Elia Group

TECHNICAL STUDY

Need for electricity market price coupling with UK to support offshore investments in the North Seas.

Technical study of the shortcomings of Explicit Allocation and Multi-Regional Loose Volume Coupling, and thus the need for re-implementing a system of price coupling between the EU (including Norway) and the GB Market to support investments in offshore infrastructure in the North Seas

Executive summary

The EU and the UK have great ambitions for harnessing offshore wind in the North Seas to meet decarbonisation targets and enable the electrification of the energy system. To transmit this offshore wind power to consumers onshore, vast investments in offshore interconnector capacity are needed.

With Brexit, full price coupling on the interconnectors between Great Britain and Continental Europe and the Nordics, respectively, was abandoned and replaced by less efficient allocation regimes. On most interconnectors, explicit auctions in the long-term, day-ahead and intraday timeframe are the means to allocate cross-zonal capacity. The EU-UK Trade and Cooperation Agreement suggests Multi-Regional Loose Volume Coupling as an allocation regime without specifying in detail its implementation.

Given this status quo, the future regarding cross-zonal capacity allocation on interconnectors with Great Britain is uncertain. This uncertainty is making investment decisions, both regarding offshore grid infrastructure and offshore wind generation capacity connecting to hybrid interconnectors, significantly more difficult to take. With lead times of several years for investments in both fields, it is a matter of urgency to create more certainty around cross-zonal capacity allocation on interconnectors with Great Britain if the offshore wind ambition in the North Seas is to be reached.

The development of offshore Hybrid Interconnectors needs to take place to allow offshore wind potential to connect to it. When there is certainty around the establishment of Hybrid Interconnectors, the foundation for development of offshore wind generation capacity connecting to them is laid.

Before taking investment decisions in offshore grid infrastructure, TSOs conduct a cost-benefit analysis. Such cost-benefit analysis assumes that the full price coupling is in place. A less efficient allocation regime – either explicit auctions or Multi-Regional Loose Volume Coupling – will diminish the benefits and can lead to costs outweighing benefits. Consequently, an investment decision is less likely to be taken – and, consequently, offshore wind generation capacity is less likely to be built.

For investments in offshore wind generation, full price coupling makes an investment significantly less risky and uncertain compared to alternative allocation regimes such as Multi-Regional Loose Volume Coupling or explicit auctions. This is certainly the case if the investment is taking place on fully merchant term as developers cannot anticipate the level of future revenues in case the market mechanism is not well defined. But this is also the case if a support mechanism (e.g. Contracts for Differences) is in place since the design and implementation of such support can be done much more effectively and with less distortion in case of price coupling.

Being fully coupled in the day-ahead timeframe delivers solid price signals for offshore bidding zones, which in turn provides higher visibility on the return on investment. In such a scenario, financial transmission rights can complement support schemes such as Contracts for Differences, providing further hedging opportunities. Once operational, a fully coupled intraday market allows for the offshore wind farms to adjust its position based on the latest wind forecasts. Explicit auctions and Multi-Regional Loose Volume Coupling fall short in providing hedging opportunities on the one hand and short-term adjustments of trading positions on the other hand.

For both the EU and the UK to achieve their ambitious offshore wind targets, a return to full price coupling including coherence across market timeframes is required. Full price coupling will give confidence to TSOs to invest in offshore grid infrastructure, needed to build offshore wind generation. Full price coupling delivers most value for society and does not jeopardise the robustness of the EU Single Day-Ahead Market Coupling and Single Intraday Market Coupling.

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1 Introduction

This technical study paper discusses the need for the re-implementation of a system price coupling between the EU including Norway and the UK to support investments in offshore infrastructure in the North Seas.

Chapter 2 introduces the great ambitions of the EU, the UK and Norway in terms of offshore wind generation in the North Seas, and the role of Hybrid Interconnectors to achieve these ambitions.

Chapter 3 explains how Hybrid Interconnectors are best integrated in the EU zonal market model. Firstly, through the ‘offshore bidding zone’ model, where the offshore wind generation is treated as a distinct bidding zone which can clear at its own price, which may be different than the price(s) in (adjacent) onshore markets. Secondly, through the application of ‘Advanced Hybrid Coupling’ on Hybrid Interconnectors connecting to flow-based areas. With Advanced Hybrid Coupling, physical impacts of flows on Hybrid Interconnectors on the onshore power system (and vice versa) can be considered without having to be forecasted. Advanced Hybrid Coupling, however, can only be realized through a price coupling allocation regime.

Chapter 4 further elaborates on the risks and uncertainties related to investments in offshore grid infrastructures. Such investments are typically assessed through Cost-Benefit Analysis, for which the benefits are highly dependent on an effective usage of the infrastructure, and for which modelling inefficient allocation regimes is more precarious (because it relies on further assumptions).

Chapter 5 lays down the advantages of price coupling, both from a technical and governance perspective. Furthermore, the benefits of Advanced Hybrid Coupling in conjunction with price coupling are highlighted.

Chapter 6 and 7 outline the drawbacks for Explicit Auctions and Multi-Regional Loose Volume Coupling, respectively, as means to allocate cross-zonal capacity on Hybrid Interconnectors. Both chapters describe how these allocation regimes struggle with price formation in offshore bidding zones and work out their incompatibility with Advanced Hybrid Coupling.

Chapter 8 provides some further concluding remarks.

For readers who prefer to forego the technical details presented in the main body of this paper, it is suggested to focus on the summary sections at the end of each of the technical chapters (chapters 2 through 7) and turn straight to the concluding remarks presented in chapter 8.

2 Offshore wind generation ambition in the North Sea

The EU, the UK and Norway (NO) have ambitious plans for harnessing the vast potential of wind energy in the North Sea for decarbonising their respective energy systems.

The countries shoring the North Seas (DK, DE, NL, BE, FR, IE, NO, UK, SE) have the ambition to grow, from the 27 GW of offshore wind generation capacity of today, to 119 GW by 2030, with plans to get to 274 GW and 332 GW by 2040 and 2050, respectively[1]. A breakdown of the ambitions for offshore wind generation developments country-level can be found in the map and table below.

2.1 Network developments across the North Seas to integrate offshore wind

Along with the increase in offshore wind generation in the North Seas, significant network developments are needed. The North Seas TSOs, under the umbrella of ENTSO-E, have put forward an offshore network development plan (ONDP) that needs to be realised to enable the large-scale integration of offshore wind in the North Sea basins. This plan includes drastically increasing interconnection capacity between the North Seas countries and building 15,000-20,000 km of offshore grid by 2040.

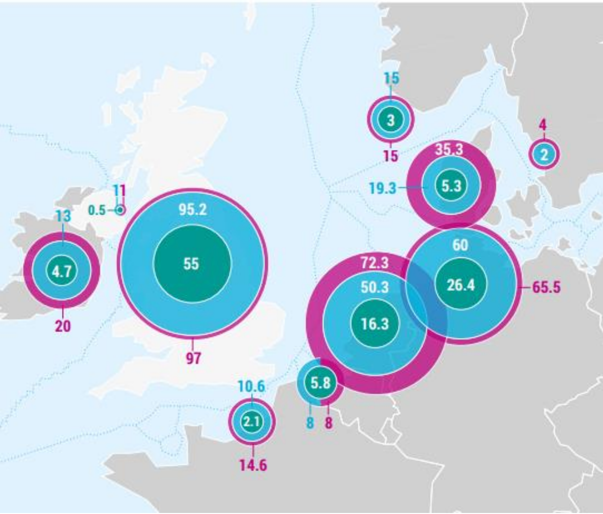

Figure 1: Offshore wind capacities for 2030, 2040, 2050. Source: ONDP Northern Seas report

Country	Today	2030	2040	2050
FR [GW]	0	2	8	17
BE [GW]	2.3	6	8	8
NL [GW]	2.5	16	50	72
DE [GW]	7	26	60	66
DK [GW]	0.8	5	19	35
SE [GW]	0	0	2	4
IE [GW]	0	5	13	20
NO [GW]	0.1	3	15	15
GB [GW]	13.7	55	95	97
Total [GW]	**27**	**119**	**274**	**332**

2.2 Combining offshore wind and cross-border connection: Hybrid Interconnectors

The integration of such considerable amounts of offshore wind into the EU and UK (and NO) energy systems, respectively, requires potent HVDC interconnectors between the Offshore Wind Platforms (OWP) and the onshore power systems. Given the geography of the North Seas with several bordering countries, OWPs are not expected to be connected to only one onshore power system. Instead, many OWPs are going to be connected to two or more onshore power systems via Hybrid Interconnectors (HIC) (or Multi-Purpose Interconnectors (MPI)). These Hybrid Interconnectors combine one (or more) OWPs with HVDC interconnectors between at least two onshore power systems. As a result, the OWPs in the North Seas are going to be integrated in a 'meshed' HVDC interconnector network spanning between EU Member States shoring the North Seas, the UK and Norway. Next to transporting offshore wind generation onshore, such a 'meshed' network of HVDC Hybrid Interconnectors allows for more

[1]ONDP Northern Seas report: [ENTSO-E TYNDP 2024 Sea-Basin ONDP Report – Northern Seas Offshore Grids]

resilience, improves security of supply and provides additional cross-zonal capacity for power exchanges, aiding market integration.

One hybrid project already under development is **Princess Elizabeth Island** in combination with the **Nautilus hybrid interconnector** between Belgium and Great Britain, this project is expected to combine 1.4 GW offshore wind generation and a similar amount for the hybrid interconnector capacity between both countries passing via the energy island to connect the offshore wind.

A Dutch OWP with 2 GW offshore wind capacity is planned to be connected to the Netherlands via a 2 GW HVDC interconnector and Great Britain (via **LionLink** at 1.8 GW of transmission capacity), respectively. Figure 2 shows the existing and planned interconnectors and Hybrid Interconnectors in the North Seas.

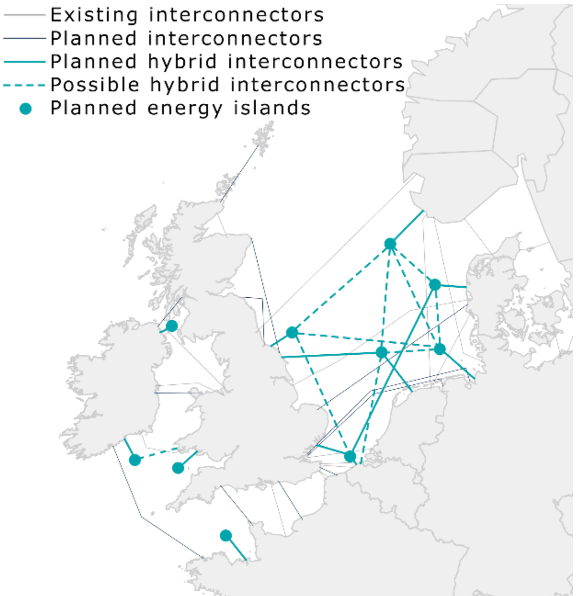

Figure 2: Existing[2] and planned[3] interconnectors and Hybrid Interconnectors in the North Seas[4]

From Figure 2 it becomes apparent that Hybrid Interconnectors will play a vital role in realising the offshore wind ambition in the North Seas. These Hybrid Interconnectors enable transmitting power onshore and increased exchanges of power across the North Seas. By that, Hybrid Interconnectors add overall exchange possibilities and contribute to security of supply in the EU, Norway and the UK.

2.3 Summary

The main takeaways from this section are:

- The EU, the UK and Norway pursue great ambitions in terms of offshore wind generation in the North Seas
- Hybrid Interconnectors will play a key role in achieving the North Seas offshore wind ambition
- Hybrid Interconnectors increase power exchange possibilities and contribute to decarbonisation objectives and security of supply in the EU, the UK and Norway.

[2] Source: ENTSO-E TYNDP 2022

[3] Source: Offshore Development Network Plan

[4] Sources: ENTSO-E ONDP, ENTSO-E TYNDP 2022 and ENTSO-E grid map

3 Integrating offshore bidding zones into the zonal market model

3.1 Offshore Bidding Zones to best integrate Hybrid Interconnectors

In conjunction with the integration of Hybrid Interconnectors into the zonal EU electricity market model, two concepts have been widely discussed. These two concepts are the 'home market' setup and the 'offshore bidding zone' (OBZ) setup.

In a 'home market' setup, the OWP is assigned to an onshore market and is part of the onshore market bidding zone (i.e. it clears at the same single price, and a single copper plate is assumed for the onshore bidding zone and the OWP).

However, the home market setup inherently suffers from inefficiencies and gaming opportunities. With the OWP being combined with the onshore bidding zone, the TSOs are required to forecast the offshore wind generation when computing cross-zonal capacities between the OWP and the onshore bidding zones. To do this computation, the forecasted wind generation is deducted from the physical capacity of the interconnector and is then offered for allocation.

On the one hand, if the wind forecast turns out to be too low, offered cross-zonal capacities end up being too high. If the available cross-zonal capacity is fully allocated, a congestion on the interconnector appears from the combined flow of the actual offshore wind generation and the cross-zonal exchange. To alleviate this congestion, TSOs have to trigger redispatch or countertrading actions, which are costly and are borne by the grid users at large.

On the other hand, if the TSOs' forecast on offshore wind generation turns out to be too high, cross-zonal capacities are reduced to lower levels than needed. As a consequence, the sum of offshore wind generation and allocated cross-zonal capacity is lower than the physical limit of the interconnector. Ultimately, the interconnector is not fully utilised by the actual offshore wind generation or by cross-zonal exchanges, leading to socio-economic welfare losses.

Gaming opportunities arise from the fact that congestion on the interconnectors between the OWP and the respective onshore power systems can be predicted and is geographically well defined. For example, market players with offshore wind generation connected to the OWP can be inclined to engage in the 'inc-dec-game', where they aggravate the congestion on the interconnector first to increase their market revenues, and are then ordered by the TSO to adapt their asset schedules[5]. This typically allows capturing an additional infra-marginal rent.

Furthermore, a home market setup is not in line with the principles of delineating bidding zones along structural congestion. The interconnector(s) between an offshore platform and the onshore power system meet the definition of structural congestion:

" 'structural congestion' means congestion in the transmission system that is capable of being unambiguously defined, is predictable, is geographically stable over time, and frequently reoccurs under normal electricity system conditions;"[6]

Congestion on Hybrid Interconnectors can be unambiguously defined and is geographically stable as such interconnectors are not meshed (as onshore AC power systems might be). It is predictable (related to the forecasted wind generation on the OWP) and is expected to occur frequently.

[5] Elia Public consultation Task Force Princess Elisabeth Zone, Chapter 4

[6] Regulation 2019/943 Article 2, Definition 6

Due to the inherent drawbacks and lack of legal compliance of the 'home market' setup, this setup is not further considered here. Instead, this paper considers the offshore bidding zone (OBZ) as the logical setup to integrate OWPs into the EU zonal market design.

The OBZ setup foresees that OWPs constitute their own bidding zone. Such a setup has the strong advantage of enabling both transferring offshore wind energy to loads onshore and allocated cross-zonal capacity most efficiently. As a consequence, an OBZ clears at its own price and both the offshore wind generation and exchanges on interconnectors contribute to maximizing socio-economic welfare. The to be established Denmark 3 bidding zone on the island of Bornholm follows this model, albeit with Bornholm having some power demand.

3.2 Cross-zonal capacity calculation with offshore bidding zones

Interconnectors connected to areas which are subject to flow-based allocation can essentially be allocated following two approaches: NTC based Standard Hybrid Coupling (SHC) or Advanced Hybrid Coupling (AHC). Both approaches are briefly described here.

In Standard Hybrid Coupling, exchanges (or net positions) are forecasted at the beginning of the capacity calculation process. These forecasted exchanges are assumed to be static in the underlying grid models and do not change as the capacity calculation process goes on. This forecasting of exchanges results in an ex-ante split of capacities between two capacity calculation regions (e.g. Core and Italy North).

