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Power Market Design
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HOW GERMAN RENEWABLES ARE TAKING OVER BELGIAN INTERCONNECTORS

A description of the loop flow phenomenon, its causes, impacts and possible solutions.

The electricity market in Europe has seen an incredible evolution in the past decades and this transformation is even accelerating today. On the one hand, production is shifting from large centralized conventional power plants to renewable and decentralized production facilities, predominantly solar and wind. On the other hand, national grids are becoming more and more interconnected as the European commission is striving for a European single electricity market for all its citizens. Both evolutions require significant improvements of the European electricity infrastructure and it is for this reason that European transmission system operators (TSO's) are heavily investing to make the grid more reliable, connected and flexible than ever before. It is however equally important to have a market design that facilitates these evolutions. Regulations should be adjusted and updated accordingly to create and maintain a level playing field. The current European electricity market design shows however different problems whereof the occurrence of loop flows is a decisive one. This is a very specific phenomenon that reduces the commercially available interconnection capacity of countries and distorts the proper functioning of the market.

The article starts with a high-level overview of the current European electricity day-ahead market and explains how loop flows arise from flaws in the current market design. Thereafter, the focus shifts to Belgium, which is heavily impacted by loop flows originating from the abundant renewable energy production in Northern Germany. The concrete impacts of loop flows are described and possible solutions are listed, which should be implemented as fast as possible to solve this problem.

The European Day-Ahead market

Electricity is a unique commodity as it cannot be stored easily and predicting its exact production and consumption is impossible. These specific characteristics resulted in the organization of a short-term market with the aim of enabling a balanced portfolio of production and consumption, especially in times when the initial expectations are out of line with reality (e.g.: more wind production than foreseen). On the Day-Ahead market traders have the possibility to commit to buy or sell electricity for the 24 delivery hours of the next day.

Historically, most countries decided to coincide bidding zones, the area in which one can trade electricity, with their borders. This is the case for Belgium, France and the Netherlands for example. Others countries have instead chosen to define multiple bidding zones within their country, which is true for Norway and Sweden, or to define a single bidding zone for more than one country (e.g.: the DE-LU bidding zone). No matter the topology, the idea was to ensure maximum efficiency for trading on an isolated bidding zone level.

An example of a trade on an isolated bidding zone level is given to better grasp the idea. Suppose a Belgian electricity supplier needs more electricity on the peak hours of the next day to balance its portfolio (demand is higher than initially forecasted). This supplier can submit a buy order on the auction defined by a volume and a price (i.e. 100 MW for 50 EUR for the hour 6pm-7pm). If, for this hour, enough electricity is being sold for an equal or lower amount of money within the Belgian bidding zone (in this case less than 50 EUR) his order is successful. The electricity is bought and assigned to the portfolio of the Belgian electricity supplier the day after.

At the end of the last century, the idea emerged to couple bidding zones and to organize a day-ahead auction across European countries; a market environment in which electricity can freely be traded between countries without any technical or legal obstacles. This idea was first executed in the Nordic regions and shortly after, in 2006, implemented by France, Belgium and the Netherlands. What followed was a rapid expansion into two large coupled zones on the European continent: the MRC region (which covers almost entire continental Europe) and the 4MMC region (comprising the Czech Republic, Hungary, Romania and Slovakia).

When multiple bidding zones are coupled the situation changes compared to trading within an isolated bidding zone. The oversupply in one bidding zone can now be used to reduce the shortage that exists in another bidding zone. For example, suppose there is an abundance of electricity in Germany due to a high availability of wind and an electricity shortage in Belgium. Electricity can, if the bidding zones are coupled, flow from Germany to Belgium resulting in a lower price difference between the two bidding zones.

Every day at noon, the orderbooks of the bidding zones are closed and submitted to the pan-European price and volume calculation algorithm, Euphemia. The objective is to maximize the social welfare of the entire coupled region and to ensure that the optimal volume and price for every hour per bidding zone is obtained. This calculation includes the optimization of the cross-border exchange between bidding zones which is limited by the interconnection capacity. In fact, cross-border trading will cause price convergence between both bidding zones that will continue as long as there is available interconnection capacity.

