CWE REPORT: COMPARISON FLOW-BASED PLAIN AND FLOW-BASED INTUITIVE

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1. Executive Summary

Background

In the 'Position Paper on Flow-Based Market Coupling '(March 2015), CWE NRAs requested CWE parties (TSOs and NEMOs) to prepare a comprehensive report based on one-year monitoring and comparison between Flow-Based Plain (FBP) and Flow-Based Intuitive (FBI) calculation modes. The aim of this document is to support CWE NRAs decision to "consider if a change towards the other version of the methodology is relevant and justified".

A first report was provided in January 2017. No decision to change to FBP was taken, and as consequence FBI remains applied.

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, to elaborate on how to deal with possible situations with an overall negative congestion income and a rough project plan to switch to FBP.

Intuitivity patch

The difference between FBP and FBI consists in applying the so-called intuitivity patch. This patch is an allocation constraint applied in the market coupling algorithm which enforces the exchanges on the different borders to go only from the most expensive bidding zone to the least expensive bidding zone. Under a flow-based allocation approach without additional constraint, it may indeed occur that, in order to maximize the overall welfare, some exchanges are going against the price difference.

Conceptually this allocation constraint, being an additional constraint in the market coupling algorithm, will reduce the welfare generated and will reduce the utilization of the grid.

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) are further illustrated in the report. 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 in the upcoming months and years (ALEGrO, Core FB, Nordic FB, market time unit of 15 min…). It is worth noting that there is a negative combinatorial effects on the performance. The increase in time to first solution due to two changes taken together will often be higher than the sum of the increases induced by each of these changes in isolation.

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. This is illustrated in the report by the analysis of some high and low price spikes. In one example and for one bidding zone, a price difference of more than 200 € 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 zone were not so significantly affected, leading to important price differentials between bidding zone. These rare but spectacular situations are not easily understood by market participants, which may in itself questions 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.

Congestion income

While the occurrence of non-intuitive situation may raise questions on how to deal with negative congestion rents, it is important to underline that this concern is solved with the current congestion income methodology. When the overall congestion income remains positive, a socialization mechanism allows to redistribute the congestion income among TSOs and avoids a pay out by TSOs. There is however one exception: Triggering of the adequacy patch may lead in some cases to an overall negative congestion income.

Two solutions can be envisioned: either the possibility of a pay-out by TSOs in case of negative congestion rent is accepted by CWE NRAs, or the adequacy patch is removed. The former is a rare case: the adequacy patch has never been triggered and even if it is triggered, it does not necessarily lead to an overall negative congestion income.

Implementation

Should NRAs decide to switch to FBP, several measures need to be implemented. The removal of the intuitive patch can be done easily by changing the configuration of the algorithm. The same holds for the removal of the adequacy patch if decided. The lead time will then be determined by transparency considerations in order to timely inform market participants, and by the update of the CWE approval package.

If it is decided to maintain the adequacy patch, it should be decided how to distribute the overall negative congestion rent among TSOs. The way a similar situation is handled in case of decoupling can be taken as a starting point for discussion.

General conclusions from CWE parties

Considering that the removal of the intuitive patch will lead to a higher welfare, a better price convergence, the avoidance of price spike situations, a higher utilization of the grid and better algorithm performances, CWE parties see strong evidences supporting a timely switch to FBP.

CWE parties expect guidance from CWE NRAs regarding the adequacy patch, and if maintained CWE TSOs expect guidance regarding the way how to share the overall negative congestion income.

2. Introduction

In the 'Position Paper on Flow-Based Market Coupling '(March 2015), CWE NRAs requested CWE parties (TSOs and NEMOs) to prepare a comprehensive report based on one-year monitoring and comparison between Flow-Based Plain (FBP) and Flow-Based Intuitive (FBI) calculation modes. The aim of this document is to support CWE NRAs decision to "consider if a change towards the other version of the methodology is relevant and justified".

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3. Data

This study covers four years of CWE Flow Based operational data, from 01 October 2015 until 30 September 2019. This period therefore includes one complete year of operational data after the introduction of congestion management on the German-Austrian border on 01 October 2018. As a consequence, all data is based on four bidding zones (BE, DE/AT/LU, FR, NL) for the period from 01 October 2015 until 30 September 2018, and on five bidding zones (AT, BE, DE/LU, FR, NL) for the period from 01 October 2018 until 30 September 2019.

The Flow Based Intuitive results considered in this study are the SDAC (previously MRC) production results, whereas the Flow Based Plain results were produced by EPEX internal simulation tool running on a production-like environment. For each delivery date, the same version of Euphemia and the same input data (market and network data) were used to produce the two sets of market coupling results.

Disclaimer: Due to some difference in the way the problem is modeled and in the systems used to produce the results to conduct this study, market results produced under FB plain calculation mode could slightly differ from market results calculated under FB intuitive, even in case the intuitive patch is not active. However the differences are considered as negligible. For the 2017 edition of this report, the difference has been quantified and did not exceed on average (in absolute values) 1K € for Welfare, 0.02 € for Prices and 16.5 MWh for Net Positions on normal days. This is also in line with the 97.82% level of repeatability of the market coupling algorithm[1]. For price spike days in particular, an analysis was already conducted for the 2017 edition of this report. This analysis showed that the differences observed between FBP and FBI and reported in this study, are only due to the FB calculation mode and not due to the repeatability issue.

[1] cf. All NEMO Committee: CACM Annual Report 2018

4. CWE FB Plain MC vs CWE FB Intuitive: Four years of operation[2]

4.1 Indicator: Frequency of non-intuitive situations under FB Plain

Observations:

During the evaluation period, the patch hast been activated in 16,2 % of the hours (5704 hours in total during the evaluation time period) and on 74% of the days (1081 in total). A clear trend over the time period is not recognizable.

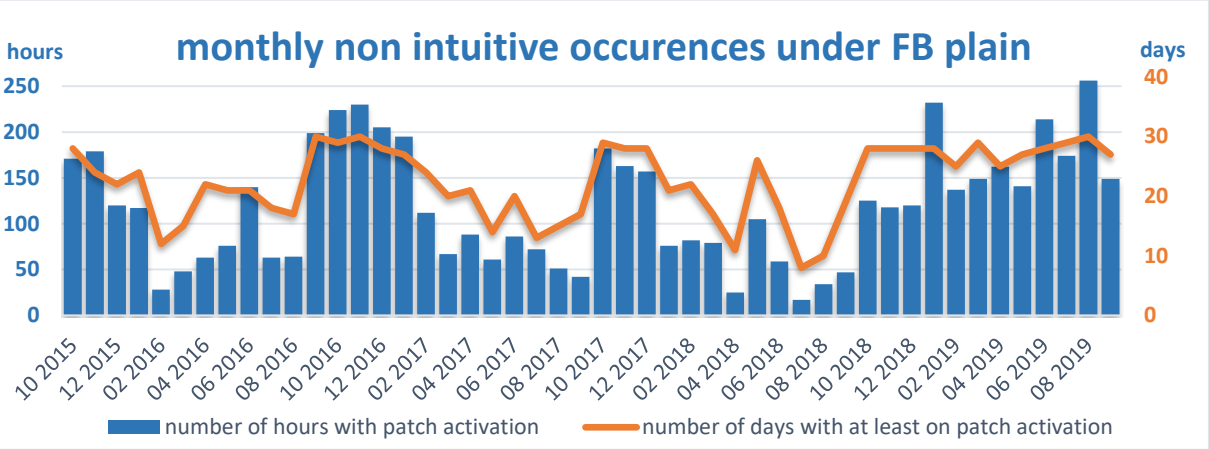

Figure 4.1-1 :monthly non intuitive occurrences

Observations :

In the years before the DE-AT-split, a significant drop of non-intuitive situations has been observed during the summer months. Since the split in 2018 the drop of non-intuitive situations in summer has not occurred anymore[3].

4.2 Indicator: WELFARE

The welfare of the simulations with FBP should lead to higher welfare as the total capacity domain could be potentially used.

On the graph below, you can find a representation of the average/minimum/maximum daily welfare difference between FBP and FBI for MRC. An increase of the average daily is observed before and after DE-AT-split with respectively an additional 17K € and 21K € due to the switch to FBP.

[2] For cases, when time intervals before and after the DE-AT-split are compared, the latter might show higher variations due to the smaller datasets available.

[3] Throughout this section, when a comparison is made between the situation before and after the DE-AT split, it has to be kept in mind that the statistical relevance of the data after DE-AT split is lower considering the shorter period.

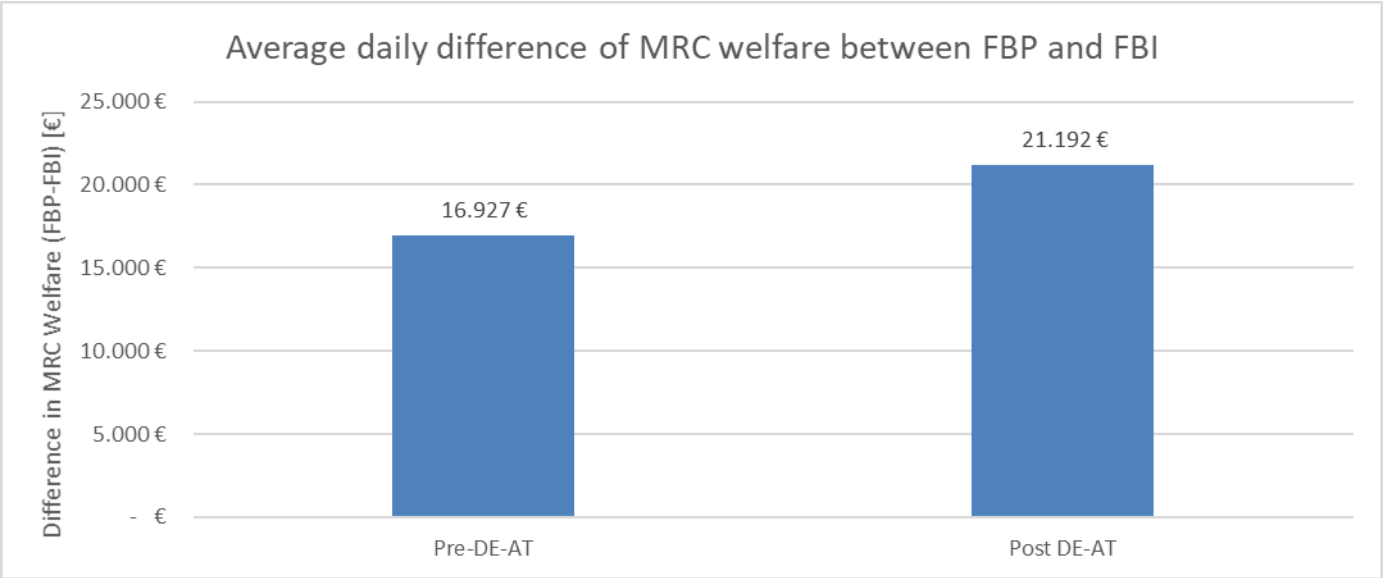

Figure 4.2-1: Average daily difference of MRC welfare between FBP and FBI

On the graph below, the average daily difference between FBP and FBI of the CWE welfare divided between consumer surplus and producer surplus is displayed.

In the period after the DE-AT-split, NL and AT are not impacted on their total welfare while DE, FR and BE are strongly positively impacted by the switch to FBP. The consumer welfare from the Belgian hub increases significantly due to the reduction of the price spikes and the average price in Belgium. The producer surplus of the German hub increased significantly due to an average increase of the price in the hub while the decrease of the consumer surplus was smaller than the previous increase. The French hub is positively impacted in both directions.