The principles of Standard Hybrid Coupling and Advanced Hybrid Coupling are shown in Figure 3. CCR_A is assumed to apply the flow-based approach. In Standard Hybrid Coupling, the margin available for cross-zonal trade on the network element is split ahead of allocation. A pre-determined share is reserved for flow-based within CCR_A, while another share is provided for exchanges with CCR_B, here assumed to be with an Available Transfer Capacity (ATC) approach.

In Advanced Hybrid Coupling, the total margin is provided to the price coupling algorithm and the 'split' is determined during allocation based on socio-economic welfare maximisation.

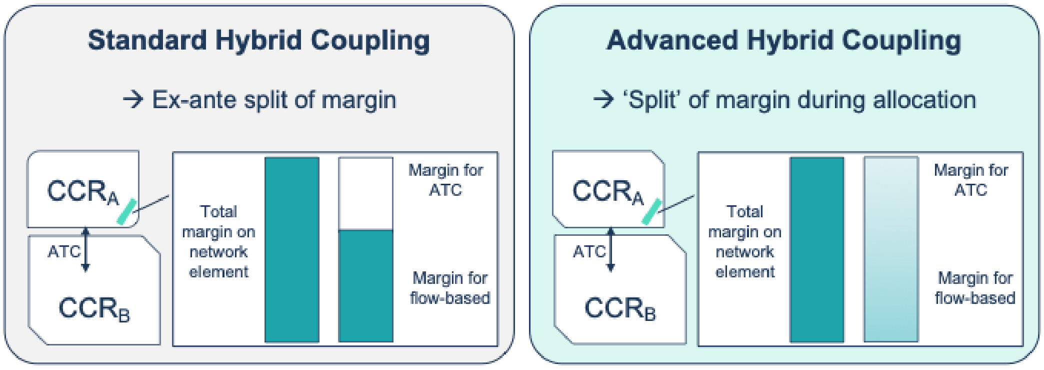

Figure 3: Comparison of Standard and Advanced Hybrid Coupling

In flow-based capacity calculation regions, the forecasts made by TSOs are not only relevant for the bordering bidding zone border(s), but the entire capacity calculation region. The forecasted exchanges result in ex-ante reservation of capacity on relevant network elements (particularly in the vicinity of the HVDC converter stations). Consequently, margins available for allocation in SDAC (or SIDC) on these relevant network elements are reduced, resulting in lower overall cross-zonal capacities of the entire capacity calculation region. If the forecast is perfectly accurate, this has no negative implications. However, typically a forecast is too low or too high, and some inefficiencies will arise, similarly as for the 'home market' setup described in the previous section.

The drawback of having to forecast exchanges on bidding zone borders can be addressed through Advanced Hybrid Coupling (AHC). AHC allows for the price coupling algorithm to determine the 'split' of the margin on relevant network elements while maximising socio-economic welfare. Therefore, no forecast of the exchanges and ex-ante split as in SHC is needed, and the inefficiencies resulting from it are avoided.

For AHC to perform fully, two prerequisites must be fulfilled. The first one is **flow-based capacity calculation**. AHC cannot be considered as part of a NTC capacity calculation approach, as sensitivities of exchanges outside the capacity calculation region cannot be considered via NTCs. The second prerequisite is **flow-based allocation**. When flow-based capacity calculation includes AHC, cross-zonal capacity allocation needs to be able to work with AHC-enabled inputs.

AHC is considered part of the Internal Energy Market (IEM) for electricity target model. AHC is going to be implemented in conjunction with Nordic flow-based and is going to enhance Core flow-based soon. The application of AHC is limited to bidding zone borders that are fully price coupled (as within SDAC) and cannot be applied when different allocation regimes (such as a combination of SDAC and explicit auctions or MRLVC) are present. For example, AHC can be applied on bidding zone borders of the Hansa capacity calculation region, as these bidding zone borders are coupled in SDAC and both Core and Nordic (i.e. the adjacent capacity calculation regions) (intend to) apply flow-based. In contrast, AHC cannot be applied on the Swiss bidding zone borders, as Switzerland is not coupled via SDAC and Swissgrid is not part of any capacity calculation region applying flow-based.

3.3 Price coupling as a means to achieve the North Seas wind ambitions

This paper supports the **necessity for a return to full price coupling with the UK to realize the ambitions for development of large-scale offshore wind in the North Seas** – both for the EU and the UK. Price coupling is key not only to efficiently operate the expected grid of HVDC interconnectors spanning the North Seas, but also to give confidence to policy makers, offshore wind developers, grid developers/TSOs and other stakeholders that the infrastructure is going to be used most efficiently.

To ensure the most efficient allocation of cross-zonal capacities, price coupling needs to be combined with AHC. AHC – both in capacity calculation and allocation - is enabled by capacity calculation regions applying flow-based, such as Core and Nordic capacity calculation. As both Core and Nordic 'interface' with Great Britain via multiple HVDC interconnectors, socio-economic welfare is maximised, and uncertainty reduced.

Furthermore, price coupling with Advanced Hybrid Coupling in the day-ahead timeframe needs to be complemented by coherent allocation of cross-zonal capacities across all market time frames. Through long-term allocation, financial transmission rights provide an additional hedging instrument to offshore wind generators as well as congestion income to TSOs. Price coupling in the intraday timeframe allows for short-term adjustments of positions and adjustments to updated wind forecasts.

Without price coupling in combination with Advanced Hybrid Coupling and coherent allocation of cross-zonal capacity across timeframes, Financial Transmission Rights in the long-term timeframe for hedging purposes cannot be offered and adapting trading positions in the intraday market is more difficult... This may negatively affect the investment climate in offshore wind and in HVDC interconnectors, as further discussed in Section 4.

In the context of this paper, the combination of price coupling with Advanced Hybrid Coupling is dubbed the 'IEM Target Model for Electricity'. This target model has previously been advocated for in the ENTSO-E paper *'Assessing Selected Financial Support Options for Renewable Generation'*[7].

3.4 Example of Hybrid Interconnector: Princess Elisabeth Island and Nautilus interconnector

The Nautilus HVDC interconnector is a planned link between the Princess Elisabeth Island (PEI) off the coast of Belgium and Great Britain. Figure 4 illustrates the set-up of Nautilus.

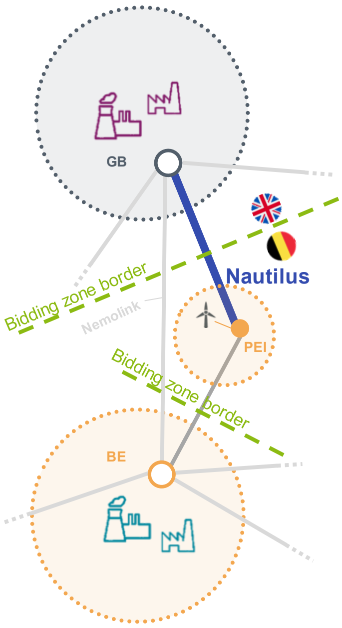

Figure 4: Illustration of topology of Nautilus Hybrid Interconnector.

In this setup, PEI would constitute an offshore bidding zone, and both the Belgium (onshore) bidding zone and the PEI OBZ would be coupled with the rest of the EU via SDAC and SIDC.

The allocation regime to be used on the bidding zone border between PEI and Great Britain is uncertain. Existing interconnectors between Continental Europe/the Nordics and Great Britain predominantly use explicit auctions. The Trade and Cooperation Agreement (TCA) signed during the Brexit negotiations proposes Multi-Regional Loose Volume Coupling. Both explicit auctions and MRLVC come with shortcomings, as discussed in Section 6 and 7 respectively. Price coupling on the PEI and Great Britain bidding zone border would provide certainty that the assets would be used in the most efficient way, which would have a positive impact on the investment decisions.

3.5 Summary

The main takeaways from this section are:

- The 'Offshore Bidding Zone' (OBZ) setup – which means that an offshore wind platform is modelled (and hence priced) separately from its connecting onshore market – is the contemplated mechanism to integrate the upcoming offshore infrastructures into the EU and

[7] ENTSO-E: Assessing Selected Financial Support Options for Renewable Generation, Link: https://eepublicdownloads.azureedge.net/clean-documents/Publications/Position%20papers%20and%20reports/entso-e_pp_Offshore_Development_05_Financial_Support_211102.pdf

UK market models, as this approach is aligned with the principles of bidding zones delineation. This approach fosters an efficient allocation of scarce transmission resources and also limits gaming opportunities. The alternative 'home market' setup – where offshore wind platforms are directly integrated into onshore bidding zones – does not offer the same advantages.

- Advanced Hybrid Coupling (AHC) is an approach to cross-zonal capacity calculation and allocation that efficiently tackles the impacts of HVDC interconnectors on meshed transmission grids. This approach, which is compatible with the price coupling regime, is part of the IEM target model that will be implemented in conjunction with flow-based in the Core and Nordic regions.
- Realising the ambitions for the development of large-scale offshore wind in the North Seas implies a market model comprising of:
    - Offshore bidding zones as the means to consider offshore wind platforms on Hybrid Interconnectors
    - Full price coupling between the EU (incl. Norway) and Great Britain in combination with Advanced Hybrid Coupling in flow-based capacity calculation regions
    - Coherent allocation of cross-zonal capacity across market timeframes

4 Investments in offshore grid infrastructure and offshore wind generation capacity

4.1 Risks and uncertainties for investments in offshore grid infrastructure

Although Hybrid Interconnectors are less costly than its alternatives of radially connected offshore wind in combination with only point-to-point interconnectors, they still require very high capital expenditures. Purely compared with the point-to-point interconnector developments alone, a hybrid interconnector is more expensive and with such high capital expenditures, uncertainty translates into higher financial risks.

Furthermore, the allocation regime used on bidding zone borders adjacent to the offshore bidding zone is uncertain. Allocation regimes other than price coupling do not provide certainty on congestion income collected on Hybrid Interconnectors. If the cash flow from congestion incomes is less certain, investments are becoming more difficult to finance. Financial risks are further amplified by the currently increasing interest rates. This trend makes investments even more expensive – at a time when they are much needed.

The common means to deal with both risk and uncertainty with envisioned investment projects it to carry out a cost-benefit analysis.

4.2 Cost-Benefit Analysis as a means to capture uncertainty

Before TSOs undertake investment decisions for major power system infrastructure, a cost-benefit analysis (CBA) is carried out. This CBA assesses the costs of a given project and compares it with the monetised benefits. The costs are determined by summing up the expected cost components for building the project, such as buying or leasing land and the actual hardware. The benefits are typically expressed in terms of socio-economic welfare gains compared to a counter factual (often the status quo or an alternative investment scenario).

To obtain the socio-economic benefits, simulations of the future power system and electricity market are performed. These simulations reflect different scenarios (with varying underlying assumptions), climate years or other variables (or sensitivities) that may impact the benefits.

As part of these simulations, cross-zonal capacity allocation is simulated to obtain insights in changes in socio-economic welfare. Cross-zonal capacity calculation and allocation is usually modelled following the EU IEM target model. That is, full price coupling in the day-ahead time frame – even on bidding zone borders where a different (and less efficient) allocation regime is used – combined with flow-based and Advanced Hybrid Coupling. Simulating an economically and technically less efficient allocation regime (such as explicit auctions or MRLVC) is more challenging than simulating an efficient allocation regime (such as full price coupling), as less efficient allocation regimes require further assumptions and/or sub-process steps to be considered or modelled (exactly to model the inefficiencies). Also, because of the high number of simulations that need to be undertaken, simulating full price coupling helps keeping the total computation time under control.

Note that other simulations in future timeframes, such as assessments on adequacy, also simulate full price coupling on all bidding zone borders.

Once the simulations are done, the socio-economic benefits can be extracted and compared to the costs. The benefits observed in a price coupled case might be lower with a less efficient allocation regime. In cases where the benefits barely outweigh the costs in a scenario with price coupling, the benefits might turn negative (i.e. not adding value for society at all). Consequently, the results of the CBA are associated with additional uncertainty.

Before TSOs take the final investment decision, regulatory authorities assess the results of the CBA themselves and, if the project is deemed beneficial, give green light for considering the investment costs in the grid tariff scheme for the TSO. Additional uncertainty in the CBA is hence expected to propagate in the decision process on offshore grid investments of regulatory authorities.

4.3 Risks and uncertainties for investments in offshore wind

Attracting the levels of investments in offshore wind generation capacity to meet the EU (incl. Norway) and UK ambitions regarding offshore wind in the North Seas will be a challenge. Support schemes, such as CfDs, can help to mitigate some risks and create incentives for building offshore wind generation capacity. However, these support schemes fall short in incentivising a sufficient level of HVDC interconnection – both radial and hybrid – needed to bring the offshore wind generation onshore and allow for additional power exchanges among North Sea basins bordering countries. **Investments in offshore grid infrastructure are a prerequisite for investments in offshore wind generation capacity.**

Uncertainties on the allocation regime used on bidding zone borders between Great Britain and the EU contribute to increased investment risks. Explicit auctions pose the challenge that cross-zonal capacity allocation and clearing of energy markets happen at different times. Furthermore, explicit auctions open up gaming opportunities through arbitrage between different allocation regimes.

MRLVC has not been implemented anywhere – certainly not on bidding zone borders with offshore bidding zones. Its expected performance is therefore unknown. In addition, at the time when MRLVC was discussed as the allocation regime to be proposed by the TCA, the particularities of OBZ (e.g. little to no demand) were not considered and the compatibility of MRLVC with bidding zone borders of an OBZ was not specifically assessed (see chapter 7). As a result, the exact design for MRLVC with OBZ remains to be established. In addition, MRLVC relies on a specific so-called "BBZ forecasting methodology" which is by nature challenging and which isn't yet existing. This makes it challenging to perform reliable MRLVC simulations that correctly reflect the expected socio-economic welfare gains generated by a specific Hybrid Interconnector. It is also therefore highly unlikely that MRLVC is established as a trusted and reliable allocation regime.

For MRLVC, no concept for the (consistent) allocation of cross-zonal capacities across time frames – from long-term to day-ahead, intraday to balancing - has been put forward and discussed.

Although a model for MRLVC in intraday is not discussed, given the needed steps performed for MRLVC it will not allow for trading close to real-time in the intraday timeframe on the respective interconnectors. The allocation regime hereby prevents harnessing flexibility from offshore wind and to trade out the most up-to-date wind production forecasts. Thus MRLVC does not allow offshore wind producers to adjust their (physical) positions in continuous trading in the intraday timeframe until shortly before real-time. Being excluded from the continuous intraday market coupling increases the likelihood for imbalances – typically significant due to the intermittent nature of wind – that need to be catered for by other means and likely make an investment decision less attractive.

4.4 Summary

Summarising the risks and uncertainties for investments in offshore infrastructure:

- TSOs face uncertainty regarding investments in offshore grid infrastructure, especially Hybrid Interconnectors. To cope with this uncertainty, TSOs typically perform a cost-benefit analysis.

A positive cost-benefit analysis that assumes price coupling might turn negative with a less efficient allocation regime,

- Certainty on investments in offshore grid infrastructures (i.e. Hybrid Interconnectors) is a prerequisite for investments in offshore wind generation capacity connected to hybrid interconnectors.
- As a consequence, the uncertainty faced by TSOs regarding investments in offshore grid infrastructure compounds to higher uncertainty for investments offshore wind generation capacity.

5 Price coupling as a means to efficiently allocate cross-zonal capacity

5.1 Most efficient transmission capacity allocation mechanism

It is commonly agreed that, from a socio-economic perspective, price coupling is the most efficient approach to allocate cross-zonal capacity. This is because cross-zonal capacity is implicitly allocated simultaneously with energy, and consequently the resulting clearing prices (both for electricity and for cross-zonal capacity) are coherently set such that they maximize the traded value (i.e. the socio-economic welfare).