ACER, the European Agency for the Cooperation of Energy Regulators has included a strong recommendation in the Clean Energy Package (a legislative document reflecting the EU energy efficiency and renewable ambitions for 2030) to increase and stimulate cross-border trading. The Council of the European Union decided that 70% of the cross-country interconnection capacity needs to be made available by 2030 for commercial cross-border trading and gives both TSO's and regulatory authorities guidance on how to do this efficiently and how to best monitor the achievement. In reality, the ACER's market monitoring report, issued in 2019, stated that on most of the analyzed bidding-zone borders, the margin available for cross-zonal trade are currently much lower than 70%, suggesting significant room for improvement. In Germany for example, not a single hour passed where all critical network elements considering contingencies reached the minimum value of 70% cross-country interconnection.

It is however important to note that that although the physical interconnection capacity between bidding zones is integrated in the market coupling algorithm, it does not matter on an individual bidding zone level, where the electricity in the bidding zone is generated and where it is consumed. The market sees this bidding zone as a node with a certain total supply and demand without taking any physical grid topology into account. This is a vital point within the current price and volume calculation that leads to problems such as loop flows.

Description of the Loop Flow Phenomenon

As stated in the previous section, the Euphemia algorithm will handle intra-bidding zone trades without any limiting grid capacity ('copper-plate grid model'). This means that intra-bidding zone supply and demand orders can be matched without considering the physical grid. It can however happen that the concentration of production and consumption are situated in completely different parts of a bidding zone. The scheduled electricity will have to be transported within the bidding zone and will ideally only create intra-bidding zone flows. However, these flows can become so large that congestion will occur on the internal transmission lines, due to an insufficient transmission capacity within the