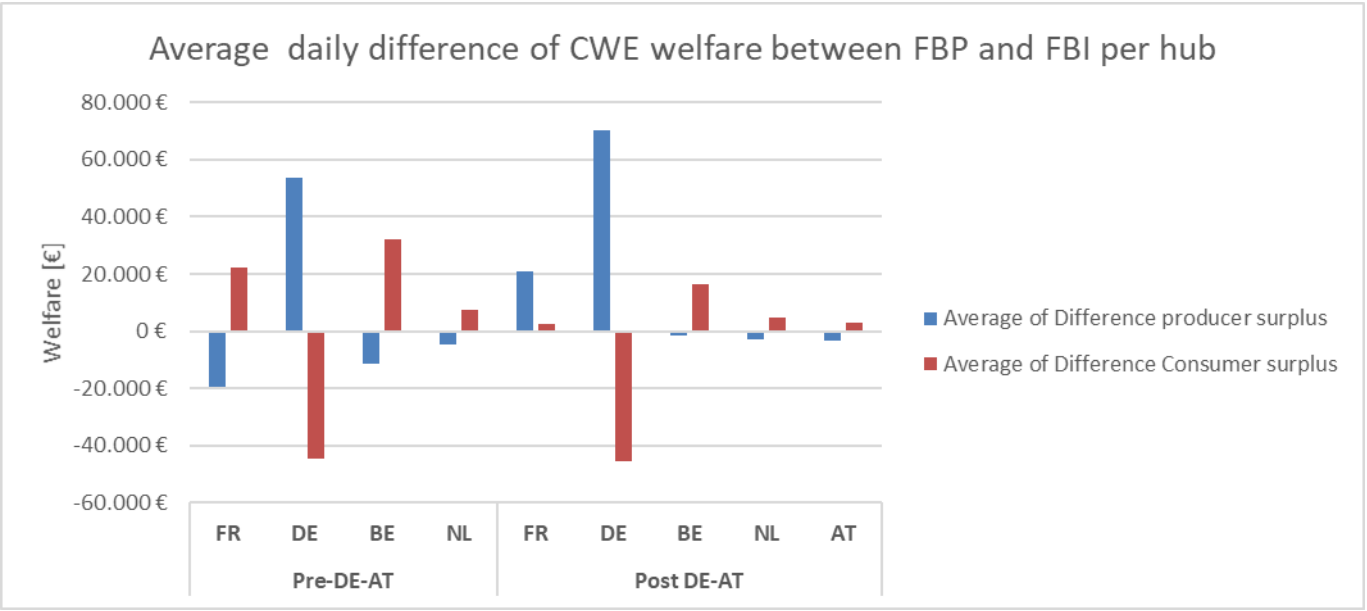

Figure 4.2-2: Average daily difference of CWE welfare between FPB and PFI per hub

4.3 Indicator: PRICES

Observations

Figures 4.3-2 - 4.3-6 show the impact of the FB market coupling mode on prices. The impact of the calculation mode on prices can be assessed for each bidding zone separately, and is measured as the difference between the market clearing price in plain mode and the market clearing price in intuitive mode. If this difference is positive, than the price of a given hour would have been higher in plain calculation mode; if the difference is negative, the price of a given hour would have been lower in plain calculation mode. Figures 4.3-2 to 4.3-6 show the scale of this impact, whereas Table 4.3-1 shows how often prices are higher and lower, but it does not give any information to what extend this happens.

Apparently, effects on prices are more pronounced in Austria, Belgium and the Netherlands, whereas they are less pronounced in Germany and France. From these graphs in Figures 4.3-2 to 4.3-6, no clear tendency can be observed in terms of increase or decrease of prices when using FB intuitive or FB plain. Moreover, Table 4.3-1 shows the distribution of price increases versus price decreases. As can be seen, the intuitiveness patch leads more often to higher prices than to lower prices in Belgium, France, the Netherlands and Austria, and the intuitiveness patch leads more often to lower prices than to higher prices in Germany.

	BE	DE/LUX (AT)	FR	NL	AT
FBP > FBI	20%	25%	19%	20%	25%
FBP < FBI	27%	20%	24%	25%	34%

Table 4.3-1: Distribution of price increases and price decreases

For the sake of enhanced readability and comparability, the y-axis (price spread) is cut to 30/-30 €/MWh. On a very few exemption days the spread is bigger than 30 €/MWh. When the difference is positive (above the horizontal axis), prices under FBP are higher than prices under FBI.

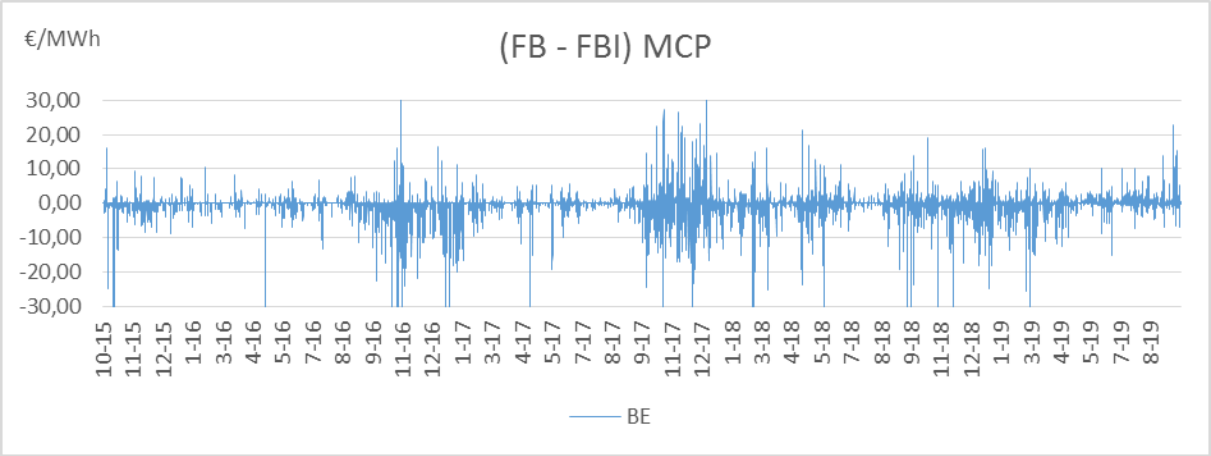

Figure 4.3-2: Price differences for Belgium

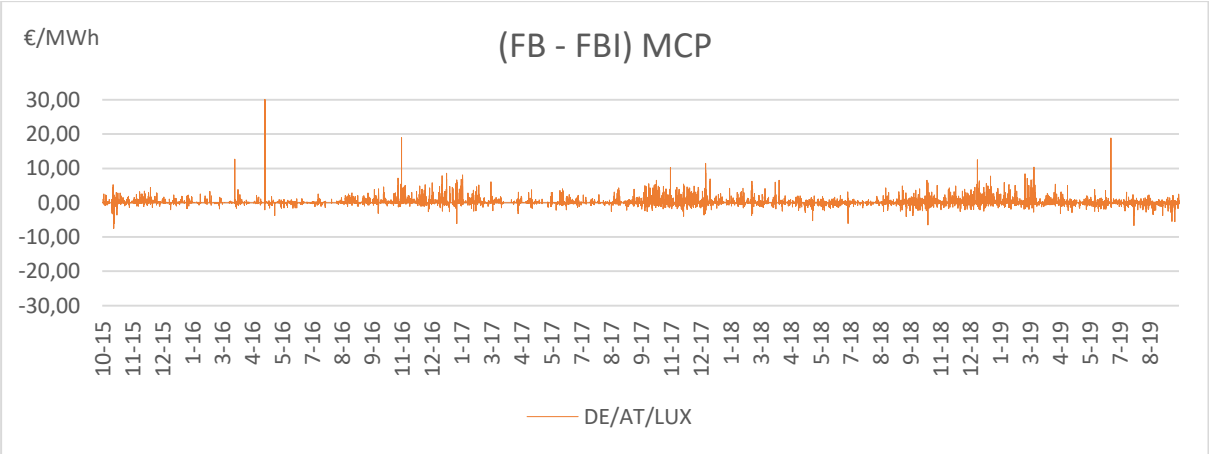

Figure 4.3-3: Price differences for Germany/Austria/Luxemburg (until 30/09/2018) // for Germany/Luxemburg (as of 01/10/2018)

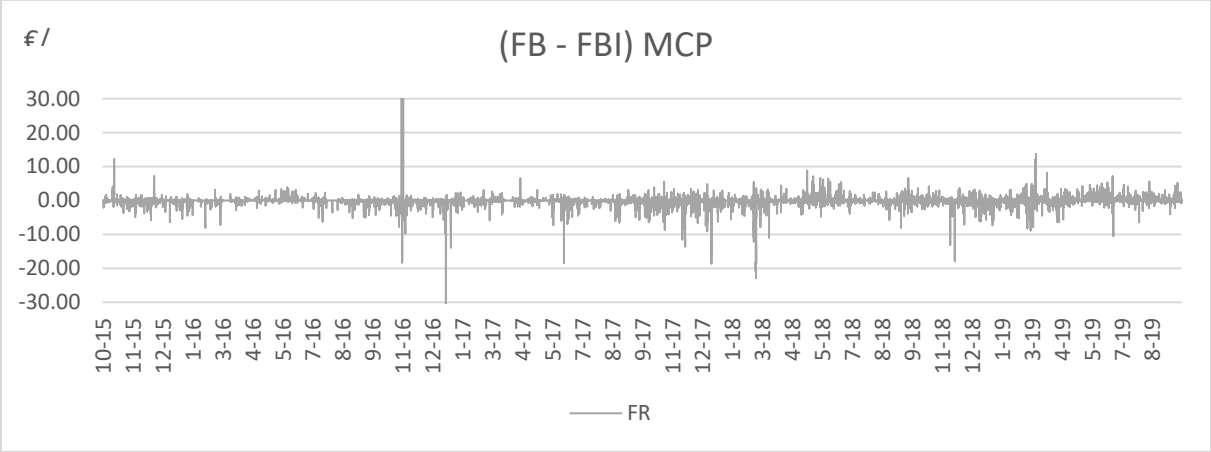

Figure 4.3-4: Price differences for France

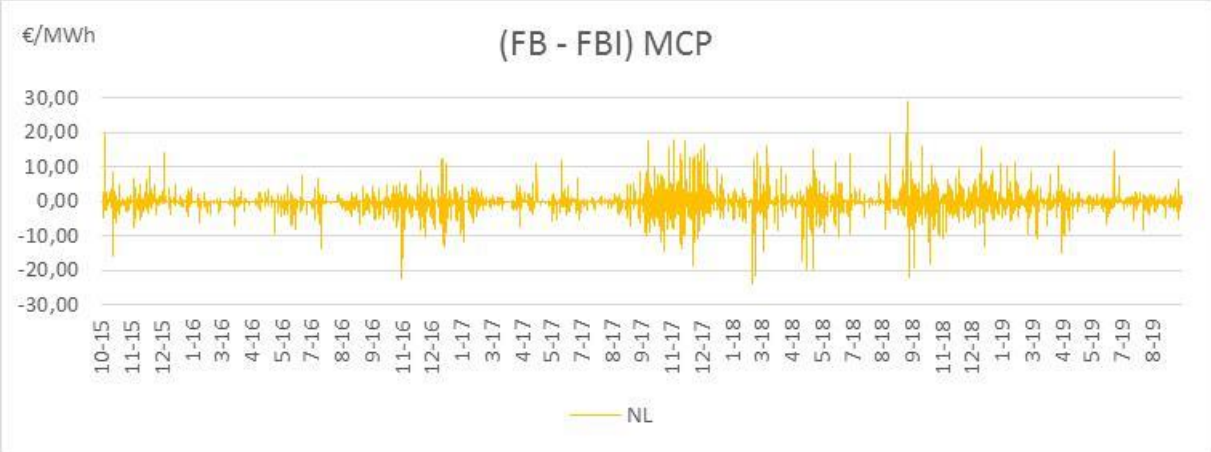

Figure 4.3-5: Price differences for the Netherlands

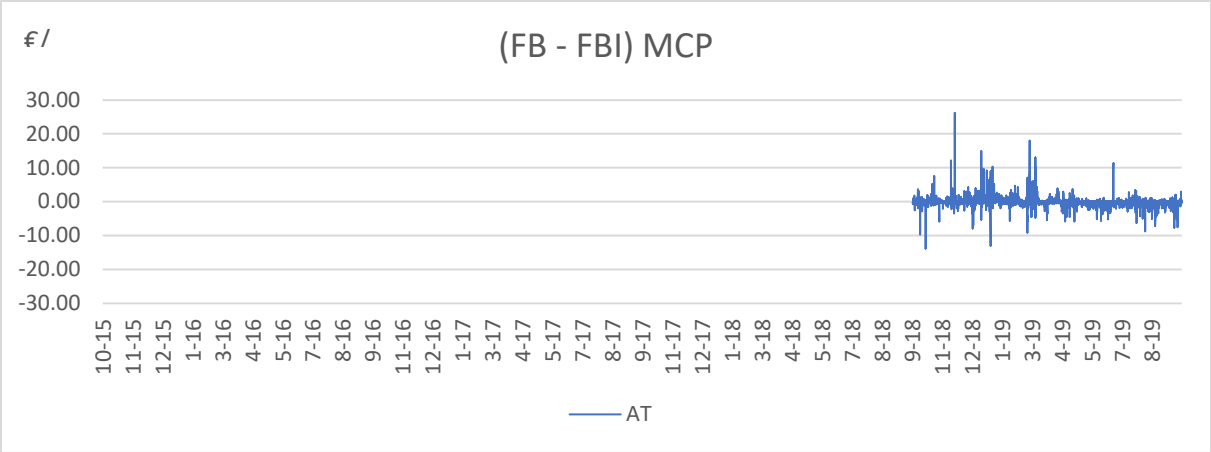

Figure 4.3-6: Price differences for Austria (as of 01/10/2018)

Additionally, the effect of the calculation mode can be assessed by calculating the monthly average price differences for each bidding zone, as included in Table 4.3-7:

	AT	BE	DE	FR	NL
October 2018	0.03	-0.20	0.10	-0.03	-0.33
November 2018	0.11	-0.90	0.14	-0.13	-0.11
December 2018	0.07	-0.66	0.16	-0.09	-0.02
January 2019	0.27	-0.87	0.40	-0.26	0.28
February 2019	0.05	-0.44	0.16	-0.12	-0.01
March 2019	0.08	-0.79	0.22	0.21	-0.15
April 2019	-0.08	-0.24	0.11	-0.05	-0.11
May 2019	-0.11	0.05	-0.01	0.13	-0.04
June 2019	-0.43	-0.07	0.01	0.22	-0.11
July 2019	-0.14	0.19	-0.03	0.15	0.00
August 2019	-0.41	0.17	-0.08	0.16	-0.14
September 2019	-0.25	0.50	-0.11	0.12	-0.01

Table 4.3-7: Monthly average price difference betweeen FBP and FBI

For the period from October 2018 to September 2019, there seems to be a seasonal effect:

- For FR and BE, the monthly average difference between FBP and FBI is negative in autumn and winter (i.e. prices are higher under FBI) and positive in spring and summer (i.e. prices are lower under FBI);
- There is an opposite trend for AT and DE;
- There is no seasonal effect for the Netherlands, prices mostly seem to be higher in FBI mode.

