Public consultation document for the final design and implementation of the CWE Flow-Based Market Coupling

Brussels, 2nd May 2013 (Start of the consultation)

Contents

1 Introduction

In the MEMORANDUM OF UNDERSTANDING OF THE PENTALATERAL ENERGY FORUM ON MARKET COUPLING AND SECURITY OF SUPPLY IN CENTRAL WESTERN EUROPE (MoU), signed in June 2007, the signatories have agreed upon the design and implementation of a Flow-Based Market Coupling (FBMC) in the CWE region.

In November 2010 an ATC Based Market Coupling was successfully launched as an important interim-step towards CWE FBMC. More than two years of operational results have proven the increased market integration of the day-ahead spot-markets, and indicate remaining potential of FBMC for even more efficient usage of cross border capacity allowing an increase in welfare and better price convergence.

Since the launch of the ATC Based Market Coupling, the project parties have made important progress on the further design, testing, internal and external parallel run of flow-based capacity calculation and FBMC.

This document reflects the result of the work of Power Exchanges (PXs) and Transmission System Operators (TSOs) experts in line with the initial project targets, the ACER Framework Guidelines on Capacity Allocation & Congestion Management and the current respective draft network code, next to other relevant draft network codes and guidelines.

It is based on the input received through extensive dialogue with stakeholders: meetings of the Pentalateral Energy Forum (PLEF) with all stakeholders, Expert Meetings with the CWE National Regulatory Authorities (NRAs), public Market Forums, ongoing flow-based User Group-meetings since 2011 and the CEWE (Central East West Europe)-coordination group with CEE (Central Eastern Europe) FB.

This **document** is issued for formal public consultation on the CWE FBMC solution with all stakeholders, who are invited to submit their comments via the transparent web based consultation tool until 30th of June 2013 at 00:00. Only comments using this communication channel can be taken into account for the consultation. All answers and comments submitted via the online survey will be published.

After due consideration and evaluation of all comments, the Project Partners will formally request approval for the CWE FB MC solution from the CWE NRAs. The next step after this regulatory approval will be the preparation for the launch of the CWE FBMC in production.

Technical guidance

For participating in the public consultation Market Parties (MPs) have to register. For details see the respective CASC-website http://www.casc.eu/en/Resource-center/CWE-Flow-Based-MC/Public-Consultation

During the CWE FBMC project, the project parties informed market parties about the project and interim-results. The following documents and publications (available together with this consultation document on the CASC-website) can further support market parties to better understand and to create positions on different issues:

CWE Enhanced FBMC feasibility report (October 2011)

CWE Enhanced Flow-Based MC intuitiveness report (October 2012)

Project Reports in the framework of the THE PENTALATERAL ENERGY FORUM ON MARKET COUPLING AND SECURITY OF SUPPLY (Brussels March 2011, Paris October 2011, Brussels March 2012. Brussels April 2013)

Presentations of the Market Forums (CWE FBMC forum, Amsterdam 1st June 2011; NWE forum with CWE FBMC presentation, 26th September 2012; CWE FBMC forum, Düsseldorf, 7th March 2013)

Ongoing monthly publications of the Social Welfare report

Questions and Answers document (December 2011)

Questions & Answers Forum on the CASC-website, started in February 2013

Publications of economic and capacity parameters

2 Coordinated Flow-Based capacity domain calculation

2.1. Input data

2.1.1. Maximum current on a Critical Branch (Imax)

The maximum allowable current (Imax) is the physical limit of a critical branch (CB) determined by each TSO in line with its operational criteria. Imax is the physical (thermal) limit of the CB in Ampere, except when a relay setting imposes to be more specific for the temporary overload allowed for a particular critical branch-critical outage (CBCO).

Both these values 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 Critical Outage (CO, cf. 2.1.5), by the Flow Reliability Margin (FRM, cf. 2.1.8) and Final Adjustment Value (FAV, cf. 2.1.3).

2.1.2. Maximum allowable power flow (Fmax)

The value Fmax describes the maximum allowable power flow on a CBCO 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 CB. The value for cos(φ) is set to 1, and U is a fixed value for each CB and is set to the reference voltage (e.g. 225kV or 400kV) for this CB.

2.1.3. Final Adjustment Value (FAV)

With the Final Adjustment Value (FAV), operational skills and experience that cannot be introduced into the FB-system can find a way into the FB-approach by increasing or decreasing the remaining available margin (RAM) on a CB for very specific reasons which are described below. Positive values of FAV in MW reduce the available margin on a CB 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 FB 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 FB domain, leading to the need to reduce the margin on one or more CBs for system security reasons. The overload detected on a CB during the verification phase is the value which will be put in FAV for this CB in order to eliminate the risk of overload on the particular CB.

Any usage of FAV shall be duly elaborated and reported by the concerned TSOs to the other CWE-TSOs.

2.1.4. D2CF Files, reference 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:

- Net exchange programs of the reference day. This is the reference program for the calculations. The reference day is:
  - for Tuesday to Friday: D-1 (most recent program)
  - for Monday: D-3 (previous Friday)
  - For Saturday and Sunday: D-7 (previous week)
  - For bank holidays and specific outages, a reference day will be determined and fixed in a separate calendar approved by all CWE TSOs
- the exchange program on DC cables for the same reference day
- 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
- best estimation for the forecasted 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 reference program, and in line with the expected total generation.

The PST tap position usage in D-2 coordination is currently discussed amongst TSOs, whereby the target is the neutral position but well justified exceptions should be allowed. Methodology of PST tap positions will be included in the final approval package for regulators.

For each timestamp, the local D2CF file has to be balanced in terms of production and consumption, in coherence with the reference program. Any residual imbalance will be adjusted by each TSO by adjusting production and/or load until balance is achieved.

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 (cf. 2.2.1).

2.1.5. CBCO-selection

A Critical Branch (CB) is a network element, significantly impacted by CWE cross-border trade, which is monitored under certain operational conditions, the so-called Critical Outages (CO). The CBCOs (Critical Branches/Critical Outages) are determined by each CWE TSO for its own network according to agreed rules, described below. The CBs 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).

Critical Outages (CO) can be defined for all CBs. CO 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 k elements.

CB selection process

The assessment of critical branches is based on the impact of CWE cross-border trade on the network elements and based on operational experience.

A CB is considered to be significantly impacted by CWE cross-border trade, if its maximum CWE zone-to-zone PTDF (Power Transfer Distribution Factor) is larger than a fixed threshold value.

CWE FB experts have agreed to a threshold value of 5%.

Practically it means that there is at least one set of two bidding zones in CWE for which a 1 MW exchange creates **an induced flow bigger than 0,05 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 FB capacity calculation.

In other words, a set of PTDF is associated to every CBCO after the initial FB parameter calculation which gives the influence of the net position of any bidding zone on the CBCO. If the PTDF = 0.1, this means the concerned hub has 10% influence on the CBCO, meaning that 1 MW in change of net position of the hub leads to 0.1 MW change in flow on the CBCO.

For each CBCO the following sensitivity value is calculated:

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

If Sensitivity is above the threshold, then the CBCO is said to be significant for CWE trade.

A pre-processing is performed during the FB parameter calculation which will result in a warning for any CBCO which does not meet pre-defined conditions. The concerned TSO then has to decide whether to keep the CBCO or to exclude it from the CBCO file.

The general rule is to exclude any CBCO which does not meet the threshold on Sensitivity.

Exceptions on the rule are allowed: if a TSO decides to keep the CBCO in the CB file, he has to justify it to the other TSOs, furthermore it will be 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.

2.1.6. Remedial Actions

During FB 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 CB file. Each measure is connected to one CBCO combination and the FB 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
- curative 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 (cf. 2.1.3) will be used as RA.

The FB software applies these measures during the FB parameter calculation and hence determines the effect on the CBs directly. The influence of implicit RA on CBs is assessed by the TSOs upfront and taken into account via the FAV factor, which changes the available margins of the CBs to a certain amount.

Each CWE TSO defines the available RAs in its control area. As cross-border remedial action will be considered only those which have been agreed 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 FB 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 CB 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 for the application of RAs imply that the RAs described in the CB files can change during the daily FB 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[1]. This means that the NTCs will not cause overloads on CBs within the Flow Based method. TSOs try to reach this by using only internal RAs as a first

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[1] NTCs will only be available during the external parallel run period. After go-live, TSOs will use another reference FB domain – based on the experience built during the external parallel run.

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:

a) local calculation: TSOs try to cover the NTC/LTA domain using their own PSTs. If this is not sufficient, 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.

b) exchange of proposals: the proposal(s) is(are) shared between TSO for review.

c) 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. The information (if necessary an updated CB file) must be transferred to the D-1 and D processes.

PSTs available for coordination are located in Zandvliet/Vaneyck, Gronau, Diele and Meeden.

