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Postbus 718, 6800 AS Arnhem, Nederland

Autoriteit Consument en Markt
T.a.v. mevr. drs. M. Leijten
Postbus 16326
2500 BH DEN HAAG

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TELEFOON DIRECT	[redacted]
E-MAIL	[redacted]@tennet.eu

BETREFT Aangevuld voorstel van CWE TSO's n.a.v. DC verbinding ALEGrO en Verordening (EU) 2019/943

Geachte mevrouw Leijten,

Op 14 mei jl. heeft TenneT met brief REC-N 20-023 bij u een voorstel van de CWE TSO's ter goedkeuring ingediend. Dat voorstel betrof aangepaste spelregels voor day-ahead CWE flow-based marktkoppeling n.a.v. de DC verbinding ALEGrO en de Verordening (EU) 2019/943.
Hierbij ontvangt u een aanvulling op dat voorstel. De aanvulling betreft intraday ATC. U wordt verzocht dit aanvullende voorstel gevoegd te behandelen met het op 14 mei ingediende voorstel. De deels bijgewerkte bijlagen van het oorspronkelijke voorstel zijn nogmaals bijgevoegd. Daarmee bestaat het totale voorstel uit de volgende documenten:

- *"Documentation of the CWE FB MC solution"* d.d. 10 juli 2020;
- *"Appendices 14.29 and 14.30 to the CWE FBMC approval document"* d.d. 6 mei 2020;
- *"CWE TSO's methodology for capacity calculation for the Intraday timeframe"* d.d. 10 juli 2020;
- *"Congestion income allocation under Flow-Based Market Coupling"* d.d. 6 mei 2020.

Bij de methodologie voor intraday is een *Explanatory Note* bijgevoegd. Ook zijn van de drie methodologieën versies met gemarkeerde wijzigingen ten opzichte van de vorige versie toegevoegd.

Dit voorstel bevat geen vertrouwelijke gegevens.
U wordt verzocht dit voorstel goed te keuren krachtens artikel 5, zesde lid, van de Elektriciteitswet 1998.

Hoogachtend,
TenneT TSO B.V.

[redacted]

Head Regulatory Affairs Netherlands

Documentation of the CWE FB MC solution

July 2020 – version 5.0, applicable as of DD MM 2020

Last updated: 10/07/2020

Note: this document is an update of the CWE FB MC approval package version 4.1, dated 11 April 2019.

The main changes compared to the version 4.1 are the following:

1. Introduction of the ALEGrO-cable in CWE FB capacity calculation: detailing how the ALEGrO HVDC between Amprion and Elia will be included in the CWE FBMC
2. Evolved Flow-based: describing the methodlogy used for HVDC borders between two Bidding Zones
3. Extended LTA inclusion: explaining the updated methodology for LTA inclusion to keep the same precision and improve performance.
4. CEP MinRAM calculation methods: detailing how each TSO calculates mininimum levels of available capacity for cross-zonal trade according to Regulation (EU) 2019/943 of 5 June 2019 on the internal market for electricity (one of the regulations of the Clean Energy Package).
5. Removal of the intuitiveness patch: switch from Flow-Based intuitive to Flow-Based based plain.

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1 Management summary

The purpose of this updated approval document is to provide all Regulators of the CWE region with complete and up-to-date information regarding the applied solution of the CWE Flow Based Marked Coupling (FB MC).

This document constitutes an update of the approval document dated 11 April 2019, now including:

1. Introduction of the ALEGrO-cable in CWE FB capacity calculation: detailing how the ALEGrO HVDC between Amprion and Elia will be included in the CWE FBMC
2. Evolved Flow-based: describing the methodlogy used for HVDC borders between two Bidding Zones
3. Extended LTA inclusion: explaining the updated methodology for LTA inclusion to remain precision and improve performance.
4. CEP MinRAM calculation methods: detailing how each member state calculates minRAM according to the CEP.
5. Removal of the intuitiveness patch: switch from Flow-Based intuitive to Flow-Based based plain.

For the sake of consistency all provisions reflected in this document are without prejudice to further methodologies and proposals, which will be implemented as required by Commission Regulation (EU) 2015/1222 (CACM) or Regulation (EU) 2019/943.

The CWE Market Coupling Solution

The specific CWE Flow Based Market Coupling solution is a regional part of the Single Day Ahead Coupling (SDAC).

During the daily operation of Market Coupling the available capacity (final Flow Based parameters including the Critical Network Elements and the PTDF-matrix) will be published at 10:30. Market Parties will have to submit their bids and offers to one of the NEMOs in their bidding zone before gate closure time. In case results cannot be calculated, the Fallback mechanism for capacity allocation will be applied at SDAC level and there will be a Full or Partial Decoupling of one or multiple NEMOs or bidding zones, following the SDAC Procedures.

The solution is operated via a set of connected systems. These systems are operated by RSCs, TSOs, jointly or individually, NEMOs, jointly or individually, JAO and clearing houses. Daily operations consist of three phases: provision of network data (Flow Based parameters), calculation of results, and post publication processes.

Fallback arrangement (capacity allocation)

In the CWE MC procedures, a Fallback situation occurs when the Incident Committee declares that, for any reason, correct Market Coupling results cannot be published before the Decoupling deadline.

The general principle of the CWE Fallback arrangement is to allocate ATCs derived from the Flow Based parameters via a "shadow explicit auction" on decoupled borders. A bidding zone remains coupled, as long as cross zonal capacities can be provided to the market coupling algorithm for at least one border of that bidding zone. If all borders of a certain bidding zone are decoupled, the order books of the NEMOs in that bidding zone are removed from the market coupling algorithm and become decoupled.

Moreover, if one NEMO cannot submit its order book of a certain bidding zone to the market coupling algorithm, the remaining NEMOs in that bidding zone remain coupled. Decoupled NEMOs run their own local fallback auctions.

The Algorithm

Market results are calculated by a centralised market coupling algorithm, which is a branch-and-bound algorithm designed to solve the problem of coupling spot markets with block orders. It handles all technical requirements set by the SDAC and CWE projects, including step and interpolated orders, flow based network under PTDF representation, ATC links and DC cables (possible with ramping, tariffs and losses). The algorithm outputs net positions and prices on each market and each hour, the set of accepted orders, and the congestion prices on each tight network element. These outputs satisfy all requirements of a feasible solution, including congestion price properties.

Capacity Calculation

The CWE TSOs have designed a coordinated procedure for the determination of Flow Based capacity parameters. This procedure consists of the following main steps

- Merging
- Pre-qualification
- Centralized Initial-Flow Based parameter computation
- Flow Based parameter qualification
- Flow Based parameter verification
- LTA inclusion check
- LTN adjustment

This method had been tested in the external parallel run since January 2013. TSOs developed the methodology from prototype to industrialization.

Any changes to the methodology during the parallel run were subject to change control, documented and published.

Economic Assessment

Extensive validation studies have been performed by the Project Partners, showing positive results. Among others, the studies show an approximate increase in day-ahead market welfare for the region of 95M Euro on an annual basis (based on extrapolated results of the average daily welfare increase, during the external parallel run from January to December 2013). Full price convergence in the whole region improves significantly, although some partial convergence is lost because of the intrinsic Flow Based price properties. The net effect though is that the spread between average CWE prices is reduced.

Impacts on price formation and volatility have also been observed (c.f. Annex 14.10).

These calculations were performed, using results of ATC MC and comparing them with simulated FB(I) MC. In order to further validate the results, the Project Partners have performed additional analyses, e.g. the domain reduction study (Annex 14.11).

Flow Based simulations can be found in the daily parallel run publication on JAO's website.

The technical and economic impact of the bidding zone border split of the German and Austrian Hub on the CWE Flow Based Market Coupling has been analysed via the standard process to communicate on and assess the impact of significant changes (SPAIC). The results of this study are attached in Annex 14.28.

Intuitiveness

Based on the dedicated studies, the feedback during the public consultation and the eventual guidance of the CWE NRAs, the Project has started with FBI.

The parallel computation of results with FBP takes place since May 2015.
The removal of the intuitiveness patch (switch to FBP) will take place as of the technical go-live of ALEGrO in Euphemia due to issues in terms of algorithm performance and optimisation possibilities with the Evolved Flow-Based approach as well as alignment with ACER's decision on algorithm methodology defined in the Article 37 of Commission Regulation (EU) 2015/1222 (CACM).

Transparency

The Project Partners publish various operational data and documents related to Flow Based Market Coupling, in compliancy with European legislation and having considered demands of the Market Parties and the Regulators. These publications support Market Parties in their bidding behaviour and facilitate an efficient functioning of the CWE wholesale market, including long term price formations and estimations.

Monitoring

For monitoring purposes the National Regulatory Authorities get additional (confidential) data and information. Based on national and EU-legislation, on reasonable request from the NRAs, the Project provides all Project related data for monitoring purposes. Publications of monitored information can be commonly agreed from case to case.

2 Introduction

After having signed the Memorandum of Understanding of the Pentalateral Energy Forum on Market Coupling and security of supply in the Central West European (CWE) region in 2007, the TSOs and PXs active at that time in CWE have put in place a project that was tasked with the design and implementation of the Market Coupling solution in their region. As a first step, the project partners have decided to implement an ATC based Market Coupling which went live on November 9th 2010.
Parallel to the daily operation of the ATC-Based Market Coupling, the Project Partners worked on the next step which is the implementation of a Flow Based Market Coupling in CWE.

Work has progressed and the Flow Based Market Coupling solution was improved. Results of more than 16 months of the external parallel run, covering all seasons and typical grid situations, have shown clear benefits of the FB methodology. After the go-live of the Flow Based Market Coupling, APG has been integrated in the CWE procedures, following a stepwise process agreed with all CWE partners.

The purpose of the report at hand with all Annexes is to provide the Regulators of the CWE region with a complete set of documentation describing the Flow Based Market Coupling solution.

The latest update of this documentation focuses on:

- Changes required in order to make the CWE Flow Based Market Coupling compliant with provisions on capacity calculation of the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, which applies from 1 January 2020.

The updated descriptions are submitted for approval according to the national approval procedures to the competent CWE NRAs and in line with Regulation (EU) 2019/943.

For the other parts of the document, CWE TSOs consider that the previous approvals of the CWE NRAs on these parts of the CWE FB MC methodology remain valid.

The CWE FB MC Approval document is structured in the following chapters:

- General principles of Market Coupling
- Coordinated Flow Based capacity calculation
- CWE Market Coupling solution
- Fallback solution
- Economic validation
- Transparency / publication of data
- Monitoring
- Calculation of bilateral exchanges
- Contractual scheme
- Change control

3 General principles of Market Coupling

1.1. General principle of Market Coupling

Market Coupling is both a mechanism for matching orders on Nominated Electricity Market Operators (NEMOs) and an implicit capacity allocation mechanism. Market Coupling optimizes the economic efficiency of the coupled markets: all profitable deals resulting from the matching of bids and offers in the coupled hubs of the NEMOs are executed subject to sufficient Cross-Zonal Capacity (CZC) being made available for day-ahead implicit allocation; matching results are subject indeed to capacity constraints calculated by Transmission System Operators (TSOs) which may limit the exchanges between the coupled markets.

Market prices and Net Positions of the connected markets are simultaneously determined with the use of the available capacity defined by the TSOs. The transmission capacity made available to the Market Coupling is thereby efficiently and implicitly allocated. If no transmission capacity constraint is active, then there is no price difference between the markets. If one or more transmission capacity constraints are active, a price difference between markets will occur.

1.2. Day-Ahead Flow Based Market Coupling

Market Coupling relies on the principle that when markets with the lowest prices export electricity to markets with the highest prices, there is day-ahead market welfare created by these exchanges. The Market Coupling algorithm (described later on in the document) will optimize the day-ahead market welfare for the whole region, based on the capacity constraints (Flow Based capacity parameters; including the Critical Network Elements and the PTDF-matrix) and the energy orders. A general example of Market Coupling for two markets illustrates how FB MC works. Two situations are possible: the margin on the Flow Based capacities is large enough and the prices of both markets are equalized (price convergence), or the margin of capacities is not sufficient (leading to one or more active constraint(s)) and the prices cannot equalize (no price convergence)[1]. These two cases are described in the following example.

Sufficient margin, price convergence

Suppose that, initially, the price of market A is lower than the price of market B. Market A will therefore export to market B. The price of market A will increase whereas the price of market B will decrease. If the margin of capacities from market A to market B is sufficiently large, a common price in the market may be reached (PA* = PB*). This case is illustrated in **Figure 3-1**.

[1] The term "convergence" is used in the context of Market Coupling to designate a situation where prices converge up to their equalization. Although prices may get closer to each other too, one says that there is "no price convergence" in all cases where the transmission capacity made available to the Market Coupling is not sufficient to lead to price equalization.

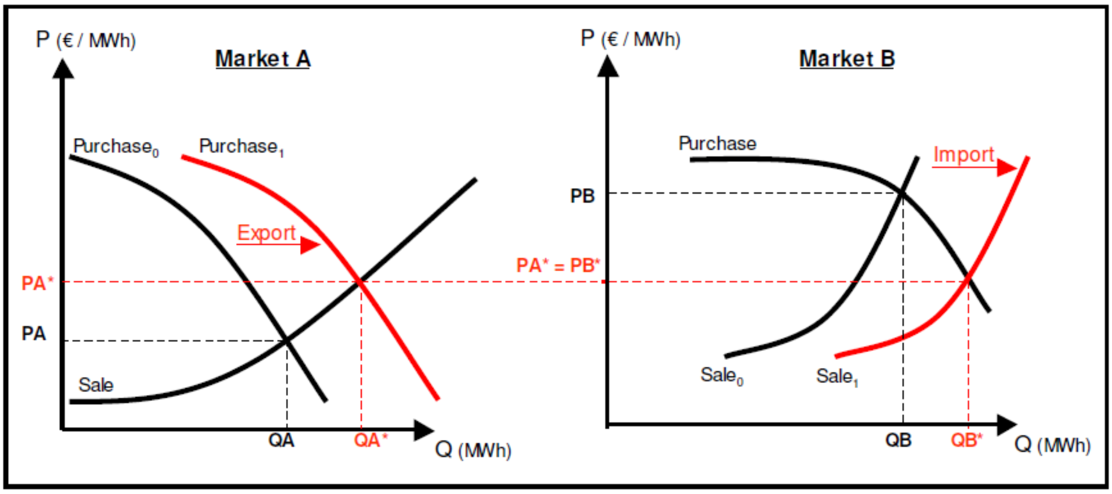

Figure 3-1: Representation of Market Coupling for two markets, no congestion.

Insufficient margin, no price convergence

Another situation illustrated in **Figure 3-2** happens when the capacity margin is not sufficient to ensure price convergence between the two markets. The amount of electricity exchanged between the two markets it then equal to the margin (or remaining capacity) on the active (or limiting) constraint, divided by the difference in flow factors (PTDFs) of the two markets.

The prices PA* and PB* are given by the intersection of the purchase and sale curves. Exported electricity is bought in the export area at a price of PA* and is sold in the import area at a price of PB*. The difference between the two prices multiplied by the exchanged volume between the two markets (bidding zones) is the congestion revenue.

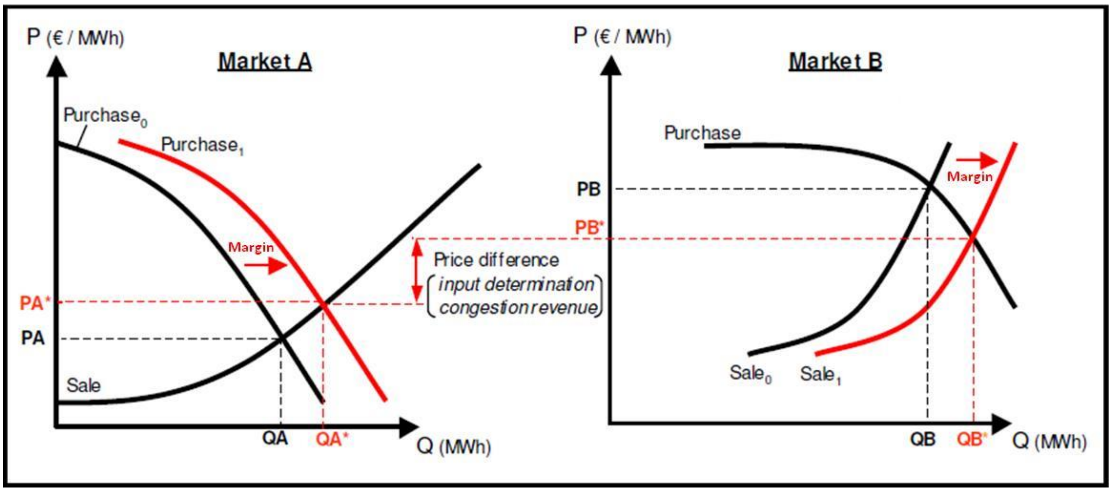

Figure 3-2: Representation of Market Coupling for two markets, congestion case

In "plain" Flow Based Market Coupling a non-intuitive exchange can occur (export from a high priced market to low priced markets), the welfare loss of this exchange is then to the benefit of a higher day-ahead market welfare gain for the whole region, which originates from other exchanges (c.f. chapter 7.3).

4 Coordinated Flow Based capacity domain calculation

The method for capacity calculation described below is fixed since the start of the external parallel run. Changes which were applied based on experience of the parallel run are documented in detail in Annex 0.

An educational, simplified and illustrative example, “How does Flow Based capacity calculation work?” can be found in Annex 14.2.

The high level business process for capacity calculation can be found in Annex 14.3.

4.1. Input data

To calculate the Flow Based capacity domain, TSOs have to assess different items which are used as inputs into the model. The following inputs need to be defined upfront and serve as input data to the model:

- Critical Network Elements / Contingencies
- Maximum current on a Critical Network Element (Imax)
- Maximum allowable power flow (Fmax)
- Final Adjustment Value (FAV)
- D2CF Files, Exchange Programs
- Remedial Actions (RAs)
- Generation Shift Key (GSK)
- Flow Reliability Margin (FRM)
- External constraints: specific limitations not associated with Critical Network Elements

4.1.1. CNEC-selection

A Critical Network Element (CNE) is a network element, significantly impacted by CWE cross-border trades, which is monitored under certain operational conditions, the so-called Contingency (C). The

CNECs (Critical Network Elements/Contingencies) are determined by each CWE TSO for its own network according to agreed rules, described below.

The CNEs are defined by:

- A line (tie-line or internal line), or a transformer, that is significantly impacted by cross-border exchanges,
- An "operational situation": normal (N) or contingency cases (N-1, N-2, busbar faults; depending on the TSO risk policies).

Contingencies (C) can be defined for all CNEs. A C can be:

- Trip of a line, cable or transformer,
- Trip of a busbar,
- Trip of a generating unit,
- Trip of a (significant) load,
- Trip of several elements,
- Trip of an HVDC interconnector under Evolved Flowbased.

CNE selection process

The assessment of Critical Network Elements is based on the impact of CWE cross-border trade on the network elements and based on operational experience that traced back to the development of coordinated capacity calculation under ATC:

Indeed, the TSOs developed the coordinated ATC methodology that was in daily operation from November 2010 until May 2015, based on FB ingredients. The so-called 16 corner check was based on a check on a limited number of grid elements: the Critical Network Elements. The advantage of this approach was that there is already significant operational experience with the application of Critical Network Elements as part of a grid security analysis, and that it facilitates a consistent transition from ATC to FB as well. Indeed, the Critical Network Elements that were applied within the 16 corner check, boiled down to relevant sets based on the operational ATC experience. The experienced gained in ATC operations therefore already provided a relevant set of initial Critical Network Elements for FB operations.

This set has then been updated according to the following process:

A set of PTDFs is associated to every CNEC after each Flow Based parameter calculation, and gives the influence of the net position of any bidding zone on the CNEC. If the PTDF = 0.1, this means the concerned hub has 10% influence on the CNEC, meaning that 1 MW in change of net position of the hub leads to 0.1 MW change in flow on the CNEC. A CNE or CNEC is NOT a set of PTDF. A CNEC is a technical input that one TSO integrates at each step of the capacity calculation process in order to respect security of supply policies. CNE selection process is therefore made on a daily basis by each TSO, who check the adequacy of their constraints with respect to operational conditions. The so-called flow based parameters are NOT the Critical Network Elements, they are an output of the capacity calculation associated to a CNE or CNEC at the end of the TSO operational process. As a consequence, when a TSO first considers a CNEC as a necessary input for its daily operational capacity calculation process, it does not know, initially, what the associated PTDFs are.
A CNE is considered to be significantly impacted by CWE cross-border trade, if its maximum CWE zone-to-zone PTDF is larger than a threshold value that is currently set at 5%.
This current threshold has been set following security assessments performed by TSOs, by the iterative process described below:

TSOs have carried out some alternative computations of Flow Based parameters, using scenarios where only the threshold was set to different values. Depending on the threshold values, some Critical Network Elements were included or not in Flow Based parameters computation, resulting in a capacity domain more or less constraining for the market. Taking some extreme "vertices" of the resulting alternative Flow Based domains, TSOs assessed whether these domains would be safe, and more precisely to identify at which point the exclusion of CNE not respecting the threshold would lead to unacceptable situations, with respect to CWE TSOs risk policies. If for one given threshold value, the analyses would conclude in unacceptable situations (because the removal of some constraints would allow an amount of exchanges that TSOs could not cope with as they would not respect standard SOS principles, like the standard N-1 rule), then this simply meant that the threshold was too high. Following this approach and assessing different values, CWE TSOs came to the conclusion that 5% was an optimal compromise, in terms of size of the domain versus risk policies.
TSOs want to insist on the fact that the identification of this threshold is driven by two objectives:

- Bringing objectivity and measurability to the notion of "significant impact". This quantitative approach should avoid any discussion on internal versus external branches, which is an artificial notion in terms of system operation with a cross-border perspective.

- Above all, guaranteeing security of supply by allowing as many exchanges as possible, in compliancy with TSOs risks policies, which are binding and have to be respected whatever the capacity calculation concept (ATC or Flow Based). In other words, this value is a direct consequence of CWE TSOs risk policies standards (which do not change with Flow Based), adapted to Flow Based principles.

It is important to keep in mind that these CNE selection principles cannot be seen as a single standalone study performed by CWE TSOs. Rather, CWE TSOs have applied over time a continuous (re-assessment process that has started with the computations of bilateral capacities and been developed with FB, in order to elaborate a relevant CNE set and determine afterwards an adequate threshold. The 5% value is therefore an ex-post, global indicator that cannot be opposed automatically, which means without human control, to an individual CNE in a given timestamp.

CWE TSOs constantly monitor the Critical Network Elements which are fed into the allocation system in order to assess the relevance of the threshold over time. During the external parallel run, active Critical Network Elements, i.e. the CNEs having actually congested the market, respected – with the exception of some rare cases – the threshold value of 5%, This would tend to confirm the adequacy of the current value.

Practically, this 5% value means that there is at least one set of two bidding zones in CWE for which a 1000 MW exchange creates an induced flow bigger than 50 MW (absolute value) on the branch. This is equivalent to say that the maximum CWE "zone to zone" PTDF of a given grid element should be at least equal to 5% for it to be considered objectively "critical" in the sense of Flow Based capacity calculation.

For each CNEC the following sensitivity value for AC borders is calculated:

Sensitivity_AC = max(PTDF (BE), PTDF (DE), PTDF (AT), PTDF (FR), PTDF (NL)- min(PTDF (BE), PTDF (DE), PTDF (AT), PTDF (FR), PTDF (NL))

If two bidding zones (A,B) are connected via HVDC connector, the sensitivity will be calculated as follows:

Sensitivity_DC = abs(PTDF(A) – PTDF(virtualhubA) + PTDF(virtualhubB) – PTDF(B))

where virtualhubs represent the sending or receiving end of an HVDC connector. More information on the treatment of DC interconnectors can be found in chapter 4.2.9.

If the sensitivity AC or DC is above the threshold value of 5%, then the CNEC is said to be significant for CWE trade.

A pre-processing is performed during the Flow Based parameter calculation which results in a warning for any CNEC which does not meet pre-defined conditions (that is, the threshold). The concerned TSO then has to decide whether to keep the CNEC or to exclude it from the CNEC file.

Although the general rule is to exclude any CNEC which does not meet the threshold on sensitivity, exceptions on the rule are allowed: if a TSO decides to keep the CNEC in the CNE file, he has to justify it to the other TSOs, furthermore it will be systematically monitored by the NRAs.

Should the case arise, TSOs may initiate discussions on the provided justifications in order to reach a common understanding and a possible agreement on the constraints put into the capacity calculation process. TSOs know only at the end of the capacity calculation process the detailed and final PTDFs, while the Critical Network Element is required in the beginning as an input of the capacity calculation process[2].

CWE TSOs therefore commit to critically assess their set of Critical Network Elements in two respects:

1. On the one hand with a "close-to-operations" perspective, considering the threshold as a fixed reference. In this framework, CWE TSOs operators and FB experts assess ex-post the relevance of the CNEs against this threshold. Eventually, this assessment may result in discarding the CNE from the FB computation, but in any case this will not happen on a daily basis, after just one occurrence, but rather after an observation and security analysis phase potentially lasting several months. On the contrary, upholding a CNE that chronically violates the present agreed threshold shall be objectively justified and reported to NRAs in dedicated reports.
2. On the second hand, the threshold itself needs to be regularly, if not changed, at least challenged. This is more a long-term analysis which needs several months of practical experi-

[2] A frequent explanation for having eventually a CNEC associated to PTDFs not respecting the threshold is the usage of a Remedial Action. Indeed, if it happens that a CNEC is too limiting, the TSO owner will try to release some margin on this CNE by implementing a Remedial Action (see dedicated section later in this document). The Remedial Action will have as an effect to decrease the sensitivity of the CNE towards the cross-border exchanges: by decreasing the influence of the exchanges on the load of the line, more trades will become possible. In this situation, it is legitimate to "keep" the CNEC.

ence with FB operations. Once this experience is gained, CWE TSOs will re-consider the relevance of the thresholds by looking at the following criteria with a focus on active CNEs :

- Frequency and gravity of the threshold violations
- Nature of the justifications given to keep some CNEs
- Or, on the contrary, absence of threshold violation.

The main idea is therefore to assess the "distance" between the threshold and the set of active CNEs. This distance can be inappropriate in two aspects:

- Either the threshold is too high, which will be the case if too many CNE violate it while valid justifications are given
- Either it will be too low, which will be the case if all active CNE systematically respect it over a representative period of time.

In both cases, the shadow price (> 0 when the CNE becomes active), that is information provided to NRAs within the monitoring framework, can also be a useful indicator to assess market impact of the active CNEs, especially when they are far from the agreed threshold.

4.1.2. Maximum current on a Critical Network Element (Imax)

The maximum allowable current (Imax) is the physical limit of a Critical Network Element (CNE) determined by each TSO in line with its operational criteria. Imax is the physical (thermal) limit of the CNE in Ampere, except when a relay setting imposes to be more specific for the temporary overload allowed for a particular Critical Network Element-Contingency (CNEC).

As the thermal limit and relay setting can vary in function of weather conditions, Imax is usually fixed at least per season.
When the Imax value depends on the outside temperature, its value can be reviewed by the concerned TSO if outside temperature is announced to be much higher or lower than foreseen by the seasonal values.
Imax is not reduced by any security margin, as all margins have been covered by the calculation of the Contingency by the Flow Reliability Margin (FRM, c.f. chapter 4.1.8 and Final Adjustment Value (FAV, c.f. chapter 4.1.4).

4.1.3. Maximum allowable power flow (Fmax)

The value Fmax describes the maximum allowable power flow on a CNEC in MW. It is given by the formula:

Fmax = $Sqrt(3)$ *** Imax * U * cos(φ) / 1000 [MW],**

where Imax is the maximum permanent allowable current (in A [Ampere]) for a CNE. The value for cos(φ) is set to 1, and U is a fixed value for each CNE and is set to the reference voltage (e.g. 225kV or 400kV) for this CNE.

4.1.4. Final Adjustment Value (FAV)

With the Final Adjustment Value (FAV), operational skills and experience that cannot be introduced into the Flow Based-system can find a way into the Flow Based-approach by increasing or decreasing the remaining available margin (RAM) on a CNE for very specific reasons which are described below. Positive values of FAV in MW reduce the available margin on a CNE while negative values increase it. The FAV can be set by the responsible TSO during the qualification phase and during the verification phases. The following principles for the FAV usage have been identified:

- A negative value for FAV simulates the effect of an additional margin due to complex Remedial Actions (RA) which cannot be modelled and so calculated in the Flow Based parameter calculation. An offline calculation will determine how many MW can additionally be released as margin; this value will be put in FAV.

- A positive value for FAV as a consequence of the verification phase of the Flow Based domain, leading to the need to reduce the margin on one or more CNEs for system security reasons. The overload detected on a CNE during the verification phase is the value which will be put in FAV for this CNE in order to eliminate the risk of overload on the particular CNE.

Any usage of FAV will be duly elaborated and reported to the NRAs for the purpose of monitoring[3] the capacity calculation.

4.1.5. D2CF Files, Exchange Programs

The 2-Days Ahead Congestion Forecast files (D2CF files), provided by the participating TSOs for their grid two-days ahead, are a best estimate of the state of the CWE electric system for day D.
Each CWE TSO produces for its zone a D2CF file which contains:

- Best estimation of the Net exchange program
- Best estimation of the exchange program on DC cables

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[3] Details on monitoring are given in the dedicated chapter 9. Besides, a template of the monitoring reports is available in Annex 14.17).

- best estimation for the planned grid outages, including tie-lines and the topology of the grid as foreseen until D-2
- best estimation for the forecasted load and its pattern
- if applicable best estimation for the forecasted renewable energy generation, e.g. wind and solar generation
- best estimation for the outages of generating units, based on the latest info of availability of generators
- best estimation of the production of generating units, in line with outage planning, forecasted load and best estimated Net exchange program.

The PST tap position is usually neutral in the D2CF but well justified exceptions should be allowed.

For each timestamp, the local D2CF file has to be balanced in terms of production and consumption, in coherence with the best estimated Net exchange program. The D2CF files will be merged together with DACF (Day-Ahead Congestion Forecast) files of non CWE-TSOs to obtain the base case according to the merging rules described in this document (c.f. chapter 4.2.1).

Individual procedures

Amprion:

For every day D there are 24 D2CF files generated by Amprion. These D2CF files describe the load flow situation for the forecasted business day as exactly as possible. In order to provide an adequate forecast Amprion generates the D2CF files in the following way:
The basis of a D2CF file is a "snapshot", (i.e. a "photo") of the grid from a reference day.
In a first step the topology is adjusted according to the business day. Here are all components put into operation (which were switched off in the snapshot) and all forecasted outages (for the business day) are included in the D2CF file. After that the genera-

tion pattern is adapted to the schedule of the exchange reference day.
In the next step the wind and solar forecasts are included in the D2CF file by using dedicated wind and solar GSKs. This process is based on local tools and uses external weather forecasts made available to Amprion.
As a next step the resulting net position is adapted to the one of the reference day. After this, the resulting so-called "slack deviation" (unbalance between generation and load) is determined and this deviation is spread over all marketbased generation units of Amprion by using GSKs.

To summarize, the provision of the Amprion D2CF data set is based on 5 main steps.

1. Take snapshot from the reference day as basis
2. Include topology for business day and adjust generation pattern
3. Include wind and solar forecast
4. Adapt net position of Amprion
5. Deviations (slack) are spread over all market based generation units

APG:

Using renewable generation-schedules, estimated total load and planned outages for the business day, and market driven generation-schedules and the load distribution from the reference day, 24 D2CF Files are being created as follows:

- Topology is adjusted according to the outage planning system
- Generation is adjusted according to the renewable schedules for the business day and the market driven schedules from the reference day

- Total load is adjusted to the forecast of the business day, and distributed according to the reference day
- Thermal rating limits are applied
- Exchange is distributed over tie-lines according to merged D2CF of the reference day

After these steps a load flow is being calculated to check for convergence, voltage- and reactive power limits.

Elia:

Load profile and cross-border nominations of the reference day are used. The topology of the grid is adjusted by use of the information of a local outage-planning-system (including generator maintenance) as known at time of preparation of D2CF, which is between 17:00 18:00. This includes possible preventive topology Remedial Actions needed for specific grid maintenance.

The load is automatically adjusted to account for the difference in the load of the reference day and the predicted load of the day D.

The best estimate is used to determine all production units which are available to run, with a determination of the Pmin and Pmax to be expected on the business day (depending on whether units are foreseen for delivery of ancillary services or not).

The production program of the flexible and controllable units is adjusted based on the calculated GSK, and on the Pmin and Pmax prepared in order to fit with the cross-border nominations of the reference day.

PST tap positions are put at 0 in order to make a range of tap positions available as Remedial Action, except if overloads can be expected in the base case in a likely market direction, in which case 2 to 4 steps could be made on some PST at Elia borders.

TransnetBW:

D2CF files are elaborated according to the following steps:

- Choose a proper snapshot (last available working-day for working-days; last weekend for the weekend) as a basis
- Adjust the topology by use of the information of a local outage-planning-system (including generator maintenances)
- Adjust generation in feed to the available generator-schedules. For generators with no schedules available adjust to the schedules of the reference day.
- Adjust the flow to the distribution grid by adapting the load and renewable generation with forecasts.
- Adjust the Net Exchange program to the forecast of the Net Exchange program.
- After all changes are made the created files will be checked for convergence.

RTE:

French D2CFs are based on an automatic generation of 24 files, created with several inputs:

- Up to 24 snapshots if available for the 24 hours, less in other cases
    - These snapshots are selected in the recent past to be the best compromise possible between the availability of snapshots, generation pattern, load pattern and exchanges.
    - Topology is adapted to the situation of the target day (planned outages and forecast of substation topology)
- Depending on the reference exchange programs, topology can also be adapted to avoid constraints in N and N-1 situations.
- Estimation of net exchange program is based on reference days

- Load is adjusted based on load forecasts for the concerned time horizon.
- Generation is adjusted based on planned "D-1" patterns or realized "D-X" patterns (meaning: historical situations anterior to the day when the D2CF process is happening), with some improvements:
    - renewable generation (PV and wind generation) is up-dated based on forecasts available for the concerned time horizon,
    - for large units, generation is adjusted, based on maintenance forecast (provided on a weekly basis by producers, and adapted during the week).

➔ 24 hourly files are produced in this way.
For each file, an adjustment is performed on generation, to reach the estimation of net exchange program and produce the final 24 French D-2 grid models.
A loadflow is launched to check the convergence.

TenneT DE:

The D2CF data generation at TenneT DE starts after the day-ahead nominations are known.
As a first step TTG creates a grid model respecting the expected switching state in order to match the outage planning. The PST taps are always set to neutral position.
The second step involves the adjustment of the active power feed-in of each node to its expected value:

- Connections to the distribution grid are described by using D-2 forecasts of renewable feed-in, e.g. wind and solar generation, as well as load.

- Directly connected generation units are described by using D-2 production planning forecasts of single units in the first step. If necessary, the Net exchange program is adjusted to meet the D-2 forecast of the Net exchange program by using a merit-order list.

Finally, additional quality checks are made (e.g. convergence, voltages, active and reactive power).

TenneT NL:

TenneT starts the D2CF creation process with a grid study model. This model which represents the topology of the business day by making use of the information of the local outage-planning (including generator maintenances) as known at time of preparation of D2CF, which is between 17:00-18:00 at D-2.
The model is then adapted for the Load & Production forecasts (directly derived from the forecasts received from the market) and cross-border nominations of the reference day, which become available at 17:00.
After the forecasts have been imported TenneT starts to redistribute the production of all dispatchable units (which are not in maintenance) above 60MW (further called: GSK Units). This redispatch of production is done in order to match the GSK methodology as described in the GSK chapter of this document. All GSK units are redispatched pro rata on the basis of predefined maximum and minimum production levels for each active unit. The total production level remains the same.
The maximum production level is the contribution of the unit in a predefined extreme maximum production scenario. The minimum production level is the contribution of the unit in a predefined extreme minimum production scenario. Base-load units will have a

smaller difference between their maximum and minimum production levels than start-stop units.

With Pi0 being the initial MW dispatch of unit i, and Pi1 being the new dispatch of unit i after the redispatch, then

$$P_{i1} = Pmin_i + (Pmax_i - Pmin_i)\frac{(\sum_k P_{k0} - \sum_k Pmin_k)}{(\sum_k Pmax_k - \sum_k Pmin_k)} \text{ (eq. 1)}$$

$$P_{i1} = Pmin_i + (Pmax_i - Pmin_i)\frac{(\sum_k P_{k0} - \sum_k Pmin_k)}{(\sum_k Pmax_k - \sum_k Pmin_k)} \text{ (eq. 1)}$$

PST tap position is put at 0 in order to make a range of tap positions available as Remedial Action, except if overloads can be expected in the base case in a likely corner, in which case 2 to 4 steps could be made on some PST

For the DC cables the Exchange programs of reference days are used. In case the cable is out of service on the target day, the program of the cable will be distributed over the loads.

Afterwards, production and load are redistributed and an AC loadflow is performed in which the grid is checked for congestions and voltage problems. During this process there is an automatic adjustment of loads to correct the difference in the balance between the reference program of the execution day and the data received in the prognosis of Market Parties for this day.

Remark on the individual procedures:

If one can observe methodological variants in the local parts of the base case process, it is to be reminded that the latter remains within the continuity of the currently applied process, and that reconsidering the Grid Model methodology (either in its local or common aspects) is not part of the CWE FB implementation project.

Currently, there exists an ENTSO-E initiative in order to align European TSOs practices towards the ACER capacity calculation cross-regional roadmap, but in any case the following sequence will have to be respected:

- Design of a CGM methodology by ENTSO-E according to CACM requirements
- Validation of the methodology by NRAs
- Design of an implementation plan.

4.1.6. Remedial Actions [4]

During Flow Based parameter calculation CWE TSOs will take into account Remedial Actions (RA) that are allowed in D-2 while ensuring a secure power system operation i.e. N-1/N-k criterion fulfilment.

In practice, RAs are implemented via entries in the CNE file. Each measure is connected to one CNEC combination and the Flow Based parameter calculation software treats this information.

The calculation can take explicit and implicit RAs into account. An explicit Remedial Action (RA) can be

- changing the tap position of a phase shifter transformer (PST)
- topology measure: opening or closing of a line, cable, transformer, bus bar coupler, or switching of a network element from one bus bar to another

[4] Didactic examples of different types of Remedial Actions (including explicit and implicit variants) can be found in Annex 14.4).

- curative (post-fault) redispatching: changing the output of some generators or a load.

Implicit RA can be used when it is not possible to explicitly express a set of conditional Remedial Actions into a concrete change in the load flow. In this case a FAV (c.f. chapter 4.1.4) will be used as RA.

These explicit measures are applied during the Flow Based parameter calculation and the effect on the CNEs is determined directly.
The influence of implicit RA on CNEs is assessed by the TSOs upfront and taken into account via the FAV factor, which changes the available margins of the CNEs to a certain amount.

Each CWE TSO defines the available RAs in its control area. As cross-border Remedial Actions will be considered only those which have been agreed upon by common procedures (for example limited number of tap position on CWE PST) or explicit agreement (as in ATC process). The agreed actions are assumed binding and available.
The general purpose of the application of RAs is to modify (increase) the Flow Based domain in order to support the market, while respecting security of supply. This implies the coverage of the LTA (allocated capacity from long term auctions) domain as a minimum target.
Some RAs, with a significant influence on elements of neighbouring grids – especially cross-border RAs – have to be coordinated before being implemented in the CNE file. The coordination of cross-border Remedial Actions maintains the security of supply when increasing the capacity that can be offered to the market. Common procedures, indicating amongst others which Remedial Actions can be applied for the capacity calculation stage, have been implemented to facilitate this.

The guidelines[5] for the application of RAs imply that the RAs described in the CNE files can change during the daily Flow Based process in the qualification and verification phase (e.g. as a result of a PST coordination process).

If needed, and in an effort to include the LTA domain, all possible coordinated Remedial Actions will be considered in line with the agreed list of Remedial Actions. Each TSO could, if this does not jeopardise the system security, perform additional RA in order to cover the LTA domain.

During the D-2 / D-1 capacity calculation process, TSOs have the opportunity to coordinate on PST settings. This coordination aims to find an agreement on PST settings which covers all the TSOs needs. The focus is to cover the LTA and if possible the NTCs[6]. This means that the LTAs/NTCs will not cause overloads on CNEs within the Flow Based method. TSOs try to reach this by using only internal RAs as a first step. If this would not be enough the CWE wide PSTs are taken into account in order to mitigate the overloads.

The basic principle of the PST coordination is the following:

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[5] These "guidelines" encompass the operators' expertise and experience gained over the years, combined with the application of operational procedures, and is neither translated nor formalized in documentation designed to external parties.

[6] NTCs were only available during the external parallel run period. After go-live, TSOs will use another reference Flow Based domain – based on the experience built during the external parallel run which will be communicated to Regulators and Market Parties.

- local calculation: TSOs try to cover the NTC/LTA domain using their own PSTs. If this is not sufficient, the TSO incorporate the PSTs of other TSOs in their local load flow calculations. In the end, every TSO comes up with a proposal for the PST tap positions in the CWE region, and the corresponding corners/situations in which the PST should be used.
- exchange of proposals: the proposal(s) is(are) shared between TSOs for review.
- review, coordination, confirmation: TSOs review the proposals and coordinate/agree on the final setting. This is to avoid that contradictory Remedial Actions are used in the same situation. The result is considered to be firm before the verification phase. The information (if necessary an updated CNE file) must be transferred to the D-1 and D processes.

PSTs available for coordination are located in Zandvliet/Vaneyck, Gronau, Diele and Meeden. PST coordination is performed between Amprion, Elia, and TenneT (DE and NL). The PSTs in Austria (Tauern, Ternitz, Ernsthofen) are coordinated in a local process between German and Austrian TSOs and are further taken into account in the coordination as described above.

The coordination process is not necessarily limited to PST adjustment, but usual topology actions can also be considered at the same time and in the same way as the PST setting adjustment.

A prerequisite of a well-functioning coordination is that all involved parties have a dedicated timeframe to perform this coordination. This timeframe should be at best in the night between the initial Flow Based computation and the final Flow Based computation. The PST coordination should start before midnight.

4.1.7. Generation Shift Key (GSK)

The Generation Shift Key (GSK) defines how a change in net position is mapped to the generating units in a bidding area. Therefore, it contains the relation between the change in net position of the market area and the change in output of every generating unit inside the same market area.

Due to convexity pre-requisite of the Flow Based domain, the GSK must be linear.

Every TSO assesses a GSK for its control area taking into account the characteristics of its network. Individual GSKs can be merged if a hub contains several control areas.

A GSK aims to deliver the best forecast of the impact on Critical Network Elements of a net position change, taking into account the operational feasibility of the reference production program, projected market impact on units and market/system risk assessment.

In general, the GSK includes power plants that are market driven and that are flexible in changing the electrical power output. This includes the following types of power plants: gas/oil, hydro, pumped-storage and hard-coal. TSOs will additionally use less flexible units, e.g. nuclear units, if they don't have sufficient flexible generation for matching maximum import or export program or if they want to moderate impact of flexible units.

The GSK values can vary for every hour and are given in dimensionless units. (A value of 0.05 for one unit means that 5% of the change of the net position of the hub will be realized by this unit).

Individual procedures

GSK for the German bidding zone:

The German TSOs have to provide one single GSK-file for the whole German Hub. Since the structure of the generation differs for each involved TSO, an approach has been developed, that allows the single TSO to provide GSK's that respect the specific character of the generation in their own control area and to create out of them a concatenated German GSK in the needed degree of full automation.

Every German TSO provides a reference file for working days, bank holidays and weekends. Within this reference file, the generators are named (with their node-name in the UCTE-Code) together with their estimated share within the specific grid for the different time-periods. It is also possible to update the individual GSK file each day according to the expectations for the target day. So every German TSO provides within this reference-file the estimated generation-distribution inside his grid that adds up to 1.

An example: Reference-file of TSO A for a working day

00:00 – 07:00:

GenA (Hard-Coal)	0,3
GenB (Hard-Coal)	0,3
GenC (Gas)	0,1
GenD (Hydro)	0,2
GenE (Hydro)	0,1

07:00 – 23:00

GenC (Gas)	0,3
GenD (Hydro)	0,5
GenE (Hydro)	0,2

23:00 – 24:00:

GenB (Hard-Coal)	0,2
GenC (Gas)	0,3
GenD (Hydro)	0,4

GenE (Hydro) 0,1

In the process of the German merging, the common system creates out of these four individual reference-files, depending on the day (working day / week-end / bank holiday), a specific GSK-file for every day. Therefore, every German TSO gets it individual share (e.g. TransnetBW: 15%, TTG: 18%, Amprion: 53%, 50HzT: 14 %). The content of the individual reference-files will be multiplied with the individual share of each TSO. This is done for all TSOs with the usage of the different sharing keys for the different target times and a Common GSK file for the German bidding zone is created on daily basis.

Example: Taking the reference-file above, assuming TSO A is TransnetBW, it leads to the following shares in the concatenated German GSK-file:

00:00 – 07:00:

GenA (Hard-Coal)	0,3*0,5 = 0,045
GenB (Hard-Coal)	0,3*0,15 = 0,045
GenC (Gas)	0,1*0,15 = 0,015
GenD (Hydro)	0,2*0,15 = 0,030
GenE (Hydro)	0,1*0,15 = 0,015

07:00 – 23:00:

GenC (Gas)	0,3*0,15 = 0,045
GenD (Hydro)	0,5*0,15 = 0,075
GenE (Hydro)	0,2*0,15 = 0,030

23:00 – 24:00:

GenB (Hard-Coal)	0,2*0,15 = 0,030
GenC (Gas)	0,3*0,15 = 0,045

GenD (Hydro)	0,4*0,15 = 0,060
GenE (Hydro)	0,1*0,54 = 0,015

With this method, the knowledge and experience of each German TSO can be brought into the process to obtain a representative GSK. With this structure, the nodes named in the GSK are distributed over the whole German bidding zone in a realistic way, and the individual factor is relatively small.

The Generation share key (GShK) for the individual control areas (i) is calculated according to the reported available market driven power plant potential of each TSO divided by the sum of market driven power plant potential in the bidding zone.

$$GShK\ TSO_i = \frac{Available\ power\ in\ control\ area\ of\ TSO\ _i}{\sum_{k=1}^{4} Available\ power\ in\ control\ area\ of\ TSO_k}$$

Where k is the index for the 4 individual German TSOs

With this approach the share factors will sum up to 1 which is the input for the central merging of individual GSKs.

Individual distribution per German TSO

TransnetBW:

To determine relevant generation units TransnetBW takes into account the power plant availability and the most recent available information at the time when the individual GSK-file is generated for the MTU:

The GSK factor for every power plant i is determined as:

$$GSK_i = \frac{P_{max,i} - P_{min,i}}{\sum_i^n \left(P_{max,i} - P_{min,i}\right)}$$

Where n is the number of power plants, which are considered for the generation shift within TransnetBW's control area.

Only those power plants which are characterized as market-driven, are put in the GSK if their availability for the target hour is known.

The following types of generation units for middle and peak load connected to the transmission grid can be considered in the GSK:

- hard coal power plants
- hydro power plants
- gas power plants

Nuclear power plants are excluded

Amprion:

Amprion established a regularly process in order to keep the GSK as close as possible to the reality. In this process Amprion checks for example whether there are new power plants in the grid or whether there is a block out of service. According to these changes in the grid Amprion updates its GSK.

In general Amprion only considers middle and peak load power plants as GSK relevant. With other words basic load power plants like nuclear and lignite power plants are excluded to be a GSK relevant node. From this it follows that Amprion only takes the following types of power plants: hard coal, gas and hydro power plants. In the view of Amprion only these types of power plants are taking part of changes in the production.

TenneT Germany:

Similar to Amprion, TTG considers middle and peak load power plants as potential candidates for GSK. This includes the following type of production units: coal, gas, oil and hydro. Nuclear power plants are excluded upfront.

In order to determine the TTG GSK, a statistical analysis on the behavior of the non-nuclear power plants in the TTG control area has been made with the target to characterize the units. Only those power plants, which are characterized as market-driven, are put in the GSK. This list is updated regularly. The individual GSK factors are calculated by the available potential of power plant i (Pmax-Pmin) divided by the total potential of all power plants in the GSK list of TTG.

Austrian GSK:

APG's method to select GSK nodes is analogue to the German TSOs. So only market driven power plants are considered in the GSK file which was done with statistical analysis of the market behaviour of the power plants. In that case APG pump storages and thermal units are considered. Power plants which generate base load (river power plants) are not considered. Only river plants with daily water storage are considered in the GSK file. The list of relevant power plants is updated regularly in order to consider maintenance or outages. In future APG will analyse the usage of dynamic GSK.

Dutch GSK:

TenneT B.V. will dispatch the main generators in such a way as to avoid extensive and not realistic under- and overloading of the units for extreme import or export scenarios. Unavailability due to outages are considered in the GSK.

All GSK units (including available GSK units with no production in de D2CF file) are dispatched pro rata on the basis of predefined maximum and minimum production levels for each active unit. The total production level remains the same.

The maximum production level is the contribution of the unit in a predefined extreme maximum production scenario. The minimum production level is the contribution of the unit in a predefined extreme minimum production scenario. Base-load units will have a smaller difference between their maximum and minimum production levels than start-stop units.

With Pi0 being the initial MW dispatch of unit i, and Pi1 being the new dispatch of unit i after the redispatch, then

$$P_{i1} = Pmin_i + (Pmax_i - Pmin_i)\frac{(\sum_k P_{k0} - \sum_k Pmin_k)}{(\sum_k Pmax_k - \sum_k Pmin_k)} \text{ (eq. 1)}$$

where "k" is the index over all active GSK units.

The linear GSK method also provides new GSK values for all active GSK units. This is also calculated on the basis of the predefined maximum and minimum production levels:

$$GSK_i = \frac{Pmax_i - Pmin_i}{\sum_k Pmax_k - \sum_k Pmin_k} \text{ (eq. 2)}$$

where "k" is the index over all active GSK units.

The 24-hour D2CF is adjusted, as such that the net position of the Netherlands is mapped to the generators in accordance to eq.1.

The GSK is directly adjusted in case of new power plants. TTB includes the outage information of generators daily in the GSK, which is based on the information sent by Market Parties.

Belgian GSK:

Elia will use in its GSK all flexible and controllable production units which are available inside the Elia grid (whether they are running or not). Units unavailable due to outage or maintenance are not included.

The GSK is tuned in such a way that for high levels of import into the Belgian hub all units are, at the same time, either at 0 MW or at Pmin (including a margin for reserves) depending on whether the units have to run or not (specifically for instance for delivery of primary or secondary reserves). For high levels of export from the Belgian hub all units are at Pmax (including a margin for reserves) at the same time.

After producing the GSK, Elia will adjust production levels in all 24 hour D2CF to match the linearised level of production to the exchange programs of the reference day as illustrated in the figure 4-1.

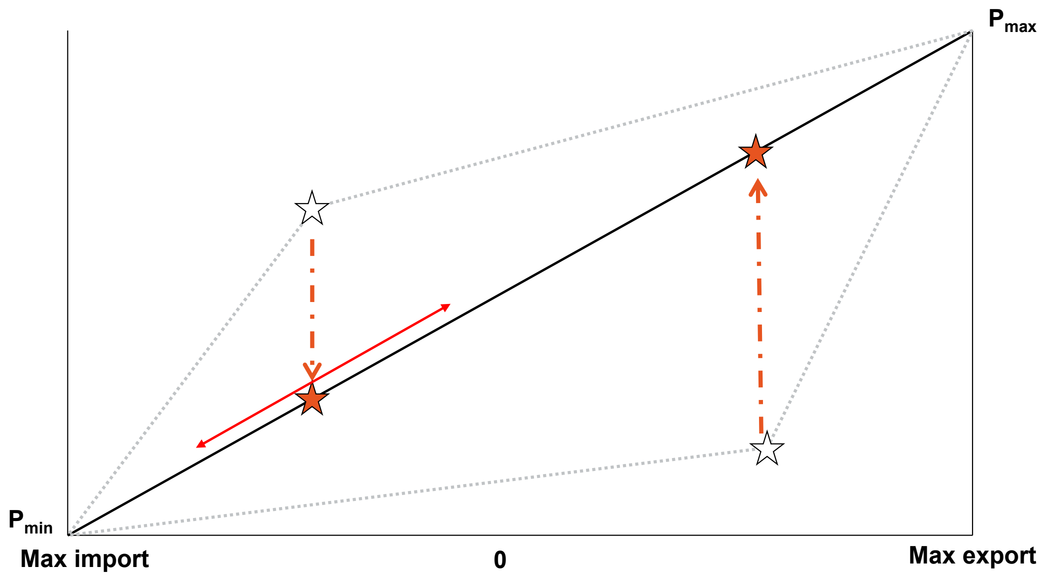

Figure 4-1: Belgian GSK.

French GSK:

The French GSK is composed of all the units connected to RTE's network.
The variation of the generation pattern inside the GSK is the following: all the units which are in operations in the base case will follow the change of the French net position on a pro-rata basis. That means, if for instance one unit is representing n% of the total generation on the French grid, n% of the shift of the French net position will be attributed to this unit.

About 50Hertz:
50Hertz sends its D2CF and GSK files which improves the quality of the German data set.

Due to the large distance of 50HZ to the CWE borders, not considering 50HZ Critical Network Elements within the CWE FB calculation is not considered a problem.

Alegro GSK:
In order to integrate ALEGrOs Evolved Flow-Based approach, two virtual bidding zones (ALBE & ALDE) are defined as described in Article 4.2.9.

The two bidding zones (ALBE & ALDE) which model the ALEGrO interconnector possess a GSK equal to 1 on the nodes where the ALEGrO Interconnector converters are installed.

Summary and overview concerning the variability of the GSKs during the day:

- APG, Elia and TTB use GSKs according to their GSK concept, which means constant values over the day.

- The German TSOs have two GSKs for two different periods of a day as described above (peak, off-peak).
- Since RTE is using pro-rata GSK, the values in the French GSK file change every hour.

4.1.8. Flow Reliability Margin (FRM)

The origin of the uncertainty involved in the capacity calculation process for the day-ahead market comes from phenomena like external exchanges, approximations within the Flow Based methodology (e.g. GSK) and differences between forecasts and realized programs. This uncertainty must be quantified and discounted in the allocation process, in order to prevent that on day D TSOs will be confronted with flows that exceed the maximum allowed flows of their grid elements. This has direct link with the firmness of Market Coupling results. Therefore, for each Critical Network Element, a Flow Reliability Margin (FRM) has to be defined, that quantifies at least how the before-mentioned uncertainty impacts the flow on the Critical Network Element. Inevitably, the FRM reduces the remaining available margin (RAM) on the Critical Network Elements because a part of this free space that is provided to the market to facilitate cross-border trading must be reserved to cope with these uncertainties.

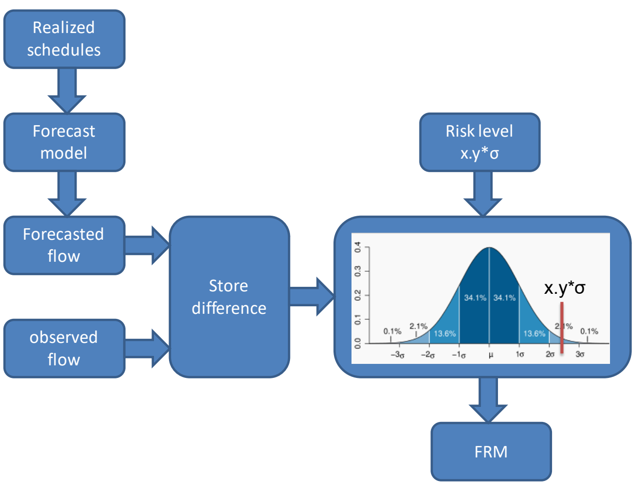

Figure 4-2: FRM Assessment Principle

The basic idea behind the FRM determination is to quantify the uncertainty by comparing the Flow Based model to the observation of the corresponding timestamp in real time. More precisely, the base case, which is the basis of the Flow Based parameters computation at D-2, is compared with a snapshot of the transmission system on day D. A snapshot is like a photo of a TSO's transmission system, showing the voltages, currents, and power flows in the grid at the time of taking the photo. This basic idea is illustrated in the figure 4.2.
In order to be able to compare the observed flows from the snapshot with the predicted flows in a coherent way, the Flow Based model is adjusted with the realized schedules corresponding to the instant of time that the snapshot was created. In this way, the same commercial exchanges are taken into account when comparing the forecast flows with the observed ones (e.g. Intraday trade is reflected in the observed flows and need to be reflected in the predicted flows as well for fair comparison).

The differences between the observations and predictions are stored in order to build up a database that allows the TSOs to make a statistical analysis on a significant amount of data. Based on a prede-

fined risk level[7], the FRM values can be computed from the distribution of flow differences between forecast and observation.
By following the approach, the subsequent effects are covered by the FRM analysis:

- Unintentional flow deviations due to operation of load-frequency controls
- External trade (both trades between CWE and other regions, as well as trades in other regions without CWE being involved)
- Internal trade in each bidding area (i.e. working point of the linear model)
- Uncertainty in wind generation forecast
- Uncertainty in Load forecast
- Uncertainty in Generation pattern
- Assumptions inherent in the Generation Shift Key (GSK)
- Topology
- Application of a linear grid model

When the FRM has been computed following the above-mentioned approach, TSOs may potentially apply a so-called "operational ad-

[7] The risk level is a local prerogative which is closely linked to the risk policy applied by the concerned TSO. Consequently, the risk level considered by individual TSOs to assess FRM from the statistical data may vary. This risk level is a fixed, reference that each TSO has to respect globally in all questions related to congestion management and security of supply. This risk level is a pillar of each TSO's risk policies.

justment" before practical implementation into their CNE definition. The rationale behind this is that TSOs remain critical towards the outcome of the pure theoretical approach in order to ensure the implementation of parameters which make sense operationally. For any reason (e.g.: data quality issue), it can occur that the "theoretical FRM" is not consistent with the TSO's experience on a specific CNE. Should this case arise, the TSO will proceed to an adjustment.

It is important to note here that:

This adjustment is supposed to be relatively "small". It is not an arbitrary re-setting of the FRM but an adaptation of the initial theoretical value. It happens only once per CNE during the FRM analysis (in other words, the TSO will not adjust its FRM at any Flow Based computation). Eventually, the operational FRM value is computed once and then becomes a fixed parameter in the CNE definition.

This adjustment process is not expected to be systematic, but rather rare on the contrary, as much effort is put on the representativeness of the theoretical values.

The differences between operationally adjusted and theoretical values shall be systematically monitored and justified, which will be formalized in a dedicated report towards CWE NRAs (cf. Annex 14.5).[8]

The theoretical values remain a "reference", especially with respect to any methodological change which would be monitored through FRM.

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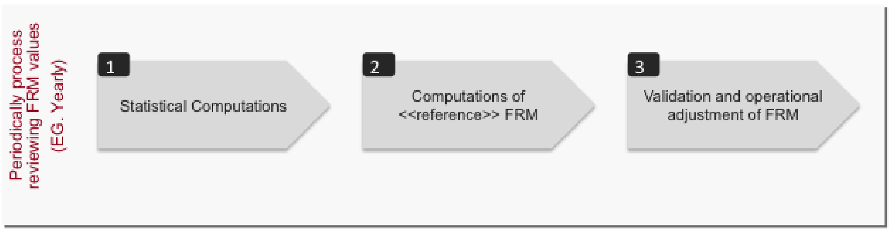
[8] A dedicated, confidential report on FRM (FRM values and operational adjustment for main active Critical Branches of the parallel run) is available in Annex 14.5.

For matter of clarification, we remind here that for each CNE (or CNEC for the N-1 cases), the FRM campaign leads to one single FRM value which then will be a fixed parameter in the CNE definition. FRM is not a variable parameter.
However, since FRM values are a model of the uncertainties against which TSOs need to hedge, and considering the constantly changing environment in which TSOs are operating, and the statistical advantages of building up a larger sample, the very nature of FRM computation implies regular re-assessment of FRM values. Consequently, TSOs consider recomputing FRM values, following the same principles but using updated input data, on a regular basis, at least once per year.

The general FRM computation process can then be summarized by the following figure:



Step 1: elaboration of statistical distributions, for all Critical Network Elements, in N and N-1 situations.
Step 2: computation of theoretical (or reference) FRM by applying of a risk level on the statistical distributions.

Step 3: Validation and potentially operational adjustment. The operational adjustment is meant to be used sporadically, only once per CNE, and systematically justified and documented.
CWE TSOs intend a regular update, at least once a year, of the FRM values using the same principles. Exceptional events[9] may trigger an accelerated FRM re-assessment in a shorter time frame, but in all cases one should keep in mind that for statistical representativeness, the new context integrated into new FRM values needs to be encompassed in several months of data.

In practice, FRM values have been computed end of 2012 on the basis of the winter 2010-2011 and summer 2011 period. The graphical overview below displays the FRM values associated to the main active CNEs of the internal parallel run of 2012. One can basically notice here that:

- FRM values spread between 5% and 20% of the total capacity Fmax of the line, depending on the uncertainties linked to the flows on the CNECs.
- Operational adjustments are performed in both directions (increase or decrease calculated FRM value), and essentially consist in correcting outliers, or missing, high reference values.

[9] Exceptional events could be: important modification of the grid (new line, decommissioning of large generating units...), change in the capacity calculation method, enlargement of the coupled area, implementation of advanced hybrid coupling etc...

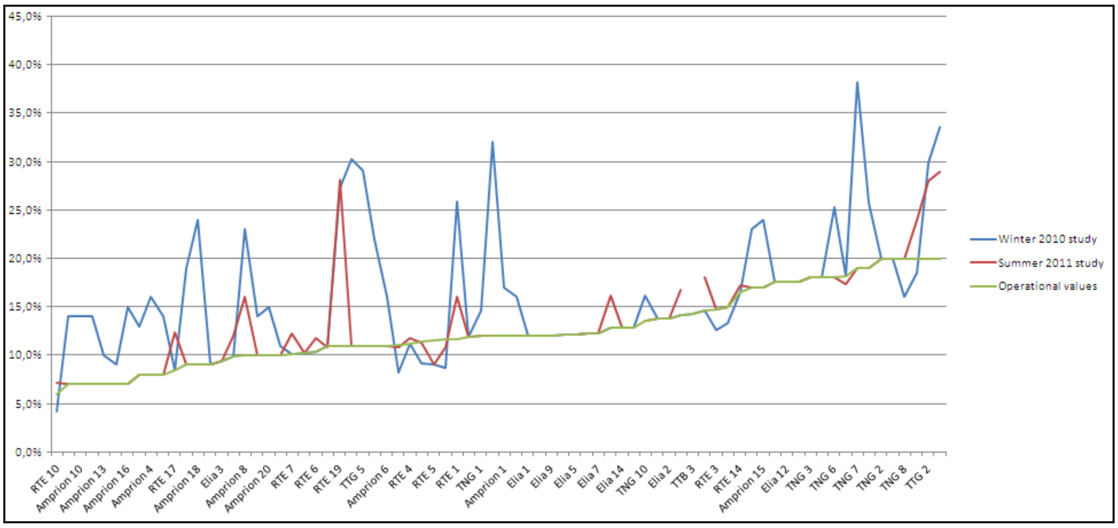


Figure 4-3: Graphical overview of the operational FRM values for the active CNEs of the parallel run (CNE labelling is purely arbitrary and does not correspond to the future fixed anonymization)

The values that will be used for go-live are currently being assessed on the basis of year 2013 data by CWE TSOs, and should be implemented by the end of May 2014. In this way, observation of new FRM values is guaranteed during the parallel run. A specific report will be communicated to the NRAs in this respect which will indicate for each active CNE of the current parallel run:

- The reference FRM
- The operational adjustment10 and its justification.

10 Operational adjustment is not a daily operational step but a single adjustment possibly done on FRM values when the latter are computed.

