ENLARGING THE FLOW-BASED DOMAIN IN THE EUROPEAN DAY-AHEAD MARKET CLEARING THROUGH THE FULL INTEGRATION OF GRID FLEXIBILITIES AND COSTLY REMEDIAL ACTIONS

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Overview

With increasing penetration of renewable energies, more and more focus is being placed on flexibility in the electricity system. Improved flexibility is required not only on the generation and consumption sides of the system, but also in the transport. Smart grids at the distribution level are already widely discussed in the literature. However, there also exist significant possibilities for grid flexibility on the transmission level. These possibilities include topological changes, phase shifting transformers (PSTs) and HVDC lines, which along with costly remedial actions such as the redispatch of generation units are necessary to achieve the secure physical execution of the electricity market outcomes.

While power flow control devices and redispatch are regularly used by Transmission System Operators (TSOs), their integration in the European electricity market framework remains incomplete.[1] Their usage is largely reserved for ensuring the security of the grid close to real time and is generally determined individually by TSOs. However, currently, in the Central Western Europe (CWE)[2] capacity calculation region (CCR), certain remedial actions are taken into account in the flow-based capacity calculation in an ad-hoc manner. After an initial calculation of the flow-based parameters, an iterative selection process is undergone as part of the qualification phase of the capacity calculation, which occurs between 8:00 PM two days before real-time (D-2) and 3:00 AM the day before real-time (D-1).

During this phase, the TSOs choose which remedial actions (only non-costly at this stage) will be used, with the goal to extend the flow-based domain in a predicted market direction. The choice of which remedial actions to use in this phase is generally based on operational experience. The scheduled extension of the flow-based method from the CWE CCR to the Core CCR[3] at the end of 2020 will lead to a significant increase in the number of available remedial actions and thus in the size of the selection problem. To cope with this increase, the currently manual process will be automated.[1] However, this method lacks generality as it will still aim to enlarge the flow-based method in a single specific predicted market direction.

This article presents a method to fully integrate costly and non-costly costly remedial actions directly into the market clearing algorithm in order to enlarge the domain of possible cross-border exchanges, thus allowing for an improved overall social welfare. To do so, several alternative flow-based domains are calculated, each corresponding to a distinct market direction and representing the effects of the optimal set of remedial actions selected for the specified direction. These multiple flow-based domains are then given to the market clearing algorithm. This methods allows for the adaptation of remedial actions in order to limit the sensitivity of the flow-based domain to an erroneous forecast of the likely market direction. Technically speaking, introducing both linearizable (e.g. PSTs) and discrete (e.g. line switching), as well as both costly (redispatch) and non-costly remedial actions, can be achieved without changing the algorithm of EUPHEMIA[4] as it exists, by an astute combination of block offers and virtual bidding zones.

Methods

To begin with, a literature review regarding the benefits and challenges of integrating the optimization of both discrete and linearizable remedial actions into the market is presented. Then, several stylized case studies are analysed in the following process. First, a module is run to calculate the flow-based parameters for several different grid topologies

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[1] A first step to increase capacity was the integration of certain remedial actions in the net transfer capacity calculation (NTC), which yielded rather significant numerical results at the time. For the switch to the flow-based market coupling, the consideration of remedial actions was quickly identified as a key lever for the credibility of the methodology.

[2] The CWE CCR includes the following countries: Austria, Belgium, France, Germany, Luxembourg and the Netherlands.

[3] The Core CCR includes the following countries: Austria, Belgium, Croatia, the Czech Republic, France, Germany, Hungary, Luxemburg, the Netherlands, Poland, Romania, Slovakia and Slovenia.

[4] EUPHEMIA is the algorithm that has been used since 2014 for the market coupling of a large part of the European electricity markets.[2]

and base cases. For this step, a remedial action optimization is performed with the goal of enlarging the domain in different discrete directions, as shown in Figure 1.

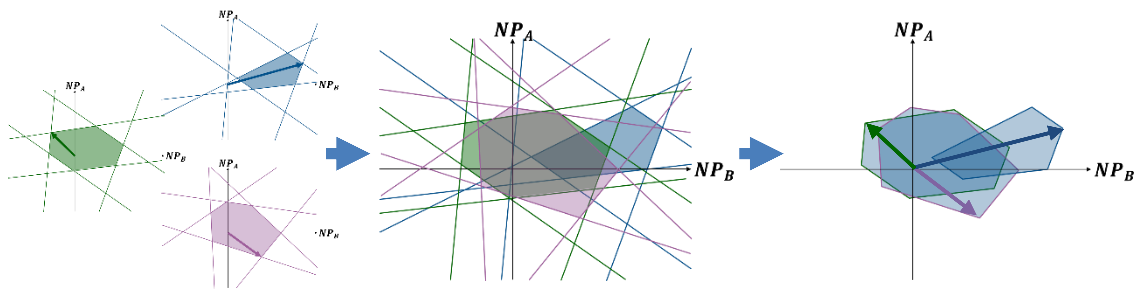

Figure 1. Integration of Multiple Flow-based Domains

For each flow-based domain generated, a new virtual bidding zone is created with a block offer of volume M, where M is much larger than the margin available on each critical branch. The block offers—which inherently imply a binary variable—allow for the market coupling algorithm to choose between multiple discrete flow-based domains. The calculated flow-based domains and virtual bidding zones are then input to the market clearing algorithm. This algorithm, a mixed integer linear program similar to EUPHEMIA[5], was developed within PROMETHEUS—a platform developed by RTE to simulate market design models. Cleared quantities and zonal market clearing prices are determined in a two-step primal-dual optimization. Costs associated with these domains can be treated with the addition of two additional virtual bidding zones.

Finally, simple cases with 3 nodes and 4 different grid topologies with costs associated were tested directly in the EUPHEMIA algorithm to ensure the feasibility of the method.

Results

This simple method can be used to deal with both linearizable and discrete remedial actions without changing the existing EUPHEMIA algorithm, allowing for a more flexible transmission system to accompany increased penetration of more uncertain production systems. More involved case studies have been successfully tested in the PROMETHEUS market clearing module, leading to increased social welfare. The gain logically depends largely on the forecast error between the predicted market direction and the actual optimal point. Additionally, simple cases of the method were successfully validated in EUPHEMIA.

Conclusions

The integration of remedial actions in the market coupling algorithm leads to clear social welfare gains through the expansion of the flow-based security domain. This paper presents a simple way to integrate these in the present European day-ahead electricity trading framework. This method does not require any changes to the existing EUPHEMIA algorithm and has in fact been successfully tested in EUPHEMIA on several small case studies. However, the number of rows in the PTDF matrix grows by around a factor of 2 with each discrete flow-based domain considered. Further research work will focus on maintaining the computational requirements of the approach at manageable levels.

References

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[5] Although EUPHEMIA includes some quadratic terms, detailed in the public documentation.[2]