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 FB computation and the final FB computation. The PST coordination should start before midnight.

2.1.7. 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 FB 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.

GSK aims to deliver the best forecast of the impact on critical branches 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.

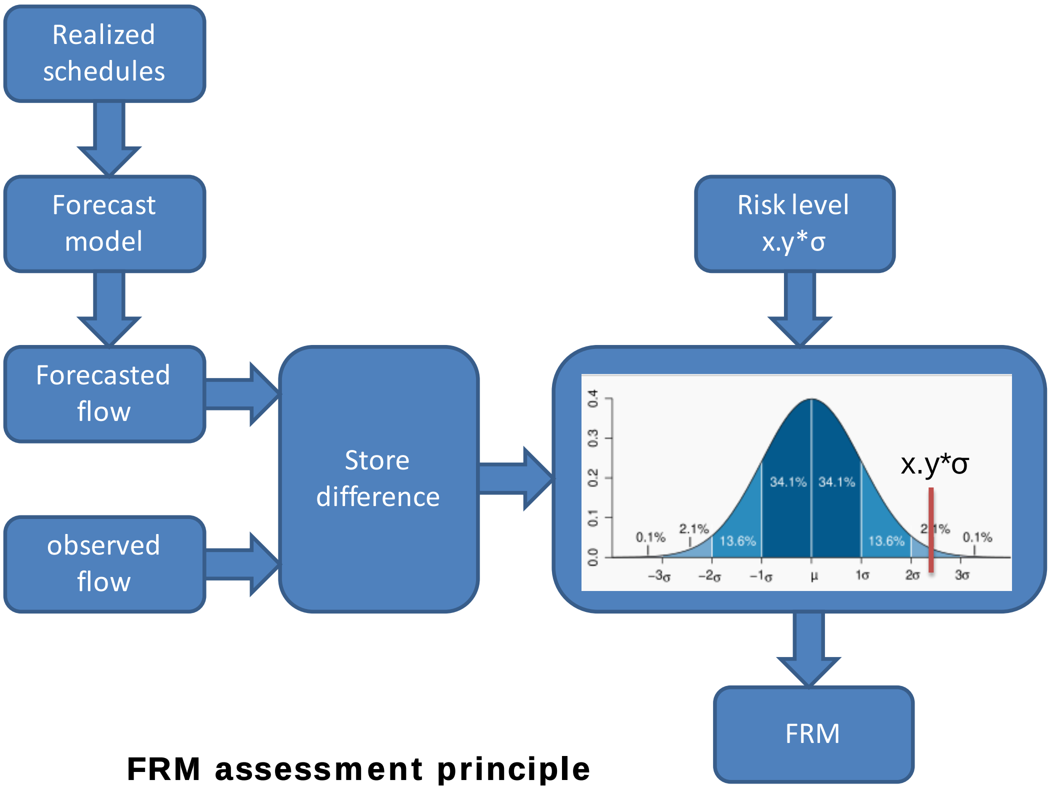
In general, the GSK includes power plants that are market driven and that are flexible in changing the electrical power output. This includes the following types of power plants: gas/oil, hydro, pumped-storage and hard-coal. TSOs will additionally use less flexible units, e.g. nuclear units, if they 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).

A more detailed methodology per TSO will be added in the final approval package for regulators.

2.1.8. 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 FB 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 branch, a Flow Reliability Margin (FRM) has to be defined, that quantifies at least how the before-mentioned uncertainty impacts the flow on the critical branch. Inevitably, the FRM reduces the remaining available margin (RAM) on the critical branches 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.



FRM assessment principle

The basic idea behind the FRM determination is to quantify the uncertainty by comparing the FB model to the observation of the corresponding timestamp in real time. More precisely, the base case, which is the basis of the FB 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 following figure. In order to be able to compare the observed flows from the snapshot with the predicted flows in a coherent way, the FB 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 predefined risk level[2], 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

[2] 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.

- 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 adjustment" before practical implementation into their CB 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 CB. 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 CB during the FRM analysis (in other words, the TSO will not adjust its FRM at any FB computation). Eventually, the operational FRM value is computed once and then becomes a fixed parameter in the CB 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.

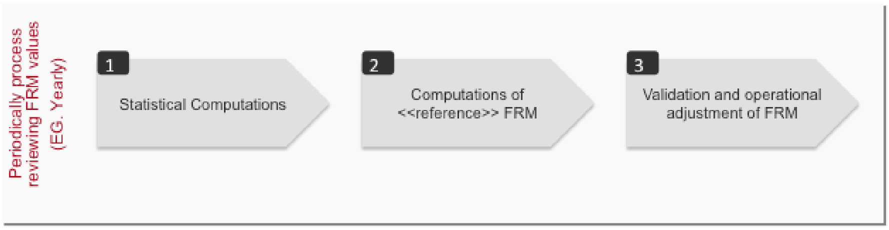
The differences between operationally adjusted and theoretical values shall be systematically monitored and justified.

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

For matter of clarification, we remind here that for each CB (or CBCO for the N-1 cases), the FRM campaign leads to one single FRM value which then will be a fixed parameter in the CB 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 to recompute 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 branches, 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 CB, and systematically justified and documented.

CWE TSOs intend a regular (probably yearly) update of the FRM values using the same principles.

2.1.9. Specific limitations not associated with Critical Branches (external constraints)

Besides electrical critical branches, other specific limitations may be necessary to guarantee a secure grid operation. These additional constraints can be justified by stability limits which are more restrictive than thermal limits, e.g. voltage stability. Import/Export limits

declared by TSO are taken into account as “special” critical branches, in order to guarantee that the market outcome does not exceed these limits.
There can be several reasons for a TSO to use external constraints. The main reasons are:
- 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 (cf. 2.2.5).

2.2. Coordinated Flow-Based Capacity Calculation Process

2.2.1. Merging

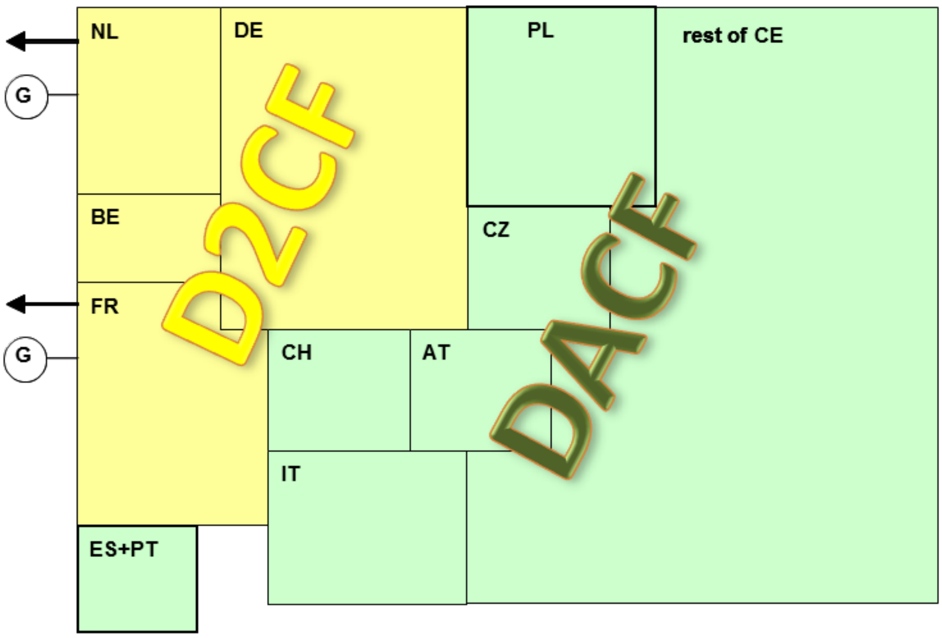
Basis for the calculation process is a model of the grid, the Common grid Model (CGM) that represents the best forecast of the corresponding hour of the execution day (day D). Due to the timeline within the process, the creation of the CGM has to be performed two-days ahead of day D. The CGM is a data 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), and 50HzT (DE)
- 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 reference exchange programs.

The DACF data sets of non-participating TSOs, corresponding to the agreed reference timestamp, are needed to take the physical influences of these grids properly into account when calculating transfers between FR-BE-NL-DE. 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:
    - o Check for format
    - o Check loadflow convergence
2. Balance check (import/export situation) according to scheduled balance of reference timestamp. 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

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

2.2.2. Pre-qualification

Before the first FB parameter calculation, every TSO checks the consistency of the applied CB-file with the forecasted grid-situation. Special attention is given to the remedial actions (RA) described in the CB-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 and coordination with adjacent TSOs.

2.2.3. Centralized Initial-FB parameter computation

The FB 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 FBMC.

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 branches given the exchange programs of the chosen reference day. Out of the formula:

RAM = Fmax – Fref – FRM - FAV

The calculation delivers, with respect to the other parameters, the free margin for every CB. This RAM is one of the inputs for the subsequent process steps.