4.1.9. Specific limitations not associated with Critical Network Elements (external constraints)

Besides electrical Critical Network Elements, other specific limitations may be necessary to guarantee a secure grid operation. Import/Export limits declared by TSO are taken into account as “special” Critical Network Elements, in order to guarantee that the market outcome does not exceed these limits. TSOs remind here that these constraints are not new, since already taken into account implicitly when computing NTCs[11]. With Flow Based, they appear explicitly and their usage is justified by several reasons, among which:

- Avoid market results which lead to stability problems in the network, detected by system dynamics studies.

Avoid market results which are too far away from the reference flows going through the network in the base-case, and which in exceptional cases would induce extreme additional flows on grid elements, leading to a situation which could not be verified as safe by the concerned TSO during the verification step (c.f. chapter 4.2.6).

[11] Discrepancies can be identified in some cases, for instance when the sum of export (respectively import) NTCs of a given hub are larger than the export (respectively import) EC of the same hub in FB. These discrepancies can have several reasons :

1. At implementation level, the ATC and FB model obviously differ, which could lead to slightly different results.
2. The NTCs belong to an « unlikely » situation (typically, the double Belgium export), therefore it is foreseeable that just summing up NTCs on borders and comparing them with ECs can lead to differences.

In other words, FB capacity calculation includes contingency analysis, based on a DC loadflow approach. This implies that the constraints determined are active power flow constraints only. Since grid security goes beyond the active power flow constraints, issues like:

- voltage stability,
- dynamic stability,
- ramping (DC cables, net positions),

need to be taken into account as well. This requires the determination of constraints outside the FB parameter computation: the so-called external constraints (ECs).

One also needs to keep in mind that EC are therefore crucial to ensure security of supply and are in this respect systematically implemented as an input of the FB calculation process. In other words, the TSO operator does not decide including or not an EC on a given day (or even hour), he will always integrate an external constraint whatever the current operational conditions are, in order to prevent unacceptable situations.

These external constraints may also be modeled as a constraint on the global net position (the sum of all cross border exchanges for a certain bidding zone in the single day-ahead coupling), thus limiting the net position of the respective bidding zone with regards to all Capacity calculation regions (CCRs) which are part of the single day-ahead coupling. When modeled as such, the EC will not form part of the FB calculation and will thus not be modeled as a Critical Network Element.

In the case that an external constraint is limiting the market, it receives a shadow price. Indeed, the shadow price indicates the welfare increase when the constrained element is marginally relieved. The shadow price, a useful indicator to assess the market impact of a given CNE, will be part of the active constraint reporting towards NRAs.

External constraints versus FRM:

FRM values do not help to hedge against the situations mentioned above. By construction, FRMs are not covering voltage and stability issues which can occur in extreme cases, not only because FB is based "only" on a DC model, but also because as they are statistical values looking "backward", (based on historical data), they cannot cover situations which never happened. And this is exactly the purpose of external constrains, to prevent unacceptable situations (which by definition did not happen), like voltage collapses or stability issues on the grid.

Therefore, FRM on the one hand (statistical approach, looking "backward", and "inside" the FB DC model) and external constraints on the other hand (deterministic approach, looking "forward", and beyond the limitations of the FB DC model) are complementary and cannot be a substitute to each other. Each TSO has designed its own thresholds on the basis of complex studies, but also on operational expertise acquired over the years.
The advantage of FB in this respect is that it makes the design and activation of external constrains fully transparent. Not only are the EC explicit Critical Network Elements (while they are taken into account implicitly when computing NTCs) but also are they easily identifiable in the publication. Indeed, their PTDFs are straightforward (0;0;0;1 or -1, the margin being the import/export limit) and can be directly linked to its owner resp. bidding zone, since it re-

lates to the 1 or -1 in the PTDF matrix. Therefore CWE TSOs consider that full transparency is already provided in this respect.

The following sections will depict in detail the method used by each TSO[12] to design and implement external constrains.

Austrian External Constraint

APG does not apply an import or export constraint.

German External Constraint:

For the German-Luxembourgian Bidding Zone no import or export constraint is applied.

Dutch External Constraint:

TenneT NL determines the maximum import and export constraints for the Netherlands based on off-line studies, which also include voltage collapse and stability analysis during different import and export situations. The study can be repeated when necessary and may result in an update of the applied values for the external constraints of the Dutch network.

Belgian External Constraint:

Elia uses an import limit constraint which is related to the dynamic stability of the network. This limitation is estimated with offline studies which are performed on a regular basis.

[12] Any time a TSO plans to change its method for EC implementation, it will have to be done with NRAs' agreement, as it is the case for any methodological change.

French External Constraint:

RTE does not apply external constraints.

4.2. Coordinated Flow Based Capacity Calculation Process

4.2.1. Merging

Basis for the calculation process is a model of the grid, the Common grid Model (CGM) that represents the best forecast of the corresponding hour of the execution day (day D). Due to the timeline within the process, the creation of the CGM has to be performed two-days ahead of day D. The CGM is a data set created by merging individual grid models by a merging entity.

This data set contains

- the single D-2CF data sets from CWE TSOs: Elia (BE), RTE (FR), TenneT (NL), TenneT (DE), Transnet BW (DE), Amprion (DE), 50HzT (DE) and APG (AT)[13]
- the DACF data sets from the non-participating TSOs of continental Europe

The network of German Control Block (GCB) is composed of EnDK (DACF), TenneT DE, Transnet BW, Amprion, 50Hertz and CREOS in a pre-merge. DC cables linked to other control blocks are handled as injections in the model. The schedules on these cables are consistent with the forecasted exchange programs.

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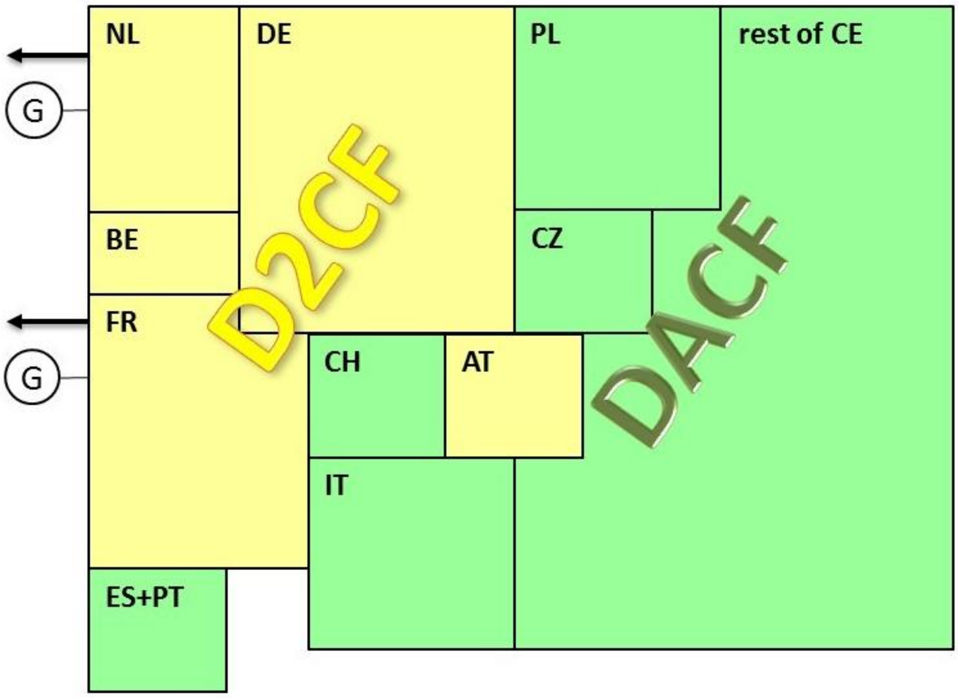
[13] The nclusion of the D-2CF data from Swissgrid (CH) is ongoing.

The DACF data sets of non-participating TSOs are needed to take the physical influences of these grids properly into account when calculating transfers between FR-BE-NL-DE-AT. In the figure below not shown zones are external zones, which are represented as positive or negative injections.



The merging process will be done in the following steps, according to the internationally agreed merging rules:

1. Check of individual data sets of the participating and non-participating TSOs:
    - Check for format
    - Check loadflow convergence
2. Balance check (import/export situation):

   In case of mismatch, balance adjustment according to the internal CWE Merging Guidelines.
3. Merging process:

- Check interconnector status. If necessary adjustment according to the CWE Merging Guidelines
- All CWE Control Blocks will be adapted by using their GSK in order to reach Balanced Day Net Positions, within a Feasibility Range provided by Control Blocks. This process, of merging by using GSK, allows CWE TSOs to provide their best estimate (shaping Flow-Based domain) and allows a merge not impacting shape of Flow-Based domain when reaching Reference Day Net Positions.

Note: the merging activity is not a fully automatic one and comprises a sanity check (format compliance, tie-lines status, bidding zone balance) of each individual file with a specific operational procedure in case of inconsistencies.

4.2.2. Pre-qualification[14]

Before the first Flow Based parameter calculation the TSO checks the consistency of the applied CNE-file with the forecasted grid-situation. Special attention is given to the Remedial Actions (RA) described in the CNE-file. Every TSO has to check, if the described RAs are available in the forecasted grid situation, or if some adaptations might have to be done. This pre-qualification step also contains, if necessary, the information sharing and coordination with adjacent TSOs.

4.2.3. Centralized Initial-Flow Based parameter computation

The Flow Based parameters computation is a centralized computation. As the whole grid is linearized, the calculation can be done with the much faster DC approach and delivers two main classes of parameters needed for the following steps of the FB MC.

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[14] Prequalification is a CNE assessment phase available at any moment of the FB process, during which each TSO can assess the relevance of its CNE set, with respect to the operating conditions at the moment of capacity calculations. Therefore, operational experience plays a major role. Concretely, this phase is facilitated by a tool which allows an efficient review of the Critical Branches, as well as a cross comparison of interconnectors and associated Remedial Actions. As such, prequalification is an introduction to qualification since it provides the first elements to be discussed and coordinated between TSOs later during the FB process, which is why it is presented here before qualification in the operational sequence. In practice, prequalification can be done before each FB common computation.

i) Remaining Available Margin (RAM):

As the reference flow (Fref) is the physical flow computed from the common base case, it reflects the loading of the Critical Network Elements given the exchange programs of the chosen reference day. The RAM is determined with the formula:

RAM = Fmax – Fref – FRM – FAV - AMR

Out of the formula, the calculation delivers, with respect to the other parameters, the remaining available margin for every CNEC. This RAM is one of the inputs for the subsequent process steps. The adjustment for minimum RAM (AMR) is applied after the qualification step[15].

ii) Power Transfer Distribution Factors (PTDFs):

The PTDFs are calculated by varying the exchange program of a zone (=market area), taking the zone-GSK into account. For every single zone-variation the effect on every CNE loading is monitored and the effect on the loadflow is calculated in percent (e.g. additional export of BE of 100 MW has an effect of 10 MW on a certain CNE => PTDF = 10%). The GSK for the zone has an important influence on the PTDF, as it translates the zone-variation into an increase of generation in the specific nodes.

The PTDF characterizes the linearization of the model. In the subsequent process steps, every change in the export programs is trans-

[15] Please refer to paragraph 4.2.5 for more details.

lated into changes of the flows on the CNEs by multiplication with the PTDFs.

4.2.4. Flow Based parameter qualification

The operational Flow Based parameter qualification process is executed locally by each TSO, and covers amongst others the following action. For each non-redundant CNE, limiting the Flow Based-domain, the TSO checks, if Remedial Actions (RA) are at hand, that could enlarge the Flow Based-domain. This is in coherence with the local capacity calculation procedures and risk policies. Depending on the nature and the complexity of the specific RA, the RAs could be applied explicitly in the CNE-file by a detailed description or, if too complex and the effect is known or can be estimated, by adapting the Final Adjustment Value (c.f. chapter 4.1.4). Close coordination between CWE TSOs is needed for the application of the different RAs. A coordination of cross-border Remedial Actions enhances the security of supply and can increase the capacity that can be offered to the market. Information sharing among TSOs plays a key role in this respect. Common procedures indicating amongst others which Remedial Actions will be applied for this capacity calculation.

The aim is to qualify in this stage the maximum Flow Based domain that can be given, with respect to the TSO’s risk policies. The following criteria and parameters can help and guide through this phase:

- The Flow Based domain should be comparable with the one of the previous day (i.e. max net positions comparison) if the environment did not change significantly (i.e. consumption forecast, outages, renewable energy forecasts)
- The Flow Based domain should be bigger than the LTA domain

- The current reference program has to be inside the Flow Based-domain, nor may there be violations of the formula: Fref < Fmax – FRM – FAV.

4.2.5. MinRAM process

The MinRAM process is applied to provide a minimal FB domain to the market and to ensure that the capacity provided within the CWE region is compliant with the provisions of Article 16 of Regulation (EU) 2019/943.

The MinRAM process is applied using the minRAM factor attribute of each CNEC which guarantees a minimal RAM per CNEC.

The minRAM factor will be set between 20% and 200%[16] at CNEC level to comply with the minimum margin of 70% and possible national derogations and/or action plans following from the relevant provisions of article 14 to 16 of Regulation (EU) 2019/943[17].

In exceptional circumstances, the minRAM factor can be set below 20% by a TSO in case required to maintain operational security, in which case the TSO needs to justify this to the regulatory authorities.

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[16] For the bidding zones which calculate the impact of non-CWE flows according to forecast, the impact of this forecast might lead to relieving flows leading to MinRAM applied higher than 70%.

[17] All derogations (AT, BE, FR & NL) can be found here. DE action plan can be found here. NL action plan can be found here.

It is the responsibility of the individual CWE TSOs to determine the appropriate values for minRAM which ensure compliance with the minimum margin of 70% and possible national derogations and/or action plans following from the relevant provisions of article 14 to 16 of Regulation (EU) 2019/943, this document does not specify which minRAM values will be applied per TSO. The responsibility for monitoring the compliance of the individual CWE TSOs, lies with their relevant NRA.

A TSO may apply his minRAM factor at different steps of the Flow based calculation process and may decide to not apply or reduce the minRAM factor in certain circumstances on specific CNECs or the full set of the TSOs' CNECs, justified to regulatory authorities. The reduction can be performed:

a. before the initial flow based parameter computation CNEC
b. at the qualification phase
c. during the verification process

The reduction of the minRAM factor can be triggered in situations when there are insufficient available remedial actions, costly or not, in order to ensure the security of supply and system security for any steps mentioned above.

The high-level calculation process is the following:

- CNECs with a RAM of less than the minRAM factor multiplied by Fmax at zero-balance are assigned an AMR value (adjustment for minRAM) in order to increase the RAM.
- Calculation of the AMR (negative value means increase in capacity same as for FAV):
    - AMR = Min(0; Fmax – Fref – FRM -FMax*X)
      and X = minRAM factor

- RAM provided in further calculations then includes also the computed AMR:
  - RAM = FMax – Fref – FRM – FAV – AMR

4.2.6. Flow Based parameter verification

After the qualification phase, the TSOs provide an updated CNE file to the Common System. Based on this updated CNE-file, a second Flow Based-parameter calculation is started. This next calculation delivers the largest possible Flow Based domain that respects the Security of Supply (SoS) domain. This domain is modified in order to take into account the "MinRAM". During the verification step, TSOs check whether the computed Flow Based domain is secure, with a possibility to identify constraints through an AC load flow analysis. Therefore, at this step of the process, TSOs have the possibility to ascertain the correctness of the Flow Based parameters generated by the centralized computation:

- TSOs can check the grid security in the relevant points (e.g. vertices) of the Flow Based domain by customizing the generation pattern to the commonly observed one for the corresponding vertex instead of using the linear GSK
- TSOs can perform a full AC load flow analysis of the relevant points, thereby taking into account reactive power flows
- TSOs can check if the voltage limits of the equipment are respected
- TSOs can assess voltage stability (voltage collapse)
- TSOs can investigate extreme net positions

If security issues are discovered, TSOs can update their Critical Network Element files (by adding new CNEs, that were not perceived upfront as being limiting (for instance in the case of combined and/or unusual scheduled outages), by adapting the Final Adjustment Value), or by excluding CNECs from the "MinRAM" application).

After the verification step and possibly adaptation of the CNE-file, the final Flow Based-parameter calculation can be performed, which includes adjustment to long-term nominations (c.f. chapter 4.2.8) and presolve (c.f. chapter 4.3.1) steps.

4.2.7. LTA inclusion check

The LTA inclusion can be performed in the Flow Based common system or by Euphemia. The execution of the LTA inclusion by Euphemia is the target solution. The current solution is the execution in the Flow Based Common System with Virtual Branches. The switch towards the target solution will be notified to Market Participants in due time.

1. Implementation of LTA inclusion at Flow Based common system side

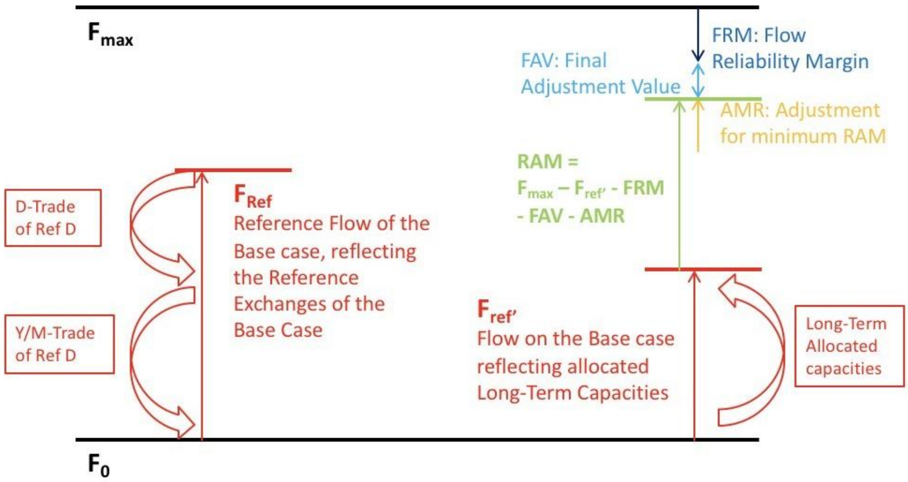
Given that Programming Authorizations for long term allocated capacity (LTA) have already been sent out in D-2 Working Days (according to the current version of the Auction Rules), the long-term-allocated capacities of the yearly and monthly auctions have to be included in the initial Flow Based-domain which is calculated, before taking into account the cross-border nominations. This will avoid that the flow based domain provided to the day-ahead allocation (after taking into account the cross-border nominations) would not include the 0 hub-position point. This can be checked after each Flow Based-parameter-calculation. The fundamental reasons for designing this "LTA coverage" are explained in details in Annex 14.6.

The figure below illustrates the calculation that has to be done:

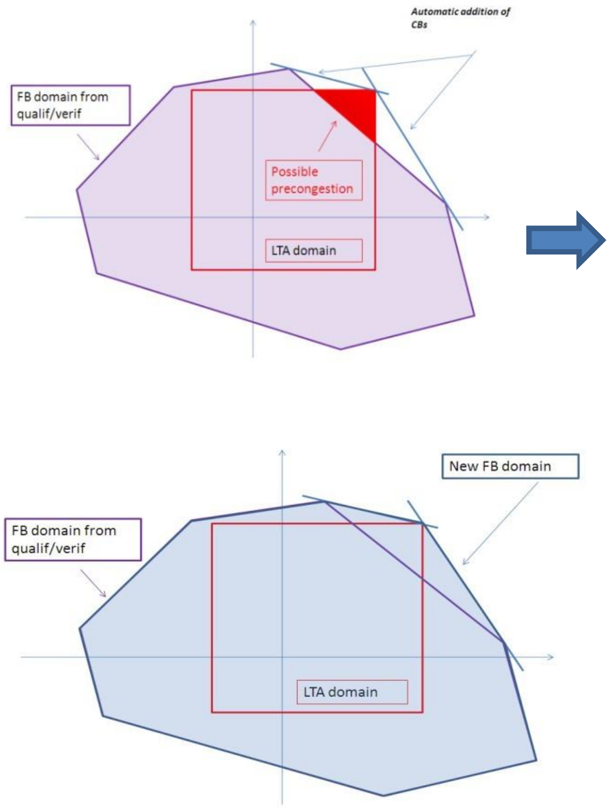
After each calculation a check can be performed if the remaining available margin after LTA adjustment is negative.
For every presolved CNE the following check is performed

$$Fref^* = Fref - \sum_{i=hub} PTDF_i * 〚(Ref〛_{prog\ i} - LTA_i)$$

and then the following equation is checked
RAM* = Fmax – Fref* - FRM – FAV- AMR < 0



If the remaining margin is smaller than zero, this means the LTA is not fully covered by the Flow Based domain. In this case, a method is applied that enlarges the Flow Based-domain in a way that all LTA are included. Virtual CNEs are created and introduced, which replace the CNE for which RAM < 0, and that guarantee the inclusion of all LTA, as illustrated in the figure below.



Experience of the LTA inclusion can be found in Annex 14.19.

2. Implementation of LTA inclusion at Euphemia side ("Extended LTA")

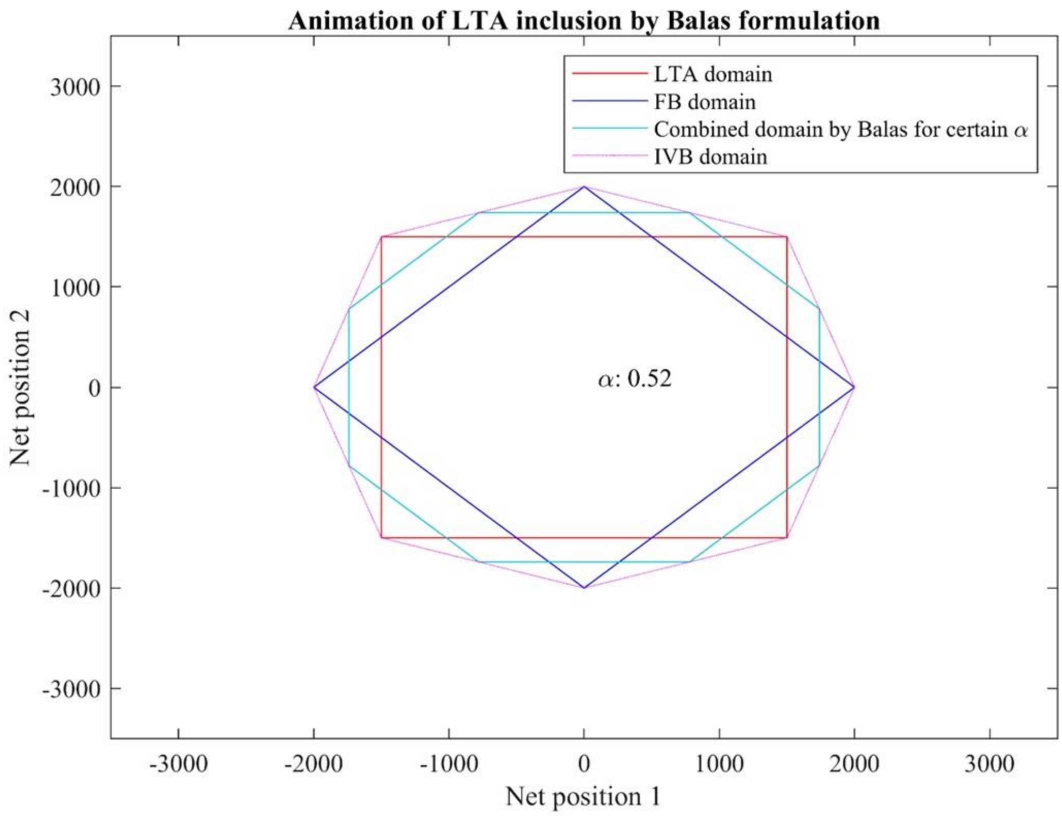
The LTA inclusion can be performed at Euphemia side. In this case TSOs send a virgin domain with MinRAM applied and a LTA domain. Euphemia will be able to combine the two domains in order to simulate similar behavior as with the Virtual Branches approach. In other words, the concept is to allow the optimizer to use any linear combination of the LTA domain and the physical FB domain. The result is similar to the Virtual Branches domain (as presented in the approach above), just without any VB creation upfront. The set of feasible market clearing points should be the same as for the VB approach, the approach is just more efficient and scalable.

The mathematical description can be found in the Annex 14.29 while the comparison between the two approaches can be found in the Annex 14.30.

Please find a pedagogical example below. In this 2D example, you can find:

- A simplified physical FB domain in blue
- A LTA domain in red
- The alpha which represents the choice from the algorithm to choose for one domain or the other
- The Virtual Branches domain in purple

The three first inputs are used by the extended LTA approach and can model the cyan domain which can be similar to the LTA domain (alpha = 1), to the FB domain (alpha =0) or to any domain in between. Therefore, the set of feasible market coupling points will be the same as for the Virtual Branches approach.



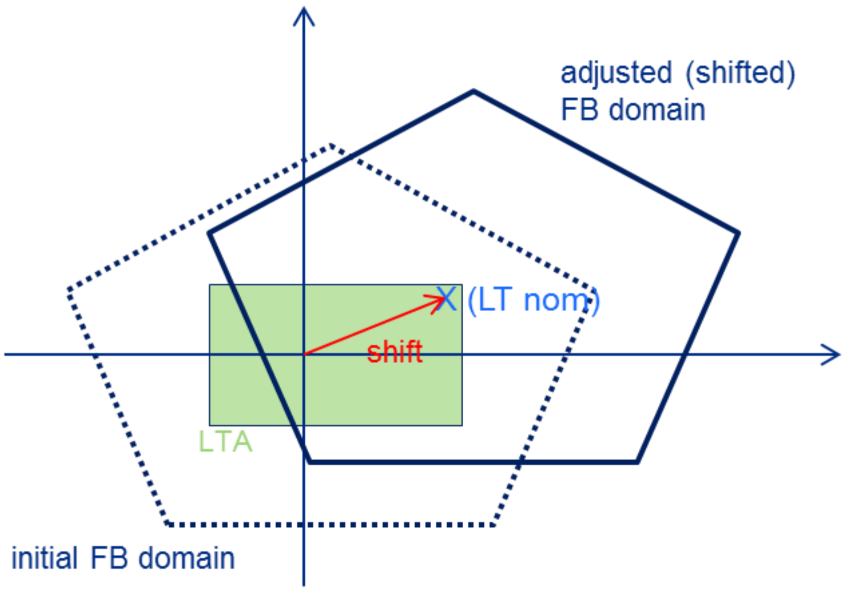
Remark: Even if the operational solution will be switched to the Extended LTA approach, the computation of a Final FB domain with Virtual Branches as presented before will remain for the sake of transparency towards Market Parties, Shadow Auctions and Intraday ATC exctraction.

4.2.8. LTN adjustment

In case all CWE borders use FTRs, LTN adjustment can be skipped.

As the reference flow (Fref) is the physical flow computed from the common base case, it reflects the loading of the Critical Network Elements given the exchange programs of the chosen reference day. Therefore, this reference flow has to be adjusted to take into account only the effect of the LTN (Long Term Nominations) of day

D as soon as they are known[18]. The effect on the domain is schematically visualized in the following figure.



For the LTN adjustment, the same principle has to be applied for every constraining element. A linear "backward-forward-calculation" with the LTNs multiplied with the PTDFs delivers the flow on the CNEs affected by these LTNs. The remaining margin for the DA-allocation can be calculated by:

[18] A description of the publication of the initial and final FB domain can be found in Annex 14.6.

RAM = Fmax – Fref' – FRM – FAV - AMR

*Fref' = Fref + (LTN – RefProg)*PTDF*

4.2.9. Integration of HVDC interconnector on CWE bidding zone borders

1 The CWE TSOs apply the evolved flow-based (EFB) methodology when including HVDC interconnectors on the CWE bidding zone borders. According to this methodology, a cross-zonal exchange over an HVDC interconnector on the CWE bidding zone borders is modelled and optimised explicitly as a bilateral exchange in capacity allocation, and is constrained by the physical impact that this exchange has on all CNECs considered in the final flow-based domain used in capacity allocation.

2 In order to calculate the impact of the cross-zonal exchange over a HVDC interconnector on the CNECs, the converter stations of the cross-zonal HVDC shall be modelled as two virtual hubs, which function equivalently as bidding zones. Then the impact of an exchange between two bidding zones A and B over such HVDC interconnector shall be expressed as an exchange from the bidding zone A to the virtual hub representing the sending end of the HVDC interconnector plus an exchange from the virtual hub representing the receiving end of the interconnector to the bidding zone B:

$$PTDF_{A\rightarrow B,l} = (PTDF_{A,l} - PTDF_{VH\_1,l}) + (PTDF_{VH\_2,l} - PTDF_{B,l})$$

with

$PTDF_{VH\_1,l}$	zone-to-slack $PTDF$ of Virtual hub 1 on a CNEC l, with virtual hub 1 representing the converter station at the sending end of the HVDC interconnector located in bidding zone A

$PTDF_{VH\_2,l}$ zone-to-slack $PTDF$ of Virtual hub 2 on a CNEC l, with virtual hub 2 representing the converter station at the receiving end of the HVDC interconnector located in bidding zone B

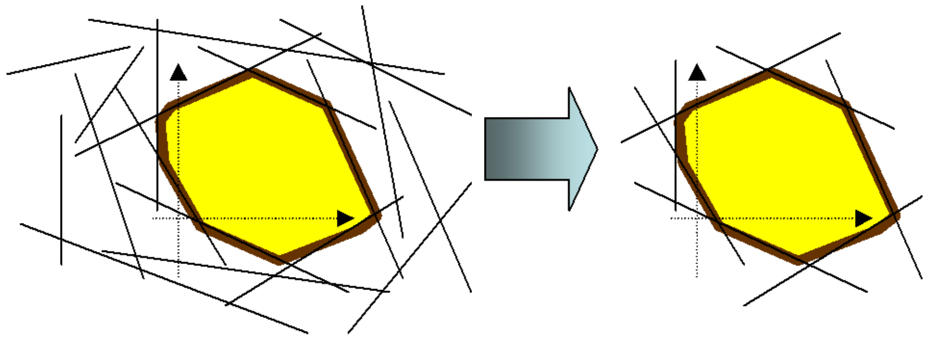
3 The PTDFs for the two virtual hubs $PTDF_{VH\_1,l}$ and $PTDF_{VH\_2,l}$ are calculated for each CNEC and they are added as two additional columns (representing two additional virtual bidding zones) to the existing $PTDF$ matrix, one for each virtual hub.

4 The virtual hubs introduced by this methodology are only used for modelling the impact of an exchange through a HVDC interconnector and no orders shall be attached to these virtual hubs in the coupling algorithm. The two virtual hubs will have a combined net position of 0 MW, but their individual net position will reflect the exchanges over the interconnector. The flow-based net positions of these virtual hubs shall be of the same magnitude, but they will have an opposite sign.

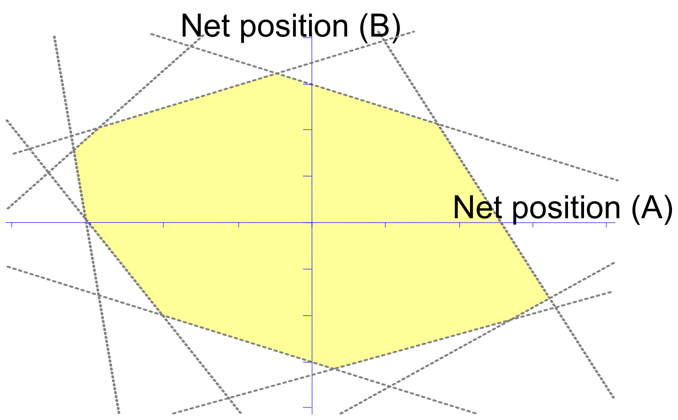
4.3. Output data

4.3.1. Flow Based capacity domain

The Flow Based parameters that have been computed indicate what net positions, given the Critical Network Elements that are specified by the TSOs in CWE, can be facilitated under the Market Coupling without endangering the grid security. As such, the Flow Based parameters act as constraints in the optimization that is performed by the Market Coupling mechanism: the net positions of the bidding zones and virtual hubs in the Market Coupling are optimized in a way enabling that the day-ahead market welfare is maximized while respecting the constraints provided by the TSOs. Although from the TSO point of view all Flow Based parameters are relevant and do contain information, not all Flow Based parameters are relevant for the Market Coupling mechanism. Indeed, only those Flow Based constraints that are most limiting the net positions need to be respected in the Market Coupling: the non-redundant constraints. The redundant constraints are identified and removed by the TSOs by means of the so-called presolve. This presolve step is schematically illustrated in the two-dimensional example below:



In the two-dimensional example shown above, each straight line in the graph reflects the Flow Based parameters of one Critical Network Element. A line indicates for a specific Critical Network Element, the boundary between allowed and non-allowed net positions: i.e. the net positions on one side of the line are allowed whereas the net positions on the other side would overload this Critical Network Element and endanger the grid security. As such, the non-redundant, or presolved, Flow Based parameters define the Flow Based capacity domain that is indicated by the yellow region in the two-dimensional figure above. It is within this Flow Based capacity domain (yellow region) that the net positions of the market can be optimized by the Market Coupling mechanism. A more detailed representation of a two-dimensional Flow Based capacity domain is shown hereunder.



The intersection of multiple constraints, two in the two-dimensional example above, defines the vertices of the Flow Based capacity domain.

4.3.2. Outputs for extended LTA implementation

When the Extended LTA inclusion is considered, TSOs will send two files in order to compute the market coupling:

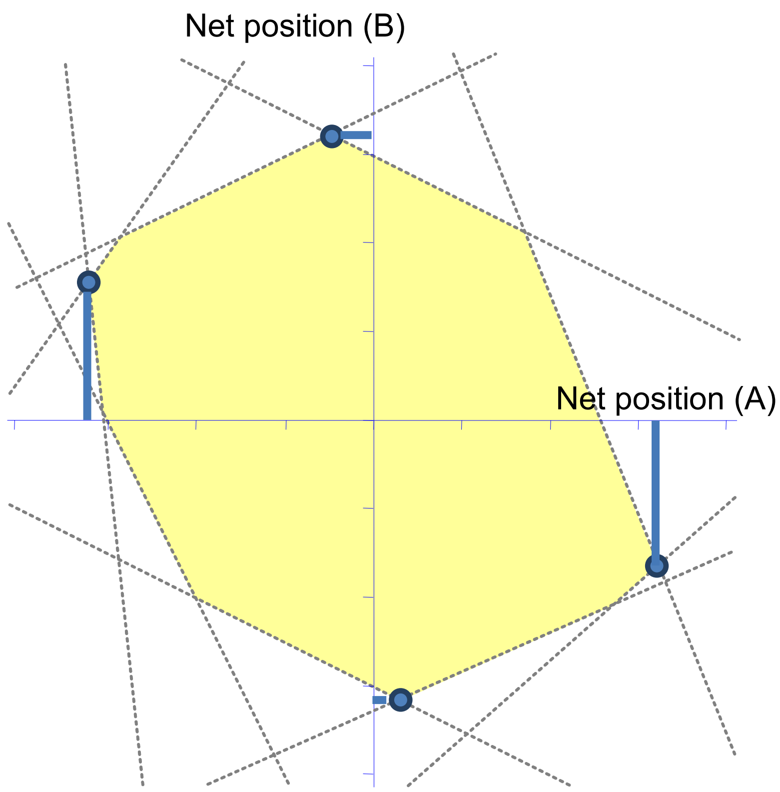
1. Virgin FlowBased domain with MinRAM applied
2. LTA domain

4.3.3. Flow Based capacity domain indicators

From the Flow Based capacity domain, indicators can be derived that characterize the Flow Based-domain and provide additional information of the domain. These indicators are published (see chapter 8) or monitored by the NRAs (see chapter 9)

- Flow Based-Volume: "volume" of the domain
  - The volume is computed in n-1 dimensions, where n is the number of hubs participating in the CWE FB MC (as the sum of the n net positions must be zero).
  - The volume can be compared with the volume of another domain, for instance the LTA domain (Long-Term Allocated capacity domain).

    - The intersection of different volumes can be computed, for instance the intersection of the Flow Based domain and the LTA domain.
- Flow Based-vertices: Net positions of the Flow Based-vertices
- Min-Max net positions: Minimum and maximum net position values for each hub, feasible within the Flow Based domain (by assuming that all other CWE hubs contribute to this specific Min-Max net position). An illustration of the Min-Max net positions feasible within the Flow Based domain for the two-dimensional example used so far, is shown in the figure below (the respective vertices are indicated by the blue dots, whereas the corresponding Min-Max net positions are highlighted by the blue lines).
- Min-Max bilateral exchanges between any two hubs, feasible within the Flow Based domain (by assuming that all other exchanges in CWE contribute to this specific Min-Max bilateral exchange).



4.4. ID ATC Computation

The methodology for capacity calculation for the Intraday timeframe, which is applied for the internal CWE borders since 30th March 2016 is attached as Annex 14.22 (Methodology for capacity calculation for ID timeframe) to this document.

If an external constraint applies on the global net position of a hub, then this external constraint will not be reflected in the presolved Flow Based parameters sent to PXs. To ensure operational security an adapted external constraint is added as an additional FB constraint, the value is set to be the global constraint minus the allocated capacities after MC (in relevant import or export direction) on non-CWE borders and capacity calculated on non-CWE borders.

4.5. Capacity calculation on non CWE borders (hybrid coupling)

Capacity calculation on non CWE borders is out of the scope of the CWE FB MC project. CWE FB MC just operates provided capacities (on CWE to Non-CWE-borders), based on approved methodologies.

The standard hybrid coupling solution, which is proposed today, is in continuity with the capacity calculation process already applied in ATC MC. By "standard", we mean that the influence of "exchanges with non-CWE hubs" on CWE Critical Network Elements is not taken into account explicitly at capacity calculation phase (no PTDF relating exchanges CWE <-> non-CWE to the load of CWE CNEs). However, this influence physically exists and needs to be taken into account to make secure grid assessments, and this is done in an indirect way. To do so, CWE TSOs make assumptions on what will be the eventual non-CWE exchanges, these assumptions being then captured in the D2CF used as a basis, or starting point, for FB capacity calculations. What's more, uncertainties linked to the aforementioned assumptions are integrated within each CNE's FRM. As such, these assumptions will impact the available margins of CWE Critical Network Elements. However, strictly speaking, no margin is explicitly booked for non-CWE exchanges on CWE CNEs.

CWE partners together with relevant parties are committed to study, after go-live, potential implementation of the so-called "advanced hybrid coupling solution", that consists in taking directly into account the influence of non CWE exchanges on CWE CNEs (which means, practically, the addition of new PTDFs columns in the FB matrix and therefore less reliance on TSOs' assumptions on non CWE exchanges, since the latter would become an outcome of the FB allocation).

4.6. Backup and Fallback procedures for Flow Based capacity calculation

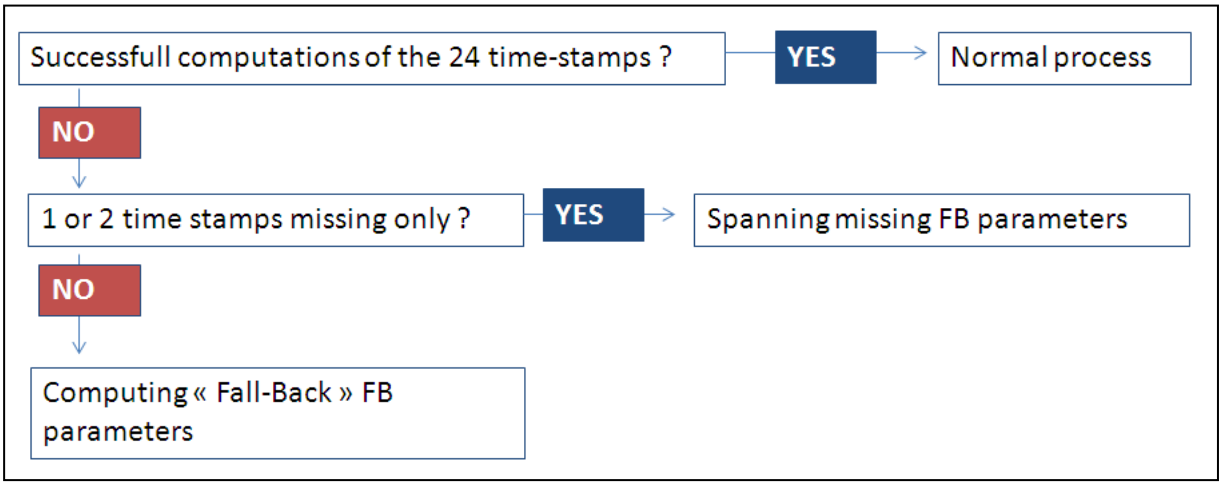
Introductory disclaimer: please note that this section is related to capacity calculation Fallback principles only. Therefore, its aim is neither to address operational Fallback procedures, nor to consider market-coupling Fallbacks (decoupling).

In some circumstances, it can be impossible for CWE TSO to compute Flow Based Parameters according to the process and principles. These circumstances can be linked to a technical failure in the tools, in the communication flows, or in corrupted or missing input data. Should the case arise, and even though the impossibility to compute "normally" Flow Based parameters only concern one or a couple of hours, TSOs have to trigger a Fallback mode in order to deliver in all circumstances a set of parameters covering the entire day. Indeed, market-coupling is only operating on the basis of a complete data set for the whole day (ALL timestamps must be available), mainly to cope with block orders.
The approach followed by CWE TSOs in order to deliver the full set of Flow Based parameters, whatever the circumstances, is twofold:

- First, TSOs can trigger "replacement strategies" in order to fill the gaps if some timestamps are missing. Because the Flow Based method is very sensitive to its inputs, CWE TSOs decided to directly replace missing Flow Based parameters by using a so-called "spanning method". Indeed, trying to reproduce the full Flow Based process on the basis of interpolated inputs would give unrealistic results. The spanning method is described in detail in the following section. These spanning principles are only valid if a few timestamps are missing (up to 2 hours). Spanning the Flow Based parameters over a too long period would also lead to unrealistic results.

- Second, in case of impossibility to span the missing parameters, CWE TSOs will deploy the computation of "Fallback Flow Based parameters". Their principles are described below in this paragraph.

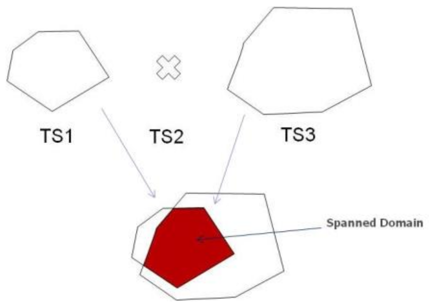
The sketch below will synthesise the general approach followed by CWE TSOs:



Spanning methodology

When Flow Based parameters are missing for less than 3 hours, it is possible to computed spanned Flow Based parameters with an acceptable level of risk, before using Fallback Flow Based parameters.
The spanning process is based on an intersection of previous and sub-sequent available Flow Based domains, after adjustment to 0 balance (to delete impact of reference program). At the end of the intersection process pre-calculated spanning margins are added.

Intersection Step: For each TSO, the active CNEs from the previous and sub-sequent timestamps are compared and the most constraining ones are taken into consideration (intersection).



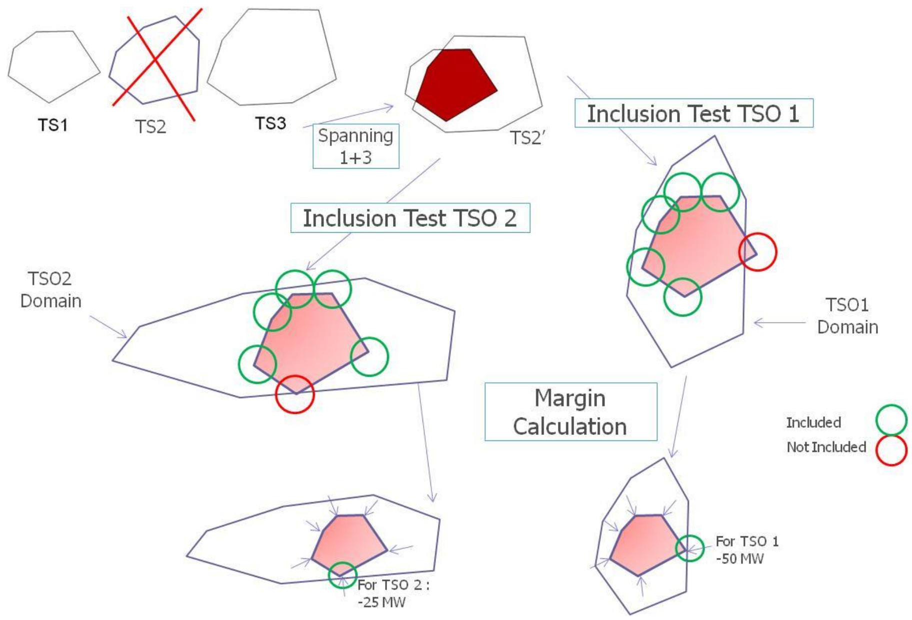
Spanning Margin calculation Step: The aim of this step is to define the spanning margin needed for each TSO to ensure the SoS in case that spanning is applied. This spanning margin is updated every day, after final Flow Based parameters calculation, based on a simulation of 'what could have been the spanned Flow Based parameters', compared to real Flow Based parameters (statistical analysis). To reduce the margin impact on the result, this process is performed per TSO (in this way, results of TSOs with Flow Based parameters that are more fluctuating from one hour to the other are not impacted by results of TSOs with more stable Flow Based parameters).

During this simulation, a raw spanned Flow Based domain is calculated, and a check is done to know if each vertex of the spanned domain is included in the real TSO Flow Based domain (inclusion test):

- If the spanning vertex is inside the original Flow Based domain, no extra margin is needed to ensure the SoS for this TSO.
- If the vertex is outside, an extra margin would have been necessary to keep the SoS. The size of this extra margin is calculated and stored.

⇨ After the full inclusion test, a new reference margin is defined as the maximum of all extra margins from the step before (for each TSO and each time stamp).

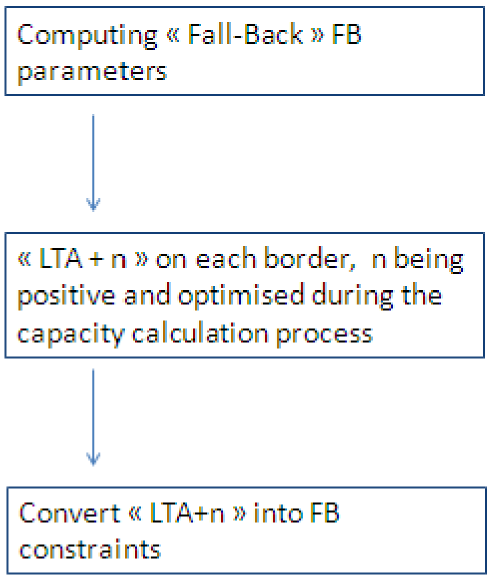
This reference margin is then added to the distribution of the already calculated reference margins from the past (for each time stamp and each TSO), in order to update (with a 90% percentile formula) the new spanning margin.



Fallback Flow Based parameters

When Flow Based parameters are missing for more than 3 hours, CWE have to recompute them in a straightforward way. Indeed, they could be in a downgraded situation where fundamental inputs and/or tooling are missing. For these reasons, CWE TSO will base the Fallback FBParam on existing Long Term bilateral capacities. These capacities can indeed be converted easily into Flow Based external constraints (i.e. import or export limits c.f. chapter 4.1.9 for more details), via a simple linear operation. In order to optimize the capacities provided in this case to the allocation system, CWE TSOs will adjust the long term capacities during the capacity calculation process. Eventually, delivered capacities will be equal to "LT rights + n" for each border, transformed into Flow Based constraints, "n" being positive or null and computed during the capacity calculation process. CWE TSOs, for obvious reasons of security of supply, cannot commit to any value for "n" at this stage.

Principles are summarized in the sketch below:



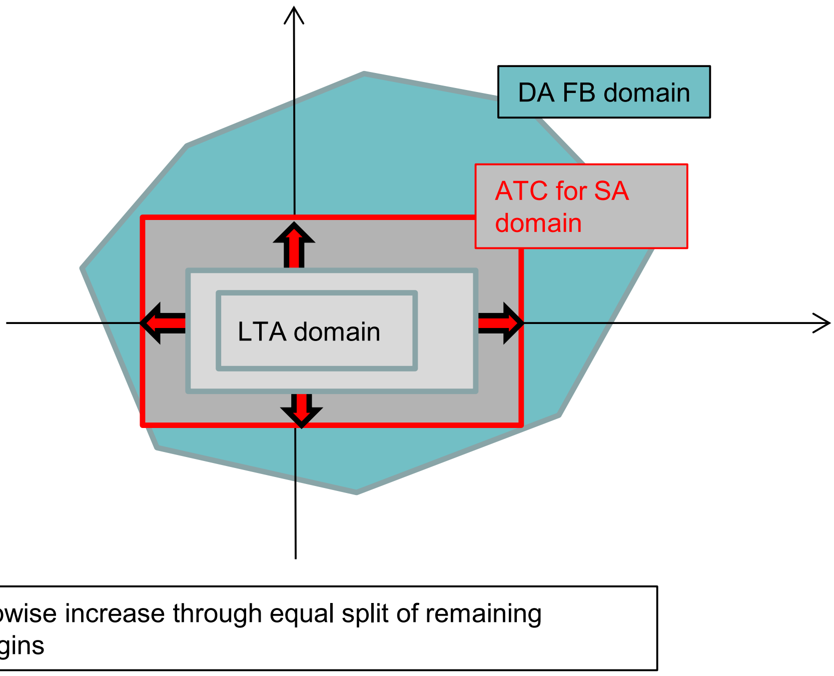
One can note that in all cases, CWE TSOs commit to deliver Flow Based constraints over the entire day to the Market Coupling system.

4.7. ATC for Shadow Auctions

Introduction: In case of a decoupling in CWE, explicit shadow auctions (SA) will be organized.

With the TSO CS daily running, 24 Flow Based domains are determined as an input for the FB MC algorithm. In case the latter system fails, the 24 Flow Based domains will serve as the basis for the determination of the SA ATCs that are input to the Shadow Auctions. In other words: there will not be any additional and independent stage of ATC capacity calculation.

As the selection of a set of ATCs from the Flow Based domain leads to an infinite set of choices, an algorithm has been designed that determines the ATC values in a systematic way. The algorithm applied for the determination of the SA ATCs is the same as the algorithm applied to compute the ID ATCs after the FB MC, though the starting point of the computation is a different one. Indeed, the iterative procedure to determine the SA ATC starts from the LTA domain [19]as shown in the graph below.



Input data:

Despite the two days per year with a clock change, there are 24 timestamps per day. The following input data is required for each timestamp:

[19] Keep in mind that that the LTA domain will systematically be included in the FB one, as explained in chapter 4.2.7.

- LTA
- presolved Flow Based parameters that were intended to be sent to the market coupling algorithm. If an external constraint applies on the global net position of a hub, then this external constraint will not be reflected in the presolved Flow Based parameters sent to the market coupling algorithm. To ensure operational security an adapted external constraint is added as an additional FB constraint, the value is set to be the global constraint minus the ATCs (in relevant import or export direction) on non-CWE borders.

Output data:

The calculation leads to the following outputs for each timestamp:

- SA ATC
- number of iterations that were needed for the SA ATC computation
- branches with zero margin after the SA ATC calculation

Algorithm:

The SA ATC calculation is an iterative procedure.

<u>Starting point</u>: First, the remaining available margins (RAM) of the presolved CNEs have to be adjusted to take into account the starting point of the iteration.

From the presolved zone-to-hub PTDFs ($\mathrm{PTDF}_{\mathrm{z2h}}$), one computes zone-to-zone PTDFs ($\mathrm{pPTDF}_{\mathrm{z2z}}$)[20], where only the positive numbers are stored:

$$\mathrm{pPTDF}_{\mathrm{z2z}}(\mathrm{A} > B) = max?\,(0, PTD\mathrm{F}_{\mathrm{z2h}}(\mathrm{A}) - \mathrm{PTDF}_{\mathrm{z2h}}(\mathrm{B}))$$

with $\mathrm{A}, \mathrm{B} = \mathrm{DE}, \mathrm{AT}, \mathrm{FR}, \mathrm{NL}, \mathrm{BE}$ connected via AC lines at the moment. Only zone-to-zone PTDFs of neighbouring market area pairs are needed (e.g. $\mathrm{pPTDF}_{\mathrm{z2z}}(\mathrm{AT} > BE)$ will not be used).

In case neighbouring market areas within CWE are connected via HVDC links and the evolved FB methodology is used for the DA market coupling the zone-to-hub PTDFs ($PTDF_{z2h}$) of the virtual hubs can be considered for the calculation of the positive zone-to-zone PTDFs (pPTDF_z2z) between both market areas (e.g. pPTDFz2z(BEDC > DEDC) = max(0, PTDFz2h(BE) – PTDFz2h(ALBE) + PTDFz2h(ALDE) – PTDFz2h(DE) where ALBE and ALDE describe the virtual hubs).

The iterative procedure to determine the SA ATC starts from the LTA domain. As such, with the impact of the LTN already reflected in the RAMs, the RAMs need to be adjusted in the following way:

$$\mathrm{RAM} = \mathrm{RAM} - \mathrm{pPTDF}_{\mathrm{z2z}} * (\mathrm{LTA} - \mathrm{LTN})$$

<u>Iteration</u>: The iterative method applied to compute the SA ATCs in short comes down to the following actions for each iteration step i:

---

[20] Negative PTDFs would relieve CNEs, which cannot be anticipated for the SA capacity calculation.

For each CNE, share the remaining margin between the CWE internal borders that are positively influenced with equal shares.

From those shares of margin, maximum bilateral exchanges are computed by dividing each share by the positive zone-to-zone PTDF.

The bilateral exchanges are updated by adding the minimum values obtained over all CNEs.

Update the margins on the CNEs using new bilateral exchanges from step 3 and go back to step 1.

This iteration continues until the maximum value over all Critical Network Elements of the absolute difference between the margin of computational step i+1 and step i is smaller than a stop criterion.

The resulting SA ATCs get the values that have been determined for the maximum CWE internal bilateral exchanges obtained during the iteration and after rounding down to integer values.

After algorithm execution, there are some Critical Network Elements with no remaining available margin left. These are the limiting elements of the SA ATC computation.

The computation of the SA ATC domain can be precisely described with the following pseudo-code:

```
While max(abs(margin(i+1) - margin(i))) > StopCriterionSAATC
        For each CNE
                For each non-zero entry in pPTDF_z2z Matrix
                        IncrMaxBilExchange = margin(i)/NbShares/pPTDF_z2z
                        MaxBilExchange = MaxBilExchange + In-
```

```
crMaxBilExchange
        End for
    End for
    For each ContractPath
        MaxBilExchange = min(MaxBilExchanges)
    End for
    For each CNE
        margin(i+1) = margin(i) – pPTDF_z2z * Max-
BilExchange
    End for
End While
SA_ATCs = Integer(MaxBilExchanges)
```

Configurable parameters:

StopCriterionSAATC (stop criterion); recommended value is 1.e-3.

NbShares (number of CWE internal commercial borders); current value after implementation of ALEGrO is 6.

For borders connected via HVDC links the bilateral exchanges cannot exceed the maximum transmission capacity of the HVDC links.

5 The CWE Market Coupling Solution / Daily schedule

This chapter describes the CWE Market Coupling Solution, embedded in and as part of the Single Day Ahead Coupling.
In the next sections the high level business process is further explained. They are devoted to:

- Terminology
- The operational procedures and the roles of the Parties

The high level functional architecture can be found in Annex 14.7.

5.1. Definitions related to MC Operation

Normal Procedure: procedure describing the actions to be taken by Agents to operate the CWE FB Market Coupling when no problem occurs.

Backup Procedure: procedure describing the actions to be taken by Agents in order to operate the CWE FB Market Coupling when a problem occurs (when for any reason, the information cannot be produced/exchanged or if a validation fails before the target time, or if it is known or may reasonably be expected that this will not happen before target time).

Fallback Procedure: procedure describing the actions to be taken by Agents in case the information cannot be produced/exchanged either by Normal or Backup Procedure or if a check fails before the Partial/Full Decoupling deadline, or if it is known that this will not happen before the Partial/Full Decoupling deadline.

Other procedures: procedure describing actions to be taken by an agent in certain specific situations, which are not directly associated to Normal procedures.

Target time (for a given procedure): estimated time to complete a procedure in a normal mode. If an incident occurs that does not allow applying the Normal procedure, and for which a backup exists, the Backup procedure is triggered.

Partial/Full Decoupling deadline: latest moment in time to complete some procedure in Normal or Backup mode. If an incident that does not allow applying Normal or Backup procedure (if any) occurs before this time, Fallback procedure is triggered.

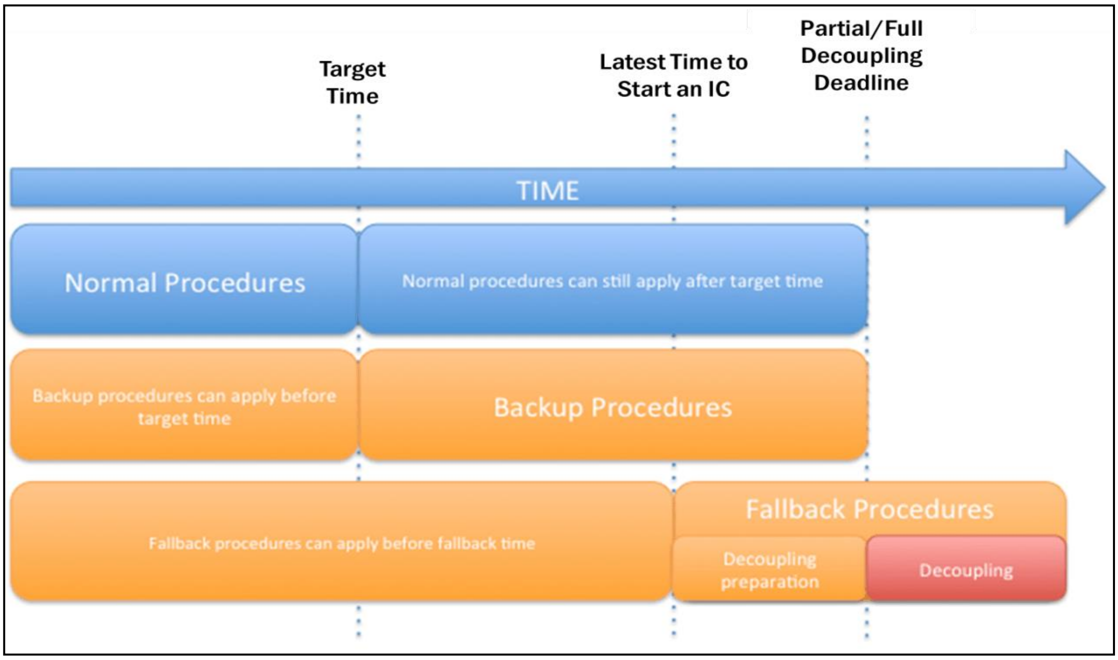


Figure 5-1: Interrelationship between Normal procedures, Backup, and Fallback.

5.2. High Level Architecture

The original High Level Architecture has been described in the final regulatory report of the MRC Day-Ahead Market Coupling Project (§3.1 resp. 3.7 of MRC Day-Ahead Market Coupling Project, Final Regulatory Report), which has been sent for approval to the MRC National Regulatory Authorities.

For completeness of the provided information, the above mentioned chapters of the MRC approval package are attached to this document (c.f. Annex 14.7).

5.3. Operational procedures

The Market Coupling process is divided into 3 different phases. During each phase, a number of common procedures will be operated under normal conditions. These procedures are called Normal Procedures and Backup Procedures. In addition there is a number of common procedures which are not associated to a specific phase. The procedures that belong to this category are Other, Special and Fallback Procedures. In this paragraph we describe them on a high level[21].

The following procedures are specific for the local CWE FB MC solution and are not part of the MRC-documentation and approval request.

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[21] Please refer to Annex 14.8 for detailed procedures.

5.3.1. Phase 1: provision of the Cross Zonal Capacities and Allocation Constraints by the TSOs

Phase 1 starts with the sending of the Cross Zonal Capacities and Allocation Constraints to the NEMO ECP Endpoint by the CWE TSO Common System and ends when the Cross Zonal Capacities and Allocation Constraints are successfully received by the NEMOs Pre-Coupling Module.

NOR_1: Cross Zonal Capacities and Allocation Constraints	This procedure describes the first phase of the business process dedicated to the sending of the Cross Zonal Capacities and Allocation Constraints by TSOs and their reception by NEMOs.
BUP_1: Cross Zonal Capacities and Allocation Constraints	Description of the actions to be performed by the operator in case the normal process described in NOR_1 does not work.

5.3.2. Phase 2: Final Confirmation of the Results

Phase 2 starts with the sending of the Price Coupling Results for the final confirmation to the CWE TSO Common System. This phase ends with the reception of the Global Final Confirmation of the results by the CWE TSO Common System. Hereby, the Price Coupling Results become firm.

NOR_2: Final Confirmation of the Results by the CWE TSO CS	This procedure describes the second phase of the business process dedicated to verify and validate the price coupling results in a normal mode.
BUP_2: Final Confirmation of	Description of the actions to be per-

the Results by the CWE TSO CS	formed by the operator in case the normal process described in NOR_2 does not work.

In case of a negative Global Final Confirmation, an Incident Committee will be triggered according to CWE_FAL_01. For a detailed description of the Fallback mechanism we refer to chapter 0.

5.3.3. Phase 3.1: Market Coupling Results and Scheduled Exchanges Transfer

This phase starts with the sending of Market Coupling Results by the CWE TSO Common System (Verification Module) to the CWE TSO Back-End Systems. Then, the CWE TSO Common System (Post Coupling Module) will create programming authorizations. These are sent via the CWE NEMOs ECP Endpoint to the Cross NEMO Clearing and Settlement Support System, to TSO Back-End Systems and to the Congestion Revenue Distribution System (CRDS). Furthermore, Market Coupling Results are sent to the CRDS.

NOR_3: Market Coupling Results and Scheduled Exchanges Transfer	This procedure describes the first part of the third phase of the business process regarding the steps that have to be performed in a normal mode.
BUP_3: Market Coupling Results and Scheduled Exchanges Transfer	Description of the actions to be performed by the operator in case the normal process described in NOR_3 does not work.

5.3.4. Phase 3.2: Local Hub Nomination, Cross-Border Nomination and Congestion Income

This phase starts with the creation of CCP information for local hub nomination and cross-border nomination by CWE NEMO back-end Systems and/or CCP/Shipping Systems and/or Cross-NEMO Clearing and Settlement Support Systems. It ends with data exchange on congestion rents from shipping modules to the CRDS.

NOR_4: Local Hub Nomination, Cross-Border Nomination and Congestion Income	This procedure describes the second part of the third phase of the business process regarding the steps that have to be performed in a normal mode
BUP_4: Local Hub Nomination, Scheduled Exchanges Notification, Cross-Border Nomination and Congestion Income	Description of the actions to be performed by the operator in case the normal process described in NOR_4 does not work.

5.3.5. Other Procedures

Other Procedures are not associated to a specific phase. They relate to certain situations, which need to be managed by a formalized procedure.

Other Procedures	Documents describing various actions to be performed under certain conditions which are not back up or Fallback actions
SPE_01 CWE Second Auction	Description of modified timeframe and actions to be performed in case of special or exceptional circumstances leading to a second auction

OTH_01 CWE Procedures Reading Instructions	Description of used terminology and abbreviations in order to facilitate the reading of procedures
OTH_02 Internal and External Communications	Description of messages that need to be sent in order to provide an official communication during some particular market situations or technical incidents
OTH_03 CWE Publications	Description of the different publications and associated timings
OTH_04 CWE Market Operator Tasks and Rotational Scheme	Description of the actions to be performed by CWE Market Operator
OTH_05 Change control procedure	Description of the process to follow by all parties in case of change in one of the systems

5.3.6. Fallback procedures

Fallback procedures are applicable as soon as an incident occurs that prevents the timely allocation of the CZCs via the implicit allocation process and/or the timely publication of the Market Coupling Results. In this case an Incident Committee is convened where the issue is assessed and in case necessary, potential Fallback solutions will be assessed and agreed upon.