This price difference pattern can be correlated to the importing or exporting situations. Since FBP will lead to more price convergence, the price in the exporting countries will tend to be slightly higher and the prices in the importing countries will tend to be slightly lower.

The graph hereunder illustrates the standard deviation of the hourly price over the whole analysed period. No significant differences can be noted aside from Belgium, where the differences remain small.

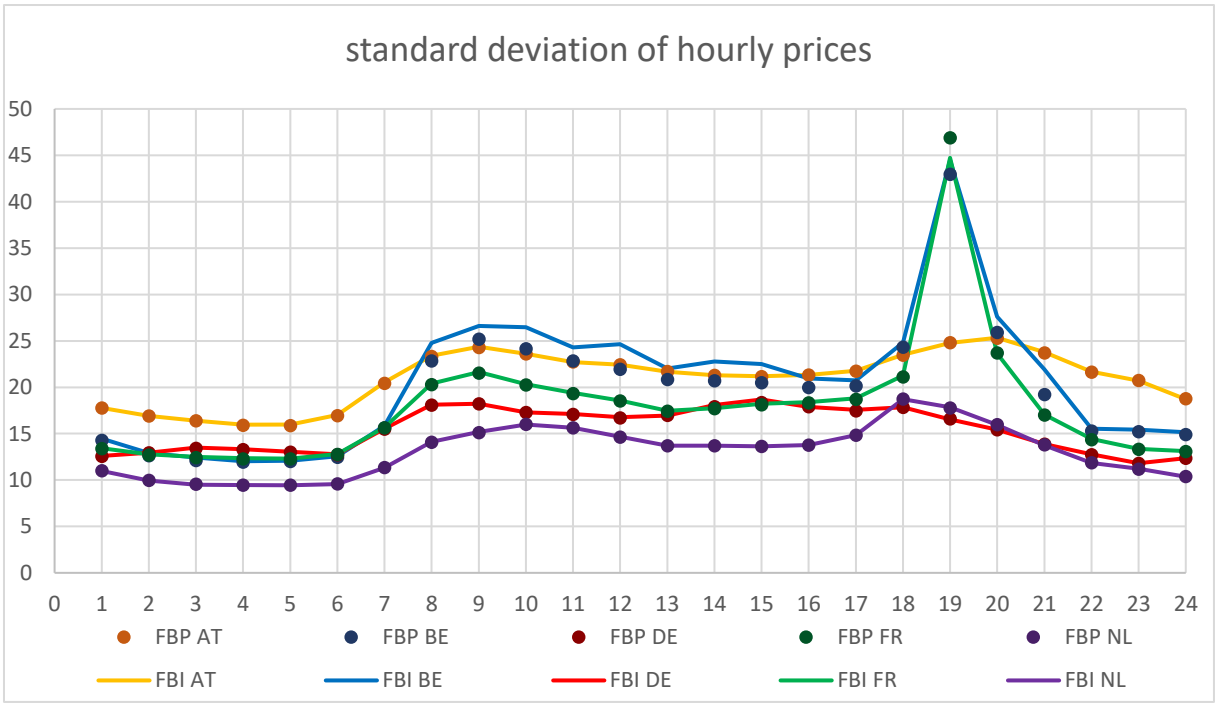

Figure 4.3-8 : standard deviation of hourly prices

Price convergence

Figures 4.3-9 and 4.3-10 show the percentage of occurrences of hourly price areas in CWE before and after the DE-AT-split.

The Figures show, that:

- The full price convergence is comparable using FBP and FBI
- FB intuitive provides a slightly higher partial convergence and less full divergence
- This does not change after the DE-AT-split

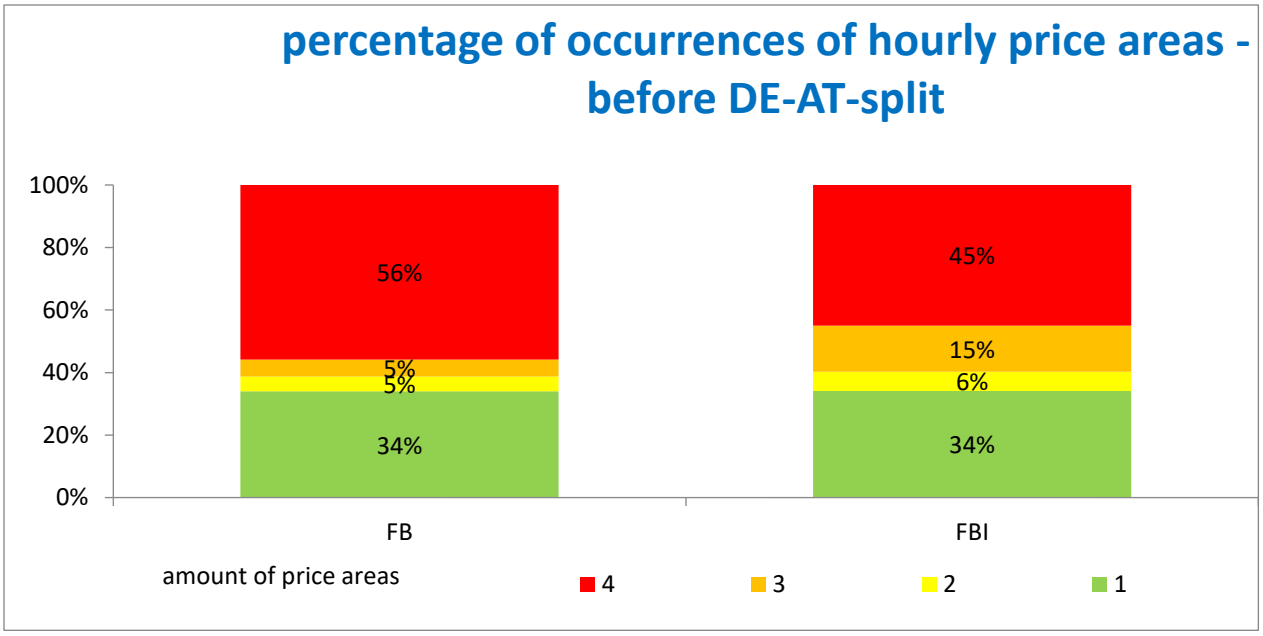

Figure 4.3-9 : percentage of occurrences of price areas resulting from market coupling using FB plain and FB intuitive before DE-AT-split

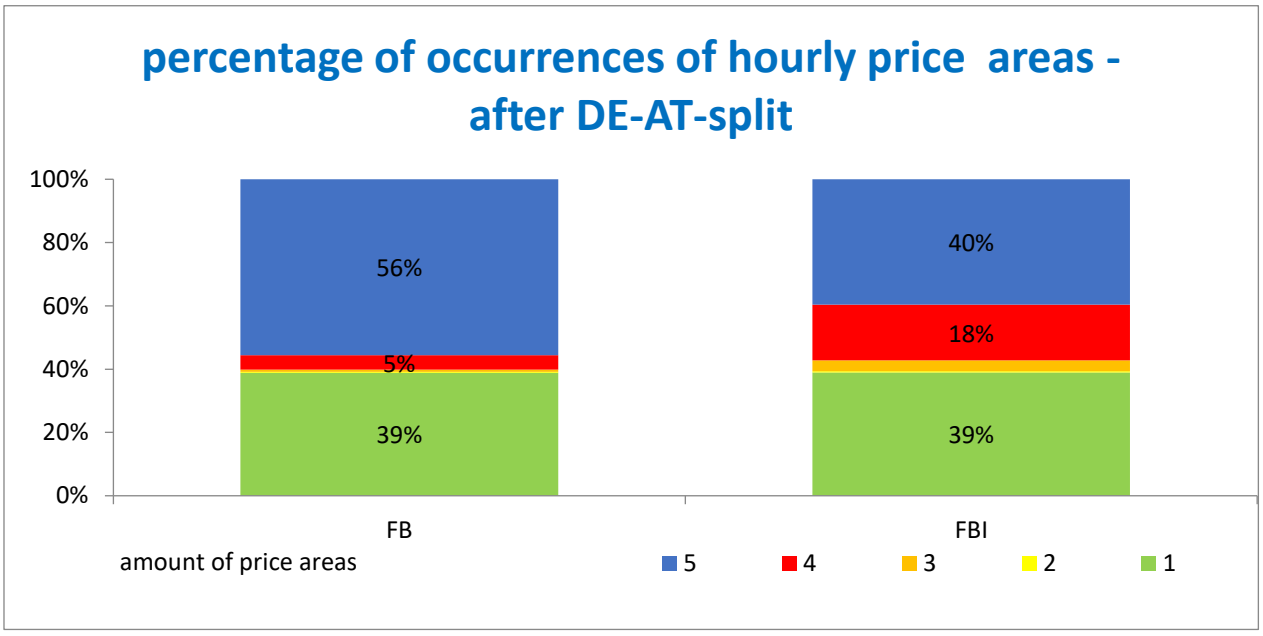

Figure 4.3-10 : percentage of occurrences of price areas resulting from market coupling using FB plain and FB intuitive after DE-AT-split

Figure 4.3-11 shows that the price convergence does not follow an apparent pattern and is not changing over the monitored period. For FBI and FBP mode, no significant deviations in price convergence can be observed. In other words, price convergence is not (strongly) dependent on the mode of FBMC.

It is reminded that the partial price convergence is observed either when the intuitivity patch is active or by an active external constraint.

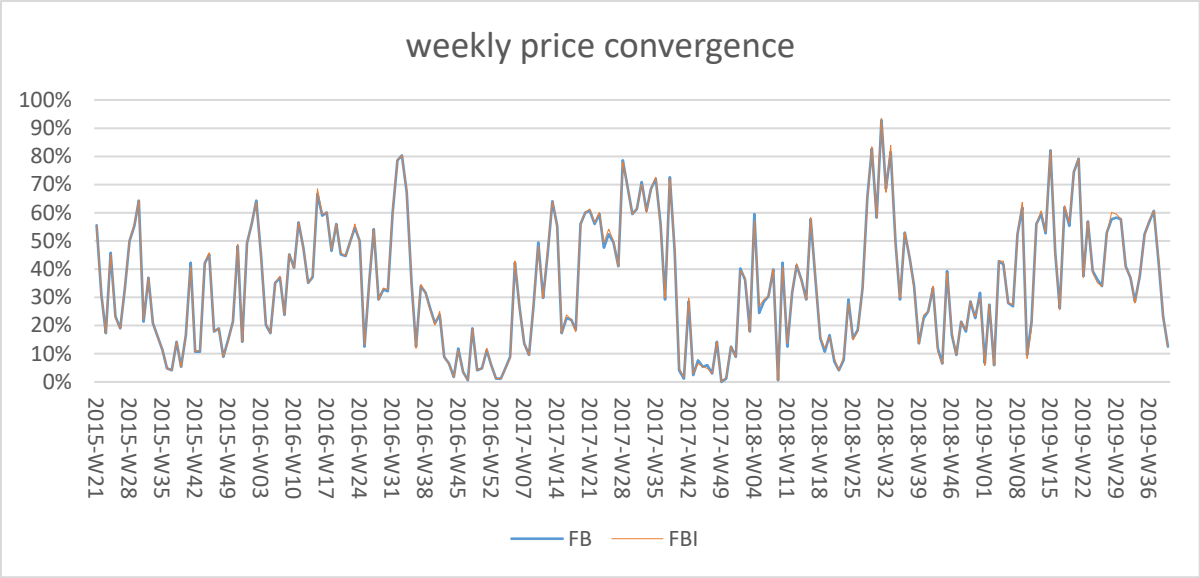

Figure 4.3-11 : weekly full price convergence

Price spread indicator

Figure 4.3-12 presents the maximum price spread levels between price areas under FBP and under FBI. There is no significant change in the price spread between the modes FBI and FBP of market coupling.