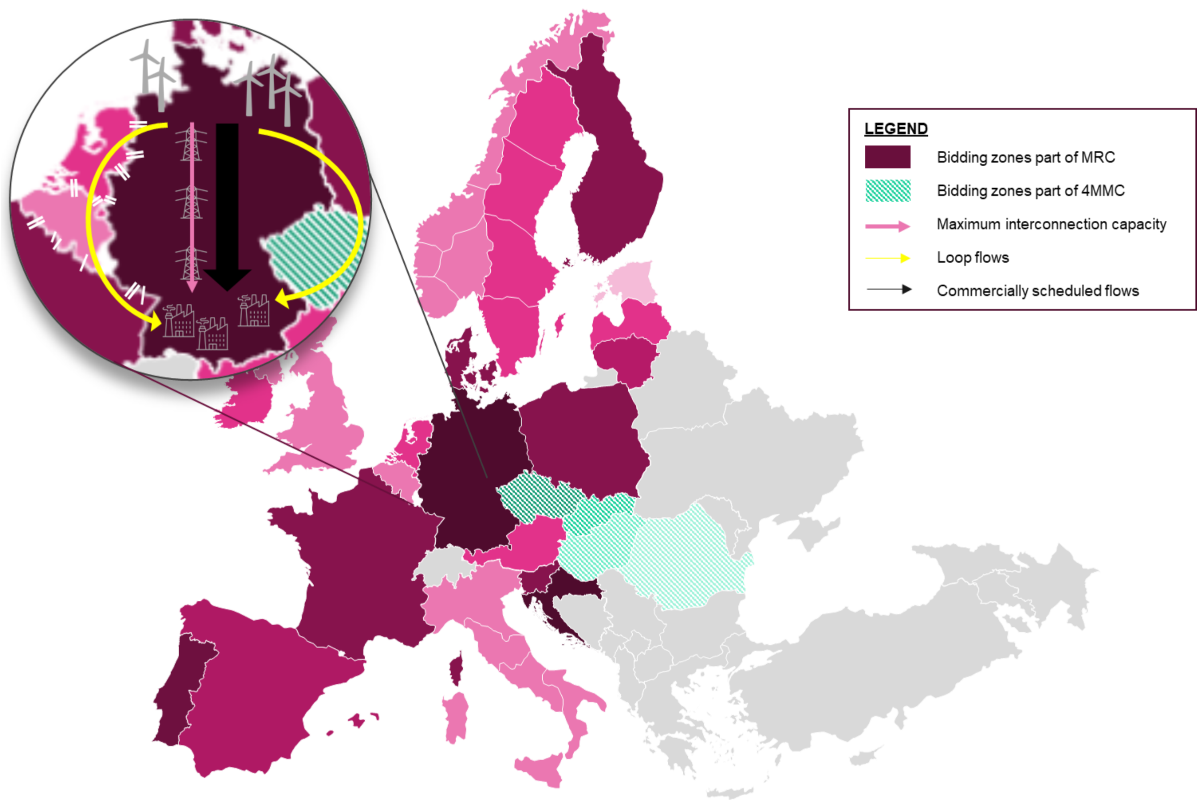

Figure I: The German loop flow phenomenon and the European bidding zones.

bidding zone. As electricity will always follow the path of least resistance, it will 'spill over' the borders (take a shortcut outside the bidding zone) to arrive in another part of the original bidding zone. These specific flows that take a detour are called loop flows.

German Case

The loop flow phenomenon is specifically severe in Germany and its neighboring countries. Wind power (both on- and offshore) is more concentrated in the Northern part of Germany while the energy consuming industries are situated in the South. Due to the limited interconnection capacity between North and South Germany, electricity spills over and flows through its neighboring bidding zones being among others Poland, Czech Republic, the Netherlands and Belgium to reach the industrial South [I]. It takes a detour through other parts of the grid – looping around the physical bottleneck.

Figure I illustrates this scenario graphically. The black arrow flowing from the North to the South of Germany corresponds to the interconnection capacity needed to cope with the commercially scheduled intra-bidding zone flows, while the pink arrow displays the current installed maximum interconnection capacity. Because the physical grid capacity is insufficient, loop flows (yellow arrows) exist which cannot pass the congested interconnector and flow from one bidding zone via another back to its initial bidding zone. In Figure I, the black arrow, which is the total commercially scheduled flow, is the sum of the pink arrow (physically possible flow) and the loop flows through the neighboring bidding zones.

Impact of Loop Flows

A significant part of the German caused loop flows goes through Belgium and has a non-negligible impact on the sourcing of Belgium's electricity (as loop flows decrease the interconnection capacity that can be traded). They are impacting, among others, the following three areas.

First, loop flows have a clear impact on the price of electricity of the affected bidding zones. The day-ahead market coupling algorithm, Euphemia, needs the available cross-border interconnection capacities to determine how much cross-border exchange will be possible the next day. An important fact is that the available cross-border capacity inputs already exclude a certain volume for the estimated loop flows that will occur the next day. This means that loop flows are intrinsically taken into account and prioritized in the current market design and will reduce commercial cross-border trading within the coupled region. In the scenario of high volumes being transferred from North to South Germany and electricity flows looping through Belgium, a vast amount of Belgium's interconnection capacity is reserved for these loop flows. When the loop flow volume is high and electricity is rather scarce in Belgium, this will lead to price peaks on the