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 CB 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 CB => 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 translated into changes of the flows on the CBs by multiplication with the PTDFs.

2.2.4. FB parameter qualification

The operational FB parameter qualification process is executed locally by each TSO, and covers amongst others the following action. For each non-redundant CB, limiting the FB-domain, the TSO checks, if remedial actions (RA) are at hand, that could enlarge the FB-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 CB-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. 2.1.3). 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 the capacity calculation stage are required to facilitate this.

The aim is to qualify in this stage the maximum FB 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 FB 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 FB domain should be bigger than the LTA domain
- Check that the current reference program is inside the FB-domain or if there are violations: Fref > Fmax – FRM – FAV.

2.2.5. FB parameter verification

After the qualification phase, the TSOs provide an updated CB file. Based on this updated CB-file, a second FB-parameter calculation is started. This calculation delivers the largest possible FB domain that respects the Security of Supply (SoS) domain. During the verification step, TSOs check whether the computed FB 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 FB parameters generated by the centralized computation:

- TSOs can check the grid security in the relevant points (e.g. vertices) of the FB 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 is respected
- TSOs can assess voltage stability (voltage collapse)

- TSOs can investigate extreme net positions

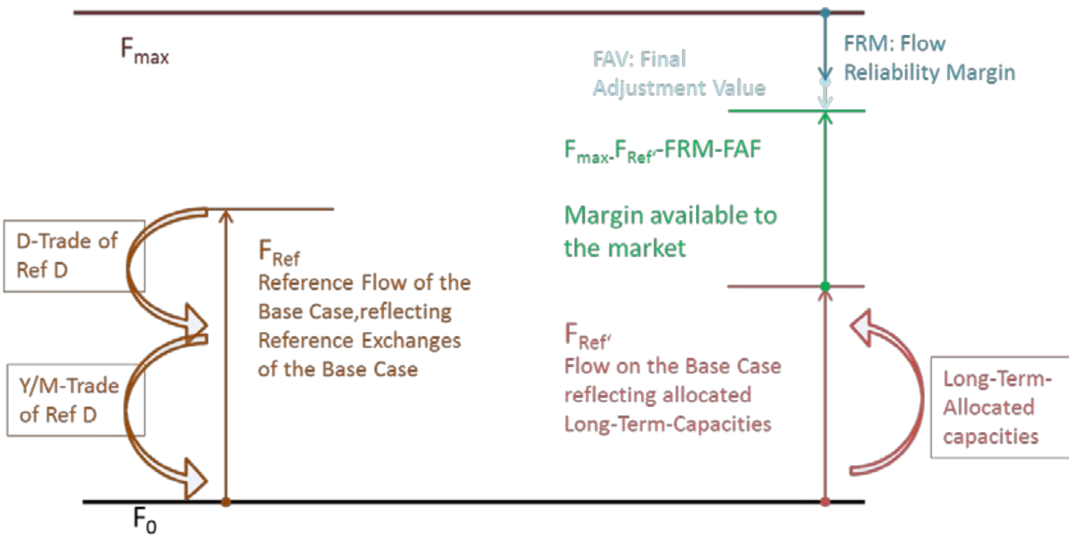
If security issues are discovered, TSOs can update their critical branch files (by adding new CBs, that were not perceived upfront as being limiting (for instance in the case of combined and/or unusual scheduled outages), or by adapting the Final Adjustment Value).
After the verification step and possibly adaptation of the CB-file, the final FB-parameter calculation can be performed, which includes adjustment to long-term nominations (cf. 2.2.7) and presolve (cf. 2.3.1) steps.

2.2.6. LTA inclusion check

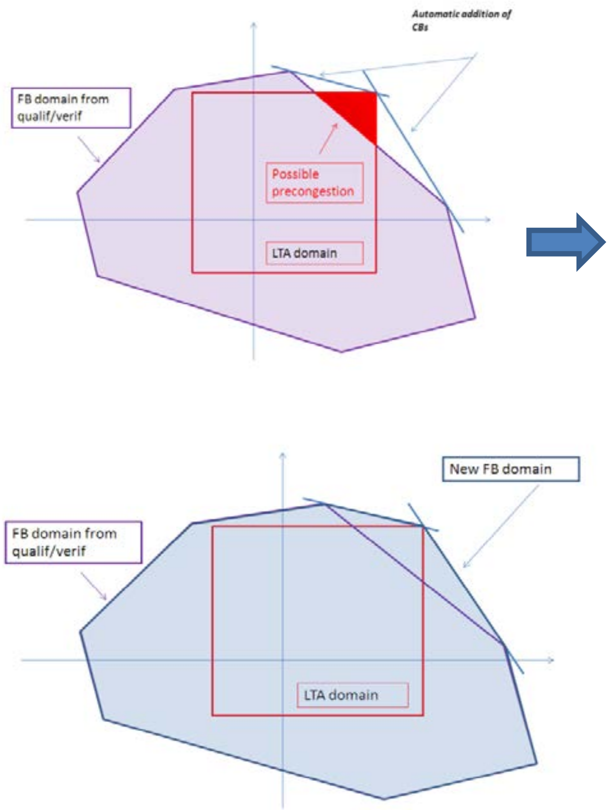
Given that Programming Authorisations for long term allocated capacity (LTA) have already been sent out in D-2 Working Days (according to the current version of the Auction Rules), the long-term-allocated capacities of the yearly and monthly auctions have to be included in the initial FB-domain which 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 FB-parameter-calculation.
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 CB 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 < 0

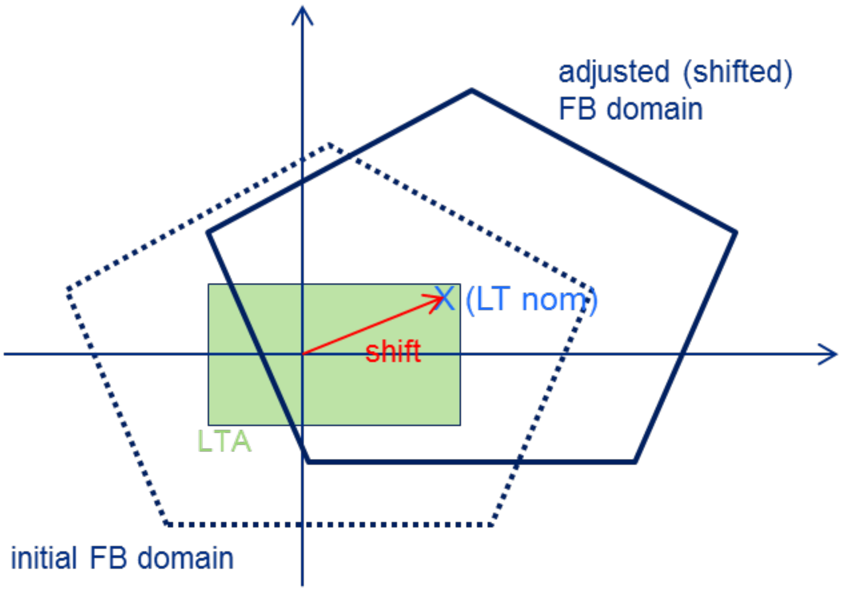


If the remaining margin is smaller than zero, this means the LTA is not fully covered by the FB domain. In this case, a method is applied that enlarges the FB-domain in a way, that all LTA are included. Virtual CBs are created and introduced, which replace the CB for which RAM < 0, and that guarantee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



2.2.7. LTN adjustment

As the reference flow (Fref) is the physical flow computed from the common base case, it reflects the loading of the critical branches 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 the maturity day D as soon as they are known. 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 CBs affected by this LTNs. The remaining margin for the DA-allocation can be calculated by:

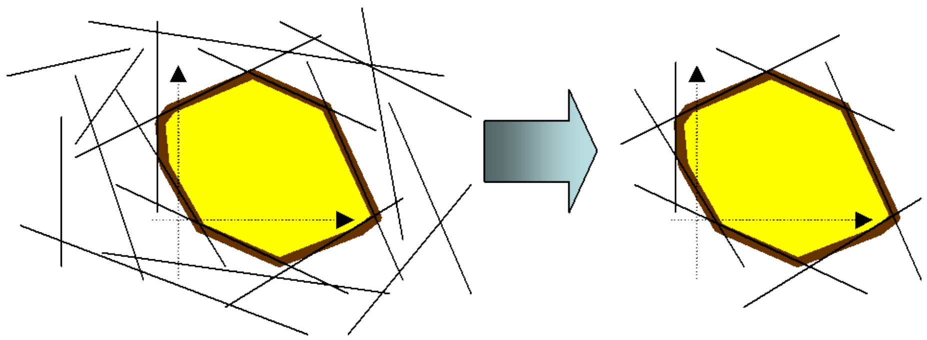
RAM = Fmax – Fref' – FRM - FAV

*Fref' = Fref + (LTN – RefProg)*PTDF*

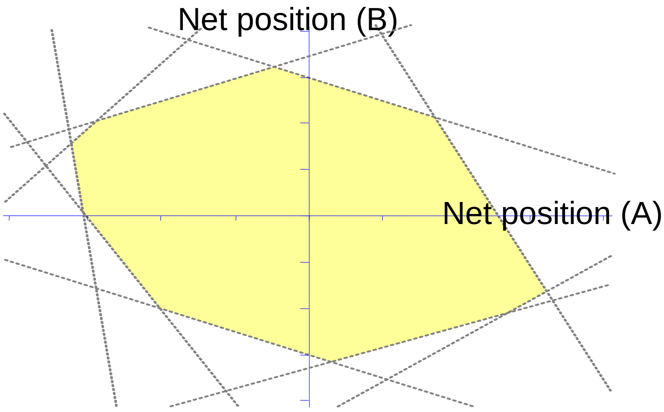
2.3. Output data

2.3.1. FB capacity domain

The FB parameters that have been computed indicate what net positions, given the Critical Branches that are specified by the TSOs in CWE, can be facilitated under the Market Coupling without endangering the grid security. As such, the FB parameters act as constraints in the optimization that is performed by the Market Coupling mechanism: the net positions of the bidding zones 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 FB parameters are relevant and do contain information, not all FB parameters are relevant for the Market Coupling mechanism. Indeed, only those FB 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 FB parameters of one Critical Branch. A line indicates for a specific Critical Branch, 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 Branch and endanger the grid security. As such, the non-redundant, or presolved, FB parameters define the FB capacity domain that is indicated by the yellow region in the two-dimensional figure above. It is within this FB 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 FB capacity domain is shown hereunder.



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

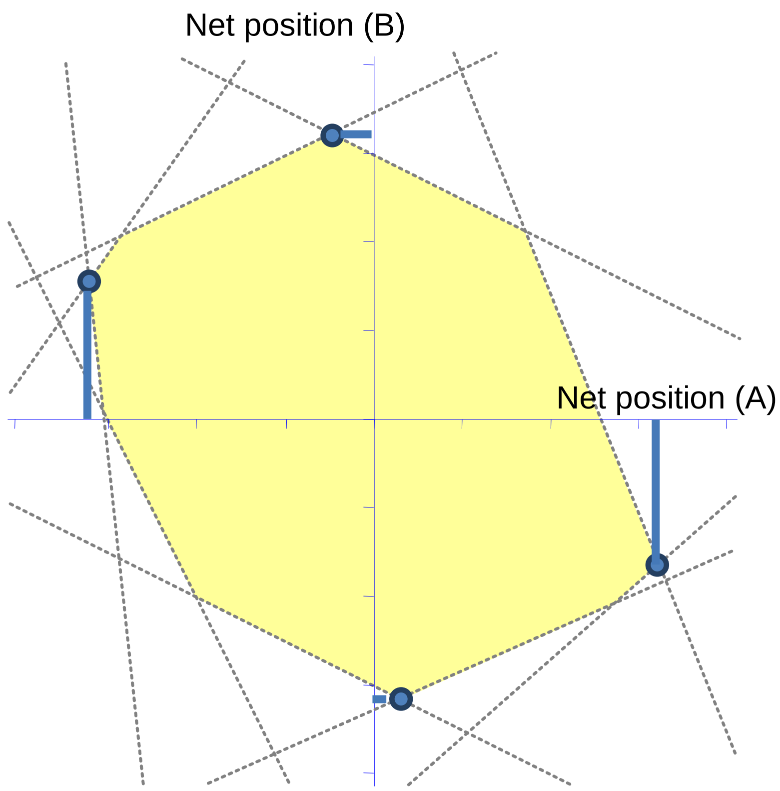
2.3.2. FB capacity domain indicators

From the FB capacity domain, indicators can be derived that characterize the FB-domain and provide additional information of the domain.

- FB-Volume: “volume” of the domain
    - The volume is computed in n-1 dimensions, where n is the number of hubs participating in the CWE FBMC (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 FB domain and the LTA domain.

- FB-vertices: Net positions of the FB-vertices
- Min-Max net positions: Minimum and maximum net position values for each hub, feasible within the FB 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 FB 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 FB domain (by assuming that all other exchanges in CWE contribute to this specific Min-Max bilateral exchange).



3 The CWE Market Coupling Solution / Daily schedule

3.1. Daily schedule

The FB parameters will be published at 10:30 (as of today for ATCs). The rest of the daily schedule will be subject to NWE process timings.

3.2. Coupling to other regions

Possible approaches and methodologies to couple to other regions are described in the feasibility report (section 4.2).

After internal assessments and discussions with the CWE NRAs there has been the decision to start with standard hybrid coupling (previously called "rough" hybrid coupling, see section 4.3.1 of the feasibility report). The main reasons for this decision are the following:

- Starting with standard hybrid coupling is consistent with current practices of ATC market coupling and provides already significant benefits compared to ATC calculations.
- Advanced approaches are currently not ready, as they still need to be developed and tested, and would therefore delay the go-live with several months.

  Advanced coupling to other regions, as an enhancement, can be further developed and agreed with non CWE-partners after the go-live.

4 Fall-back arrangement for Market Coupling (capacity allocation)

The following is still under consideration by the CWE project partners, these principles are not finalized. The fallback process described hereunder is applicable under NWE full decoupling and CWE partial decoupling if decided under NWE project. This option is still to be validated within the NWE framework

The PXs and TSOs have created back up procedures for their normal operational proceedings to guarantee a well-functioning of the main operational phases of CWE FBMC:

Phase 1: Provision of the capacity parameters by the TSOs
Phase 2: Result calculation
Phase 3: Post publication procedures

In exceptional cases, when CWE market coupling (therefore implicit auctions) cannot be performed, a fall-back to explicit ATC shadow auctions becomes necessary.
The solution for CWE FBMC is the same as under the currently practiced CWE ATC MC.

4.1. Principle of the fall-back arrangement

In the CWE FBMC procedures, a fall-back situation occurs when, for any reason, correct market coupling results cannot be published before the critical deadline. This triggers the fall-back procedure.
The fall-back 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. In other words, the fall-back is pronounced if no market coupling result can be calculated and validated before the critical deadline of phase 2. For instance:

- some network/ 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.

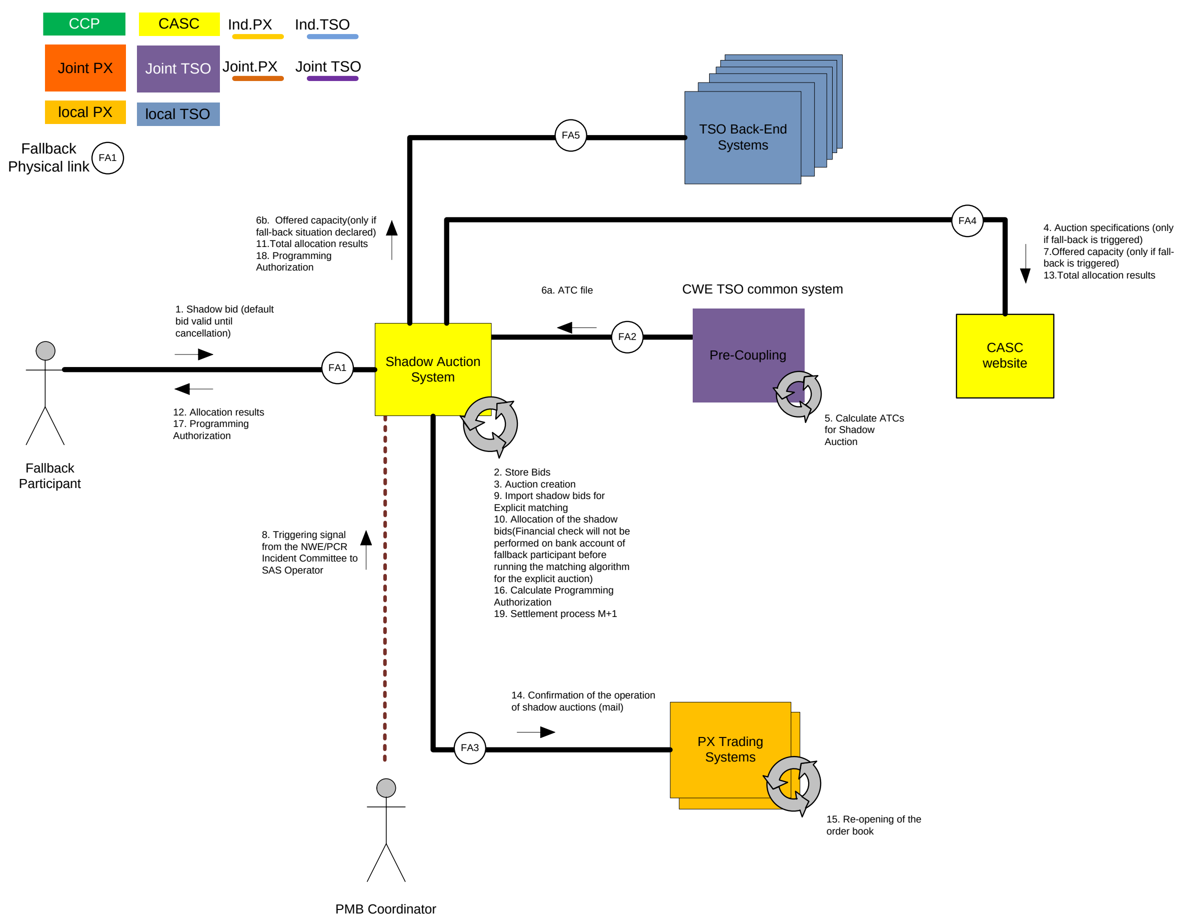
The principle of the proposed fall-back arrangement is to allocate the fall-back ATCs derived from the FB parameters via a “shadow explicit auction” and a full decoupling of the PXs. This means an isolated fixing by the 4 PXs, performed after having reopened their order books. The shadow explicit auction consists of:

- maintaining a permanent data base where all pre-registered market parties (fall-back participants) may file, amend or withdraw, bids for capacity. During normal operation, these bids are not used;
- should a fall-back situation be declared on a particular day in case of an incident during the daily session, the fall-back operator performs a fall-back auction to allocate the available transmission capacities according to the merit order determined by the filed bids; from the time of the confirmation of fall-back allocation, the participants are not allowed to update their bids for the upcoming shadow auction.
- should a fall-back 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 fall-back operator; the fall-back operator performs a fall-back auction to allocate the available transmission capacities according to the merit order.

4.2. High level architecture (HLA)

This paragraph contains the high-level functional architecture and business process of the fall-back solution (following diagram). It is explained in the following sections, which are devoted to:

- The System components shown,
- The Agents shown,
- The information produced and exchanged



4.3. Systems

The following systems, involved in the Shadow Auction process, are distinguished.

- The back-end systems of the 6 TSOs involved are grouped together as the „TSO Back-End Systems" (For information: Creos is not connected to the Shadow Auction System). This grouping is made on the assumption that these systems each manipulate essentially similar information.

- The 2 Trading Systems used by the PXs involved are represented together as the PX Trading Systems
- The TSO Common Pre-Coupling FB system. This Pre-Coupling system produces the ATCs for the Shadow Auctions.
- CASC's website is the platform on which all relevant information concerning the Shadow Auction procedure will be published.
- The Shadow Auction System is the EXAU platform, owned by CASC and used to perform Explicit Auctions on all CWE borders. Systems are interconnected via Interfaces. Each Interface serves one or more information flows.

4.4. External Agents

An External Agent in the framework of the fall-back solution is a non-automated entity interacting with one or more Systems or other Agents from the information perspective on the Solution. The Agents are represented in the diagram as abstract human figures. Just like the Shadow auction components are abstract systems, the Agents distinguished are logical or virtual agents. An Agent is distinguished according to the role he plays. In the High Level Architecture (HLA) for Shadow Auctions the identified External Agents are the “Fall-back participant”, i.e. the entity submitting shadow bids to the Shadow Auction System, and the “fall-back service operator/ PMB (PCR Matcher and Broker) coordinator”.

4.5. Information created and exchanged

The information created and exchanged is represented in the diagram by arrows with a label. The small arrows point in the direction

of the information flow. The circular arrows indicate information produced in processes internal to a System. The label indicates the contents of the piece of information transferred or produced. The numbering of the information flows does not always respect the sequence of the actions.
The real frequency, timing and sequences are being defined in the procedures and in the business process. It should be stressed that only flows of information are shown in the diagram. Other flows, like energy and money flows, are not taken into account.

Related to the diagram above, the following table summarizes and highlights the important processes for the Fall-back Participants.

Flow Nb*	**Info**	**From**	**To**	**Predecessor**
1	Shadow bid (default bid valid until cancellation /modification. The number of bids is limited to 20).	Fall-back Participant (whenever they want except when the DB is frozen (=when the Shadow Auction process is running)	Shadow Auction System (SAS)	-
12	Allocation results	Shadow Auction System (SAS)	Fall-back participant	10
17	Programming Authorization (max 15 min after Auction result)	Shadow Auction System (SAS)	Fall-back participant	16

*The numbering of the interfaces doesn't necessarily respect the sequence of the actions.

5 Roll-back to ATC Market Coupling

The following is still under consideration by the project partners,

these principles are not finalized

The launch of Flow Based Market Coupling (FB MC) is a major change including the introduction of new or adapted systems and new operational procedures. Even when tested thoroughly, there is still a risk of failure when switching from the ATC based systems to FB systems on the launch day itself as well as during the first period after the launch. In order to mitigate this risk, the Project Parties will keep possible roll back options as a backup available for one to two months after launch of the FBMC. The next paragraphs describe the roll back solutions.

5.1. Roll-back situations

The decision to roll back from the FB MC to ATC based MC would be a CWE Steering Committee decision in close cooperation with the CWE NRAs. The rare situation in which roll back will be applied:

- The Incident Committee has decided for full decoupling due to an incident regarding the FB capacity delivery and/or results consistency (e.g. no market results or unacceptable grid or market results); the capacity is auctioned via the Shadow Auction.
- During the investigation it becomes apparent:
  - o that the incident is found but cannot be resolved instantly or within an acceptable period of time or that the incident is not found / cannot be reproduced and therefore the period to solve the issue is unknown and
  - o that the risk to continue with the FB MC is estimated too high
- The CWE Steering Committee decides based on the above arguments to resort to roll back.

5.2. Roll-back solutions

After such a decision of the CWE Steering Committee, the Parties need at least 3 to 5 working days for the technical aspects of the roll-back, i.e. reinstall the roll-back systems, test the connections and run a couple of test scenarios. Parties have prepared procedures and checklists for such a roll back situation before the launch of FB MC and will make sure that the procedures are known internally.

During the interim period necessary to install the roll back, the daily explicit auctions will be held with the Shadow Auction system. Once the Shadow auction completed, each involved PX will run a local auction.

All necessary information will be given to the market parties regarding the practical modalities of the roll back.

After this interim period where the Shadow Auction system is used, the ATC based TSO Common System will be reactivated and operated as during the coming NWE DA ATC based Market Coupling.

The roll back will continue to function until the re-launch of FB Market Coupling, which is decided by the CWE Steering Committee.

In case a roll-back situation occurs, CWE parties will roll back to the currently used solution:

- CWE TSOs will roll back to the ATC based version of the TSO Common System
- CWE TSOs will roll back to the ATC based versions of their back-end systems
- PX will still use the PMB as market coupling system
- Trading system interfaces will remain unchanged

All interfaces between TSOs, between PXs, and between TSOs and PXs will be re-established in case of roll back.

6 Economic Assessment

6.1. Introduction

The economic impact and outcome of FBMC is reported continuously during the whole period of the external parallel run (whole year 2013) and therefore cannot be completely part of this consultation document.

As communicated close to the start of the external parallel run, Flow-Based parameters and a report of market simulation results of the previous week are published **every Thursday before 12:00** via an ftp server hosted on CASC’s website. MPs are kindly requested to comment directly on the weekly reports being available until the end of the consultation period (comments to be located/ reference chapter for the survey/consultation-tool: 6.1).

These weekly reports include the following information resulting from current ATC based operation and from Flow Based simulation: hourly prices, volumes and net positions for all CWE market areas, graphs on price convergence/divergence and welfare calculations.

In a dedicated section on CASC’s website, available for all market participants, it is possible to access the Utility tool displaying the relevant Flow-Based parameters, including historical data since the 1st of January 2013 in order to support MPs in their simulations.

In the second part of the external parallel run a daily publication of Flow-Based parameters and of market simulation results is foreseen.

6.2. Economic Assessment based on January to February 2013 results

The market impact analysis performed jointly by PXs/TSOs based on the external parallel run period 1st January to 5th March 2013 (weeks 0-9 of the external parallel run) can be found in Annex 1.

Similar ongoing reporting is foreseen during the whole period of the external parallel run. Anyhow published data enable market parties to perform similar or different reports on their own.

7 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 welfare under FBMC, it can happen that there is an exchange from a higher price area to a lower price area, which is non-intuitive.

Related to FBMC, a situation (a combination of market clearing prices and Net Export Positions) is said to be 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 2012 the Project Partners published the CWE Enhanced Flow-Based MC intuitiveness report to explain all details related to intuitiveness. The report can be found on the websites of the Project Partners and CASC and is included in the package of CWE FBMC publications.