Fallback Procedures	Documents describing the actions that should be performed under Fallback conditions.
FAL_01 Incident Management	Description of the initiation of the Incident Committee and the way discussions

	should be handled.
FAL_02 Full Decoupling	Description of the actions to be initiated by the operator in case Full Decoupling is declared by the Incident Committee.
FAL_03 Partial Decoupling	Description of the actions to be initiated by the operator in case Partial Decoupling is declared by the Incident Committee.

6 Fallback arrangement for Market Coupling (capacity allocation)

This chapter presents the description of the proposed CWE MC Fallback arrangement in case of a problem in the coupling process once the capacities (Flow Based parameters) have been received by NEMOs.
Regarding the Flow Based capacity calculation Fallback solution, please refer to chapter 4.6.
The Fallback arrangement is described in following sections:

- Fallback situations
- Fallback solutions
- Principle of the Fallback arrangement
- Description of explicit PTRs allocation
- Bids
- Database tool
- Sequence of operations
- Matching and price determination rules

6.1. Fallback situations

A Fallback situation occurs when no market coupling results are generated until the time limit to trigger the Fallback. The Fallback solution for the CWE Region is described in the Fallback HLFAs of the approved MRC Price Coupling Solution documentation (§9.1 of MRC Day-Ahead Market Coupling Project, Final Regulatory Report), c.f. Annex 14.9.
The following paragraphs summarize the most important characteristics related to Fallback from the perspective of Market Parties, operating in the CWE region.

The Fallback is caused by the failure of one or more processes in the Market Coupling session, that affect the completion of the Business process phase 2 (see 5.3, operational procedures). In other words, the Fallback is declared if no Market Coupling result can be calculated and validated before the Partial/Full Decoupling deadline of phase 2. For instance:

- some market data may not be generated,
- the algorithm, or the system on which it runs may fail,
- technical validations may return a "non-compliant" result.

One can note that in all cases, CWE TSOs commit to deliver Flow Based Parameters over the entire day to the Market Coupling system.

6.2. Fallback solutions

The Incident Committee will assess and agree on the potential Fallback solution which can be either partial or full decoupling of SDAC according to the observed incidents and deadlines.

A Partial Decoupling is a situation where it is not possible, for a specific day, to allocate the capacities via the implicit allocation for one or several areas and/or interconnectors before the relevant Partial Decoupling Deadline. After the Partial Decoupling declaration by the Incident Committee, the process will be followed through the relevant Normal procedures, even though the timings are delayed accordingly for the remaining coupled areas and/or interconnectors. For the decoupled areas and/or interconnectors the Local procedures are followed accordingly. If, at the regular publication time, Market Coupling Results have not been published, an external communication message informs Market Parties about a delay in the process and the risk of Full Decoupling. In case the Full Decoupling has been declared by the Incident Committee, each NEMO will run its local backup auction. The Fallback solution for the allocation of capacity on CWE internal borders is shadow explicit auctions via JAO, described in the next paragraphs

A Full Decoupling known in advance can only be declared in case the previous Market Coupling Session has resulted in a Full Decoupling and the corresponding critical issue could not be solved until the target time for publishing the CZCs.

6.3. Principle of the CWE Fallback Arrangement

The principle of the proposed Fallback arrangement is to allocate the ATCs for shadow auctions derived from Flow Based parameters via a "shadow explicit auction". The shadow explicit auction consists of:

- maintaining a permanent data base where all pre-registered Market Parties (Fallback participants) may submit, amend or withdraw, bids for capacity. During normal operation, these bids are not used;
- should a Fallback situation be declared on a particular day in case of an incident during the daily session, the Shadow Auction System Operator (JAO) performs a Shadow Auction to allocate the Available Transmission Capacities based on the available valid bids; from the time of running the Fallback auction, the participants are not allowed to update their bids for the upcoming shadow auction.
- should a Fallback situation be declared in advance for the next sessions of CWE MC in case of any foreseen unavailability, the participants are allowed to update their bids according to the time schedule communicated by the Shadow Auction System

Operator (JAO); the Shadow Auction System Operator (JAO) performs a Shadow Auction to allocate the available transmission capacities.

For the High-level Fallback Architecture, please refer to Annex 14.9. The publication of Shadow Auction ATCs is described in chapter 8.

6.4. Description of explicit PTRs allocation

The Shadow Auction allocates Physical Transmission Rights (PTRs) for each oriented bidding zone border and for each hour of the day. Using the ATC, provided by TSOs, and the auction bids from the Shadow Auction System, the Shadow Auction System calculates the PTRs allocated to the participants and the corresponding programming authorizations. The PTRs resulting from the auction may not exceed the ATCs. The unused PTRs are lost by the Fallback participants (UIOLI) if they are not nominated.
Since PTRs and programming authorizations are only options, the Fallback arrangement cannot take into account any netting of opposed capacities.

6.5. Bids in case of explicit PTR allocation

6.5.1. Content

A bid entered in the Shadow Auction System contains the following information:

- the bidding zone border for which the bid applies (Belgium-Netherlands, Netherlands-Germany, Germany-France, France-Belgium, Germany-Austria or Germany-Belgium),

- the direction for which it applies (two directions for each bidding zone border),
- the hourly period for which it applies,
- a price to be paid for the capacity.

Bids inserted by the participants in the Shadow Auction System are unconditional and irrevocable once the Fallback mode has been declared in case of an unforeseen unavailability of the CWE FB MC or according to the new time schedule communicated in advance if an unavailability of the CWE FB MC is forecasted for the next daily sessions.

Bid(s) submitted by the participant to a Shadow Auction are submitted in a priority order according to their Bid Identification. Lowest ID number has the highest priority. When a Shadow Auction is run, bids are created according to the priority order until the Bids meet the available capacity. The last created bid that exceeds the Available Capacity is reduced so the total of Bids does not exceed the Available Capacity.

6.5.2. Ticks and currency

Bids contain whole MW units, and Bid Prices in Euros per MWh expressed to a maximum of two decimal places.

6.6. Shadow Auction System tool and bid submitters

The Shadow Auction System enables participants to submit bids, according to the conditions set out in the documentation available on the Shadow Auction System Operator’s (JAO) website. In particular, bids must be submitted in accordance with the formats defined in the relevant documentation.

6.7. Sequence of operations in case of explicit PTR allocation

The sequence of operations is applicable after a decision to resort to Fallback after the Partial/Full Decoupling deadline or in case a Fallback situation is announced in advance at 10:30. The process and contractual basis remains the same as under CWE ATC MC.

1. At any time, Market Parties are invited to register by means of entering into an agreement with the Shadow Auction System Operator (JAO) through applicable Shadow Allocation Rules. From then on, they become "Fallback participants".
2. At any time, Market Parties are invited to register by means of entering into an agreement with the TSOs for the nomination part (meaning that the Market Parties should sign a nomination contract or designate their nomination responsible according to each country's regulation).
3. Fallback participants are allowed to enter bids into the Shadow Auction System and amend or withdraw them.
4. TSOs provide the Shadow Auction System Operator (JAO) with ATCs.
5. Should a Fallback situation be declared, Market Parties will be informed and can update their bids according to the new time schedule communicated.
6. The Shadow Auction System Operator (JAO) then performs the Shadow Auction: it determines the PTRs allocated to each Fallback participant and the corresponding programming authorizations.
7. The Shadow Auction System Operator (JAO) provides each Fallback participant with the results and prices resulting from the auction.
8. The Shadow Auction System Operator (JAO) provides each TSO/Fallback participant with all programming authorizations.

9. The Shadow Auction System Operator (JAO) publishes transparency data, as defined in chapter 0.

10. Market Participants submit their orders through the CWE NEMO Trading modules for day ahead market, per NEMO Trading Hub. . The NEMOs then match and publish their results separately.

11. Fallback participants submit their nominations to TSOs according to the existing local processes.

6.8. Matching and price determination rules in case of explicit PTR allocation

The Shadow Auction is performed for each bidding zone border within CWE, each direction and each hour, by the following steps:

1. The bids are ranked according to the decreasing order of their price limit.
2. If the total capacity for which valid bids have been submitted is equal to or lower than available capacity for the auction in question, the marginal price is nil.
3. If the total capacity for which valid bids have been submitted exceeds the available capacity for the auction in question, the marginal price is equal to the lowest bid price selected in full or in part.
4. The highest bid(s) received for a capacity requested which does (do) not exceed the available capacity is (are) selected. The residual available capacity is then allocated to the participant(s) who has (have) submitted the next highest bids price, if the capacity requested does not exceed the residual capacity; this process is then repeated for the rest of the residual available capacity.
5. If the capacity requested under the next highest bid price is equal to or greater than the residual available capacity, the bid is selected either in full, or partially up to the limit of the residual available capacity. The price of this bid constitutes the marginal price.

6. If two (2) or more participants have submitted valid bids with the same bid price, for a total requested capacity which exceeds the residual available capacity, the residual available capacity is allocated in proportion to the capacity requested in the bids by these participants, in units of at least one (1) MW. The capacities attributed are rounded down to the nearest megawatt. The price of these bids constitutes the marginal price.

6.9. Daily schedule

A Fallback situation may be declared at any time before publication of FB MC results. However, the timing of procedures may depend on the moment it is triggered: if known sufficiently in advance the timing will be adapted to the prevailing conditions, this will be communicated to the market as early as possible. The timings presented in this document correspond to the worst case, which is when Fallback is triggered at the MC results publication deadline.
In the worst case, i.e. when the Fallback situation is declared at 13:50, the underlying hypotheses are:

- The timespan between publication of the local NEMO market results and cross-border nominations is at least 45 minutes.
- 20 minutes are reserved for Market Parties to amend their orders on the NEMOs after the allocation of capacity via Shadow Auctions..
- Sufficient time must remain for the TSOs to respect deadlines of the day ahead processes (e.g. ENTSO-E, Intra-day capacity calculation, margins calculation)

6.10. Opening hours

The access to the Shadow Auction System is open 24h a day and 365 days a year, except for system maintenance periods, announced by the Shadow Auction System Operator (JAO) generally 15 days in advance. In exceptional circumstances this notice may be shorter.

7 Economic Assessment

7.1. Results of the 2013 external parallel run

The economic impact of FB MC compared to ATC MC on market and prices was initially demonstrated in the feasibility report.

Based on the first year of the external parallel run an extensive study of the impact of FB(I) MC has been performed (Annex 14.10). The study shows an approximate day-ahead market welfare increase of 79M€ (307 days simulated of 365) for 2013 with an average daily gain of 257 K€. Therefore a social welfare increase for the region of nearly 95M Euro on an annual basis can be expected (based on extrapolated results of the average daily welfare increase, during the external parallel run from January to December 2013).

The parallel run also showed some increases in price volatility and a limited correlation with prices under ATC Market Coupling, especially in the smaller markets.

Simulations comparing ATC, FB MC and FBI MC in 2013 gave furthermore the following results:

- Day-Ahead Market Welfare and Convergence indicators are significantly better with FB MC or FBI MC than with ATC MC.
- Non-intuitive situations were found. Enforcing intuitiveness through FBI MC deteriorates only very slightly the indicators. Moreover, non-intuitive situations represent a minor proportion of the analysed cases.

Notwithstanding the limitations mentioned in chapter 1.2.2 of the study in Annex 14.10, the market impact analysis concludes that FB

MC and FBI MC have a positive impact on welfare, compared to ATC MC.

7.2. Sensitivity i.e. domain reduction study

The domain reduction study aims at providing some insights into the sensitivity of the market results to different FB parameters. The margin reduction is a simple tool to model impact, although it lacks a link with physical reality.

- The objective of this study was to answer what impact changes to the FB domain have on market results. A series of trivial qualitative results could be obtained by simple reasoning and was confirmed in our study: The level of price convergence increases with additional margin;
- The day-ahead market welfare increases with additional margin;

We tried to quantify the impact.

Impact on price

The annual average prices are little affected by the margin reductions. However once the isolated case is being approached the effects, especially for BE become more noticeable (e.g. for BE the average price under FB is € 44.44, but this would increase to € 57.83 when margins are reduced to only 10% of the current level. When margin is reduced to 90% of the current level the BE would increase to € 44.92).

Impact on welfare

The difference in welfare between the 100% scenario and the infinite scenario is 383k€ average per day. This suggests that under the current market conditions welfare could be further increased with additional margin.

When we consider the relative increase in welfare (distance from isolated scenario over distance between infinite scenario and isolated scenario) we observe that 90.3% of the welfare potential is realized. This would increase to 92.8% when margin is increased to 110%, or drop to 87.03% when margin is decreased to 90%.

There are limitations too: diminishing return to scales: each subsequent increase in margin will increase welfare by less than it increased by earlier margin increases. This means that increasing margin from 10% to 20% raises average daily welfare by 470k€, whereas increasing margin from 20% to 30% only raises welfare an additional 380k€. The increase from 90% to 100% only added 119k€ and from 100% to 110% 93k€. Realizing the full remaining welfare potential with the infinite scenario would likely require vast increases in margin.

Overall

Comparing the results from this study with the results from ATC, it appears that as long as margins are at least 90% of their current values the FB methodology still outperforms the ATC approach, both in terms of welfare and price convergence.

The domain reduction study can be found in Annex 14.11.

7.3. Decision on Intuitiveness

Buying at low(er) prices and selling at high(er) prices is an intuitive fundamental for all kinds of trading and business activities. However, for maximising total day-ahead market welfare under FB MC, it

can happen that there is an exchange from a higher price area to a lower price area, which is non-intuitive.
Related to FB MC, a situation (a combination of market clearing prices and Net Export Positions) is said to be (bilateral-)intuitive, if there exists at least one set of bilateral exchanges that satisfies the following property: "exchanges on each interconnector occur from the low price area to the high price area".

In October 2013 the Project Partners published an update of the CWE Enhanced Flow Based MC Intuitiveness Report to explain all details related to intuitiveness. This version of this Intuitiveness Report is annexed to this approval document (c.f. Annex 14.12).
The economic assessment for the complete year 2013 of external parallel run indicates 421 non intuitive hours (5,7% of all hours and 8,2% of the congested hours).

The main outcome of the project's assessment whether to go-live with plain or intuitive CWE Flow Based market coupling is presented in the following overview, assessing the differences between FB and FBI against a set of criteria. The exhaustive study can be found in Annex 14.13.

Criterion	In favour of FB “plain”	In favour of FB “intuitive”
Volatility	inconclusive	
Price Signal	Negligible difference	
Liquidity	resilience analysis: inconclusive	
Welfare (global)	Unknown	Unknown
Welfare (DAMW)	X (though relatively small)	
Welfare repartition	No statistically significant difference	
ID	X (considering DA capacity should not be allocated to ID)	X (considering ID capacity is higher; mitigates DA welfare loss)
Investment	inconclusive	
SoS	inconclusive	
Communication to general public	Arguments against either alternative exist	

Based on the inconclusive outcome of the study, the Project initially has not been in a position to make a recommendation whether to start with FB or FBI. The outcome of the public consultation of the NRAs of June 2014 has given additional guidance for the decision.

Based on guidance by the CWE NRAs CWE FB MC has started with FB intuitive.

Regardless of this decision, the Project has monitored the Flow Based plain and kept the possibility to reassess the decision after go-live.

Key descriptions and confirmation related to the FBI-decision, requested by the NRAs after the June 2014 consultation can be found in Annex 14.18.

During Q4 2019, CWE NRAs requested CWE parties to update the report, taking into account 4 years of data, including one full year of data after DE/AT split. It was also required to include additional considerations related to performances. The full report can be found in Annex 14.31 while the main results are written below.

Main results

Non-intuitive situations occurred for 16.2% of the hours when the intuitivity patch is not applied.

The welfare loss related to the application of FBI over the investigated period is 26 Mio. € for the whole MRC region, or 18K € per day on average or 0.0002 % in relation to the welfare that would have been generated under FBP. In relations to total welfare, the impact appears quite small. Still it represents significant amount in absolute terms and the discussion on this difference appears to be relevant.

Some redistributive effects between countries and between producers and suppliers exist. When a bidding zone exports, its price will slightly increase under FBP and inversely. This denotes a better price convergence. As a consequence, the producers in the exporting zones and the consumers in the importing zones see an increase of their surplus.

The average time to first solution for the market coupling algorithm decreases by 14.1% in the latest bidding zone configuration after DE/AT split, which is the most demanding situation. This is an important consideration taking into account the challenges the algorithm will have to face for the upcoming developments (ALEGrO, Core FB, Nordic FB, market time unit of 15 min…).

The average welfare loss mentioned above is unevenly distributed. While for most days the differences between FBP and FBI are somewhat small (in terms of prices and volumes), some specific days are illustrating that import differences occur. In one example and for one bidding zone, a price difference of more than 200 €/MWh was observed between the price that would have been observed under FBP and the price that was actually observed under FBI. The price differences in the other bidding zones were not so significantly affected, leading to important price differentials between bidding zones. These rare but spectacular situations are not easily understood by market participants, which may in itself question the additional value in terms of intuitivity of the application of FBI.

The reduced utilization of the grid is illustrated by analyzing the impact on ALEGrO interconnector. This HVDC interconnector between Belgium and Germany will be implemented with the so-called Evolved Flow Based (EFB) approach where the flow on the interconnector is determined by the market coupling algorithm in order to maximize the welfare. FBI leads to set this flow to zero in 33.27 % more cases than under FBP, and these cases relate to situations with price differences. One may find counter-intuitive that the flow on a controllable HVDC interconnector is set to zero even when there is price difference.

Conclusions of the report

Considering that the removal of the intuitiveness patch will lead to higher welfare, a better price convergence, the avoidance of price spike situations, a higher utilization of the grid and better algorithm performances, CWE NRAs agreed to remove the intuitiveness patch as of the technical go-live of ALEGrO (CWE NRA EM 16th of March).

8 Publication of data

This paragraph describes how the Project aims to provide the necessary data towards Market Parties of the CWE Flow Based Market Coupling, in order to facilitate the market and to comply with EU-legislation.

The issue of data publication (transparency) was a key issue in the responses of the first public consultation in May-June 2013 (c.f. Annex 14.14). The results have been discussed with the CWE NRAs in expert meetings afterwards. Additionally there have been exchanges with MPs about transparency needs in Flow Based User Group meetings and Market Fora. To keep business secrets and confidentiality, the Project furthermore had bilateral discussions with some MPs to better understand processes and data needs on MPs' side.

As a result, an approach for data-supply and transparency, which covers the main needs of MPs has been defined. An overview over all data directly published by the project via the Utility Tool on the JAO website is provided in form of a publication handbook, which can be found on the JAO website[22] as well.

For monitoring purposes the National Regulatory Authorities get additional (confidential) data and information (further described in chapter 9). Based on national and EU-legislation, on reasonable request from the NRAs, the Project will provide all Project related data for monitoring purposes. Publications of monitored information can be commonly agreed from case to case.

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[22] http://www.jao.eu/cwemc_publicationhandbook

8.1. Relation to EU Regulations

Transparency obligations related to congestion management are currently mainly regulated by Regulation (EC) No 714/2009 and its Annex 1 § 5, and the Commission Regulation (EU) No 543/2013 on submission and publication of data in electricity markets and amending Annex I to Regulation (EC) No 714/2009 of the European Parliament and of the Council (entered into force in June 2013).

The transparency regulation and the abovementioned paragraphs of these CM-Guidelines oblige TSOs to publish a broad variety of data related to congestion management in general, and implicit FB MC in specific. Specifically for Flow Based, the transparency regulation foresees in its article 11 §1 that TSOs, for their control areas or, if applicable, transmission capacity allocators, shall calculate and provide the following information to the ENTSO for Electricity sufficiently in advance of the allocation process:

"b) The relevant flow based parameters in case of flow based capacity allocation".

Next, for transparency issues, there is the EC Regulation 1227/2011 on wholesale energy market integrity and transparency (REMIT) and the competition law, the Project has to comply with. To the opinion of the Project Partners, it is the responsibility of the individual PXs and TSOs to fulfil the requirements of all EU-regulations.
In this chapter we especially present the data which will facilitate the Market Parties in their bidding behaviour, as far as it concerns data produced by the common MC system and commonly published by the Project Partners. The publication of data via ENTSO-E as required by Commission Regulation (EU) No 543/2013, can be found on https://transparency.entsoe.eu.

8.2. General information to be published

The following general information is already covered within this document and will be updated and published when needed:

- Description of the coordinated Flow Based capacity calculation methodology,
- High-level business process of Flow Based capacity calculation
- A description of the CWE FB MC solution,
- Fallback arrangements in case of decoupling.

Furthermore, a description of the market coupling algorithm is published by the NEMOs operating this algorithm. -

8.3. Daily publication of Flow Based Market Coupling data

It is the obligation of ENTSO-E to publish relevant data related to the cross border exchanges on the ENTSO-E platform. TSOs can mandate a third party, like JAO, to deliver the data on their behalf to the ENTSO-E Transparency platform. For the time being, the Project Partners have decided to provide easily accessible data as set out in the next two subsections on a common website (www.JAO.eu).

8.3.1. Daily publication of data before GCT

Intitial Flow-Based parameters (without LT-nominations)

Based on requests from MPs' side, the Project provides for information and analysing purposes initial Flow-Based parameters at D-1.

For this set of FB-parameters all long term nominations at all CWE-borders are assumed as zero (LT-noms=0).

The technical provision is similar to the below mentioned, via the Utility Tool.

Final Flow-Based parameters

The TSOs will publish for each hour of the following day the Flow-Based parameters i.e. the fixed Critical Network Elements, Power Transfer Distribution Factors (PTDFs) and the Remaining Available Margin (RAM) on Critical Network Elements. In addition for each CNEC, the applied Adjustment for Minimum RAM (AMR) and the minRAMfactor values along with a justification of calculations behind the minRAMfactor based on derogations (if any) will be published. This publication shall comply with the obligations of Art. 11 (1b) of the transparency regulation.

The Flow Based parameters will be available at D-1 (10:30 CET – target time) via the Utility Tool, daily fed with new input data of the next day from the JAO website. The Utility Tool can be downloaded from JAO website.

The look and main features of the Utility Tool are presented in Annex **Fout! Verwijzingsbron niet gevonden.**.

Content	**Where/ Who**	**When**	**Unit**
Harmonized human readable name Critical Network Elements	JAO	D-1 (10:30 CET)	-
EIC codes of Critical Network Elements and Contingency	JAO	D-1 (10:30 CET)	-
Zonal PTDFs	JAO	D-1 (10:30 CET)	-
RAMs	JAO	D-1 (10:30 CET)	MW
Fmax	JAO	D-1 (10:30 CET)	MW
Fref	JAO	D-1 (10:30 CET)	MW
FRM	JAO	D-1 (10:30 CET)	MW

FAV	JAO	D-1 (10:30 CET)	MW
AMR	JAO	D-1 (10:30 CET)	MW
minRAM factor	JAO	D-1 (10:30 CET)	%
MinRAM Factor Justification	JAO	D-1 (10:30 CET)	-

Final Virgin Flow Based domain

The TSOs will publish for each hour of the following day the Flow-Based parameters similarly to the specifications mentioned above at D-1 10h30. The final virgin flow based domain should be interpreted as the final FB domain with MinRAM applied without LTA inclusion.

Final Shadow Auction ATCs

The final Shadow Auction ATCs (border and direction) per market time unit will be published at D-1 (10:30 CET – target time) together with the FB parameters. The form of publication can be found in Annex 14.16.

8.3.2. Publication of data after Market Coupling calculation

The Project will comply with the respective obligations of Art. 12 (a) & (e) of the transparency Regulation.
Additionally, in the framework of separate CWE FB MC publications, the following data is published:

On JAO Website:

- Capacity allocated
- The total congestion income in the CWE area

In addition to the data above, the Project Partners publish the following data:

- market prices: the market prices for each bidding zone and market time unit of the day will be published on daily basis on the ENTSO-E platform (https://transparency.entsoe.eu/).
- Aggregated supply and demand curves for each market time unit of the day will be published by the individual NEMO for their hub.

These data will be published after Flow Based allocation for each market time unit (presently an hour) of the day.

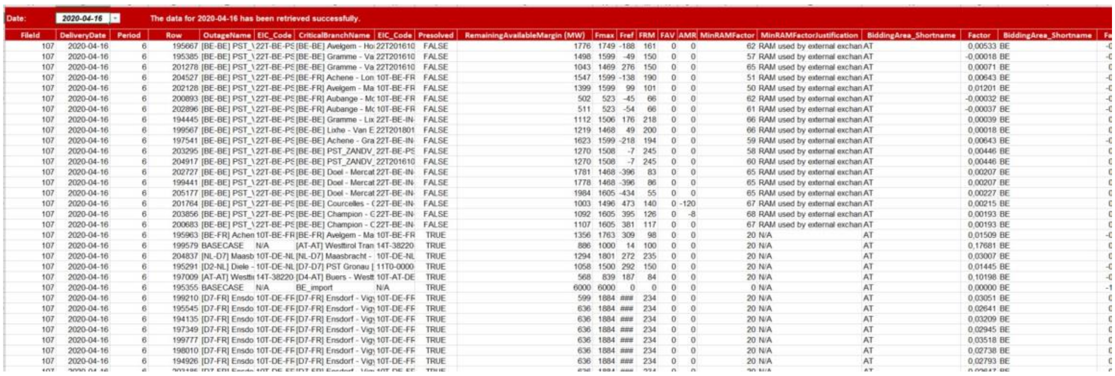
Content	**Where/ Who**	**When**	**Unit**
Capacity allocated (used margin on Critical Network Elements)	JAO/ ENTSO-E	13:00 CET	MW
Congestion income	JAO/ ENTSO-E	19:00 CET	€
Individual bidding zone prices	NEMOs' websites	13:00 CET	€/MWh
Aggregated supply and demand curves for each market time unit	NEMOs' websites	14:00 CET	-
Overview CWE bidding zone prices	ENTSO-E	14:00 CET	€/MWh
Net positions per bidding zone	JAO / ENTSO-E	13:00 CET	MW

8.3.3. Publication of additional CNEC information

CWE partners will publish, for each day with an hourly resolution, the list of all Critical Network Elements, disclosing the location aggregated by bidding zone or border ("BE", "DE", “AT”, "FR", "NL", “DE-AT”, "DE-NL", "FR-BE", "FR-DE", BE-NL",”BE-DE”).

In other words, CWE partners will publish the equivalent of the PTDF sheet of the utility tool, but will publish the Critical Network Element and Contingency Name, the EICs if applicable of the CNE and C, RAM, Fmax, Fref, FRM, FAV, AMR, MinRAMFactor, MinRAMFactorJustification, presolved status, bidding area and the PTDF factors linked to the CNEC harmonized human readable names (detailed in a next paragraph).

This additional publication will be realized at 10:30 AM in D-1.
The content and style of this additional data supply related to the Critical Network Elements is the outcome of intensive exchange with Market Parties and NRAs.



Date: 2020-04-16 The data for 2020-04-16 has been retrieved successfully.

FileId	DeliveryDate	Period	Row	OutageName	EIC_Code	CriticalBranchName	EIC_Code	Presolved	RemainingAvailableMargin (MW)	Fmax	Fref	FRM	FAV	AMR	MinRAMFactor	MinRAMFactorJustification	BiddingArea_Shortname	Factor	BiddingArea_Shortname	Fa
107	2020-04-16	6	195667	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Avelgem - Ho	22T201610	FALSE	1776	1749	-188	161	0	0	62	RAM used by external exchan	AT	0,00533	BE	-0
107	2020-04-16	6	195385	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Gramme - Va	22T201610	FALSE	1498	1599	-49	150	0	0	57	RAM used by external exchan	AT	-0,00018	BE	-0
107	2020-04-16	6	201278	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Gramme - Va	22T201610	FALSE	1043	1469	276	150	0	0	65	RAM used by external exchan	AT	0,00071	BE	0
107	2020-04-16	6	204527	[BE-BE] PST_\	22T-BE-PS	[BE-FR] Achene - Lon	10T-BE-FR	FALSE	1547	1599	-138	190	0	0	51	RAM used by external exchan	AT	0,00643	BE	-0
107	2020-04-16	6	202128	[BE-BE] PST_\	22T-BE-PS	[BE-FR] Avelgem - Ma	10T-BE-FR	FALSE	1399	1599	99	101	0	0	50	RAM used by external exchan	AT	0,01201	BE	-0
107	2020-04-16	6	200893	[BE-BE] PST_\	22T-BE-PS	[BE-FR] Aubange - Mc	10T-BE-FR	FALSE	502	523	-45	66	0	0	62	RAM used by external exchan	AT	-0,00032	BE	-0
107	2020-04-16	6	202896	[BE-BE] PST_\	22T-BE-PS	[BE-FR] Aubange - Mc	10T-BE-FR	FALSE	511	523	-54	66	0	0	61	RAM used by external exchan	AT	-0,00037	BE	-0
107	2020-04-16	6	194445	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Gramme - Lix	22T-BE-IN-	FALSE	1112	1506	176	218	0	0	66	RAM used by external exchan	AT	0,00039	BE	0
107	2020-04-16	6	199567	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Lixhe - Van E	22T201801	FALSE	1219	1468	49	200	0	0	66	RAM used by external exchan	AT	0,00018	BE	0
107	2020-04-16	6	197541	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Achene - Gra	22T-BE-IN-	FALSE	1623	1599	-218	194	0	0	59	RAM used by external exchan	AT	0,00643	BE	-0
107	2020-04-16	6	203295	[BE-BE] PST_\	22T-BE-PS	[BE-BE] PST_ZANDV_	22T-BE-PS	FALSE	1270	1508	-7	245	0	0	58	RAM used by external exchan	AT	0,00446	BE	0
107	2020-04-16	6	204917	[BE-BE] PST_\	22T-BE-PS	[BE-BE] PST_ZANDV_	22T201610	FALSE	1270	1508	-7	245	0	0	60	RAM used by external exchan	AT	0,00446	BE	0
107	2020-04-16	6	202727	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Doel - Mercat	22T-BE-IN-	FALSE	1781	1468	-396	83	0	0	65	RAM used by external exchan	AT	0,00207	BE	0
107	2020-04-16	6	199441	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Doel - Mercat	22T-BE-IN-	FALSE	1778	1468	-396	86	0	0	65	RAM used by external exchan	AT	0,00207	BE	0
107	2020-04-16	6	205177	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Doel - Mercat	22T-BE-IN-	FALSE	1984	1605	-434	55	0	0	65	RAM used by external exchan	AT	0,00227	BE	0
107	2020-04-16	6	201764	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Courcelles - (	22T-BE-IN-	FALSE	1003	1496	473	140	0	-120	67	RAM used by external exchan	AT	0,00215	BE	0
107	2020-04-16	6	203856	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Champion - C	22T-BE-IN-	FALSE	1092	1605	395	126	0	-8	68	RAM used by external exchan	AT	0,00193	BE	0
107	2020-04-16	6	200683	[BE-BE] PST_\	22T-BE-PS	[BE-BE] Champion - C	22T-BE-IN-	FALSE	1107	1605	381	117	0	0	67	RAM used by external exchan	AT	0,00193	BE	0
107	2020-04-16	6	195963	[BE-FR] Achen	10T-BE-FR	[BE-FR] Avelgem - Ma	10T-BE-FR	TRUE	1356	1763	309	98	0	0	20	N/A	AT	0,01509	BE	-0
107	2020-04-16	6	199579	BASECASE	N/A	[AT-AT] Westtirol Tran	14T-38220	TRUE	886	1000	14	100	0	0	20	N/A	AT	0,17681	BE	0
107	2020-04-16	6	204837	[NL-D7] Maasb	10T-DE-NL	[NL-D7] Maasbracht -	10T-DE-NL	TRUE	1294	1801	272	235	0	0	20	N/A	AT	0,03007	BE	0
107	2020-04-16	6	195291	[D2-NL] Diele -	10T-DE-NL	[D7-D7] PST Gronau [	11T0-0000	TRUE	1058	1500	292	150	0	0	20	N/A	AT	0,01445	BE	-0
107	2020-04-16	6	197009	[AT-AT] Westti	14T-38220	[D4-AT] Buers - Westt	10T-AT-DE	TRUE	568	839	187	84	0	0	20	N/A	AT	0,10198	BE	-0
107	2020-04-16	6	195355	BASECASE	N/A	BE_import	N/A	TRUE	6000	6000	0	0	0	0	0	N/A	AT	0,00000	BE	-1
107	2020-04-16	6	199210	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	599	1884	###	234	0	0	20	N/A	AT	0,03051	BE	0
107	2020-04-16	6	195545	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,02641	BE	0
107	2020-04-16	6	194135	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,03209	BE	0
107	2020-04-16	6	197349	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,02945	BE	0
107	2020-04-16	6	199777	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,03518	BE	0
107	2020-04-16	6	198010	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,02738	BE	0
107	2020-04-16	6	194926	[D7-FR] Ensdo	10T-DE-FR	[D7-FR] Ensdorf - Vig	10T-DE-FR	TRUE	636	1884	###	234	0	0	20	N/A	AT	0,02793	BE	0

Figure 8-1: All CNEC fixed label publication

8.4. Harmonized human readable name convention

The following harmonized human readable name convention is used.

CNE publication name:

[hubFrom-hubTo] CNE name [Direction] (+ [TSO] if a tie-line)

- HubFrom, HubTo and TSO can be BE, NL, FR, AT, D2, D4, D7, D8.
- Direction can be DIR or OPP. DIR means that the CNE is monitored from firstly mentioned hub/substation to the secondly mentioned hub/substation. OPP inverts the order.
- The CNE name always has to include the human readable connected substation names divided by a hyphen. Substations could be listed in alphabetical order (TNG will do so. But I think it is not crucial to do so or harmonize this).
- TSOs use DIR and OPP to indicate the direction and do not change the order of substations.
- If there is a hyphen in a substation name, no spaces are used
- Examples:
    - [BE-FR] Achene – Lonny 19 [DIR] [BE]
    - [BE-BE] Avelgem – Horta 101 [DIR]

Tripods publication name:

[hubFrom-hubTo] Y - substation (- substation 2 - substation 3) [Direction] (+ [TSO] if a tie-line)

- Y stands for the node connecting all three branches of the tripod. [substation] defines the branch of the tripod that is monitored. If it is monitored from the Y-node to the substation the direction is DIR. Otherwise it is OPP.
- [hubFrom] indicates where the first node is located
- TSOs use DIR and OPP to indicate the direction and do not change the order of substations.
- If there is a hyphen in a substation name, no spaces are used

- Example: [D4-D4] Y - Engstlatt (- Oberjettingen - Pulverdingen) rot [DIR]

PSTs publication name:

[hubFrom-hubTo] PST name [Direction] (+ [TSO] if a tie-line)

- Each TSO does their best effort for the direction
- If there is a hyphen in a substation name, no spaces are used

8.5. Publication of aggregated information related to the D-2 common grid model

Daily at D-1 the following aggregated hourly information related to the common grid model will be published:

1. Vertical Load
2. Generation
3. Best forecast Net Positions for BE, DE, AT, NL, FR, AL-BE, ALDE which represent the total Net Positions of each bidding zone, and not only the CWE Net Positions.

Information related to this data items are described in the chapter "D2CF Files, exchange Programs". Wind- and solar generation is taken into account (subtracted from) the vertical load.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Date:	######	The data for 2018-02-22 has been retrieved successfully.													
	D2CF per Hub (in MW)														
	Vertical load					Generation					Best Forecast Net Positions				
imeStamp	AT	BE	DE	FR	NL	AT	BE	DE	FR	NL	AT	BE	DE	FR	NL
1	8849	41657	56722	9175	7800	47996	61393	11264	-1279	5238	3457	1910	7752	5993	-1848
2	8552	40101	54990	8796	7265	46363	59136	11270	-1510	5160	2938	2292	7483	5710	-1857
3	8486	39306	54196	8663	6976	45277	57920	11049	-1732	4851	2556	2201	7747	5655	-2170
4	8523	40137	51774	8601	6780	45605	56106	10727	-1964	4424	3245	1953	8148	5584	-2632
5	8550	40175	51255	8691	6799	44845	56674	11069	-1974	3626	4351	2217	7372	5657	-1798
6	8583	42563	53602	9132	7546	47248	58857	11932	-1262	3655	4192	2633	8052	5848	-2291
7	9751	50334	58256	10314	8093	54989	63548	12463	-1896	3745	4261	1958	9159	7053	-2211
8	10255	55858	62622	12164	9477	59317	68305	13333	-1031	2595	4571	955	10133	8367	-1891
9	10204	56160	64811	13019	9847	59761	69498	13305	-615	2755	3611	63	10459	8583	-2004
10	10039	53012	64643	13106	9836	57742	69762	13356	-459	3866	4018	27	10554	8507	-2174
11	9644	50140	63777	12584	9463	56206	68026	13411	-429	5123	3180	601	10582	8165	-2539
12	9467	48134	62838	11994	8982	55446	66583	13352	-726	6331	2719	1128	10541	7869	-2789
13	8988	45723	61263	11675	8787	54951	65854	13265	-438	8225	3582	1362	10329	7646	-2798
14	9016	45178	59652	11561	8569	54867	65707	13318	-682	8688	5080	1525	10256	7638	-2733
15	9083	45298	58101	11544	8569	54942	65183	13332	-750	8652	6133	1564	10164	7769	-2511
16	9327	45946	56586	11824	8561	55200	65224	13338	-1004	8280	7769	1298	10155	7969	-2305
17	9564	47530	56141	12506	8879	55673	65548	13437	-923	7205	8556	715	10297	8229	-2191
18	9925	52343	57606	12794	9220	57750	66333	13598	-949	4625	7762	592	10600	8957	-1777
19	10493	54792	62446	12523	9592	61695	68053	13658	-1154	6071	4580	916	10657	9088	-1705
20	10185	52945	66129	12243	9560	61898	70311	13665	-877	8102	2941	1187	10219	8961	-1392
21	9733	48144	62295	11590	9106	58332	68227	13006	-872	9323	4689	1189	9608	7994	-1734
22	9269	45272	59395	10896	8471	55144	64982	12398	-1035	8922	4312	1276	8980	6284	-2790
23	9483	43546	58503	10085	8072	53233	64190	11881	-1648	8710	4303	1585	8809	5744	-3151
24	9424	40100	60380	9470	7908	49618	65092	11405	-1751	8422	3351	1732	8261	5320	-3020

Figure 8-2: Aggregated hourly information related to the common grid model

In addition, Refprog Bilateral exchanges on the following CWE-borders and non-CWE borders are published for every hour[23]:

AT=>CZ, AT=>HU, AT=>SI, BE=>NL,BE=>DE (DC), BG=>TR, CH=>AT, CH=>DE, CH=>FR, CH=>IT, CZ=>SK, DE=>AT, DE=>CZ, DE=>NL, DE=>PL, ES=>MA, ES=>PT, FR=>BE, FR=>DE, FR=>ES, FR=>IT, GR=>AL, GR=>BG, GR=>IT, GR=>RS, GR=>TR, IT=>AT, IT=>SI, PL=>CZ, PL=>SK, RO=>BG,RO=>HU, SI=>HU, SK=>HU, RS=>AL, RS=>BG, RS=>HU, RS=>RO, RS=>SI, UA=>HU, UA=>RO, UA=>SK

23 Note that Refprog bilateral exchanges refer to exchanges between control blocks.

8.6. Publication of data in Fallback mode

The Fallback solution for CWE FB MC is coordinated with the MRC-/PCR Fallback arrangements. It will be ATC based explicit shadow auctions. These explicit auctions will be performed by the Shadow Auction System Operator (JAO).

The Shadow Auction System Operator (JAO) will publish and update when necessary the following general information on its website:

- Shadow auction rules;
- names, phone and fax numbers and e-mail addresses of persons to be contacted at the Shadow Auction System Operator (JAO);
- the forms to be sent by participants;
- the information related to the time schedule of the shadow auctions when they are decided in advance (auction specifications);
- the shadow auction results, including the anonymous complete Bid curves (amongst others the requested capacity, the capacity allocated, the auction clearing price and the auction revenue); the results should be published 10 min after the allocation.;
- Data of past days will be archived.

8.7. Cooperation with the Market Parties after go-live

A Flow Based User Group meeting (CWE Consultative Group) will be held on a regular basis to discuss all relevant issues related to FB MC operation from MPs’ perspective and to further improve the FB MC solution.

9 Monitoring

9.1. Monitoring and information to the NRAs only

For monitoring purposes the CWE Project provides the following additional data-items on a monthly basis to the NRAs only:

Items related to the FB capacity calculation

1. Results of the hourly LTA checks
2. Results of the hourly NTC checks
3. Line Sensitivity Check
4. Hourly Min/Max Net Positions
5. Hourly Intraday ATCs for all CWE borders
6. AT - Max Bilateral Exchanges (hourly)
7. BE - Max Bilateral Exchanges (hourly)
8. FR - Max Bilateral Exchanges (hourly)
9. DE- Max Bilateral Exchanges (hourly)
10. NL - Max Bilateral Exchanges (hourly)
11. Volume of the Flow-Based domains (hourly)
12. Usage of the Final Adjustment Value FAV
13. External Constraints
14. Hourly Shadow Auction ATCs for all CWE-borders
15. Overview of timestamps where spanning is applied (per month)
16. Overview of timestamps for which default FB parameters were applied (per month)
17. Hourly non-anonymized presolved CNECs, disclosing

    PTDF, FMAX, FRM, FAV, RAM, FREF, AMR
18. Key aggregated figures per bidding zone and border (weekly aggregations)

    Number of presolved CNEs

    Number of precongested cases

Number of CNEs exceeded by LTA

Number of CNEs exceeded by ATC

Number of of presolved CNEs with RAs applied

Number of presolved CNEs without RAs applied

Number of presolved CNEs, breaching the 5% rule

Number of hours using the FAV

Number of hours, spanning technology was applied

Number of hours, default FB parameters were applied

19. In case of occurrence: justification when FAV is used
20. In case of occurrence: justification when 5% is breached (of pre-solved CNEs)
21. In case of occurrence: justification when a CNEC is excluded from the MinRAM process

Items related to the FB capacity allocation (after market coupling)

1. Active CNEs (Hourly)
2. Shadow prices (Hourly)
3. Monthly top 10 of active constraints
4. Number of days or hours, allocation used Shadow Auction ATCs instead of FB parameters
5. Number of congested CNEs
6. Number of congestions in the timestamps with non-intuitive prices (pending technical feasibility)
7. Price convergence indicator
8. Price convergence indicator: border-per-border price differences diagrams
9. Welfare loss compare to infinite capacity
10. CIA-Reporting (congestion income allocation)

The templates for the foreseen reporting towards the CWE NRAs are presented in Annex 14.20.

10 Scheduled Exchanges and Net Position Validation

Scheduled Exchanges

Scheduled Exchanges are calculated according to the methodology for Calculating Scheduled Exchanges resulting from single day-ahead coupling in accordance with Article 43 of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management.

Net Position Validation

After completing the Market Coupling Process, the MC System sends the net positions for validation to the TSO Common System, for formal approval.

As the MC system and the TSO CS use the same algorithm for validation of the net positions (with the only difference in the tolerance levels), the results will normally be the same. The output of this verification is a full acceptance or full rejection of results of the Market Coupling process.

Validation performed is based on simple principles:

- Abs(NPout * NPin) < Tolerance Margin

2 Net Positions per Market Area are produced by the process: one in and one out. Only one can be non-zero.

- (NPout - NPin) < Tolerance Margin

Global CWE Net position is zero.

- (($NPout_i$ - $NPin_i$) * $PTDF_i$) < Margin (CNE_j) + Tolerance $margin_i$

All CNEs, adjusted to NetPosition to be validated, are safe

The tolerance margins are parameters with small positive values.

If all these inequalities are correct, the result of the validation process is a “Go” message to the MC System as the confirmation of the acceptance of Net Positions.

11 Contractual scheme

In this chapter the contractual scheme put in place for the operation of CWE FB MC is presented.

CWE FB MC shall be seen in the context of the European Price Coupling. To that extend, the CWE agreements as regional arrangements of the CWE region shall be compliant with the principles set forth in the Day-Ahead Operations Agreement (DAOA).

In this chapter, we will focus in particular on the:

- Principles of the CWE Framework agreement
- Parties involved in the daily operation and their tasks
- Risk management

11.1. Principles of the Framework Agreement

The daily operation and maintenance of the CWE FB MC is governed by a number of contracts between subsets of parties. These contracts are governed by the CWE Framework Agreement, the overall contract between CWE NEMOs and CWE TSOs. The subsidiary agreements between subsets of parties must be compliant with the principles of the CWE Framework Agreement. The principles of the CWE Framework Agreement have been discussed with regulators.

11.2. Roles and responsibilities of the Parties

In order to operate Market Coupling to the required standards, the Parties have agreed to allocate the involved tasks and actions to certain individual Parties or a subset of Parties. By doing so, it is ensured that all tasks and actions are performed by the most competent body, and are executed in an efficient way. One can distinguish the following actors:

- Individual TSOs

- Joint TSOs
- Individual NEMOs
- Joint NEMOs
- Joint Parties
- External service providers

In this section we listed the legal entities having an operational role in the Market Coupling. In the next sections we will further explain the roles of these involved actors.

11.2.1. Roles of the individual/joint TSOs

The individual TSOs are responsible to calculate on a daily basis the day-ahead Cross-Zonal Capacities (CZCs) for the operation of Market Coupling. In the context of FB MC, CZCs are Flow Based parameters. Flow Based parameters are determined by the joint TSO pre-coupling system according to the method described in chapter 1.1 on capacity calculation. After their determination, the joint TSO pre-coupling system sends the Flow Based parameters to the NEMOs active in CWE, which forward them to the PMB. The joint TSO pre-coupling system is operated by all TSOs taking weekly shifts.
The joint TSOs are also responsible for the final validation of the net positions and of the calculation of bilateral cross border exchanges that result from the net positions. These cross border exchanges are necessary for the nomination of the cross border flows at each TSO. The calculation of bilateral cross border exchanges is performed by the joint TSO post-coupling system. JAO is the operator of that system on behalf of the TSOs.

11.2.2. Roles of the individual NEMOs

The individual NEMOs are responsible to collect all bids and offers from their participants, and to submit their aggregated and anonymous order books to the PMB, a joint NEMO system. The NEMO order books are transferred and injected directly into the Market Coupling database. The order books contain all the bids of the Market Parties in an aggregated and anonymous format.

After the Market Coupling has been performed and the price has been set, the individual NEMOs are responsible for executing all orders placed by their participants that are within the calculated price, and to form the contracts with them.

11.2.3. Roles of the joint NEMOs

The joint CWE NEMOs are responsible for building, operation and maintenance of the PMB system and the market coupling algorithm together with further relevant NEMOs of the SDAC. NEMOs are responsible to calculate net positions and market prices for all bidding zones of the SDAC.

11.2.4. Roles of joint Parties

The CWE NEMOs and TSOs are together responsible for the management of the CWE FB MC solution. Decisions regarding the solution will be taken by all the parties. In order to perform this task, the Parties will set up a joint steering committee, an operational committee and an incident committee.

11.2.5. Roles of external service providers

In order to operate an efficient Market Coupling, the CWE Parties have decided to outsource a number of tasks to external service providers (e.g. JAO and Coreso). Other tasks to be performed by service providers are:

- Shipping agent activities (nomination of cross border exchanges, financial clearing and settlement).
- Reception of congestion rents and distribution to the individual TSOs. This task will be operated by JAO.

11.2.6. Summary of operational roles

Entity	Role
TSOs	• Determine CZCs
Coreso & TSCNET	• Operate the TSOs pre coupling system on behalf of TSOs
NEMOs	• Collection of bids and offers from their participants in their hub, and submission of their aggregated and anonymous order books to the PMB. •
Clearing Houses	• Financial clearing and settlement , nomination of cross border exchanges
JAO	• Operation of the TSO post-coupling system (calculation of bilateral exchanges) • Congestion revenue distribution among TSOs

Operational roles at the time of submission of the approval document.

11.3. Risk management

In order to mitigate risks related to changes to all components that make the Market Coupling solution work as it is supposed to, e.g. systems, procedures and interfaces, the Parties have implemented a change control procedure (c.f. chapter 121).

11.4. Other risks addressed prior Go Live

There were some risks on which the project worked further and whose resolutions are an integral part of the project's Go Live acceptance criteria:

- Negative welfare days and control of quality of FB solution with respect to the size of the FB domain when reference to ATC is not available anymore. This aspect was addressed in the second report on specific parallel run investigations available in September 2014).
- Risk of lack of coupling capacity (in particular for smaller hubs) due to a combination of possible changes to nomination behavior and FB domain sometimes just covering some critical LTA corners. This aspect were addressed by further analysis of the risk and mitigation measures.

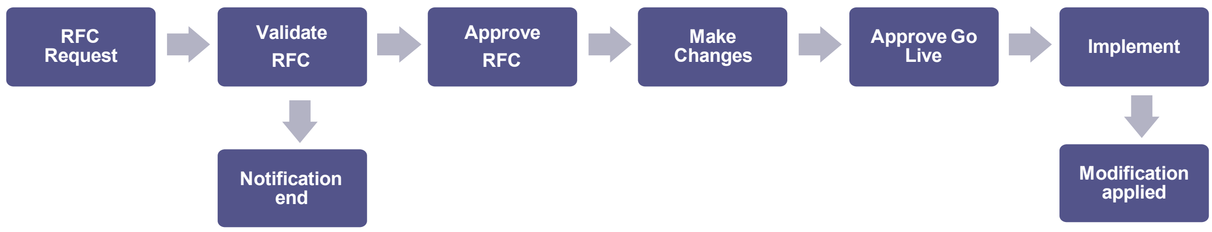
12 Change control

12.1. Internal change control processes of the Project

The change control procedure aims at tracking any change, small and large, in software, systems, procedures and in documents. Whilst the majority of changes are likely to be simple operational changes or small textual changes, it is still important that the procedure is robust to the processing of more complex changes. The relevant Steering Committee (e.g. CWE TSO Steering Group, CWE Joint Steering Committee) shall decide on the final approval of changes. Changes in the SDAC or the market coupling algorithm fall under the responsibility of the respective steering committees.

In case a change is needed, a request for change document is filled. This document shall contain the details, the consequences such change could have for the other parties and any other relevant information on the requested change. Then, an impact assessment is performed in order to determine whether the requested change will have a material impact on the common operations and systems. The proposal is checked to see if it is correct. After approval, the change is performed.

Example given of a RFC Procedure control



Simple changes with a low-risk solution affect a small number of components owned by a single or joint party, and change only local items with no identified impact on common items. Project Partners are informed of such changes, with a fast track procedure if required.

All other changes which are more complex, of a higher risk category, affecting multiple components or components which are the responsibility of more than one project party are handled as real modifications, but can be managed in fast track if needed.

For simple changes, the change will be recorded on just one form. This will contain all the information required including the cause of the change, the proposed solution, its impact and the way in which the change will be implemented. In this case no other forms will be required to be completed.

12.2. Approval of changes of the CWE FB MC solution

Changes in the CWE FB MC methodology will be published. If needed, a formal approval request towards the NRAs will be started to be commonly approved. All changes will be documented and attached to the initial approval document.

13 Glossary

AC	Active constraint
AMR	Adjustment for Min RAM
ATC	Available Transfer Capacity
ATC MC	ATC Market Coupling
CNE	Critical Network Element
CNEC	Critical Network Element Contingency
CCP	Cross Clearing Party
CEE	Central Eastern Europe
CET	Central European Time
CEWE	Central East West Europe
CGM	Common Grid Model
C	Contingency
CS	Common System
CWE	Central Western Europe
CWE MO	CWE Market Operator
CZCs	Cross Zonal Capacities
D	Delivery Day
D-1	Day Ahead
D-2	Two-Days Ahead
D-2CF or D2CF	Two-Days Ahead Congestion Forecast
DA	Day Ahead
DACF	Day-Ahead Congestion Forecast
EC	External Constraints
ENTSO-E	European Network of Transmission System Operators for Electricity
EVB	Evolved Flow Based
FAV	Final Adjustment Value
FB	Flow Based
FB MC	Flow Based Market Coupling
FBI MC	Flow Based Intuitive Market Coupling

Fmax	Maximum allowable flow on a given Critical Network Element
FRM	Flow Reliability Margin
GCB	German control block
GCT	Gate Closure Time
GSK	Generation Shift Key
HLA	High Level Architecture
IC	Incident Committee
ID	Intraday
IFA	Interconnexion France Angleterre
Imax	Maximum current on a Critical Network Element
LT	Long Term
LTA	Allocated capacity from LT auctions
LTN	Long Term Nominations
MC	Market Coupling
MinRAM	Minimum RAM
MoU	Memorandum of Understanding
MP	Market Party
MRC	Multi Regional Coupling (successor of the former NWE project)
NA	Not applicable
NEMO	Nominated Electricity Market Operator
NRA	National Regulatory Authority
PCR	Price Coupling of Regions
PLEF	Pentalateral Energy Forum
PMB	PCR Matcher and Broker (Joint PX IT System which embeds the PCR Algorithm calculating the MRC Net Positions, Prices and Scheduled Exchanges on the non CWE interconnectors)
PCR Coordinator	PX operating the PMB system
PTDF	Power Transfer Distribution Factor

PST	Phase-Shifting Transformer
PX	Power Exchange
RA	Remedial Action
RAM	Remaining Available Margin
RSC	Regional Security Cooperation
SAS	Shadow Auction System
SDAC	Single Day Ahead Coupling
SoS	Security of Supply
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UCTE	(formerly Union for the Coordination of Transmission of Electricity (today integrated into ENTSO-E)

14 Annexes

14.1. Documentation of all methodological changes during the external parallel run

14.2. Educational example "How does Flow Based capacity calculation work?"

14.3. High level business process FB capacity calculation

14.4. Examples of different types of Remedial Actions (will be provided later)

14.5. Dedicated report on FRM (confidential)

14.6. Information regarding LTA inclusion

14.7. CWE High level architecture (confidential)

14.8. Technical Procedures (confidential)

14.9. CWE High level Fallback architecture (confidential)

14.10. Economic assessment

14.11. Domain reduction study

14.12. Intuitiveness report

14.13. Intuitiveness, Analysis for the FB/FB(I) selection

14.14. Results of the survey/ consultation in May/June 2013

14.15. Presentation of the Utility Tool

14.16. Publication of Shadow ATCs

14.17. Monitoring templates

14.18. Flow-based “intuitive” explained

14.19. Preliminary LTA inclusion statistics

14.20. Mitigation to Curtailment of Price Taking Orders

14.21. Implementation of FTR Options and temporary LTA+ solution

14.22. Methodology for capacity calculation for ID timeframe

14.23. Context paper CWE Intraday

14.24. Congestion income allocation under flow-based Market Coupling

14.25. Adequacy Study Report

14.26. Annex C_1_Transparency

14.27. Annex C_2_Transparency

14.28. Report on SPAIC results for the integration of the DE-AT border into CWE Flow Based

14.29. Extended LTA formulation (*to be included May 2020)*

14.30. Pedagocical information on Extended LTA formulation (*to be included May 2020*)

14.31. CWE report: comparison flow-based plain and flow-based intuitive (2020)

14.32. Report on Congestion Income Distribution in Central Western Europe Flow Based Market Coupling after

Twelve Months of Operation of the Bidding Zone Border between Austria and Germany/Luxembourg (2020)

14.33. Evaluation of ALEGrO impact on CID results - 12 SPAIC Day assessment (2020)

14.34. Explanatory Note for ID Capacity Calculation (2020)

Note: The current status of the annexes of the CWE FB MC approval package listed above is available in the table below. It should be noted that most of the annexes listed have been published at the time of the Go-live (May 2015):

Name of the annex	Status of the document
Annex 14_1 Documentation of all methodological changes during the external parallel run	**Historically relevant**: description changes during parallel run
Annex 14_2 Educational example “How does Flow Based capacity calculation work”	**Valid**
Annex 14_3 High level business process FB capacity calculation	**Valid**
Annex 14_4 Example of different types of Remedial Actions	**Valid**
Annex 14_5 Dedicated report on FRM (**confidential)**	**Historically relevant**, data of 2013
Annex 14_6 Information regarding LTA inclusion	**Valid**
Annex 14_7 CWE High level architecture (**confidential)**	**Not up to date**
Annex 14_8 Technical procedures (**confidential)**	**Not relevant anymore**
Annex 14_9 CWE High level Fallback architecture (**confidential)**	**Not up to date**
Annex 14_10 Economic assessment	**Valid**

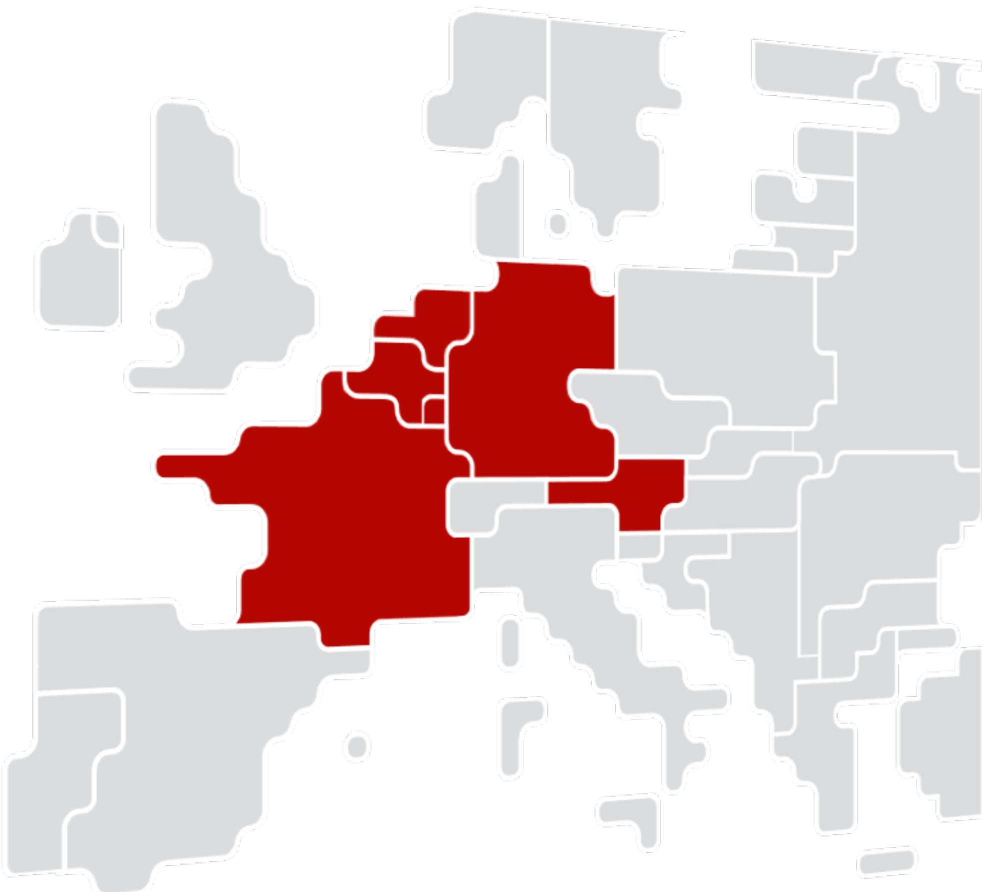
Annex 14_11 Domain Reduction Study	**Valid**
Annex 14_12 Intuitiveness report	**Valid**
Annex 14_13 Intuitive Analysis for the FB-FBI selection	**Valid**
Annex 14_14 Results of the survey-consultation in May_June 2013	**Not relevant** anymore
Annex 14_15 Presentation of the Utility Tool	Replaced by Publication Handbook: http://www.jao.eu/cwemc_publicationhandbook
Annex 14_16 Publication of shadow ATCs	**Valid**
Annex 14_17 Monitoring Templates	**Valid**
Annex 14_18 Flow-Based “intuitive” explained	**Valid**
Annex 14_19 Preliminary LTA inclusion statistics	**Historically relevant**, statistics before go-live 2014.
Annex 14_20 Mitigation to Curtailment of Price Taking Orders	**Valid**
Annex 14_21 Implementation of FTR Options and temporary LTA+ solution	**Historically relevant**, Temporary procedure in 2015 for 6 months.
Annex 14_22 Methodology for capacity calculation for ID timeframe	Updated in June 2018 in combination with the update of the main document CWE FBMC approval document (v3.0)

Annex 14_23 Context paper CWE Intraday	**Valid**
Annex 14_24 Congestion income allocation under Flow-Based Market Coupling	Updated in June 2018 in combination with the update of the main CWE FBMC approval document (v3.0)
Annex 14_25 Adequacy Study Report	**Valid**
Annex 14_26 Annex C_1_Transparency	**Not up to date**
Annex 14_27 Annex C_2_Transparency	**Not up to date**
Annex 14_28 Report on SPAIC results for the Integration of the DE-AT border into CWE Flow Based	Updated in June 2018 in combination with the update of the main CWE FBMC approval document (v3.0)

CWE

Annex 14.29: extended LTA inclusion

Submitted as part of the CWE Day Ahead FB MC approval package 06/05/2020



May 2020

Extended formulation for LTA inclusion

Description, shadow prices and price formation

October 2019

N-SIDE S.A. - Boulevard Baudouin 1er 25, 1348 Louvain-La-Neuve, Belgium

www.n-side.com

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1 Introduction

We first consider in Section 2 a three nodes flow-based network example to cover concrete aspects of the LTA coverage problem and of the new methodology. The new methodology is based on a standard result to describe the "convex hull of the union of two polyhedra"[1].

The example is used to compare (a) models and market outcomes, (b) shadow prices and price formation, and (c) the congestion rent compared to LTA liabilities. It is shown that formulas relating bidding area market prices to shadow prices of PTDF or LTA constraints are identical to their classic flow-based or ATC counterparts. It is also discussed why the LTA coverage process guarantees to avoid a missing money issue to cover LTA liabilities.

Appendix A then presents the same developments with general notation to describe the approach and related results in full generality.

2 A detailed example

The base case example[2] is first presented, where a missing money problem for LTA liabilities occur. Next Sections then discuss approaches for the LTA coverage process.

2.1 The base case

We consider first a base case example with a three-node network (see figure 1 below) where:

- node A has two supply orders:
  400MWh @ 10€/MWh
  600MWh @ 20€/MWh
- node B has two demand orders:
  100MWh @ 70€/MWh
  900MWh @ 60€/MWh
- node C has one demand order:
  1000MWh @ 50€/MWh

and the following PTDF constraints apply:

$$0.75netpos_b + 0.5netpos_c \leq 250$$
$$netpos_a \geq -1500$$

Market outcome:

- A exports 450MWh, $price_a = 20$ €$/MWh$
- B imports 100MWh, $price_b = 65$ €$/MWh$
- C imports 350MWh, $price_c = 50$ €$/MWh$
- Welfare = 19 500 €
- Congestion rent $= -450 \times 20 + 100 \times 65 + 350 \times 50 = 15\ 000$€
- Order surpluses = 4 500 €

This market outcome can be obtained by solving the following welfare optimization problem (for each constraint, the associated shadow price variable is indicated on the right in square brackets, to ease later discussions.):

[1] See for example Theorem 1 in [1], or Chapter 2 "Polyhera" in [2]. It is briefly formally described in Appendix.