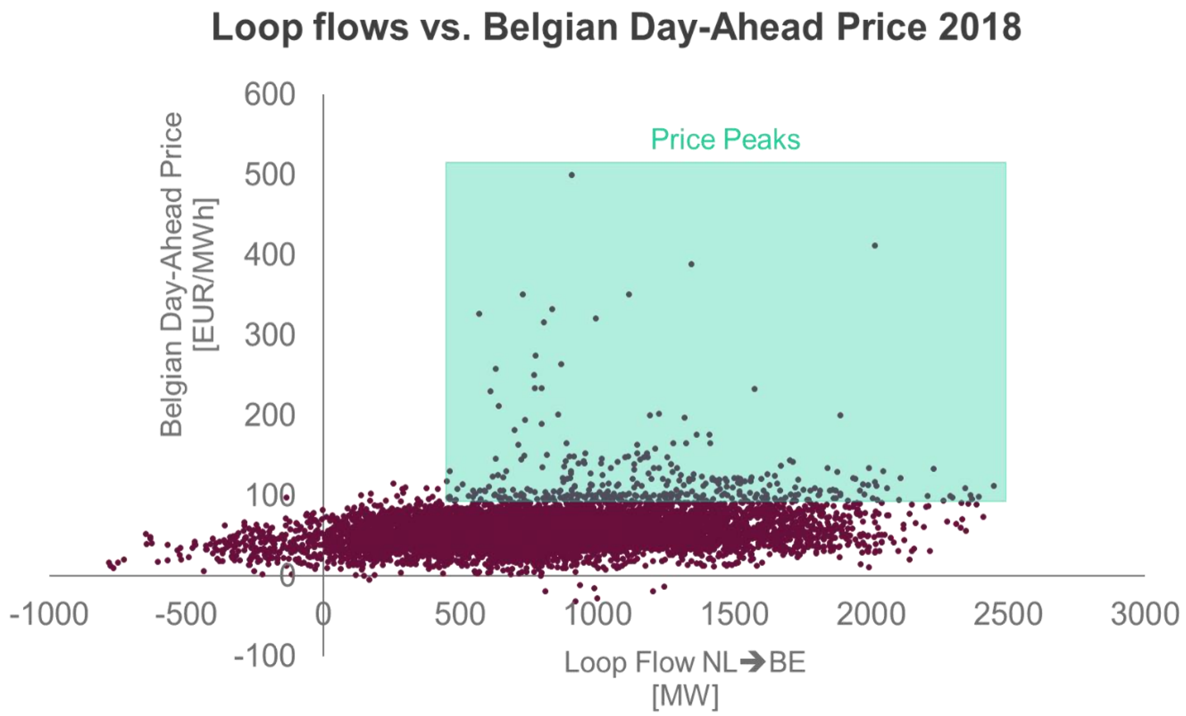

Figure II: The prices on the Belgian Day-Ahead market for all hours of 2018 compared to the volume of loop flows on the Dutch-Belgian border. Price peaks only occurred in 2018 when loop flows surpassed 500 MW.

Belgian day-ahead market. As a result, Belgian interconnectors and its electricity grid are used to relief Germany's internal congestions making it impossible for Belgium to use its connections to import more and cheaper electricity when available. This price peak phenomenon is endorsed by Figure II which shows the day-ahead price for Belgium for every hour of 2018 compared to the amount of loop flows during that hour flowing through Belgium from North to South (negative flows go in the opposite direction, FR⇨BE⇨NL). It is apparent that price peaks in the Belgian bidding zone only occur when loop flows cross a certain value (500MW). As a reference, the maximum physical flow on the Northern border flowing from the Netherlands to Belgium was 3755 MW in 2018 [II]. Price peaks can be very severe and can go up to 500 EUR/MWh. As a comparison, the yearly averaged day-ahead wholesale electricity price in Belgium for 2018 was 55.3 EUR/MWh. [II]

Secondly, the necessity of strategic reserves and the operation of the system itself is impacted. Having a large amount of loop flows increases the uncertainty on the system operation which results in significant economic costs. In a study executed by Elia [III], it was identified that the scenario of high wind infeed in North Germany results in the maximum Belgian import capacity and the highest need for reserves. Reinforcements of the Belgian grid could reduce the described impact but are by no means able to solve the problem alone. Elia estimated in its Adequacy Study for 2018-2019 that Belgium and France are only able to import a capacity of 2000 MW which is only half of the capacity needed to successfully cope with the problems of loop flows.