This report provides a broad and sound basis for discussion and for a decision that will be taken with the input of all stakeholders, especially market parties and regulators.

8 Publication of data

This paragraph describes how the Project aims to provide the necessary data towards market participants 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) has been discussed with the CWE NRAs in expert meetings, with market parties in the framework of the market forums and the flow-based user group. The conclusions are taken into account for the data publication foreseen by the Project.

For monitoring purposes the national regulatory authorities get further (confidential) information. Based on national and EU-legislation, on reasonable request of the (national) authorities / the NRAs the Project will provide all Project related data for monitoring purposes.

Data provision is the main interface between the MPs and FBMC operation, thus a key success factor for a well-functioning FBMC. Therefore it is important to get final feedback also on this topic in the framework of the public consultation.

8.1. Relation to EU Regulations

Transparency obligations related to congestion management are currently mainly regulated by the Directive 714/2009 and it's Annex 1 § 5, but will soon be largely replaced by the Commission Regulation 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. End December 2012 the latter has been approved by the Cross Border Committee and the formal phase of Comitology will aim at an entry into force for June 2013.

During an interim-period of 18 month after the entry into force of transparency regulation points 5.5 to 5.9 of the annex to the EC Regulation 714/2009 (also known as Congestion Management Guidelines) remain valid for transparency obligations. 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 FBMC 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 Parties, it is the responsibility of the individual PX, 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 Parties.

8.2. General information to be published

The following general information is published in this document and updated when needed:

- Description of the coordinated flow based capacity calculation methodology,
- A description of the CWE FB market coupling solution,

- Fall-back arrangements in case of decoupling,
- Roll-back arrangements.

Furthermore, as general information, the high level description of the principles of the clearing-algorithm, already published on PX's websites, will be updated.

8.3. Daily publication of FB 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 CASC, to deliver the data on their behalf to the ENTSO-E Transparency platform. For the time being, the Project Parties have decided to provide easily accessible data as set out in the next two subsections on common websites (www.CASC.eu and www.Europeanpricecoupling.eu).

8.3.1. Daily publication of data before GCT

The TSOs will publish for each hour of the following day the flow-based parameters i.e. the anonymized critical branches, Power Transfer Distribution Factors (PTDFs) and the remaining available margin (RAM) on critical branches. 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 CASC website. The Utility Tool can be downloaded from CASC website and tested since the start of the external parallel run.

Content	Where / Who	When	Unit
Anonymized Critical Branches (CBs)	CASC/ ENTSO-E	D-1 (10:30 CET)	Anonymized names
PTDFs	CASC/ ENTSO-E	D-1 (10:30 CET)	-
RAMs	CASC/ ENTSO-E	D-1 (10:30 CET)	MW

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 FBMC publications, the following data is published:

On CASC Website:

- Capacity allocated (being defined as the sum of the used margins on the tie-lines of a bidding zone border)
- The total congestion income in the CWE area

On Europeanpricecoupling.eu Website:

- Result in a Bilateral Exchange flow
- Indication of economic capacity value, given by the price difference between two hubs in implicit allocation schemes

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

The standard timing for publication of these data is one hour after the capacity allocation (Target time for publication: 14:00 CET). Of course deviations are possible in case of exceptional circumstances or re-opening of markets.

In addition to the data above, it is the aim of the Project Parties to publish the following data:

- PX market prices: the market prices for each market time unit of the day will be published on daily basis on the common CWE website (Europeanpricecoupling.eu) and by the individual PXs for their hub.
- Aggregated supply and demand curves for each market time unit of the day will be published by the individual PX for their hub.

Content	**Where/ Who**	**When**	**Unit**
Capacity allocated (used margin on critical branches)	CASC/ ENTSO-E	14:00 CET	MW
Congestion income	CASC/ ENTSO-E	14:00 CET	€
Individual Hub prices	PXs' websites	14:00 CET	€/MWh
Aggregated supply and demand curves for each market time unit	PXs' websites	14:00 CET	-
Overview CWE-Hubprices	www.europeanpricecoupling.eu	14:00 CET	€/MWh
Hubs net positions	CASC / ENTSO-E	14:00 CET	MW

8.4. Publication of data in fall back mode

The fall-back solution for CWE FB market coupling is coordinated with the NWE-/PCR fallback arrangements. It will be ATC based explicit shadow auctions. These explicit auctions will be performed by the fall-back operator (CASC).

The fall-back operator 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 fall-back operator;
- the forms to be sent by participants;
- Market Data
- the ATCs for each shadow auction (border and direction) per market time unit; ATC must be published at the latest 1 hour before market gate closure;
- 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

9 Glossary

ATC	Available Transfer Capacity
ATC MC	ATC Market Coupling
CASC	Capacity Allocating Service Company
CB	Critical Branch
CBCO	Critical Branch Critical Outage
CEE	Central Eastern Europe (Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia)
CEWE	Central East West Europe
CGM	Common Grid Model
CWE	Central Western Europe (Belgium, France, Germany, Luxembourg, Netherlands)
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
ENTSO-E	European Network of Transmission System Operators for Electricity
FAV	Final Adjustment Value
FB	Flow Based
FBMC	Flow-Based Market Coupling
FBIMC	Flow-Based Intuitive Market Coupling
Fmax	Maximum allowable flow on a given critical branch
FRM	Flow Reliability Margin
GCB	German control block
GCT	Gate Closure Time
GSK	Generation Shift Key
HLA	High Level Architecture
ID	Intraday
Imax	Maximum current on a Critical Branch
LT	Long Term
LTA	Allocated capacity from LT auctions

LTN	Long Term Nominations
MC	Market Coupling
MoU	Memorandum of Understanding
MP	Market Party
NA	Not applicable
NRA	National Regulatory Authority
NWE	North Western Europe (CWE countries + Denmark, Finland, Norway, Sweden, United Kingdom)
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 NWE Net Positions, Prices and Scheduled Exchanges on the non CWE interconnectors)
PMB 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
SAS	Shadow Auction System
SoS	Security of Supply
TSO	Transmission System Operator
UCTE	(formerly Union for the Coordination of Transmission of Electricity (today integrated into ENTSO-E)

10 Annex 1: Flow-Based MC Economic assessment

Annex 1

Flow-Based MC
Economic assessment

Glossary

ATC	Available Transfer Capacity
ATCMC	ATC Market Coupling
CB	Critical Branch
CC	Capacity Calculation (ATC or FB)
CEE	Central Eastern Europe (Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, Slovenia)
CGM	Common Grid Model
CSE	Central South Europe (Austria, France, Germany, Greece, Italy, Slovenia)
CWE	Central Western Europe (Belgium, France, Germany, Luxembourg, Netherlands)
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
DAMW	Day-Ahead Market Welfare
DCV	Demand Clearing Volume
ENTSO-E	European Network of Transmission System Operators for Electricity
FB	Flow Based
FBMC	Flow-Based Market Coupling
FBIMC	Flow-Based Intuitive Market Coupling
FBV TF	Flow-Based Validation Task Force (joint group CWE PX & CWE TSO)
FB WG	Flow-Based Working Group (CWE TSO group only)
Fmax	Maximum allowable flow in a given critical branch
FRM	Flow Reliability Margin
FTR	Financial Transmission Right
GSK	Generation Shift Key
ID	Intraday
IDCF	Intraday Congestion Forecast
ITVC	Interim Tight Volume Coupling
LT	Long Term
LTA	Allocated capacity from LT auctions
MC	Market Coupling
MCV	Market Clearing Volume
NP or NEX	Net Position or Net Export Position (sum of commercial exchanges for one bidding area)
NTC	Net Transfer Capacity
NWE	North Western Europe (CWE countries + Denmark, Finland, Norway, Sweden, United Kingdom)
PCR	Price Coupling of Regions
PDCA	Plan > Do > Check > Act
PTDF	Power Transfer Distribution Factor
PST	Phase-Shifting Transformer
PX	Power Exchange
RA	Remedial Action

RAM	Remaining Available Margin
R4CA	Regional Coordinated Capacity Calculation and Capacity Allocation
RCA	Party Responsible for Common Activities
SN	Snapshot
SoS	Security of Supply
SWE	South Western Europe (France, Portugal, Spain)
TCV	Total Clearing Volume
TF	Task Force
TRM	Transmission Reliability Margin
TSO	Transmission System Operator
TS	Timestamp (hourly)
TTC	Total Transfer Capacity
UCTE	(formerly) Union for the Coordination of Transmission of Electricity (today integrated into ENTSO-E)
UIOSI	Use It Or Sell It
WG	Work Group

1. Price / Market impact analysis performed jointly by PXs / TSOs

1.1 Introduction

This chapter presents the **market impact analysis** performed in order to assess SoS domain modelling effects with FB constraints (FBMC) rather than ATCs (ATCMC) on market and prices. Their main results are the market clearing prices and the bidding areas net positions obtained by "replaying" modified historical clearings in which ATCs are replaced by FB constraints.