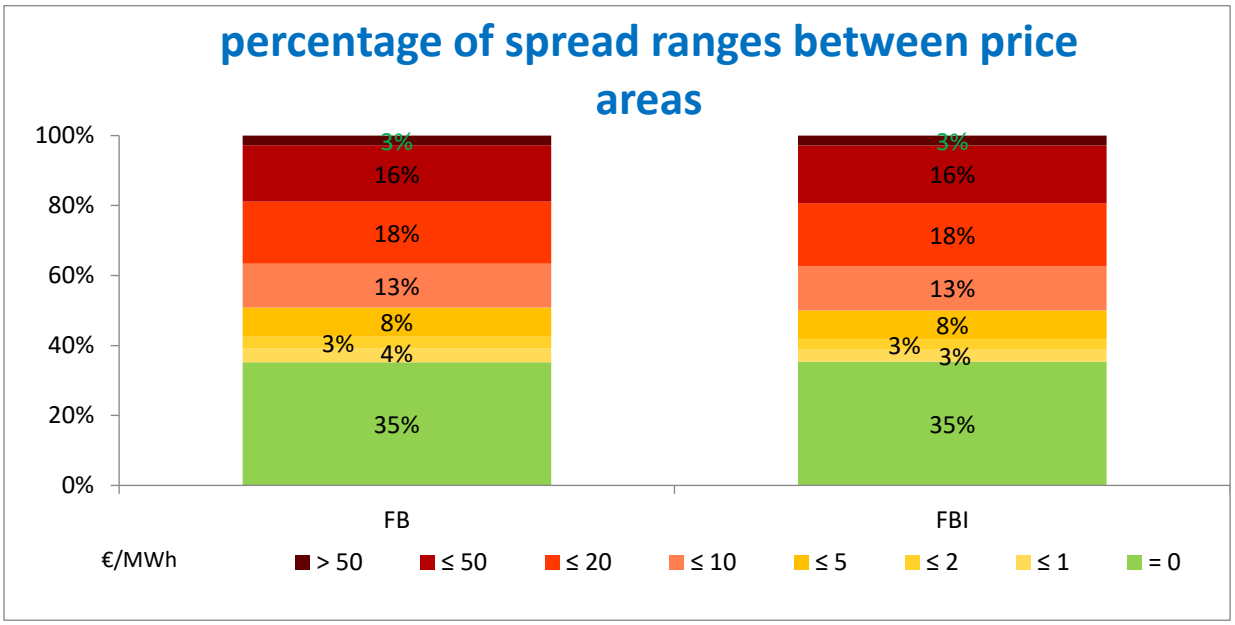

Figure 4.3-12 : maximum price spread levels between price areas using FB plain compared to using FB intuitive

4.4 Indicator: Net Positions

Total Daily Exchanges

Observations

Figure 4.4-1 gives an overview of differences in net positions for the five CWE bidding zones, sorted in the form of a load duration curve. Among others, FBP would allow e.g. for a higher export from the German bidding zone and (right hand side of the graph), and would also allow for higher imports e.g. in France and the Netherlands (left hand side of the graph). Differences in net positions have been calculated for each hour, and the observations have been sorted for each bidding zone. On average, using FB plain results in higher exchanges compared to using the FB intuitive patch. However, the differences can be considered as almost negligible for more than 50% of hours.

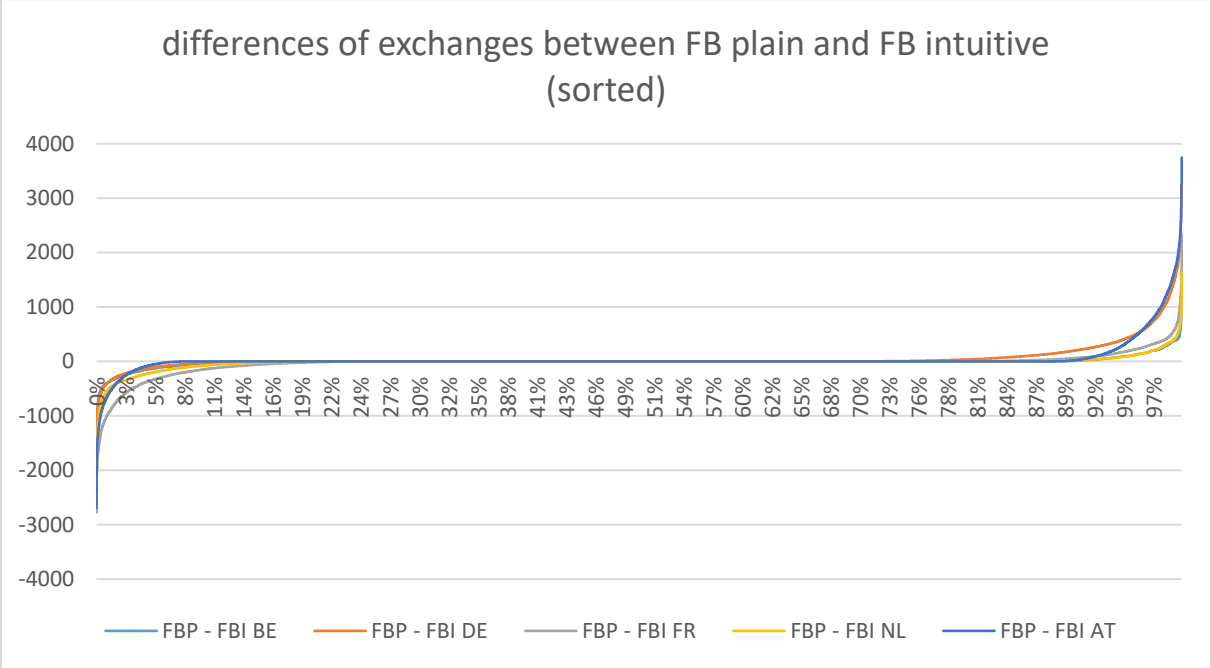

Figure 4.4-1 : differences of exchanges between FB plain and FB intuitive

When comparing the total CWE exchanges, calculated by taking the sum of the exporting hubs, it is clear that FBP would on average allow for higher exchanges within CWE. This is shown in Figure 4.4-2, where for each quarter the average exchanges during non-intuitive hours are compared for FBP and FBI. Furthermore, the number of non-intuitive hours per month is given.

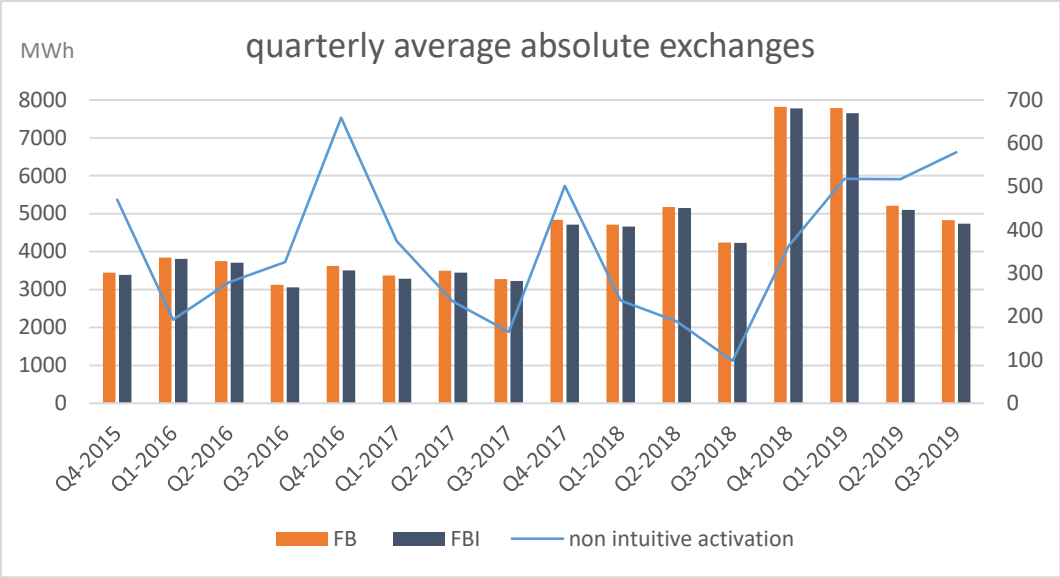

Figure 4.4-2 : quarterly average absolute exchanges

4.5 Indicator: Total volume executed

The total Market Cleared Volume (MCV = the matched supply + imports = the matched demand + exports) per market in the CWE region are presented in Figure 4.5-1.

The total MCV difference between FBP and FBI is not noteworthy as can be seen in Table 4.5-2, in which the percentage of difference in MCV in relation to the total MCV using FBI is displayed.

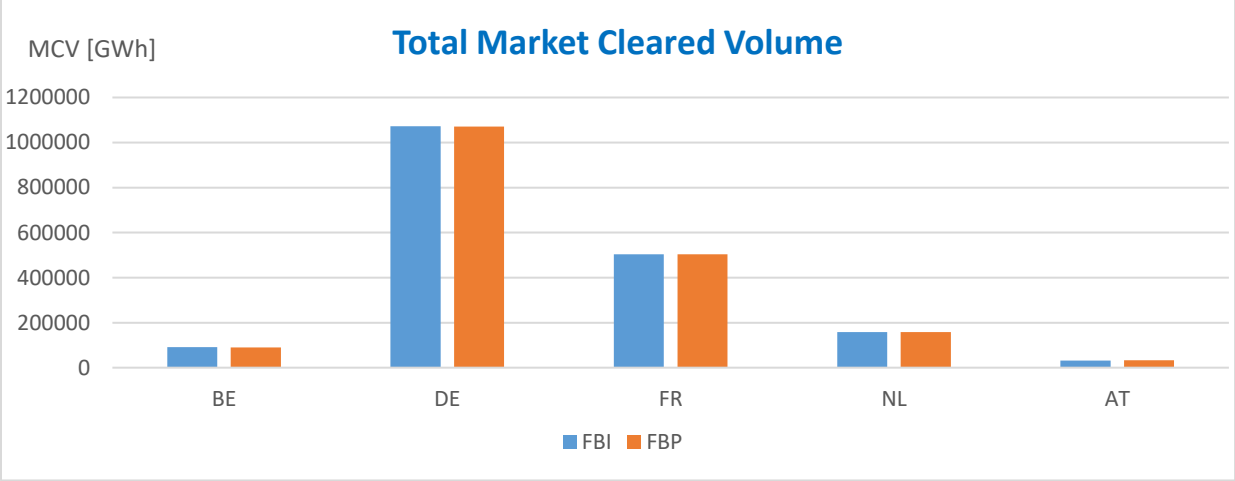

Figure 4.5-1 Total market cleared volume per hub for FBP and FBI

	BE	DE	FR	NL	AT	CWE
FBP - FBI [GWh]	-338	-1143	-86	-404	705	-1267
percentage of MCV FBI	-0,37%	-0,11%	-0,02%	-0,25%	2,19%	-0,07%

Table 4.5-2: Difference of Market Clearing Volume between FBP and FBI over the evaluation period

4.6 Indicator: Paradoxically rejected bids

The Figure 4.6-1 shows, that the number of Paradoxically Rejected Bids (PRB) is reduced slightly under FBP compared to FBI.