Due to its economic efficiency, price coupling has been adopted as the pillar of the IEM integration for electricity. Literature on the efficiency and benefits of price coupling is abundant and unequivocally favourable to this concept, while the Capacity Allocation and Congestion Management Guidelines prescribe its application for all bidding zone borders of the IEM in the day-ahead timeframe.

The intrinsic advantages of price coupling are sufficiently clear and acknowledged by all stakeholders that it is not necessary to further argue at length in favour of it in the present document. Instead, this chapter discusses the key advantages of using the available SDAC price coupling mechanism (and its intraday complement SIDC) to allocate cross-zonal capacity on interconnectors with Great Britain. These key advantages are put in the context of a massive investments plans into new offshore infrastructures systems and the interconnectors between the EU IEM and Great Britain.

Price coupling has been gradually implemented throughout the EU and Norway since the inception of the EU IEM for electricity, with Great Britain being a part of it until 31 December 2020.

The rollout of price coupling throughout Europe has not been straightforward, because many significant technical, governance, legal and regulatory challenges had to be addressed. This development process nonetheless resulted in a robust SDAC technical solution which – in addition to its efficiency – is versatile and satisfies a large set of constraints.

SDAC notably encompasses several ways of modelling cross-zonal capacities, while a large set of suitable products are made available for trading on SDAC. Furthermore, the SDAC processes respect many additional operational constraints stemming from the stakeholders involved in its implementation and daily execution and have a track record of robustness of more than 10 years of successful experience.

The UK was part of the SDAC implementation process before Brexit, and the SDAC technical solution therefore already embeds specific requirements and constraints from the UK. It can therefore be reasonably expected that the (re-)introduction of the UK markets (both GB and Northern Ireland as part of SEM) in the SDAC solution implies a relatively modest technical implementation effort. The same reasoning applies in principle for the overarching legal, contractual and governance arrangements, although additional adaptations of the SDAC organizational framework would be required because the UK is not part of the IEM. Therefore, it can be reasonably expected that the effort to embed specific arrangements for the (re-)integration of the UK into SDAC is less substantial than setting up completely distinct arrangements, while such alternatives would not be able to harness the same efficiency of as a single price coupled electricity market.

In other words, **(re)introducing price coupling between UK and SDAC,** employing SDAC as a robust and proven solution to allocate capacity on interconnectors between UK & SDAC, **would at the same time constitute to the most efficient regime and require less implementation effort compared to**

any volume coupling alternative (which would have to set-up an entirely new regime and arrangements).

Next to SDAC, SIDC is about to implement three intraday auctions. The main driver behind these intraday auctions is the pricing of cross-zonal capacity in the intraday timeframe, next to bundling liquidity in a closer to real-time timeframe. These intraday auctions are performed using the SDAC infrastructure. Hence, in analogy to SDAC, the UK could be efficiently integrated into the execution of these intraday auctions with reasonable efforts. While day-ahead price coupling with UK through SDAC is the enabler for the implementation of SIDC in UK, **full integration of UK within the IEM is probably even more important in the intraday timeframe for what concerns Hybrid Interconnectors and OBZs, since adjustments closer to real-time of cross border capacity and pricing are of particular relevance for wind production assets**.

5.2 Efficient price formation in areas with no or limited price-setting assets

Economic theory suggests that power spot prices reflect the short-term marginal value of power. In practice, day-ahead prices are the result of a sophisticated calculation process that takes buy and sell orders from the market participants as input – those bids being expected to represent the marginal cost/value of electricity at a given moment.

Price coupling is the mechanism that further improves the efficiency of short-term price formation by taking into account cross-zonal capacity: by purchasing electricity in bidding zones with low prices and exporting it to bidding zones with higher prices, cross-zonal capacity is used to optimally integrate multiple bidding zones while respecting the available cross-zonal transmission capacity. As a result, the prices in the coupled bidding zones become closely and efficiently interlinked.

The exact same principles apply to OBZs. However, OBZs are different from other bidding zones in the sense that they are (exclusively)[8] composed by offshore wind farms. Wind production has no intrinsic marginal cost (such as fuel cost) and therefore the price of an OBZ hardly represents its actual electricity value if the OBZ is priced in isolation (because the value of the demand – which is in practice located elsewhere - cannot be easily expressed in an OBZ). By contrast, if an OBZ is price coupled with its adjacent bidding zones, the prices in the OBZ are naturally aligned with the price of at least one of its neighbouring bidding zones[9] where the demand value for electricity is duly represented. **This means that the value of electricity of an OBZ can be reliably set when its interconnectors are applying the price coupling principles**. Price coupling hence offers an efficient way to allocate the OBZs' interconnectors because the available transmission capacity between the offshore infrastructure and the onshore grid is directly modelled in the price coupling algorithm.

This also means that the congestion income collected by the transmission owners is set as the difference between the clearing prices in the bidding zones at either end of an interconnector (represented through ATC constraints). In case there is no congestion, cross-zonal capacity on the interconnector is not scarce and no congestion income is collected – there is no price difference. While when there is a congestion, then the electricity always flows from the low-priced bidding zone to the high-priced bidding zone, resulting in congestion income for the interconnector.

[8] Whether significant load,e.g. from electrolysers, is going to be established on OWP is uncertain. However, it is unlikley that electrolyser capacity is going to match the installed capacity of offshore wind on a given OWP.

[9] Under the reasonable/realistic assumption that the total wind production capacity is inferior to the transmission capacity of the interconnector, it can be guaranteed that the OBZ price always equals to the price of at least one neighbouring bidding zone

5.3 Compatible with refined grid representation

The Nordic and Core capacity calculation regions – which are central in the IEM and to which the present and anticipated interconnectors with Great Britain do or will connect to – will implement flow-based capacity calculation with Advanced Hybrid Coupling (AHC).

AHC is an improvement of the flow-based capacity calculation and allocation approach, which considers the physical peculiarities of power flows in power systems composed by both HVDC and HVAC network elements. Technically, AHC means that the HVDC converter stations are represented as "virtual bidding zones" in the price coupling algorithm. Such virtual bidding zones do not receive supply and demand orders, such that their clearing prices are not directly influencing the market (as they do not apply to any trade). The objective of these virtual bidding zones is to accurately represent the impact of HVDC links on the onshore meshed grid, hence removing the need to forecast the flows on HVDC network elements when determining cross-zonal HVAC capacities. Instead, the AHC approach allows for flows on HVDC interconnectors to explicitly "compete" with the other flows in the region, such that available capacity on onshore network elements is used in the socio-economic most beneficial manner.

The AHC approach requires that a) flow-based is applied and b) that cross-zonal capacity on HVDC interconnectors is allocated simultaneously with the cross-zonal capacity of the onshore grid.

Further, in case of a hybrid HVDC interconnector with an OBZ, the clearing price of the OBZ should be such that the power flows from the lower price area to the higher price area when the interconnection is congested. Without congestion, the OBZ price equals to the connected onshore zonal price. Given that – under AHC – such a price relation applies to a virtual bidding zone and given that clearing prices between adjacent bidding zones may be non-intuitive in flow-based areas, forecasting the OBZ price becomes by nature intricate as it depends fundamentally on the entire flow-based region. Unlike with explicit allocation, OBZ prices do not need to be forecasted in case of full price coupling in conjunction with AHC, as the OBZ clearing price is coupled with its adjacent bidding zones. This is why full price coupling in conjunction with AHC ensures that the clearing prices in OBZs are coupled with all adjacent bidding zones.

5.4 Summary

Key take aways from this chapter:

- Price coupling is the most efficient allocation regime for hybrid (or traditional) interconnectors, as it explicitly optimizes the socio-economic welfare that interconnectors can generate in a single calculation step. Consequently, it remunerates transmission owners with the actual value of the allocated cross-zonal capacity.
- Price coupling is compatible with the Offshore Bidding Zone (OBZ) model where the OWPs are priced separately at their true intrinsic value.
- Flow-based with Advanced Hybrid Coupling (AHC) allows to model impact of the onshore grid on HVDC infrastructure and vice versa.
- The combination of Offshore Bidding Zones and Advanced Hybrid flow-based Coupling will lead to the most efficient possible usage of the transmission assets – both onshore and offshore.
- Price coupling at the day-ahead timeframe is an enabler for an efficient allocation of these interconnectors in the intraday timeframe – especially through the upcoming SIDC Intra-Day Auctions (IDA). The intraday timeframe is particularly relevant in the context of investments in offshore infrastructures which embed intermittent wind generation.

- Implementing price coupling for the interconnectors with Great Britain implies to reintegrate the UK into SDAC. Such an implementation is expected to be facilitated by the fact that SDAC has already been designed taking the main UK's requirements into account.

6 Shortcoming of explicit allocation

6.1 Explicit cross-zonal capacity allocation

When bidding for cross-zonal capacity in an explicit auction, market participants must place their orders based on a forecast of price differences at given bidding zone border (potentially next to having to live up to obligations on power deliveries on the other side of the bidding zone border). To obtain a price spread at a bidding zone border, market parties forecast the clearing prices in the respective bidding zones. These clearing prices are dependent on several factors, such as available cross-zonal capacities, infeed from wind and solar, load and imports/exports to/from other bidding zones. Getting such a forecast right is difficult and market parties often fail to forecast correct price differences (or even the “market direction”, i.e. from a lower priced bidding zone to a higher priced bidding zone).

Clearing the explicit auction for cross-zonal capacity is only the first step in cross-zonal trading, where the offered cross-zonal capacities are valued. Following the explicit auction, successful market participants can nominate physical flows over the cross-zonal capacity. Nominations are done in line with the market participants’ bids in the energy markets on either side of the bidding zone borders. As these nominations are again based on a forecast of the clearing prices in the bidding zones in question, market participants make yet another decision on how much (of the previously obtained) cross-zonal capacity to nominate.

Once the nomination deadline has passed and the TSOs operating a given bidding zone border have received all nominations, these nominations (which can be from A→B and B→A) are netted. This netting results in a net schedule on the bidding zone border. In practice, this netted schedule does not always equal the cross-zonal capacity offered during the explicit auction (simply because all individual nominations by market participants are not necessarily in the “market direction”). Consequently, the netted schedule does not fully utilise the cross-zonal capacity offered on the bidding zone border. This aspect highlights one major inefficiency of explicit auctions, namely that cross-zonal capacities are not fully utilised in the market favourable direction. Therefore, price differences between bidding zones are not minimised and social economic welfare is not maximised.

If market participants were not able to identify the direction of the price spread, the above aspect may be amplified to the extent that the net schedule goes against the market favourable direction. In such situations, the socio-economic welfare loss is even worsened compared to a situation where the cross-zonal capacity is not used at all (and therefore obviously also compared to using the cross-zonal capacity in the market favourable direction).

6.2 Showcase: Different timings per Great Britain interconnector

On 1 January 2021, when Brexit materialised and the UK was no longer part of EU market coupling, interconnectors between EU Member States and GB reverted to allocating cross-zonal capacity via explicit auctions. These (day-ahead) explicit auctions are, however, only partially harmonised, and generally follow different sets of allocation rules. This lack of harmonized auction rules, especially timings for when explicit auctions are cleared and nominations are due, make it harder for market participants to perform correct predictions as more uncertainty is added (especially because such distinct explicit auctions are operated on several interconnectors). Table 1 below shows the current times at which clearing of the explicit auction takes place and by when nominations are due (all times are CET).

Table 1: Timings for explicit auctions on GB bidding zone borders with Continental Europe[10]. All times are CET.

Bidding zone border	Interconnector	Day-ahead explicit auction cleared at	Day-ahead nominations due by
Belgium – Great Britain	Nemo Link	9:30	14:00
Netherlands – Great Britain	BritNed	9:10	13:50
France – Great Britain	IFA-1, IFA-2	10:00	14:00
France – Great Britain	ElecLink	9:50	14:00

In additional to explicit auctions on most interconnectors with Great Britain, cross-zonal capacity on the North Sea Link (NSL) on the bidding zone border between Norway 2 (NO2) and Great Britain is implicitly allocated at 10:50 CET and coupled with N2EX day-ahead auction operated by Nordpool[11]. It should be noted that such bilateral initiatives of implicit allocation of cross-zonal capacities are not considered a viable solution for bidding zone borders (incl. between OBZ bidding zone borders) between the EU and Great Britain. Such arrangements would compete with SDAC (and potentially SIDC) and split liquidity.

Note that EPEX SPOT's GB market imposes a gate closure time at 10:20.

6.3 Price formation with explicit auctions

The formation of clearing prices in bidding zones with (partially) explicit allocation on their bidding zone borders happens outside the explicit auction itself. In principle[12], the explicit auction takes place before the gate-closure time for the clearing of the electricity market. This implies for market participants to first obtain cross-zonal capacity through explicit auction, then place bids in the energy market reflecting their expected cross-zonal nominations, and finally nominate the full or a share of their transmission right. The energy market thus clears based on bids resulting from expected cross zonal trades and the bids coming from the 'domestic' market (i.e. from within the bidding zone).

A "traditional bidding zone" that allocates all its bidding zone borders via explicit auctions, such as Switzerland, holds a certain level of domestic liquidity. In contrast, offshore bidding zone do not contain a decent liquidity, as there is only offshore wind generation and no (considerable) demand. As a result, the offshore bidding zone cannot set meaningful prices by itself and relies on cross-zonal capacity to export power (and 'import' prices).

Offshore bidding zones under EU jurisdiction that share at least one bidding zone border with Great Britain and at least one bidding zone border with another EU bidding zone will be coupled with SDAC and SIDC on the EU bidding zone border and explicitly allocate cross-zonal capacity on the bidding zone border with Great Britain. In such a case, the offshore wind farm connected to this offshore bidding zone is bound to take decisions whether it should obtain cross-zonal capacity on the bidding zone border with Great Britain and at which price.

The price offered for the cross-zonal capacity on the explicit auction is a function of the forecasted price difference between the OBZ and Great Britain. After having explicitly obtained cross-zonal capacity, the wind farm has to place orders in the OBZ market (and the GB market) to represent the

[10] Sources: JAO and dedicated interconnector websites

[11] Nordpool N2EX day-ahead auction

[12] A noticeable exception are the GB-FR interconnectors with gate closure time for their explicit auctions occurring later (or at the same time) than day-ahead market auctions in GB. This further adds trading risks as a participant does not know its availability to trade cross-zonal while bidding in the day-ahead auctions.

proportion of its production that he intends sell into SDAC (the remaining being nominated towards, and sold into, Great Britain). Such an apportioning (which in practice reduces the volume supplied in the OBZ orderbook in SDAC) influences the OBZ price as calculated by SDAC. As a result, the OBZ price will inexorably be influenced by decisions of the offshore wind farm, which, in turn, depends on the OBZ price expectations.

Price formation in an OBZ with explicit auctions is different compared to other bidding zone borders under an explicit allocation regime (e.g. the Swiss bidding zone borders), because OBZs suffer from intrinsic supply disequilibrium (i.e. there is no local demand for the offshore wind production). The supply-demand equilibrium of an OBZ can only be reached through exports, and – while under full price coupling such exports would be automatically calibrated to a supply-demand equilibrium from adjacent bidding zones – the supply-demand equilibrium can only be reached through forecasting with explicit allocation. This is why the price formation of OBZ under explicit allocation is particularly challenging.

6.4 Cross-zonal capacity calculation

When TSOs compute cross-zonal capacities for explicit auctions, they need to follow the Standard Hybrid Coupling approach. In case of explicit allocation, where energy is cleared separately from cross-zonal capacity, TSOs are bound to forecast the expected flow. This forecasting of flows – and consequent ex-ante split of capacities on relevant network elements – is inherent to the presence of two (or more) allocation regimes on the borders of a given bidding zone.