[2] The base case is an example illustrating flow factor competition in flow-based models presented in *CWE Market Coupling, Flow-Based Forum, Amsterdam, 1st of June 2011, online:* https://www.apxgroup.com/wp-content/uploads/Final_presentation_June_2011.pdf.

$$\max \ welfare := (100)(70)x_{b1} + (900)(60)x_{b2} + (1000)(50)x_c - (400)(10)x_{a1} - (600)(20)x_{a2} \quad (1)$$

$$netpos_a = -400x_{a1} - 600x_{a1} \qquad [price_a = 20] \qquad (2)$$

$$netpos_b = 100x_{b1} + 900x_{b2} \qquad [price_b = 65] \qquad (3)$$

$$netpos_c = 1000x_c \qquad [price_c = 50] \qquad (4)$$

$$0 \leq x_i \leq 1 \qquad \forall i \qquad (5)$$

PTDF constraints:

$$0.75netpos_b + 0.5netpos_c \leq 250 \qquad [ShadowPrice_1^{FB} = 60] \qquad (6)$$

$$-netpos_a \leq 1500 \qquad [ShadowPrice_2^{FB} = 0] \qquad (7)$$

Net exports can be linked to (non-unique) commercial flows:

$$netpos_a = flow_{ba} + flow_{ca} - flow_{ab} - flow_{ac} \qquad [price_a^{FB} = 20] \qquad (8)$$

$$netpos_b = flow_{ab} + flow_{ac} - flow_{ba} - flow_{bc} \qquad [price_b^{FB} = 20] \qquad (9)$$

$$netpos_c = flow_{ac} + flow_{bc} - flow_{ca} - flow_{cb} \qquad [price_c^{FB} = 20] \qquad (10)$$

$$f \geq 0 \qquad (11)$$

Note that (8)-(10) imply :

$$netpos_a + netpos_b + netpos_c = 0 \qquad (12)$$

- If we assume that the contracted volume of LTA rights is 400 MWh in the direction $A \rightarrow B$,

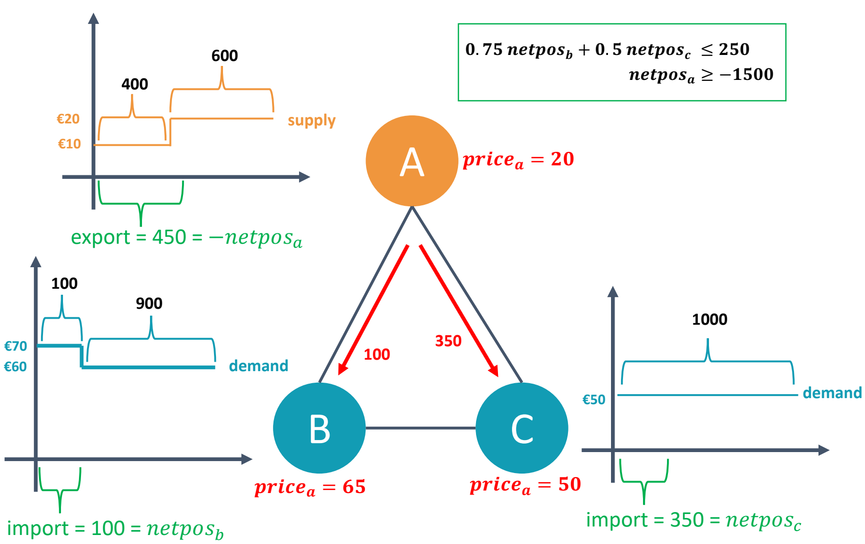


Figure 1: Base case example.

as the price difference is $65 - 20 = 45$, the LTA liabilities are $45 \times 400 = 18000$€.

- However, the congestion rent is equal to: $-450 \times 20 + 350 \times 50 + 100 \times 65 = 15\,000$€. Hence, the congestion rent does not cover the LTA liabilities of 18 000€.
- This is related to the fact that a solution where A exports to B 400MWh and $netpos_c = 0$, i.e. where $netpos_a = -400, netpos_b = 400, netpos_c = 0$, "commercial flow" $flow_{ab} = 400$ and all other variables are null, is not feasible for the network model: constraint (6) would be violated[3].
- To solve this issue, a preferred solution is to enlarge the FB model "just enough" so as to contain that possibility $netpos_a = -400, netpos_b = 400, netpos_c = 0, flow_{ab} = 400$ (other variables null).
- This is done by considering the smallest network model that can be described by linear constraints of the form $ax \leq b$, which contains both the initial feasible points and the new possibility $netpos_a = -400, netpos_b = 400, flow_{ab} = 400$. Technically, we want the adherence of the convex hull of the union of the initial flow-based domain, and of the LTA domain(the new possibility to add), denoted $\overline{conv}(FB \cup LTA)$.[4]

2.2 The virtual branch approach for $\overline{conv}(FB \cup LTA)$

2.2.1 Model and market outcome

For the base case example above, let FB be the set of feasible net positions and flows described by conditions (6)-(11) and let LTA be the set of net positions that can be obtained by allowing a flow $f_{ab} \in [0; 400], netpos_a = -f_{ab}, netpos_b = f_{ab}, netpos_c = 0$ (and all other flows set to zero). Actually, for LTA, only the extreme case $f_{ab} = 400, netpos_a = -400, netpos_b = 400, netpos_c = 0$ (other flows null) needs to be considered for inclusion in the network model: all intermediate cases with $f_{ab} \in [0; 400]$ will automatically be included as well.

In the Virtual branch approach, one uses new PTDF constraints to describe $\overline{conv}(FB \cup LTA)$. The market outcome obtained is further discussed below and depicted on figure 2. It can be shown that for our example, the new PTDF constraints (18)-(20) together with the system condition $netpos_a + netpos_b + netpos_c = 0$ (here replaced by (21)-(23) as done in the base example above) exactly describes $\overline{conv}(FB \cup LTA)$.

The following small welfare optimization problem hence describes the market clearing problem with the network model enlarged just enough as to *guarantee* that the congestion rent will cover the LTA liabilities.

$$\max\ welfare := (100)(70)x_{b1} + (900)(60)x_{b2} + (1000)(50)x_c - (400)(10)x_{a1} - (600)(20)x_{a2} \quad (13)$$

[3] It is shown below that if this possibility is feasible for the network model, it is guaranteed that the congestion rent covers the LTA liabilities.

[4] Technically, one wants this convex hull "with its boundary included", hence the notation $\overline{conv}$ to distinguish from *conv*, to ensure that the enlarged set is still a polyhedron of the form $\{x|Ax \leq b\}$. This is because if P_1 and P_2 are two polyhedra, i.e. two sets of the form $\{x|Ax \leq b\}$, $conv(P_1 \cup P_2)$ might not be a polyhedron as it might "not contain its boundary", see Appendix C for a small illustrative example and discussion.

$$netpos_a = -400x_{a1} - 600x_{a1} \quad [price_a = 20] \quad (14)$$
$$netpos_b = 100x_{b1} + 900x_{b2} \quad [price_b = 63.75] \quad (15)$$
$$netpos_c = 1000x_c \quad [price_c = 50] \quad (16)$$
$$0 \leq x_i \leq 1 \quad \forall i \quad (17)$$

PTDF constraints including (VB):

$$-2netpos_a + netpos_b \leq 1200 \quad [ShadowPrice_1^{FB} = 0] \quad (18)$$
$$-24netpos_a + 11netpos_b \leq 14000 \quad [ShadowPrice_2^{FB} = 1.25] \quad (19)$$
$$-netpos_a \leq 1500 \quad [ShadowPrice_3^{FB} = 0] \quad (20)$$

Net exports can be linked to (non-unique) commercial flows,:

$$netpos_a = flow_{ba} + flow_{ca} - flow_{ab} - flow_{ac} \quad [price_a^{FB} = 50] \quad (21)$$
$$netpos_b = flow_{ab} + flow_{ac} - flow_{ba} - flow_{bc} \quad [price_b^{FB} = 50] \quad (22)$$
$$netpos_c = flow_{ac} + flow_{bc} - flow_{ca} - flow_{cb} \quad [price_c^{FB} = 50] \quad (23)$$
$$f \geq 0 \quad (24)$$

Market outcome for LTA inclusion based on the virtual branch approach:

- A exports 537.5MWh, $price_a = 20$ €$/MWh$
- B imports 100MWh, $price_b = 63.75$ €$/MWh$
- C imports 437.5MWh, $price_c = 50$ €$/MWh$
- Welfare = 22 125 €
- Congestion rent $= -537.5 \times 20 + 100 \times 63.75 + 437.5 \times 50 = 17\ 500$€
- Order surpluses = 4 625 €

2.2.2 Shadow prices and price formation

One can observe the following classical relations:

$$price_l = price^{FB} + \sum_m ptdf_{m,l} ShadowPrice_m \quad (25)$$

where $price^{FB}$ corresponds to the "system price" equal to $50 = price_a^{FB} = price_b^{FB} = price_c^{FB}$ in the example, see (13)-(24). One can derive from these relations:

$$price_k - price_l = \sum_m ShadowPrice_m (ptdf_{m,k} - ptdf_{m,l}) \quad (26)$$

For example, the price difference

$$price_b - price_a = 63.75 - 20 = 43.75 \tag{27}$$

is equal to

$$ShadowPrice_2^{FB}(ptdf_{2,b} - ptdf_{2,a}) = 1.25[11 - (-24)] = 43.75 \tag{28}$$

2.2.3 Congestion rent and LTA coverage

We observe now that the congestion rent covers the LTA liabilities:

- LTA liabilities are given by the contracted volume times the price difference between area B and area A, that is $400 \times (63.75 - 20) = 400 \times 43.75 = 17500$€
- On the other side, the congestion rent is equal also to 17500€, cf. the computation above.

The missing money problem has disappeared.

Let us see on this example the reason why the missing money disappears in general when one considers $\overline{conv}(FB \cup LTA)$ (the statement with more general notation is discussed in Section A.3 below).

This is related to the following: for the market prices $price_a^* = 20, price_b^* = 63.75, price_c^* = 50$ considered as fixed parameters, the operation of the transmission system given by the market out-

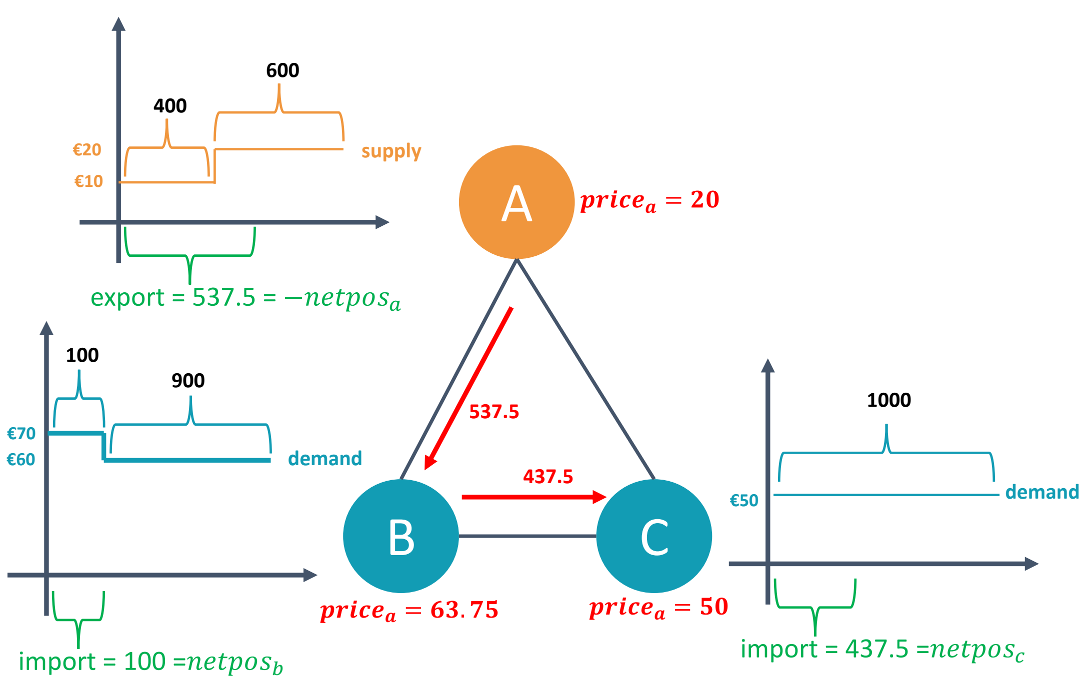


Figure 2: Market outcome with LTA coverage

come $netpos_a = -537.5, netpos_b = 100, netpos_c = 437.5$ is optimal for the following maximization problem:

$$\max congestion\ rent = 20 netpos_a + 63.75 netpos_b + 50 netpos_c \tag{29}$$

subject to the network model constraints (18)-(24)

As the constraints (18)-(24) contain "by construction" the point $netpos_a = -400, netpos_b = 400, netpos_c = 0$, we know that the maximum obtained in (29) is at least equal to $20 \times (-400) + 63.75 \times 400 = 17500$€.

So whatever the solution of the market outcome is, as the net positions will be optimal for (29) (assuming that we know that 20, 63.75 and 50 are the fixed market prices obtained from the market outcome), the congestion rent will be at least 17 500 €. In the present example, using the optimal net positions $netpos_a = -537.5, netpos_b = 100, netpos_c = 437.5$ given by the market outcome, the congestion rent is actually exactly equal to 17 500 €.

2.3 The Extended formulation approach for $\overline{conv}(FB \cup LTA)$

Exactly the same market outcome as with the virtual branch approach in Section 2.2, depicted on figure 2 above, is obtained with the following model based on the new methodology proposed for LTA coverage. The only difference lies in the set of shadow prices "explaining" the (same) bidding area market prices and bidding area price differences.

2.3.1 Model and market outcome

Extended formulation approach:

$$\max\ welfare := (100)(70)x_{b1} + (900)(60)x_{b2} + (1000)(50)x_c - (400)(10)x_{a1} - (600)(20)x_{a2} \tag{30}$$

$$netpos_a = -400x_{a1} - 600x_{a1} \qquad [price_a = 20] \tag{31}$$

$$netpos_b = 100x_{b1} + 900x_{b2} \qquad [price_b = 63.75] \tag{32}$$

$$netpos_c = 1000x_c \qquad [price_c = 50] \tag{33}$$

$$0 \le x_i \le 1 \qquad \forall i \tag{34}$$

Virgin PTDF constraints with dedicated net export and flow variables for FB:

$$0.75 netpos_b^{FB} + 0.5 netpos_c^{FB} \le \alpha_1 250 \qquad [ShadowPrice_1^{FB} = 55] \tag{35}$$

$$-netpos_a^{FB} \le \alpha_1 1500 \qquad [ShadowPrice_2^{FB} = 2.5] \tag{36}$$

$$\tag{37}$$

$$netpos_a^{FB} = flow_{ba}^{FB} + flow_{ca}^{FB} - flow_{ab}^{FB} - flow_{ac}^{FB} \qquad [price_a^{FB} = 22.5] \tag{38}$$

$$netpos_b^{FB} = flow_{ab}^{FB} + flow_{ac}^{FB} - flow_{ba}^{FB} - flow_{bc}^{FB} \qquad [price_b^{FB} = 22.5] \tag{39}$$

$$netpos_c^{FB} = flow_{ac}^{FB} + flow_{bc}^{FB} - flow_{ca}^{FB} - flow_{cb}^{FB} \qquad [price_c^{FB} = 22.5] \tag{40}$$

$$flow^{FB} \ge 0 \tag{41}$$

LTA constraints with dedicated net export and flow variables for LTA

$$flow_{ab}^{LTA} \leq \alpha_2 400 \qquad [ShadowPrice_{ab}^{LTA} = 43.75] \quad (42)$$

$$other\ flow\ variables = 0 \quad (43)$$

$$(44)$$

$$netpos_a^{LTA} = flow_{ba}^{LTA} + flow_{ca}^{LTA} - flow_{ab}^{LTA} - flow_{ac}^{LTA} \qquad [price_a^{LTA} = 20] \quad (45)$$

$$netpos_b^{LTA} = flow_{ab}^{LTA} + flow_{ac}^{LTA} - flow_{ba}^{LTA} - flow_{bc}^{LTA} \qquad [price_b^{LTA} = 63.75] \quad (46)$$

$$netpos_c^{LTA} = flow_{ac}^{LTA} + flow_{bc}^{LTA} - flow_{ca}^{LTA} - flow_{cb}^{LTA} \qquad [price_c^{LTA} = 50] \quad (47)$$

$$flow^{LTA} \geq 0 \quad (48)$$

Constraints relating the original net export and flow variables to their duplicates used to describe respectively the virgin flow-based and LTA domains:

$$netpos_i = netpos_i^{FB} + netpos_i^{LTA} \qquad i \in \{a, b, c\} \quad (49)$$

$$flow_{ij} = flow_{ij}^{FB} + flow_{ij}^{LTA} \qquad i, j \in \{a, b, c\} \quad (50)$$

$$\alpha_1 + \alpha_2 = 1 \quad (51)$$

$$\alpha_1, \alpha_2 \geq 0 \quad (52)$$

Market outcome for LTA inclusion based on the extended formulation approach:

- A exports 537.5MWh, $price_a = 20$ €$/MWh$
- B imports 100MWh, $price_b = 63.75$ €$/MWh$
- C imports 437.5MWh, $price_c = 50$ €$/MWh$
- Welfare = 22 125 €
- Congestion rent $= -537.5 \times 20 + 100 \times 63.75 + 437.5 \times 50 = 17\ 500$€
- Order surpluses = 4 625 €

2.3.2 Shadow prices and price formation

Let us first observe that we have the same bidding area market prices but a different set of shadow prices as we now have the virgin flow-based constraints and LTA constraints (somehow "scaled" by the α) to model the network, instead of virtual branches.

However, market price differences are explained by similar relations via the shadow prices of the PTDF constraints involved, namely:

Relation identical to (25):

$$price_l = price^{FB} + \sum_m ptdf_{m,l} ShadowPrice_m \quad (53)$$

where $price^{FB}$ corresponds to the "system price" now equal to $22.5 = price_a^{FB} = price_b^{FB} = price_c^{FB}$ in the example, see (38)-(40).

For example,

$$price_c = 50 = 22.5 + 55(0.5) + 2.5(0) \quad (54)$$

We can then also derive:

Relation identical to (26):

$$price_k - price_l = \sum_m ShadowPrice_m(ptdf_{m,k} - ptdf_{m,l}) \tag{55}$$

For example, the price difference

$$price_b - price_a = 63.75 - 20 = 43.75 \tag{56}$$

is equal to

$$\begin{aligned} &ShadowPrice_1^{FB}(ptdf_{1,b} - ptdf_{1,a}) + ShadowPrice_2^{FB}(ptdf_{2,b} - ptdf_{2,a}) \\ &= 55[0.75 - 0] + 2.5[0 - (-1)] = 43.75 \end{aligned} \tag{57}$$

2.3.3 Congestion rent and LTA coverage

Discussions regarding the congestion rent would be exactly the same as the discussions in Section 2.2.3 for the virtual branch based approach. Only the constraints of the network model needs to be adapted in the optimization problem for the operation of the transmission system, which is here:

$$\max congestion\ rent = 20netpos_a + 63.75netpos_b + 50netpos_c \tag{58}$$

subject to the network model constraints (35)-(52)

(Conditions (35)-(52)have replaced conditions (18)-(24).)

3 Observations and practical questions for implementation in production

3.1 Assessment of performance gains

Let us first emphase that the new extended formulation methodology presented on an example in Section 2.3 is much more scalable than the approach based on virtual branches: in the extended formulation approach, the number of constraints required is the number of virgin PTDF constraints plus the number of LTA capacity constraints and a number of constraints directly proportional to the number of bidding areas and lines (to link the "duplicate" net position and flow variables for respectively the virgin flow-based and LTA domains to their counterpart lying in the convex hull of the union of these domains).

On the other hand, the virtual branch approach requires to pre-compute a number of PTDF constraints which becomes quickly very large with an increased number of bidding areas. Also, the computation of virtual branches becomes itself very challenging.

The added value of the new methodology is hence two-folds:

- For network models with many more bidding areas as for CORE Region, it makes it tractable to consider the "tight version" of a LTA coverage process (enlarging the original PTDF domain *"just enough"*).
- For network models with a few more bidding areas as required in some Evolved Flow-Based modeling applications, it allows to greatly reduce the number of constraints required to describe the enlarged domain for LTA coverage, with a substantially positive impact on Euphemia performances.

The following figure 3 shows performance gains with preliminary performance tests for Evolved Flow-Based with 7 CWE bidding areas (instead of 5) to model the inclusion of the Alegro HVDC inter-connector, for flow-based plain:

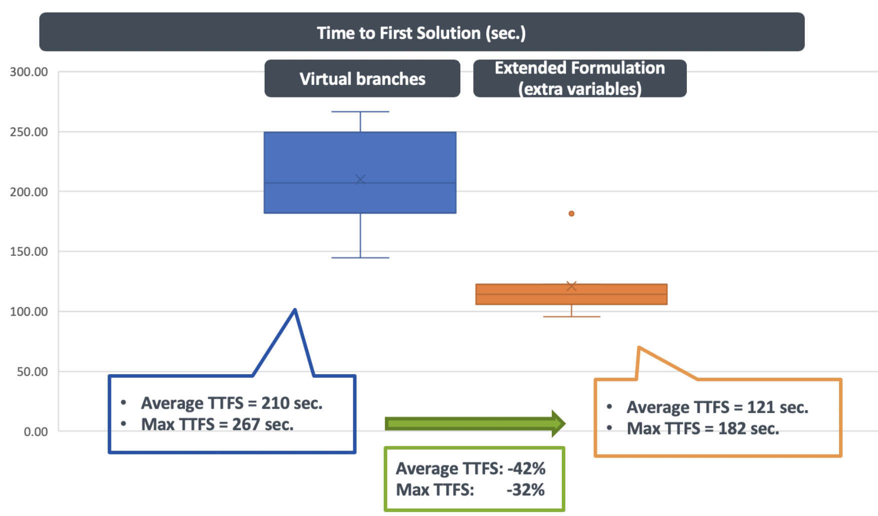


Figure 3: Comparison of Times to First Solution (in seconds), based on Euphemia 10.4, 7 sessions in November 2018 to April 2019 with inclusion of the Alegro HVDC inter-connector, Flow-Based Plain (FBP)

3.2 Interactions with bidding zones outside the balancing area

The modeling alternative only concerns the CWE balancing and the corresponding "net exports" (net positions on the balancing area). It has no impact on other bidding areas such as neighbouring bidding areas connected via ATC lines.

3.3 Interface and PMB changes

For the current prototype implementation, minor changes are needed in the Euphemia input interface:

- Columns LTA_DOWN and LTA_UP should be added to table LINE_CAPACITIES (alternatively, columns CAPACITY_UP and CAPACITY_DOWN could be used as currently no capacity is otherwise specified for "TOP" lines of the CWE area).
- A column (e.g. ISVIRGIN) has to be added to table SESSION_BALANCINGAREAS to indicate if LTAs are to be taken into consideration for the balancing area (note that if the parameter indicates that LTAs should be considered but an empty LTA domain is provided, the behavior is similar to the case where no LTAs should be taken into consideration, although extra variables for LTAs not needed in that case would be created).

Note that the virgin PTDF data is provided via the usual tables for PTDF constraints.

To use the feature, the user has to provide a non-empty LTA domain, via table LINE_CAPACITIES, and specify a virgin domain is used via table SESSION_BALANCINGAREAS. If the LTA domain is empty, the behavior is similar to the case where classical PTDF constraints are provided.

Regarding the Euphemia output interface, shadow prices of the virgin flow-based constraints can be reported as the classical shadow prices of input PTDF constraints. The only new information of interest would be the shadow prices of constraints of the LTA domain. These shadow prices directly explain bidding area price differences as in a classic ATC network model (if a "LTA flow" occurs between bidding areas with different prices, the shadow price of the LTA capacity is equal to the price difference, and the "LTA flow" goes from the cheaper area to the more expensive area), cf. the example discussed in Section 2 and also price conditions derived in Appendix A.2. Note that the price difference between bidding areas can also be explained via the shadow prices of the virgin PTDF constraints, cf. again Section 2 and the example discussed therein.

3.4 Interaction with the intuitiveness patch

Intuitiveness is now enforced via the virgin flow-based domain which might be more restrictive than when the additional conditions to enforce intuitiveness are related to the enlarged flow-based domain $\overline{conv}(FB \cup LTA)$.

Although this requires further assessment and would require advanced technical work, it should be possible to circumvent this by generating those additional conditions to enforce intuitiveness which are related to the enlarged flow-based domain $\overline{conv}(FB \cup LTA)$.

3.5 Impact on the adequacy patch

The behavior of the adequacy patch is not impacted by the reformulation of the LTA coverage: the original net position and flow variables $netpos, flow$ are still available and used for related computations.

The only impact on curtailment aspects could in theory come from restrictions of additional transmission capacities due to intuitiveness being enforced on the virgin flow-based domain which is more restrictive than enforcing intuitiveness on the enlarged domain after LTA coverage, but this impact is not specifically related to the adequacy patch.

3.6 Validation of the implementation

To validate the implementation, it is recommended to design various functional tests based on virtual branches exactly describing $\overline{conv}(FB \cup LTA)$, so that market outcome results computed by Euphemia with virtual branches can be directly compared to market results obtained with the new methodology which has been prototyped in Euphemia. As discussed in the example above, with flow-based plain, market results must be identical. With flow-based in intuitive mode, market results can differ due to the way intuitiveness is, for now, enforced in the new methodology.

A Extended formulation for LTA inclusion in general

The extended formulation is described here with general notation for sessions with classical step bid curves. How the formulation is obtained is briefly discussed in Appendix B.

A.1 Welfare maximization model

$$\max \sum_i Q^i P^i x_i \tag{59}$$

s.t.

$$\sum_{i \in Orders(l)} Q^i x_i = netpos_l \qquad [price_l] \quad \forall l \in Locations \tag{60}$$

$$0 \leq x_i \leq 1 \qquad \forall i \tag{61}$$

$$\tag{62}$$

$$netpos_l = \widetilde{netpos}_l^{FB} + \widetilde{netpos}_l^{LTA} \qquad [\widetilde{price_l}] \tag{63}$$

$$flow_{l,k} = \widetilde{flow}_{l,k}^{FB} + \widetilde{flow}_{l,k}^{LTA} \tag{64}$$

$$\alpha_1 + \alpha_2 = 1 \qquad [\eta] \tag{65}$$

$$\alpha \geq 0 \tag{66}$$

$$\sum_l ptdf_{m,l} \widetilde{netpos}_l^{FB} \leq \alpha_1 \ RAM_m \qquad [ShadowPrice_m] \forall m \tag{67}$$

$$\widetilde{netpos}_l^{FB} = \sum_{k \neq l} \widetilde{flow}_{k,l}^{FB} - \widetilde{flow}_{l,k}^{FB} \qquad [price_l^{FB}] \ \forall l \in Locations \tag{68}$$

$$\widetilde{flow}^{FB} \geq 0 \tag{69}$$

$$\widetilde{flow}_{l,k}^{LTA} \leq \alpha_2 \ capacity_{l,k}^{LTA} \qquad [w_{l,k}^{LTA}] \qquad \forall l, k \in Locations \tag{70}$$

$$\widetilde{netpos}_l^{LTA} = \sum_{k \neq l} \widetilde{flow}_{k,l}^{LTA} - \widetilde{flow}_{l,k}^{LTA} \qquad [price_l^{LTA}] \qquad \forall l \in Locations \tag{71}$$

$$\widetilde{flow}^{LTA} \geq 0 \tag{72}$$

A.2 Shadow prices and price formation

Conditions dual to the variables $netpos_l$:

$$\widetilde{price}_l = price_l \tag{73}$$

Next conditions are written by taking (73) into account and replacing $\widetilde{price_l}$ with $price_l$.

Conditions dual to the variables $netpos_l^{FB}$:

$$price_l = price_l^{FB} + \sum_m ptdf_{m,l} ShadowPrice_m \quad (74)$$

Conditions dual to the variables $netpos_l^{LTA}$:

$$\boxed{price_l = price_l^{LTA}} \quad (75)$$

Conditions dual to the variables $flow_{l,k}^{LTA} \geq 0$:

$$w_{l,k}^{LTA} \geq price_k^{LTA} - price_l^{LTA} \quad (76)$$

Using the associated complementary condition $flow_{l,k}^{LTA}(w_{l,k}^{LTA} - price_k^{LTA} + price_l^{LTA}) = 0$, we have:

$$\boxed{flow_{l,k}^{LTA} > 0 \Rightarrow price_k^{LTA} - price_l^{LTA} = w_{l,k}^{LTA} \geq 0} \quad (77)$$

Conditions dual to the variables $f_{l,k}^{FB} \geq 0$:

$$0 \geq price_k^{FB} - price_l^{FB} \quad (78)$$

Considering (78) for all pairs l, k gives $price_k^{FB} = price_l^{FB}$ (assuming that locations form a connected component), and conditions (74) can be rewritten as:

$$\boxed{price_l = price^{FB} + \sum_m ptdf_{m,l} ShadowPrice_m,} \quad (79)$$

where $price^{FB}$ corresponds to the "system price".

We then have the usual relations:

$$\boxed{price_k - price_l = \sum_m ShadowPrice_m (ptdf_{m,k} - ptdf_{m,l})} \quad (80)$$

A.3 Congestion rent and LTA coverage

We show here with general notation that with the LTA coverage methodology, the congestion rent is always sufficient to cover LTA liabilities.

Let us consider an optimal solution $(x, netpos, flow)$ to the welfare maximization problem (59)-(72) and consider the market prices $price_l^*$ obtained as optimal dual variables of (60).

We want to prove the following inequality:

$$\sum_l netpos_l^* \; price_l^* \geq \sum_{l,k} (price_k^* - price_l^*)^+ capacity_{l,k}^{LTA} \quad (81)$$

The congestion rent appears on the left-hand side of the inequality and is expressed as the revenue from operating the transmission network, i.e. realized from the buy/sell operations: $netpos_l^* > 0$

if a volume is sold by the operator to location l, $netpos_l^* < 0$ if a volume is bought from location l and the left-hand side represents the sum of the associated money transfers given the locational market prices $price_l^*$.

The right-hand side represents LTA liabilities. The notation $(price_k^* - price_l^*)^+$ means the price in location k minus the price in location l counted only of the price is higher in location k, and 0 otherwise ($(price_k^* - price_l^*)^+$ is hence non-null only if the price in location k is higher than in location l, in which case $(price_k^* - price_l^*)^+$ is equal to that price difference). Multiplying $(price_k^* - price_l^*)^+$ by the volume of LTA rights in the direction $l \to k$ denoted by $capacity_{l,k}^{LTA}$, and summing up over all possibilities for l, k, provides the total LTA liabilities.

To prove (81), we will use the fact that $(netpos^*, flow^*)$ obtained from the market clearing process solves the following profit maximization problem for the transmission system, where locational market prices $price^*$ are fixed parameters and where the operator seeks to find best import/export decisions $(netpos, flow)$ given those prices and assuming "infinite market depth" (i.e. without worrying about the order books):

$$\max_{(netpos, flow)} \sum_l netpos_l \; price_l^* \tag{82}$$

s.t. to network constraints (63)-(72).

To prove the inequality (81), it is hence sufficient to find a solution $(\overline{netpos}, \overline{flow})$ feasible for (63)-(72) such that:

$$\sum_l \overline{netpos}_l \; price_l^* \geq \sum_{l,k} (price_k^* - price_l^*)^+ capacity_{l,k}^{LTA}, \tag{83}$$

as the congestion rent is at least as high as the left-hand side.

Such a feasible solution can be straightforwardly constructed as the network model has been enlarged for that purpose, and can be given by:

$$flow_{l,k} = flow_{l,k}^{LTA} := capacity_{l,k}^{LTA} \qquad if \quad price_k^* > price_l^*$$

$$flow_{l,k} = flow_{l,k}^{LTA} := 0 \qquad if \quad price_k^* \leq price_l^*$$

$$netpos_l = netpos_l^{LTA} := \sum_{k \neq l} (flow_{k,l} - flow_{l,k}) = \sum_{k \neq l} (flow_{k,l}^{LTA} - flow_{l,k}^{LTA})$$

$$\alpha_{LTA} = 1$$

$$\alpha_{FB} := 0, netpos_l^{FB} := 0, flow_{l,k}^{FB} := 0$$

B From convex combinations to the extended formulation for $\overline{conv}(FB \cup LTA)$

A convex combination of two points x, y is the set of points that can be written as $\alpha_1 x + \alpha_2 y$ with $\alpha_1 + \alpha_2 = 1, \alpha_1 \geq 0, \alpha_2 \geq 0$.

It is the goal of the constraints (87)-(96) where one makes a convex combination of a point $(netpos^{FB}, flow^{FB})$ in the flow-based domain described by conditions (91)-(93) and a point in the LTA domain described by conditions (94)-(96). These constraints (87)-(96) are then transformed via a substitution of variables into the formulation (63)-(72). Details follow in next paragraphs, where cases with $\alpha_1 = 0$ or $\alpha_2 = 0$ are also discussed.

For $\alpha_1 > 0, \alpha_2 > 0, \alpha_1 + \alpha_2 = 1$, constraints (91)-(93) are fully equivalent to the original flow based constraints (just multiplied by a strictly positive number α_1) and constraints (94)-(96) are similarly fully equivalent to the original LTA constraints.

Making the substitution $\widetilde{netpos}^{FB} := \alpha_1 netpos^{FB}, \widetilde{flow}^{FB} := \alpha_1 flow^{FB}, \widetilde{netpos}^{LTA} := \alpha_2 netpos^{LTA}, \widetilde{flow}^{LTA} := \alpha_2 flow^{LTA}$ then exactly provides the extended formulation (63)-(72) in Appendix A.

Let us check that this formulation (63)-(72) also works when $\alpha_1 = 0$ or $\alpha_2 = 0$.

If $\alpha_1 = 0, \alpha_2 = 1$, assuming the PTDF polyhedron is bounded[5], only the solution $\widetilde{netpos}^{FB} = 0, \widetilde{flow}^{FB} = 0$ is feasible for (67)-(69) and we actually pick-up a point in the LTA domain, as constraints (70)-(72) with $\alpha_2 = 1$ are the original LTA constraints. Similarly, if $\alpha_1 = 1, \alpha_2 = 0$, it implies that $\widetilde{netpos}^{LTA} = 0, \widetilde{flow}^{LTA} = 0$ and we actually pick up a point in the flow-based domain, as constraints (67)-(69) with $\alpha_1 = 1$ are the original flow-based constraints.

$$\max \sum_i Q^i P^i x_i \tag{84}$$

$$\sum_{i \in Orders(l)} Q^i x_i = netpos_l \tag{85}$$

$$0 \leq x_i \leq 1 \qquad \forall i \tag{86}$$

$$netpos_l = \alpha_1 \; netpos_l^{FB} + \alpha_2 \; netpos_l^{LTA} \tag{87}$$

$$flow_{l,k} = \alpha_1 \; flow_{l,k}^{FB} + \alpha_2 \; flow_{l,k}^{LTA} \tag{88}$$

$$\alpha_1 + \alpha_2 = 1 \tag{89}$$

$$\alpha \geq 0 \tag{90}$$

$$\alpha_1 \sum_l ptdf_{m,l} \; netpos_l^{FB} \leq \alpha_1 RAM_m \tag{91}$$

$$\alpha_1 netpos_l^{FB} = \alpha_1 \sum_{k \neq l} (flow_{k,l}^{FB} - flow_{l,k}^{FB}) \tag{92}$$

$$\alpha_1 flow^{FB} \geq 0 \tag{93}$$

$$\alpha_2 flow_{l,k}^{LTA} \leq \alpha_2 capacity_{l,k}^{LTA} \tag{94}$$

$$\alpha_2 netpos_l^{LTA} = \alpha_2 \sum_{k \neq l} (flow_{k,l}^{LTA} - flow_{l,k}^{LTA}) \tag{95}$$

$$\alpha_2 flow^{LTA} \geq 0 \tag{96}$$

[5] We refer to the reference [2] for the general case where polyhedra P_1, P_2 involved in the present method to describe $\overline{conv}(P_1 \cup P_2)$ are unbounded.

C An example illustrating the difference between $conv(P_1 \cup P_2)$ and $\overline{conv}(P_1 \cup P_2)$

Consider:

- $P_1 = \{(x, y)|y = 1\}$, the blue line in the figure 4 below,
- $P_2 = \{(x, y)|x = 2, y = 2\}$, the red point in the figure 4 below.

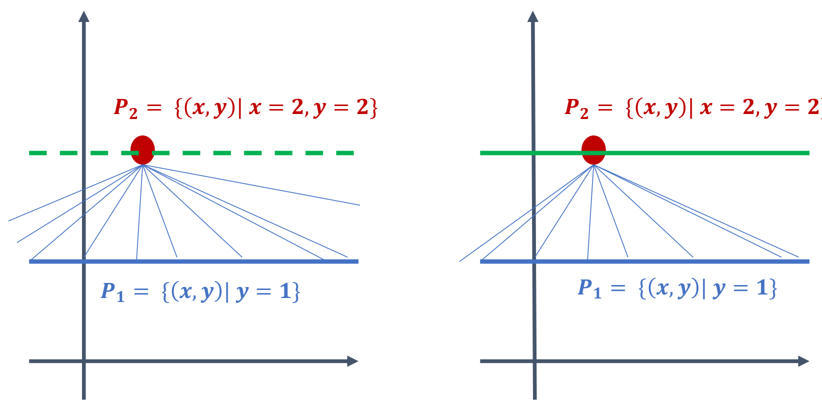


Figure 4: Difference between $conv(P_1 \cup P_2)$ and $\overline{conv}(P_1 \cup P_2)$.

One can check that all the possible convex combinations of the red point P_2 and a point in the blue line P_1 are all the points between the blue line included, and the dotted green line excluded, plus the red point: the dotted green line is a part of the boundary which is not included in "$conv(P_1 \cup P_2)$". Formally:

$$conv(P_1 \cup P_2) = \{(x, y)|(y \geq 1, y<2)\} \cup \{(x = 2, y = 2)\} \tag{97}$$

This set cannot be described as a polyhedron, i.e. via non-strict linear inequalities.

However, if we include the boundary green line, cf. the right-hand side of figure 4, i.e. we consider "$conv(P_1 \cup P_2)$ plus its boundary included", which is written $\overline{conv}(P_1 \cup P_2)$, one has:

$$\overline{conv}(P_1 \cup P_2) = \{(x, y)|\ y \geq 1, y \leq 2\} \tag{98}$$

which is now a polyhedron.

For applications in optimization, one needs to work with the second option (otherwise, maximum or minimum might not exist).

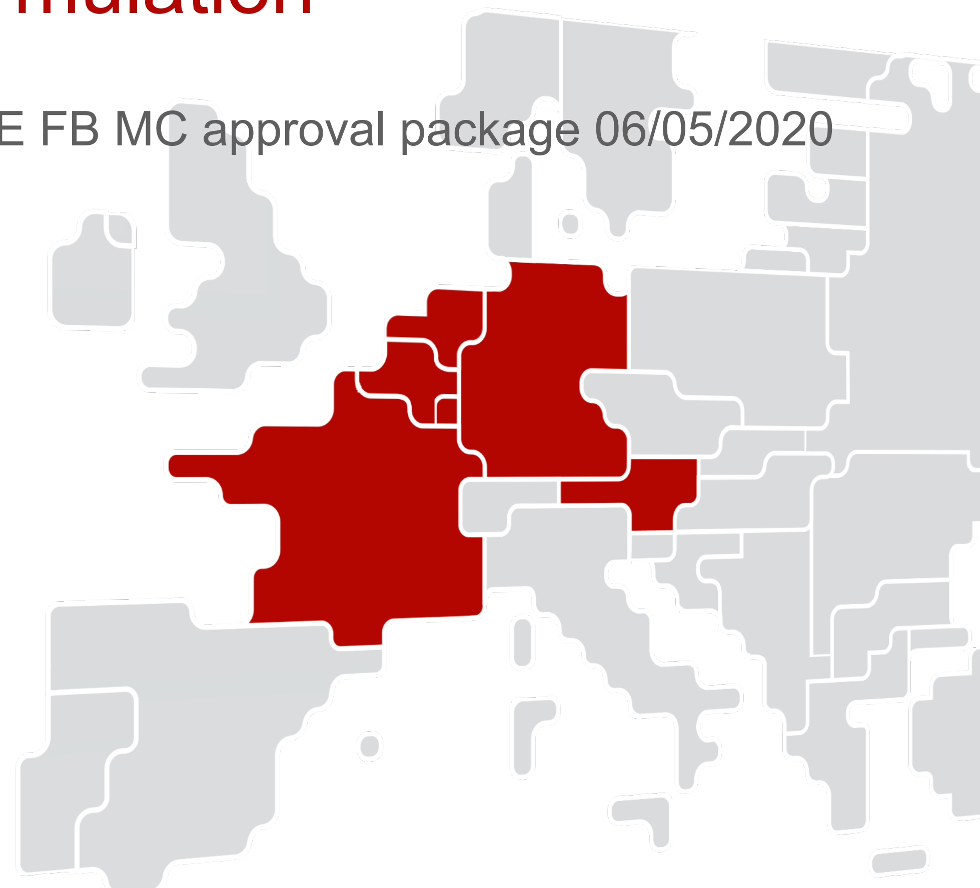
D Bibliography

[1] Michele Conforti, Marco Di Summa, and Yuri Faenza. Balas formulation for the union of polytopes is optimal. *Mathematical Programming*, pages 1–16, 2017.

[2] Giuseppe Lancia and Paolo Serafini. *Compact extended linear programming models*. Springer, 2018.

Annex 14.30 - Pedagogical information on Extended LTA formulation

Submitted as part of the CWE FB MC approval package 06/05/2020



About this document

This document explains the methodologies used for LTA inclusion. This document aims to provide an overview of the changes that are expected considering the performance upgrades for CWE. It consists of the following:

- Reminder of current approach
- Improved virtual branches
- Extended LTA

By means of a high-level introduction, the performance mitigations will significantly reduce the amount of constraints needed for the capacity calculation. This in turn improves performance on both capacity calculation ad allocation side. The improved performance allows the market coupling algorithm to find more optimal solutions, possibly increasing the social welfare.

The implementation of the performance upgrades are expected in Q4 2020

- Improved virtual branches can be expected as of ALEGrO go-live
- Extended LTA with a new release of the market coupling algorithm around Q4 2020

Introduction and current approach

Updates to include changes related to performance mitigations:

- As informed during the CCG of 03/04, performance challenges of FBCE & Euphemia with additional borders became apparent with the preparations for the implementation of ALEGrO: there was lack of scalability of the IT system.
  - The issue: the number of virtual branches which are created for the LTA inclusion process is exponentially linked to the mathematical dimensionality.

Current process

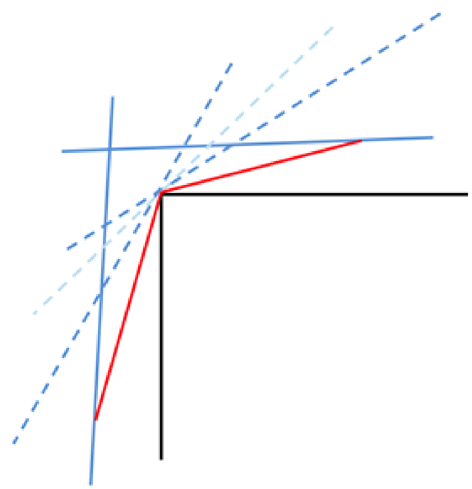
- Currently each real branch is replaced by its virtual counterpart in case the LTA corner creates an overload– leading to a high number of duplicate virtual branches. Hence, the number of virtual constraints generated during the LTA inclusion can be significantly reduced by removing this duplication step
- With the current approach, each virtual branch will be scaled with the corresponding RAM. It will lead to non-physical PTDFs for the virtual branches.
- A detailed example can be found in the annexes of the slides.

TSOs accordingly developed updates of the methodology to perform the LTA inclusion in order to improve performance and the reasons why both are needed:

- Improved virtual branches – Reduction of virtual constraints
- Extended LTA inclusion – Novel way of doing LTA inclusion in the Market Allocation part

Improved virtual branches

- CWE TSOs developed the Improved virtual branches in order to reduce the number of virtual branches. Improved Virtual Branches will not create duplicate as it was the case in the current LTA inclusion.
- Detailed example can be found in annex.
- The Virtual branches will not be scaled with the RAM like in the past.
- For the sake of transparency,
  - The most limiting line (Highest LTA margin) will give its name to the newly constructed branches (virtual branches).
  - The other lines will be shifted similarly to an application of FAV while with the current approach they were deleted.
- Moment of application: ALEGrO technical go-live



ALEGrO technical go-live will happen a bit prior the commercial go-live with ALEGrO constrained to 0.

Extended LTA inclusion

An R&D track with N-SIDE under SDAC governance successfully elaborated an alternative way for LTA inclusion directly in Euphemia.

- In the extended LTA inclusion process, the market coupling algorithm now receives two domains (one FB domain with MinRAM and one LTA domain) representing the flow-based Capacities of the CWE region.
- Euphemia does not recalculate the flow-based domain (it does not create an LTA included domain). Instead, the “Balas formulation for LTA inclusion” allows Euphemia to choose which combination of both domains creates most social welfare, where the share of the LTA domain and the share of virgin FB domain is expressed with a factor alpha.
- Mathematical formulation can be found in *Annex 14.29 – Extended LTA formulation*

Extensive analysis has shown that the implementation of the ‘Balas formulation’ (Extended LTA inclusion) **yields the same market coupling results** as LTA inclusion via improved virtual branches:

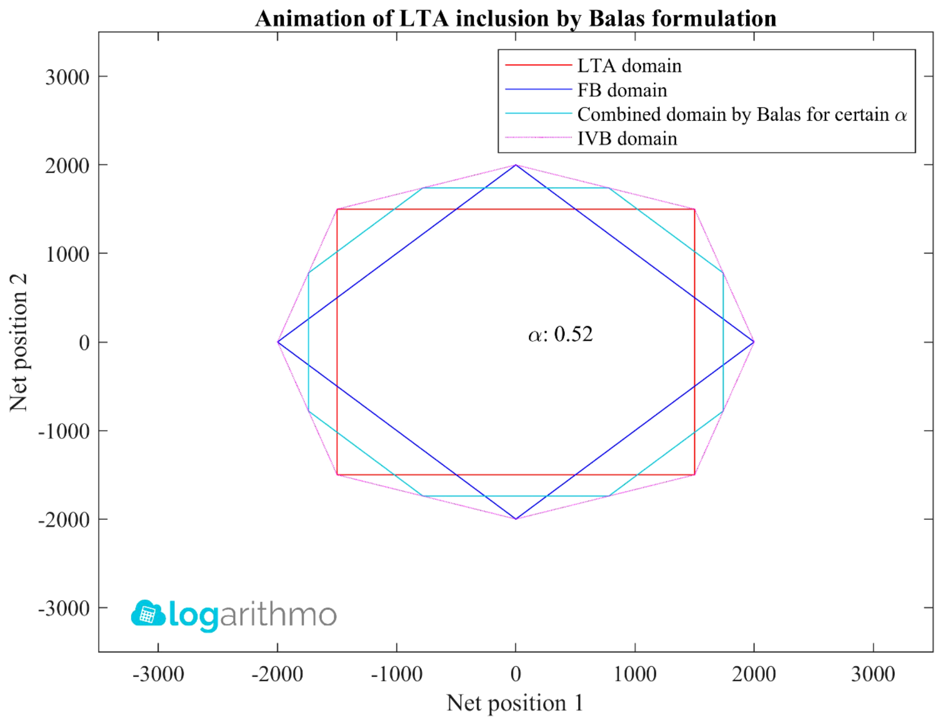
- The min max net position of the FB domain correspond
- In addition, running market coupling simulations generated comparable welfare
- Minor differences have been observed due to rounding and because the ‘Balas formulation’ is more precise than the virtual branch creation
- Summary of the analysis can be found in annex.

It has been demonstrated that the Extended LTA formulation delivers significant gain in the performance of Euphemia.

- Extended LTA will be used from the introduction of Euphemia 10.5 onwards.
- Even after the switch towards Extended LTA, the improved Virtual Branches Process will be kept for transparency (Final Flow-Based domain), ID ATC extraction, ATC extraction SA … *Improved Virtual branches is not scalable to a large number of BZs (e.g. Core)*

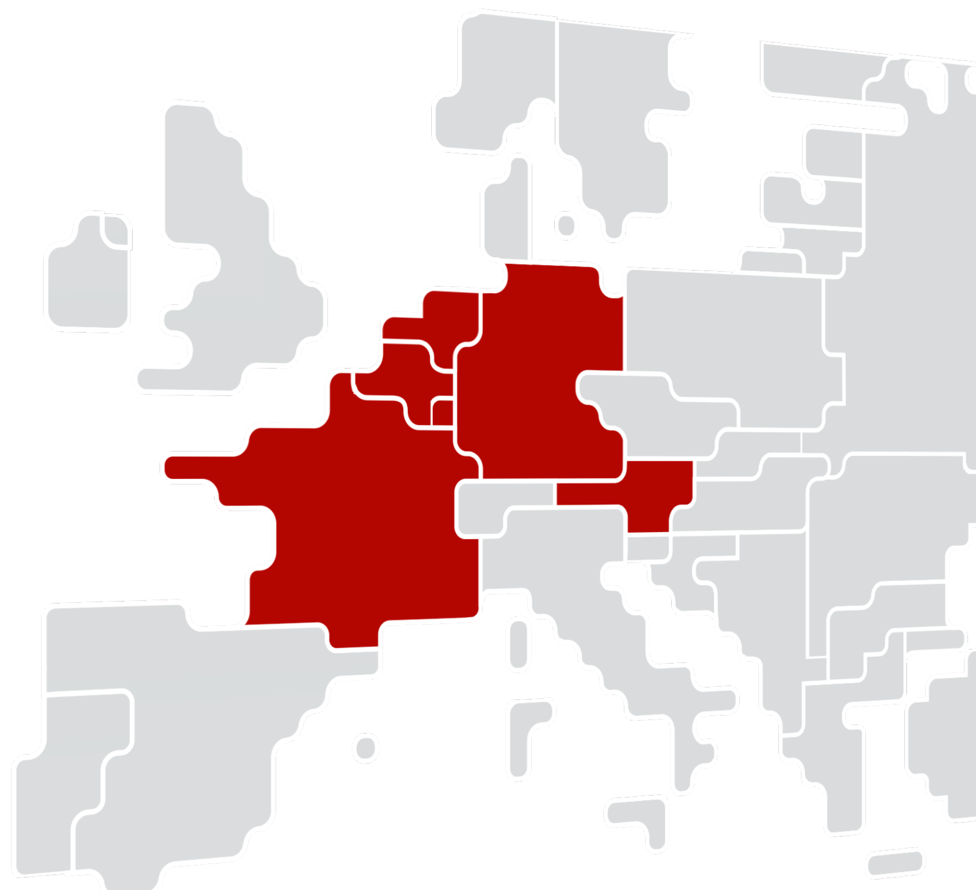
Video exemplifying the extended LTA inclusion method

- https://fileserver.logarithmo.de/s/dJNRbzsDQjcKLi6

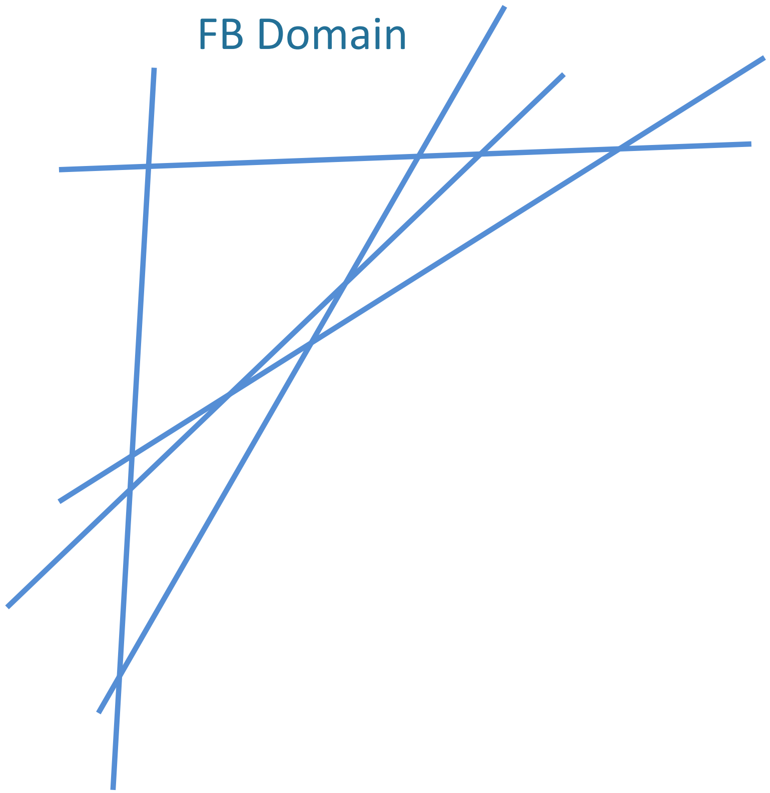


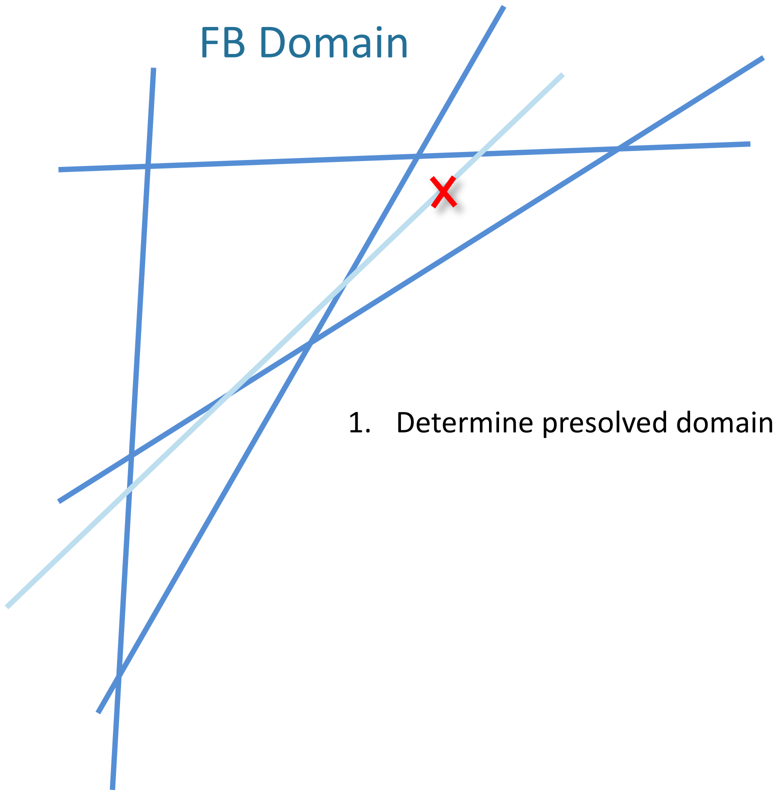
- The current link shows an animation of how extended LTA inclusion works. You can find in blue and in red, the FB domain and the LTA domain respectively which would be given as inputs to the market coupling as explained in the previous slide. The pink domain represents the domain created thanks to LTA inclusion done with virtual branches.
- As you can see in the animation, the cyan domain is the linear combination of the blue and the red domain considering different values of alpha (LTA - alpha=1 & FB - alpha=0). The animation shows that the set of feasible market coupling points will be the same as for the Virtual Branches approach.