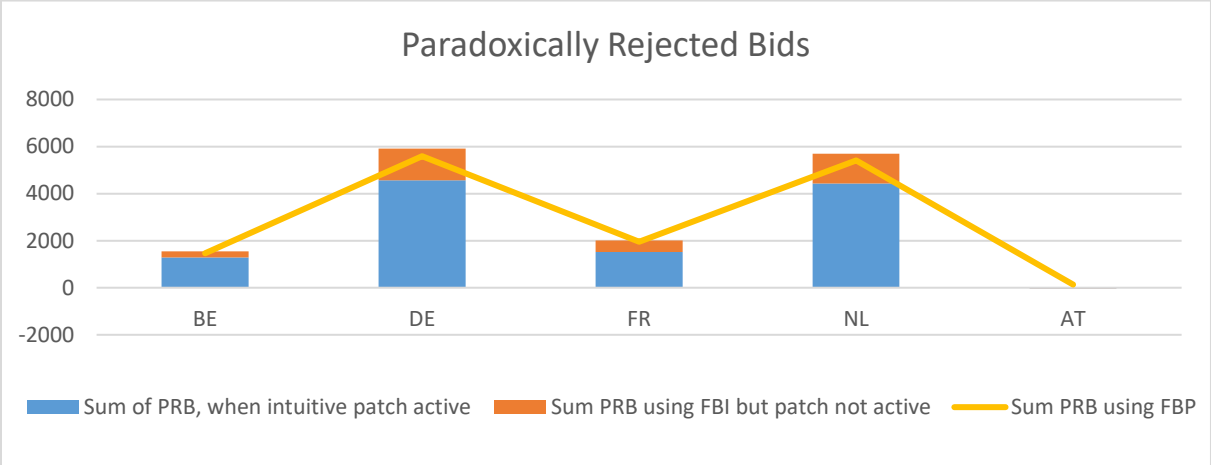

Figure 4.6-1: Sum of PRBs

4.7 Performances

The graph below shows the maximum and average Time to First Solution (TTFS) between FBI and FBP. Furthermore, the graph has been divided between timestamps before and after DE-AT split. Indeed, the addition of a new hub will increase the complexity. As there is a combinatorial effect[4], the negative impact of FBI on the TTFS will be more important on a topology with more hubs. Similar behavior has been studied in the Alegro analysis included in Section 7.

[4] The increase in time to first solution due to two changes taken together will often be higher than the sum of the increases induced by each of these changes in isolation.

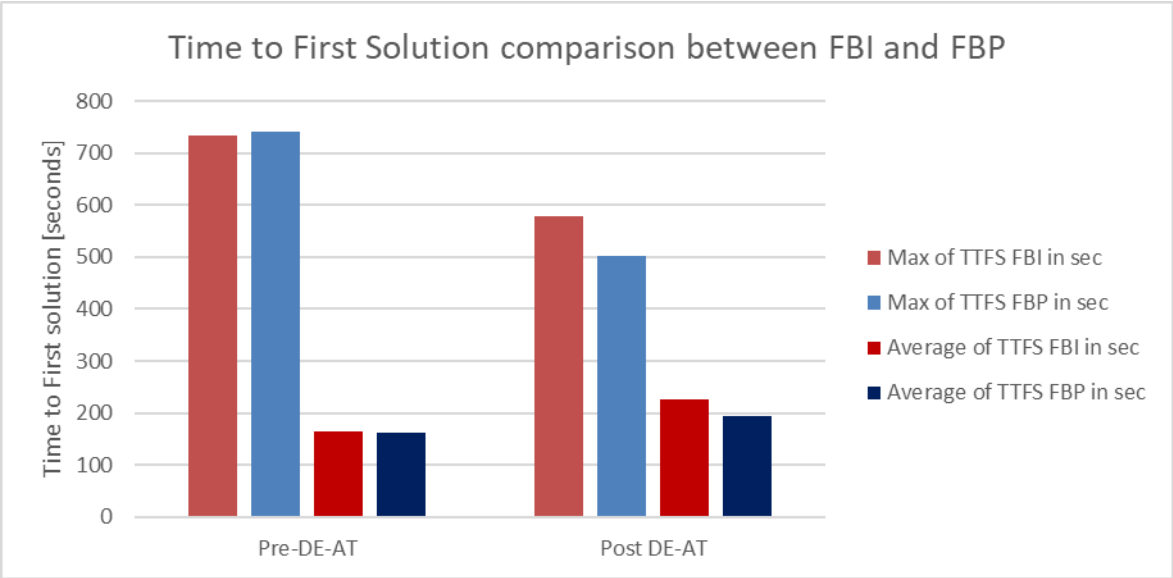

Figure 4.7-1: Time to first solution comparison

The average TTFS is 2.2% lower with FBP than with FBI for the situation pre DE-AT split, and 14.1% lower with FBP than with FBI for the situation post DE-AT split.

5. Focus on relevant intuitive and non-intuitive situations

5.1 Intuitive patch

The intuitive patch aims at avoiding so called non-intuitive flows, which are cross-border flows that run from a bidding zone with a higher price to a bidding zone with lower price. Consequently, the patch either prevents that an expensive market is exporting to a less expensive market, or avoids that a cheap market is importing from a more expensive market.

Example 1: 16 October 2015, hour 19. In Flow Based Plain mode, DE/AT/LU (53.83 €/MWh) imports from FR (60.10 €/MWh), which is a non-intuitive flow. The Flow Based Intuitive mode prevents this, by creating a price convergence between DE/AT/LU and FR and truncating NL to zero net position, in order to prevent NL to import like DE/AT/LU did before. The reduction in DE imports reduces the BE imports, and results in BE price to increase from 91 € to 280 €.

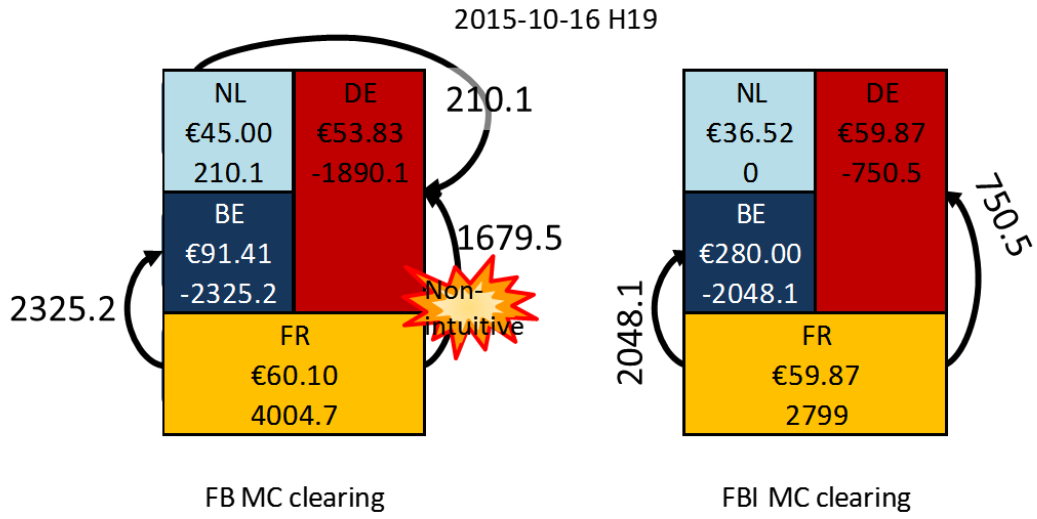

Figure 5.1-1: Example 1 on outcomes of prices using the intuitivity patch

Example 2: 07 November 2016, hour 19. In Flow Based Plain mode, DE/AT/LU (71.34 €/MWh) exports to NL (43.48 €/MWh), which is a non-intuitive flow. The Flow Based Intuitive mode solves this, by creating a price convergence between DE/AT/LU and NL, so they can jointly export to BE and FR. The flow from DE/AT/LU to NL is reduced, and this in consequence also limits the flow from DE/AT/LU to FR. In this specific situation, GB import is now reduced, letting the FR price decrease in FBI. Although within CWE the FR imports decrease, this is offset by the reduction in export to GB.

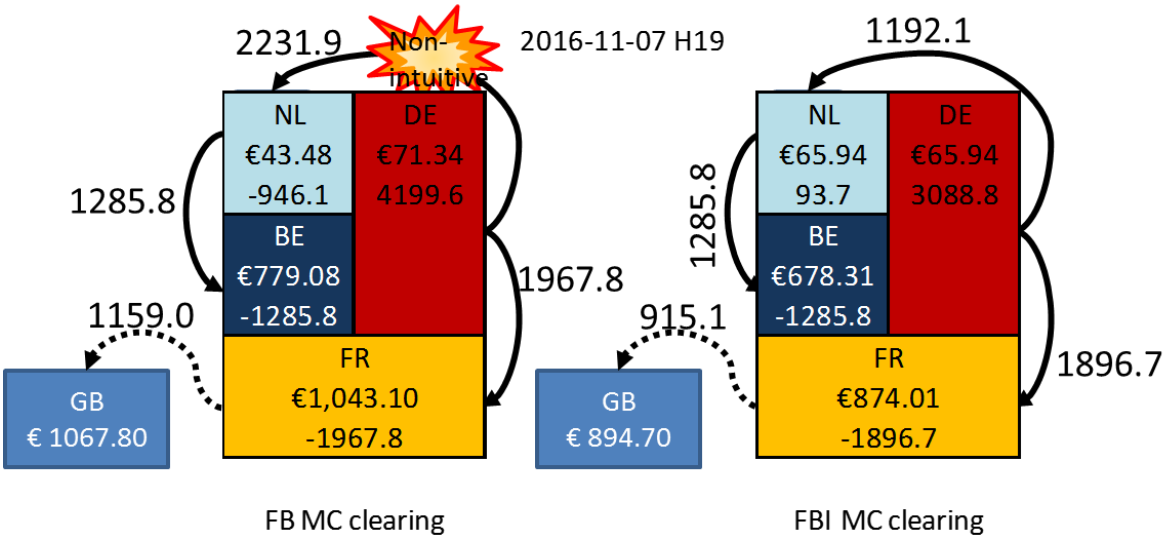

Figure 5.1-2 : Example 2 on outcomes of prices using the intuitivity patch

5.2 High price spike

This section focusses on the high price spike day of 11th of November 2018 where significant prices have been reached. The timestamp has been chosen as it is the biggest difference between FBP and FBI after the DE-AT split. The Figure 5.2-1 shows the hourly prices on Nov 5th 2018

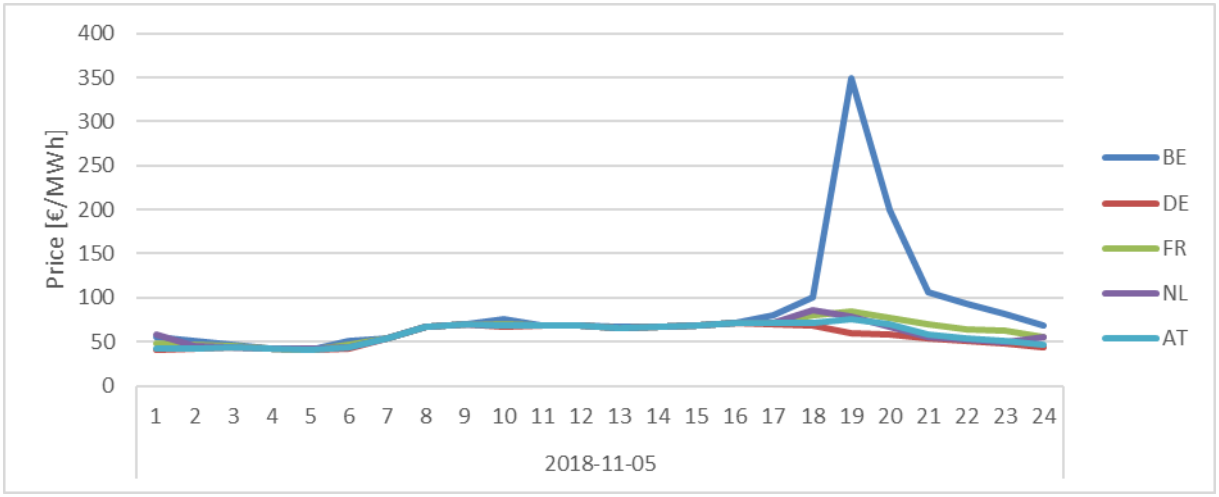

Figure 5.2-1: Hourly prices per hub

Indicator: WELFARE

The Figure 5.2-2 shows the difference in welfare between FBP and FBI. FBP results in a significant shift of producer surplus to consumer surplus in Belgium, overall the welfare in Belgium increases. The overall bidding zone welfare increased as well for each hub with an overall increase of about 1 Mio. €.
Bidding Zone welfare increase:

- AT: 17.982 €

- BE: 958.798 €
- DE: 8.430 €
- FR: 30.108 €
- NL: 5.871 €

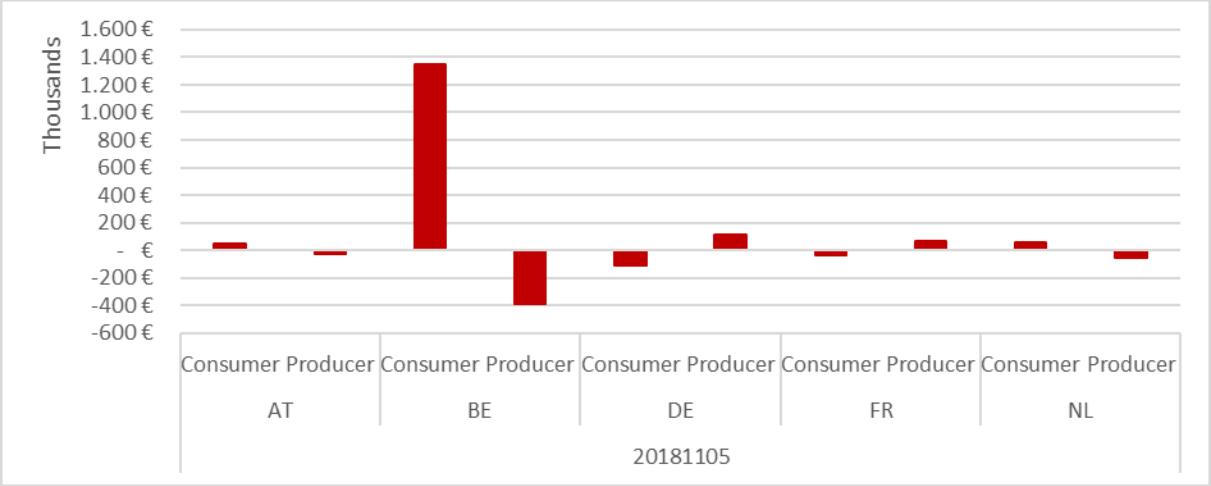

Figure 5.2-2: Welfare changes per hub

Indicator: PRICES

When looking at the price difference between the FBP and FBI results in Table 5.2-3, it is clear how these are linked with the change in welfare. FBP reduced the prices in Belgium with a maximum of 201 €/MWh. The largest deviation for the other CWE hubs was limited to a reduction of price in The Netherlands and Austria of respectively 14.36 €/MWh and 11.89 €/MWh and an increase of 5.03 €/MWh and 3.01 €/MWh in Germany and France.