As the principles for allocation and their timings do not align, the cross-zonal capacities offered to an explicit auction that takes place before SDAC hold assumptions on what is forecast to happen in SDAC and vice versa. Ultimately, this leads to a less efficient allocation of cross-zonal capacities. As a result, socio-economic welfare is not maximised to the extent possible when too high exchanges are assumed; or operational security is at risk when too low exchanges are assumed.

In case of Hybrid Interconnectors, TSOs need to forecast a) wind power generation at the OWP, and b) the exchange on the interconnector. As two parameters need to be forecast, there is a risk for higher (compounding) forecast errors.

6.5 EU IEM target model and explicit auctions

Explicit auctions do not directly interact with the EU IEM target model, but have implicit impacts.

First, explicit auctions prevent the application of Advanced Hybrid Coupling on bidding zone borders adjacent to capacity calculation regions using flow-based. As such, allocation of cross-zonal capacities cannot maximise the use of grid infrastructure (both onshore and offshore) at the expense of socio-economic welfare.

Second, explicit auctions do, by design, not allocate cross-zonal capacity implicitly (i.e. outside SDAC and SIDC). Therefore, explicit auctions run separate from SDAC/ SIDC and can result in economically inefficient allocation of cross-zonal capacity.

6.6 Economic inefficiencies of explicit auctions on existing interconnectors

Since 1 January 2021, cross-zonal capacity on interconnectors between Continental Europe and Great Britain is allocated via explicit auctions (see Table 1 above). In 2023[13], on these bidding zone borders, the percentage of market time units (MTUs) during which scheduled commercial exchanges went against the 'market direction' (i.e. from lower priced to higher priced bidding zone) is, respectively, 22%, 23% and 20%.

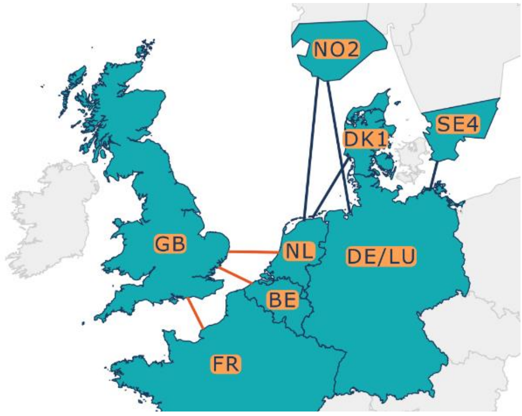

Figure 5: Illustration of considered interconnectors

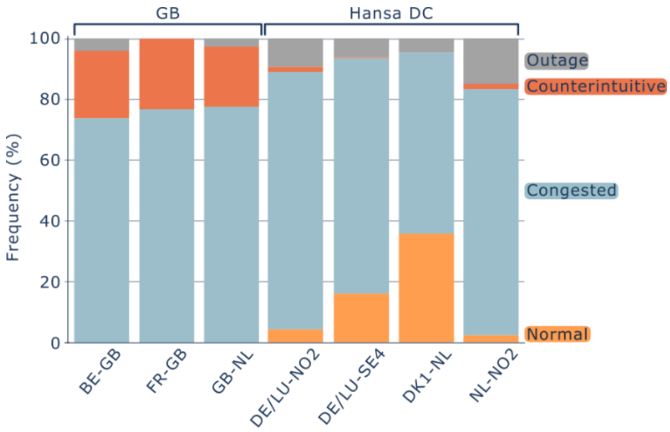

Figure 6: Frequency of schedules leading to uncongested, congested or counterintuituve market outcomes incl. outages

For comparison, the occurrence of commercial flows against the "market direction" is below 2% for the interconnectors of the Hansa capacity calculation region[14]. In these cases, where cross-zonal capacity is implicitly allocated in SDAC via standard hybrid coupling[15], such non-intuitive flows are however economically duly justified by the applicable ramping limits. See Figure 5 for illustration of considered interconnectors and Figure 6 for results.

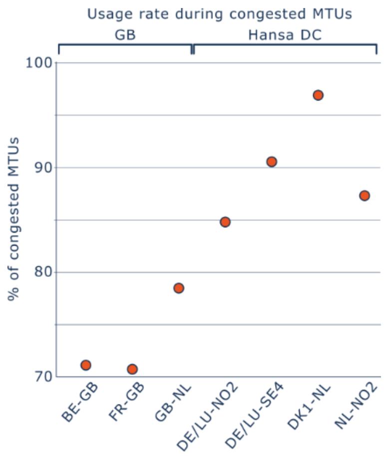

Figure 7: Capture factor of selected HVDC interconnectors in the day-ahead timeframe[13]

[13] Analysis based on data from ENTSO-E transparency platform and RTE eco2mix platform

[14] These bidding zone borders were selected based on requirements a) bidding zone borders with only DC interconnections (excluding the DE/LU-DK2 border), b) bidding zone borders not in the same CCRs (as e.g. Belgium – Germany) and c) bidding zone borders without Allocation Constraints (excluding the PL-SE4 border) to avoid interference.

[15] At the time when this analysis was performed, Advanced Hybrid Coupling was not implemented in Core or Nordic.

Another key parameter to evaluate is the utilization rate (or "capture factor") of the interconnector capacity. In this regard, the average utilization rate on GB bidding zone borders in the day-ahead timeframe is approximately 71%, 71% and 78% for Belgium – Great Britain, France – Great Britain, Netherlands – Great Britain, respectively, while it is approximately 90% on the selected Hansa interconnectors. Also, for this indicator, the selected Hansa interconnectors perform significantly better than the interconnectors between Continental Europe and Great Britain.

6.7 Congestion rent and explicit auctions

Congestion rent from explicit allocation is obtained right after clearing the auction. The congestion rent corresponds to the clearing price multiplied by the cleared volume (i.e. the allocated cross-zonal capacity) of the explicit auction. There may be congestion rent from allocation of cross-zonal capacities in both directions during the same auction and across several market time frames (e.g. from long-term, day-ahead and intraday). In contrast to price coupling, the congestion rent is not related to the ultimate difference in clearing prices between two adjacent bidding zones. As such, TSOs miss out on congestion rent when the cross-zonal capacity is not valued at the actual price difference.

6.8 Summary

The main take aways for this section are:

- Timings for explicit auctions on existing interconnectors with Great Britain are neither harmonized nor aligned. This exacerbates the challenges related to explicit allocation.
- Explicit allocation on existing interconnectors with Great Britain shows economic inefficiencies (especially compared to comparable interconnectors implicitly allocated in SDAC)
- Price formation in OBZs is particularly challenging when its bidding zone border towards Great Britain is allocated explicitly, because the OBZ price becomes a function of the proportion of the local wind production to be exported to Great Britain – which in turn is a decision to be made by the offshore wind farm based on the same OBZ price forecast.
- Explicit allocation prevents the application of Advanced Hybrid Coupling and thereby does not allow for the most efficient use of the grid infrastructure, both onshore and offshore
- Explicit auctions do not directly interfere with SDAC and SIDC. Nevertheless, market liquidity is split, and arbitrage possibilities (incl. gaming opportunities) open up.

7 Shortcomings of MRLVC

7.1 Introduction

Following the UK's exit from the EU, Great Britain is now excluded from the EU IEM arrangements – in particular, from SDAC. Annex 29 of the EU-UK Trade and Cooperation Agreement (TCA) introduces the concept of **Multi-Region Loose Volume Coupling (MRLVC)** as the solution for the allocation of cross-zonal capacities on bidding zone borders between Great Britain and the EU for the day-ahead market (while explicit allocation has been implemented awaiting the implementation of MRLVC). The TCA calls for a Cost Benefit Analysis (CBA) and outline of proposals for technical procedures. This chapter is largely based on the observations made in this MRLVC CBA (2021) (for which the main conclusions are depicted in Annex C)

Volume Coupling is an implicit allocation mechanism. Unlike price coupling, it only determines cross-zonal flows, while clearing prices are determined in subsequent steps. That is, prices and other results are calculated independently for Great Britain and SDAC, while taking into account the flows between Great Britain and SDAC as determined by MRLVC. Loose Volume Coupling (as opposed to Tight Volume Coupling) implies that the cross-zonal flows are determined without having access to the entire set of necessary information, which means certain input values need to be forecasted or are even not considered.

There is a lot of uncertainty about how well the proposed MRLVC arrangements would operate. This uncertainty relates to how MRLVC would be implemented in detail (as 'loose volume coupling' can cover a range of different arrangements). The restrictions set out in the TCA (See Annex A), the impact on existing market processes (particularly those of SDAC) and a lack of experience of successful operation of directly comparable arrangements (See Annex B), particularly in relation to the size and complexity of MRLVC and SDAC, all contribute to this uncertainty.

MRLVC has been thoroughly assessed by the group of impacted TSOs (See Annex C). The relevant takeaways from this assessment for the present paper are:

- Implementing MRLVC is undeniably complex and will have significant impacts on the well-functioning SDAC and Great Britain markets, including severe risks to increase the occurrence of SDAC decoupling, decreasing SDAC robustness.
- Although by construction volume coupling regime is not able to reach the socio-economic gains that can be obtained by price coupling, MRLVC has the potential to increase the socio-economic welfare compared to explicit allocation if the BBZ forecaster methodology performs sufficiently well in all scenarios. Such a forecasting methodology does not yet exist, and is by nature challenging (particularly for atypical market circumstances, for which efficient allocation is particularly important)
- Negative economic impacts of MRLVC are expected to be mostly reflected in reduced congestion income from interconnectors. Hence, the business case risks for interconnections with Great Britain (especially Hybrid Interconnectors) are increased.
- MRLVC has not been intended to cope with hybrid offshore infrastructure and needs to be refined/adapted to do so.

This chapter further discusses these challenges. The focus is set on the implications of MRLVC on offshore bidding zones, with the objective to highlight the practical consequences that MRLVC has on the risk assessments of investments in offshore wind connected to Hybrid Interconnectors.

7.2 Significant changes and challenges with SDAC

The impact of MRLVC on the SDAC operational timeline and processes is one of the biggest acknowledged practical challenges for the implementation of an effective MRLVC design. As the volume coupling concept is sequential by nature (flows to/from Great Britain must be computed separately after the day-ahead market gate closure but prior the commencement of SDAC and Great Britain price calculation), additional procedural steps are required and therefore additional time in the overall market clearing process is needed. Daily processes are already on a tight sequence, among other aspects because of the number of fallback and backup arrangements designed to cope with market or operational problems. In addition, it will be important to have appropriate further incident management processes to manage the risk of decoupling of MRLVC, while minimizing the impacts on the already complex SDAC procedures for such exceptional situations.

In short, the **implementation of MRLVC would require solving significant operational challenges related to timings, which impact the operational robustness of SDAC.** Given the inevitable interdependency between SDAC and MRLVC – especially for exceptional circumstances with decoupling risks – solutions must be found and agreed upon by EU and UK TSOs and NEMOs.

There are multiple other significant challenges to overcome in order to successfully implement MRLVC trading arrangements. The most significant (as reported in MRLVC reports of the impacted TSOs summarized in Annex C) are:

- Four discrete distinct yet interdependent processes (MRLVC, SDAC, BBZ flow forecaster, and Great Britain day-ahead market clearing), most likely managed by different parties, need to be developed, tested and operated in close coordination with each other.
- Lack of established frameworks in which to undertake the implementation tasks (e.g., organization and resources, decision-making, funding) for the two not existing processes MRLVC and BBZ flow forecaster (in addition to the need for a single Great Britain day-ahead market clearing process).
- Potential requirements to undertake tenders for systems and service providers.
- Regulatory changes as modifications are needed to SDAC processes and timelines (in particular, if CACM GL needs to be amended).
- Significant new business processes to be implemented (systems, organization, operational procedures, agreements, regulatory approvals/changes).

These required adaptations on governance, IT and communication systems and business processes would upset the operational robustness of the operational SDAC process and by that pose a risk for the robustness of the EU IEM as a whole.

7.3 Inefficient price formation in Offshore Bidding Zones

For an OBZ to fully deliver on economic efficiency, an allocation regime that ensures efficient pricing and cross-zonal capacity utilization on the hybrid offshore network is essential. Compared to established bidding zones, OBZs are more sensitive to flows on adjacent borders, because they don't contain significant demand and cross-zonal flows are needed to match the OBZ wind supply. The efficiency of the allocation is therefore more sensitive to BBZ flow forecasting errors.

It is also worth to note that the TCA requirements do not take into account that in an OBZ set up, MRLVC would still have to receive input from the onshore BBZs (even if they do not strictly border GB). This would imply a partial adaptation or interpretation of the TCA.

Efficient allocation of cross-zonal capacity to/from OBZs is far more challenging under MRLVC than under a price coupling regime, notably because the TCA requirements for the MRLVC do not explicitly consider how cross-zonal capacity on OBZs bidding zone borders should be allocated. In general, because OBZs are composed exclusively of assets with no intrinsic marginal costs, price formation in OBZs is challenging and hence dependent on an efficient price coupling mechanism to determine its clearing price.

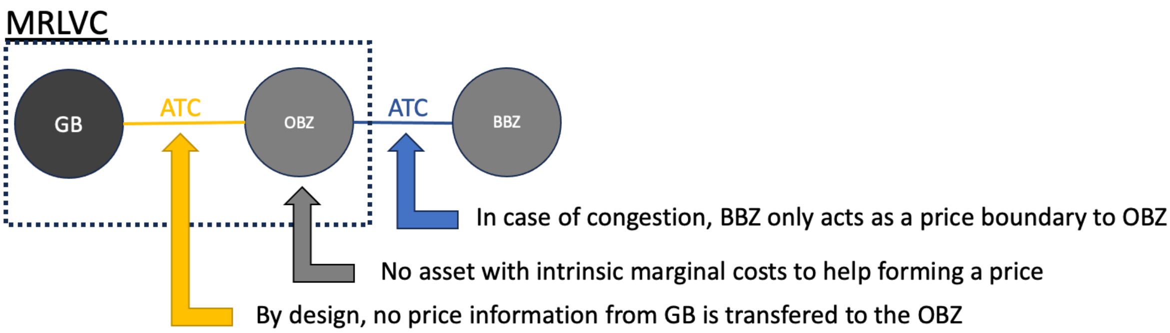

Figure 8: MRLVC does not provide sufficient information for price formation in case of congestion

Figure 8 illustrates why MRLVC cannot generate efficient OBZ prices (irrespective of any BBZ forecasting error) when the OBZ interconnector that is not allocated through MRLVC is congested. Suppose a perfectly forecasted scenario with relatively high wind predictions in GB and on the OBZ, and relative high demand in the BBZ. The optimal allocation for this example is a flow from GB to BBZ with a higher flow on the (congested) OBZ-BBZ interconnector compared to the GB-BBZ one, because the export from GB is complemented by the offshore wind production.

When an ATC interconnector is congested, a price coupling algorithm determines that energy flows from the lower to the higher price area, i.e. SDAC will impose that the price of OBZ is lower than - or equal to - the price of the BBZ. Another optimality condition of a price coupling algorithm is that prices must be equal at each side of an uncongested ATC-based interconnection. Under price coupling, the OBZ price would thus equal to the GB price for this example, both being lower than the BBZ price. This makes perfect sense from an economic viewpoint: the wind production in OBZ is valued at the GB price, and both collectively export the maximum possible to BBZ.

MRLVC, however, would not be able to provide such an optimal price result because – by construction – the OBZ price formation is not influenced by GB (i.e. this is in fact the "volume coupling paradigm"). Instead, the OBZ price would only be constrained by SDAC to be (1) between the price of the last accepted OBZ supply order (typically close to 0 €/MWh) and below the maximum allowed price on the SDAC (currently 4000€/MWh); and (2) at most equal to the BBZ price – to ensure intuitiveness of the flow over a congested interconnector. In practice, the current SDAC algorithm will select a price as close as possible to the "mid-point" of the feasible range as defined by (1) that also satisfies the constraint set by (2). For all typical cases, such a mid-point is usually around 2000€/MWh (i.e. the average of the price of the last accepted OBZ wind offer – typically around 0€/MWh, and of the technical maximum price SDAC which currently set to 4000€/MWh). The price that is the closest to 2000€/MWh and which does not exceed the BBZ price is the BZZ price. As a consequence, OBZ will typically be priced at the same price as the BBZ, and the interconnector between OBZ and BBZ will typically not generate any congestion revenue leading to a flawed repartition of generated socio-economic welfare and hence inefficient (short-term and long-term) price signals (Annex D explains the challenge to set OBZ prices under MRLVC more in details through numerical toy example).

