the market coupling mechanism, to the market participants and the Power Exchanges (PXs) on day D-1. In the market coupling mechanism run by the PXs, the supply and demand bids that originate from the various bidding zones are matched such that the Day-Ahead market welfare is maximized, thereby respecting the grid constraints that are imposed by the TSOs. The trade programs that result from this market clearing are executed by the market participants on day D.

The market coupling (MC) mechanism, run by the Power Exchanges (PXs) to match the demand and supply bids of the various bidding zones, is an optimization algorithm:

Objective function: maximize social welfare
Control variables: net positions of the bidding zones
Subject to: sum of net positions = 0

TSO’s grid constraints

The TSO’s grid constraints can be either ATCs (Available Transmission Capacities), imposing limitations to exchanges from one zone to a neighboring one, or FB constraints, that specify how much flow can be induced on selected grid elements by the market’s (bidding zones) net positions.

The FB grid constraints are a function of (in principal all) the bidding zones’ net positions, and establish a translation between the bidding zones’ net positions on the one hand and the approximate resulting physical flows on selected grid elements on the other:

Induced flow(all bidding zones’ net positions) ≤ flow margin

The objective of the FB capacity calculation process is to determine the FB constraints as mentioned above, in such a way that the market is facilitated in the best possible way, while at the same time safeguarding the grid security.

The group of TSOs performing the FB capacity calculation makes use of a common grid model as a basis. Each TSO provides a best estimate of its grid two days ahead: one grid model for each hour. Those individual pieces of the puzzle, the 24 hourly grid models of all TSOs, are then merged together in order to constitute 24, so-called, D2CF (two-days ahead congestion forecast) grid models. Those grid models contain a.o. the expected topology, renewable generation, (generator) outages, and intrazonal generation and consumption. Indeed, the (forecast of the) unallocated flows are taken into account in this process step.

The effect of changing net positions on the flows induced on the selected grid elements are captured in the PTDF factors (Power Transfer Distribution Factors). The flow margin is determined by the maximum allowed flow (Fmax), reduced by the Flow Reliability Margin (FRM; needed by the TSO to hedge against all uncertainties that are linked to the DA capacity calculation) and by the flow that is already there before taking into account the effects of the import/export positions of the bidding zones, i.e. the flows resulting from the unallocated exchanges.

In a flow-based allocation method, all exchanges subject to the allocation mechanism compete with one another for all the scarce capacity. Indeed, in principle, the impact of all bidding zones’ net positions are taken into account when assessing whether or not any of the grid constraints is violated.

The combined use of bidding zone delimitation and FB capacity calculation and allocation is demonstrated by means of a fictive three-zone example in the next section.

IV. BIDDING ZONE DELIMITATION AND FB CAPACITY CALCULATION AND ALLOCATION: AN EXAMPLE

In this section a fictive example will be elaborated upon, where three zones are interconnected by the simple grid that is depicted by the black lines in Figure 4. A FB capacity calculation and allocation mechanism is put in place in order to allow a fair competition for the use of the scarce capacity between the three zones. The surplus and shortage areas are indicated along with the commercial exchanges and the resulting flows in Figure 5.
In this graph, the yellow arrows correspond to flows that are caused by exchanges that are not subject to an allocation mechanism. The grey arrows correspond to flows that are caused by exchanges that are subject to an allocation mechanism.

The example in Figure 5 shows that the flows resulting from the commercial exchanges (the thick blue arrows, labeled with ‘exchange’) would lead to a congested situation on the border between the two zones A and B. As such, this situation is not a feasible one.

In the (coordinated) FB capacity calculation stage of this three-zone region, the flows that result from all unallocated exchanges, i.e. the exchanges that are not subject to the regional allocation mechanism, are forecasted (in the D2CF grid model) in order to assess the capacity that can be given to the allocation mechanism and used by the market. The exchange within zone C is an intrazonal one, and is not subject to the allocation mechanism. This means that in the capacity calculation stage, the (forecasted) impact of this exchange needs to be taken into account. As such, the flows resulting from this intrazonal exchange receive a priority access to the grid and reduce the capacity available on the border between A and B that can be given to the allocation mechanism.

The exchange between zone A and B is subject to the regional allocation mechanism. It is this exchange that will be reduced in order to prevent the congestion on the border between A and B. This is illustrated in Figure 6.

When in country C a new bidding zone would be introduced, zone D, which separates the source and the sink of the former intrazonal exchange within zone C, the former unallocated exchange is turned into an allocated one as it is made subject to the regional FB allocation mechanism, as shown in Figure 7. In this situation, both the exchanges between zone A and B, and between zone D and C compete with one another to make use of the scarce capacity on the border between zone A and B, that is expressed by a FB constraint that for example may look as follows:

\[
\text{Induced flow} = 0.6 \times \text{NetPosition}(A) - 0.6 \times \text{NetPosition}(B) + 0.3 \times \text{NetPosition}(D) - 0.3 \times \text{NetPosition}(C) \leq 1000 \text{ MW}
\]

This formula illustrates that all exchanges within the allocation region compete for the scarce capacity as the NetPositions are defined by the net exchanges of the bidding zones.

It is now an outcome of the regional Day-Ahead market welfare optimization, i.e. a market driven mechanism, which exchange will be reduced and to what extent. In principle both exchanges might be reduced in order to prevent the congestion on the border between A and B; this is depicted in Figure 8.

Note that in an ATC allocation mechanism the situation would not by definition be solved by introducing the new bidding zone D. Given the fact that zone C was one single bidding zone, that could handle the large intrazonal exchange without any problems, the ATC between zones C and D might be so large, that it does not limit the exchange between C and D. Indeed, it is then the ATC between A and B that should be reduced in the capacity calculation stage to prevent the
congestion on the border between A and B. Anyhow, this decision is not market driven and does not by definition lead to the most efficient solution.

The intention of the fictive example above is to illustrate that bidding zone delimitation provides an instrument to make exchanges subject to an allocation mechanism. Please note that the question whether or not to apply a bidding zone delimitation is a complex one that is not touched upon in this paper. In combination with a FB capacity calculation and allocation mechanism, where all exchanges that are subject to the allocation mechanism compete with one another to make use of the scarce capacity, an efficient allocation can be achieved.

V. CONCLUSIONS

In this paper it has been elaborated upon that

- only with a flow-based approach, a true competition between all relevant exchanges for the scarce capacity can be established,
- bidding zone delimitation defines which exchanges are subject to the allocation mechanism,

and that with a combination of these two, key ingredients are at hand to establish an efficient allocation mechanism for the European integrated electricity market.

VI. REFERENCES