Lastly, the integration of renewable energy sources gets hindered by a large availability of loop flows. Today, an enormous bottleneck exists where German wind energy produced in the North is unable to be transported to its neighboring countries. If more electricity is generated than the capacity of the interconnectors the prices in Germany will be lowered (and sometimes even be negative) making renewable energy a less attractive investment. If export of wind is hampered by loop flows, the market integration of renewables on a larger scale is affected accordingly.

The economic impact of loop flows is visible today. The loss in social welfare has been estimated by ACER to be about 445 million € in 2015 which can only be decreased if the market design correctly reflects the grid topology both on a single bidding zone level as well as on a coupled level [IV]. Instead of minimizing this phenomenon, there are strong indications that the magnitude and the frequency of loop flows will only grow in the future due to recent governmental decisions. On the one hand, Germany will try to minimize its dependency on coal and nuclear power by completely phasing out these types of electricity production by 2038 and 2022 respectively. This results in an increased reliance on renewable energy (80% in 2050) and especially wind energy from the North. On the other hand, improvements to the German North-South connection remain vague and clear go-live dates are not yet communicated to the public. Both aspects cause a prominent increase of loop flows as the increase of renewable energy occurs before the initiation of a better North-South linkage.

Solutions

Reducing the amount of German loop flows is a very complex matter as it is not only analytically challenging but will require negotiations and discussions with all stakeholders. From a purely theoretical point of view, German grid reinforcement, splitting the German bidding zone or an improved market design are all feasible solutions to lower the loop flows passing through Germany's neighbors.

The reinforcement of the linkage between North and South Germany, would increase the maximum interconnection capacity within Germany, directly resulting in a reduction of the congestion and as consequence the loop flow volumes. Secondly, splitting the current German bidding zone would take better into account the physical grid capacity. The North-South interconnection capacity serves as an input for the market coupling algorithm and a more correct allocation of capacity would be possible. This is a highly political matter, as multiple bidding zones would mean different prices for German consumers depending on their region.

The last option would be to adjust the market design to better handle the loop flow phenomenon. Multiple ideas have been proposed and it should become clear soon what kind of modifications can be done. An example is the Flex-in-Market model as proposed by ELIA. This solution would use dispatch hubs that are optimized during the market coupling to manage congestions in a welfare optimal way.

Conclusion

The loop flow problematic has a non-negligible impact on electricity sourcing and price formation in Belgium. It prevents the Belgian bidding zone to fully rely on its maximum interconnection capacity during market coupling with neighboring countries. A significant part of the interconnection capacity is occupied by loop flows, which are caused by structural congestions within the German bidding zone. This phenomenon causes price peaks on the Belgian day-ahead market and is expected to worsen in the future, as Belgium will be more relying on electricity imports.

In order to obtain a well-functioning European electricity market that is a level playing-field for all countries and helps to achieve the objectives of the Clean Energy Package, Europe does not only need a proper grid infrastructure, but a well-designed electricity market model is equally important. Market coupling has brought a lot of social welfare gains for European consumers, but the current market design still needs further improvements to cope with the flaws of which loop flows are only one. Multiple solutions are proposed and available today, but the involved parties should work closer together to solve the described problematic urgently.

I ENTSO-E Transparency Platform: www.entsoe.eu
II CREG. “Study on the Functioning and Price Evolution of the Belgian Wholesale Electricity Market – Monitoring Report 2018.” CREG, 5 Sept. 2019.
III CREG. Functioning and Design of the Central West European Day-Ahead Flow Based Market Coupling for Electricity: Impact of TSOs Discretionary Actions. CREG, 2017.
IV “Future-Proofing the EU Energy System towards 2030.” Elia and 50Hertz Publish a Joint Study on Futureproofing the EU Energy System towards 2030, 12 Dec. 2019, www.50hertz.com/en/News/FullarticleNewsof50Hertz/id/6174/elia-and-50hertz-publish-a-joint-study-on-futureproofing-the-eu-energy-system-towards-2030.

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