Based on this reasoning, it can only be concluded that MRLVC has not been designed to be compatible with hybrid offshore grid infrastructures, because - irrespective of the risks related to forecasting errors – **price formation of OBZs is flawed when market coupling price properties with GB cannot be duly properly applied**.

It must be understood that this problem is solely caused by the "volume coupling" aspect of MRLVC and does not relate to the "loose coupling" part. Thus even the alternative of thigh volume coupling would still show major intrinsic deficiencies when applied on OBZ. In other words, this issue is caused by the absence of GB price information when SDAC sets the OBZ prices, although this GB price information is actually crucial to define suitable prices which optimally allocate the generated socio-economic welfare. Hence, this issue will materialize even if MRLVC is provided with the entire SDAC dataset (or equivalently if MRLVC perfectly forecasts the net positions of the SDAC bidding zones which have no direct interconnector with GB).

A possible solution to include GB price information and allow GB to set the OBZ price when the BBZ leg is congested, would be to allow SDAC to use the information of the GB price calculated in MRLVC. However, it remains an open question whether SDAC would accept to rely to a process outside its direct control.

7.4 Forecast error risks - especially with flow-based areas

The BBZ flow forecast methodology – that substitutes the orderbooks that are not directly connected to GB (i.e. non-BBZ) – is also critical to MRLVC's efficiency. The forecasting methodology will inevitably induce risks that cannot be managed easily by the affected stakeholders, including TSOs. As a result, the BBZ flow forecast reduces the potential value created by Hybrid Interconnector infrastructure.

A bad forecast of the flows between the bidding zones bordering GB (i.e. BBZs) and the other SDAC bidding zones will influence the flows on the GB interconnectors, and thereby the entire SDAC market results and prices. Poor BBZ flow forecasts will have significant impacts on all day-ahead prices, not only in GB or SEM (where prices are more impacted by the affected interconnectors' flows), but also across all SDAC markets.

The risk of negative impacts stemming from bad forecast is even more severe for flow-based areas such as applied in Core and soon applied in the Nordic regions. The TCA requirements indeed do not take into account the concept of flow-based capacity calculation and allocation in SDAC – let alone AHC.

BBZ Flow forecast risk in ATC (Available Transmission Capacities)

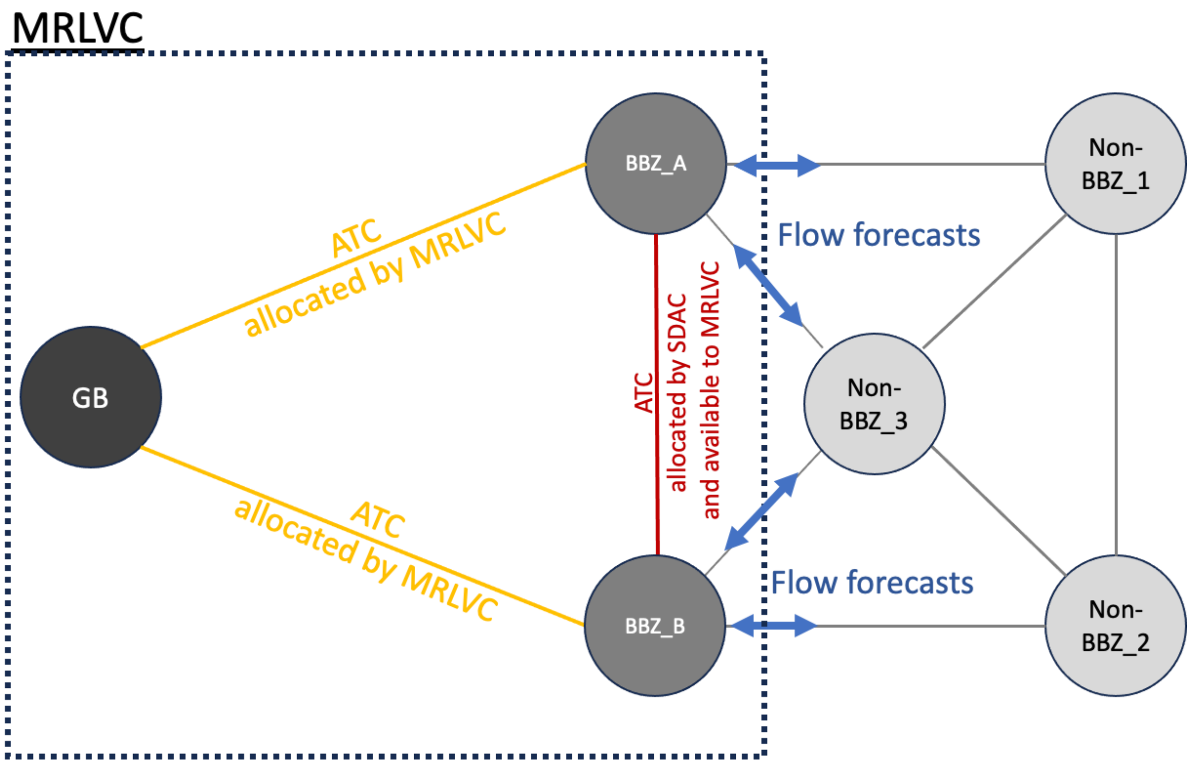

Figure 9: Schematical representation of MRLVC (ATC model)

Figure 9 illustrates the market model to be used by MRLVC when SDAC does not implement flow-based grid models (this is referred to as the "Available Transmission Capacity", i.e. ATC, model). To determine the flows of the interconnectors GB<->BBZ_A and GB<->BBZ_B (yellow), MRLVC takes as input the Available Transmission Capacities of these (yellow) interconnectors to be allocated, as well as the bids and offers from the GB, BBZ_A and BBZ_B bidding zones. In addition, MRLVC is also provided with the forecasted flows between the BBZs and the non-BBZs (blue), as well as the Available Transmission Capacities between BBZ_A and BBZ_B (red). Even if this latter interconnector will not be allocated by MRLVC, providing this data to MRLVC improves its efficiency.

Suppose for example that the ATC_BBZ_A<->BBZ_B is sufficiently ample to not become binding, and that the forecasted flows (blue) contain some random errors. The results of MRLVC + SDAC will nonetheless have the following properties:

- Firstly, the individual flow forecast errors will not directly influence the MRLVC performance. Instead, only the sum of the 4 blue arrows will be impacted (because the two BBZs will behave as an uncongested area only influenced by their total position against non-BBZs). Forecasting errors in opposite direction can thus cancel out in this scenario.
- Secondly, forecasting the (blue) flows can be done independently from the rest of the SDAC flows. For example, the forecaster does not need to estimate the flow between Non-BBZ_1 and Non-BBZ_2.
- Thirdly, irrespective of whether the forecast errors are large or small, the two interconnectors to GB will be consistently (although possibly falsely) allocated, in the sense that the two (yellow) interconnectors will necessarily flow in the same direction. This is because MRLVC will see GB as interconnected to an uncongested area.

The implication of such properties relates to the fact that, without flow-based modeling, the forecasting tool only needs to focus on the net position of a BBZ against its neighboring SDAC non-BBZ areas, and that the interconnections between BBZs can be remain modeled within MRLVC. This however is not the case if MRLVC is applied to flow-based areas. As a result, MRLVC is even less suited to a context where BBZs implement flow-based allocation.

The approach is indeed much more restrictive under flow-based allocation because, by construction, flow-based parameters do not explicitly consider interconnections between pairs of bidding zones. Instead, the flow-based parameters are sets of constraints that concurrently apply to the net positions of all bidding zones in the region modeled through flow-based. This notably implies that all these bidding zones' net positions and prices are interlinked, and that it is no longer possible to isolate the flows between two sets of zones (as probably supposed when designing MRLVC, and as is the case in the above Figure 9 where the blue arrows are all on the dashed line at the edge of the MRLVC scope).

BBZ Flow forecast risk with Flow Based Allocation

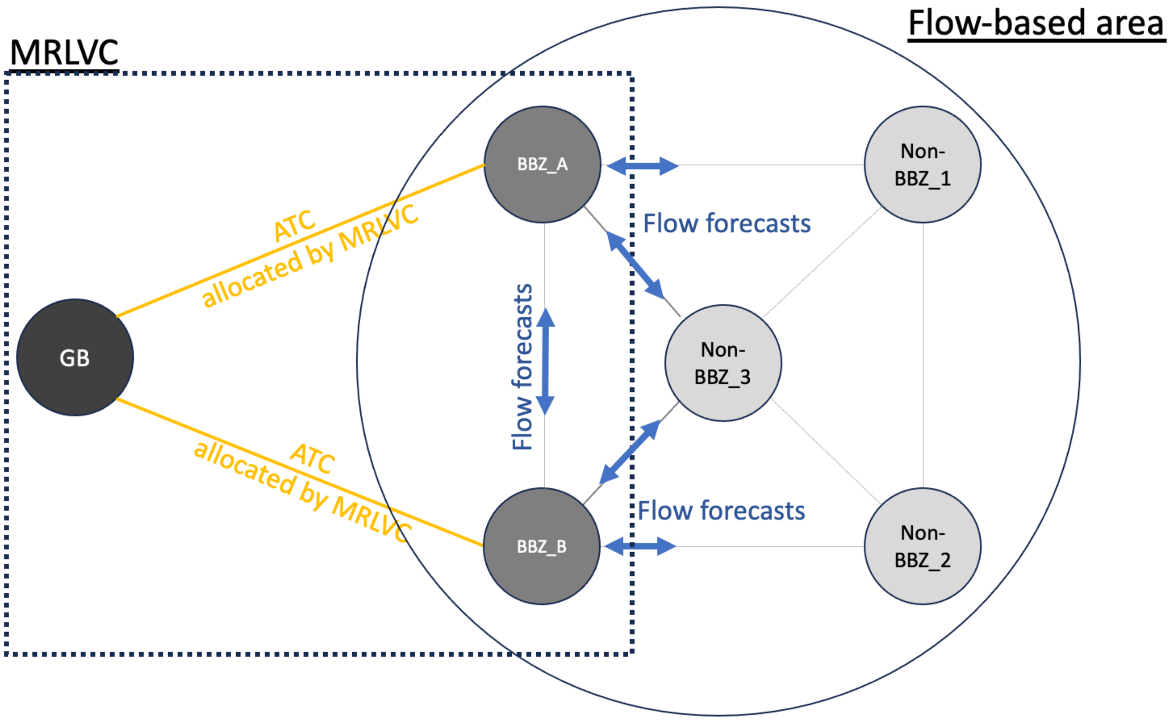

Figure 10: Schematical representation of MRLVC (flow-based model)

Figure 10 illustrates the same example as above, but with GB being connected to a flow-based region. In this case, it is not possible to estimate only the flows between BBZs and non-BBZs. Instead, it is only possible to forecast the two separate (and fixed) values for (1) net positions of BBZ_A against the rest of SDAC; and (2) the net position of BBZ_B against the rest of SDACC. This is because the net positions within the entire flow-based area are interlinked – and that their sum must be equal to zero. It is therefore not possible to provide MRLVC with the equivalent of the available capacity between BBZ_A and BBZ_B. MRLVC is thus not able to consider any transmission capacity other than the interconnectors it allocated. This has the following consequences:

- **MRLVC can in practice only consider a "radial grid" where all BBZs are treated independently from each other, each individually connecting to GB (even they are heavily interconnected)**. MRLVC is thus not able to route the import/exports of the flow-based area into one or the other interconnector when there are multiple possible routes for efficient flows.

- An individual BBZ net position forecasting error will have a direct impact over the allocation of its related interconnector to GB, without the possibility of netting forecast errors in opposite directions over different BBZs.
- Because in a flow-based region, a constraint physically located outside of the BBZ areas (e.g. between non-BBZ_1 and non-BBZ_2) definitively needs to be respected by the BBZ forecaster, the forecasting tool directly impacts the set of feasible net positions of all flow-based areas (i.e. including non-BBZ areas). Or otherwise said, a forecast error of a BBZ net position will not only negatively impact the MRLVC results but may also restrict the trades between non-BBZ areas in the subsequent SDAC process.
- Even in case the entire flow-based area is uncongested, it remains possible that – due to forecast errors and the radial grid considered by MRLVC – flows on GB interconnectors (yellow) are not aligned (i.e. some flows between GB and the uncongested flow-based area are in opposite directions; meaning some must necessarily be opposite to the market favorable direction).

The above discussion suggests that **the "loose" aspect of MRLVC performs poorly when allocating cross-zonal capacity toward flow-based areas.** This expected poor performance results from the BBZ flow forecaster having to fix the individual net positions of each BBZs[16], and that MRLVC will only consider that GB is connected to a radial network of separated BBZs (despite these BBZs being efficiently interlinked through flow-based allocation). This is particularly pertinent given that the Core region already uses flow-based, the Nordic region is about to implement flow-based, and these two regions encompass nearly all present and future interconnectors between GB and SDAC.

7.5 Incompatibility with Advanced Hybrid Coupling

It is explained in §7.3 that the MRLVC cannot efficiently price OBZs due to their lack of price-setting assets (in conjunction to the volume coupling paradigm which does not allow the GB prices to impact any SDAC prices). §7.4 also explains why MRLVC is deficient when allocating interconnectors towards flow-based areas. This section explains why MRLVC cannot be considered as a market-based allocation mechanism when Advanced Hybrid Coupling (AHC) is implemented.

AHC implies that HVDC interconnectors (including those connected to OBZs) are modelled through onshore virtual bidding zones. Such virtual bidding zones are then accounted for in the flow-based constraints and the impact of HVDC interconnectors on the meshed AC grid can be directly and efficiently considered.

Whether – according to the TCA requirements – virtual bidding zones should be considered as a BBZ or not is irrelevant in practice, because they receive no bids and offers and because their net positions need to be forecasted in any case. This is because of the reasoning held in §7.4, where it is explained that MRLVC needs to model flow-based areas as radial connections towards GB. Therefore, a virtual hub needs to be modeled in MRLVC as a separate market with solely a forecasted net position that needs to be satisfied by import/exports by MRLVC.

MRLVC in conjunction with AHC then implies a conceptual conflict:

- On the one hand, MRLVC is provided with the actual (bids and) offers of the OBZ in order to allocate cross-zonal capacity on its interconnectors.

[16] as opposed to the "*expected commercial flows of electricity interconnections between bidding zones connected to the United Kingdom and other bidding zones in the Union*" as set in the TCA.

- But on the other hand, the flow between the OBZ and the flow-based area is fixed prior to the MRLVC calculation by the BBZ flow forecaster (MRLVC has no choice but to generate a flow from/to the virtual bidding zone exactly equal to its forecasted net position, given that this zone by construction contains no order). As a result, the forecasted net position will unequivocally set the flow over the OBZ-BBZ interconnector, and thereby also fix the share of the OBZ supply that flows to GB.