Annex – Current LTA

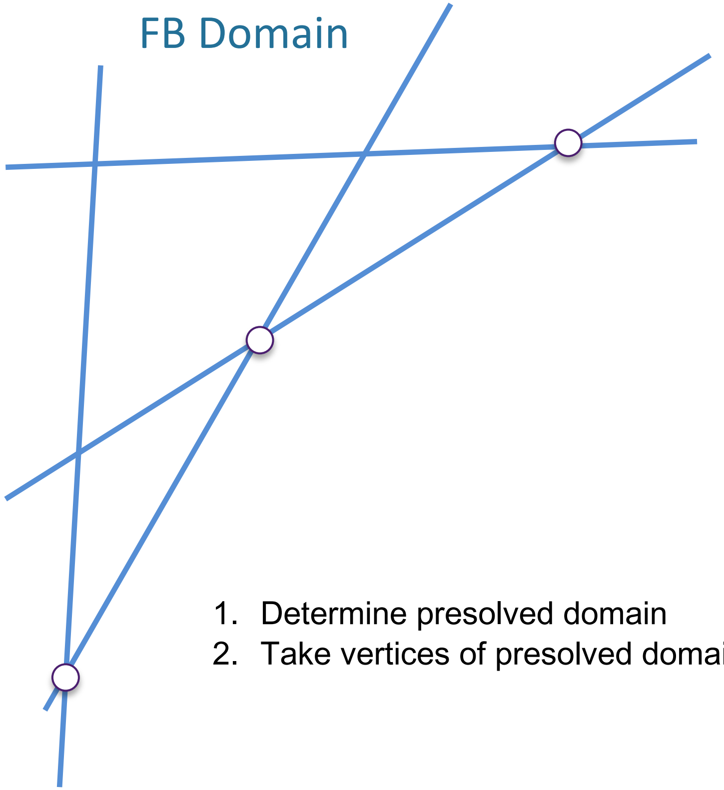


Introduction and Current approach

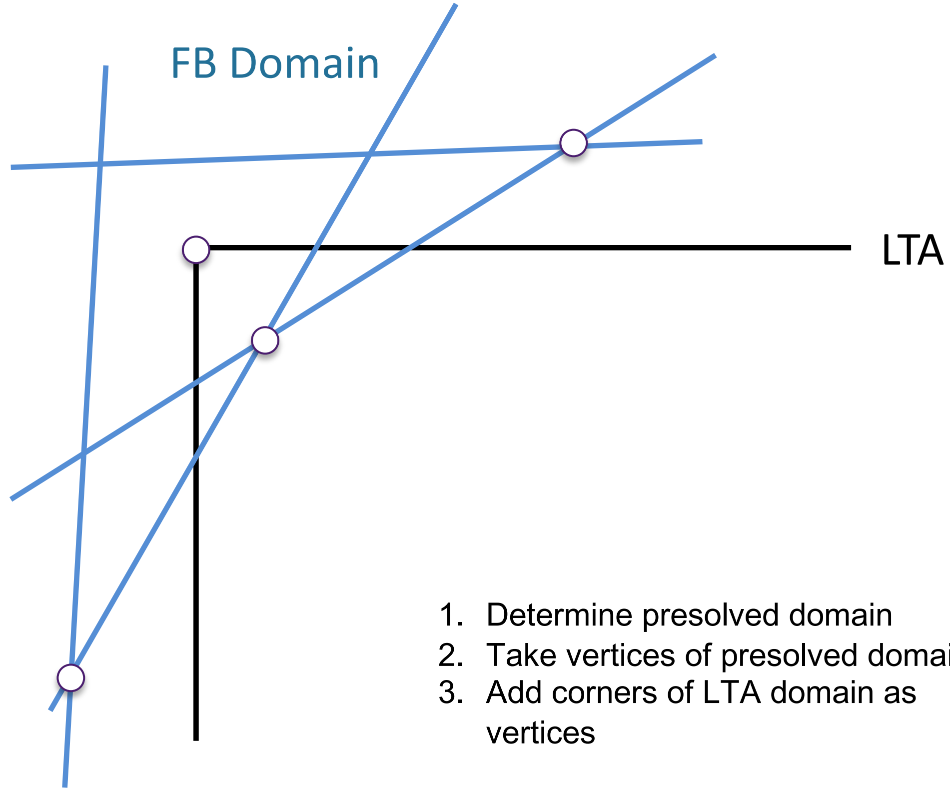




1. Determine presolved domain



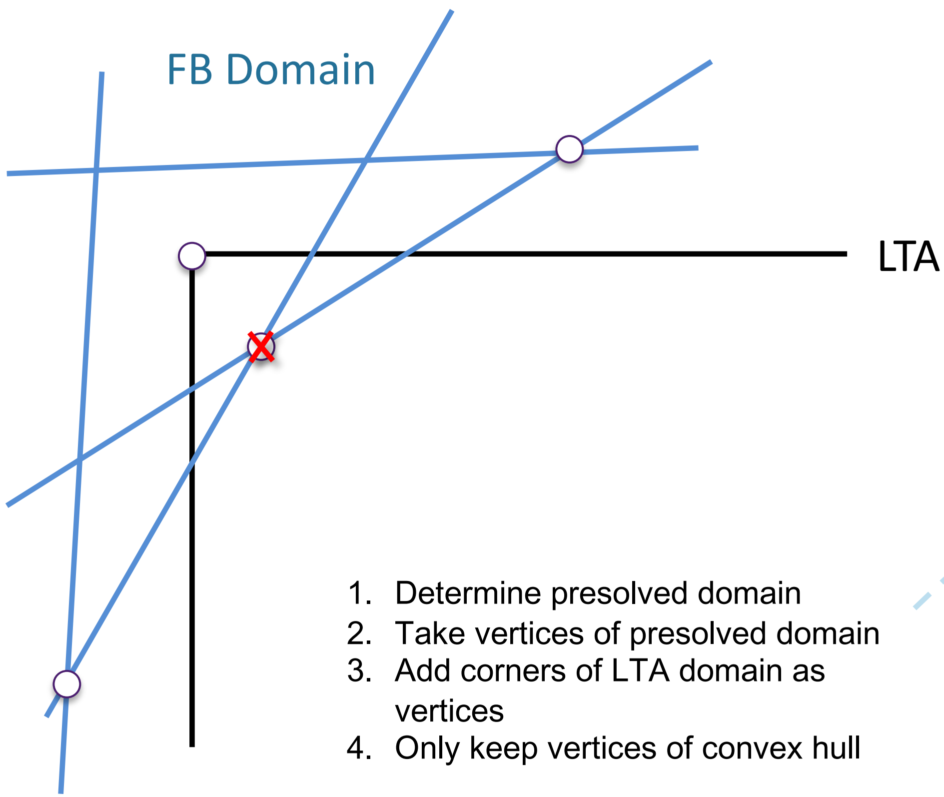
1. Determine presolved domain
2. Take vertices of presolved domain



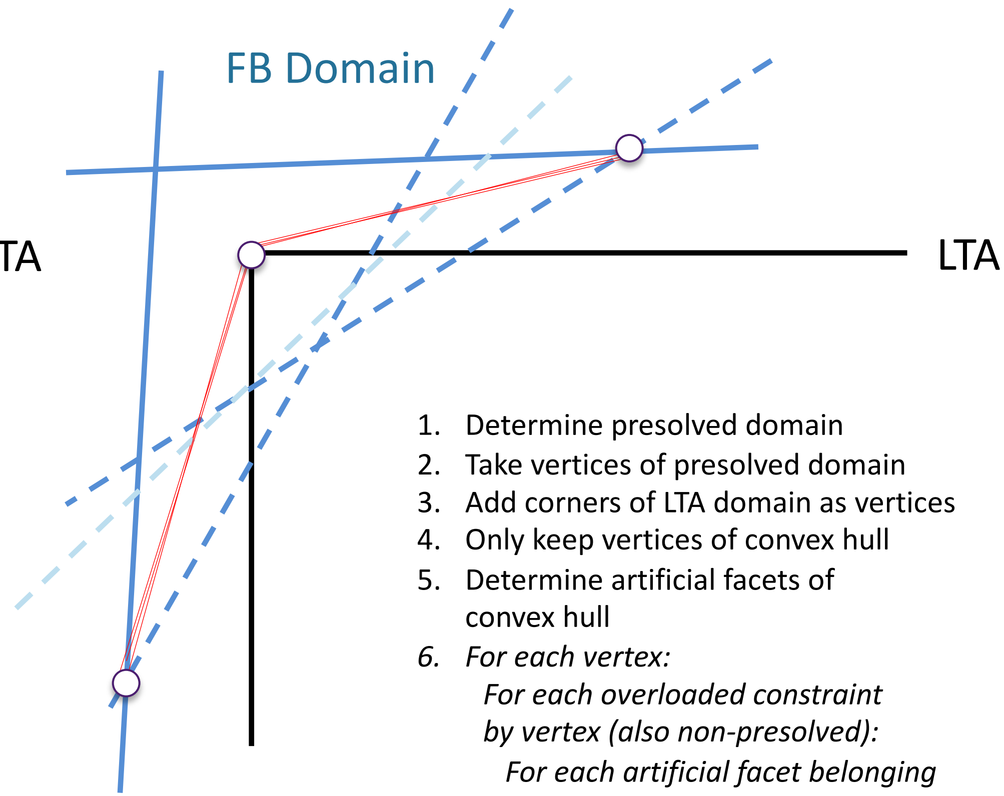
1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices

Update CWE methodologies for CEP and ALEGrO implementation

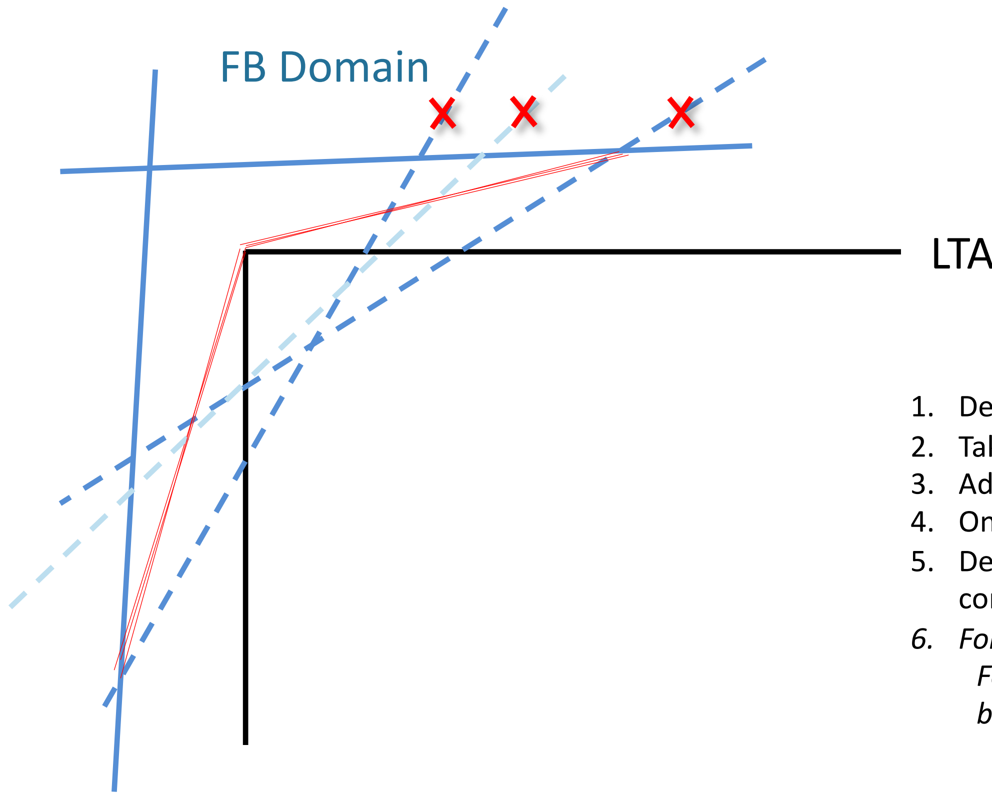
Introduction and Current approach



1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull

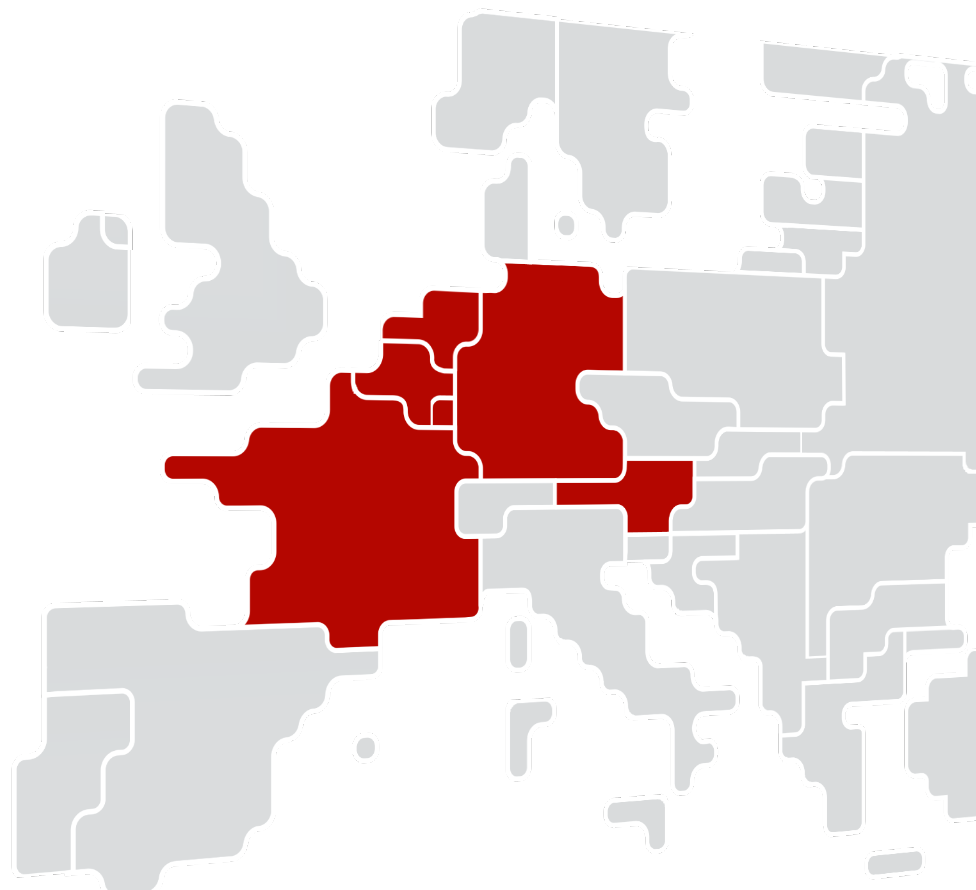


1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull
5. Determine artificial facets of convex hull
6. *For each vertex:*
   For each overloaded constraint by vertex (also non-presolved):
   For each artificial facet belonging to vertex:
   Add a virtual branch based on artificial facet but scaled to constraints desired RAM

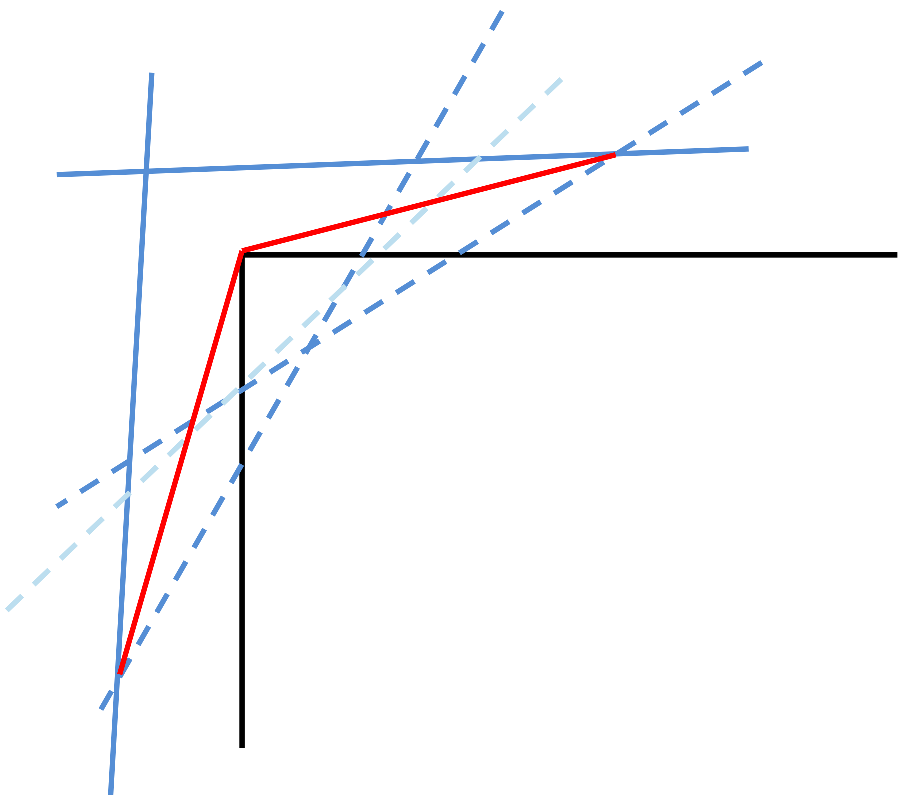


1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull
5. Determine artificial facets of convex hull
6. *For each vertex:*
   For each overloaded constraint by vertex (also non-presolved):
      For each artificial facet belonging to vertex:
         Add a virtual branch based on artificial facet but scaled to constraints desired RAM
7. Delete overloaded constraints

Annex – Improved Virtual Branches



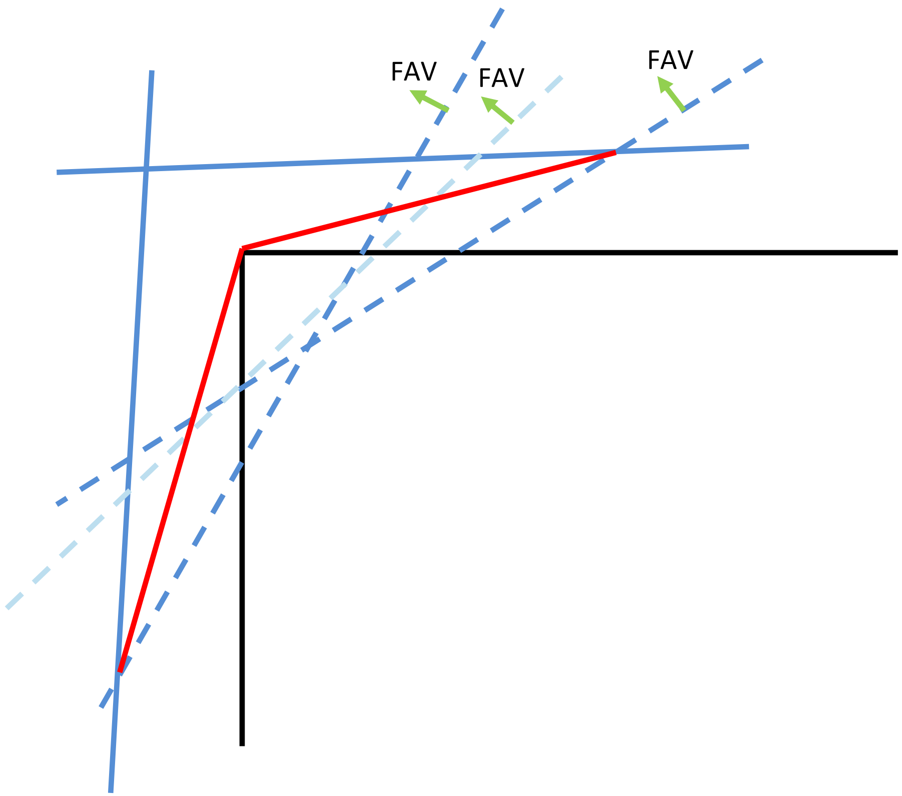
Improved Virtual Branches



1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull
5. Determine artificial facets of convex hull
6. *For each artificial facet:*

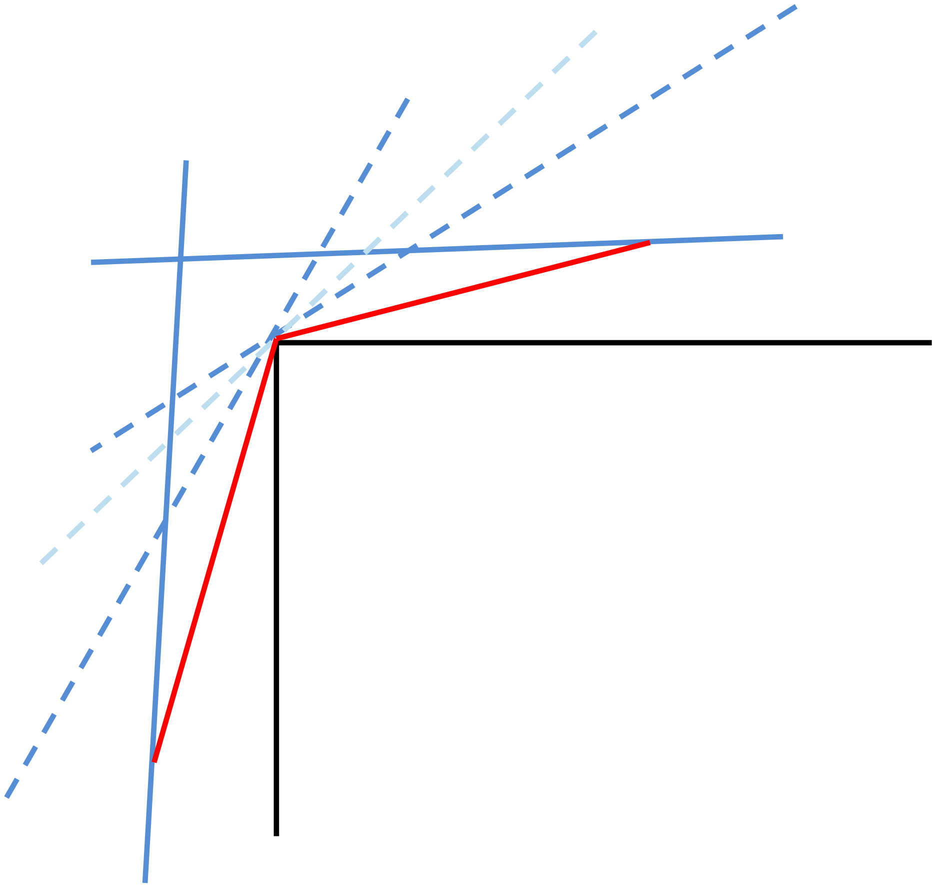
   Add a virtual branch (only once!)

Improved Virtual Branches



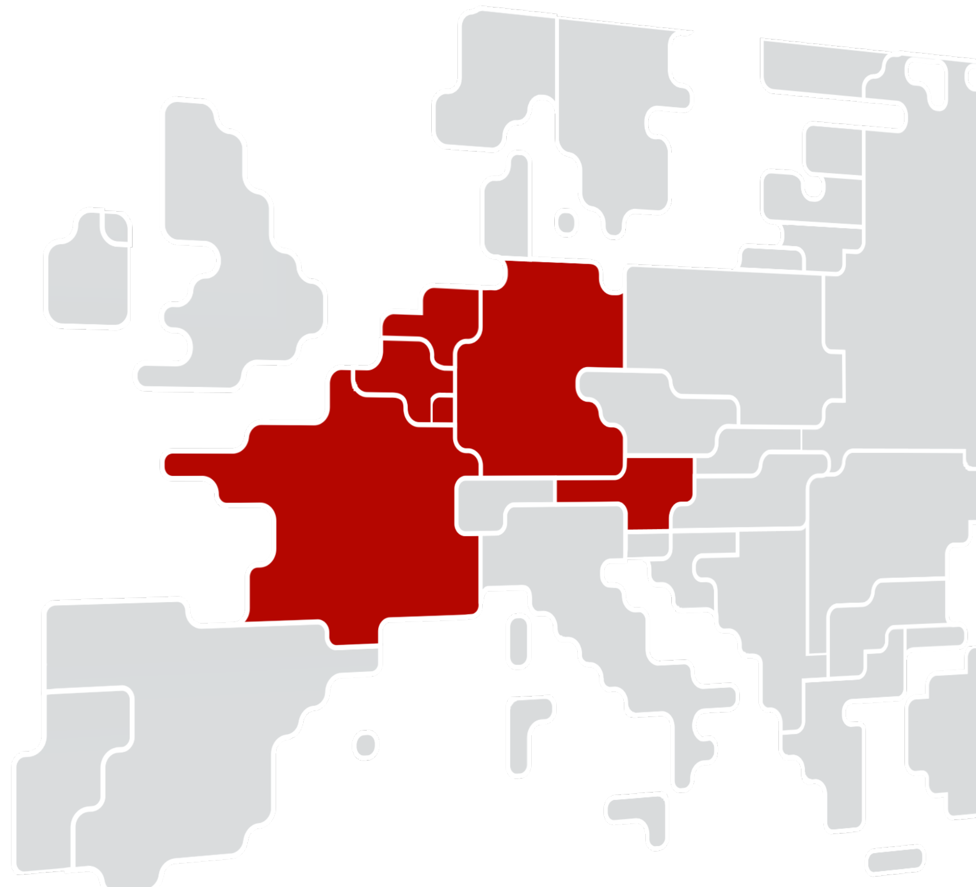
1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull
5. Determine artificial facets of convex hull
6. *For each artificial facet:*
   Add a virtual branch (only once!)
7. *For each overloaded constraint:*
   Apply FAV approach with LTA margin for LTA corner with highest LTA overload

Improved Virtual Branches



1. Determine presolved domain
2. Take vertices of presolved domain
3. Add corners of LTA domain as vertices
4. Only keep vertices of convex hull
5. Determine artificial facets of convex hull
6. *For each artificial facet:*
   Add a virtual branch (only once!)
7. *For each overloaded constraint:*
   Apply FAV approach with LTA margin for LTA corner with highest LTA overload

Annex – Comparison IVB and Extended LTA



Validation of flow-based domain

- Analysis performed:
  - Obtain Min/Max NP from classical Virtual Branch (VB) domain (F206)
  - Obtain Min/Max NP from the Extended LTA inclusion
    - Extended LTA inclusion has been modelled by logarithmo in an optimization prototype
    - F204 virgin domain and LTA domain are used as input domains, and the Min/Max NP are determined by the optimization constrained by the Extended LTA domain formed by these two domains jointly (Balas formulation)
- Key results:
  - **Min/Max NP are almost identical for Extended LTA and VB approach, proving the general applicability of the Extended LTA approach from a CC perspective**
    - Mean deviations of Min/Max NPs are for all bidding zones below 0.02% (< 1 MW)
    - Max deviation of Min/Max NPs is 13MW
      - Even if the deviation is small, it is worth mentioning that this is an extreme outlier for an unlikely market direction, where the VB generation made the FB domain actually too large in the past
    - These slight deviations are due to rounding and small inaccuracies in the creation of Virtual Branches

CWE TSO's methodology for capacity calculation for the Intraday timeframe

CWE NRA approval package

Version	3.0	
Date	10-07-2020	
Status	☐ Draft	☒ Final

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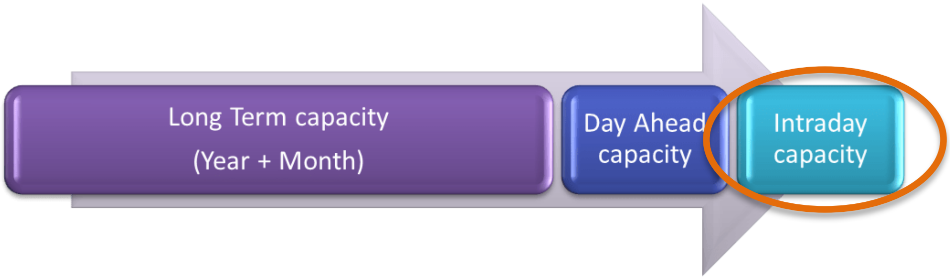
1 Introduction and purpose

This document gives a description of the calculation of the intraday (ID) capacity for the CWE internal borders. Pursuant to Regulation (EU) 2019/943 of 5 June 2019 on the internal market for electricity (which is part of the Clean Energy Package – "CEP") and based on regulatory approved splitting rules, TSOs allocate capacity in different market timeframes (long term, LT; day-ahead, DA; and intraday, ID). TSOs try to maximize available capacity in all time frames.



The scope of this methodology is strictly limited to the ID timeframe. This model is part of a coordinated approach by the TSOs involved in accordance with the ENTSO-E policies and assumes that the day-ahead capacity, allocated to the market, is the result of the CWE Flow Based Market Coupling.

Up to now no capacity is reserved for ID allocation. All ID capacity given to the market is a result of non-used DA capacity, increase processes after DA allocation, or due to the netting effect.

The target of the CWE Flow Based Market Coupling (FBMC) project was to increase efficiency of capacity allocation in the DA timeframe. This goal was achieved as the increase of DA net positions refering to higher market activity at the border with a higher trade volume. As FBMC is a process for the entire CWE region on all time frames for the capacity market (LT, DA, ID), an increase in the DA net position by default means a decrease in available capacity for the ID market.

The aim of this ID capacity calculation methodology is to have the possibility to release additional capacity to the market players after the Flow Based Market Coupling.

Note: this document is an update of the Methodology for capacity calculation for ID timeframe version 2.1 as submitted to CWE NRAs on 15.02.2019.

The main changes compared to the version 2.1 are the following:

- Updates related to the CEP Implementation: introduction of ID minRAM factor to recompute a Flow Based Domain from which to extract ID ATCs, to avoid security issues in ID when high virtual capacities are used in DA.
- Updates related to ALEGrO commercialization (new DC border BE-DE).

2 Definitions

- **CMT**: Central Matching Tool. Central tool used for intraday increase/decrease process to consolidate the increase requests and the decrease notifications.
- **CNEC**: Critical Network Element (also known as CBCO, Critical Branch Critical Outage).
- **D2CF**: Two-Days ahead Congestion Forecast. Daily procedure to create a representative load flow model of the grid for the region of the participating TSOs for a specific hour. The dataset to create this model includes the best estimation for: the planned grid outages, the outages of generators, the representative load pattern, wind and solar generation and the load-forecast.

- **DA CGMs & ID CGMs** are the Day Ahead & Intraday Common Grid Models which are the result of the merging of the Individual Grid Models provided by TSOs in day-ahead or in intraday as their best forecast of the topology, generation and load for a given hour of the Day D.
- **Day D**: delivery day for which capacity increases or rejection are considered.
- **Day D-1**: day before Day D, day ahead.
- **DACF**: Day-Ahead Congestion Forecast.
- **HVDC**: High Voltage Direct Current.
- **ID ATC**: Intraday Available Transfer Capacity.
- **Increase Feedback Deadline**: this is the latest time a CWE TSO may introduce a feedback for the request of increase on one of the borders for the applicable MTP: acceptance, partial acceptance or justified rejection.
- **Increase Request Deadline (IRD) and decrease Notification Deadline (DND)**: this is the latest time a CWE TSO may introduce a request for increase or a notification of decrease on one of his own borders.
- **Initial ID ATCs**: output results of Initial ID ATC computation (left-over capacities after DA FBMC).
- **Firmness**: arrangements to guarantee that capacity rights remain unchanged or are compensated.
- **Full acceptance**: situation in ID increase/decrease process when a TSO will fully accept the requested increase.
- **Market Coupling net positions**: sum of power flows per hub induced by the accepted orders.
- **MinRAMfactor:** Minimum margin on CNECs that will be guaranteed for crossborder exchanges
- **MTP**: Market Time Period. This is a group of consecutive hours within the Day D.
- **Own border of TSO x**: bidding zone border within CWE across which TSO x has at least one (tie)-line.
- **Partial acceptance**: situation in ID increase/decrease process when a TSO will partially accept the requested increase on the borders on a non-discriminatory basis. This occurs when the requested capacity increases on different borders compete for available margin on the same network element.
- **Post-coupling process**: activities to check the DA MC result and to transform the Net Positions, computed as a result of the market coupling, into bilateral exchanges for further processes.
- **Pre- coupling**: activities to compute the DA capacities that will be sent to the MC system.
- **PTDF**: Power Transfer Distribution Factor. Factors showing the impact of the various bilateral exchanges on the overloaded branch.
- **RAM**: Remaining Available Margin on CNECs.
- **Rejection**: situation in ID increase/decrease process when a TSO will reject the increase requested because the consequences of the request cannot be fully nor partially accepted by the TSO.
- **VH**: Virtual Hub used for the Evolved Flow Based Methodology.

3 General principles of ATC ID CC after FBMC

As it was the case in the former CWE DA capacity calculation (CC) process, the proposed ID ATC capacity calculation process combines different local processes with coordination on CWE level in different steps.

1. First, a Final Flow Based domain will be recomputed for ID ATC extraction purpose, taking into account the input parameters of the final FB domain used for the DA market coupling with updated minRAM factors. The minRAM factors are updated based on an ID minRAM factor defined by each TSO.
   - The ID minRAM factor does not cause any limitation of the RAM per CNEC, which is calculated without virtual capacities.
   - The ID minRAM factor does not cause any limitation of the RAM per CNEC, which is needed to ensure LTAs.
2. The second step for the proposed ID CC methodology is the intitial calculation of the ID ATCs. This Initial ID ATC computed out of the Flow Based domain based on the minRAM set for ID timeframe around the DA market clearing point is the result of a unique and common centralized computation.
3. The third step is a local evaluation by each involved TSO to request a possible increase (Basecase) or decrease (in special situations) on his own borders.
4. The fourth step is a merging step by a common system. The Central Matching Tool (CMT) consolidates the increase requests and the decrease notifications.
5. During the fifth step, based on this consolidated input, each involved TSO performs a local analysis that enables him to accept fully, accept partially or reject the requested capacity increases in a justified manner.
6. In the sixth step, these acceptance or rejection messages are then gathered and handled in a common way by the CMT. The System will distribute these consolidated acceptances and rejections back to the local TSOs.
7. In the last and seventh step, each TSO will then be able to use these common CWE ID ATCs and NTCs as input for the capacity allocation of their respective borders.

The steps 5 to 7 can be performed serveral times a day for a certain period of trading. For example, the assessment can be done during the evening for the night hours and during the night for the day hours. The number of iterations depends on the border. For an overview of the proposed ID ATC capacity calculation process see Figure 1.

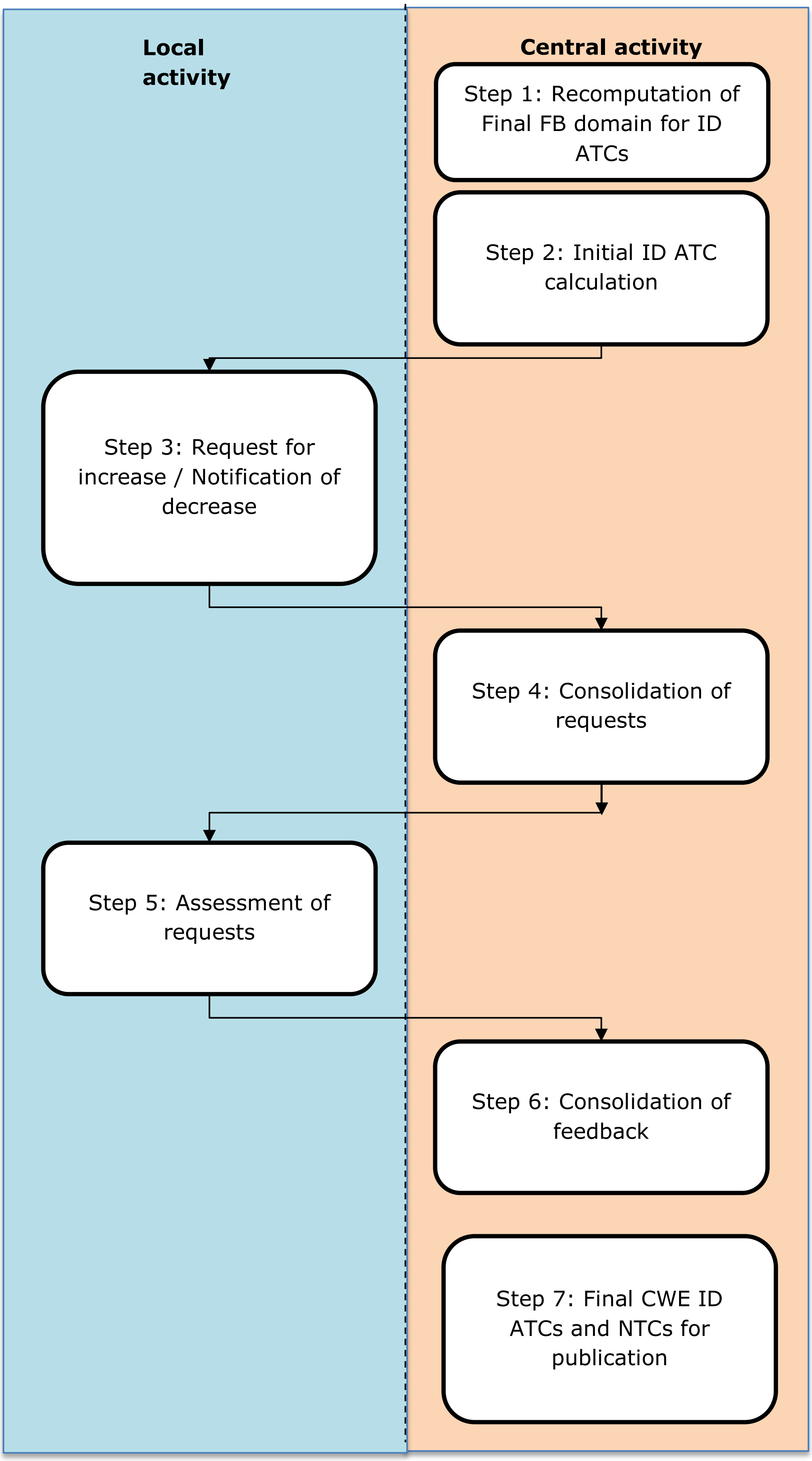


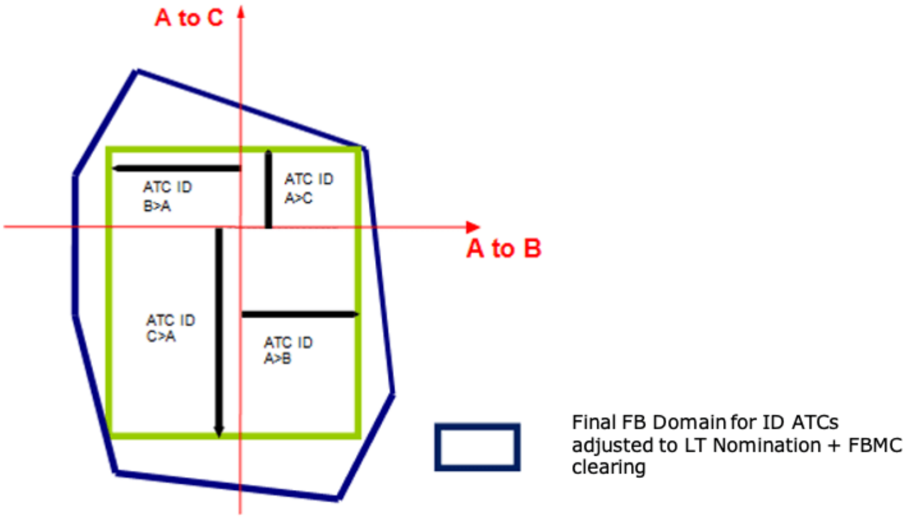
Figure 1: High-level process of ID ATC CC methodology.

4 Coordinated ID ATC CC after FBMC process

4.1 Initial ID ATC Computation

4.1.1 Introduction

The hereafter described procedure is an intermediate step, to make the D-1 Flow Based method compatible with the current ID ATC process. The aim is to assess ID ATC values deduced from the D-1 Flow Based parameters, which have been adjusted according to the D-1 FB MC results. The ID ATCs can be considered as a leftover of an updated D-1 Flow Based capacity as illustrated below. With that respect the initial ID ATC computation is not a new capacity calculation process.



The calculated ID ATCs are then used in the same way as the current ID ATCs. This chapter focuses on the process of the ID ATC computation. The input and output parameters are described and the iterative method is explained using a pseudo-code and an example calculation.

4.1.2 Input data

Despite the two days per year with a long-clock change, there are 24 timestamps per day. The following input data is required for each timestamp:

- Market Coupling net positions.
- An initial ID minRAM factor set by each TSO to recompute[1] the Flow Based domain used for the ID ATC process.
  - **All CWE TSOs have agreed to set their initial ID minRAM factor at 20%.** This value guarantees there is no regression compared to the pre-CEP situation. Also, TSOs have sufficient operational experience with an ID ATC extraction based on a minRAM factor of 20%. It has proven to be a secure starting point for the subsequent ID ATC increase process, where the possibility of ID ATC increases will be assessed when better and updated information is available.
- Presolved Flow Based parameters curtailed at Market Coupling Point to zero margins in case of a negative RAM. Due to the update of the Flow Based domain the DA Market Coupling Point can be outside of the Flow Based domain. Curtailment of the negative RAM to zero ensures the inclusion of the Market Coupling Point for the ID ATC extraction process.

***** Output data

The calculation leads to the following outputs for each timestamp:

- initial ID ATC
- number of iterations that were needed for the ID ATC computation
- branches with zero margin after the ID ATC calculation

4.1.3 Algorithm

Recomputation of Final FB domain for ID ATCs

First, the FB domain will be recalculated based on the input parameters of the final FB domain used for the DA market coupling <u>with updated minRAM factors</u>, resulting in a new final FB domain for ID ATCs.

Except for the new minRAM factors, the inputs (CGMs, CNECs, RAs, LTAs, External Constraints) will not be changed. Therefore, LTA inclusion remains guaranteed for the new final FB domain for ID ATCs.

The 'final ID minRAM factors' which are used as input for the new final FB domain for ID ATCs are calculated as follows for each CNEC:

---

[1] According to Article 16(8) of the Regulation (EU) 2019/943, it is foreseen that TSOs will provide 70 % of their transmission capacity for cross-zonal trade by the 1st of January 2020, unless there is an approved derogation (Article 16(9)) or action plan (Article 15) in place. In this case, the capacities provided for cross-zonal trade from the 1st of January 2020 and onwards can be lower than 70 %, but will not be lower than the current capacities. With the coming months and years some TSOs begin to raise their minRAM from currently 20 % to higher values. This process will from then on continue gradually. With higher minRAM values in DA capacity calculation, the resulting domains will also increase and consquently the extracted intraday ATCs will increase, leading to high virtual capacities in Intraday.

To start the ID ATC after FBMC process with secure initial ID ATCs, the ATCs will be extracted from a recomputed final Flow Based domain with dedicated ID minRAM values. The usage of this domain with a different minRAM is justified because TSOs see a risk for the security of the grid if ID ATC are directly extracted from a Flow Based Day Ahead domain with high virtual capacities. Indeed in the Intraday timeframe, there is neither sufficient time to perform security analysis in all extreme directions allowed by the ID ATC, nor enough time to coordinate RAs.

Therefore the aim of this process is to start with secure ID ATC values and wait to have updated information (grid situation) to then assess the feasibility of potential increases.

$$Final\ ID\ minRAM\ factor_{CNEC} = MIN(DA\ minRAM\ factor\ after\ validation_{CNEC}\ ; Initial\ ID\ minRAM\ factor_{TSO})$$

Where the 'initial ID minRAM factor' is a parameter that can be set at TSO level.

This results in the following logic:

- If the applied minRAM factor from the DA process is LOWER than the initial ID minRAM factor, the lower value from DA will be kept as the final ID minRAM factor (i.e. the minRAM factor will not be changed). Reductions from the DA validation process below the initial ID minRAM factor are taken into account for the new final FB domain for ID ATCs.
- If the applied minRAM factor from the DA process is HIGHER than the initial ID minRAM factor, the final ID minRAM factor will be equal to the initial ID minRAM factor.

The numerical example on the next page provides an illustration of the ID minRAM factor functionality. The first table represents the reference DA final FB domain. The second table represents the new final FB domain for ID ATCs based on an initial ID minRAM factor setting at 20%.

Information provided for these final FB domains:

- **Fmax** - The maximum admissible power flow per CNEC.
- **FRM** - The flow reliability margin per CNEC.
- **F_{REF}** - The reference flow per CNEC without commercial exchanges within CWE.
- **RAM before AMR & LTA** - The remaining available margin per CNEC before adding any virtual capacities.
- **DA minRAM factor after validation** - The minimum level of RAM per CNEC from the DA capacity calculation process, including possible reductions from the validation step.
- **Initial ID minRAM factor** - Parameter set per TSO for the calculation of the final ID minRAM factor. Only relevant for the new final FB domain for ID ATCs.
- **Final ID minRAM factor** - Minimum level of RAM per CNEC that will be guaranteed for the calculation of ID ATCs, as derived from the DA minRAM factor and the initial ID minRAM factor. Only relevant for the new final FB domain for ID ATCs.
- **AMR** - The adjustment to respect the minimum level of RAM defined by the relevant minRAM factor (DA minRAM factor after validation for the DA final FB domain & Final ID minRAM factor for the new final FB domain for ID ATCs).
- **RAM after AMR** - The remaining available margin per CNEC after addition of the AMR.
- **RAM required to ensure LTA inclusion** - The minimum level of RAM per CNEC which is required to ensure LTA inclusion.
- **LTA margin** - The adjustment to respect the minimum level of RAM required for LTA inclusion.
- **RAM after AMR & LTA** - The remaining available margin per CNEC after addition of the AMR and the LTA margin.

Table 1 – Reference DA final FB domain

CNEC	Fmax	FRM	F_{REF}	RAM before AMR & LTA	DA minRAM factor after validation	|AMR|	RAM after AMR	RAM required to ensure LTA inclusion	|LTA margin|	RAM after AMR & LTA
1	1000	100	100	800	70%	0	800	500	0	800
2	1000	100	400	500	70%	200	700	600	0	700
3	1000	100	300	600	20%	0	600	200	0	600
4	1000	100	750	150	30%	150	300	400	100	400
5	1000	100	800	100	20%	100	200	100	0	200
6	1000	100	900	0	10%	100	100	0	0	100
7	1000	100	200	700	40%	0	700	900	200	900

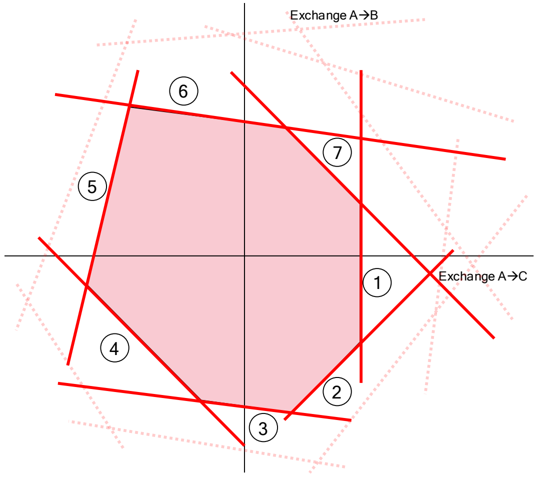
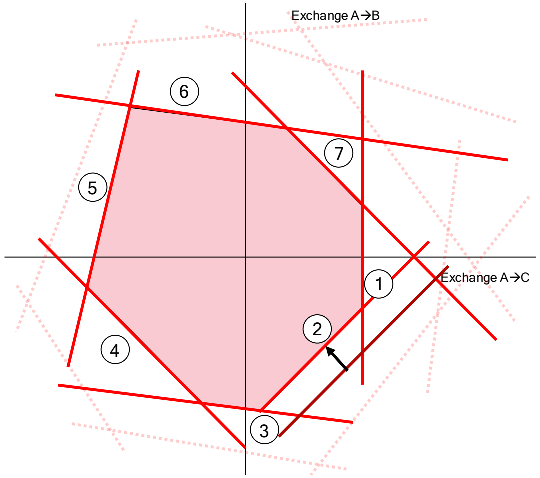


Table 2 – New final FB domain for ID ATCs

CNEC	Fmax	FRM	F_{REF}	RAM before AMR & LTA	DA minRAM factor after validation	Initial ID minRAM factor	Final ID minRAM factor	|AMR|	RAM after AMR	RAM required to ensure LTA inclusion	|LTA margin|	RAM after AMR & LTA
1	1000	100	100	800	70%	20% →	20%	0	800	500	0	800
2	1000	100	400	500	70%	20% →	20%	0	500	600	100	600
3	1000	100	300	600	20%	20% →	20%	0	600	200	0	600
4	1000	100	750	150	30%	20% →	20%	50	200	400	200	400
5	1000	100	800	100	20%	20% →	20%	100	200	100	0	200
6	1000	100	900	0	10% →	20% →	10%	100	100	0	0	100
7	1000	100	200	700	40%	20% →	20%	0	700	900	200	900



Starting point for ID ATC calculation

The ID ATC calculation is an iterative procedure and part of the so-called post-coupling process.

Second, the remaining available margins (RAM) of the pre-solved CNECs of the new Flow Based domain used for ID ATCs have to be adjusted to the MC results. Due to ID minRAM set by TSOs to calculate this new domain, the pre-solved CNECs may be different from the actual pre-solved CNECs given to the DA market. The adjustment is performed using the net positions resulting from the day-ahead MC and the corresponding zone-to-hub PTDFs. The resulting margins serve as a starting point for the iteration (step i=0) and represent an updated Flow Based domain from which the ID ATC domain is determined.

From the non-anonymized presolved zone-to-hub PTDFs ($PTDF_{z2h}$), one computes zone-to-zone PTDFs ($pPTDF_{z2z}$), where only the positive numbers are stored[2]:

$$pPTDF_{z2z}(A > B) = \max(0, PTDF_{z2h}(A) - PTDF_{z2h}(B))$$

Equation 1

with $A, B = DE, FR, NL, BE, AT$.

A zone-to-zone PTDF represents the influence of a variation of a commercial exchange from bidding zone A to bidding zone B on CNEC l. The zone-to-zone PTDF is derived from the zone-to-slack PTDFs as seen above.

Only zone-to-zone PTDFs of neighbouring market area pairs connected via AC lines are needed (e.g. $pPTDF_{z2z}(DE > BE)$ will not be used).

In case neighbouring market areas within CWE are connected via HVDC links and the evolved FB methodology is used for the DA market coupling the zone-to-hub PTDFs ($PTDF_{z2h}$) of the virtual hubs can be considered for the calculation of the positive zone-to-zone PTDFs ($pPTDF_{z2z}$) between both market areas.

For example:

$$pPTDF_{z2z}(BE_{DC} > DE_{DC}) = \max(0, PTDF_{z2h}(BE) - PTDF_{z2h}(ALBE) + PTDF_{z2h}(ALDE) - PTDF_{z2h}(DE)$$

Equation 2

where ALBE and ALDE describe the virtual hubs.

The impact of the cross-zonal exchange over a HVDC interconnector on the CNECs, the converter stations of the cross-zonal HVDC shall be modelled as two virtual hubs, which function equivalently as bidding zones. Then the impact of an exchange between two bidding zones over such HVDC interconnector shall be expressed as an exchange from the first bidding zone to the virtual hub representing the sending end of the HVDC interconnector plus an exchange from the virtual hub representing the receiving end of the interconnector to the second bidding zone. The two virtual hubs will have a combined net position of 0 MW, but their individual net position will reflect the exchanges over the interconnector.

Iteration

The iterative method applied to compute the ID ATCs comes down to the following actions for each iteration step i:

1. For each CNEC, share the remaining margin between the CWE internal borders that are positively influenced with equal shares.

[2] Negative PTDFs would relieve CNECs, which cannot be anticipated for the ID capacity calculation.

2. From those shares of margin, maximum bilateral exchanges are computed by dividing each share by the positive zone-to-zone PTDF.
3. The bilateral exchanges are updated by adding the minimum values obtained over all CNECs.
4. Update the margins on the CNECs using new bilateral exchanges from step 3 and go back to step 1.

This iteration continues until the maximum value over all CNECs of the absolute difference between the margin of computational step i+1 and step i is smaller than a stop criterion.

The resulting ID ATCs get the values that have been determined for the maximum CWE internal bilateral exchanges obtained during the iteration and after rounding down to integer values.

After algorithm execution, there are some CNECs with no remaining available margin left. These are the limiting elements of the ID ATC computation.

The computation of the ID ATC domain can be precisely described with the following pseudo-code:

```
While max(abs(margin(i+1) - margin(i))) > StopCriterionIDATC
        For each CNEC
                For each non-zero entry in pPTDF_z2z Matrix
                        IncrMaxBilExchange = margin(i)/NbShares/pPTDF_z2z
                        MaxBilExchange = MaxBilExchange + IncrMaxBilExchange
                End for
        End for
        For each ContractPath
                MaxBilExchange = min(MaxBilExchanges)
        End for
        For each CNEC
                margin(i+1) = margin(i) – pPTDF_z2z * MaxBilExchange
        End for
End While
ID_ATCs = Integer(MaxBilExchanges)
```

Configurable parameters:

- StopCriterionIDATC (stop criterion); recommended value is 1.e-3.
- NbShares (number of CWE internal commercial borders); current value is 6.

For borders connected via HVDC links the bilateral exchanges cannot exceed the maximum transmission capacity of the HVDC links.

4.2 Re-computation of ID ATC during intraday timeframe

After the first computation, the TSOs have the possibility to re-assess the new capacities. This chapter describes the process after the first computation.

4.2.1 Requesting increase or notifying decrease of capacities on own borders

4.2.1.1 Requesting increased capacities on own borders

Capacity increases can be requested by all CWE TSOs for each hour of the Day D on their own borders via the CMT.

The starting point for the local analysis to launch an increase request is the already available initial ID ATCs. In order to maximize the acceptance of the requests, the TSOs should favour a request for the borders and directions where the available capacity provided to the market after the FB MC is low.

Every increase request is capped with a fixed value per border and direction. These fixed values are proposed by each TSO for their own borders and commonly approved by the involved CWE TSOs.

The requested capacity increase is an intention for a capacity increase. However, due to constraints identified during the local analysis (during the fourth step of the process cf §4.2.3), it can be the case that a proposed capacity increase for a specific border is rejected by the same TSO who requested it.

The Increase Request Deadline is set for all MTP simultaneously to ensure a coordinated assessment on local side.

Every 3 months, an overview of the individual increase requests per TSO (per oriented CWE border and per hour) will be provided to CWE NRAs for monitoring purposes.

4.2.1.2 Notification of a decrease of capacities on own borders

All TSOs have the possibility to take the necessary steps to guarantee the security of the grid. Intraday capacity reduction is a pragmatic process that allows involved TSOs for any hour of the Day D to reduce Intraday ATCs, on their own borders, in cases operational security issues arise.

As the notification for decrease is an emergency process, a capacity reduction is an input to the assessment of capacity increases and cannot be rejected by other TSOs.

As firmness of the trades applies, only capacity that was not yet allocated will be reduced, even if a higher decrease is requested.

Every 3 months, an overview of the individual decrease notifications per TSO (per oriented CWE border and per hour) will be provided to CWE NRAs for monitoring purposes.

4.2.2 Consolidation of the requests of increase and notification of decrease

When the Increase Request/Decrease Notification deadline is reached, the CMT will immediatly proceed for each hour of the Day D with the consolidation per border and direction of the received information respecting the following rules:

- In case only Increase Request have been sent, the CMT will take the maximum of the requests. If this value is higher than the fixed maximum increase authorized on this border, the CMT will cap the request to this maximum authorized increase.
- In case a Decrease Notification has been sent, the notification for decease will prevail over an increase request for the same hour. The CMT will consider the minimum value of the notified decrease[3].
- Increase request for borders connected via HVDC links will be capped to the maximum transmission capacity of the HVDC links.

The CMT will then send for each hour of the Day D and for each CWE border and direction (which is covered by the re-computation process) the resulting increase or decrease to the CWE TSOs.

4.2.3 Assessing the feasibility of requested increases

After receiving the requests of increase and notification for decrease, the involved TSOs have to assess locally the feasibility of the requests.

A request for increase can be:

- **Fully accepted**
- **Partially accepted**

[3] For example, the CMT will receive two requests for decrease (-100 MW and -200 MW) and one increase request (100 MW), in this case the CMT will consider the minimum value, namely –200 MW, as consolidated notification of decrease.

There are situations when requested capacity increases on different borders compete for available margin on the same network element.

In this case, the TSO will partially accept increases on the borders on non-discriminatory basis.

- **Rejected** in case the consequences of the requests cannot be fully nor partially accepted by the TSO.

After the assessment, the TSO will notify the CMT with the status of each request for each MPT before the Increase Feedback Deadlines.

Local implementation

This section lists a short summary of each TSOs local implementation of the evaluation of increase requests. A more detailed description of the increase/decrease functionality can be found in the "Explanatory Note on individual TSO's increase/decrease process for ID Capacity Calculation".

Every 3 months, an overview of the individual acceptances/rejections per TSO (per oriented CWE border and per hour) will be provided to CWE NRAs for monitoring purposes.

Amprion

Amprion checks upon the feasibility of capacity increases via a local simulation tool that models the effect of capacity increases of Amprion's network. The tool uses DA CGMs or ID CGMs and models the impact of capacity increases via linear sensitivities.

APG

APG assesses the increase requests with a load flow tool that uses day ahead models (DACF) and the D-1 market clearing point. The security assessments considers the DA CGM and models the impact of capacity increases via linear sensitivities. The assessment of increase requests for all MTPs takes place when the DACF files are available. In case full acceptance is not possible, the values are checked for partial increase requests according to the common rules.

Elia

ELIA assesses ATC around the clearing point in D-1 and in intraday on Belgian borders and in all directions based on DA CGMs or ID CGMs. Calculation will be performed for a given MTP on representative hour(s) for this period. In this assessment, realistic values in the direction of the likely corner(s) are considered for the non-Belgian borders. Based on this, ELIA defines for this period the (partial) increase ID ATC possible on the Belgian borders and motivated (partial) acceptances or rejections for other borders, if any.

For the assessment, the same set of acceptance criteria and remedial actions as the ones used locally at Elia for the DACF process is considered.

On request of ELIA, Coreso may be in charge for Elia of the assessment whether or not to increase capacity for the aforementioned time periods. Based on this information Elia's operator will decide about possible rejections of capacity increases.

RTE

For each hour of the day, RTE checks the inclusion of the increased ATC domain into a Flow Based domain.

The ATC domain is the initial ATC domain centrally computed increased by the requests on each border. If the resulting domain is larger than the normal behaviour of the market players in the intraday timeframe, the domain is reduced in this market direction.

The Flow Based domain used for the inclusion is the Flow Based domain with only the CNECs of RTE.It also means that none of the CNECs of other CWE TSOs and none of the external constraints are in this domain.

TenneT TSO B.V.

For the Dutch-German and Dutch-Belgian borders harmonized procedures were already developed, meaning that the capacity analyses are running in parallel and use identical parameters for the decision making for the intraday capacity.

For both borders, several timeframes are used to analyse the capacity increases for the forthcoming hours. The analyses is in line with the agreed feedback deadlines.

The current local assessment looks at the thermal loading of a predefined set of network elements (CNEC) under all relevant (n-1)-contingencies. If thermal loadings per CNEC are below a certain threshold (Imax of a certain CNEC in the N-1 situation),the capacity increase is permitted. In case operational security issues are expected/arise for the coming hours, operators can take these results into account when releasing intraday capacity. Consequently, a decision whether or not to accept an increase request is made hour-wise.

TenneT TSO GmbH

The increase requests are assessed starting from DA CGM and the D-1 clearing point. Maximum utilization of potential ID ATCs (total of initial ATCs, decrease notifications and increase requests) is simulated for the most likely combinations of simultaneous exchanges on all five borders. Security assessment is performed using AC load flow and CNECs of TenneT TSO GmbH. If the network security assessment fails for at least one likely market direction, it is repeated with reduced increase requests in order to check for the possibility of partial acceptance.

The assessment of increase requests takes place for all MTPs simultaneously.

TransnetBW

TransnetBW assesses the increase requests with the help of local load flow tool that uses DA CGMs as basis for the security analysis which starts shorty after the CGMs are available for the dedicated Business Day. The focus of increase assessment is on the internal and cross-border CNECs in the control area. Requests are checked simultaneously in likely market directions, meaning simultaneous (increased) exchanges on all borders. In case full acceptance is not possible, the process is repeated with partial increase requests according to the common rules. The results of possible reductions of the local assessment are sent to CMT.

4.2.4 Consolidation of acceptances/rejections

When an Increase Feedback Deadline is reached, the CMT will immediatly proceed for each hour of the applicable MTP with the consolidation per border and direction of the received information respecting the following rule:

- In case justified rejections are received, the CMT will consider the lowest value as the result of the applicable increase.

The CMT will then send for each hour of the Day D and for each CWE border and direction to the CWE TSOs the resulting ID ATCs/NTCs as the sum of the initial ID ATCs and the consolidated increase/decrease for the applicable MTP.

4.2.5 Providing ID ATCs for allocation

After receiving the updated capacity from the CMT, the responsible TSOs offer the capacity to the market players with the allocation rules and platforms.

Explanatory Note on individual CWE TSO's increase/decrease process for Intraday Capacity Calculation

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Date	10-07-2020

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1 Management summary

1.1 Purpose of the document

The purpose of this explanatory note is to explain the individual increase/decrease process of the ID ATC after flow-based market coupling process as described in the *CWE Methodology for capacity calculation for the Intraday timeframe*.

2 Overview Table

TSO	INCREASE PROCESS	DECREASE PROCESS	How many assessment for Increase/Decrease Process
Amprion	No local process to ask for increase requests in operation. Increase requests for Amprion borders are performed by other CWE TSOs/RSCs. Feasibility of increase requests is checked by local tool considering the latest DA and ID CGMs available. Two validations are performed per Business Day using linear sensitivities similar to a Flow Based approach.	No local process to assess decreases before increase/decrease deadline is operation at the moment. Decreases of capacities for Amprion borders during the increase/decrease process on request by other TSOs possible.	2 (Based on DACF/IDCF)
APG	An automatic import/export increase request is generated internally, if the FB day ahead leftover in combination with the NP is below a certain threshold. APG then assesses this internal increase requests with a load flow tool that uses day ahead models (DACF) and the D-1 market clearing point. The security assessments considers the DA CGM and models the impact of capacity increases via linear sensitivities. The assessment of increase requests for all MTPs takes place when the DACF files are available.	APG does not have a local tool to assess decreases based on schedules or ATCs/day ahead leftovers. After the DACF load flow calculation process to ensure possible increase requests, a unilateral decrease by APG is possible.	1 (Based on DACF)
ELIA	An increase of 300 MW is requested for one or both directions of the Belgian borders. Market directions may be prioritised. 2 assessments are performed per business day. Increase requests are evaluated by performing a detailed security analysis for a set of representative timestamp/corner combinations.	No local process to assess decreases before increase/decrease deadline is foreseen at the moment.	2 (Based on DACF/IDCF)

RTE	Automatic increase request sent in case of FB day ahead leftover in combination with the NP is below a certain threshold on FR-DE and FR-BE frontiers; Feasibility of the increase requests based on some verification of the absence of overload on the French CNEC on the Final flow Based Domain.	Functionality not foreseen to be used on RTE's side	1 (Based on D2CF)
TenneT DE	No local process to ask for increase requests in operation. Increase requests for TenneT DE borders are performed by other CWE TSOs/RSCs. Likely Comers for Increase Requests are checked for likely corners and TenneT DE CNECs via load-flow calculations. In case of an overload the partial acceptance steps are checked for the concerned corner until no overload is detected anymore or the increase request is zero.	No local process to assess decreases before increase/decrease deadline is foreseen at the moment.	1 (Based on DACF)
TenneT NL	Semi-automatic increase request (max feasible value) is sent for the borders BE-NL and DE-NL in both directions.	Based on 2 possibilities a decrease can be applied: • *Critical Grid Situation* (CGS) confirm ENTSO-E definitions. • Unplanned outage in the 380kV grid	4 to 6 (Based on DACF/IDCF)
Transnet BW	No local process to ask for increase requests in operation. Increase requests for TransnetBW borders are performed by other CWE TSOs/RSCs. Feasibility of increase requests is checked by local tool considering the latest CGMs available. Currently with likely corners approach but exchanged in the near future to a linear sensitivity analysis similar to a flow based approach.	No local process to assess decreases before increase/decrease deadline is foreseen at the moment.	1 (Based on DACF)

3 Maximum Increase request on borders

The maximum increase request for borders involving Belgium is 300 MW (e.g. BE <-> FR, BE <-> DE, BE <-> NL), for other border it's 200 MW (e.g. DE <-> FR, AT <-> DE, DE <-> NL).

4 Individual Increase/Decrease Process for ID ATC Extraction

4.1 Amprion

4.1.1 Increase Process

There is no local process to ask for increase requests in operation. Increase requests for Amprion borders are performed by other CWE TSOs/RSCs.

Assessing the feasibility of the consolidating increase requests:

To assess the feasibility of increase requests, two local validations are performed per Business Day using linear sensitivities similar to a Flow Based approach. The assessment is performed by a local tool considering the latest DA and ID CGMs available.

1. h01-h09: DACF CGM (D-1)
2. h10-h24: IDCF CGM (D)

The local validation tool computes the sensitivities (zone2zone PTDFs for the CWE ATC borders) and initial loadflows for each critical network element of Amprion in a basecase or n-1 situation.

Possible loadlflow changes from zone A to zone B due to increase request and leftover ATCs can be described as

$$\Delta flow_{A\rightarrow B} = PTDF_{A\rightarrow B} \cdot (increase\_request_{A\rightarrow B} + ATC_{A\rightarrow B})$$

Only positive PTDF factors are considered for the dedicated critical network element. Both directions of a critical network element are evaluated seperately.

The additional flow for one critical network element can be determined by the sum of the delta flows of each ATC border

$$additional\ flow = \sum_{j=1}^{\substack{number\ of \\ ATC\ borders}} \Delta flow_j$$

In case the additional flow leads to an overload of a critical network element for a basecase or n-1 situation after respecting a security margin (FRM), the initial increase requests will be reduced until no overloads occur anymore.

The reduction of increase requests is performed successively for all borders applying the same partial acceptance steps (200 MW, 100 MW, 50 MW) followed by a full rejection (0 MW). If different increase requests for several borders are made, the increase requests are curtailed to a common level before all borders are reduced. This ensures non-discriminatory among increase requests for all borders.

4.1.2 Decrease Process

No local process to assess decreases before the increase/decrease deadline is in operation at the moment. However, a new local process to assess and apply decreases before the increase/decrease deadline could be developed in the future. Decreases of capacities for Amprion borders during the increase/decrease process on request by other CWE TSOs is possible.

However, when network security in Amprion's, RTE's or TransnetBW's network is endangered, the operator at Amprion's control centre may decide at any time to reduce capacities. When another TSO informs Amprion's control centre via telephone about capacity decreases, Amprion's operator will decide whether or not to apply a capacity reduction.

4.2 APG

4.2.1 Increase Process

Capacity increases are only requested by APG for the Austrian-German border.

An import/export increase of 200 MW is generated internally until 6 pm D-1 , if the FB day ahead leftover in combination with the NP is below a certain defined thresholds for import/export. These thresholds are based on historical data and can vary due to seasonal effects or based on new knowledge gained in the course of using the increase / decrease process.

APG then assesses this internal increase request with a load flow tool that uses day ahead models (DACF) and the D-1 market clearing point. The security assessments considers the DA CGM and models the impact of capacity increases via linear sensitivities.

In detail, for every APG CNEC and MTU, the maximal possible increase (for import/export) is calculated by the formula:

$$Inc_{\max\ i} = \frac{F_{\max\ i} - F_{DA\ i}}{PTDF_{\ i}}$$

$Inc_{\max i}$ … maximum possible increase on a certain CNEC i
$F_{\max i}$ … maximum thermal capacity of a certain CNEC i
$F_{DA\,i}$ … Flow on a certain CNEC i after FB DA MC
$PTDF_{\ i}$ … Power Transfer Distribution Factor for a certain CNEC i for the Border DE/AT based on DACF

After that, the CNEC with the smallest Inc_{max} of a MTU which had an aggregated increase request ≠ 0 MW defines the maximum increase for this MTU by the following formulas:

$200\ MW < Inc_{max}$ → accepted increase = 200 MW
$100\ MW < Inc_{max} < 200\ MW$ → accepted increase = 100 MW
$50\ MW < Inc_{max} < 100\ MW$ → accepted increase = 50 MW
$Inc_{max} < 50\ MW$ → accepted increase = 0 MW

At the end of the process, the operators are in charge to finally accept or decline the import/export increase for every MTU, which was provided by the local tool.

4.2.2 Decrease Process

APG does not have a local tool to assess decreases based on schedules or ATCs/day ahead leftovers.

After the the DACF loadflow calculation process to ensure possible increase requests, a unilateral decrease by APG is possible.

4.3 ELIA

4.3.1 Increase Process

Increase requests

Capacity increases are requested by Coreso on behalf of Elia. An increase of 300 MW is requested for one or both directions of the Belgian borders. Market directions may be prioritised.

Assessing the feasibility of the consolidated increase requests

The local validation of CWE ID ATC increase requests is performed by Coreso on behalf of Elia. 2 assessments are performed per business day:

1. Evening Process:
   - Increase requests for period [00h00-09h00] are evaluated
   - Assessment is based on DACF information.
   - Results are sent to CMT before 21h45 in D-1.
2. Nightly Process:
   - Increase requests for period [09h00-24h00] are evaluated.
   - Assessment is based on IDCF information.
   - Results are sent to CMT before 05h30.

The approach for both processes is the same:

Step 1: Selection of representative timestamps/corners

Considering the already allocated capacity, the initial ATC and the ID ATC increase requests per oriented CWE border, a set of representative timestamp/corner combinations is determined. Different sets of likely corners are evaluated. This is done by making use of sensitivity coefficients which reflect the impact of each CWE commercial exchange on the physical flows in the network.

Corner variations consider both initial ATC and ID ATC increase requests. If the initial ATC is very high for a specific border, it will be capped to a more realistic value based on the ID nominations observed in the past. This is done to avoid being too conservative in the assessment of the ID ATC increase requests.

The selection of the representative timestamp/corner combinations is cross-checked with the Elia operator.

Step 2: Detailed security analysis

A detailed security analysis is performed for the selected timestamp/corner combinations. The same set of acceptance criteria and remedial actions than the ones used locally at Elia for the DACF/IDCF processes is considered. Both preventive and curative RA are taken into account.

Step 3: Validation of results

Coreso calls the Elia operator to present the results. Overloaded CNEC pairs are reported for each timestamp/corner combination which was analysed. The Elia operator can overrule the result in specific situations (i.e. incident has occurred, adequacy issues, voltage issues, …). Based on the studied timestamps, the ID ATC increase requests for the full period are either accepted or rejected.

Step 4: CMT upload

Coreso uploads the Elia feedback for the different ID ATC increase requests to the CMT.

In exceptional situations, Elia can ask Coreso to split the period of the Evening Process or the Nightly Process into 2 sub-periods.

4.3.2 Decrease Process

No local process to assess decreases before increase/decrease deadline is foreseen at the moment.

4.4 RTE

4.4.1 Increase Process

The following process is operated by CORESO on behalf of RTE

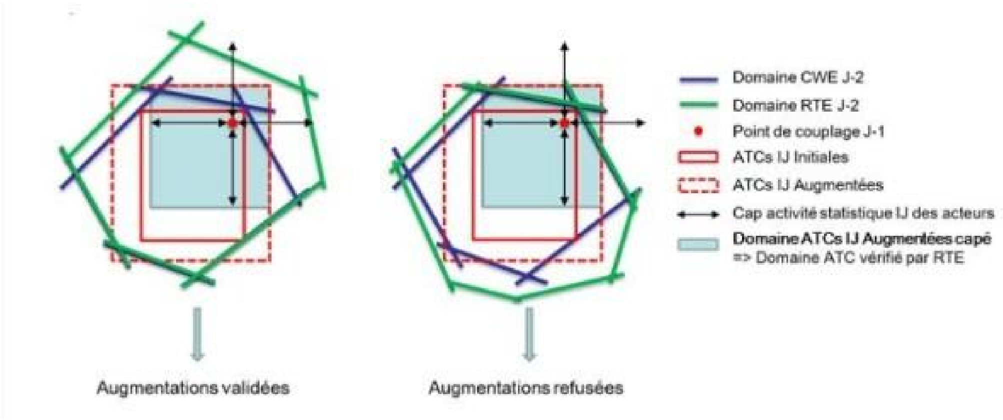
- ✓ If the ATC FR<>BE is below 500 MW, a request for increase of 300MW is sent, nothing otherwise
- ✓ If the ATC FR<>DE is below 1000 MW, a request for increase of 200MW is sent nothing otherwise

Assessing the feasibility of the consolidating increase requests:

The requests are tested on the final Flow Based Domain containing only the RTE CNECs, therefore this process is based on the D2CF CGM used for the Final FlowBased Day Ahead Domain.