Results are analysed through a series of indicators ranging from day-ahead market welfare (DAMW) to price divergence (cf. Section 1.4).

1.2 Data

1.2.1 Data used

The data used will be the following:

Network data

The FB parameters that have been used for the economic assessment originate from the external parallel run, which started January 1st 2013. Since the capacity calculation is not yet a fully industrialized process, it can happen that for some days no FB parameters are available. The precise dates that have been used can be found in the table at the bottom of this section.

The ATC data against which comparisions are made, are the historical data for the corresponding dates.

Lastly a set of of (artificial) network data is used where ATCs are set to zero. This allows us to set a benchmark assuming no network restrictions would exist.

Order data

PXs provided historical order books.

For the entire duration of the period under consideration the CWE regions were coupled via a coordinated ATC MC.

The included dates are highlighted in green:

Year	Wed	Thu	Fri	Sat	Sun	Mon	Tue
2013							2013-01-01
	2013-01-02	2013-01-03	2013-01-04	2013-01-05	2013-01-06	2013-01-07	2013-01-08
	2013-01-09	2013-01-10	2013-01-11	2013-01-12	2013-01-13	2013-01-14	2013-01-15
	2013-01-16	2013-01-17	2013-01-18	2013-01-19	2013-01-20	2013-01-21	2013-01-22
	2013-01-23	2013-01-24	2013-01-25	2013-01-26	2013-01-27	2013-01-28	2013-01-29
	2013-01-30	2013-01-31	2013-02-01	2013-02-02	2013-02-03	2013-02-04	2013-02-05
	2013-02-06	2013-02-07	2013-02-08	2013-02-09	2013-02-10	2013-02-11	2013-02-12
	2013-02-13	2013-02-14	2013-02-15	2013-02-16	2013-02-17	2013-02-18	2013-02-19
	2013-02-20	2013-02-21	2013-02-22	2013-02-23	2013-02-24	2013-02-25	2013-02-26
	2013-02-27	2013-02-28	2013-03-01	2013-03-02	2013-03-03	2013-03-04	2013-03-05

1.2.2 Limitations

The following limitiations apply:

- The order books are based on the knowledge of the ATC MC system.
- Rather than a full year of results only a limited amount of days are available. These days are not equally distributed among the year, but are concentrated during the beginning of 2013.
- Therefore it is not possible to extrapolate indicators to a yearly period.
- Potential discrepancies depending on the ITVC solution being based on ATC. Indeed, ITVC results in bidding orders corresponding to the volume exchanged with the Nordic area. This volume is computed with ATCs while it should be computed with FB constraints, but this is not supported by ITVC.
- The external parallel run remains a project phase in which some last small changes might for example be applied to the FB method or the process after having been submitted to a change procedure.

1.3 Intuitiveness Definition

The term “counter-intuitiveness” was introduced in Q4 2007 to describe some results of a FB market coupling test that did not match what market players generally think a coupling should yield.

Several approaches were discussed by the PXs and the TSOs. The current section is intended to fix clear definitions related to the “intuitiveness concepts”. Let us first start with an example in order to illustrate how the problem was identified:

Example

Let us consider the following 3-node example in which the flow from A to C is limited to 100 MW. An export from A to C uses twice as much of the “scarce” resource than an export from B to C. Therefore an export from A to C should provide double the welfare compared to an export from B to C in order to use the resource.

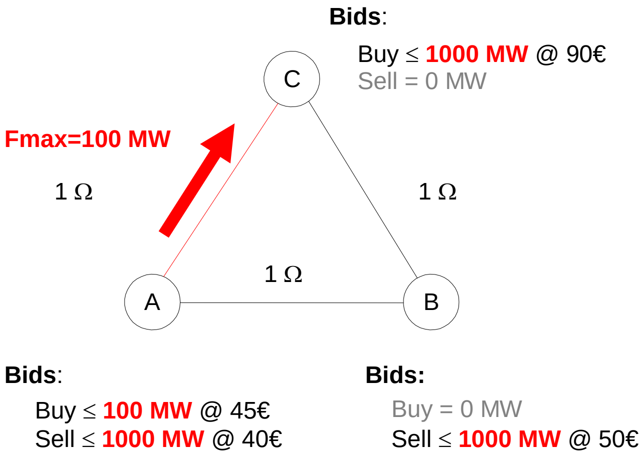


Figure 1: Three-node non-intuitive example (inputs)

The optimal situation is given below:

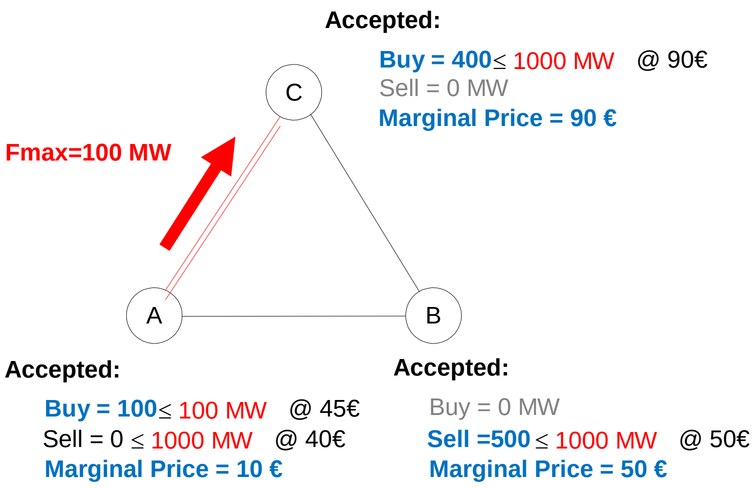


Figure 2: Three-node non-intuitive example (results)

The optimal solution gives a welfare of 15 500€:

- A imports 100 MW and has a marginal price of 10€
- B exports 500 MW and has a marginal price of 50€
- C imports 400 MW and has a marginal price of 90€

The situation is non-intuitive, because the cheapest area (area A) imports. The 100 MW commercial exchange between B and A “destroys” welfare because it is from a high price to a low price area. In other words, if it was the only exchange to take place, the welfare would be negative. It takes place because it relieves the congestion and thus allows an exchange between B and C that “creates” more welfare than the “destroyed” welfare.

On the contrary, the intuitive solution (definitions precised below) would be:

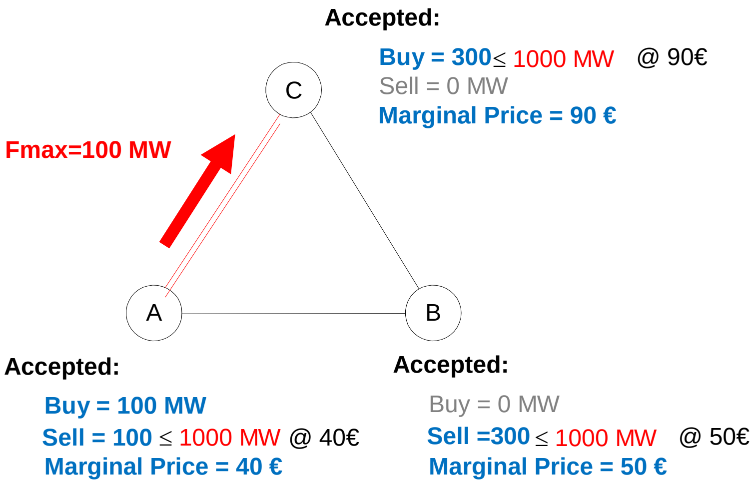


Figure 3: Three-node intuitive example (results)

The 'optimal' solution gives a welfare of 12 500€:

- A imports 0 MW and has a marginal price of 40€
- B exports 300 MW and has a marginal price of 50€
- C imports 300 MW and has a marginal price of 90€

The situation is intuitive, to the detriment of the welfare.

1.3.1 "Bilateral Intuitiveness" considering existence of interconnections

We define direct bilateral (commercial) exchange as an exchange between two electrically-connected bidding areas. For example, no direct bilateral exchange is possible between France and Netherlands or between Belgium and Germany because there is no interconnector interlinking the two countries. Note that this is currently the case with ATCMC because the ATCs are non-null only on existing electrical boundaries.

Definition: We define a situation as being "bilateral intuitive" if there exists at least one decomposition of the net exchange positions into a set of intuitive direct bilateral exchanges (from relatively cheaper bidding areas to the relatively more expensive bidding areas, across existing electrical boundaries only).

Corollary: There exist at least one set of positive ATCs on each existing interconnector for which this solution is optimal.

Remark: Solutions not compliant with this definition will be called "bilateral non-intuitive" solutions or "non-intuitive" situations.

Note: The present definition of non-intuitiveness is strictly limited to the Day-Ahead Market Coupling results.