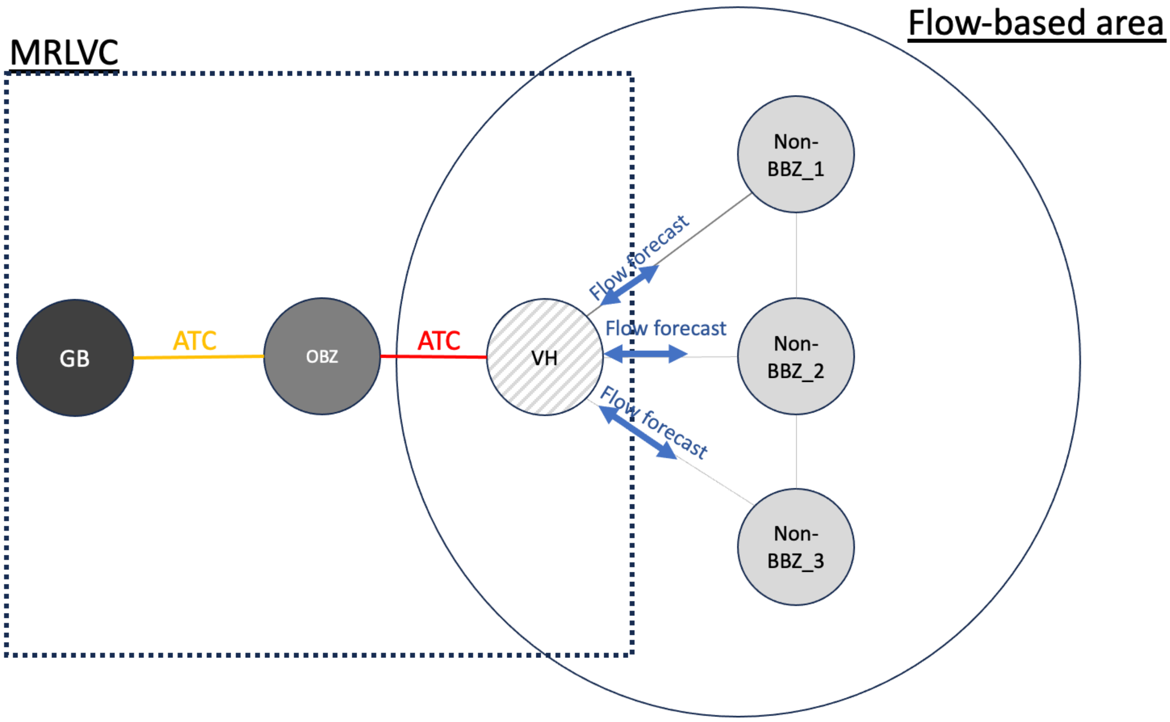

Figure 11 schematically represents MRLVC allocating a single interconnector towards an OBZ (yellow) which is in turn connected to a flow- based area (red) through AHC[17]. This means that the "entry point" of the OBZ in the flow-based domain is a "virtual hub" (VH) which contains no order. From the TCA requirements, the flow between this virtual hub and the other flow-based areas needs to be forecasted (as non-BBZ market data cannot be input to MRLVC). Consequently, MRLVC has no other choice than assuming a flow between OBZ and the virtual hub (red) exactly equal to the forecasted net position of the virtual hub (blue). The share of the OBZ's wind production towards GB (yellow) and SDAC (red) is thus univocally set ex-ante by the forecasting methodology of MRLVC. This thus becomes some sort of a "self-fulfilling prophecy": irrespective of the quality of the forecasted virtual hub net position in terms of market efficiency, this forecasted value will always materialize in practice.

[17] In this example, there are no other BBZ for simplicity/pedagogical reasons, but the exact same reasoning holds for any AHC configuration (notably because the MRLVC grid model must be radial in case connecting to a flow-based area. Cfr. Infra).

<u>**MRLVC with OBZ+AHC**</u>

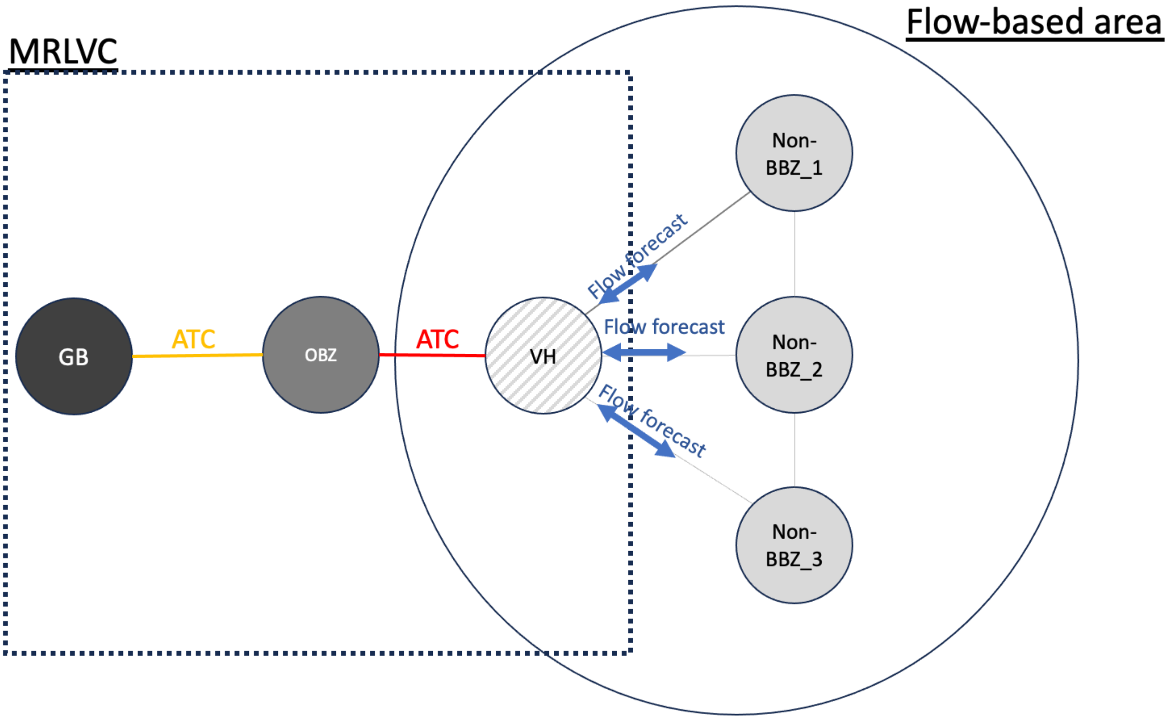

Figure 11: Illustration of MRLVC and Advanced Hybrid flow-based Coupling

In short, this means that - when interconnectors are modeled through AHC - MRLVC is no longer a market-based allocation mechanism, because flows are entirely determined by the forecasting methodology – and not by market data.

Note that this reasoning equally holds for “traditional interconnectors” (those without OBZs) that are modeled through AHC, as the virtual hub forecasted net position is also here univocally set by its forecast.

In other words, the MRLVC concept is not compatible with the AHC that will be implemented in Core and Nordic regions.

7.6 Degraded long-term transmission rights

Because, in general, MRLVC does not necessarily calculate the flows that would result from fully efficient price coupling allocation, there may be material differences between Financial Transmission Rights (FTRs)[18] payouts and the day-ahead congestion revenues received by TSOs.

In case MRLVC allocates flows opposite to the market direction, negative congestion revenues do obviously not cover the FTRs’ compensations. But even if the power flows “in the right direction” after MRLVC, the transmission capacity that has been allocated prior to the day-ahead market may not be fully utilized by MRLVC; resulting in price differences without congestion – even though the entire transmission capacity is subject to FTR compensations based on the price differential. Whenever the transmission capacity is not fully efficiently allocated, the day-ahead congestion revenue stemming from implicit allocation may thus not be sufficient to cover the compensation of holders of long-term rights.

[18] Or equivalently PTRs/UIOSI (Physical Transmission Rights under Use-It-Or-Loose-It)

Because of this risk, either long-term capacity rights may be withdrawn, or the FTR terms or financing mechanisms will have to be changed. For example, compensations of FTRs may be subject to caps, or long-term transmission rights may become "fully physical" under a Use-It-Or-Loose-IT (UIOLI) regime. Both examples will degrade the value of transmission capacity rights, and hence TSOs' revenues.

An imperfect day-ahead allocation will thus

- Affect the overall revenues of the interconnector owners, in both the day-ahead timeframe (e.g. no full flow despite a price difference or even flow against the price difference) as well as in longer-term timeframes (e.g. either FTRs' compensations cost more than the related day-ahead congestion revenues, or the FTRs are refactored to cope with such situations and their intrinsic value is decreased because of these modified terms).
- Have as a consequence negative impacts over the formation of forward energy prices and the ability of market participants to manage cross-border risks, on top of the more direct impacts for the transmission owners.
- As MRLVC does not support efficient forward trading, MRLVC goes against the spirit of the Electricity Market Design Regulation, which emphasizes the importance of liquid forward markets.

7.7 Disabler for efficient intraday markets

Efficient intraday transmission capacity allocation is going to be increasingly important given the growing penetration levels of intermittent renewable generation. This is even more the case for offshore infrastructure, especially Hybrid Interconnectors encompassing wind generation.

The TCA and its annexes do not prescribe any specific requirement for intraday cross-zonal capacity allocation on the GB interconnectors[19], at the same time the SCE is mandated at any point in time to review arrangements for intraday[20]. There is, however, considerable work underway within the IEM to implement intraday implicit auctions (IDA) closely modelled on the day-ahead arrangements in SDAC.

The question may arise whether the MRLVC approach could be replicated to the intraday timeframe. In principle, the assessment of applying MRLVC in the intraday would be similar to that for the day-ahead, with the addition of an even more restricted timeline for intraday auctions, as well as an unknown impact on price formation of possibly reduced liquidity in intraday markets. The application of MRLVC in the intraday timeframe is therefore not considered a realistic option, while applying "price coupled intraday auctions" may be ruled out if following the TCA's spirit. Including the GB interconnectors in the Intraday Auctions using SDAC/SIDC infrastructure in addition to implementing MRLVC at the day-ahead stage would be a nonsense as a principle (because then there would be absolutely no reason not to implement the same approach for day-ahead).

Note also that implementing a continuous allocation mechanism for the interconnectors to GB based on the continuous SIDC infrastructure is in principle possible, and such an approach would correct any inefficient flow resulting from MRLVC. It would however not be correct the possibly inefficient revenues collected by the transmission owners.

[19] Article 311(f) calls for the coordinated development of arrangements to deliver efficient and robust outcomes on all timeframes, including intraday, without however providing specific suggestions (or restrictions).
[20] Article 312 states that the SCE shall keep under review the arrangements for all timeframes and could request EU and GB TSOs to prepare technical procedures.

7.8 Summary

This chapter has identified a series of significant drawbacks for MRLVC.

In general, MRLVC implies major implementation challenges, notably related to changes to SDAC (and to the GB markets) which will induce supplementary risks for the SDAC operations and ultimately possibly more decoupling occurrences.

MRLVC is not designed to cope with Offshore Bidding Zones, because – in case the interconnector between the OBZ and the rest of SDAC is congested – MRLVC does not provide to SDAC the necessary information to correctly set the OBZ price. As a consequence, some “price indeterminacy rule” needs to arbitrarily set the OBZ prices in SDAC. In practice, this implies that the interconnector between the Offshore Bidding Zone and SDAC will never generate any congestion revenue (i.e. even in case the flows are optimal, the congestion revenue will automatically be “redistributed”).

MRLVC requires the development of a robust forecasting methodology, which however doesn’t exist yet, and on which the efficiency of MRLVC is highly dependent on. Arguably, the MRLVC approach has been designed without any consideration for the flow-based methods mandatorily applied in SDAC, as MRLVC fails to adequately use the available information over SDAC transmission capacities (i.e. it requires MRLVC to model Great Britain as being encircled by radially connected to independent bidding zones, despite these zones being strongly connected in practice). A poor performing MRLVC forecasting tool will even more negatively impact the entire SDAC markets implementing flow-based, hence all the TSOs in practice (not only the ones operating interconnectors with GB).

Furthermore, MRLVC is incompatible with the concept of Advanced Hybrid Coupling (AHC) flow-based modelling, because – when MRLVC is implemented in conjunction with AHC – the MRLVC forecasting methodology univocally defines the flows (MRLVC therefore is no longer an allocation regime based on market orders, but solely on a forecasting methodology)

Implementing MRLVC also restricts the deployment of efficient allocation regimes for interconnectors with on other timeframes, be it for long-term transmission rights or for intraday trading.

All these drawbacks can only negatively affect the business cases applicable to investments in North Seas interconnectors.

8 Concluding remarks

Brexit implied Great Britain exiting from the EU Internal Energy Market, meaning in practice **replacing efficient price coupling by inferior allocation regimes** (i.e. explicit allocation to start with, and to be replaced by MRLVC at a later stage). This has been a **conscious choice made in the context of the Brexit Trade and Cooperation Agreement that increases risk and uncertainty in hybrid projects as well as implying a loss in socio-economical welfare. However, these inefficiencies are now clearly preventing to move towards the significant offshore ambitions** of all North Seas countries and is particularly hindering the implementation of Hybrid Interconnectors. These more recent offshore wind ambitions should be seen as a **change in the political context, that should give the opportunity to decision markers to also change the legal framework** to facilitate the reach of these serious ambitions.

Certainty on the establishment of offshore grid infrastructure – especially Hybrid Interconnectors – is a prerequisite for investments in offshore wind generation capacity. **Neither explicit auctions nor Multi-Regional Loose Volume Coupling can deliver sufficient comfort for investment decisions** in offshore grid infrastructure to be taken. **Coherent allocation of cross-zonal capacity across all market timeframes, next to full price coupling, creates a more attractive environment for investments in offshore wind** generation capacity. In addition, a return to full price coupling is the way to maintain robustness of SDAC and SIDC and eliminates potentially blocking points from EU TSOs and NEMOs. This section details these points in more detail.

8.1 The need for certainty for investments in offshore grid infrastructure

When TSOs intend to take major investment decisions, such as in for offshore grids, these need to be approved by regulators. The decision basis for both TSOs and regulators is the Cost-Benefit Analysis (CBA). As such a CBA typically assumes full price coupling, the socio-economic benefits with a less efficient allocation regime will be lower. The results of CBA with full price coupling showing clear benefits can be (partially) rendered void by using a less efficient allocation regime, such as explicit auctions or Multi-Regional Loose Volume Coupling. **Considering a less efficient allocation regime can lead to reduced benefits or even 'negative benefits'** (i.e. a loss for society).

However, the reduced level of benefits is difficult to determine. As modelling explicit auctions or Multi-Regional Loose Volume Coupling requires further assumptions on the (inefficient) functioning of explicit auctions or Multi-Regional Loose Volume Coupling and, by that, adding to the overall complexity of a CBA, an additional uncertainty about the future of the project is created. In the presence of higher uncertainty, neither TSOs nor regulators will be inclined to take or favourably support investment decisions in offshore grids. Thereby, investments in offshore grid infrastructure are jeopardised.

Certainty around the development of offshore grids is a prerequisite and key dependency for investors to even assess investments in offshore wind generation capacity. If certainty on offshore grid development cannot be granted, investors will shy away from investing in the offshore wind generation capacity altogether. As a consequence, the offshore wind potential of the North Seas cannot be harnessed.

8.2 The need for investments in offshore wind generation

Investment decisions on offshore wind generation capacity need certainty that a given offshore wind platform and associated Hybrid Interconnectors will be built. If this prerequisite is not met, investments in offshore wind generation capacity will not take place.

Next to the prerequisite that offshore grid infrastructure needs to be in place, investments in offshore wind generation capacity are incentivised through supporting mechanism, such as Contracts for Differences. One fundamental property of a Contract for Difference is its strike price, which determines up to which wholesale price the offshore wind generator is compensated. In case of offshore wind generation connected to an offshore wind platform which is operated as an offshore bidding zone, this wholesale price is the (day-ahead) clearing price of this offshore bidding zone.