The ATC domain with the increased capacity is combined with a statistical plausible approach. This ATC domain is curtailed to the maximum activity already observed in the ID process by Market Participants.

If, on the corners of this ATC domain combined with statistics approach, no French CNECs are overloaded therefore the increase requests are accepted, otherwise there is a rejection.



The square in light blue represents the ATC domain combined with a statistical plausible approach.

The domain delimited by the green CNECs represents the Final FlowBased domain containing only the RTE CNECs.

On the left, the light blue domain is included inside the RTE Green domain so the requests are accepted, on the right, the requests are rejected because some French CNEC will be overloaded on some corners of the light blue domain.

The assessment of consolidated increase/decrease requests is done once per day, in the evening of the D-1.

4.4.2 Decrease Process

This functionality is not foreseen to be used on RTE's side

4.5 Tennet DE

4.5.1 Increase Process

There is no local process to ask for increase requests in operation. Increase requests for TenneT DE borders are performed by other CWE TSOs/RSCs according to the agreed rules about maximum increases.

The increase requests are assessed starting from DA CGM and the D-1 clearing point. Maximum utilization of potential ID ATCs (total of initial ATCs, decrease notifications and increase requests) is simulated via CWE GSKs for the most likely combinations of simultaneous exchanges on all five borders (hereafter referred to as likely corners). Security assessment is performed for all defined likely corners using AC load flow security analysis and CNECs of TenneT DE. If the network security assessment fails for at least one likely corner, the PTDF of each border is checked against a threshold (currently 5%) and the security assessment is repeated with reduced increase requests for those borders with PTDF higher than the threshold in order to check for the possibility of partial acceptance. Borders with PTDF lower than the threshold remain unchanged to not prevent increases on non-impacting borders for concerned CNECs.

The assessment of increase requests takes place for all MTPs simultaneously once per day using the merged DA CGMs.

Note: there might be changes needed due to ALEGrO, i.e. 6 borders instead of 5, increasing to corners further. The impact assessment is not finalized yet.

4.5.2 Decrease Process

No local process to assess decreases before increase/decrease deadline is foreseen at the moment.

4.6 Tennet NL

4.6.1 Increase Process

TenneT NL sends every day an increase request for the borders BE-NL and DE-NL in both directions. By default it's always the maximum capacity increase per border and direction. The request only deviates if an decrease situation occurs (see Decrease Process). After D-1 18:00 TenneT NL validates the increase request from each border via a TTC (Total Transfer Capacity) computation. The loadflow application calculates the max feasible transfer capacity per border and direction againt the following components:

- Most recent Common Grid Model (CGM), DACF or IDCF
- Newest forecast information from marketpaties
- Only 380kV Critical network elements from the Dutch are taken in to account (impact only on own grid)
- Left over capacity from Flowbased DA (Intaday ATC)
- Validations steps with rounding (50MW)
- Depending on the grid situation, TenneT NL validates min. 4 times till 6 times per business day. It respects the gate opening and closures timing from the ID CMT.

4.6.2 Decrease Process

Based on 2 posibillities a decrease can be applied:

- *Critical Grid Situation* (CGS) according to ENTSO-E definitions.
- Unplanned outage in the 380kV grid or on Dutch HVDC interconnector(s)

If one of the possibilities occur before D-1 18:00 than the grid operator analyses the unexpected grid situation. Based on the outcome, the operator can decide to reduce the left-over intraday ATC till it's minimum capacity.

The Intraday ATC without virtual capacity is seen as the minimum capacity which can be given to the market based on the information available.

The $\Delta flow_{A\rightarrow B}$ will be provided to the ID CMT as decrease request.

if $\text{ATC}(\text{without virtual capacity})_{\text{A}\rightarrow\text{B}} > \text{ATC}(\text{left over capcity})_{\text{A}\rightarrow\text{B}}$ then

$\Delta\text{flow}_{\text{A}\rightarrow\text{B}} = 0$ else

$$\Delta\text{flow}_{\text{A}\rightarrow\text{B}} = -(\text{ATC}(\text{left over capcity})_{\text{A}\rightarrow\text{B}} - \text{ATC}(\text{without virtual capacity})_{\text{A}\rightarrow\text{B}})$$

4.7 TransnetBW

4.7.1 Increase Process

There is no local process to request an increase of capacity in operation. Increase requests for TransnetBW borders are performed by other CWE TSOs/RSCs.

Assessing the feasibility of the consolidating increase requests:

For assessing the feasibility of the increase requests, local validations are performed per Business Day with a load flow tool which uses Day Ahead Common Grid Models as basis. Shortly after the CGMs are available the ID assessment process starts with a simultaneous check of the increase requests if they can be granted. In case a full acceptance is not possible, the process is repeated with the partial increase requests according to the common rules.

The current process will be exchanged with a new process based on linear sensitivities similar to the flow based process. The calculation of PTDFs is based on a common grid model. The local tool calculates the zonal PTDF at the CWE borders for the base case and relevant n-1 cases.

The load flow changes from zona A to B with the increase request $request_{A\rightarrow B}$ and the available transfer capacity on the border $ATC_{A\rightarrow B}$ can be described as:

$$\Delta flow_{A\rightarrow B} = PTDF_{A\rightarrow B} \cdot (request_{A\rightarrow B} + ATC_{A\rightarrow B})$$

During the calculation positive PTDF Factors are considered to determine the maximum influence on each CNE. At the end of the process the individual influences are added up to gain the total additional flow for each critical network element with a certain contingency (CNEC)

$$\Delta TotalFlow = \sum_{j=1}^{\substack{number\ of\\ ATC\ border}} \Delta flow_j$$

If the total additional flow overloads a given CNEC the initial request will be reduced until no CNEC is overloaded.

The reduction of increase requests is performed successively for all borders applying the same partial acceptance steps (200 MW, 100 MW, 50 MW) followed by a full rejection (0 MW). If different increase request for several borders are requested, the increase requests are curtailed to a common level before all borders are reduced. This prevents discrimination among increase requests of different borders.

4.7.2 Decrease Process

No local process to assess decreases before increase/decrease deadline is foreseen at the moment. However, when network security is endangered on TransnetBW grid or surrounding borders which could be eliminated by a decrease of ID ATC on the border DE/LU-FR, DE/LU-AT the TransnetBW operators may inform Amprion or APG operators that a decrease of capacities is necessary to ensure grid security.

Congestion income allocation under Flow-Based Market Coupling

CWE Market Coupling

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Introduction

The sharing of the congestion income under Flow-Based Market Coupling (FB MC) between the hubs of the CWE (Central-Western Europe) region is described in this document. This description is only valid for the standard hybrid coupling method. The treatment of remuneration costs resulting from Long-Term Capacity Rights is integral part of the methodology.

Due to the inclusion of the DE-BE border via the direct current (DC) interconnector ALEGrO in CWE FB MC this document is updated especially by implementing the Evolved Flow-Based (EFB) methodology. With the help of this methodology, flows over the new DC interconnector ALEGrO within the highly meshed CWE alternating current (AC) network can be adequately considered. The EFB methodology is described in-depth in chapter 4.2.9 "Integration of HVDC interconnector on CWE bidding zone borders" of the *CWE FB DA MC approval document*.For 2020 for CWE FB-Market Coupling it is planned to switch from Flow Based Intuitive[1] (FBI) to Flow Based Plain approach jointly with the introduction of ALEGrO. The congestion income allocation methodology however is independent of the selected approach, only the absolute results may differ. Furthermore also in the past for both types (FPI and FBP) results were calculated by TSOs, but FBI was used so far for distribution of CI among TSOs. The example in this methodology is reflecting a Flow-Based Plain approach.

For transparency purposes, the DE-AT report and the SPAIC analysis for ALEGrO have been added as annex 3 and annex 4 respectively. These annexes are for information purposes only.

When updating the document, the principles of the Congestion Income Distribution Methodology (CIDM) related to CACM2, Article 73, were taken into account.

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[1] FBI is assured by a specific patch integrated to the market coupling tool to avoid any commercial flows against intuitive market direction.

[2] CACM: REGULATION (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management

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1 General definitions

The overall congestion income (CI) can be calculated by the following formula:

$$CI = -\sum_{i=1}^{NRH} netPOS_i \times CP_i \quad \text{(Eq. 1)}$$

Where:

$netPOS_i$: net position of real hub i ; for CWE real hubs are FR, BE, NL, DE/LU[3] and AT

CP_i: clearing price of real hub i

NRH: total number of real hubs

To calculate the CI only the real hubs are considered. Virtual hubs as shown in Figure 1 for ALBE (connection of the ALEGrO line – BE) and ALDE (connection of the ALEGrO line – DE) are only used as an enabler for increased exchanges between real hubs. In contrast to real hubs, there do not exist any bids at the virtual hubs in the market coupling algorithm Euphemia and therefore there is also no CI generated at the virtual hubs (and therefore also no CI distributed to any virtual hub).

The impact of commercial flows on the critical branches (CB) is given by the power transfer distribution factors (PTDF) which are organized in the so-called PTDF-Matrix. This matrix translates the net positions into physical flows on the critical branches. Hence, the additional aggregated flow - AAF_i - associated to network constraint i can be calculated by multiplying the according power transfer distribution factor $PTDF_{i,j}$, where j refers to the respective hub (real or virtual), by the net hub position, using the following equation (Eq. 2). For clarification and delimitation issues it might be helpful to mention that for calculating the AAFs for Congestion Income Distribution (CID) -calculation the PTDF matrix differentiate from the PTDF matrix that is used for the calculation of the Flow Based Domain in such way, that for CID-AAFs only cross border network elements within the Flow Based Region (i.e. internal cross border lines) are taken into account in a base case (N) and no hub internal ones[4].

$$AAF_i = \sum_{j=1}^{NH} PTDF_{i,j} \times netPOS_j \quad \text{(Eq. 2)}$$

Where:

AAF_i: additional aggregated flow associated to network constraint *i*

$PTDF_{i,j}$: power transfer distribution factor of hub j on critical branch i

$netPOS_j$: net position of hub j

[3] Please note that in case there is a reference to hubs automatically always the hub DE/LU is meant, this is also the case if only DE is written here in this document

[4] Please note that the formulation is also applicable in EFB for DC interconnectors, as the flow over a DC interconnector in EFB is modelled by a network constraint with a single PTDF of 1 for the corresponding virtual hub and PTDFs of zero for all other hubs (as part of the modelling of the external constraint). This gives the AAF over the cross-border network element (the DC interconnector) which is directly equal to the corresponding virtual hub's net position. This is elaborated in detail in Annex 2.

NH: total number of hubs (including all real hubs and all virtual hubs)

Definition of shadow price

In mathematical terms for more academic evaluation, the FBMC algorithm is an optimization procedure that generates so-called shadow prices on every Flow-Based (FB) constraint, i.e. on each modelled network element that is monitored under certain operational conditions (such as outages).

The shadow price represents the marginal increase of the objective function (Day Ahead (DA) market welfare) if the constraint is marginally relaxed. In other words: the shadow price is a good indication of the increase in DA market welfare that would be induced by an increase of capacity on the active network constraint. As a consequence, non-binding network constraints in the market coupling solution have a shadow price of zero, since an increase of capacity on those network elements would neither change the optimal market coupling solution nor the flow on the network element concerned.

The overall congestion income for flow-based market coupling can therefore also/alternatively be calculated on the basis of the shadow prices (*SP)* and the flows induced by the net positions resulting from the market coupling as well, using the expression

$$CI = \sum_{i=1}^{NC} AAF_i \times SP_i + \sum_{i=1}^{NDC} ATC_i \times SP_i \qquad \text{(Eq. 3)}$$

Where:

SP_i: shadow price associated to constraint *i*

NC: total number of network constraints

ATC_i: corresponding ATC-limit of DC link *i* (hourly operational limit on the energy flow over the DC link, which is adjustable independent from the AC-grid situation)

NDC: total number of ATC constraints due to modelling DC links in Evolved Flow-Based approach

Hence, equation (Eq. 3) represents the mathematical equivalent to equation (Eq. 1).

For explanatory purposes, this document uses a consistent set of market results that have been calculated by the Price Coupling of Regions (PCR) simulation facility for one example hour. These market results are displayed in Figure 1. The same example is used throughout the document except in Annex 1.

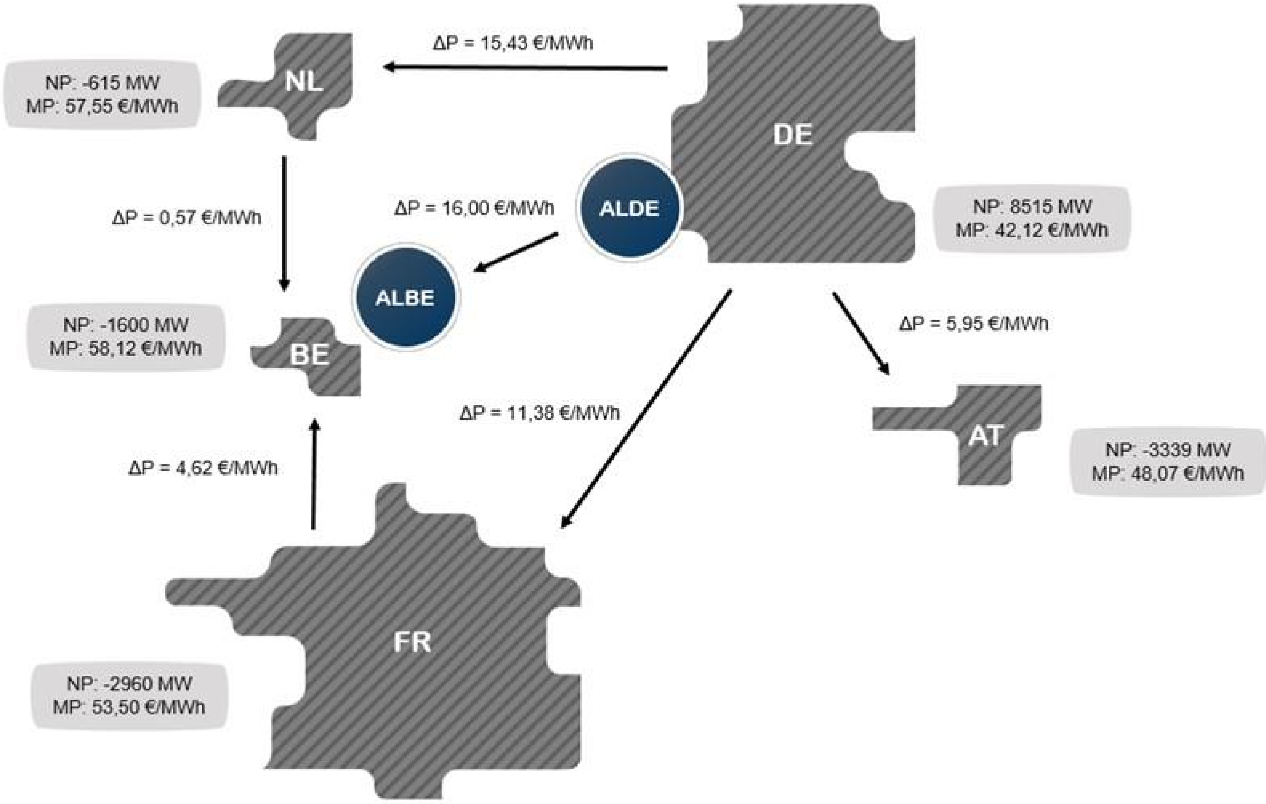

Figure 1: Flow-based market coupling results for the hour used in the example throughout this document.

In addition to the real hubs (FR, BE, NL, DE/LU, and AT), Figure 1 above shows the two virtual hubs ALBE and ALDE which help to model the flow on the DC interconnector ALEGrO in the context of EFB. It is important to note that all data given in the example used throughout this document are related to the real hubs and not the virtual hubs. For example, the price difference of 16,00 €/MWh as shown in Figure 1 is the price difference between the real hubs BE and DE. This is because the calculation of CI is based on the real hubs only, namely on the real hubs' NPs and price difference. The virtual hubs are solely used to help calculate the flow between the real hubs.

In order to model the impact on the AC grid of an exchange over the DC cable, TSOs need to be able to calculate the impact of an injection or offtake of the HVDC converter stations. This can be done by calculating the PTDFs of these HVDC converter stations, however these PTDFs cannot be linked to real bidding zones (such as BE or DE) since they already have their proper PTDF. Hence the introduction of virtual bidding zones allows TSO to calculate the PTDFs of the converter station and use the PTDFs in the FB calculation. The virtual bidding zones can thus be considered as a modelling features which allows TSOs to see the impact of an exchange over ALEGrO on the AC grid. The PTDFs calculated for the real hubs, represent the impact of a change in net position of that specific hub. For the virtual hub, the PTDFs represent a change in offtake / injection of the HVDC cable.

Back to the numbers in Figure 1 due to rounding, the sum of the net positions of the hubs does not equal zero.

From the net positions and prices we can obtain the congestion income according to (Eq. 1):

$$CI = -(-615 \times 57{,}55 - 1600 \times 58{,}12 - 2960 \times 53{,}50 - 3339 \times 48{,}07 + 8515 \times 42{,}12) = € \, 88.658{,}23$$

2 Criteria for sharing income

The qualitative criteria are depicted below in more detail.

2.1 Short & Long Term Incentive compatible

According to Article 19.1 of Regulation (EU) 2019/943 of the European Parliament and of the Council the procedure for the distribution of congestion income shall not provide a disincentive to either reduce congestion nor to distort the allocation process in favour of any party requesting capacity or energy.

Objectives: Efficient use of existing and efficient investments in transmission assets.

2.2 Transparent and easy to understand

Objectives: The distribution of congestion income should be transparent and auditable, which means that very complex sharing keys are not preferred. It should be easy to show in which way the congestion income is shared by the hubs and how this is integrated in the total picture of the congestion income cycle.

2.3 Robustness against gaming

Objectives: The sharing key should not give room for optimisation of any individual hub's share of the congestion income by gaming on data manipulation.

2.4 Fairness and Non discriminatory

Objectives: The sharing key should be based on elements related to the management of capacity for cross-border transactions.

2.5 Predictability and Limited volatility

Objectives: The sharing key should allow a forecast of the financial outcome and should not lead to a higher volatility of each share compared to the status quo, in order to allow a reasonable financial planning and cash flow management.

2.6 Smoothness of transition

Objectives: the current congestion income distribution should not be changed in a radical way in the short term in order to limit the financial impact on all parties.

2.7 Positive income per hub

Objectives: As long as the long term allocated (LTA) capacity domain is included in the FB domain, the hourly individual net income of each hub remains positive[5].

2.8 Stability in case of extension

Objectives: The current congestion income distribution for the CWE hubs should not be changed in a radical way when new hubs are joining the FB region.

Within the process of developing the sharing methodology for the congestion income, these criteria and objectives were taken into account. Therefore, the presented solution is one that fits the criteria best.

[5] As a matter of exception, by activating the so called 'Adequacy Patch' by the market coupling algorithm, the overall net congestion income could become negative. Overall negative net congestion income due to this situation will be dealt with according to the procedure of chapter 8.3.

The part of 'Nomination proof' was relevant as long as there were on internal BZBs PTRs and FTRs allocated in parallel on different BZBs. As from 01.01.2020 on all CWE internal BZBs only FTRs are allocated, it is on the one hand for market participants no longer possible to nominate LTRs (in form of PTRs) and on the other hand the mechanism to consider different principles and nomination level for LTRs is no longer needed. Therfore the amount of LT-nomination for the whole following document shall automatically always considered to be zero. This also has the side effect, that by principle the 'nomination proof' part is no longer needed at all. However as it is currently implemented in all IT-tools, this part is also kept in this document, but always knowing that only FTRs are in place at CWE internal BZBs and therefore no LT-nomination is possible (LTN = 0 MWh).

For external BZBs and their flows (see Chapter 5) the kind of LTRs (PTRs or FTRs) is not relevant in any way for the distribution of CI as LT-remuneration of LT-capacity allocated on external BZBs is not part of that methodology at all (also only CI generated by FBMC on internal BZBs is considered).

In case where long term physical transmission rights (PTRs) were issued on any of the borders the sharing of congestion income and remuneration costs of each hub should be made independent of the actual nomination level on a border by the market participants that hold the long term physical transmission rights. In this case the sharing key should be made ´nomination proof´. This is achieved in the way that the hourly remuneration costs per hub border are calculated from the total volume of allocated long term rights multiplied by the hourly price difference that occurs on that border, instead of only considering the resold part of the LTA multiplied by the price difference. Furthermore, the net positions to derive the overall congestion income need to be corrected with the Long-Term Nominations (LTN), such that the income is shared as if all LTA have not been nominated.

Since the net positions change with (past) possibility of LT-nomination, the AAFs change accordingly (Eq. 4), which is an adaptation of the earlier shown equation (Eq. 2). The flows on the critical branches on a border are aggregated on a hub border level.

$$AAF_i = \sum_{j=1}^{NH} PTDF_{i,j} \times netPOS(FBMC + LTN)_j \qquad \text{(Eq. 4)}$$

<u>Where</u>:

$PTDF_{i,j}$: power transfer distribution factor of hub *j* on critical branch *i*

$netPOS_j$: net position of hub *j*

NH: total number of hubs

FBMC: the part of the net position allocated through the daily flow-based market coupling (resold LTA and additional margin provided by the TSOs)

LTN: a correction of the net position due to the level of Long-Term Nominations (since January 2020 this correction is 0, i.e. LTN=0 caused by FTRs on all internal CWE BZBs)[6]

[6] Starting from January 2020 long term Financial Transmission Rights (FTRs) are implemented on all internal CWE borders. Thus there are no more borders with long term Physical Transmission Rights

The resulting net positions, additional aggregated flows and prices are depicted in the Figure 2 below (as the delta price in this example hour is positive from DE to BE, but the flow goes from BE to DE, there is a non-intuitive flow between BE and DE, which is possible under FBP). The CWE net positions of Germany, France and Austria do however not balance by the aggregated flows as part of the real physical flows leave and re-enter the CWE region through external borders. The concept of internal and external pot as discussed in Chapter 5 has been designed to address this issue.

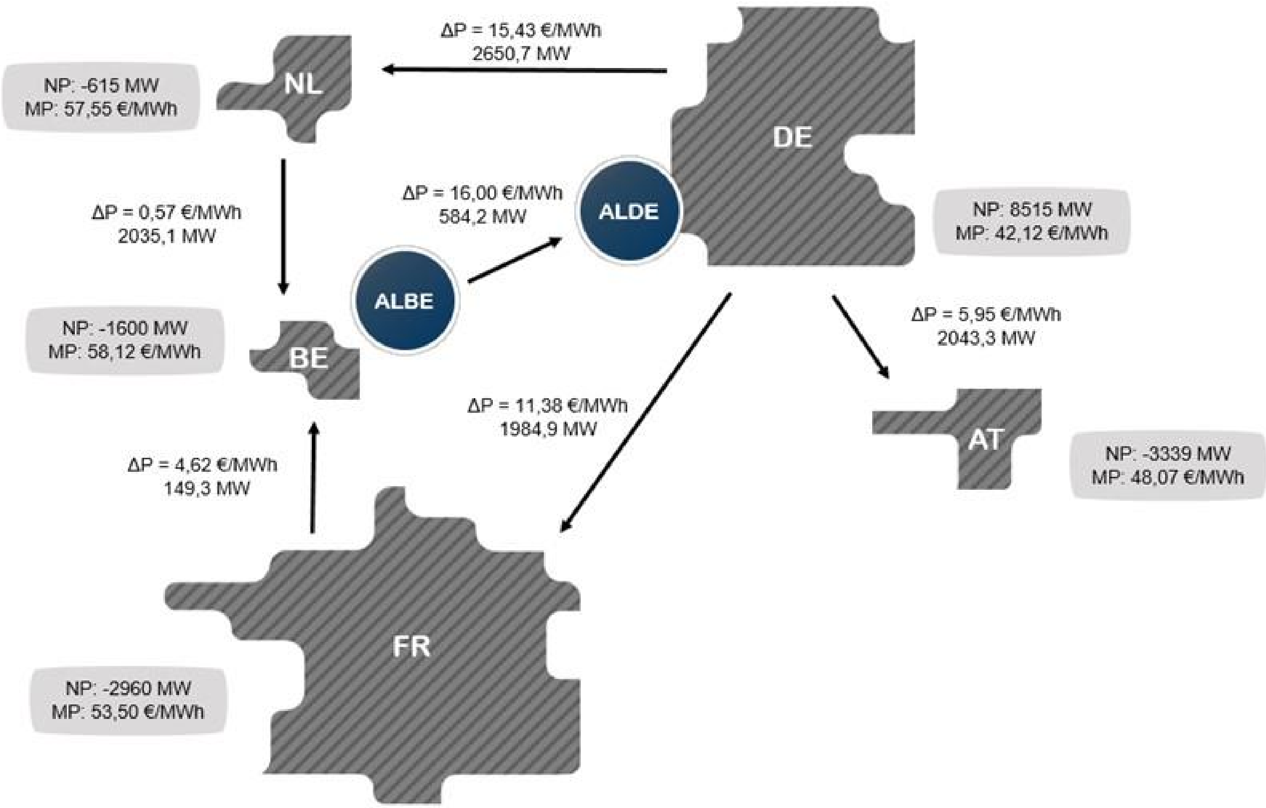

Figure 2: The calculated additional aggregated flows, based on the PTDFs and net positions.

(PTRs) within the region and consequently no Long Term Nominations based on allocated long term PTRs are needed (LTN=0). There is also no need to apply 'nomination proof' calculation. However, for the sake of completeness, the general form of equation 4 is kept as it refers to general case when either FTRs or PTRs could be used on specific borders in the region.

4 Cross Border clearing price times market flows absolute (CBCPM abs)

The Congestion Income Allocation mechanism for CWE takes up the fundamental characteristics of the well-known ATC scheme. Even though the results of CWE FB MC are hub net positions and clearing prices, the FB sharing key (CBCPM abs) – in a first step – assigns a Border Value to each individual hub-border in order to allocate the congestion income to the respective capacity holders. The idea is to share the congestion income based on economic indicators related to the allocation of cross-border capacity in zonal-markets, i.e. market price differences and allocated cross-border flow. Additionally, the FB sharing key is also in line with the principle of price formation in FB (Eq. 5):

$$\frac{\Delta CP_{hub\ i\rightarrow j}}{\Delta PTDF_{hub\ i\rightarrow j,k}} = Shadow\ Price\ \geq 0 \qquad \text{(Eq. 5)}$$

Where:

$\Delta PTDF_{hubi\rightarrow j,k}$: power transfer distribution factor difference between hub i and j for critical branch k

$\Delta CP_{hubi\rightarrow j}$: clearing price difference between hub i and hub j

ΔPTDF of the limiting CB is proportional to ΔCP. The ΔPTDF between the hubs close to the limiting CB is larger than the ΔPTDF between the hubs far away. Therefore, the price difference between the hubs close to the limiting CB is larger than the price difference between hubs far away.

The aforementioned Border Value is calculated by multiplying the respective AAFs by the price difference of the neighbouring hubs.

Under FB MC negative Border Values might occur if AAFs are directed against the clearing price difference (the price difference of the neighbouring hubs is – in the direction of the AAF – negative)[7]. Those flows contribute to the maximization of day-ahead market welfare within the entire Region, therefore Border Values are always taken into account in absolute terms. Since the absolute value of the Border Values is taken into account, a rescaling to the original overall congestion income is required.

4.1 Calculations of sharing key for CI

For the calculation of the CBCPM ABS key, the absolute Border Value per hub is considered as shown below:

[7] This situation can also occur within FB Intuitive MC, since a situation is defined as intuitive if there exist at least one possible set of intuitive bilateral exchanges. The AAFs resulting from the FBI MC are different from this set of bilateral exchanges.

$$CI\_Hub_i^{CBCPM\ ABS} = \frac{1}{2} \times \frac{\sum_{j=1}^{NRH} \left| AAF_{hub\ i\to j} \times \Delta CP_{hub\ i\to j} \right|}{\sum_{i=1}^{NRH} \sum_{j>i}^{NRH} \left| AAF_{hub\ i\to j} \times \Delta CP_{hub\ i\to j} \right|} \times CI \qquad \text{(Eq. 6)}$$

Where:

CI_Hub_i: congestion income associated to real hub i

$AAF_{hub\ i\to j}$: sum of additional flows from real hub i to real hub j (includes both AC and DC exchanges)

$\Delta CP_{hub\ i\to j}$: clearing price difference between real hub i and real hub j

NRH: total number of real hubs

4.2 Properties of the proposed sharing key

The CBCPM abs sharing key can be seen as an "evolution" of the ATC sharing key principle to rationalize the sharing of congestion income. The basic idea of the CBCPM sharing key is transparency and easiness to understand.

The income is linked to congested CB(s) that set(s) the prices: the ΔPTDF close to the limiting branch is large and therefore, the price difference is also large. This means a large congestion income on the borders close to the congestion. So the price difference is an indication of the location of the congestion. As such, the congestion income is an indication of the criticality of a congestion.

The sharing key has a good stability in case of extensions. In case a hub with a border with recurrent congestions joins, the congestion income sharing is mainly attributed to that border and vice versa: if a hub without congestion on its borders joins, few congestion incomes will be attributed to this hub.

The absolute variant of the sharing key avoids negative net congestion income on a hub border.

5 Determination of the internal and external pot

As previously mentioned, the total congestion income is related to the shadow prices of the congested critical branches somewhere inside CWE. After adaption of the net positions with the Long-Term nominations and calculating AAFs, it is possible to divide this global income into an "internal" and an "external" pot. This external pot is related to the flows exiting and re-entering the CWE FB area through neighbouring hubs. The external flows are calculated as a complement to the internal flows in order to balance the net position of all hubs in the CWE CCR.

As not all CWE net positions can be balanced by internal flows (AAFs) the concept of an external pot was introduced and was updated with the implementation of DE-AT border. Without that border, there was only one external flow between FR and DE/LU/AT hubs, which was easy to calculate. Considering the DE-AT border, the situation became more complex and individual external flow components would be much more difficult to determine.

In accordance with the Congestion Income Distribution Methodology (CIDM) proposal based on CACM Article 73 and approved by ACER on December 2017, the so cold 'Slack Zone' approach was selected for the determination of external flow values. This approach was also prepared in this document by former Chapter '10.1.1 Determination of the unique price of the slack zone' for the case of extensions of the CWE-CCR. In Figure 3 the principle of this Slack Zone approach is illustrated. Therefore all external flow components between different hubs needed to balance the respective hubs in CWE (which are FR, DE/LU and AT) are substituted by only one virtual flow for each relevant hub and the Slack Zone. Of course the net position of the virtual Slack Zone is zero and a price of the Slack Zone has to be determined in an appropriate way.

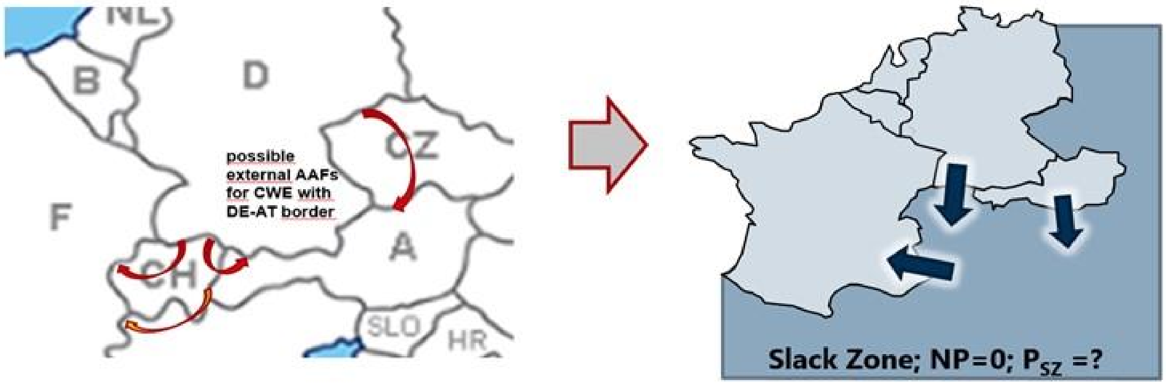

Figure 3: The principle of the Slack Zone approach.

Transferring this Slack Zone approach to the figure used before results in Figure 4, now also including the Slack Zone which acts as a source or sink for all the external flows. The external flow is calculated as the flow needed to balance the net positions in addition to the already calculated AAF.

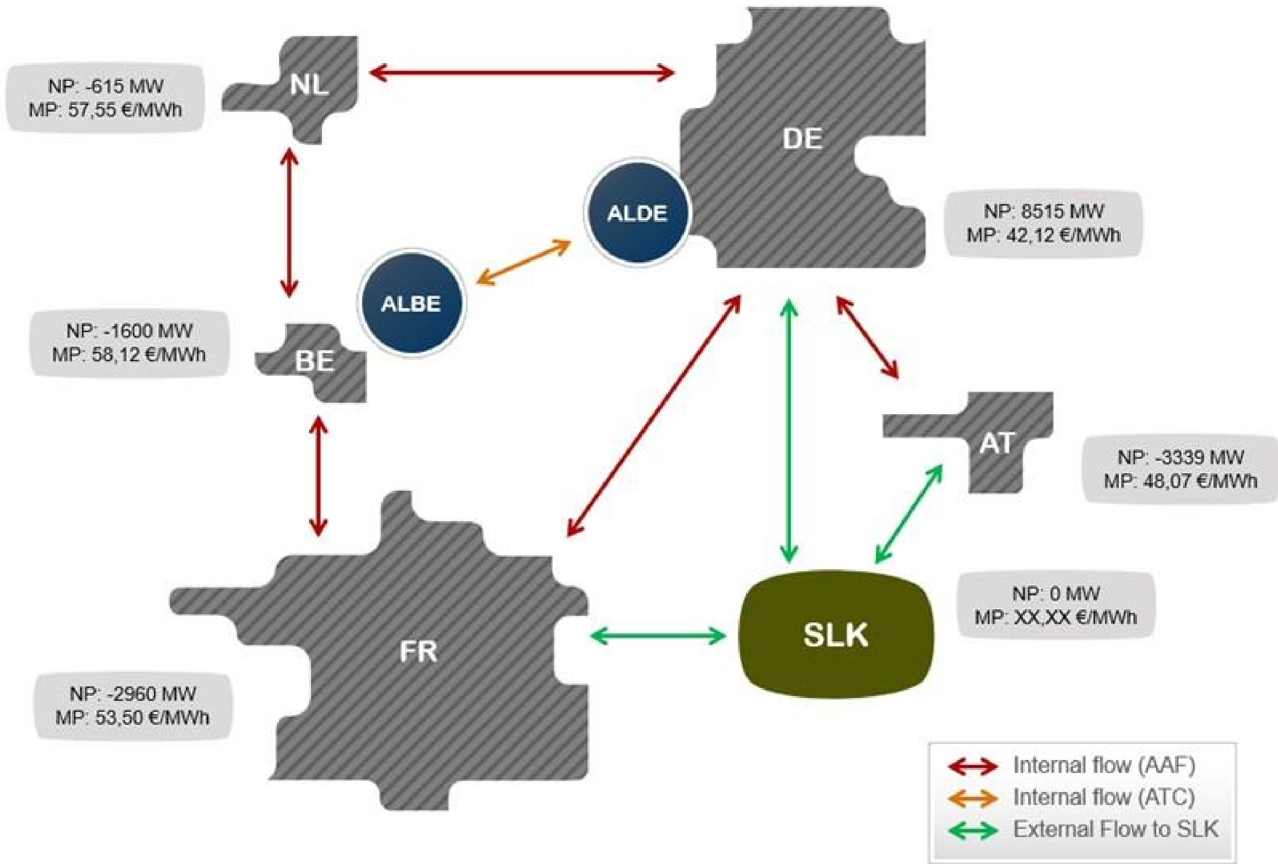

Figure 4: The principle of external flows towards the slack zone.

For bidding zones, where external flows are needed to balance the updated net position the market spread of such external flows are calculated as:

$$EMS_{j,SZ} = P_j - P_{SZ} \quad \text{(Eq. 7)}$$

And P_{SZ} is the price that minimizes the sum of external flows flowing in the opposite direction of EMS (i.e. non-intuitive external flows) using the following optimization:

$$P_{SZ} = \arg\min_{P} \sum_{j=1}^{n} (P_j - P_{SZ}) \times EF_{j,SZ} \quad \text{(Eq. 8)}$$

Where:

$EMS_{j,SZ}$ market spread for the external flow of a bidding zone j to the Slack Zone;

P_j clearing price of a bidding zone j resulting from SDAC (single day-ahead coupling);

P_{SZ} price of the virtual Slack Zone, which represents a common sink or source for all external flows;

$EF_{j,SZ}$ external flow of bidding zone j to Slack Zone;

n number of bidding zones having external flows.

If there is no unique solution for P_{SZ} then P_{SZ} shall be calculated as the average of the maximum and the minimum value from a set of P_{SZ} satisfying the formula above.

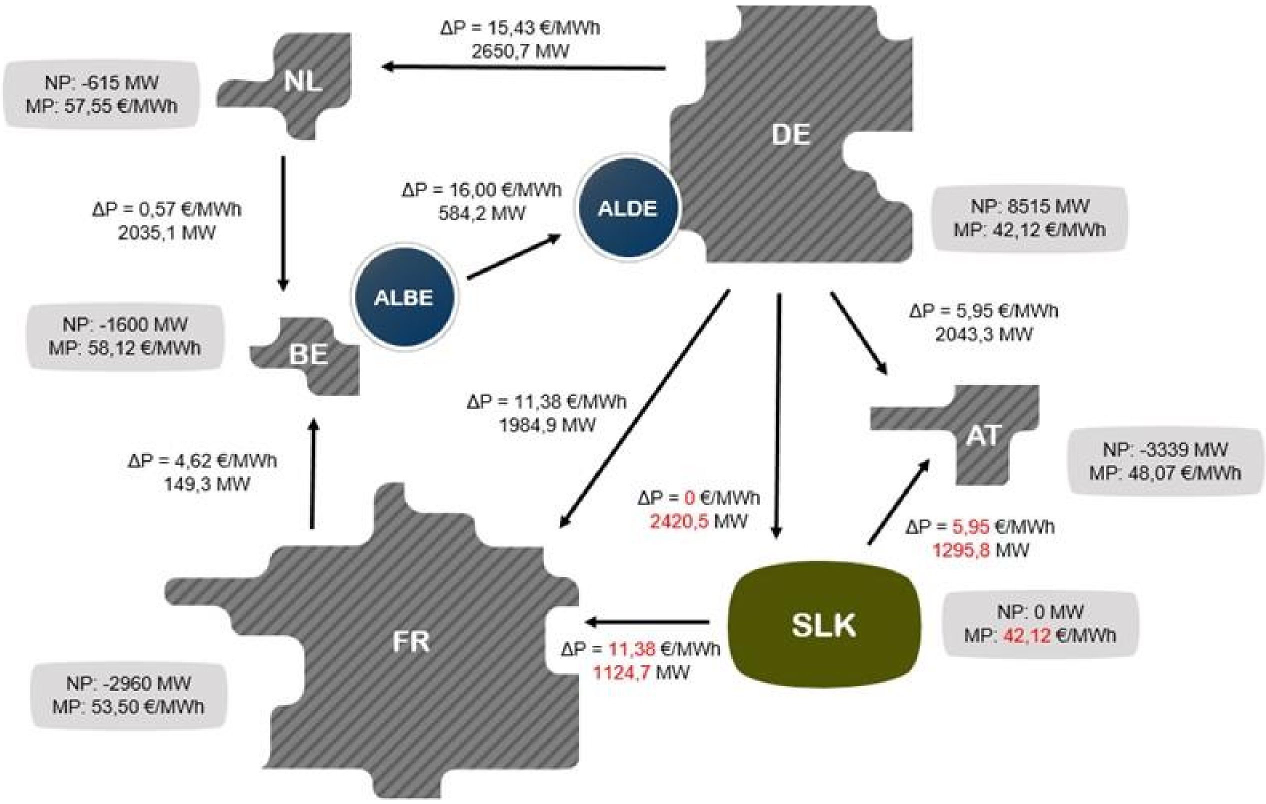

Figure 5: External flows towards the slack zone, based on the price optimization of the slack zone.

5.1 Calculation

For the computation of both the internal and external pot, we consider that all flows (AAFs) help to reach the optimum in CWE day-ahead market welfare, whatever the direction of the flow (with or against the price difference). This is in line with the choice of the CBCPM absolute key that was selected. It also ensures that both incomes are positive, which would not always be the case without considering absolute values. This means that we sum up the absolute Border Values for all internal and external hub borders respectively:

- Unscaled Internal pot = $\sum|(AAF(\text{internal hub borders})\times\Delta P)|$ (Eq. 9)
- Unscaled External pot = $\sum|(AAF(\text{external hub borders})\times\Delta P)|$ (Eq. 10)

The use of absolute values implies that the sum of the two pots may exceed the overall CWE congestion income. When sharing each of the pots, a pro-rata rescaling is then needed to correct this effect as shown in (Eq. 11) and (Eq.12).

- $internal\ pot = \frac{unscaled\ internal\ pot \times overall\ CI}{(unscaled\ internal\ pot + unscaled\ external\ pot)}$ (Eq. 11)

- $external\ pot = \frac{unscaled\ external\ pot \times overall\ CI}{(unscaled\ internal\ pot + unscaled\ external\ pot)}$ (Eq.12)

For the sharing of each of the pots keys based on the CBCPM absolute sharing key of internal flows (AAFs) or external flows are used:

5.2 Example

The updated net positions, market clearing prices and AAFs are already shown in Figure 6:

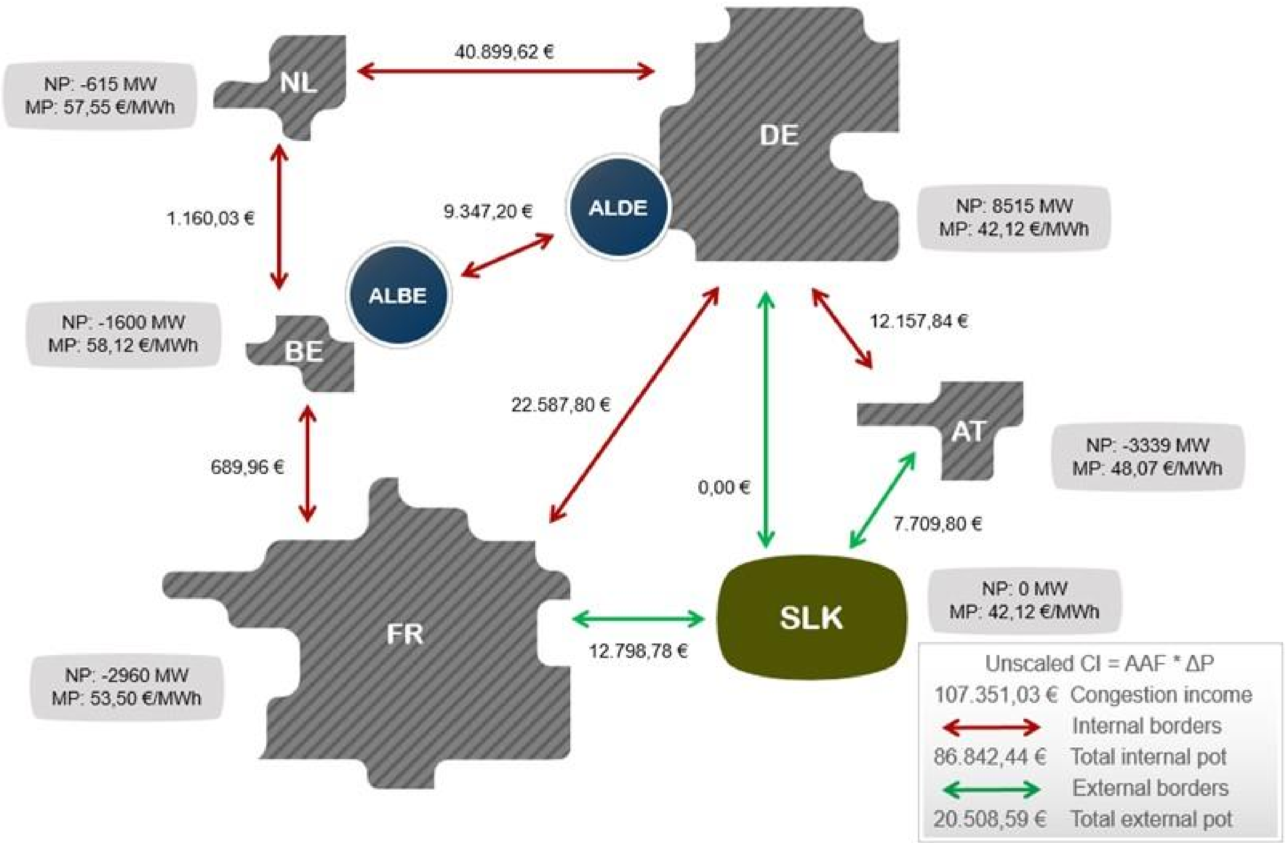

Figure 6: The unscaled congestion income per hub border, based on the market results as shown in Table 1

Applying these principles to our example leads to these computations (Table 1):

Unscaled internal pot = Σ │(AAF(internal)×ΔP)│ = 86.842,44 €

Unscaled external pot = Σ │(AAF(external)×ΔP)│= 20.508,59 €

Border	**Flow×│ΔP│**
DE-FR	1.984,9 × 11,38 = 22.587,80 €
DE-NL	2.650,7 × 15,43 = 40.899,62 €

BE-NL	2.035,1 × 0,75 = 1.160,03 €
BE-FR	149,3 × 4,62 = 689,96 €
BE-DE	584,2 × 16,00 = 9.347,20 €
DE-AT	2.043,3 × 5,95 = 12.157,84 €
Sum of absolute Border Values for all internal hub borders => **Unscaled internal pot**	**86.842,44 €**
FR-SZ	1.124,7 x 11,38 = 12.798,78 €
DE-SZ	2.420,5 x 0,00 = 0,00 €
AT-SZ	1.295,8 x 5,95 = 7.709,80 €
Sum of absolute Border Values for all external hub borders => **Unscaled external pot**	**20.508,59 €**

Table 1: Calculation of the border values

As the sum of the unscaled internal pot and unscaled external pot (107.351,03 €) exceeds the overall CWE congestion income (88.658,23 €), a proportional rescaling is applied to unscaled CI amounts of the internal and external pot (Table 2) by a scaling factor of 88.658,23/107.351,03 = 0,8259

Border	**Rescaled Congestion Income**
DE-FR	22.587,80 x 0,8259 = 18.654,63 €
DE-NL	40.899,62 x 0,8259 = 33.777,86 €
BE-NL	1.160,03 x 0,8259 = 958,03 €
BE-FR	689,96 x 0,8259 = 569,82 €
BE-DE	9.347,20 x 0,8259 = 7.719,59 €
DE-AT	12.157,84 x 0,8259 = 10.040,82 €
Internal pot	**71.720,76 €**
FR-SZ	12.798,78 x 0,8259 = 10.570,16 €
DE-SZ	0 €
AT-SZ	7.709,80 x 0,8259 = 6.367,31 €
External pot	**16.937,47 €**

Table 2: Calculation of the rescaled congestion income on borders of the internal and external pot

Internal pot = 71.720,76 €

External pot = 16.937,47 €

The congestion income on the borders is shown in Figure 7.

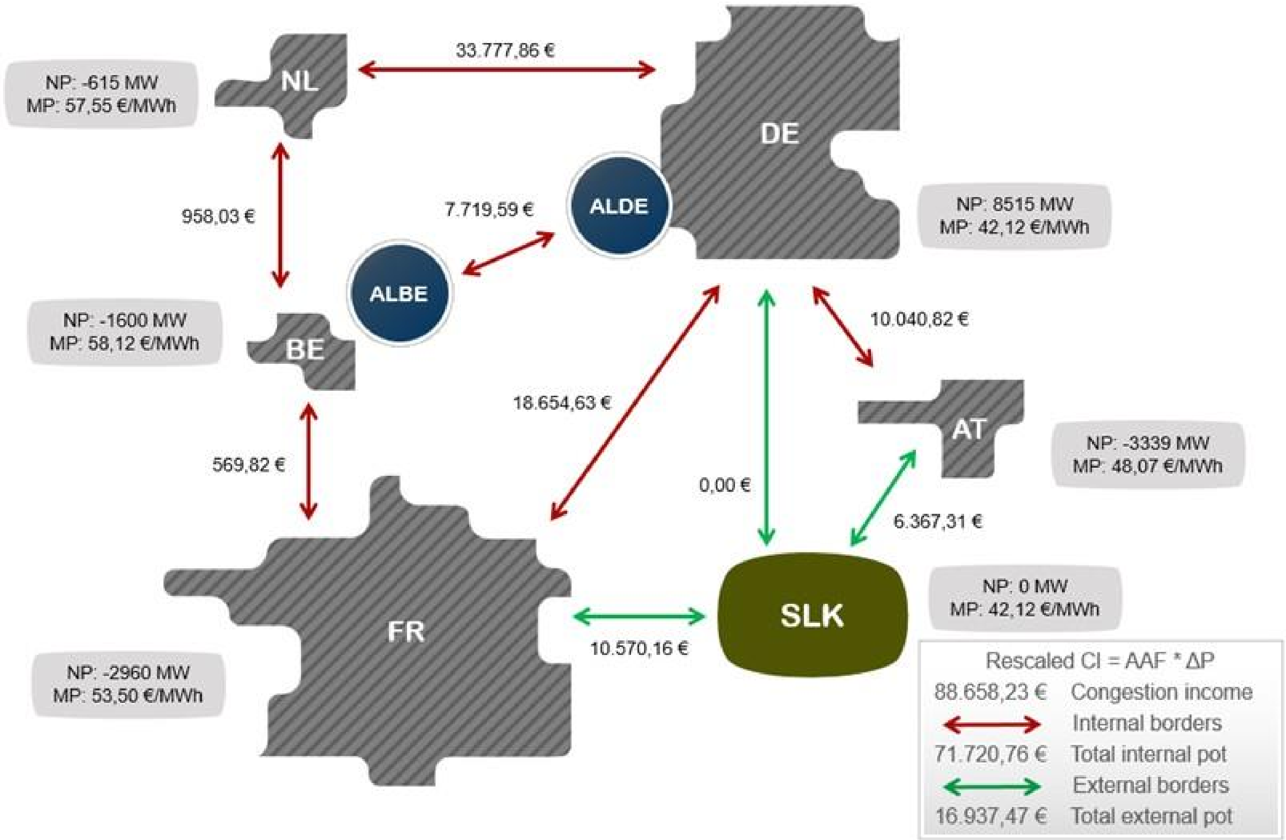

Figure 7: The scaled congestion income per hub border.

6 Sharing of the hub border income

The (rescaled) congestion income on the hub borders is shared equally (50/50) between the neighbouring hubs as shown in Figure .

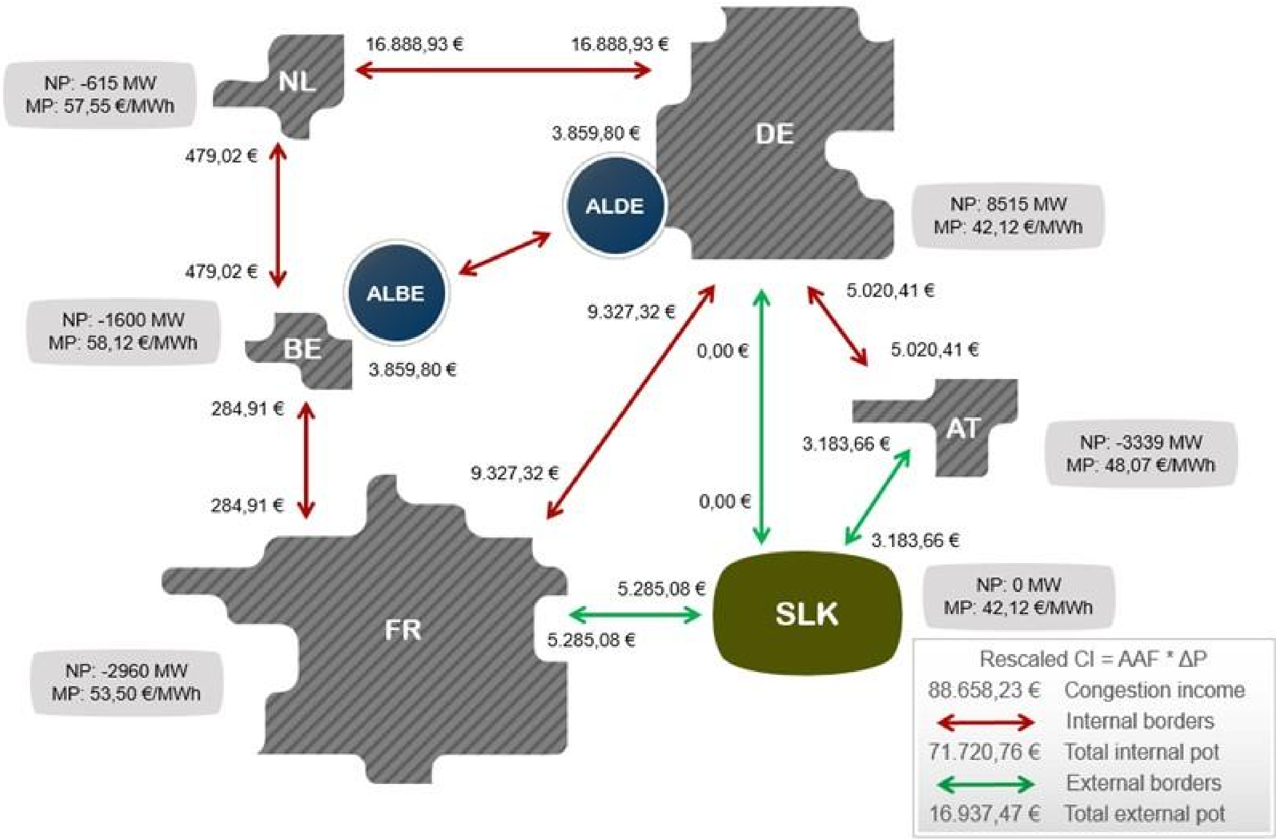

Figure 8: The scaled congestion income per hub border shared equally between each side of the border.

7 Principles of the remuneration of LTRs under Flow-Based MC

7.1 Cost for remuneration of Long-Term remuneration cost

The TSOs, through the "Use It Or Sell It" principle, enable the Market Participants that acquire some bilateral Long-Term capacities (based on ATC) in Yearly and Monthly auctions to automatically remunerate these capacities at the daily allocation in case they do not nominate these capacities in case of physical transmission rights (PTRs) on a border. In case of financial Transmission rights (FTRs) all allocated long-term rights are self-acting financially remunerated and no nomination is possible. Such remuneration will lead, in ATC but also in Flow-Based, to the payment of the positive price spread between the two hubs multiplied with the volume of Long-Term capacity remunerated. The remuneration costs in Flow-Based can be defined in 2 ways as shown in (Eq. 13) and (Eq.14);

$$Remuneration\ Cost = \sum_{i,j} \left(LTA_{i\to j} - LTN_{i\to j}\right) \times \max\left(0, \Delta CP_{hub\ i\to j}\right) \quad \text{(Eq. 13)}$$

$$Remuneration\ Cost = \sum_{NC} AAF_{rem,i} \times SP_i + \sum_{i=1}^{NDC} ATC_{rem,i} \times SP_i \quad \text{(Eq.14)}$$

Where:

$LTA_{,i\to j}$: long term allocated capacity on the border in the direction from i to j.

$LTN_{,i\to j}$: long term nominated capacity on the border in the direction from i to j (since January 2020 LTN=0)[8]

$\Delta CP_{hub\ i\to j}$: clearing price difference between hub i and hub j

$AAF_{rem,I}$ positive margin freed by the remuneration on critical branch i.

SP_i: shadow price associated to constraint *i*

NC: total number of network constraints

$ATC_{rem,i}$: positive margin freed by the remuneration on DC link *i* modelled by Evolved-Flow-Based approach

NDC: total number of ATC constraints due to modelling DC links in Evolved Flow-Based approach

7.2 Maximum amount available for remuneration of the return of LTRs

From (Eq.14), one can see that if the overall margin freed by all returns of LTRs to daily markets on each critical branch is lower than the margin made available by the TSOs to the Market Coupling, the congestion income from Flow-Based Market Coupling is higher than the remuneration cost as shown in Figure . We can conclude that if the Long Term ATC domain is included in the Flow-Based domain, the remuneration costs are covered by the hourly congestion income. The numerical proof that the remuneration costs are smaller than or equal to the overall congestion income is assured because of the automatic LTA inclusion in the FB domain. An explanation can be found in Annex 1.

[8] As already stated in chapter 3 starting from January 2020 long term FTRs are implemented on all internal CWE borders and consequently no Long Term Nominations based on allocated long term PTRs are needed (LTN=0). However, for the sake of completeness, the general form of equation 13 is kept as it refers to general case when either FTRs or PTRs could be used on specific borders in the region.

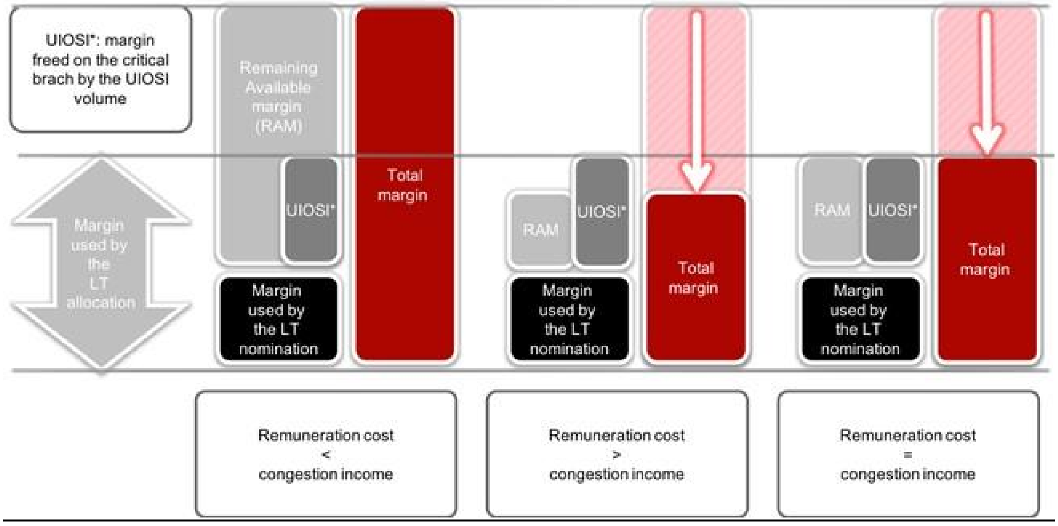

Figure 9: Relationship between overall congestion income, remuneration cost and margin on a critical branch

Following Eq. 13, the total remuneration cost can be calculated. This amount in total has to be remunerated to the market participants. Following the same calculation principle, also the remuneration cost per direction of a BZB respectively per BZB can be calculated (please be aware that remuneration costs only exist in case of positive market spread). For each BZB the resulting remuneration costs were shared 50% to 50% between the TSOs of a border and have to be remunerated to market participants by TSOs. Figure 10 is showing the netted (allocated minus nominated) LT-capacity relevant for remuneration, whereas Figure 11 is showing the effective remuneration cost per BZB considering market spread orientation.

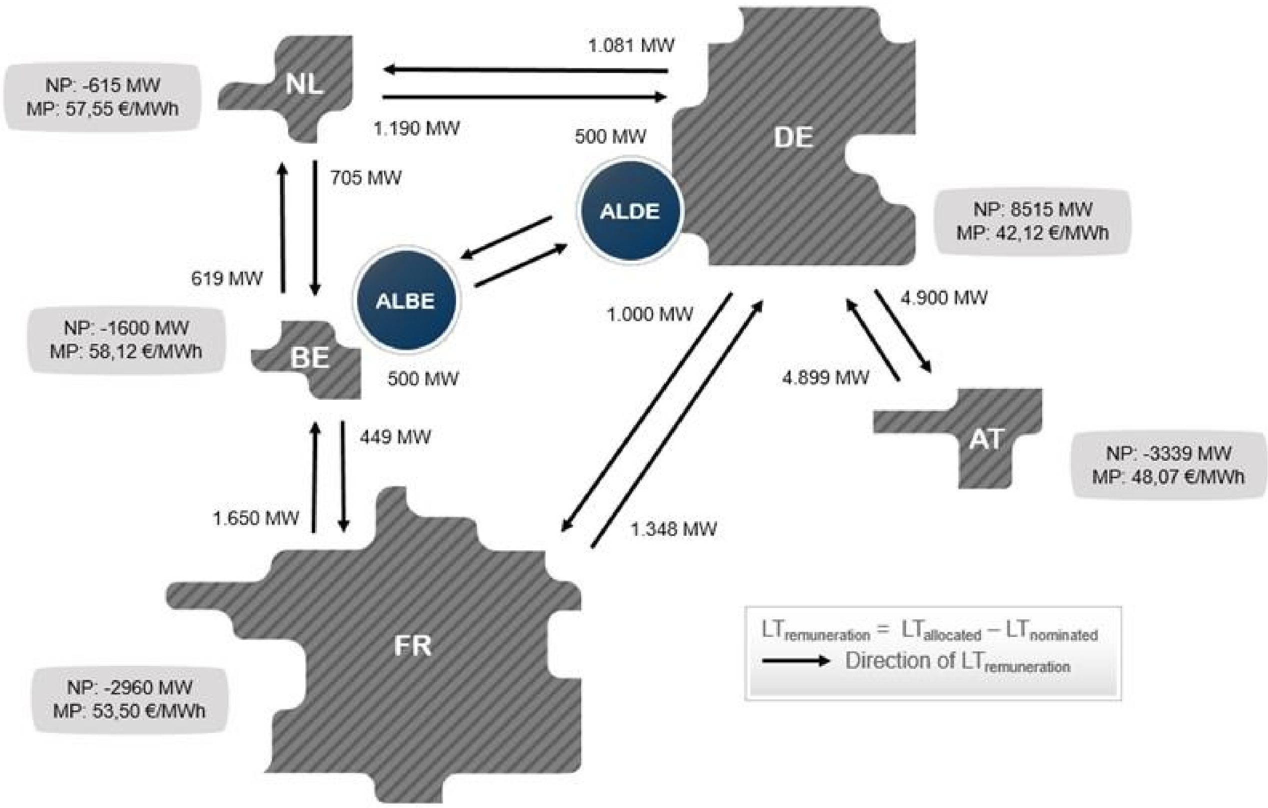

Figure 10: Amount of LT-Capacity for remuneration per BZB and direction

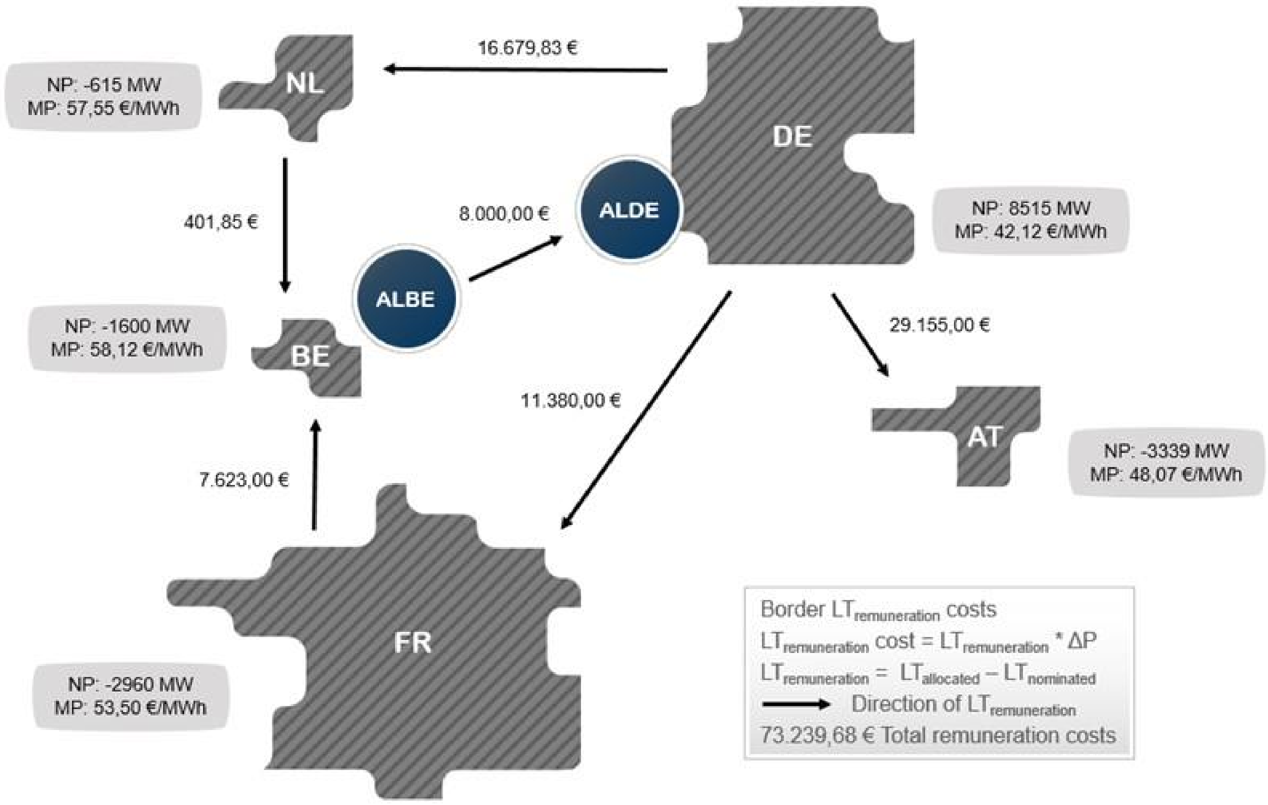

Figure 11: Effective remuneration cost per BZB caused by LT-remuneration

The total sum of remuneration cost according to (Eq. 13) is 73.239,68 € as shown in Figure 11. This is the amount which has to be paid to market participants for LT-remuneration.