	BE	DE	FR	NL	AT
Maximum price difference [€/MWh]	5,24	5,03	3,01	0,54	0,94
Minimum price difference [€/MWh]	-201	-1,3	-0.49	-14,36	-11,89

Table 5.2-3: Maximum and minimum price differences between FBP and FBI per bidding zone in CWE

Indicator: Net Positions

FBP allowed Belgium to import 24 MW more on average and 240 MW more on the 19th hour of the day. To allow this increase in import, French and German export increased more than respectively 1.3 GW and 800 MW. On the other hand, Austria imported up to 1.6 GW and the Netherlands slightly import more.

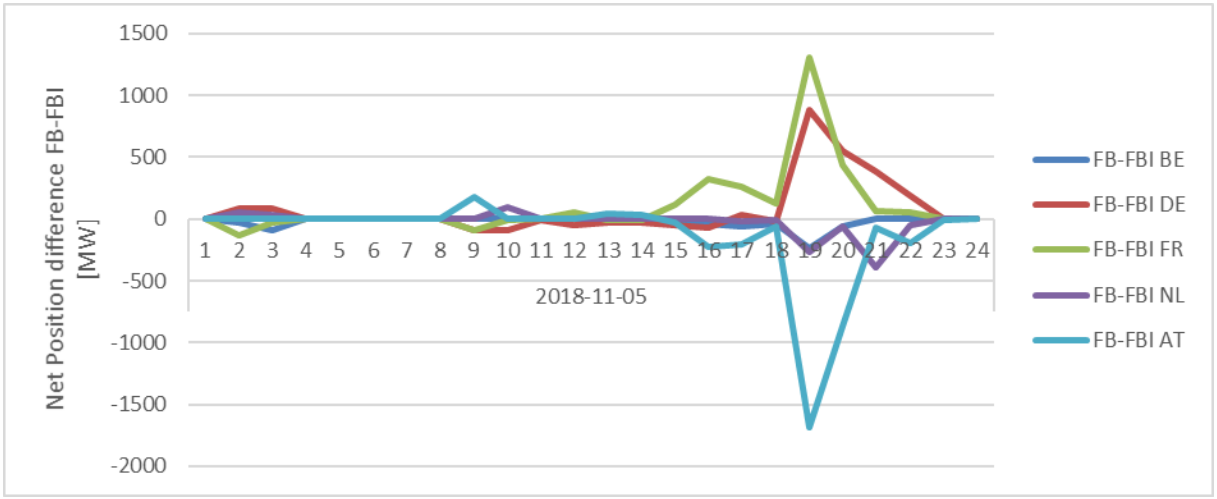

Figure 5.2-4: Hourly net position difference

Indicator: Total volume executed

During hours 19th and 20th, Belgium and The Netherlands imported an additional 306MWh and 329MWh while Austria imported an additional 2551MWh. Germany and France exported additional 1433MWh and 1748MWh.

5.3 Low price spike

The analysis of a low price spike is similar to the one presented in previous report. Indeed, there was not a more relevant low price spike to analyze.

This section focusses on the low price spike day of 8th of May 2016 where negative prices have been reached.

Welfare

Observations:

The Figure 5.3-1 shows the difference in welfare between FBP and FBI. For 8th of May 2016 the FBP mode mainly impacted BE results and more largely DE/AT/LUX ones. Under FBP, we can observe a significant shift of surplus from DE/AT/LUX consumers towards DE/AT/LUX producers and to a lesser extend a shift of surplus from BE producers towards BE consumers. The total welfare increase under FBP is less significant than for the high price spike days and amounts 0.29 Mio. €.

CWE Surplus and distribution per seller/buyer and per market

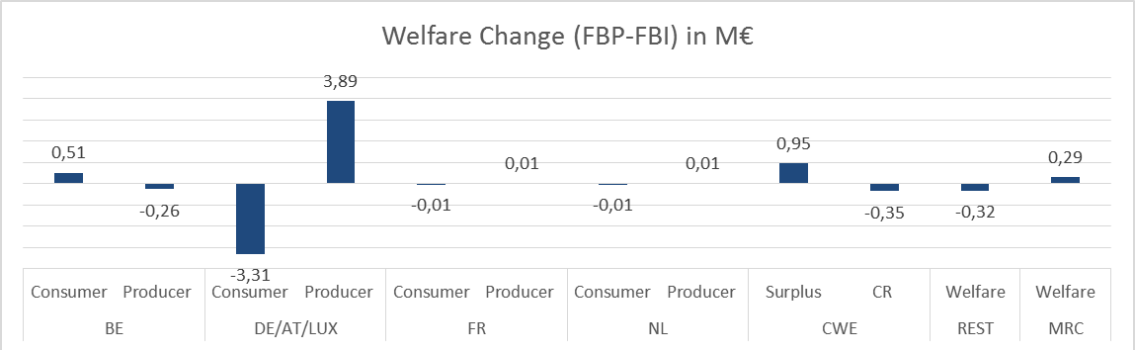

Figure 5.3-1: Distribution of welfare (producer and consumer surplus and CR) on the 08/05/2016

Indicator: PRICES

Observations:

Figure 5.3-2 illustrates the price differences between FBP and FBI in CWE. Figure 5.3-3 shows DE/AT/LUX and BE prices under FBP and FBI modes. On both figures we retrieve the hours for which the intuitive patch has been activated. As for welfare indicators, the FBP mode mainly impacted DE/AT/LUX and BE prices. On the other markets, the impact on prices is very limited. FBP would have increased DE/AT/LUX prices (but would remained negative) and have reduced BE prices (to deeply negative value on some hours). As decreasing prices are favorable to consumers whereas increasing prices are favorable to producers, the price changes explain the changes observed in welfare.

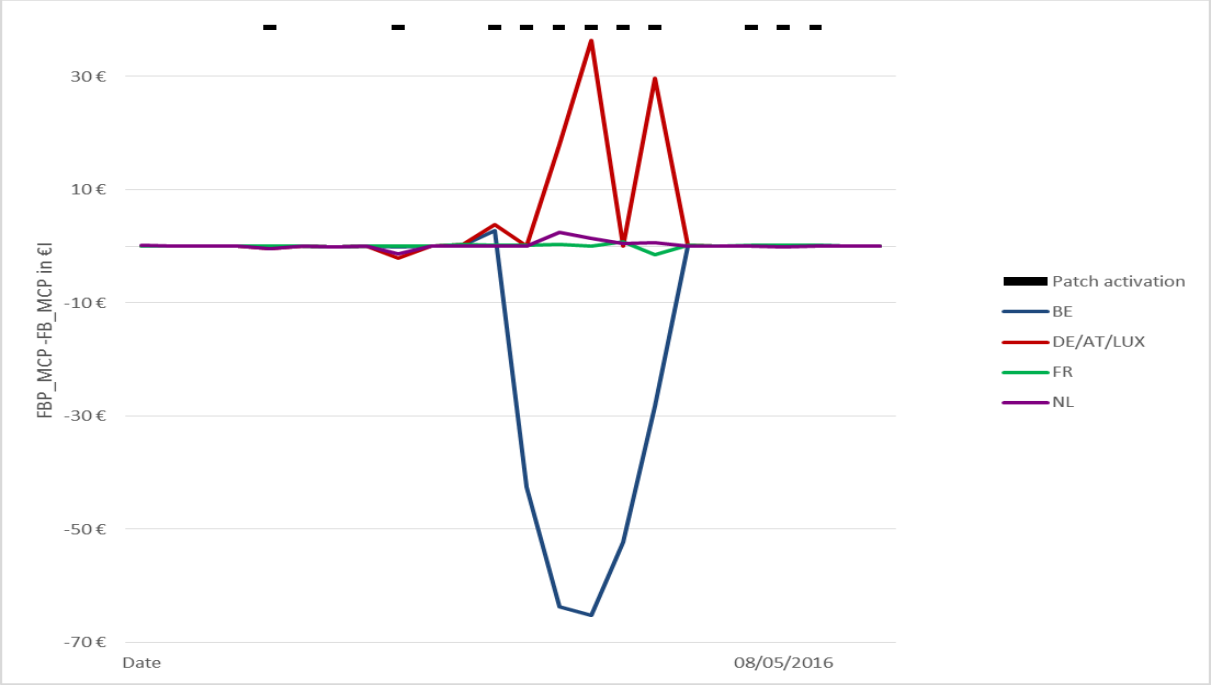

Figure 5.3-2: Price differences (FBP-FBI) on the 08/05/2016

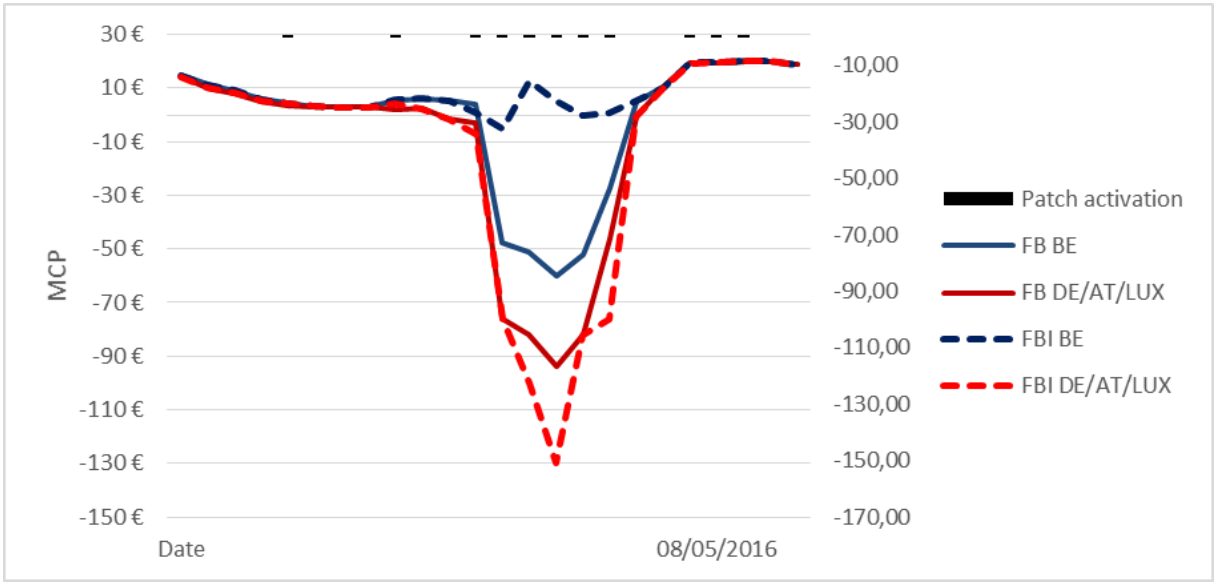

Figure 5.3-3: DE/AT/LU- and BE prices under FBP and FBI modes on the 08/05/2016

Indicator: Net Positions

Figure 5.3-4 shows the net positions of DE/AT/LUX and BE under FBP and FBI modes. Table 5.3-5 reports the total net positions (sum of the hourly net positions) in CWE.