In case explicit auctions or MRLVC are used, the clearing price of the OBZ cannot be coupled (with at least one of) its adjacent bidding zones. Such an outcome leads to a degraded and less robust price signal which is compared to the Contract for Difference strike price when compensating the offshore wind farm. Consequently, the entity backing the Contract for Difference does not compensate the offshore wind generator based on a solid and robust price signal, posing inefficiencies and perverse distribution effects that are borne by the entity backing the Contract for Difference, which is usually a public entity (or another entity representing the society at large). However, in a fully price coupled environment, compensation through a Contract for Difference would be based on a solid price reference and, by that, the **society can rely on paying only for incentivising offshore wind generation capacity and not also for an inefficient allocation regime**.

8.3 Impacts on other market timeframes

Risks associated with investments in offshore infrastructure can largely be addressed by support schemes (such as Contract for Differences for wind generation or grid tariffs for interconnections). What remains, however, are operational risks amplified by inefficient allocation regimes across timeframes.

Long-term transmission rights (LTTRs) can offer an (additional) hedging instruments for offshore wind farms and market participants active in an offshore bidding zone. Physical Transmission Rights are offered on most interconnectors with Great Britain today. However, nominations due to Physical Transmission Rights might take cross-zonal capacity out of the allocation in the day-ahead and intraday timeframes. Financial Transmission Rights would provide hedging opportunities without ex-ante allocating physical cross-zonal capacity ahead of the day-ahead timeframe. Financial Transmission Rights on interconnectors with Great Britain (incl. between an offshore bidding zone and onshore Great Britain) can only be integrated in a fully price coupled allocation regime, such as EU Single Day-Ahead Coupling. The process of compensating Financial Transmission Rights holders with the difference between clearing price of the Financial Transmission Rights in the long-term explicit auction and the day-ahead price spread only reliably works with a fully coupled clearing prices. Otherwise, the compensating entity, in case of Long-Term Transmission Rights the TSO (or interconnector operator), runs the risk of violating revenue adequacy and grid user paying for unjustified compensations**. Both explicit auctions and Multi-Regional Loose Volume Coupling in the day-ahead (and intraday timeframes) are not compatible with Financial Transmission Rights for hedging purposes.**

At present, the day-ahead market cleared through Single Day-Ahead Coupling bundles high liquidity and high allocated volumes. Offshore bidding zones with their generally low liquidity would greatly benefit from the combination of Advanced Hybrid Coupling in the Single Day-Ahead Coupling. In fully price coupled scenario, clearing prices in an offshore bidding zone are coupled to the clearing prices in the adjacent bidding zones and cross-zonal capacity is allocated to maximise socio-economic welfare. Furthermore, full price coupling delivers solid and robust clearing prices in the offshore bidding zone, enabling compensation of both holders of Financial Transmission Rights and Contracts for Differences based on a clear reference and by that making investments in offshore wind generation more appealing.

In the intraday timeframe, offshore wind generators seek to adjust their positions based on updated wind forecasts. To enable making such adjustments, liquidity needs to be accessible from the offshore bidding zone through auctions and/or continuous trading. Adjusting positions in an explicit auction set-up is costly/risky as cross-zonal capacity (potentially in both directions) needs to be obtained ex-ante, making trading for the offshore wind farm less effective, more complicated and costly. There is no concept how the intraday timeframe can be addressed with Multi-Regional Loose Volume Coupling and such a scenario poses therefore uncertainty. **The complexity and additional costs in case of explicit auctions and the uncertainty in case of Multi-Regional Loose Volume Coupling for adjusting positions in the intraday frame pose risks for wind farm operators and make investments in offshore wind capacity less attractive**.

Full integration of the Great Britain bidding zone borders in the allocation regimes across market timeframes will make that investments in offshore wind are more (or possibly even sufficiently) attractive. Starting with Financial Transmission Rights in the long-term timeframe, which are remunerated based on fully coupled clearing prices in the day-ahead timeframe. Secondly, the access to vast liquidity in the Single Day-Ahead Coupling through full price coupling ensures that offshore wind generation connected to offshore bidding zones contributes at maximum to both socio-economic welfare and decarbonisation targets, next to delivering solid and robust price signals for compensations based on Contracts for Differences. And last, but not least, being able to participate in the Single Intraday Coupling, allows offshore wind generation to adjust positions until shortly before real-time and alleviate the impact from intermittent wind generation on their balance.

8.4 Robustness of Single Day-Ahead Coupling and Single Intraday Coupling

Allocation regimes other than full price coupling on Great Britain bidding zone borders must be designed to work with – and around – both Single Day-Ahead Coupling and Single Intraday Coupling. In particular, the process timings agreed and dictated by both legislation (e.g. gate closure times for Single Day-Ahead Coupling and Single Intraday Coupling) and various methodologies (e.g. capacity calculation, scheduled exchange calculation) must be respected. In case of full price coupling, the already agreed and implemented timings would be applicable and no adjustments are needed. However, in case of either explicit auctions or Multi-Regional Loose Volume Coupling, this is not necessarily the case.

In a scenario with explicit auctions on the Great Britain bidding zone borders in the day-ahead timeframe, the timings for explicit auctions can be set with a certain degree of independency, such that trading opportunities are maximised. In the day-ahead time, it makes most sense to perform an explicit auction ahead of Single Day-Ahead Coupling gate closure time to allow market participants who successfully obtained cross-zonal capacity in the explicit auction to nominate (part of) this capacity and place (price-taking) bids in Single Day-Ahead Coupling. The timings of Single Day-Ahead Coupling are not affected, and market participants can – albeit via the 'de-tour' of explicit auctions – partake in Single Day-Ahead Coupling. Thus, despite that explicit auctions are clearly an inferior allocation mechanism, they have the advantage of being fairly independent from the Single Day-Ahead Coupling and Single Intraday Coupling.

Following the logic of an explicit auction ahead of Single Day-Ahead Coupling, explicit auctions could be run ahead of the pan-EU intraday auctions to allow for cross-zonal capacity allocation in the intraday timeframe. However, it is unlikely to run an explicit auction preceding the first intraday auction at 15:00 D-1 CET. Compared to the day-ahead timeframe, timings are much more constrained and dependencies with processes before and after the intraday auctions more pronounced. As in the case of the day-ahead timeframe, the timings of the pan-EU intraday auctions are not affected and the timings for the explicit auction(s) come with a degree of freedom.

In contrast to explicit auctions, the timings and processes around Multi-Regional Loose Volume Coupling are not flexible. Due to the inherent link of the Multi-Regional Loose Volume Coupling concept with Single Day-Ahead Coupling and its timings, the timings in Single Day-Ahead Coupling would be affected in one way or the other if Multi-Regional Loose Volume Coupling was to be implemented. Single Day-Ahead Coupling would either have to run later and/or run for longer, depending on the exact way of implementing MRLVC. These changes in timings would have to be made compliant with pre- and post-coupling processes (incl. backup and fallback) and be accepted by all EU TSOs and NEMOs.

Next to the impact in Single Day-Ahead Coupling, **no concept for introducing Multi-Regional Loose Volume Coupling in the intraday timeframe has been presented or analysed**. Assuming that a concept in analogy with Multi-Regional Loose Volume Coupling and Single Day-Ahead Coupling would be implemented in conjunction with the pan-EU intraday auctions, the timings of the intraday auctions or their run times would be impacted. As in the case of the day-ahead timeframe, combability with processes before and after the pan-EU intraday auctions would have to ensured and all EU TSOs and NEMOs would have to accept adopted timings for the pan-EU intraday auctions to allow for implementation of Multi-Regional Loose Volume Coupling in the intraday timeframe.

For both explicit auctions and Multi-Regional Loose Volume Coupling in the intraday timeframe, continuous cross-zonal intraday trading via Single Intraday Coupling is not possible and, by that, short-term adjustments of trading positions is strongly hindered.

Robustness in both Single Day-Ahead Coupling and Single Intraday Coupling is better ensured by explicit auctions than Multi-Regional Loose Volume Coupling. Because explicit auctions and their timings can be designed around Single Day-Ahead Coupling and Single Intraday Coupling, the robustness of both EU allocation regimes is not affected. However, Multi-Regional Loose Volume Coupling would have a strong impact on the robustness of Single Day-Ahead Coupling (and Single Intraday Coupling if adopted to the intraday timeframe). By that, all EU TSOs and NEMOs are impacted and would have to accept a potential degradation of robustness when implementing Multi-Regional Loose Volume Coupling on Great Britain bidding zone borders.

8.5 Compatibility with the EU Internal Energy Market target model

Legislation and regulation define price coupling as the pillar of electricity market integration in the EU (and Norway). Legal EU context imposes to use the Single Day-Ahead Coupling approach as the single mechanism to implement price coupling in the EU Internal Energy Market (incl. regulating the function of the market coupling operator). The legal text is however more prescriptive in several aspects.

The regulation also imposes that structural congestions should be reflected in the delineation of bidding zones. Despite the numerous challenges related to the implementation of such a principle in existing bidding zones, it is obviously different for Hybrid Interconnectors yet to be constructed. Indeed, the structural congestion on these specific single lined grid infrastructures are easy to identify and do not suffer from any historical legacy. Therefore, applying the Offshore Bidding Zone to Hybrid Interconnectors is implied by the current legislation. Neither explicit allocation nor MRLVC are compatible with the offshore bidding zone setup, due to the lack of liquidity embedded in such offshore wind platforms composed exclusively by limited price-setting production assets and with no (or limited) demand. It becomes thus urgent to agree and develop a solution, ie price coupling, that allows the implementation of OBZs and thus hybrid interconnectors in the North Sea.

In addition, CACM stipulates the allocation of cross-zonal capacities through the flow-based approach. The two main regions to which offshore interconnectors with Great Britain are connected to – namely Core and Nordic – will apply flow-based in conjunction with Advanced Hybrid Coupling. Neither explicit allocation nor Multi-Regional Loose Volume Coupling are compatible with flow-based and Advanced Hybrid Coupling.

In other words, **the implementation of explicit allocation or Multi-Regional Loose Volume Coupling – even when solely applied to the bidding zone border between offshore bidding zones and Great Britain – prevents the implementation of the full EU Internal Energy Market target model.**

8.6 Compatibility with a potential zonal model in Great Britain

Recently, it was announced that the UK will embark on a trajectory towards fundamental market reforms[21], including a potential implementation of a zonal model in Great Britain. The introduction of a zonal model in the UK would require cross-zonal capacity calculation and allocation on its internal bidding zone borders in analogy to the zonal model of the EU Internal Energy Market.

With cross-zonal capacity allocation in place within the UK, the arguments presented here on the incompatibility of explicit auction and Multi-Regional Loose Volume Coupling with the EU Internal Energy Market also largely apply to the UK because of the exact same reasoning.

The step to potentially go for a zonal model in the UK should be regarded as an opportunity to align allocation regimes between the EU including Norway and the UK and re-integrate the UK in the EU Internal Energy Market. The flows on interconnectors – both hybrid and point-to-point - between the EU and Great Britain have an impact on the internal (onshore) flows in the EU and UK and vice versa. Power infrastructure – including Hybrid Interconnectors – are best utilised and add most benefit for society in a price coupled scenario – both in the EU and the UK.

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See fore example https://www.gov.uk/government/consultations/review-of-electricity-market-arrangements-rema-second-consultation

8.7 Visual summary

Figure 12 shows the overall scoring of the different allocation regimes on criteria discussed in this paper.

		Price coupling	Explicit auctions	MRLVC
IEM target model	Compatible with offshore bidding zone	+	−	+/−
IEM target model	Compatible with Advanced Hybrid Coupling	+	−	−
IEM target model	Compatible with Financial Transmission Rights on offshore bidding zone bidding zone borders in long-term timeframe	+	−	−
	Congestion rent for interconnector	+	+/−	−
	Optimal utilisation of interconnector capacity	+	−	−
	Robust price formation in offshore bidding zone	+	−	+/−
	Liquidity in offshore bidding zone	+	−	+/−
	Effectiveness of supporting scheme (e.g. CfD)	+	+/−	+/−
	Gaming opportunities	+	−	+
	Compatibility with Single Day-Ahead Coupling[1]	+	+/−	−
	Compatibility with Single Intraday Coupling[1]	+	+/−	⚠[2]

[1] Timings, governance and robustness of operations incl. backup and fallback processes (i.e. mitigated decoupling risk)
[2] MRLVC in the intraday timeframe is not a realistic option due to tight process timings

Figure 12: Overall scoring of allocation regimes against aspects and criteria discussed in this paper

Overall, price coupling is the only allocation regime that can effectively reduce uncertainty for investments in offshore infrastructure. Explicit auctions suffer from inefficiencies and Multi-Regional Loose Volume Coupling in the context of offshore bidding zones is, by and large, incompatible with Single Day-Ahead Coupling and Single Intraday Coupling or the EU Internal Energy Market in a wider sense and they both bring a significant number of uncertainties on price formation and social welfare creation.

Annex A: MRLVC design requirements & assumptions

This annex lists the requirements for MRLVC as set in the TCA (despite these requirements, there remains uncertainty about how MRLVC would be implemented in detail).

TCA requirements

The minimum requirements for MRLVC as set out in the Annex 29 of the EU-UK Trade and Cooperation Agreement (TCA) are:

- MRLVC uses a distinct/separate algorithm from SDAC
- MRLVC takes as input
    - the bids and offers of the day-ahead markets of GB
    - only the bids and offers of the SDAC bidding zones that are directly connected to the GB by an interconnector (so-called "bordering bidding zones, or BBZs)
    - the network capacity data and system capabilities
    - data on the expected commercial electricity flows between the BBZs and the other SDAC bidding zones (non-BBZs bids and offers cannot be used by MRLVC)
- MRLVC produces reliable and reproducible results sufficiently in advance of the SDAC and the GB DAM so that such results can be used as input in these markets.
- MRLVC results determine the net electricity positions of UK and of the BBZs.

These requirements notably imply that:

- Clearing prices are not determined by MRLVC.
- It is required to use a forecast for expected commercial flows between BBZs and the rest of SDAC (the tool to do this is referred to as the "BBZ flow forecaster").
- MRLVC allocation, SDAC matching and GB matching are distinct processes.

Further assumption: common orderbook

To further evaluate the MRLVC solution, a "common orderbook[22]" approach is assumed. This high-level design supposes that MRLVC will use the identical order books (representing the aggregated and anonymous orders from the relevant GB power exchange and BBZ SDAC NEMO) as used in the GB DAM and SDAC (for the BBZs) respectively.

Using the same order books implies a sequential process:

- The MRLVC algorithm cannot begin until after SDAC gate closure time when the final order books for the relevant BBZs and GB are available.
- SDAC and GB cannot begin their matching process until after the MRLVC has calculated the interconnector flows.

[22] Another variant (referred to as "preliminary orderbook") has been contemplated. However, it has been assessed that this alternative provides no benefit over the common orderbook variant and is therefore not discussed here

As shown in Figure 13, the sequence DAM Gate Closure Time → MRLVC → SDAC/GB DAM would require changes to the timing and/or processes involved in SDAC.