7.3 Remuneration methodology in line with treatment of external pot

Remuneration costs for TSOs to market participants are based on a scheduled flow and resulting as already shown in Figure 11.

To make the remuneration cost independent of the nomination level (nomination proof; which is especially important if on a CCR PTRs with LT-nomination are in place on some borders in parallel to other borders based on FTR principle), in a first step theoretical remuneration cost are calculated again following (Eq. 13) for each BZB, however without any nomination considered (remuneration cost based on allocated capacity and positive Market Spread).

In our Example there is no LT-nomination, so no rescaling needs to be performed.

In a next step the (rescaled) remuneration cost per BZB are further distributed because CI sharing key for TSOs is based on physical flows considering AAFs and external flows. To avoid an inconsistency between the remuneration methodology and the CI sharing principles, the remuneration cost shall also be assigned to internal and external borders (with external flows).

Therefore the following principle is applied:

- For a hub with closed borders the remuneration cost divided by two is assigned to its side of the respective closed border.

- For a hub with open borders, the part of the remuneration cost that is linked to the internal flow (AAF), divided by two, is assigned to its side of the closed border, whereas the part of the remuneration cost that is linked to the difference between the remunerated volume and the external flow, divided by two, is assigned to the open border to the Slack Zone. As a consequence, both sides of a border can have a different remuneration cost as shown in Figure 12

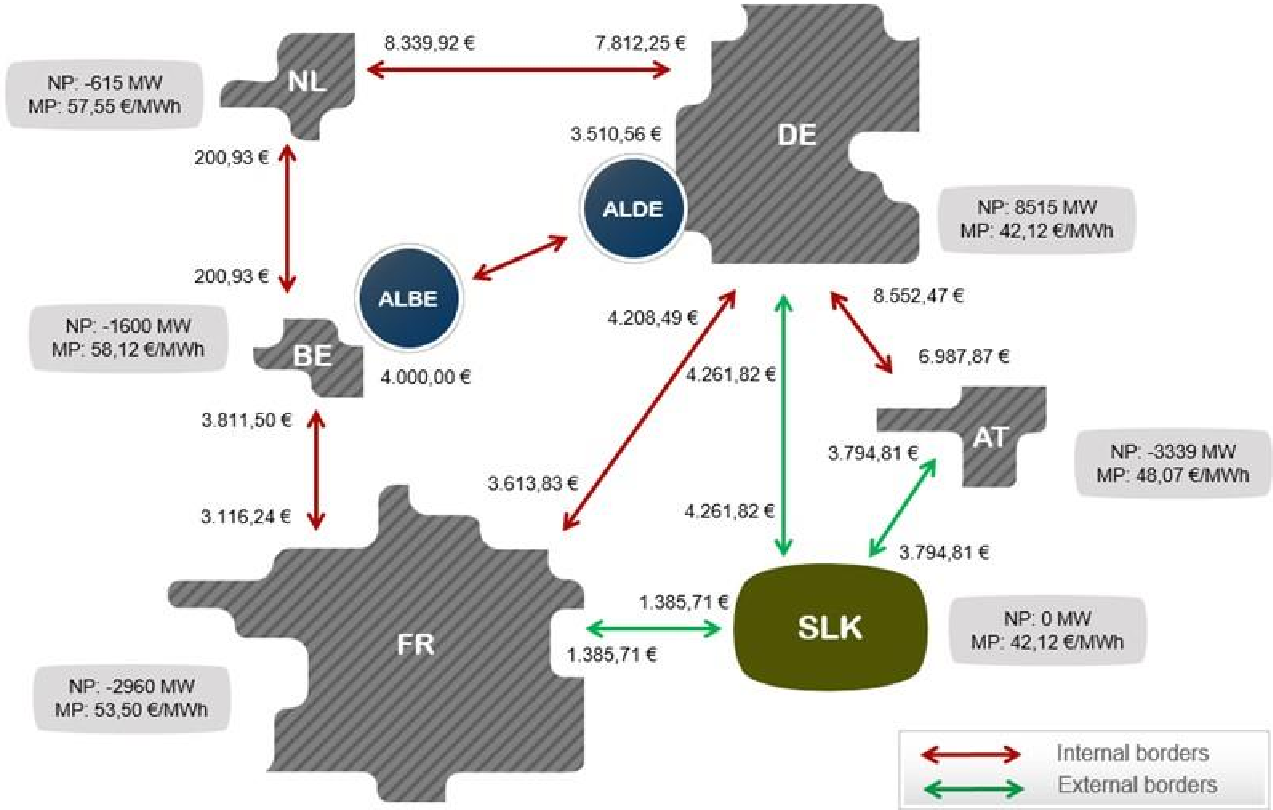

Figure 12: Assigned remuneration cost per border after distribution to internal and external borders

In Figure 12, between Belgium and the Netherlands the remuneration cost are equally at 200,93 €, because both hubs have only closed borders (no external flows), whereas on all physical hubs with external flows (FR, DE/LU, AT) the remuneration cost on their BZB are different. The remuneration cost between those hubs with external borders and their SZ-border however is also equal, because the Net Position of the Slack Zone is always zero and therefore no flows relevant for remuneration are generated by this virtual hub.

7.4 Socialization methodology

The remuneration cost is calculated on a hub border basis; for internal and external borders. Each TSO is responsible for compensating the remuneration costs on its side of the border (based on hourly CI-income according distribution methodology). The steps to arrive at the remuneration cost per side of a hub border are reflected in the chart below (Figure 13).

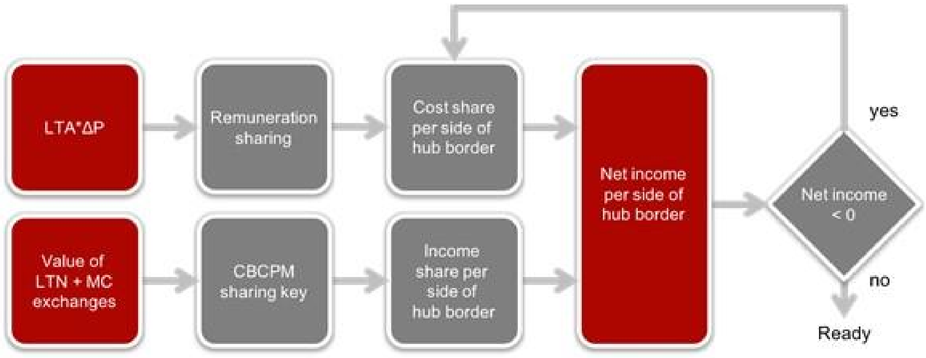

Figure 13: Socialization methodology principle

Figure shows the congestion income per hub border on each side of the hub border and Figure shows the remuneration costs on each side of the hub border. The difference between these values is the net congestion income per hub border (i.e. income after considering of cost for LT-remuneration) as shown in Figure 16.

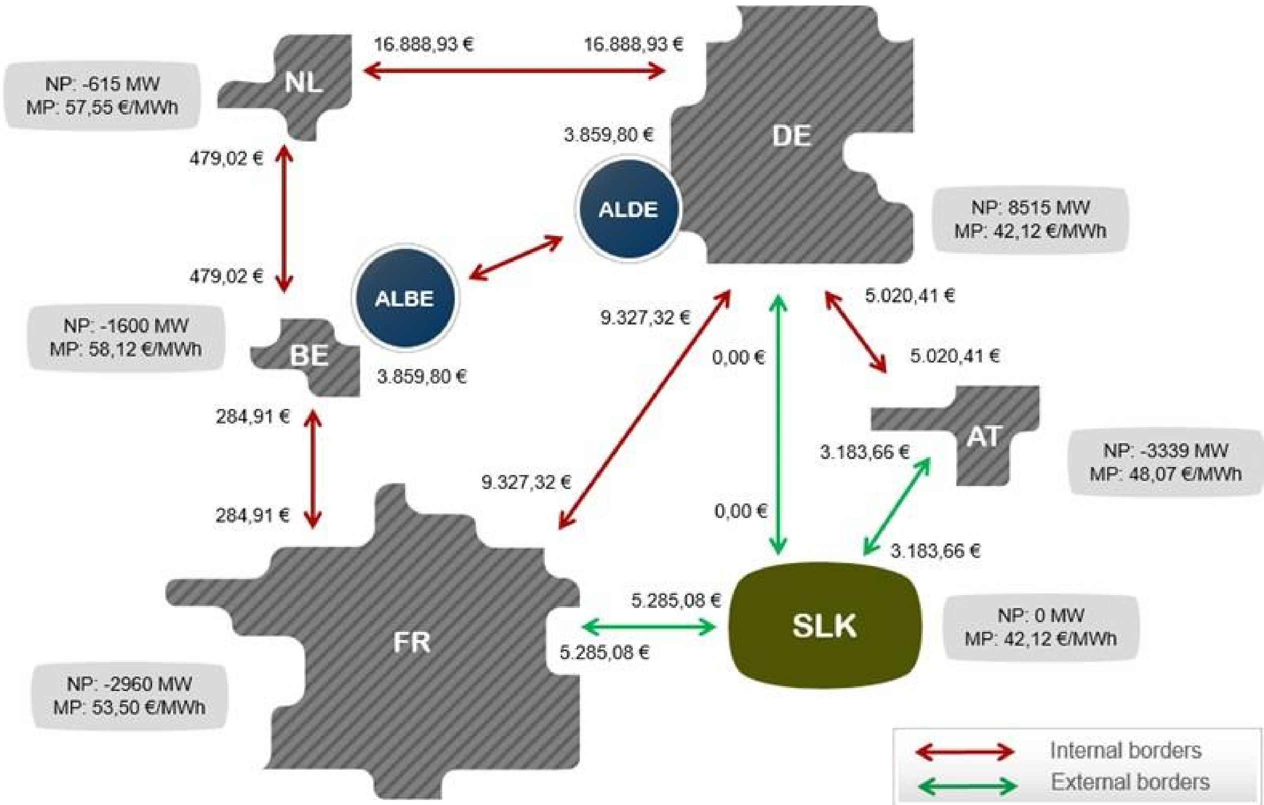

Figure 14: The congestion income per hub border on each side of the border, as calculated in paragraph 5.2.

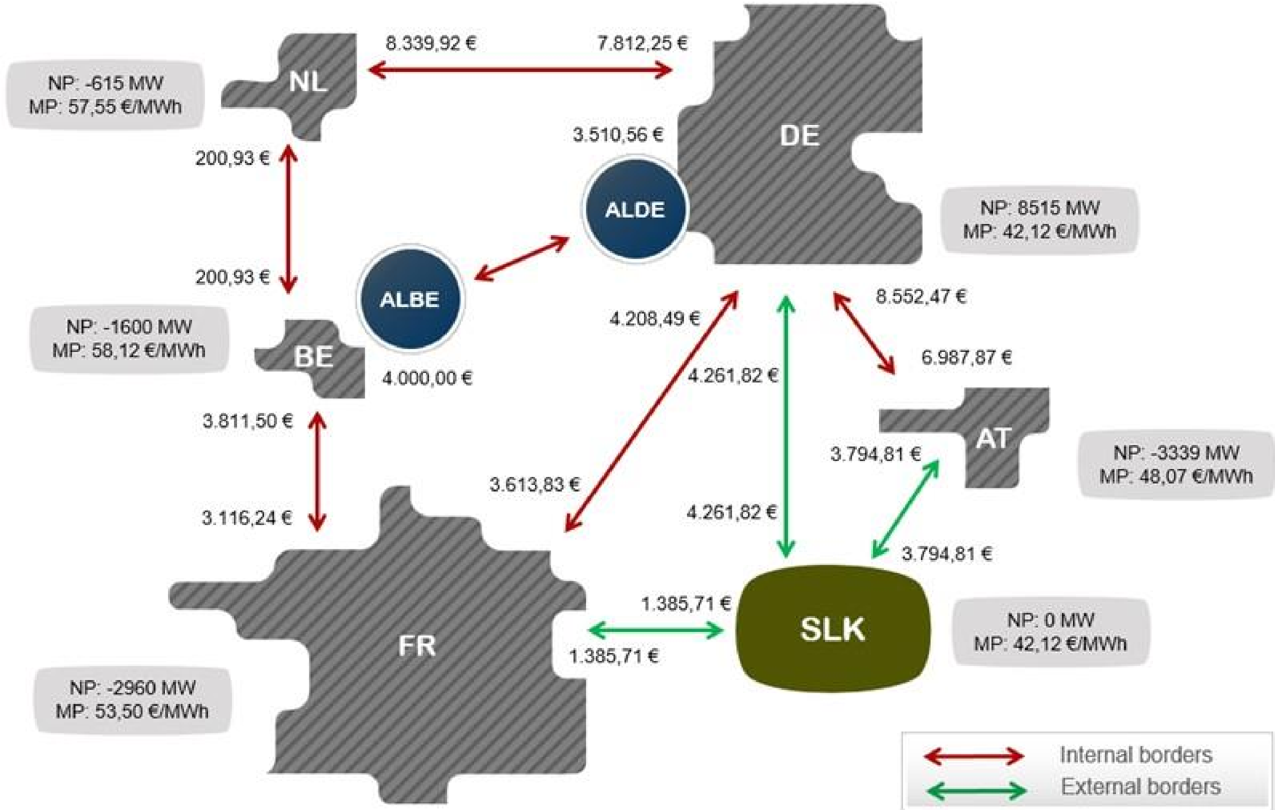

Figure 15: Long-term remuneration cost per hub border on each side of the border.

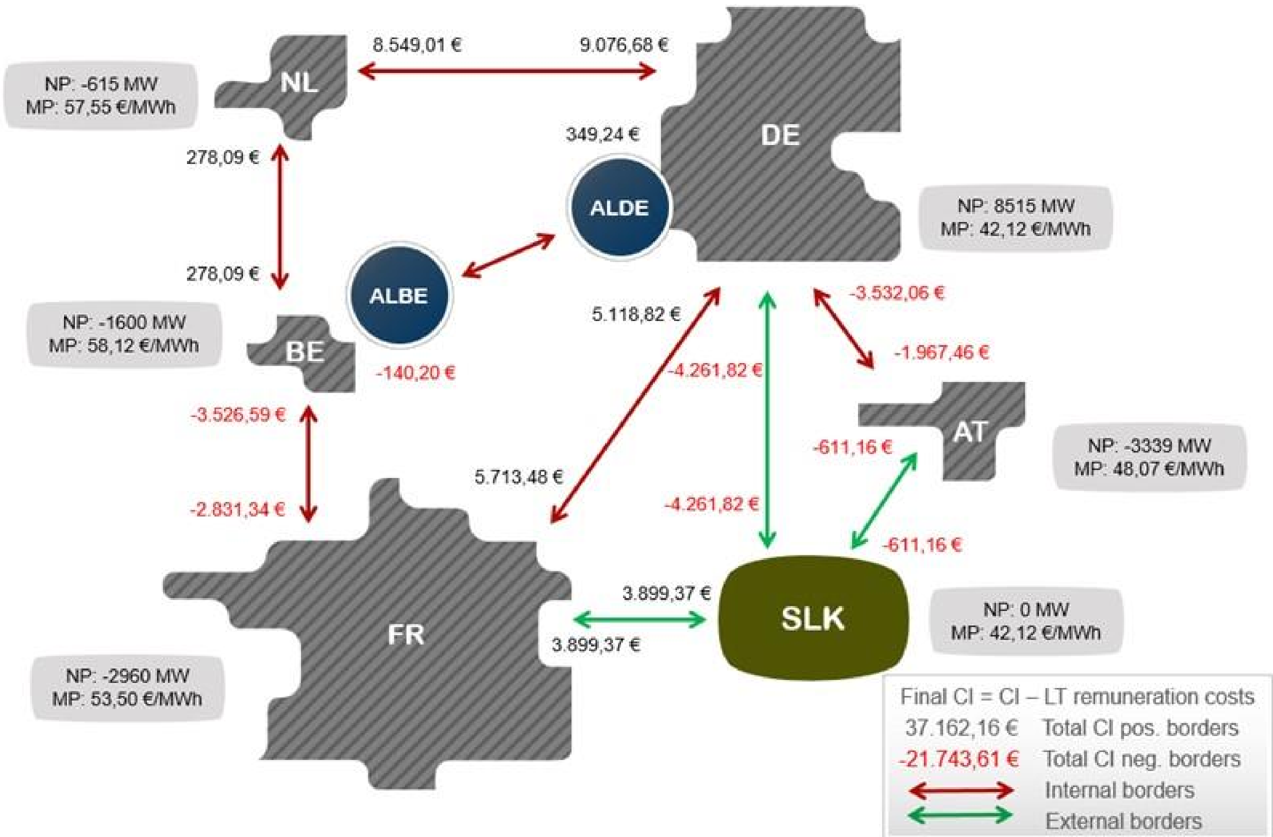

Figure 16: Combination of congestion income and long-term remuneration costs per hub border on each side of the border.

The hourly net income (income minus remuneration cost) should not lead to negative income per side of a hub border. In line with the remuneration methodology, the remuneration for any side of the hub border will initially be borne by its TSO. However, in case the income on a particular side of the hub border is not sufficient to cover these remuneration costs, these costs will be borne pro rata by the other hub borders (shown in the iteration of the cycle in Figure 1). This is referred to as 'socialization'.

In the given example only on the borders BE-NL, DE-FR, DE-NL and FR-SZ the resulting CI for both directions are positive and also the border direction BE-DE:DE is positive. For all other borders, the amount of remuneration is larger than the CI. However the total CI of the positive borders with 37.162,16 € is larger than the outstanding remuneration cost of -21.743,61 € for negative borders and therefore the CI of the positive borders will be proportionally assigned to the negative borders to balance them to zero (in fact based on LTA-inclusion principle of the DA-FB domain, the total CI shall be always larger or at least equal to the total remuneration cost).

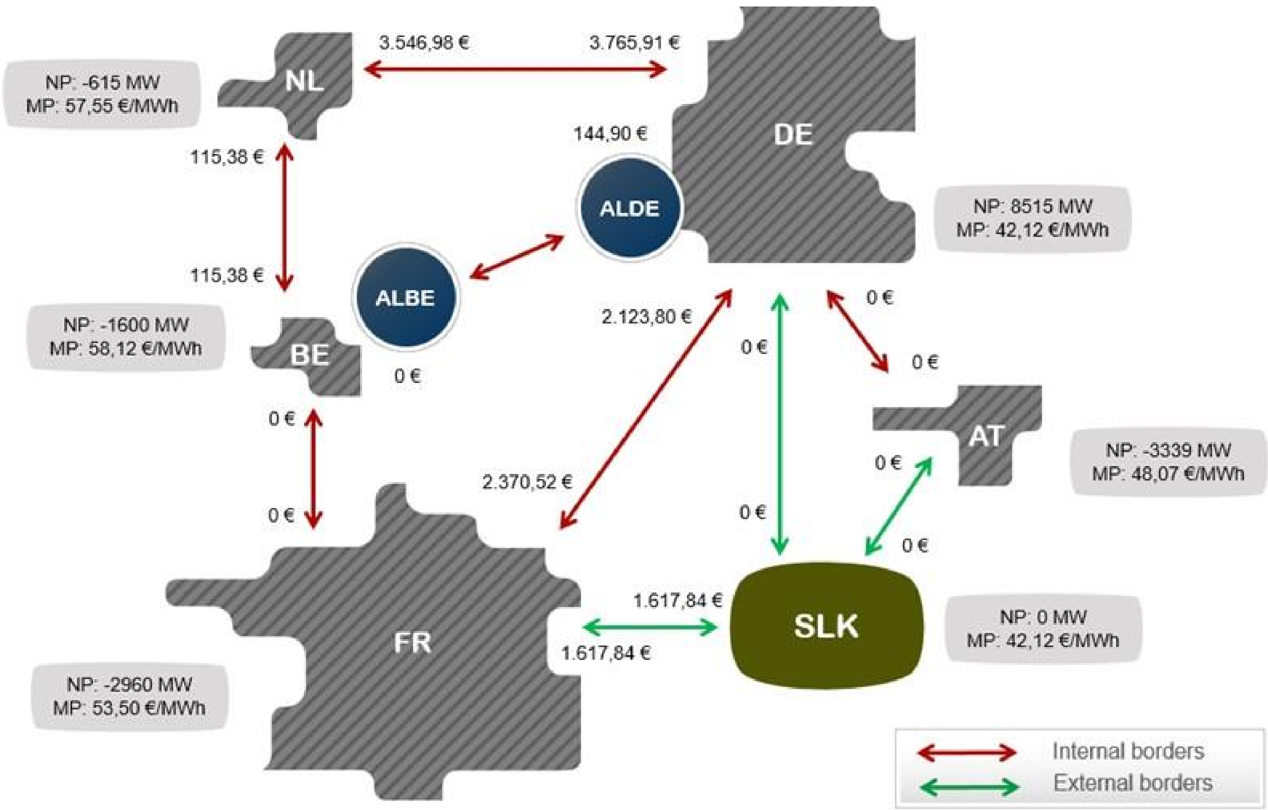

Figure 17: Net congestion income after socialization to all borders

After this socialization step it may occur that some CI is also assigned to the Slack Zone. As this is only a virtual hub, this does not make sense and therefore in a last step the CI resulting for the Slack Zone (1.617,84 € in our example) is proportional to the AAFs distributed to the internal BZBs. Summing up this to the CI per direction of BZBs resulting after consideration of remuneration cost and socialization, the final CI per direction of BZB is calculated as shown in Figure 18 and in Table 3. For the example the CI for evaluated sample hour is equal to 15.419 €. Based on the CI per side of BZB it is easy to sum up the CI per hub respectively per TSO(s).

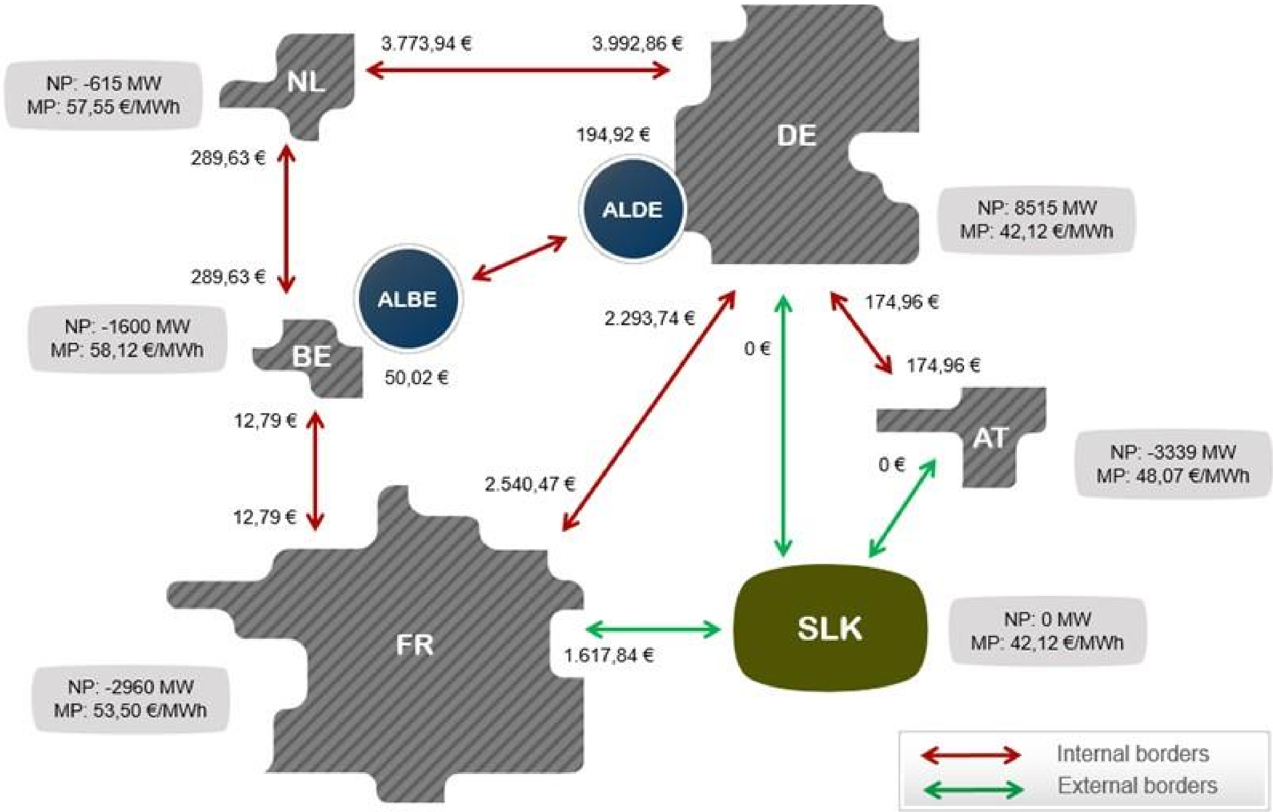

Figure 18: Net congestion income per hub border on each side of the border, after consideration of LT remuneration costs, socialization and sharing of the CI of the Slack Zone

Border	**Final CI per side of BZB** **15.419 €**
DE-FR.DE	2.293,74 €
DE-FR.FR	2.540,47 €
DE-NL.DE	3.992,86 €
DE-NL.NL	3.773,94 €
BE-FR.BE	12,79 €
BE-FR.FR	12,79 €
BE-NL.BE	289,63 €
BE-NL.NL	289,63 €

BE-DE.BE	50,02 €
BE-DE.DE	194,92 €
DE-AT.DE	174,96 €
DE-AT.AT	174,96 €
DE-SZ.DE	0 €
FR-SZ.FR	1.617,84 €
AT-SZ.AT	0 €

Table 3: Final congestion income on each side of the BZB

7.5 Additional issue linked to the remuneration with Flow-Based daily allocation

In the previous chapters, we have already seen that there is a one-to-one relation between the Long Term ATC capacity and the available margins on day-ahead critical branches.

For the above-mentioned reason, TSOs need to evaluate clearly what are the possible effects on the congestion income sharing, of the Long Term (non-harmonised) bilateral allocation of capacity on the one hand and of the fully coordinated Flow-Based allocation of capacity on the other.

Indeed, TSOs know that the Long-Term allocation income will be received by the two TSOs issuing the capacity on that border. In line with the remuneration methodology, the remuneration will initially be borne by those TSOs. However, in case their income through the Flow-Based allocation is not sufficient to cover this, the costs for that border might be borne by other/all TSOs (socialization), therefore also the Long-Term Rights need to be coordinated within the region.

8 Fallback Solutions

8.1 Application of Spanning

In case of application of the Spanning methodology as described in section 4.6 (*Backup and Fallback procedures for Flow Based capacity calculation*) of the Documentation of the CWE FB MC solution, the Congestion Income Allocation methodology cannot be applied due to missing input parameters. As a fallback solution, CWE TSOs will share the net congestion income based on a predefined distribution key in the hours that are affected by Spanning. This distribution key is equal to the relative shares of the total net congestion income of the month prior to the Spanning event. For example, if Spanning is applied during a single hour on 12 February 2020, each CWE TSO will receive a share of the CWE net congestion income of that hour that is equivalent to the TSO's share of the total monthly CWE congestion income that was generated in January 2020. For the avoidance of doubt, it should be noted that the regular allocation methodology[9] will be applied to the remaining hours that were not affected by the Spanning event.

8.2 Decoupling Situations (following the principles as defined in FCA article 61)

In case of decoupling of CWE bidding zones as described in section 6.2 (Fallback solutions) of the Documentation of the CWE FB MC solution, no congestion income from implicit market coupling is generated on CWE bidding zone borders. In such a situation, the income from explicit shadow auctions and the remuneration costs of LTRs will be shared on a per-border basis. Income and remuneration costs of a bidding zone border will be shared between the TSOs based on the distribution key that is applied to the sharing of income from the allocation of LTRs. For the avoidance of doubt, it should be noted that this principle also applies if the remuneration costs exceed the income from explicit shadow auctions.

The sharing keys for the distribution of income from the allocation of LTRs are subject to local arrangements and are not covered by the Congestion Income Allocation methodology at hand.

Section 8.2 is without prejudice to the provisions of the methodology FCA Art 61 currently under discussion.

8.3 Situation with activation of adequacy patch

In case the 'adequacy patch' in the market coupling algorithm as defined in Annex 14.31 – CWE Report: Comparison of Flow-Based Plain and Flow-Based Intuitive (2020) of the FBMC document is activated, the total net congestion income for TSOs could become negative. In such exceptional situations10, the sharing key of this negative net congestion income between the CWE TSOs will be elaborated ex-post by the CWE TSOs in coordination with CWE NRAs. The expectation is that costs resulting from such negative congestion income are recoverable as cost for allocation of capacity.

[9] In case of spanning, for the relevant hour(s) the CRDS-data shall be prepared without the PTDF values to avoid calculation of CIA-results based on incorrect input-data. For NRA-reporting however hors with spanning shall be considered for all evaluation where correct data (in accordance with data used for JAO invoicing) are available.

[10] Since the start of CWE Flow-Based Market Coupling in May 2015, the adequacy patch has not ever been activated.

9 Glossary

AAF	Additional aggregated flow
AC	Alternating current
ATC	Available Transfer Capacity
ATC MC	ATC Market Coupling
BZB	Bidding Zone Border
CB	Critical Branch
CBCPM	Cross Border Clearing Price x Market flows
CI	Congestion Income (from day-ahead Market Coupling)
CIA	Congestion Income Allocation
CIDM	Congestion Income Distribution Methodology
CP	Clearing Price
CRDS	Congestion Rent Distribution System
CWE	Central Western Europe
D-1	Day Ahead
DA	Day Ahead
DC	Direct current
EF	External Flow
EMS	Market Spread of External Flow
FB	Flow-Based
FBI	Flow Based Intuitive
FBP	Flow Based Plain
FBMC	Flow-Based Market Coupling
FTR	Financial Transmission Right
EFB	Evolved Flow-Based methodology
JAO	Joint Allocation Office
LT	Long Term
LTA	Allocated Long Term Transmission Capacity
LTN	Nominated Long Term Transmission Capacity
MC	Market Coupling
NP	Net Position (sum of commercial exchanges for one bidding area)
PCR	Price Coupling of Regions
PTDF	Power Transfer Distribution Factor
PTR	Physical Transmission Right
RAM	Remaining Available Margin
SZ	Slack Zone
SP	Shadow Price
TSO	Transmission System Operator
UIOSI	Use It or Sell It

Annex 1: Numerical example and proofs of remuneration costs versus flow-based income

1.1 Example: Remuneration costs higher than hourly congestion income in Flow-Based.

In order to understand better how the remuneration costs 'work' in Flow-Based, let's assume the following example, for illustration purpose:

- Critical Branch CB1: internal line with increasing flows for any export outside hub A - margin available 100MW
- Remuneration of capacity from Hub A towards Hub B: 200MW – influencing factor on CB1 = 20%
- Remuneration of capacity from Hub A towards Hub C: 250MW – influencing factor on CB1 = 30%
- The double export of energy from Hub A is unrealistic since there is not enough production in Market A for this configuration.

In this situation, we know that we have sold too much capacity simultaneously, on both interconnections, however there is no physical risk due to the constraint on the production availability in hub A.

Nevertheless, if the clearing result of Market Coupling leads to the congestion of the Critical Branch CB1, we will have the following situation (by assuming a shadow price on CB1 = 50€):

- Overall congestion income :
  Margin on CB1 × Shadow Price on CB1 = 100 × 50 = **5 000€**
- Remuneration cost linked to 200MW of capacity between Hub A and Hub B
  (Capacity resold × influencing factor CB1)[11] × Shadow Price CB1[12]= 200 × 20% × 50 = **2 000€**
- Remuneration cost linked to 250MW of capacity between Hub A and Hub C
  (Capacity resold × influencing factor CB1 × Shadow Price CB1[13] = 250 × 30% × 50 = **3 750€**

In this situation, we have a remuneration cost that is higher than the total hourly congestion income from the Flow-Based Market coupling. In addition, we have to point out the fact that the congestion of this Critical Branch might appear even if the market results is not a double export from Hub A.

1.2 Example for the remuneration proof

The example described in this section shows that the remuneration cost are covered by the hourly congestion income as long as the LTA domain is within FB domain. The three nodes (shown in Figure) are connected by three lines that have equal impedance. Node C acts as the swingbus / slacknode. Let's assume that the lines are unloaded and have a maximum capacity of 9MW.

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[11] Margin freed by the resale of capacity on the critical branch

[12] Calculation linked to the high Level Property of Flow-Based allocation. In that respect, the Price in market A will be 2 000/200 = 10€ less expensive than in Market B.

[13] Calculation linked to the high Level Property of Flow-Based allocation. In that respect, the Price in market A will be 3 750/250 = 15€ less expensive than in Market C.

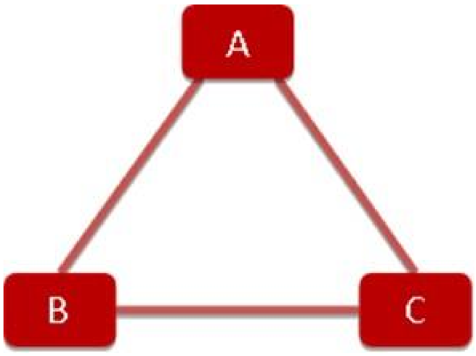


Figure 19: Example with three nodes

$$\begin{matrix} AB: \\ BC: \\ AC: \\ AB: \\ BC: \\ AC: \end{matrix} \begin{bmatrix} 1/3 & -1/3 \\ 1/3 & 2/3 \\ 2/3 & 1/3 \\ -1/3 & 1/3 \\ -1/3 & -2/3 \\ -2/3 & -1/3 \end{bmatrix} \begin{bmatrix} NP(A) \\ NP(B) \end{bmatrix} \leq \begin{bmatrix} 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \end{bmatrix}$$

Figure 20: PTDF matrix

The FB domain is visualized in Figure .

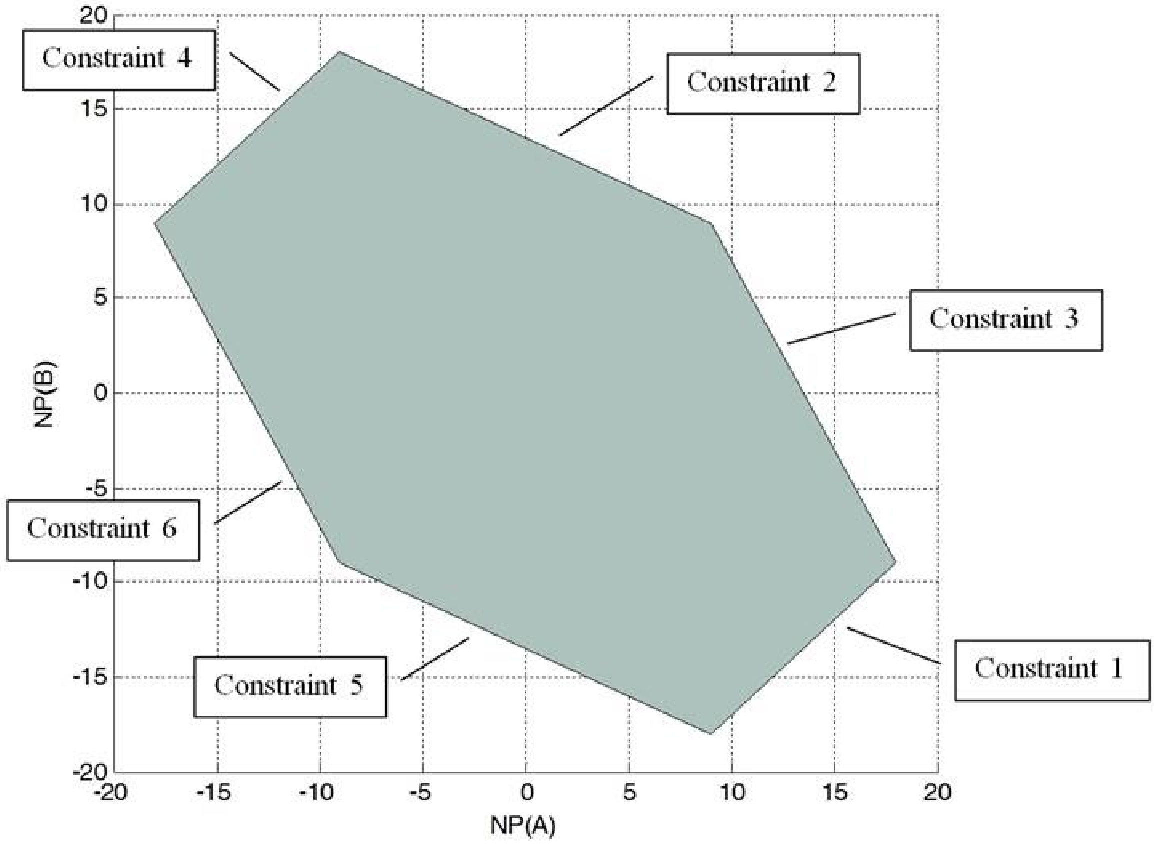


Figure 21: FB domain

The LTA are as follows: $\begin{bmatrix} A > B \\ A > C \\ B > C \\ B > A \\ C > A \\ C > B \end{bmatrix} = \begin{bmatrix} 13.5 \\ 0 \\ 13.5 \\ 0 \\ 13.5 \\ 0 \end{bmatrix}$

The LTA domain is shown, together with the FB one, in the following figure.

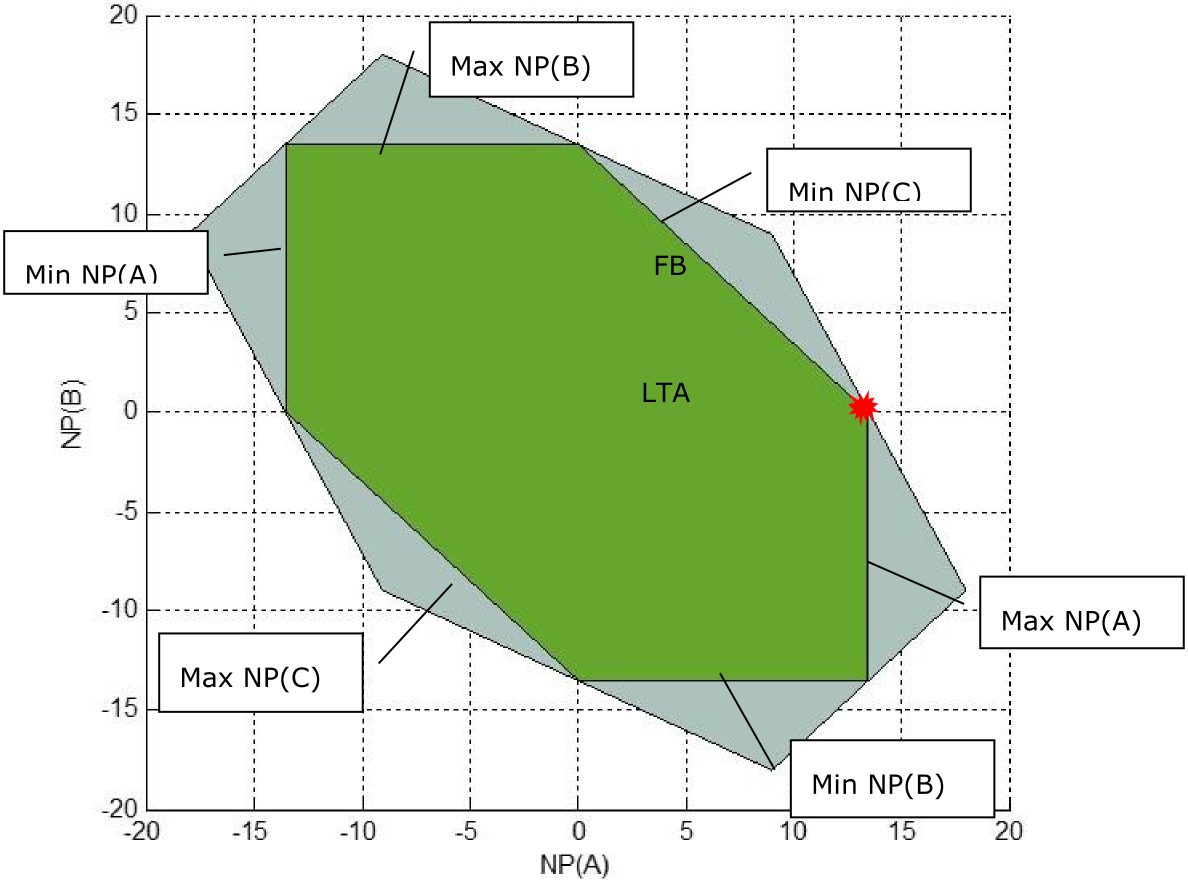


Figure 22: FB and LT domain

After the FBMC, a congested situation appears. Constraint 3 is hit (✸), and the following shadow price results: $\mu = 30$ €.

The resulting prices and net positions are:

$P_A = 10$ €, $NP_A = 13.5$

$P_B = 20$ €, $NP_B = 0$

$P_C = 30$ €, $NP_C = -13.5$

Maximum Remuneration Costs compensated at price spread is "Max RC":

$$\text{Max RC} = \sum_i \sum_{j \neq i} LTA_{i \to j} . \max\left(\left(P_j - P_i\right), 0\right) = 13.5 * 10 + 13.5 * 10 \; + 0 = 270 \text{ €}$$

For each border i→j, a set of bilateral exchanges $BE_{i \to j}$ is:

$$\begin{cases} BE_{i \to j} = LTA_{i \to j} & \text{if } P_j > P_i \\ BE_{i \to j} = -LTA_{j \to i} & \text{if } P_j < P_i \\ BE_{i \to j} = 0 & \text{if } P_j = P_i \end{cases}$$

$BE_{A \to B} = 13.5$, $BE_{B \to A} = -13.5$

$$BE_{A\to C} = 0,\ BE_{C\to A} = 0$$

$$BE_{B\to C} = 13.5,\ BE_{C\to B} = -13.5$$

Consider Q'_i as the net position associated with this set of exchanges $BE_{i\to j}$:

$$\forall i\ \ Q'_i = \sum_{j\neq i} BE_{i\to j} \qquad [b]$$

$$\forall i, j\ \ BE_{i\to j} = -BE_{j\to i}$$

$$\sum_i Q'_i = \sum_i \sum_{j\neq i} BE_{i\to j} = 0 \qquad [c]$$

$$Q'_A = BE_{A\to B} + BE_{A\to C} = 13.5$$

$$Q'_B = BE_{B\to A} + BE_{B\to C} = -13.5 + 13.5 = 0$$

$$Q'_C = BE_{C\to A} + BE_{C\to B} = 0 - 13.5 = -13.5$$

Indeed, $\sum_i Q'_i = 0$.

With [a] and [b], we are now able to rewrite:

$$\text{Max RC} = \sum_i \sum_{j>i} BE_{i\to j} \cdot (P_j - P_i) = -\sum_i (Q'_i \cdot P_i) \qquad [d]$$

$$\text{Max RC} = BE_{A\to B} * (P_B - P_A) + BE_{A\to C} * (P_C - P_A) + BE_{B\to C} * (P_C - P_B) = -P_A * (BE_{A\to B} + BE_{A\to C}) - P_B * (-BE_{A\to B} + BE_{B\to C}) - P_C * (-BE_{A\to C} - BE_{B\to C}) = -P_A Q'_A - P_B Q'_B - P_C Q'_C = -10 * 13.5 - 20 * 0 - 30 * -13.5 = 270\ €$$

Moreover the net position Q'_i is within the FB domain. Then:

$$\forall l \in CB, \sum_i Q'_i \cdot PTDF_{i,l} \leq m_l \qquad [e]$$

Where CB is the group of all critical branches and m_l is the margin (available for DA MC) on the critical branch l. This margin is positive if the LT domain is included in the FB domain.

Indeed, the net positions are within the FB domain:

$$\begin{matrix} AB: \\ BC: \\ AC: \\ AB: \\ BC: \\ AC: \end{matrix} \begin{bmatrix} 1/3 & -1/3 \\ 1/3 & 2/3 \\ 2/3 & 1/3 \\ -1/3 & 1/3 \\ -1/3 & -2/3 \\ -2/3 & -1/3 \end{bmatrix} \begin{bmatrix} 13.5 \\ 0 \end{bmatrix} = \begin{bmatrix} 4.5 \\ 4.5 \\ 9 \\ -4.5 \\ -4.5 \\ -9 \end{bmatrix} \leq \begin{bmatrix} 9 \\ 9 \\ 9 \\ 9 \\ 9 \\ 9 \end{bmatrix}$$

The Congestion Income « CI » collected in D-1 can be written as:

$$CI = -\sum_i (Q_i \cdot P_i) = \sum_{l\in CB} (\mu_l \cdot m_l) \qquad [f]$$

where μ_l is the shadow price of the critical branch l.

The Congestion Income in our example amounts

based on the computation with net positions and prices:

$\text{CI} = -10 * 13.5 - 20 * 0 - 30 * -13.5 = 270\ €$

based on the computation with shadow price and margin:

$\text{CI} = 9 * 30 = 270\ €$

Flow-Based clearing also has the following properties[14] :

$\forall \text{l} \in \text{CB}, \mu_{\text{l}} \geq 0$ [g]

$\exists \text{P}_{\text{ref}}$ such that $\forall \text{i}, \text{P}_{\text{i}} = \text{P}_{\text{ref}} - \sum_{\text{l}\in\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}$ [h]

With [f] and [d], we finally have:

$$\text{CI} - \text{Max RC} = \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} - (-\sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \text{P}_{\text{i}})$$

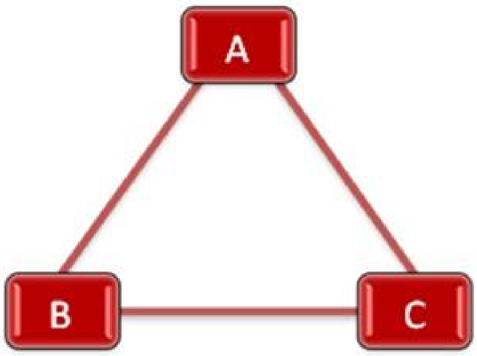
With [h], $= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} + \sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \left(\text{P}_{\text{ref}} - \sum_{\text{l}\in\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}\right)$

$= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} + \text{P}_{\text{ref}} \cdot \sum_{\text{i}} \text{Q}'_{\text{i}} - \sum_{\text{i}}\left(\text{Q}'_{\text{i}} \cdot \sum_{\text{l}\in\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}\right)$

With [c], $= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \left(\text{m}_{\text{l}} - \sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \text{PTDF}_{\text{i,l}}\right)$

1.3 Example (non-intuitive) for the remuneration proof

The example described in this section shows that the remuneration cost are covered by the hourly congestion income as long as the LTA domain is within the FB domain. The three nodes are connected by three lines that have equal impedance as shown in Figure . Node C acts as the swingbus / slacknode. Let's assume that the lines are unloaded and have different maximum capacities.



$$\begin{matrix} AB: \\ BC: \\ AC: \\ AB: \\ BC: \\ AC: \end{matrix} \begin{bmatrix} 1/3 & -1/3 \\ 1/3 & 2/3 \\ 2/3 & 1/3 \\ -1/3 & 1/3 \\ -1/3 & -2/3 \\ -2/3 & -1/3 \end{bmatrix} \begin{bmatrix} NP(A) \\ NP(B) \end{bmatrix} \leq \begin{bmatrix} 14.67 \\ 9.67 \\ 15.33 \\ 3.33 \\ 8.33 \\ 2.67 \end{bmatrix}$$

[14] Based on the following FB equation: $\frac{P_j - P_i}{PTDF_i - PTDF_j} = \mu_l \geq 0$

Figure 23: Example with three nodes

Figure 24: PTDF matrix

The FB domain is visualized in the graph hereunder.

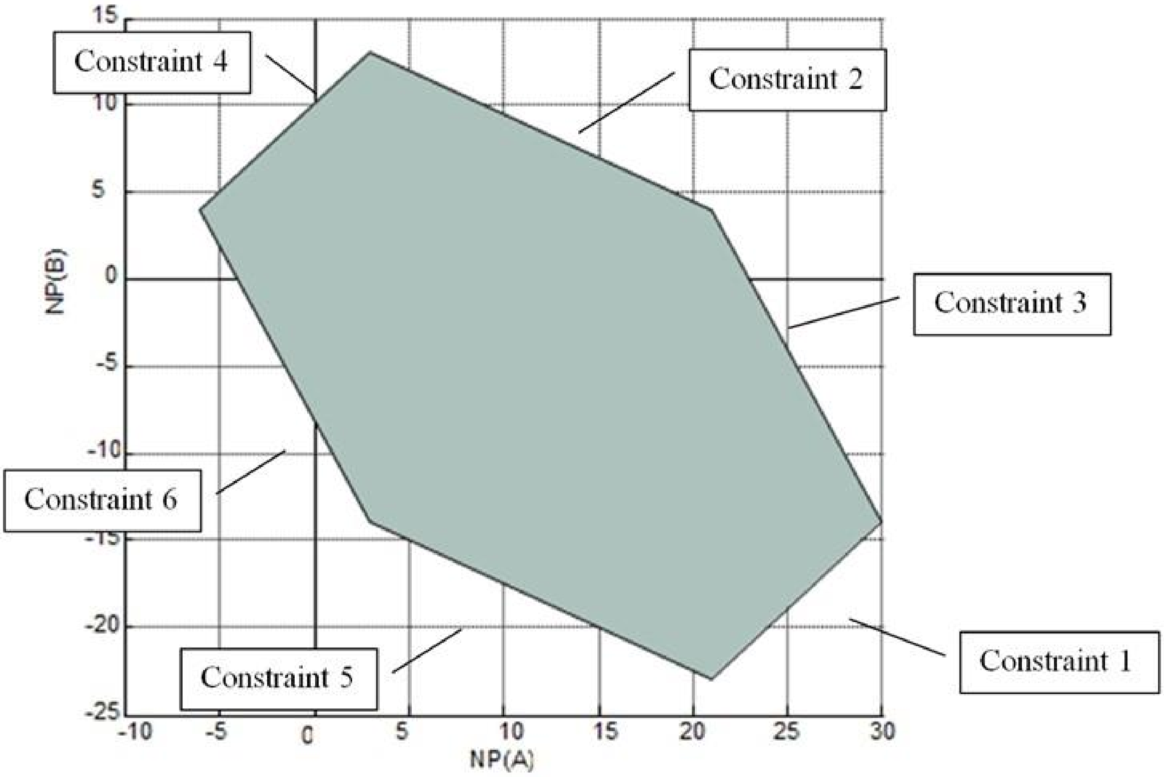


Figure 25: FB domain

The LTA are as follows: $\begin{bmatrix} A > B \\ A > C \\ B > C \\ B > A \\ C > A \\ C > B \end{bmatrix} = \begin{bmatrix} 7 \\ 8 \\ 10 \\ 0 \\ 0 \\ 8 \end{bmatrix}$.

The LTA domain is shown, together with the FB one, in the following figure.

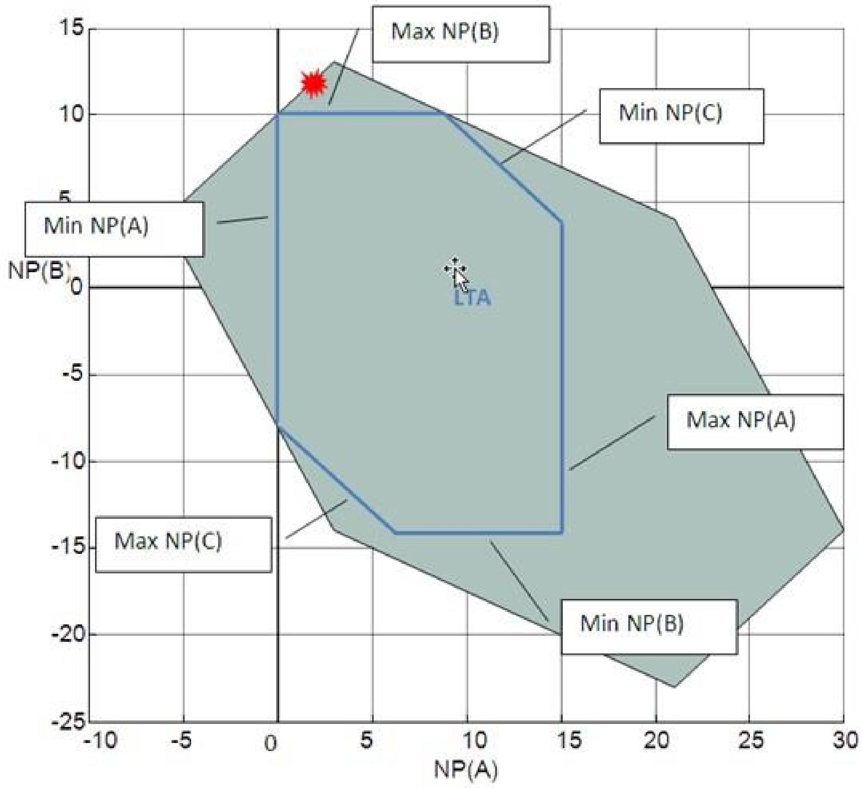


Figure 26: FB and LTA domain

After the FBMC, a congested non-intuitive situation appears. Constraint 4 is hit (✸), and the following shadow price results: $\mu = 30$ €.

The resulting prices and net positions are:

$P_A = \quad 0$ €, $NP_A = 2$

$P_B = -20$ €, $NP_B = 12$

$P_C = -10$ €, $NP_C = -14$

Maximum Remuneration Costs compensated at price spread is « Max RC » :

$$\text{Max RC} = \sum_i \sum_{j \neq i} LTA_{i \to j} . \max\left(\left(P_j - P_i\right), 0\right) = 0 + 0 + 10 * (-10 + 20) + 0 = 100 \text{ €}$$

For each border i→j, a set of bilateral exchanges $BE_{i \to j}$ is:

$$\begin{cases} BE_{i \to j} = LTA_{i \to j} & \text{if } P_j > P_i \\ BE_{i \to j} = -LTA_{j \to i} & \text{if } P_j < P_i \\ BE_{i \to j} = 0 & \text{if } P_j = P_i \end{cases}$$

$BE_{A \to B} = 0$, $BE_{B \to A} = 0$

$BE_{A \to C} = 0$, $BE_{C \to A} = 0$

$BE_{B \to C} = 10$, $BE_{C \to B} = -10$

Consider Q'_i as the net position associated with this set of exchanges $BE_{i\to j}$:

$\forall i \;\; Q'_i = \sum_{j\neq i} BE_{i\to j}$ [b]

$\forall i,j \;\; BE_{i\to j} = -BE_{j\to i}$

$\sum_i Q'_i = \sum_i \sum_{j\neq i} BE_{i\to j} = 0$ [c]

$Q'_A = BE_{A\to B} + BE_{A\to C} = 0 + 0 = 0$

$Q'_B = BE_{B\to A} + BE_{B\to C} = 0 + 10 = 10$

$Q'_C = BE_{C\to A} + BE_{C\to B} = 0 - 10 = -10$

Indeed, $\sum_i Q'_i = 0$.

With [a] and [b], we are now able to rewrite:

$\text{Max RC} = \sum_i \sum_{j>i} BE_{i\to j} \cdot (P_j - P_i) = -\sum_i (Q'_i \cdot P_i)$ [d]

$\text{Max RC} = BE_{A\to B} * (P_B - P_A) + BE_{A\to C} * (P_C - P_A) + BE_{B\to C} * (P_C - P_B) = -P_A * (BE_{A\to B} - BE_{A\to C}) - P_B * (BE_{A\to B} - BE_{B\to C}) - P_C * (BE_{A\to C} - BE_{B\to C}) = -P_A Q'_A - P_B Q'_B - P_C Q'_C = 0 * 0 - (-20 * 10) - (-10 * -10) = 200 - 100 = 100$ €

Moreover the net position Q'_i is within the FB domain. Then:

$\forall l \in CB, \sum_i Q'_i \cdot PTDF_{i,l} \leq m_l$ [e]

where CB is the group of all critical branches and m_l is the margin (available for DA MC) on the critical branch l. This margin is positive if the LT domain is included in the FB domain.

Indeed, the net positions are within the FB domain:

$$\begin{matrix} AB: \\ BC: \\ AC: \\ AB: \\ BC: \\ AC: \end{matrix} \begin{bmatrix} 1/3 & -1/3 \\ 1/3 & 2/3 \\ 2/3 & 1/3 \\ -1/3 & 1/3 \\ -1/3 & -2/3 \\ -2/3 & -1/3 \end{bmatrix} \begin{bmatrix} 0 \\ 10 \end{bmatrix} = \begin{bmatrix} -3.33 \\ 6.67 \\ 3.33 \\ 3.33 \\ -6.67 \\ -3.33 \end{bmatrix} \leq \begin{bmatrix} 14.67 \\ 9.67 \\ 15.33 \\ 3.33 \\ 8.33 \\ 2.67 \end{bmatrix}$$

The Congestion Income « CI » collected in D-1 can be written as :

$CI = -\sum_i (Q_i \cdot P_i) = \sum_{l\in CB} (\mu_l \cdot m_l)$ [f]

where μ_l is the shadow price of the critical branch l.

The Congestion Income in our example amounts

based on the computation with net positions and prices:

$\text{CI} = -0 * 2 - (-20 * 12) - (-10 * -14) = 240 - 140 = 100\,€$

based on the computation with shadow price and margin:

$\text{CI} = 3.33 * 30 = 100\,€$

Flow-Based clearing also has the following properties[15] :

$\forall \text{l} \in \text{CB}, \mu_{\text{l}} \geq 0$ [g]

$\exists \text{P}_{\text{ref}} \text{ such that } \forall \text{i}, \text{P}_{\text{i}} = \text{P}_{\text{ref}} - \sum_{\text{l}\epsilon\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}$ [h]

With [f] and [d], we finally have:

$$\text{CI} - \text{Max RC} = \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} - \left(-\sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \text{P}_{\text{i}}\right)$$

With [h]

$$= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} + \sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \left(\text{P}_{\text{ref}} - \sum_{\text{l}\epsilon\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}\right)$$

$$= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \cdot \text{m}_{\text{l}} + \text{P}_{\text{ref}} \cdot \sum_{\text{i}} \text{Q}'_{\text{i}} - \sum_{\text{i}}\left(\text{Q}'_{\text{i}} \cdot \sum_{\text{l}\epsilon\text{CB}} \text{PTDF}_{\text{i,l}} \cdot \mu_{\text{l}}\right)$$

With [c],

$$= \sum_{\text{l}\in\text{CB}} \mu_{\text{l}} \left(\text{m}_{\text{l}} - \sum_{\text{i}} \text{Q}'_{\text{i}} \cdot \text{PTDF}_{\text{i,l}}\right)$$

With [g] and [e],

$$\geq 0$$

In our example, the Congestion Income is equal to the Remuneration Costs:

$$\text{CI} - \text{Max RC} = 100 - 100 = 0$$

[15] Based on the following FB equation: $\frac{P_j - P_i}{PTDF_i - PTDF_j} = \mu_l \geq 0$

Annex 2: Detailed modelling of the special ALBE-/ALDE-PTDFs for the BE-DE border

The impact of ALEGrO on the CIA is twofold

(1) Impact on the AAFs of all AC-borders

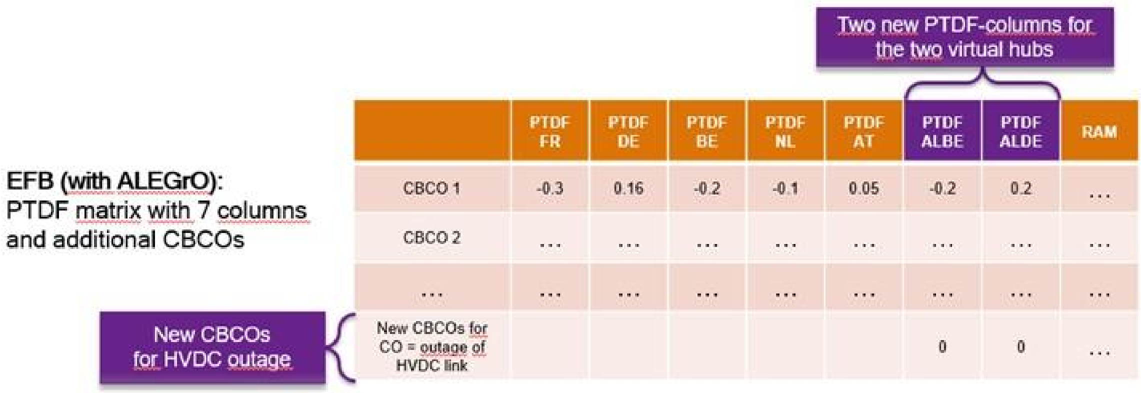
- For this the classical relationship AAFs = PTDFs * NetPositions holds directly true, also with virtual hubs (see Eq. 2).

(2) A new AAF at the DC-border BE-DE

- For this the same equation should hold true, which requires some care in the used PTDFs

Difference of an active DC link (e.g. ALEGrO) vs. passive AC lines

- The DC link is an active, controllable element of the grid. The flow through it is actively chosen (a setpoint, selected in the day-ahead by market coupling).
- This is a significant contrast to a passive AC element: the flow through an AC element depends on the topology and the generation/load situation
  - In FB, the flow through an AC element is described as a function of zonal PTDFs and net positions
  - The same applies to the AAF for a border where the XB-lines are AC links (current status quo of CIA)



	PTDF FR	PTDF DE	PTDF BE	PTDF NL	PTDF AT	PTDF ALBE	PTDF ALDE	RAM
CBCO 1	-0.3	0.16	-0.2	-0.1	0.05	-0.2	0.2	…
CBCO 2	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
New CBCOs for CO = outage of HVDC link						0	0	…

The AAF for the DC link on the BE-DE borders is obtained as follows:

- The flow through ALEGrO is not a result of all other net positions. Nevertheless, the AAF of the BE-DE border is modelled in the same way as for all AC-borders (see Eq. 2).
- This is ensured by making use of the ALEGrO modelling in EFB by two virtual hubs. The net positions of these virtual hubs are equal to the flow through the DC link (e.g. a flow from Germany to Belgium is 100 MW leads to a net position in ALBE of +100 and in ALDE of -100).