The main differences between FBP and FBI occur on hours 12-17 where the intuitive patch has prevented DE/AT/LU to export and BE to import because this would have induced non-intuitive flows.

On hour 15 for instance, to allow the FBP solution, BE, which has a negative price, imports from FR non-intuitively. FBI solves this, preventing BE imports. The consequence is that DE exports are reduced, aggravating the DE negative prices: price decreases from 94 € to 130 €.

The Table 5.3-5 shows that the total exchange would have been higher under FBP.

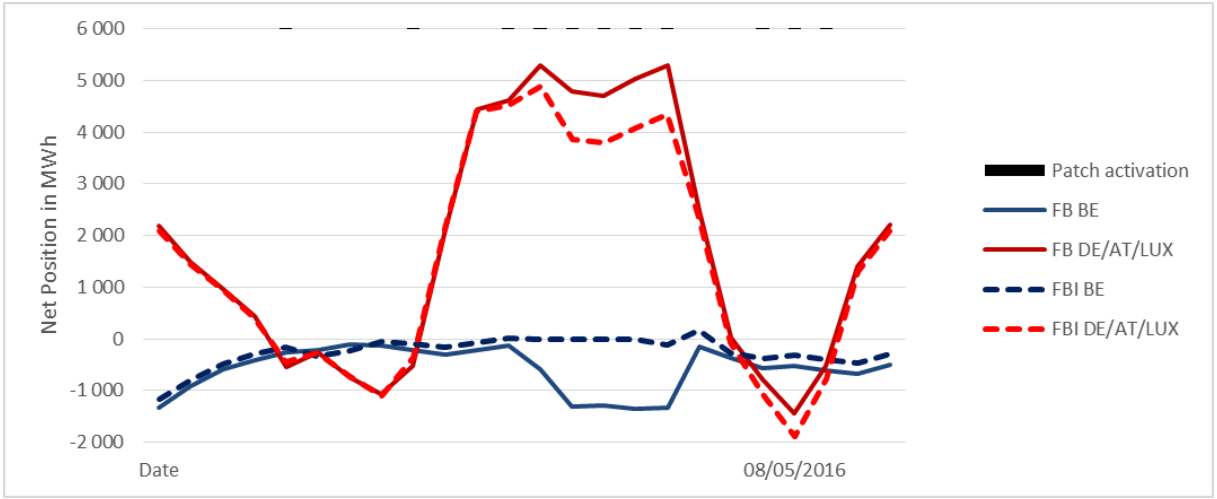

Figure 5.3-4: DE/AT/LU and BE Net positions under FBP and FBI modes on the 08/05/2016

Net position	BE	DE/AT/LUX	FR	NL
FBP	-14060,8	41609,8	42732,6	-70281,5
FBI	-5908	35895,6	41781,9	-71769,4
FBP_NP-FBI_NP	More import of 8152 MW	More export of 5714 MW	More export of 950 MW	Less import of 1487 MW

Table 5.3-5: Total net position of CWE markets on the 08/05/2016

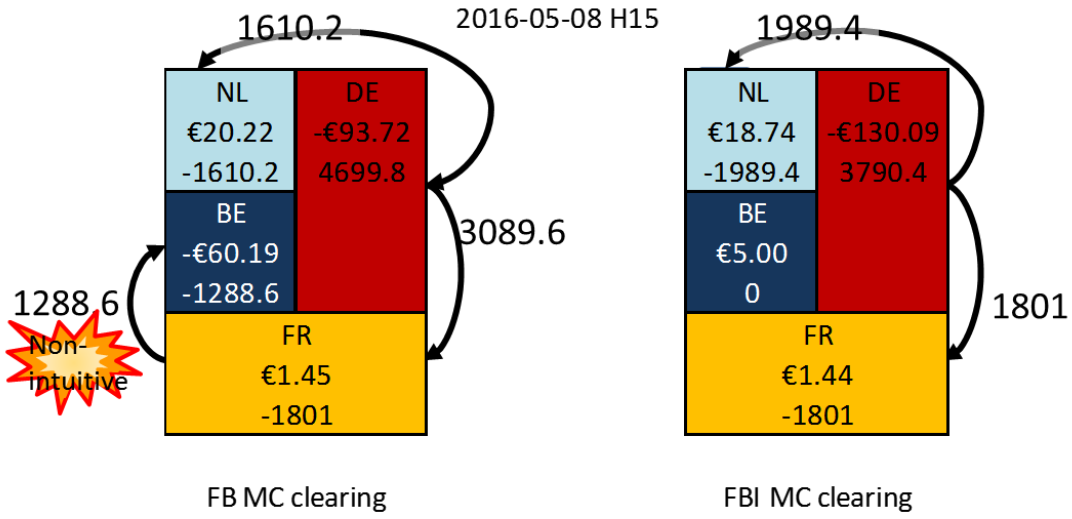

Figure 5.3-6: focus on FBP and FBI results on hour 15

Indicator: Total volume executed

The Table 5.3-7 presents the total volume executed under FBP and FBI mode in CWE and shows that FBP would have increased the total volume executed in CWE.

MCV	BE	DE/AT/LUX	FR	NL	CWE
FBP	60619	1512143	490109	131879	2194750
FBI	57025	1509191	491621	132498	2190335
FBP_MCV-FBI_MCV	3594	2952	-1512	-619	4415

Table 5.3-7: Total volume executed in CWE

6. Impact on Intraday timeframe

The impact on intraday timeframe was not revised compared with previous report. Indeed, same conclusions are to be expected.

As a general principle, Flow Based Plain will make more extensive use of available capacities in the Day Ahead timeframe. Therefore, it is expected that in non-intuitive situations, the resulting initial ID ATC capacities will be smaller in Flow Based Plain mode.

Figure 6-1 indicates the number of hours with zero intraday capacity for non-intuitive hours in Flow Based Plain mode (red) in comparison to the same selection of hours in Flow Based Intuitive mode (blue). As expected, the increase in zero intraday capacity is evident.[5]

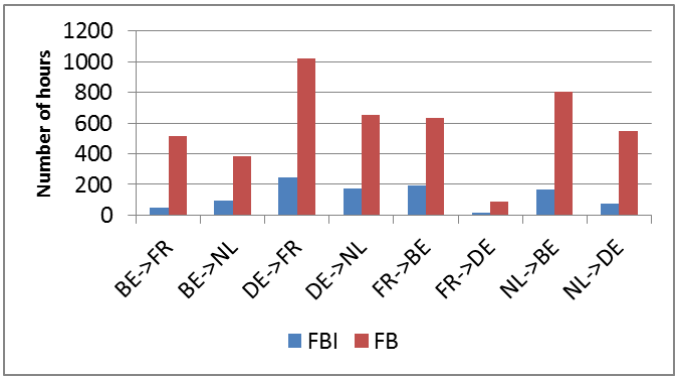

Figure 6-1 : Number of hours with zero intraday capacitity for non- intuitive hours

However, when there is capacity available (so non-zero intraday capacity), the average volume of this capacity is slightly higher under FB Plain.

[5] This quantitative assessment mainly aims at illustrating the underlying general principle of the impact of FB Intuitive and FB Plain modes on ID ATC calculation. Therefore the figures in this section of the report are still based on the data of the original 2017 study and thus do not include the DE-AT border; however they have been checked and confirmed for the 2020 update of this report.

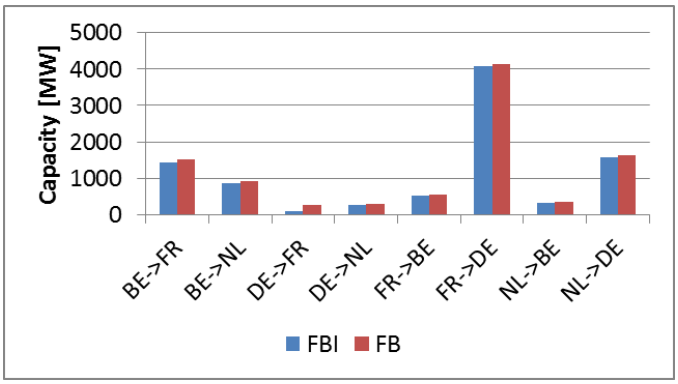

Figure 6-2 : Average volume of intraday capacity when capacity is above zero

Proxy of welfare gain in ID (DA price spread multiplied by ID ATC)

Since there is no commonly agreed methodology for the quantification of the monetary value of Intraday capacity, this report is limited to a basic proxy for the welfare effects on the Intraday market. The value of the remaining initial Intraday capacity is roughly estimated by multiplying the remaining capacity times the DA market spread. However, there are multiple drivers which can influence the result of this indicator:

- Price: FBP will typically reduce the market spread between all CWE hubs by allowing more exchanges in non-intuitive situations;
- Volume: FBP will typically increase the amount of zero ID ATC capacity and non-zero capacity slightly increases.

For the original 2017 report, the welfare loss due to lower capacities in the Intraday market under FBP has been calculated as 800,000 € for a period of one year after CWE Flow Based MC go-live. This is equivalent to a welfare loss of 30% compared to Flow Based Intuitive mode.

7. New developments

7.1 Upcoming changes

The following section will analyze the difference between FBI and FBP looking at the upcoming changes (ALEGrO & requirements resulting from Regulation (EU) 2019/943).

ALEGrO

This report showed that FBI configuration induces higher running time for Euphemia than the FBP configuration. As highlighted during the DE-AT split, the performance of the algorithm is becoming a concern due to the increasing number of hubs and the difficulty encountered with the Virtual Branches. The integration of ALEGrO increases the complexity of the market coupling algorithm leading to an increase of the Time to First Solution as you can see on Figure 7.1-1.

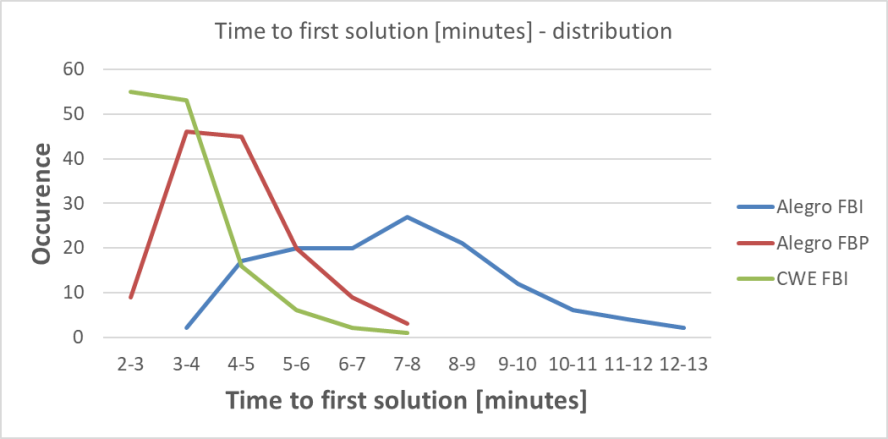

Figure 7.1-1 : Time to First Solution - Impact of ALEGrO & FBP

Throughout this report, it has been demonstrated that FBI induces a decrease of welfare. Furthermore, this behavior rises with an increase of the number of hubs. Indeed, the more dimensions you have, the more the cut from the patch is significant. Therefore, the use of ALEGrO will be decreased due to the application of the intuitiveness patch[6]. Capacity allocation has been performed for 5 months of data with ALEGrO. The results can be found in Figure 7.1-2.

[6] Similar impact is expected in the Core region.