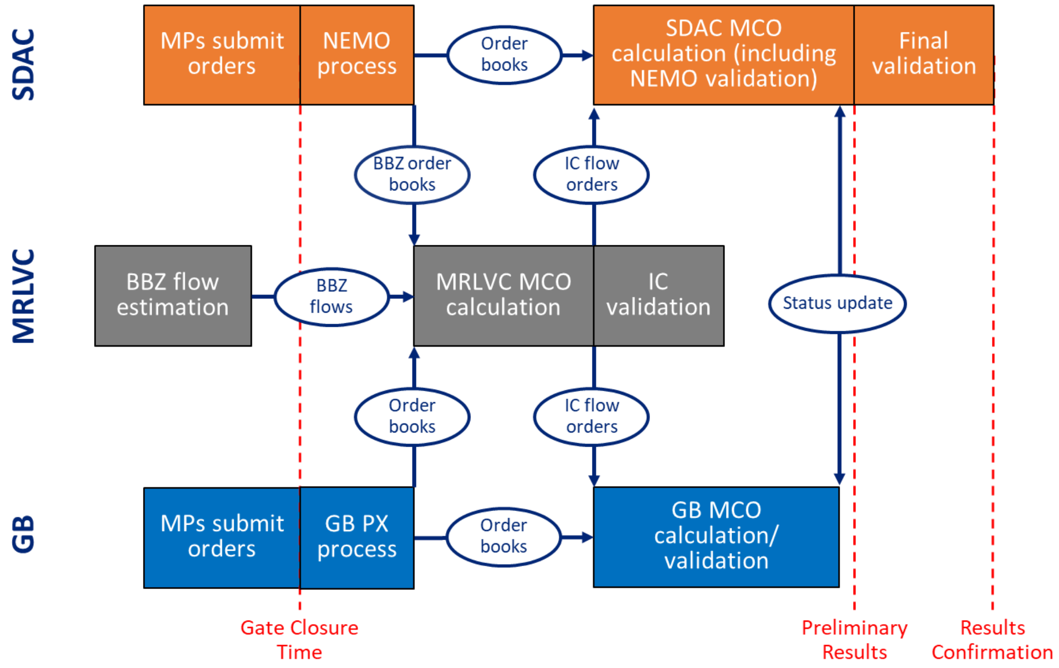


Figure 13 Indicative timeline for MRLVC (Common Order Books option). Source MRLVC CBA, 2021

<u>Further assumption: single GB clearing price</u>

The TCA is silent on the issue of GB price formation as this is a UK-specific matter which falls outside of the scope of interconnector capacity allocation mechanism. However, two significant aspects are worth noting.

Firstly, EPEX and Nord Pool currently operate separate day-ahead markets in the UK, which implies that they publish distinct GB clearing prices. Keeping such a setup would surely be detrimental for any market coupling solution, including MRLVC. Although the development of a single price in GB is outside of the scope of the TCA, it is presumed that this can be resolved and that all power exchanges operating in GB cooperate to share their orderbooks and publish the same clearing prices (hence assuming that the relevant market operators in GB will support the implementation of the TCA arrangements by developing similar cooperation arrangements as prior to Brexit, for example inspired the by the multi-NEMO arrangements prescribed in CACM GL).

Secondly, while currently the day-ahead market in GB does not consider transmission constraints, the implementation of some form of "locational pricing" is being contemplated in UK as part of the Review of Electricity Market Arrangements (REMA) process. While this topic is also out of the scope of the TCA and the present discussion, it is obvious that departing from a single GB price zone (towards locational prices or several bidding zone within GB) would create further complexity to any transmission capacity allocation scheme within GB.

For the sake of the present discussion, it is assumed that there is only one GB bidding zone that clears at one single price (in the day-ahead timeframe).

Annex B: Previous experiences with volume coupling

During the CACM GL drafting period, volume coupling has been contemplated for implementation in the IEM, because of its apparent governance and organizational advantages. It has however been acknowledged during this process (also given the practical experience acquired with volume coupling – see below) that price coupling is genuinely superior to volume coupling from an economic efficiency perspective, while volume coupling provides little (or no?) benefits with respect to organizational, practical, implementation or governance aspects. This is why CACM GL explicitly sets price coupling as the pillar of IEM for electricity.

Practical experience of volume coupling is limited. A few examples worth mentioning are

- the Kontek cable between Germany and Denmark (2008),
- the Interim Tight Volume Coupling (ITVC) between Central Western Europe and the Nordics operated by EMCC (2010 – 2014);
- and the BritNed solution between NL and GB operated by APX (2011 – 2014).

Kontek

The Kontek coupling is undeniably the worst experience with volume coupling. The solution went live on 29 September 2008 to be stopped on 9 October 2008 (after 10 days!) due to unsatisfactory results. In particular, "flows against price differences" undermined confidence in the approach. Interestingly, this is the only practical experience of some form of "loose volume coupling", in the sense that – even though the coupling solution used all relevant data for the coupling calculation – the market rules were loosely mirrored in the coupling solution, which was therefore unable to provide acceptable results. The volume coupling experience from Kontek has clearly shown that "*the complexity of the approach has proved difficult in practice and is not seen as a preferred model*"[23].

ITVC

After two years of "rework", a similar volume coupling solution was re-introduced in 2010 between the Central Western European region and the Nordic region. This solution (referred to as ITVC -Interim Tight Volume Coupling) provided more acceptable results thanks to the significant work on "algorithm tweaks" specifically targeted to favor coherence between flow direction and the prices calculated in the subsequent steps. In addition to a better alignment of the ITVC algorithm with the market clearing rules of the subsequent price calculation engines, the ITVC algorithm passes on "expected clearing price information" to the subsequent matching engines to facilitate coherent prices across the interconnector (i.e. on top of being a "tight volume coupling" solution, it required to transfer information on the prices as tentatively calculated by ITVC to the actual matching engines). The relatively favorable market conditions also contributed to improved results, in the sense that the direction of the flows from e.g. a cheap Nordic area to more expensive Germany is rather easy to determine, irrespective of the details of the transmission capacity allocation mechanism (i.e. any mechanism performs relatively well under such circumstances). The solution was replaced by a price coupling solution in 2014, which provided optimal results under all circumstances, and paved the way towards the current SDAC solution.

Britned

The Central Western Europe and GB coupling that was operated by APX between 2011 and 2014 can also be qualified as a form of volume coupling. However, the flows were not calculated during a

[23] Ofgem's Electricity interconnector policy (26 January 2010)

distinct process. Instead, the GB market orders were "embedded" into the NL market data while taking into account the BritNed interconnector capacity (as if a BritNed operator would be directly buying or selling in the NL market based on the GB orders at his disposal). To do this, any inter-temporal features for GB and BritNed had to be disabled: the GB market was unable to offer multi-period products and the flows on BritNed could not respect ramping constraints. Although not all necessary market and grid requirements were taken into account in this solution, the results were considered acceptable (despite minor price discrepancies) in terms of coherence and price formation.

Summary

In summary, experience from past volume coupling solutions has shown that some of the benefits of implicit allocation of cross-zonal capacity can be achieved through volume coupling. These benefits have, however, materialized largely thanks to favorable market conditions which showed unambiguous economically efficient flow direction between the coupled bidding zones. Experience has also shown significant implementation and operational challenges – especially to manage exceptional market circumstances.

Past events with volume coupling also demonstrated unacceptable risks when deviating from a "tight volume coupling" scheme with perfectly aligned algorithm requirements (complemented with "tweaks" to facilitate the discovery of coherent price differences on each side of the volume coupled interconnectors[24]).

[24] Remarkably, the MRLVC requirements explicitly prohibits to take advantage of this experience, while price formation will be even more challenging for offshore infrastructures due to their lack of price setting assets.

Annex C: Main findings of the MRLVC CBA

MRLVC has been evaluated in 2021 through a qualitative and quantitative cost-benefit analysis (MRLVC CBA[25]) which concluded with the following main findings:

1. *"MRLVC is potentially able (subject to the quality of the BBZ flow forecast) to offer improved economic welfare compared to the counterfactual of the current arrangements.*
2. *<u>TSO congestion revenue under MRLVC is very dependent on the BBZ flow forecast and market conditions, and the impact can vary by border.</u>*
3. *The Preliminary Order Books MRLVC design option presents major risks in terms of welfare, interconnector revenues, and meeting market needs.*
4. *<u>The Common Order Book MRLVC design option requires material changes to SDAC timings and processes, which have not yet been resolved.</u>*
5. ***<u>A modified MLRVC may be necessary to support the development and operation of hybrid offshore projects in the North Seas.</u>***
6. *<u>A poor quality MRLVC adversely impacts the operation of and confidence in the energy markets, including the impact DAM price formation and the potential loss of forward trading opportunities.</u>*
7. *Efficient intraday allocation is very important but there are challenges to adopting the MRLVC model for intraday.*
8. *<u>The interaction of four separate processes (MRLVC, BBZ flow forecasting, SDAC and GB DAM) increases operational and governance complexity."</u>*

This analysis has been complemented by further work carried out by the involved TSOs in 2023. From this work[26] ,the following quotes are worth being highlighted

- *"In a number of instances, experts who successfully manage and operate SDAC on a day-to-day basis have raised significant concerns with the feasible use of some of the suggested changes to operational processes that have been examined to accommodate MRLVC."; "the implementation of MRLVC will directly impact the SDAC process and increase the risks of decoupling of the European day-ahead market with all its consequences"; "There will be a trade-off between on the one hand minimizing the risk of negative impact on the European day-ahead market and, on the other hand, leaving enough time for MRLVC to maximise welfare gains"*
- *"MRLVC can potentially provide improved economic welfare compared to existing explicit allocation mechanisms but this is heavily dependent on the quality of the Bordering Bidding Zone (BBZ) methodology"; "the accuracy of the BBZ methodology is a significant challenge and it is difficult to obtain very accurate forecasts for all scenarios"; "The comparative analysis shows that the simple MRLVC assessment using the BBZ net position forecasts from the commercial forecaster outperforms explicit auctions in terms of lost welfare compared to implicit price coupling on the FR-GB, BE-GB, and NL-GB borders."*

[25] Cost Benefit Analysis of Multi-Region Loose Volume Coupling (MRLVC) arrangements to apply between the UK and the bidding zones directly connected to the UK, May 2021

[26] ENTSO-E publishes non-confidential version of the Responses from the TSO group to technical questions on Multi-Region Loose Volume Coupling between EU and UK (entsoe.eu)

- *“almost all negative impacts of Flows Against Price Differences and inaccurate flow forecasts are entirely shifted to the interconnector TSOs. They face the downsides as negative congestion incomes and as unfunded Use It Or Sell It (UIOSI) payouts. This will significantly impact the revenue stream of existing interconnectors as well as future (hybrid) interconnectors”; “It is far from certain if BBZ in conjunction with MRLVC will provide better answers to the offshore challenges compared to explicit auctions”.*
- *“MRLVC is a complex multi-jurisdictional delivery program that will introduce significant changes to existing, stable pan-European and UK electricity market places” “Based on an estimated duration of 4 years and 4 months, the overall high-level costs for the MRLVC and SDAC streams is estimated at around xx m, including a 40% contingency. This estimate does not include the cost of procuring the BBZ Net Position Forecaster as that is highly uncertain at this stage, as well as operation costs and local implementation costs”.*

MRLVC volume coupling is not designed to cope with OBZ

A Volume Coupling regime (whether "loose volume coupling" or "tight volume coupling") cannot efficiently set OBZ prices when the OBZ-BBZ interconnector is congested.

- If the OBZ-BBZ interconnector is congested, then the GB-OBZ interconnector is typically uncongested and the optimal OBZ price equals to the GB Price.
- However, MRLVC does not provide any GB price information to SDAC, and there are limited (or no) price-setting assets in OBZ
- Hence OBZ cannot be efficiently priced under MRLVC, and prices must be set arbitrarily

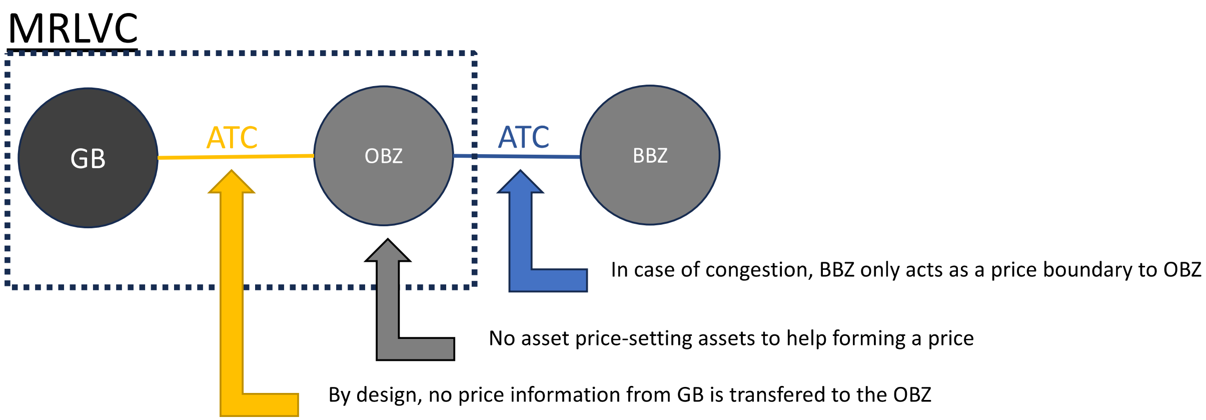
With the current SDAC algorithm rules, OBZ-BBZ interconnection will **never** generate any congestion revenues on the OBZ-BBZ link

- either because OBZ-BBZ is not congested – which logically generates no congestion revenue
- or SDAC arbitrarily sets the OBZ price based on its "price indeterminacy rule"*, which currently implies that SDAC typically equals the OBZ price to the BBZ price

NB: remedies may exist but all boil down to

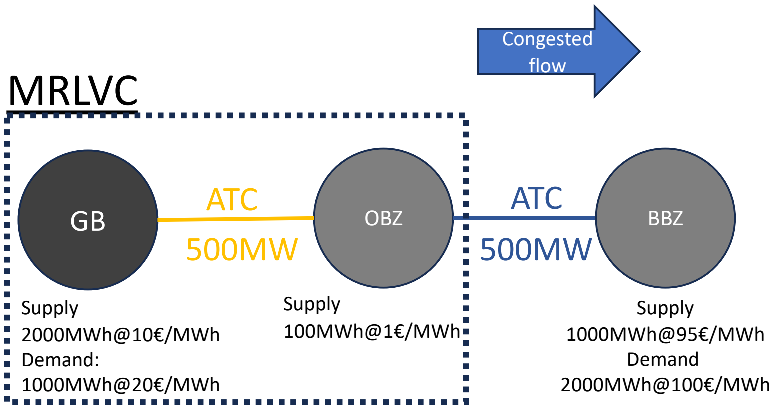
(1) transfer GB price information to SDAC (which isn't conform to the "spirit of MRLVC" as MRLVC isn't supposed to calculate prices)

(2) modify the SDAC algorithm and its price indeterminacy rules (which is far from trivial in practice for several technical or economic reasons)



*Euphemia current rule in case of price indeterminacy (i.e. when prices can not be uniquely set with accepted/rejected bids and offers) is to select a price that is as close as possible to the « mid-point of the feasible price range » (where the feasible price range is such that prices are above accepted supply orders and below accepted demand orders; or to above/below the min/max prices if there are no accepted order), which nonetheless respecting all « optimality conditions » (e.g. intuitive flows on ATC lines)

When OBZ-BBZ is congested and in absence of GB price information, SDAC will arbitrarily select the feasible OBZ price that is closest to the mid-point of the indeterminated price range (i.e. in this example closest to +/-2000€/MWh while at most equal to BBZ price)



	GB	GB<->OBZ	OBZ	OBZ-BBZ	BBZ
Optimal allocation (with both price coupling & MRLVC with perfect forecast)	Cleared S: 1400MWh Cleared D: 1000MWh export 400MWh	Flows >>400MW>>	Cleared S: 100MWh export 100MWh	Flows >>500MW>>	Cleared S: 1000MWh Cleared D: 1500MWh Import 1500MWh
Optimal prices (price coupling)	10€/MWh	0€/MW (no congestion)	10€/MWh	90€/MW CR = 45 000€	100€/MWh (partial acceptance of demand bid)
MRLVC prices	10€/MWh	90€/MW CR = 36 000 € no congestion	100€/MWh	0€/MW though congested	100€/MWh

Upper bound of the price indeterminacy is the maximum price = +4000 €/MWh
Lower bound of the price indeterminacy is the accepted supply at +1€/MWht
Mid-point of the price indeterminacy (=target) equals 1995.5€/MWh
OBZ price = price within the range that is closest to the target while being at most equal to BBZ price
OBZ price = BBZ price