The flow through ALEGrO can be deducted directly from the net position of either one of the virtual hubs. This is represented by a "virtual tie-line" for CIA purposes in the PTDF matrix file, where we find the following.

Constraint	PTDF ALBE	PTDF ALDE	All other PTDFs
BLIXHE12 XLI_OB1B 1	1	0	0
D7OBZI1A XLI_OB1A 1	0	1	0

It must be considered that this information is available **twice**, because we have two virtual hubs while there is only one single flow through the interconnector.

Hence, for determining correct AAFs for CIA, we only need to take into account the flow through ALEGrO once. Hereby it is ensured that the Equation 2 still holds true also for the AAF of the BE-DE border. Therefore only one of the PTDF values of the virtual hubs needs to be taken into account (the other one should be "neglected") to ensure a correct congestion income allocation[16].

[16] This attention point is operationally ensured in two ways. Within the Matlab scripts used in the CRDS tool it is directly encoded that only one PTDF value of a virtual hub is considered. For the delivery of the excel CRDS files by JAO on a daily basis to TSOs. JAO only takes into account the hubs/border directions which are predefined in the CRDS Input file. For the BE-DE border this is the direction BE>DE. This means that the border direction ALBE-BE>DE (0) and ALDE-BE>DE (1) is used. And the border direction ALBE-DE>BE (1) and ALDE-DE>BE (0) is ignored, which gives as outcome that only once the PTDF value of a virtual hub is considered.

Report on Congestion Income Distribution in Central Western Europe Flow Based Market Coupling after Twelve Months of Operation of the Bidding Zone Border between Austria and Germany/Luxembourg

1. Introduction

With the introduction of the bidding zone border between Germany/Luxembourg and Austria, the approval documents of the CWE Flow Based Market Coupling have been amended. This also included an amendment of the Congestion Income Allocation approval document, which was adjusted in order to detail the distribution of congestion income between the five bidding zones of the CWE region. At the time the approval document was submitted to regulatory authorities, CWE parties did not have reliable information regarding the development of market parties behavior and the evolvement of order books after the introduction of the additional bidding zone border. Consequently, there was very little insight into the actual distributional effects of the amended Congestion Income Allocation methodology. Therefore, a disclaimer was included in the amended methodology document which stated that an analysis of these distributional effects needs to be performed after six and after twelve months of operation of the German-Austrian bidding zone border within the CWE region.

The document at hand is the final report on the distributional effects of the Congestion Income Allocation methodology after the introduction of the German-Austrian bidding zone border, covering twelve months of operational data from 01 October 2018 until 30 September 2019. In order to evaluate the observations, the distribution of income is compared against a period of twelve months before the introduction of the additional bidding zone border, with data from 01 October 2017 until 30 September 2018 as reference period. The report aims at giving insights into the distributional effects of the CWE Congestion Income Allocation methodology, with a clear focus on the socialization principle and on the treatment of external flows.

2. Background and Approach

Flow Based Market Coupling has been introduced on 20 May 2015 in the bidding zones of Belgium, France, Germany/Austria/Luxembourg and the Netherlands. The flow based allocation of cross-zonal capacities required a completely new design of congestion income distribution principles, as this income could not be calculated and distributed on the basis of simple bilateral flows. Therefore, a distribution methodology has been implemented that coped with the complexities of this allocation approach. This methodology is based on a principle that is called *Cross Border Clearing Price times Market Flows Absolute (CBCPM ABS)*, which best met the nine selected design criteria. Since its introduction, CWE Flow Based Market Coupling has undergone several changes, e.g. the inclusion of a minimum Remaining Available Margin (RAM) of 20% in April 2018.

However, it was only until the introduction of an additional bidding zone border that a change in the congestion income allocation methodology was required, namely the split of the German/Austrian/Luxembourgian bidding zone into separate German/Luxembourgian and Austrian bidding zones and the addition of the new bidding zone border between these separated bidding zones. This new setup resulted in two changes in the congestion income allocation methodology, with the mere addition of an additional bidding zone as one change. However, the treatment of external flows also required a design change. External flows have always been handled in the CWE congestion income allocation methodology, as not all CWE net positions can be balanced by internal flows only (the so-called *additional aggregated flows, AAF*). Before the introduction of the separate Austrian hub, the external flow was easily determined as the flow that balanced the hubs of France and Germany/Austria/Luxembourg after considering their relevant AAFs (internal flows), as these were the only hubs with an open (i.e. non-CWE) AC border. With the introduction of the Austrian bidding zone, there are now three hubs with open borders. As a consequence, the provisions in the CWE congestion income allocation methodology regarding the determination and the sharing of the external pot needed to be completely revised, which resulted in the introduction of the *Slack Zone* approach. Three external separate flows are determined (Austria to Slack Zone, France to Slack Zone and Germany/Luxembourg to Slack Zone) such that these flows balance the internal net position of the Austrian, French and German/Luxembourgian hubs. The virtual price of the Slack Zone is calculated such that it minimizes the value of the so-called external pot.

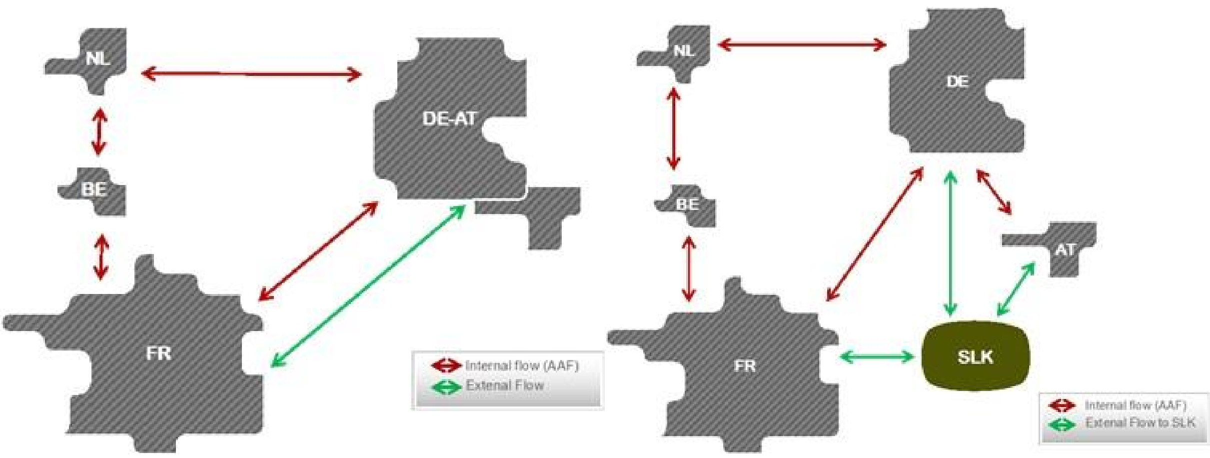


Figure 1: Structure of CWE CCR before- and after the split

The report at hand therefore aims at evaluating the distributional effects of the abovementioned two changes. The interest in this evaluation is even higher against the background of the amount of 4.9 GW of Long Term Transmission Rights, which are allocated on the bidding zone border between Germany/Luxembourg and Austria in the form of Financial Transmission Rights (FTRs). As one of the features of Flow Based Market Coupling, there is no immediate link between the allocation of cross-zonal capacities in different timeframes, meaning that – even though 4.9 GW of LTTRs have been allocated on the DE/AT border, there does not need to be a flow in the day-ahead timeframe that is equivalent to these 4.9 GW. Even though the so-called Long Term Inclusion guarantees that sufficient cross-zonal capacity is available that would allow for a flow of 4.9 GW in the day-ahead timeframe, the utilization of these capacities is determined by the welfare-optimizing market coupling algorithm. Consequently, the remuneration of LTTRs (which is equivalent to the day-ahead price spread times the volume of LTTRs) is not necessarily covered by the congestion income that has been generated in the day-ahead timeframe (this is in contrast to ATC DA-Market Coupling,, where the remuneration of LTTRs from income that is generated in the day-ahead timeframe is a well-established principle). Against this background, the CWE congestion income allocation methodology foresees a socialization principle. This means that any deficit for the remuneration of LTTRs on an individual border is covered pro-rata by day ahead congestion income of other borders, following the rationale that these other borders have gained from using the margins that have not been allocated to the border with insufficient day ahead income. This principle is also in line with an orientation on welfare distribution, as the welfare optimizing market algorithm distributes the margins to those flows that generate the highest additional welfare. If a bidding zone profits from this additional welfare, it is in the position to support those bidding zone borders where the day ahead congestion income is not sufficient to cover the remuneration costs of LTTRs (socialization principle). Moreover, the total congestion income of the region that applies flow based market coupling is always sufficient to cover all LTTR remuneration costs of the region, provided that the volumes of LTTRs are covered within the flow based capacity domain (so-called Long Term Inclusion). This reports aims at investigating to what the extent the bidding zone border between Germany/Luxembourg and Austria with its 4.9 GW of LTTRs behaves proportionally in comparison to other bidding zone borders of the CWE region. This includes aspects of the overall amount of socialization volumes, and their distribution between borders and bidding zones.

In order to exclude as much as possible seasonal effects, the approach of this evaluation has been to compare twelve calendar months from before and after the implementation of the bidding zone border between Germany/Luxembourg and Austria. Twelve months of operational data from 01 October 2018 until 30 September 2019 is compared against twelve months of operational data from 01 October 2017 until 30 September 2018. Operational data was taken from the monthly Congestion Income Allocation reports to CWE regulatory authorities and from the daily input and output files of the Congestion Revenue Distribution System (CRDS), which is operated by the Joint Allocation Office on behalf of CWE TSOs. Quantitative indicators were defined and calculated from this data, and additional indicators were defined to structure the analysis and enable to answer above questions.

3. Factual Information

This report compares operational data from two different periods (01 October 2017 until 30 September 2018 against 01 October 2018 until 30 September 2019) in order to evaluate methodological changes that were introduced with the go-live of the bidding zone border between Germany/Luxembourg and Austria on 01 October 2018. However, the operational results of the congestion income allocation methodology are highly dependent on the overall market conditions. Therefore, all results in this report only give an indication of possible effects of the amended distribution methodology; however there are multiple other factors of influence on the final congestion income allocation. These factors include, among others, changes in generation costs of thermal power plants which are linked to commodity prices like steam coal, natural gas or emission certificates. Additionally, also the availability of thermal power plants, especially of nuclear power plants, has an effect on market results and thus on the congestion rents. Moreover, the availability of renewable energies is an exogenous factor with impact on the indicators that are observed here. It should be also noted that this report also covers the extremely dry summer season of 2018, which was characterized by low availability of hydro power plants and high transportation costs for steam coal on river barges. Generally, and as has already been noticed in multiple other reports, the actual infeed from renewable energy sources and the load are very sensitive to weather conditions, especially during the winter period.

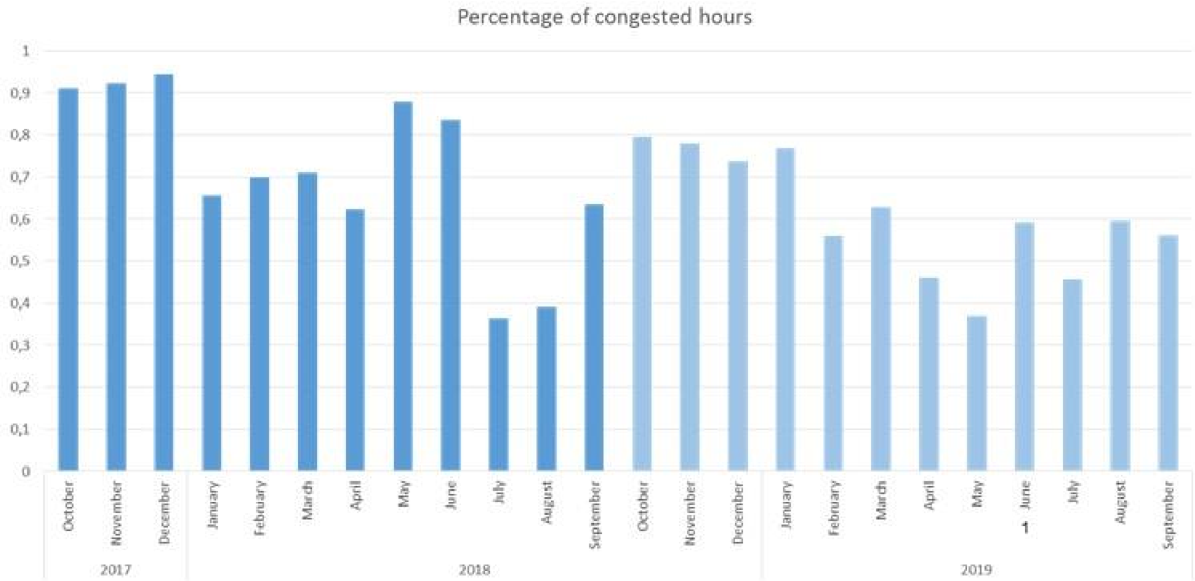
The introduction of the 20% minRAM measure on 26 April 2018 also constituted a structural change in the availability of cross-zonal capacities and thus in the overall market conditions. Furthermore, the split of the German/Austrian/Luxembourgian bidding zone itself resulted in changes in the bidding behavior of market participants, as OTC trades between Germany and Austria were not possible anymore and all trades had to be shifted to Nominated Electricity Market Operators (NEMOs). This structural change of the bidding behavior distorts the calculation of producer surplus and consumer surplus for the German/Luxembourgian and the Austrian bidding zone, as results before and after the split of the joint bidding zone cannot be compared to each other.[17]

All these considerations underline that the changes that can be observed in the different indicators of this report cannot be ultimately linked to the go-live of the bidding zone border between Germany/Luxembourg and Austria, as it was not possible to isolate different factors of influence.

[17] The shift of trading activities to the NEMOs increases welfare by definition, as previously the OTC trades within the joint German/Austrian/Luxembourgian bidding zone have not been included in the calculation of welfare indicators

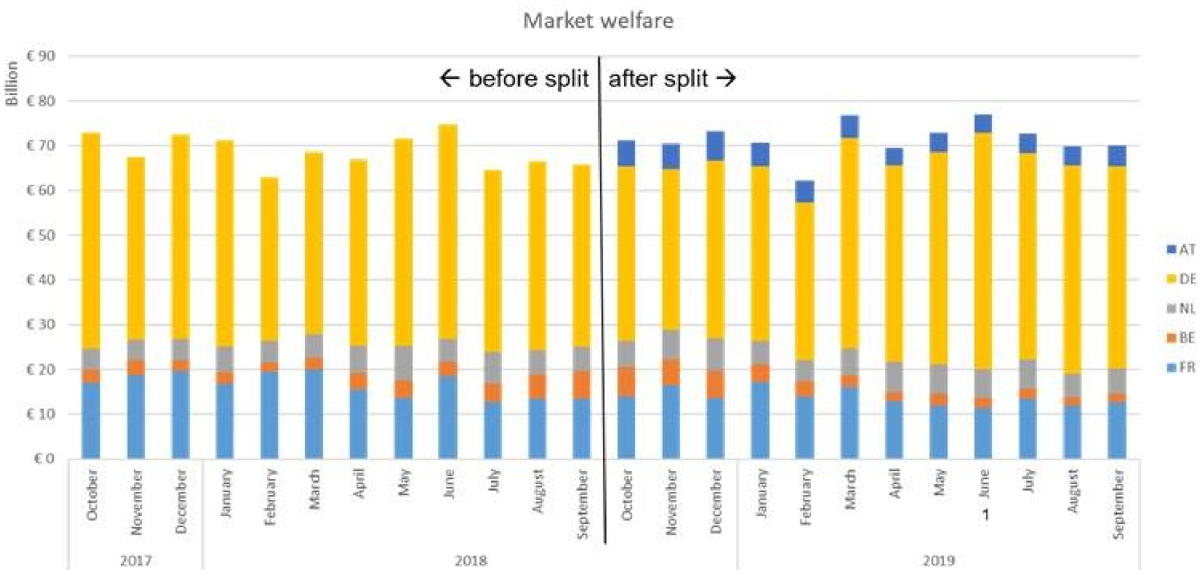
a. Percentage of congested hours

This indicator details the percentage of hours in which at least two different prices occurred in the flow-based capacity calculation region. Price convergence (i.e. all bidding zones of the CWE region had the same market clearing price) increased after the split by about 10 percentage points (from 71% of congested hours to 61%).

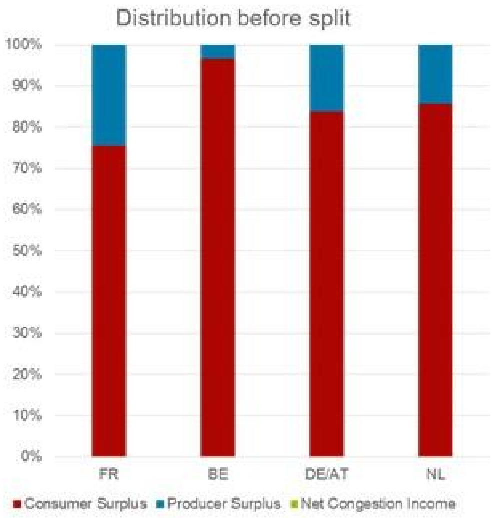


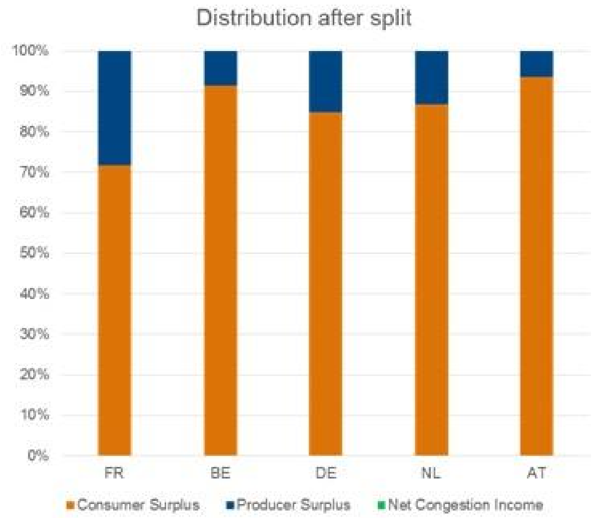
b. Total market welfare

This indicator describes the development of total market welfare (i.e. the total of consumer surplus, producer surplus and congestion rents) over time and per bidding zone, as calculated by the market coupling algorithm. Again, it should be noted that welfare indicators for the separated German/Luxembourgian and Austrian bidding zones are hard to be compared before and after the split of the joint bidding zone, as the shift of orders from OTC trade to the Single Day Ahead Coupling inevitably resulted in increased trading volumes, and consequently higher welfare numbers.



1) For June 2019 the day of the decoupling was excluded.

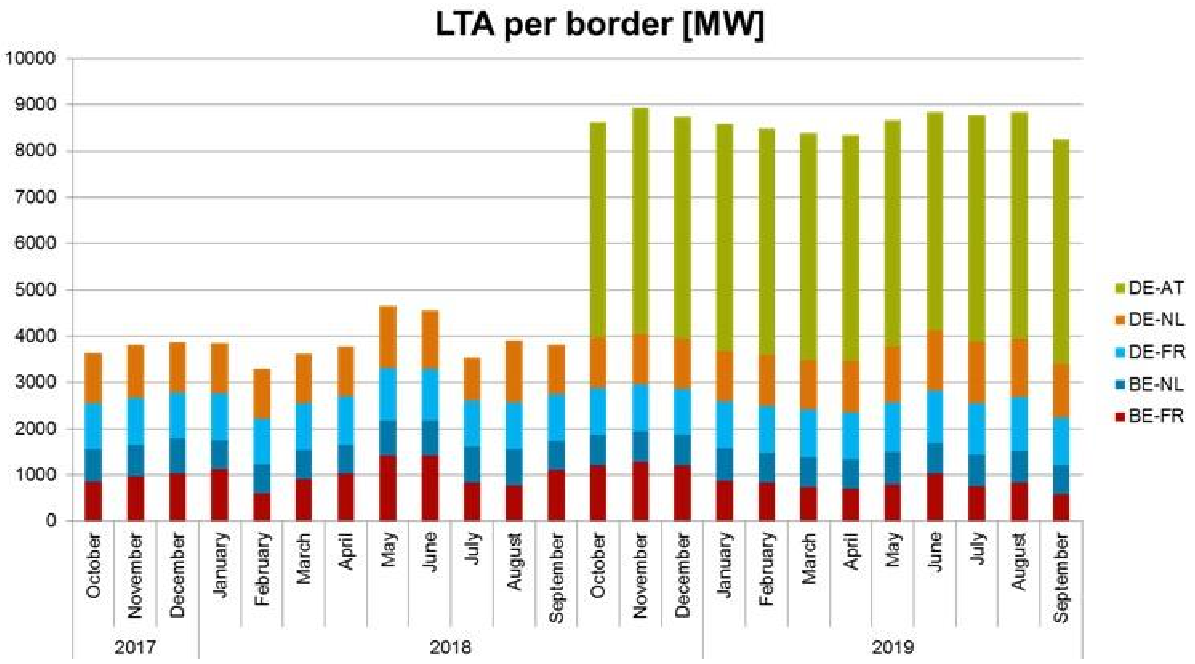




In line with the overall development of total social welfare, the individual share of consumer surplus, producer surplus and congestion income can be displayed for each bidding zone separately. Most notably, the share of congestion income is negligible in comparison to consumer and producer surplus.

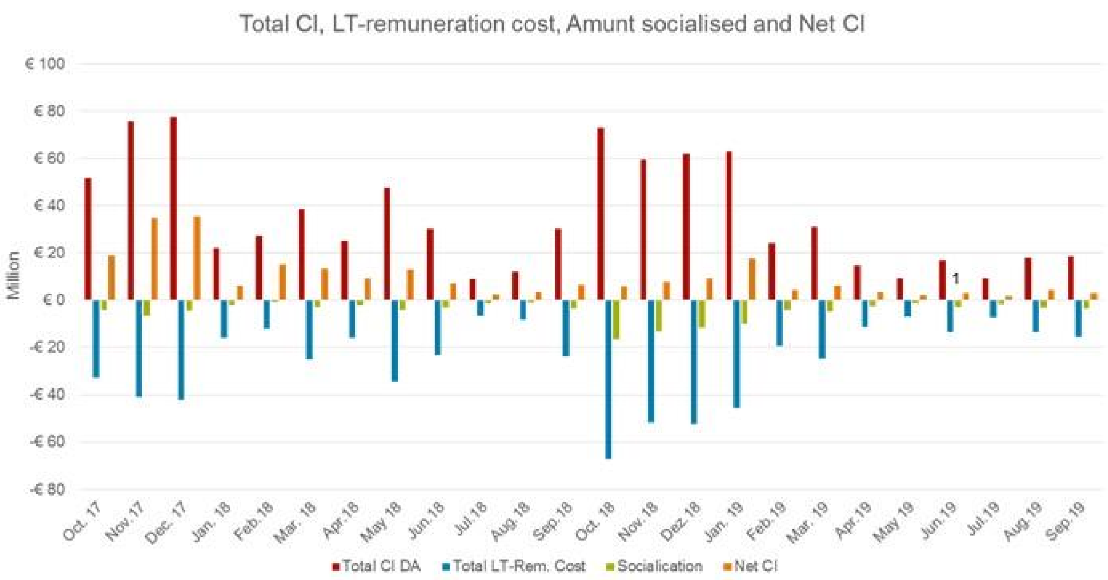
c. Long Term Transmission Rights (LTTRs) allocated per border

This indicator displays the Long Term Transmission Rights (LTTRs) allocated per border by JAO as sum of yearly and monthly auctions.



d. Overview of Congestion Income, remuneration costs and socialization of LTTRs

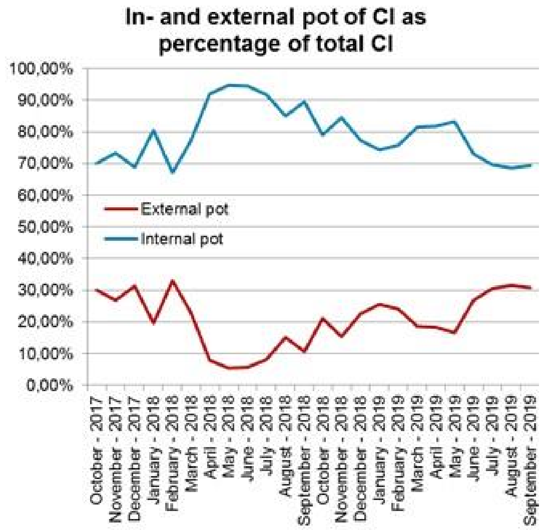
The below graph comprises four different indicators. The total congestion income is the absolute value of congestion income generated by day ahead market coupling before remuneration of LTTRs (gross congestion income). Additionally, the costs for the remuneration of LTTRs are shown, as well as the amount of remuneration costs which are not covered by the day ahead congestion income on a given bidding zone border and which consequently are socialized (socialization), and finally the resulting net congestion income. All indicators are summed up over all CWE internal borders and are therefore totals for the entire CWE region.

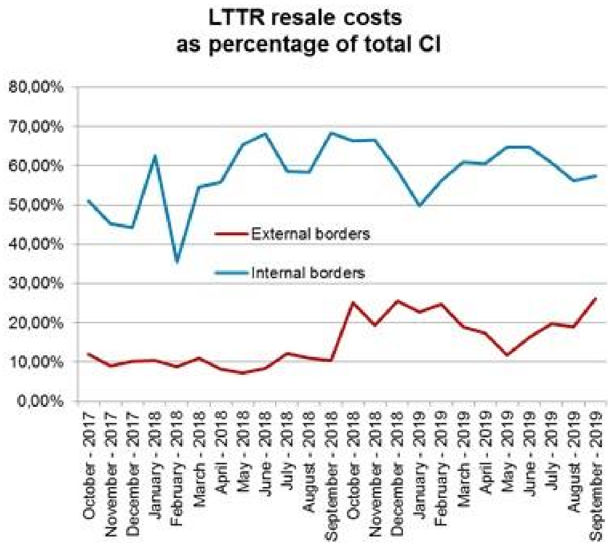


1) For June 2019 the day of the decoupling was excluded.

e. Remuneration costs

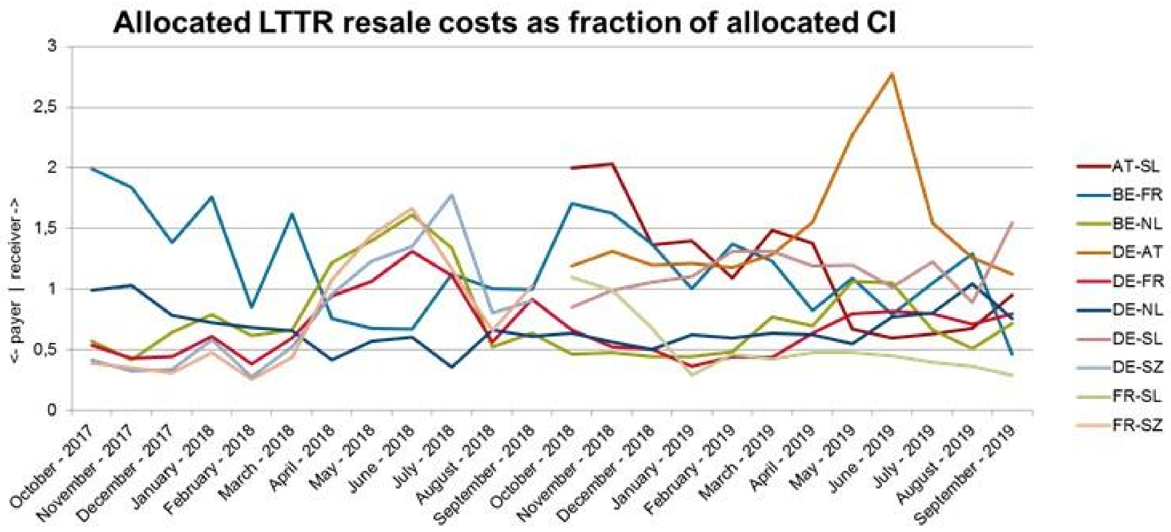
The two graphs below compare the relative distribution of remuneration costs for LTTRs in the internal and external pots. The left graph indicates the division of the total Congestion Income between the internal and external pots for the entire CWE region, whereas the right graph indicates the remuneration costs of LTTRs relative to the total congestion income, and split up according to their allocation to internal and external borders.





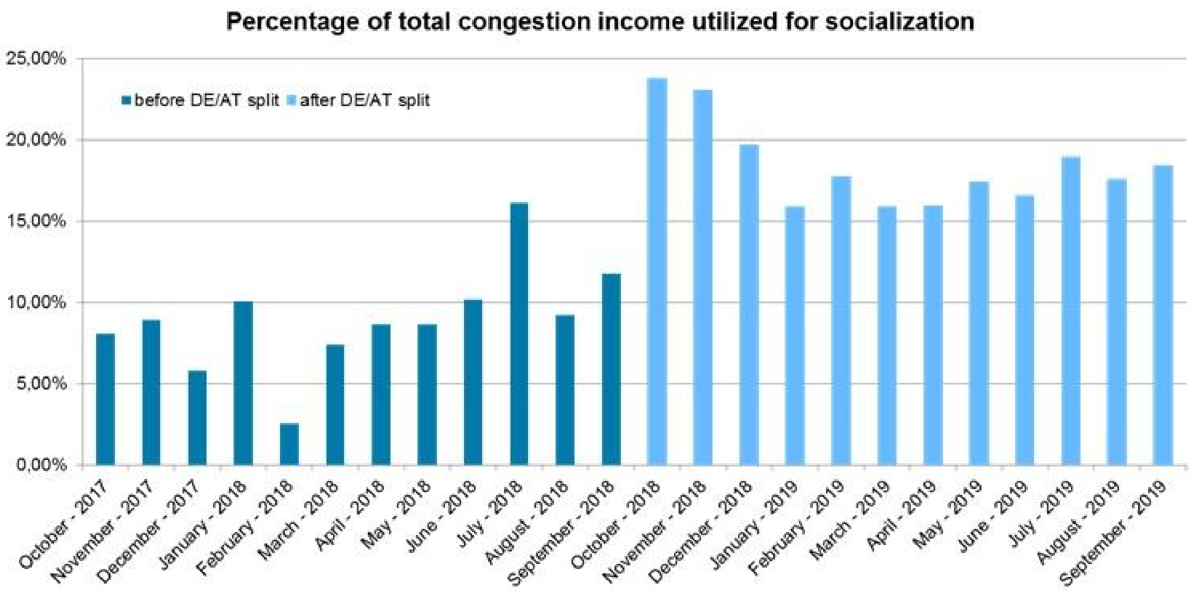
f. Allocated LTTR remuneration costs as fraction of allocated congestion income per border

The graph below indicates the amount of remuneration costs per border divided by the congestion income per border. A value larger than unity indicates that the remuneration costs exceed the day ahead gross congestion income that is assigned to an individual bidding zone border.



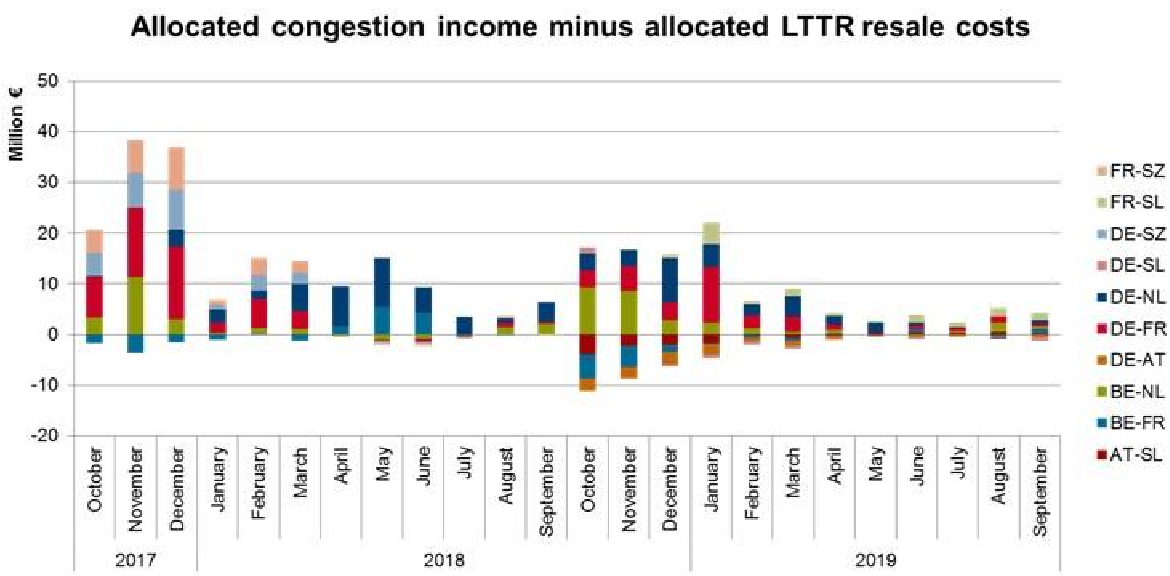
g. Percentage of total Congestion Income utilized for socialization for the region

The graph below shows the percentage of total congestion income of the CWE region that is used for socialization purposes. A higher value indicates that a higher share of congestion income was redistributed due to the socialization principle.



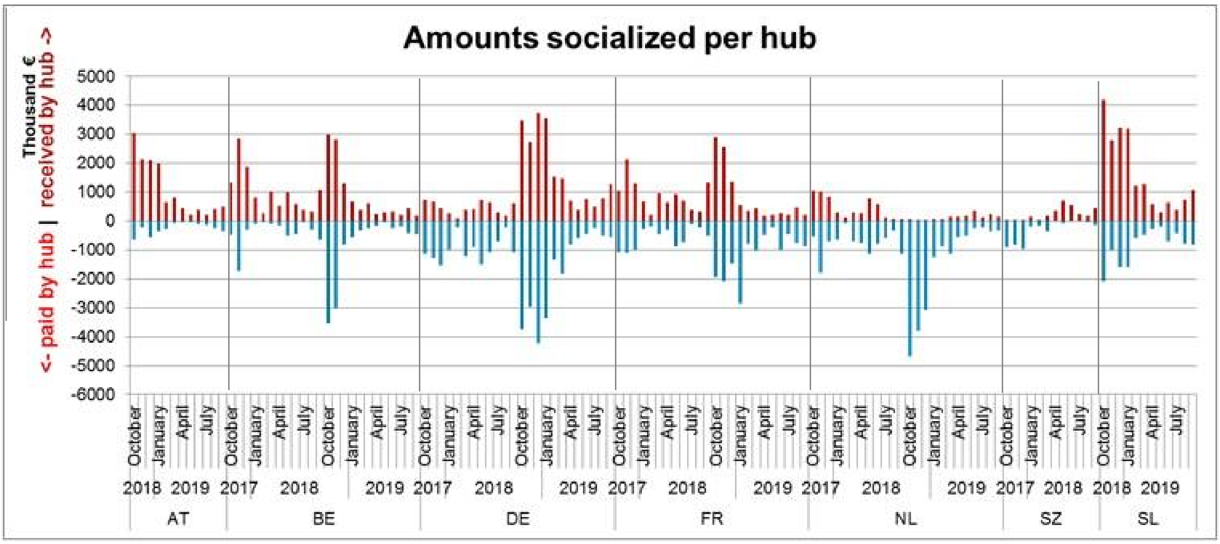
h. Allocated congestion income minus allocated LTTR remuneration costs per border

The graph below displays the difference between the allocated congestion income and the remuneration costs for LTTRs for each bidding zone border, summed up over all hours of a month. If the congestion income from day ahead market coupling is sufficient to cover the remuneration costs for LTTRs of a given border, this difference results in a positive number, and the bidding zone border is shown above the horizontal axis of the below graph. However, if the congestion income from day ahead market coupling does not suffice to cover the remuneration costs of LTTRs of a given border, this difference results in a negative number, and the respective bidding zone border is shown below the horizontal axis in the graph below.



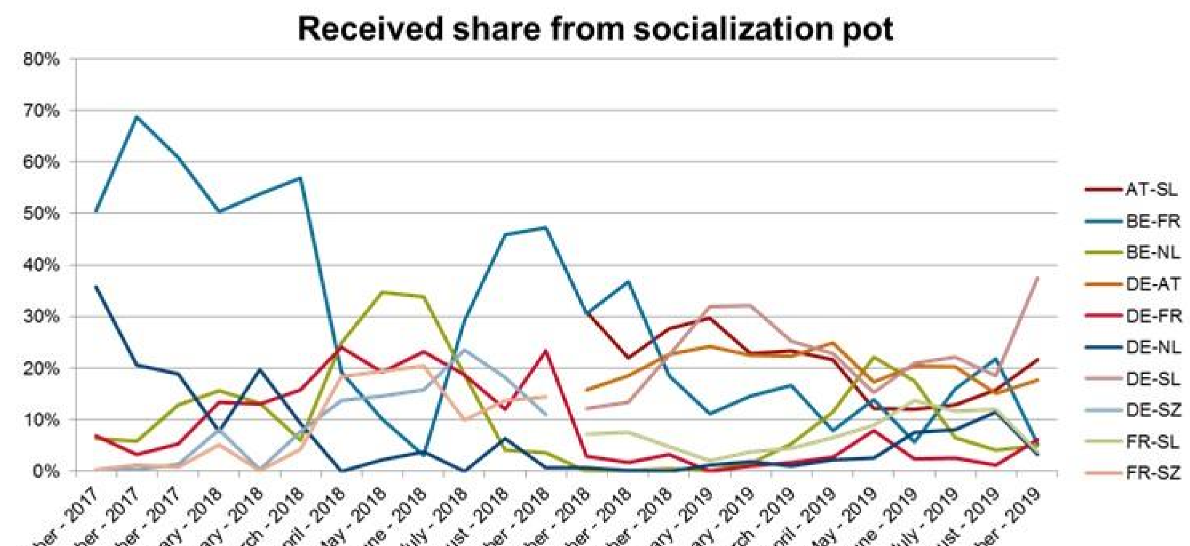
i. Amounts socialized per hub

The figure below indicates the monthly totals paid and received due to the socialization principle for each hub. The concept of the external pot is visible in the SZ hub (until September 2018) and the SL hub (as of October 2018). A negative amount indicates the payment of money to socialization, and a positive amount indicates the money received from socialization (the monthly sum of positive and negative amounts over all hubs has to be equal).



j. Share of total received amounts from socialization pot

The figure below indicates the total amount received per border, divided by the total amount socialized for the region. It is therefore an indicator for the distribution of money from the socialization pot. A higher percentage indicates a higher share received from socialization.



4. Analysis

k. Analysis of fundamental market data

The evaluation of congested hours during a period of twelve months shows that the number of hours with price full convergence increased by ca. 10 percentage points after the introduction of the bidding zone border between Germany/Luxembourg and Austria. Apart from changes in general market conditions, a possible reason for this increase can be seen in the transition of trades between Germany and Austria which were formerly considered as internal trades, but which are now considered as cross-zonal transactions. This change in status means that margins that previously have been taken as granted for internal trades are now available for all trades within the CWE region. This additional control variable adds new options for welfare optimal allocation of cross-zonal capacities, and finally helps to increase the number of hours with full price convergence.

As can be expected, the distribution of hours with full price convergence still shows the same seasonal pattern, with higher shares in spring and summer, and lower shares of hours with full price convergence in autumn and winter. Moreover, also the total monthly market welfare shows more or less the same seasonal patterns before and after the introduction of the bidding zone border between Germany/Luxembourg and Austria. Total market welfare 12 months after the split has increased with about 3,8% (31,3 Billion EUR) compared to the same period before the split of the joint German/Austrian/Luxembourgian bidding zone. Compared to the observed months before the split the social welfare of France and Belgium was reduced whereas in the German, Dutch and for the new Austrian bidding zone higher total welfare numbers were registered.

Total congestion income, as one of the components of total social welfare, shows more or less the same seasonal pattern before and after the introduction of the additional bidding zone border; however the turn from higher to lower congestion income periods occurred one month after the split.

Congestion incomes in the same calendar months were higher before the split than after, except for October, January and August. As the number of congested hours has decreased, there are less hours generating congestion income.

Regarding the volume of allocated LTTRs in the CWE region, it must be noted that the total amount of allocated LTTRs almost doubled with the introduction of the bidding zone border between Germany/Luxembourg and Austria. This is a direct consequence of the significantly high amount of 4.9 GW of LTTRs that are offered in yearly and monthly auctions for the additional bidding zone border.

l. Analysis of the Slack Zone approach

The relative shares of the internal and the external pot of congestion income have slightly shifted towards the internal pot in winter period and towards external pot in summer period. In consequence the external pot receives a smaller share of congestion income during winter period. For bidding zones with an open border, the congestion income allocation methodology assigns remuneration costs both to their internal borders and their borders with the Slack Zone (hereafter: external borders). In line with the increased amount of LTTRs, the remuneration costs have increased both for the internal and external borders.

For the borders with the Slack Zone, the share of the congestion income needed to cover for LTTR remuneration costs roughly doubled after the split (from about 10% to about 20%), whereas for the internal pot it is only increased by about 30% on average in winter period and remained similar in summer period. This increase in the share of remuneration costs of external borders is in strong contrast to the decreasing share of congestion income that is allocated to these external borders. Consequently, it appears that the share of remuneration costs of LTTRs that is allocated to these external borders has increased substantially (as now not only a part of the remuneration costs on the German-French border is partly allocated to an external flow, but also a part of remuneration cost on the German-Austrian bidding zone border with its substantial LTTR volume) while the income that is allocated to these borders did not increase with the same ratio (especially since the financial volume of the slack zone is minimized in line with the design of the CWE congestion income allocation). This finally raises the need for socialization of remuneration costs.

m. Analysis of distributional effects and the socialization principle

In general, the share of congestion income that is used for socialization was higher in each calendar month after the split compared to the same calendar month one year earlier. The relative amount needed for socialization increased from about 6% of the gross congestion income before the split to about 18% of the gross congestion income after the split.

Some borders consistently reach or lack sufficient congestion income from the day ahead market coupling to cover remuneration costs for LTTRs on their borders. This is valid for the most of the year for the new bidding zone border between Germany/Luxembourg and Austria and the border between Germany and the Slack Zone and during winter period for the borders between Belgium and France and between Austria and the Slack Zone. It can be noted that both the new bidding zone border and the border between Austria and the Slack Zone have been added as mostly net receivers from the socialization pot.

Furthermore, it must be noted that the contribution to the socialization principle is not equally distributed over the different hubs. The separated Austrian hub appears to be a clear net receiver from the socialization principle. The hub of the Belgian bidding zone used to be a clear net receiver before the introduction of the fifth bidding zone border, but changed to a net payer to the socialization pot during the first two months after split and more or less balanced position afterwards The joint German/Austrian/Luxembourgian bidding zone was to some extend a limited net receiver before the split of this bidding zone. After the go-live of the market separation, payments of the now separate hub of the German/Luxembourgian bidding zone to and from the socialization pot are more or less balanced. The French hub generally used to be a net receiver before the split and for the first two months of the new market setup; since then it is a net payer to the socialization pot. The Dutch hub had a more or less neutral position before October 2018; since then it is a substantial net payer to the socialization principle especially for the first six months after the split, whereas in the remaining months it was almost balanced again. Additionally, it should be noted that the Slack Zone (formerly the external flow) changed from being a net payer to being a net receiver with the amendment of the methodology.

Regarding the shift of remuneration costs of LTTRs from internal borders towards the external pot, three factors causing this were identified. First, the uneven distribution of LTTRs among borders need to be considered. The amount of 4.9 GW that is reserved for LTTRs on the bidding zone border between Germany/Luxembourg and Austria must be considered as a high value compared to other bidding zone borders, as it has resulted in a doubling of the total volumes of LTTRs in the CWE region. Secondly, the grid topology of the CWE region and the location of the Austrian hub within the CWE region causes relatively high external flows dedicated to the Austrian hub, especially when compared against the remaining borders of the CWE region. Finally, different distribution methods for the allocation of congestion income towards the Slack Zone (based on a price differences times the external flow) and the allocation of LTTR remuneration costs towards the Slack Zone (proportional to the External Flows) lead to an imbalanced distribution of the financial burden. The significance of this imbalance has increased and is now even more pronounced due to the volume of LTTRs on the bidding zone border between Germany/Luxembourg and Austria. Consequently, the (basically virtual) external borders now need to receive money from the socialization as a result of design choice: the remuneration costs assigned to external borders have increased, but the CI assigned to external borders did not increase proportionally.

5. Conclusion

Despite the difficulties of multiple factors influencing the market results and therefore the CID results, this report shows in the four initial months after the split an imbalance in the distribution of socialisation costs. In this period, large sums were needed to socialise costs on the bidding zone border between Germany and Austria. Considering the relaxation in the eight following months, a transitory process following the introduction of a new border to the CWE region might explain those variances occurring in the first phase after the split. The risk of cost imbalances for bidding zones depending on the general CWE market situation remains. In particular unfavourable or stressed market conditions, such as those in autumn 2018 could lead to similar cost imbalances to reoccur.

The methodology itself succeeded in minimizing the amount of congestion income allocated to the Slack zone. However, the method for allocation of LTR remuneration costs to external borders was not changed, which contributed to a higher need to socialise these costs.

The impact of the methodology changes due to the German Austrian bidding zone split, stresses the need for proper assessment of CID methodology changes before further structural changes like ALEGrO and Core are implemented in the future.

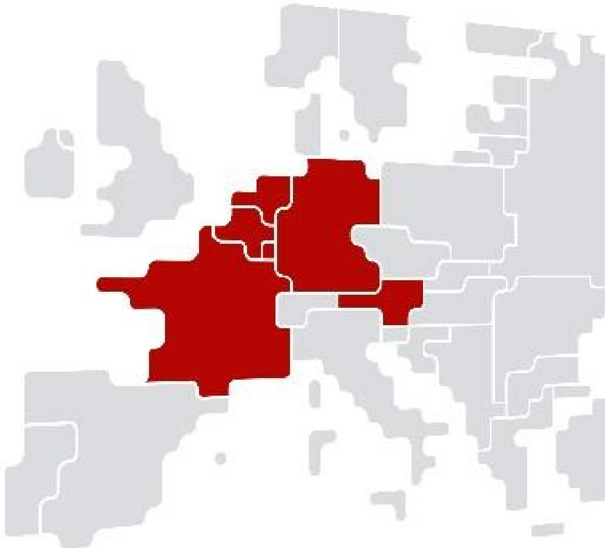
With the transition to Core, a CID methodology will be introduced, which addresses some of the now existing risks, like the cost imbalances for bidding zones due to the socialisation of remuneration costs, which will persist in CWE in the meantime.

In summary CIA WG concluded, that despite the unforeseen effects on socialization for some months following the split, CIA WG does not identify a justification for changing the expiring methodology, which is currently applied in CWE. None the less, this change could be a request from NRAs based on the results presented in this report.

Annex 4 (for information): Evaluation of ALEGrO impact on CID results - 12 SPAIC Day assessment

Evaluation of ALEGrO impact on CID results
12 SPAIC Day assessment

21/02/2020



1. ALEGrO implementation
Goal & Methodology

Goal

Share the obtained insights on the effects of

- the introduction of ALEGrO with Evolved Flow based into the CWE region (only) on the CIA Methodology (correctness of implementation) and;
- on the distributional effects on the CIA flows (delta comparison)
- Provide a transparent overview of how the analysis was done

Methodology:

- Calculations are made using the prepared Excel CRDS templates with and without ALEGrO as provided by Logarithmo which implement the introduced changes in the CWE CIA Methodology
- Input parameters used + assumptions made are elaborate
- Results are represented for several indicators in order to
  - Evaluate the correctness of the introduction of update CWE CIA Methodology (Based on outcomes of the scenario with ALEGrO)
  - Evaluate the impact of the introduction of ALEGrO on each indicator (comparison of the outcomes of scenario with and without ALEGrO)

Way Forward:

- Conclusions on the assessed results are included
- Next steps for the way forward for the CIA approval package are proposed

2

1. ALEGrO implementation

Analysis of 12 SPAIC Days

Following 12 SPAIC days were used for the analysis.
CWE official representative SPAIC days for the 12 month period after DE/AT split (1/10/2018 – 30/09 2019):

- 05.10.2018
- 17.11.2018
- 28.11.2018
- 28.12.2018
- 22.01.2019
- 21.03.2019
- 01.05.2019
- 10.05.2019
- 13.06.2019
- 16.06.2019
- 27.08.2019
- 11.09.2019

3

1. ALEGrO implementation

Input parameters & assumptions made

- **LTA values:**
  - For the existing CWE borders, the LTA values of the respective BD were included (source: JAO CRDS files)
  - For the BE-DE border the LTA values of respectively 500 MW in winter period and 400 MW in summer period are used

- **LTN values:**
  - 0 MW, no LTN were applied on the respective SPAIC days (source: JAO CRDS files)

- **CIA PTDF values:**
  - A reference F151 day file was prepared which included ALEGrO values
  - For the CIA calculations without ALEGrO the same reference F151 day was used but the ALEGrO-related PTDFs were removed
  - ➔ see tab "Aggregated PTDFs" in each excel file

- **Market Parameters (prices, Net positions):**
  - Market simulations were performed by external provider (EPEX) which resulted in Net Positions & market prices
  - Market simulations for a scenario with ALEGrO and without ALEGrO were executed:
    - This would allow a more 1 to 1 comparison of the effect of the introduction of ALEGrO
  - Outcomes of the Net positions & prices were included in the Excel files
  - Simulations were made in flow Flow Based Intuitive & Flow Based Plain (see next slide for explanation)

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1. ALEGrO implementation

Encountered issues during the assessment

While performing the 12 SPAIC day assessment some issues were encountered by Elia/Amprion/Logarithmo & EPEX

1. Issue on External Constraint for BE in Euphemia 10.4

- An inconsistency was detected by the way how the External constraint was implemented in E10.4. This occasionally lead to very high price peaks for Belgium, despite that there were no net positions in Belgium surpassing the EC.
- It resulted in strange effects on the CI for CWE in both w and w/o ALEGrO
- For the assessment the EC for Belgium was removed in order to obtain representative results (which was confirmed).
- Error was communicated to NEMOs/PCR who are currently investigating the issue.

2. Issue related to the interaction between the intuitiveness patch and the introduction of Evolved Flow based

- On regional level the revenue adequacy principle seemed to be breached, leading to more situations & higher amounts of negative net congestion income hours
- First impression seems to indicate that the intuitiveness patch cuts too severely on the BE-DE border leading to a 0 MW flow while still a price difference between BE-DE exists
- The issue is under further investigation by Elia/Amprion experts in collaboration with NEMO experts. First reasoning:
  - The initial FB domain provided to EUPHEMIA ensures LTA coverage and revenue adequacy. If this initial domain is fully considered – as is the case in FBP –, the CI will always be sufficient to cover LT resale costs.
  - The FBI patch in EUPHEMIA "cuts off" a part of the initial FB domain (to prohibit non-intuitive exchanges). This can lead to cases where an LTA corner is not part of EUPHEMIA's solution space anymore and where the CI is then not sufficient to cover LT resale costs anymore.
  - This issue can also occur currently in CWE with 5 hubs (under investigation). With the new market topology with 7 hubs and new borders, this effect is intensified.
- Additional simulations were performed with ALEGrO and Flow Based Plain, which resolved this issue

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1. ALEGrO implementation

Shown Results

The results are therefore calculated for the following 4 scenario's:

Scenario 1
- FB Intuitive
- Without ALEGrO

Scenario 2
- FB Intuitive
- With ALEGrO

Scenario 3
- FB Plain
- Without ALEGrO

Scenario 4
- FB Plain
- With ALEGrO

In the result slides each time results for each of the 4 scenario's are provided

Focus is on

- The correctness of the introduction of ALEGrO (results of Scenario 2 & 4)
- The distributional effects of ALEGrO on the CIA flows (delta comparison Scenario 1 vs Scenario 2 and Scenario 3 vs Scenario 4)

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Scenario 2
- FB Intuitive
- With ALEGrO

High negative CWE net CI observed in some hours for the case with ALEGrO when using **FBI** market results:

- Out of 288 hours, in 11 hours there is a negative CWE net CI of < -200 €

date	hour	sum TSOs
05.10.2018	6	-265
05.10.2018	7	-992
05.10.2018	11	-2.150
05.10.2018	23	-1.311
17.11.2018	21	-426
28.11.2018	7	-787
22.01.2019	1	-2.730
22.01.2019	8	-544
22.01.2019	9	-971
22.01.2019	10	-388
21.03.2019	8	-473

- FBI with this introduction of Evolved Flow Based is "incompliant" with principle of revenue adequacy (which now becomes clearer in a scenario with additional borders and a new topological situation)

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

The problem of high negative CWE net CI disappears when using ALEGrO with **FBP** market results

- The minimum CWE net CI (with ALEGrO) is -27 € over the whole time period which can be explained by rounding errors
- Similar effects as experienced today in CWE

The methodology for ALEGrO works as expected for **FBP**

- Prices of the virtual Hubs are always equal
- The ALEGrO flow is indeed sometimes 0 MW, but this only occurs when there is also full price convergence in CWE, hence it does not lead to additional socialization on this border in such cases
- The CI on the BE-DE border is indeed equal to the ALEGrO flow x the spread between DE-BE (before rescaling)
- It holds that: Total CI – Resale costs = net CI
- The overall amounts paid and received for socialization are identical. Therefore, the net total is zero, as it should be. The socialization mechanism works also with ALEGrO

Listed points above also apply to **FBI** (except for bullet point 2)

- Thus the methodology seems to behave also well on almost all parts when applying FBI, except for the bullet 2 which is linked to the revenue adequacy
- The ALEGrO flow is also in case of FBI sometimes 0 MW, but this is not only in case of full price convergence
- Hence when there is still a delta P between BE-DE it leads, for the case of FBI only, to additional socialization on this border

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1. ALEGrO implementation

Conclusion for the CIA methodology & the CIA approval package

Conclusions

Results included in the slides below give following main conclusions

	FB Intuitive + ALEGrO	FB Plain + ALEGrO
Effect Regional CWE-level	✗	✓
Correctness of CIA Methdology with ALEGrO	✓	✓
Effect of ALEGrO on CI distribution	✓	✓

Scenario FB Plain with Evolved FB with ALEGrO

- The simulations prove that the introduction of ALEGrO as currently foreseen & developed in the CIA Methodology is correctly working:
- The introduction of ALEGrO in the CRDS files does not lead to any deficiencies or imbalance effects in the distribution of the congestion income, socialisation costs

Scenario FB Intuitive with Evolved FB with ALEGrO

- The current results for this scenario shows that the interference of the FB Intuitive and the introduction with ALEGrO leads to negative effects for the Congestion in the entire CWE region
  - FBI is "incompliant" with revenue adequacy (which now becomes clearer in a scenario with additional borders and a new topological situation)
- Despite the negative effects on the CWE regional level the Introduction of ALEGrO seems to be working correctly and does not lead to any inefficiencies for the distribution of CI

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1. ALEGrO implementation

Next steps & way forward for the CIA methodology & the CIA approval package

Way Forward

- Ongoing discussions on Flow Based Plain vs Flow Based Intuitive → switch to Flow Based Plain is sought after before the Go live of ALEGrO
- Within this context the results of the assessment of the FB Plain scenario show that the introduction of ALEGrO in the CIA Methodology is compliant with the main principles of the methodology
  - Methodology proves to work correctly
  - No imbalances in the distributions of CI or socialization costs

- *Since FB Plain will most likely be introduced before the Go live of ALEGrO, the inclusion of ALEGrO in the CIA Methodology proves to be working correctly. No disclaimer is needed for this scenario.*

- However it is acknowledged that an introduction of ALEGrO with Flow Based Intuitive is not fully reassuring yet.
  - Further investigations might be required if it concerns an incorrectness or an incompliance
  - The incompliance of FBI with the revenue adequacy becomes more explicit with this introduction of topology

- *For this situation an introduction of a disclaimer in the current version of the CIA Methodology for the approval package seems to be the best option available*
  - The disclaimer specifies that if ALEGrO is introduced in the context of FBI, then there is the need to develop a methodology on how to split the negative CI between the TSOs
  - In the meanwhile discussions with Regulators on the way forward on the switch for FB Plain can continue and take into account this additional insight as another advantage of the implementation of Flow Based Plain

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Percentage of congested hours

- Indicates the percentage of hours where at least two different prices occurred in the flow-based capacity calculation region.

FBI

- Price convergence increases with ALEGrO by about 4 percentage points (from 65% of congested hours to 61%).

FBP

- Price convergence increases with ALEGrO by about 4 percentage points (from 65% of congested hours to 61%).

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Total CI

- CWE total

Case	FBI	FBP
W/O ALEGrO	10.297.947	9.987.165
W/ ALEGrO	10.187.032	9.811.531
Diff	-110.915	-175.634

As expected, less total CI is generated with FBP compared to FBI and less total CI is generated with ALEGrO than without ALEGrO. This is because ALEGrO as well as FBP will lead to more market exchanges and thus smaller prices difference which in turn will lead to a reduction of congestion income.

- Per hub

FBI

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	1.167.117	1.922.924	1.918.051	3.082.059	1.041.811	1.165.986
W/ ALEGrO	1.294.399	1.599.461	1.488.688	3.429.133	1.178.071	1.197.280
Diff	127.282	-323.462	-429.363	347.074	136.260	31.294

FBP

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	1.118.571	1.761.663	1.936.363	2.985.241	1.071.094	1.114.234
W/ ALEGrO	1.286.345	1.452.612	1.452.216	3.317.655	1.179.708	1.122.994
Diff	167.774	-309.051	-484.147	332.414	108.614	8.761

With the implementation of ALEGrO, the ALEGrO parties receive more total CI while most other parties lose total CI due to the lower price differences.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Internal pot

- CWE total

Case	FBI	FBP
W/O ALEGrO	7.965.974	7.758.698
W/ ALEGrO	7.792.472	7.565.542
Diff	-173.502	-193.156

External pot

- CWE total

Case	FBI	FBP
W/O ALEGrO	2.331.973	2.228.467
W/ ALEGrO	2.394.560	2.245.989
Diff	62.587	17.522

The internal pot decreases with ALEGrO compared to without ALEGrO whereas the external pot marginally increases.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Remuneration costs

- CWE total

Case	FBI	FBP
W/O ALEGrO	7.499.023	7.642.679
W/ ALEGrO	8.817.599	8.746.380
Diff	1.318.576	1.103.701

Remuneration costs increase with ALEGrO. The effect is slightly less pronounced with FBP.

- Per hub

FBI

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	997.721	1.106.947	980.080	2.336.684	1.090.063	987.528
W/ ALEGrO	1.217.510	1.045.451	956.626	3.035.303	1.369.937	1.192.773
Diff	219.789	-61.496	-23.454	698.619	279.874	205.244

FBP

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	999.036	1.085.547	1.064.370	2.402.289	1.097.387	994.050
W/ ALEGrO	1.219.007	1.010.388	952.314	2.996.404	1.382.853	1.185.415
Diff	219.972	-75.159	-112.056	594.115	285.465	191.365

Remuneration costs increase for those hubs which receive more CI, while resale costs decrease for those hubs which receive less CI.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Socialization → received due to the socialization

- CWE total

Case	FBI	FBP
W/O ALEGrO	1.805.115	1.899.659
W/ ALEGrO	2.217.341	2.221.029
Diff	412.226	321.370

Socialization → paid due to the socialization

- CWE total

Case	FBI	FBP
W/O ALEGrO	1.805.115	1.899.659
W/ ALEGrO	2.217.341	2.221.029
Diff	412.226	321.370

Socialization → total

- CWE total

Case	FBI	FBP
W/O ALEGrO	0	0
W/ ALEGrO	0	0

The amounts paid and received are identical for FBP and also FBI. Therefore, the net total is zero, as it should be. The socialization mechanism works also with ALEGrO.

With ALEGrO there is more socialization needed. The effect is less pronounced with FBP.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Socialization → total

- Per hub

FBI

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	87.097	-192.173	-290.011	87.888	120.594	186.605
W/ ALEGrO	56.220	-284.087	-209.428	55.861	213.460	167.974
Diff	-30.878	-91.914	80.583	-32.026	92.866	-18.632

FBP

Case	BE	FR	NL	DE	AT	SL
W/O ALEGrO	100.892	-180.284	-297.984	136.617	89.201	151.559
W/ ALEGrO	58.521	-302.564	-178.716	56.699	217.082	148.978
Diff	-42.370	-122.280	119.268	-79.918	127.881	-2.580

A positive value indicates that the hub is a net receiver. A negative value indicates a net payer.

The effect of ALEGrO is that:

- The hubs NL and AT receive more/have to pay less for socialization,
- While the hubs BE, DE and FR receive less/have to pay more for socialization.

This effect is more pronounced with FBP.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Socialization → total

- Per border

FBI

Case	BE-FR	BE-NL	DE-FR	DE-NL	DE-AT	BE-DE	AT-SL	DE-SL	FR-SL
W/O ALEGrO	414.468	-321.608	-445.517	-272.950	252.397		140.954	466.556	-234.300
W/ ALEGrO	339.211	-222.078	-508.486	-219.760	382.895	-107.729	255.383	353.405	-272.841
Diff	-75.257	99.530	-62.969	53.190	130.498	-107.729	114.429	-113.152	-38.541

FBP

Case	BE-FR	BE-NL	DE-FR	DE-NL	DE-AT	BE-DE	AT-SL	DE-SL	FR-SL
W/O ALEGrO	434.929	-321.413	-383.993	-292.403	259.764		72.443	504.496	-273.821
W/ ALEGrO	361.506	-179.674	-514.042	-199.510	412.641	-178.876	234.273	376.336	-312.652
Diff	-73.423	141.739	-130.049	92.893	152.877	-178.876	161.830	-128.160	-38.831

ALEGrO is a net payer and even more so under FBP.

For a lot of borders, ALEGrO helps to even out the net payers and the receivers. For example, the DE-NL border is always a net payer, but has to pay less with ALEGrO.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Net CI

- CWE total

Case	FBI	FBP
W/O ALEGrO	2.798.924	2.344.486
W/ ALEGrO	1.369.433	1.065.151
Diff	-1.429.491	-1.279.335

As expected, less net CI is generated with FBP compared to FBI and less net CI is generated with ALEGrO than without ALEGrO.

- Per hub

FBI

Case	BE	FR	NL	DE	AT
W/O ALEGrO	316.536	955.751	695.693	724.540	106.403
W/ ALEGrO	174.872	503.306	310.887	349.200	31.167
Diff	-141.664	-452.445	-384.806	-375.340	-75.236

FBP

Case	BE	FR	NL	DE	AT
W/O ALEGrO	260.649	815.217	541.419	634.732	92.470
W/ ALEGrO	144.244	407.990	156.762	335.111	21.043
Diff	-116.405	-407.227	-384.656	-299.620	-71.427

All hubs receive less net CI with ALEGrO.

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1. ALEGrO implementation

Evaluation of ALEGrO impact on CID results

Net CI

- Per TSO

FBI

Case	Amprion	APG	Elia	RTE	Tennet BV	TenneT Gmbh	Transnet
W/O ALEGrO	635.517	106.403	316.536	695.693	724.540	108.788	211.446
W/ ALEGrO	377.926	31.167	174.872	310.887	349.200	55.254	70.127
Diff	-257.592	-75.236	-141.664	-384.806	-375.340	-53.534	-141.319

FBP

Case	Amprion	APG	Elia	RTE	Tennet BV	TenneT Gmbh	Transnet
W/O ALEGrO	550.313	92.470	260.649	541.419	634.732	93.751	171.153
W/ ALEGrO	322.417	21.043	144.244	156.762	335.111	49.074	36.500
Diff	-227.896	-71.427	-116.405	-384.656	-299.620	-44.677	-134.653

All TSOs receive less net CI with ALEGrO.