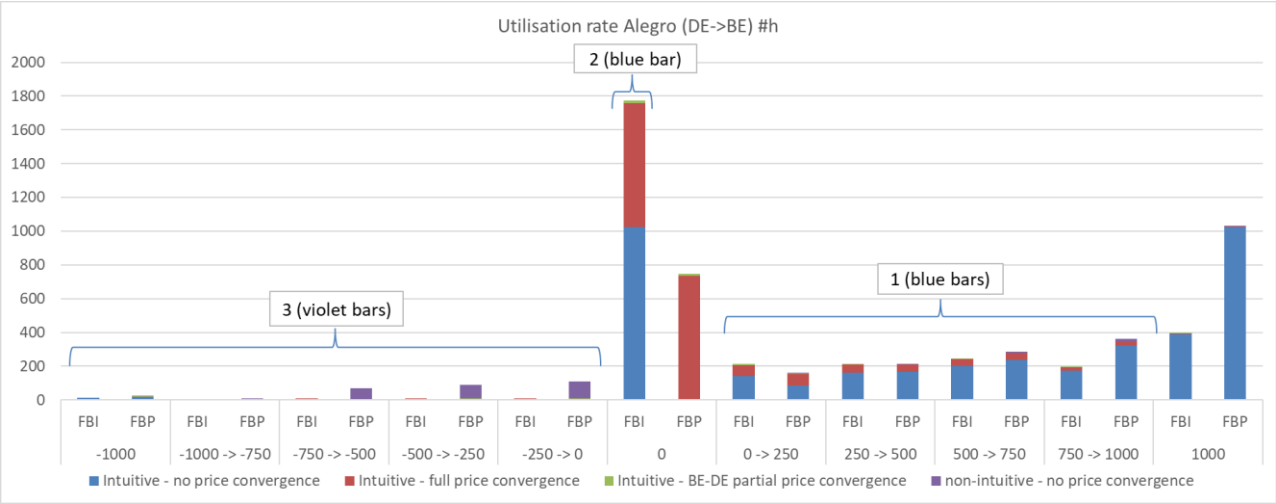

Figure 7.1-2 : Distribution of utilization of ALEGrO under FBP or FBI

Three behaviors can be drawn from the first capacity allocation with ALEGrO:

1. In certain situations there is no full price convergence between BE and DE and the interconnector is not fully used. This is a clear example of Flow Factor Competition and the application of Evolved Flow Based. In such case, an exchange on ALEGrO generates less welfare than an AC exchange in CWE (either due to lower price difference or higher impact on congestion), and hence the AC exchange is preferred.
2. Activation of the intuitiveness patch increases significantly the cases where the flow on ALEGrO are set to zero even when there is a price difference between BE and DE.
3. Flow Based Plain allows non-intuitive flows over ALEGrO. ALEGrO would be used to relieve congestion in CWE and allow for increased AC exchanges

As a conclusion, the cable is significantly more used when using FBP. The application of FBI could double the time when there is no flow on the cable.

Requirements resulting from Regulation (EU) 2019/943: The CEP 70 requirement is one of the big change affecting the market coupling in the future years. It could decrease the number of application of the intuitiveness patch as more timestamps with price convergence could be expected. However, the other observations made in this report are not affected .

7.2 Negative congestion income under FBP with adequacy patch

The Flow Based Intuitive mode, by definition, ensures that the decomposition of net positions into bilateral flows always leads to flows from low price to high price areas only. Consequently, the congestion income from Day Ahead MC that is generated on each border is positive (or zero in the case of price convergence). In contrast to that, flows from high price to low price areas are possible in Flow Based Plain mode. However, the total congestion income for the whole Flow Based is still non-

negative.[7] Even though negative congestion income can occur on individual borders, the design of the Congestion Income Distribution methodology that is applied in CWE ensures that no individual TSO has to pay a negative congestion income.[8]

Still, there is one situation in which a negative total congestion income is possible. This can occur in an extreme event when the price cap of 3000 €/MWh is reached in a bidding zone. If total demand still exceeds total supply in that bidding zone, the Adequacy Patch is triggered, and the Market Coupling algorithm (Euphemia) internally attributes a much higher price to that bidding zone (e.g. 1,000,000 €/MWh), which helps to attract additional flows to this bidding zone and thus to prevent a curtailment situation. These additional flows are triggered by this artificially increased price, as flows to other areas (where there is no artificially increased price) are outperformed. Once the net positions are determined, the price is capped back again to 3000 €/MWh, and the congestion income is also collected based on this capped price. This however can lead to negative total congestion income.

A simplified example can be described as follows: Assume there are three bidding zones (A, B and C). Zone A has a buy position of 10 MW, and since it is threatened by curtailment, the Adequacy Patch is triggered and the algorithm internally attributes a price of 1,000,000 € to this zone. Zone B has a buy position of 100 MW at -500 € (oversupply), and zone C has a sell position of 100 MW at 2000 €. The only constraint in this example has a RAM of 4 MW, and PTDFs are 0.0 for zone A, 0.6 for zone B, and 0.5 for zone C, leading to the constraint of $0.6 \cdot NP_B + 0.5 \cdot NP_C \leq 4$.

Under Flow Based Intuitive, only flows from low price to high price zones are possible, so a flow from zone C (2000 €) to zone B (-500 €) can be excluded. Consequently, the only flow will go from zone C to zone A, leading to the net positions of $NP_A = -8$, $NP_B = 0$ and $NP_C = 8$ (any higher net position would violate the allocation constraint). The price in zone A is then capped to 3000 € in a subsequent step, and the resulting congestion income collected from CCPs is $-\{(-8 \cdot 3000\ €) + (8 \cdot 2000\ €)\} = 8000€$.

Under Flow Based Plain, the optimal solution would result in a slightly different outcome. Now, a non-intuitive flow from zone C (2000 €) to zone B (-500 €) is possible and brings a relief to the allocation constraint, and the welfare-maximizing algorithm would now allocate the net positions $NP_A = -10$, $NP_B = -10$ and $NP_C = 20$. Again, the price in zone A is capped from its artificial internal value of 1,000,000 € to the regular price cap of 3000 €. However, it is exactly this capping of the price in zone A which leads to a negative total congestion income of $-\{(-10 \cdot 3000\ €) + (-10 \cdot (-500\ €)) + (20 \cdot 2000\ €)\} = -15{,}000\ €$.[9] Additionally, remuneration costs of Long Term Transmission Rights need to be added to this amount.

[7] For a mathematical proof of the non-negativity, please refer to annex 1.3 of the *Congestion income allocation under Flow-Based Market Coupling* approval document

[8] This is ensured by using absolute values as input parameter, and by rescaling the individual incomes such that the total amount of congestion income in the Flow Based area is distributed amongst the individual TSOs.

[9] Note that the overall congestion income would have been positive when calculated with the internal value of 1,000,000 € for zone A.

This simple example shows that a negative congestion income is possible in principle. However, it should be noted that the adequacy patch has never been triggered since CWE Flow Based MC go-live, and even during price spike events the actual market clearing prices still remained well below the critical threshold. Given this lack of historical data, an assessment of the likelihood of negative congestion income situations is not trivial. It is clear however that the possibility of an adequacy patch activation cannot be completely excluded for the future, especially against the background of future changes in generation capacities in CWE and CCR Core bidding zones, even though local scarcity situations might also be mitigated by growing cross-zonal trading capacities.

Against this background, two general alternatives can be identified. One option is to completely discontinue the adequacy patch, which for obvious reasons is not a preferred solution. The alternative option is to maintain the patch, and - in the extreme event of its activation – to allocate the associated costs from negative congestion income to the TSO(s) of the bidding zone which triggered the adequacy patch activation[10]. As the risk of an activation of the adequacy patch is apparently not controlled by TSOs, a local cost recovery mechanism is a prerequisite for this option.[11]

7.3 Time needed and costs of a switch to Flow Based Plain

The switch from Flow Based Intuitive to Flow Based Plain is a configurational change in the market coupling algorithm, which does not lead to further operational changes and thus would not require detailed preparations neither on TSOs' nor on NEMOs' side. Moreover, the lead-time would mainly be determined by transparency considerations, such that market parties have sufficient time to prepare for the slightly changed market setup. A lead time of four to six weeks appears appropriate. However, due to the heavy roadmap in terms of evolution in the DA market coupling, synergies with other changes would be sought in order not to multiply the number of go-lives and the related testing required. To ensure the coordination with other projects and the availability of resources, the switch shall be fixed in due time. As indication, 6 months in advance allows for a reasonable lead time.

However, in case the adequacy patch is maintained under Flow Based Plain mode, a change on short notice would need clear regulatory guarantees regarding cost recovery in case of negative congestion income. These however need to be safeguarded by amendments to relevant CWE and all TSO methodologies. From past experience, this process takes approximately 6 months (3 months for the preparation on TSOs' side and for alignment with NRAs, and then 3 months for NRAs' approval), and can be sped up on TSOs' side if needed. The impact on operational contracts would need to be further

[10] A similar situation is already in place for the case of a decoupling, as experienced on June 18th, 2019. An overall negative congestion may occur and a cost recovery mechanism has been agreed for TSOs.

[11] As the possibility of negative congestion income is currently not regulated in the relevant methodologies, this second option would most probably require the amendments of the CWE Congestion income allocation under Flow-Based Market Coupling approval document, and the Congestion Income Distribution methodology in accordance with Art 73 of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a Guideline in Capacity Allocation and Congestion Management, and possibly other relevant methodologies.

assessed but it should be possible to accommodate required changes in parallel of the regulatory process.

Project parties expect limited implementation costs as the changes are mostly configuration changes (i.e. change of Euphemia configuration). Moreover, there are some accompanying tasks that are likely to trigger certain costs (test run, communication to market participants etc.).

8. Main conclusion and conclusion on the matters raised by NRAs

Conclusion after four years of FBI operation

The conclusions drawn after analyzing four years of FBI operations are comparable to the conclusions stated in the 2017 report. Compared to the one-year analysis of the 2017 report (with data from May 2015 to May 2016) the recent analysis shows a slightly higher occurrence of the activation of the intuitive patch than in the 2017 analysis. FBP calculation mode still slightly outperforms FBI calculation mode in following indicators: welfare, total daily exchanges, PRB number, total MCV and time to first solution (algorithm performance).

On exceptional market coupling conditions (high price spike and low price spike), the produced indicators reflect more contrast and most indicators on FBP mode still outperform indicators on FBI mode. In addition, the indicators show that FBP mode compared to FBI mode could be more beneficial to small markets (BE) and large markets (DE) during exceptional market coupling conditions.

Distribution of welfare, in particular between small and large bidding zones

The welfare loss related to the application of FBI over the investigated period is 26 Mio. € for the whole MRC region, or 18 k€ per day on average or 0.0002 % in relation to the welfare that would have been generated under FBP. All CWE bidding zones would have observed higher market surpluses under FBP, with the highest increase for the Belgium market before, and German, French and Belgium markets after the DE-AT-split. In addition, the analysis shows higher total welfare losses for FBP for the post-split period - on MRC and CWE level. Before the split the gain in markets loss has its origin in decreasing consumer surplus, except for the German bidding zone, were the producer surplus is shrinking. After the split, the welfare loss is more evenly distributed between costumer and producer surplus: The welfare loss in Germany and France origins from loss in producer surplus, while the welfare loss in Belgium, the Netherlands and Austria is lost surplus from costumers.

The welfare loss is unevenly distributed between bidding zones. While for most days the differences between FBP and FBI are small (in terms of prices and volumes), some specific days are illustrating that import differences occur. In this report an analysis of high and low price spikes was performed to show the influence of price spikes on different indicators. In one example and for one bidding zone, a price difference of more than 200 € 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 zone were not so significantly affected, leading to important price differentials between bidding zone. 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.

ALEGrO

The analysis in this report addressed the reduced utilization of the grid, especially for the new interconnector between Germany and Belgium: the ALEGrO interconnector. This HVDC interconnector 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 Euphemia in order to maximize the welfare. FBI leads to set this flow to zero in 33.27 % more cases than under FBP, even though in many of these cases there is still a price difference and therefore exchange would be efficient. One may find counter-intuitive that the flow on a controllable HVDC interconnector is set to zero even when there is price difference.

Possible negative congestion income with FBP

Non-intuitive situation may raise questions on how to deal with negative congestion rents. This concern is mostly covered with the current congestion income methodology. When the overall congestion income remains positive, a socialization mechanism can allow to redistribute the congestion income among TSOs and to avoid a pay out by TSOs. There is one exception: Triggering the adequacy patch could lead in some cases to a congestion income that would be overall negative.

Two possible solutions are highlighted : 1.) the possibility of a pay-out by TSOs in case of negative congestion rent is accepted when it occurs, or 2.) the adequacy patch is removed. The adequacy patch has never been triggered in CWE and even if it is triggered, it does not necessarily lead to an overall negative congestion income. Therefore solution 1.) would be a very rare case.

Impact on intraday timeframe (from previous report)

Welfare should be optimized for the whole time frame ranging from intraday to years ahead. Specifically, there is a risk that the gain of FBP versus FBI could be traded away in the intraday timeframe.

It can be concluded that there is an impact of FBP on the intraday market. Since FBP will make better use of the available Flow-Based domain by allowing non intuitive market situations, the initial ID capacity will be lower. Furthermore, with the help of a welfare proxy, it seems that this reduction in initial ID capacity leads to a reduction of possible welfare in the ID welfare. However, this effect is limited due to limited available initial ID capacity under FBP and FBI and the reduction of price spread under FBP.

Security of supply (from previous report)

Bidding zones can be dependent on import to ensure security of supply on the short term, i.e. avoiding curtailment in the DA market. While TSOs make available a certain FB domain, from which maximum combined import values can be derived, the application of the intuitiveness patch could in reality limit the maximum import of certain hubs. If under certain circumstances counter intuitive flows are required to allow a Bidding Zone to reach its maximum import, then these exchanges will be limited by the intuitiveness patch. This behaviour was noted for Belgium during some of the peak days.