1.4 Analysis

1.4.1 Simulation

The simulation will consist in running COSMOS over the period of the study with the following configurations:

- Isolated (no capacity) *(ISO)*
- ATC market coupling *(ATCMC)* mode
- FB with intuitive market coupling *(FBIMC)* mode
- FB with market coupling *(FBMC)* mode
- Infinite capacity market coupling *(INF)* mode

The implementation of FBIMC is a heuristic which finds bilateral intuitive solutions but does not guarantee their optimality (cf. Section 1.4.8 for details).

No ramping constraint on the net position has been activated, i.e. no limitation of the net position change from one hour to the next has been set.

The comparison of ATCMC, FBIMC and FBMC is based on a set of indicators which is described in this section.

1.4.2 Day ahead market welfare (DAMW)

The day ahead market welfare (DAMW) is the welfare computed by COSMOS. It is the sum of the buyer surplus, the supplier surplus and the congestion rent. It does not take into account the welfare linked to futures and to grid management and SoS costs. This indicator is usually called social welfare and is identical to the welfare computed in the previous market impact analysis[1]. It is called day ahead market welfare to make clear that it does not represent all the welfare associated with the clearing process.

Figure 4 illustrates the overall DAMW change in FBMC, FBIMC, and INF compared to ATCMC (column “Total”) and the split of the change between buyers, suppliers and congestion rent (first three blocks of columns). Consistently with the expectations linked with the fact that the ATC domain is generally included in the FB domain, the welfare increases and the congestion rent decreases. As expected, welfare is reduced in FBIMC compared to FBMC but the decrease is small compared to the difference with ATCMC. Globally, the welfare increase covers more than 87% of the maximum possible increase reached by using infinite capacities (87% for FBIMC and 88% for FBMC). The congestion rent shows a decrease of 78% in FBMC and 77% in FBIMC compared to ATCMC.

Figure 5 illustrate the DAMW change by area. It is noticeable that all areas see a welfare increase because it is not a theoretical expectation.

Figure 6 details the DAMW change by area and by actors. Globally, as expected from a theoretical point of view due to the capacity increase, supplier surplus increases in areas that are exporting more and buyer surplus increases in areas importing more and vice-versa. This is not specific to FBMC or FBIMC.

[1] Market Validation Analysis II – External Report, CWE Market Coupling Project, 2008.

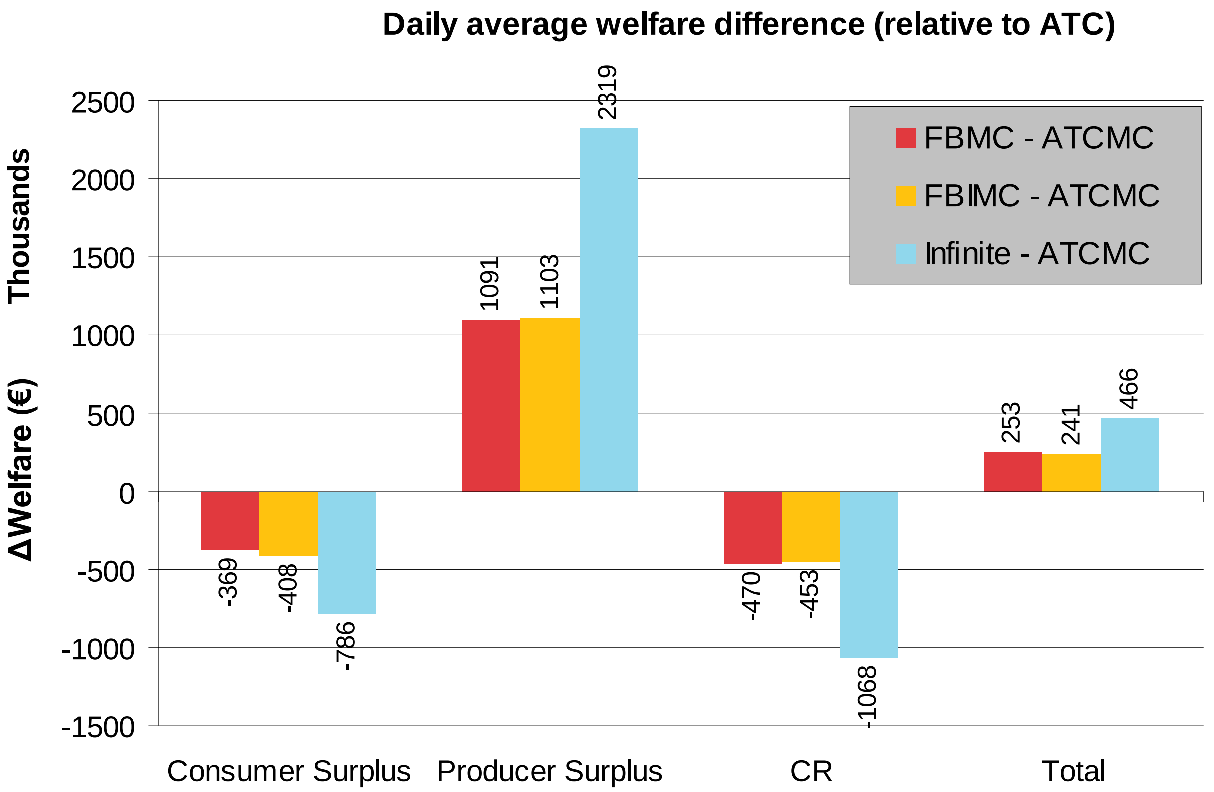


Figure 4: Daily average welfare difference relative to ATCMC split by actor in k€/day

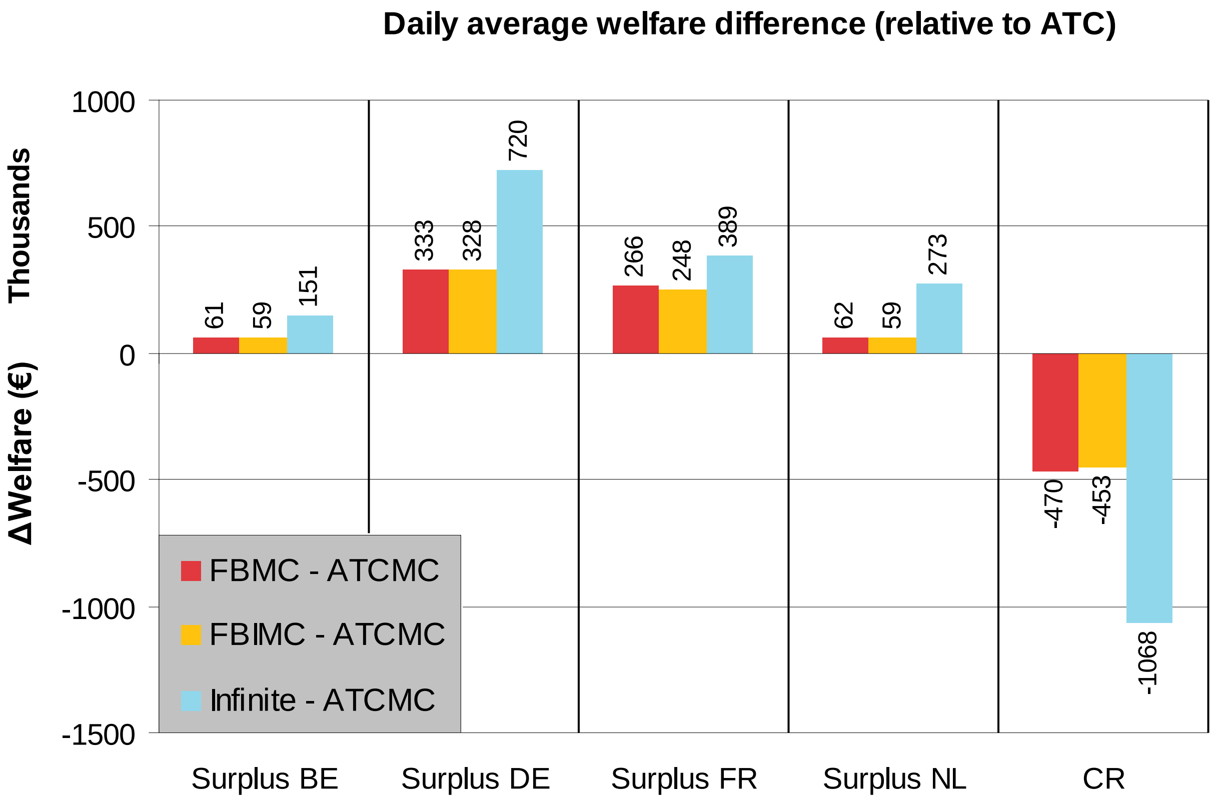


Figure 5: Daily average welfare difference relative to ATCMC split by area in k€/day

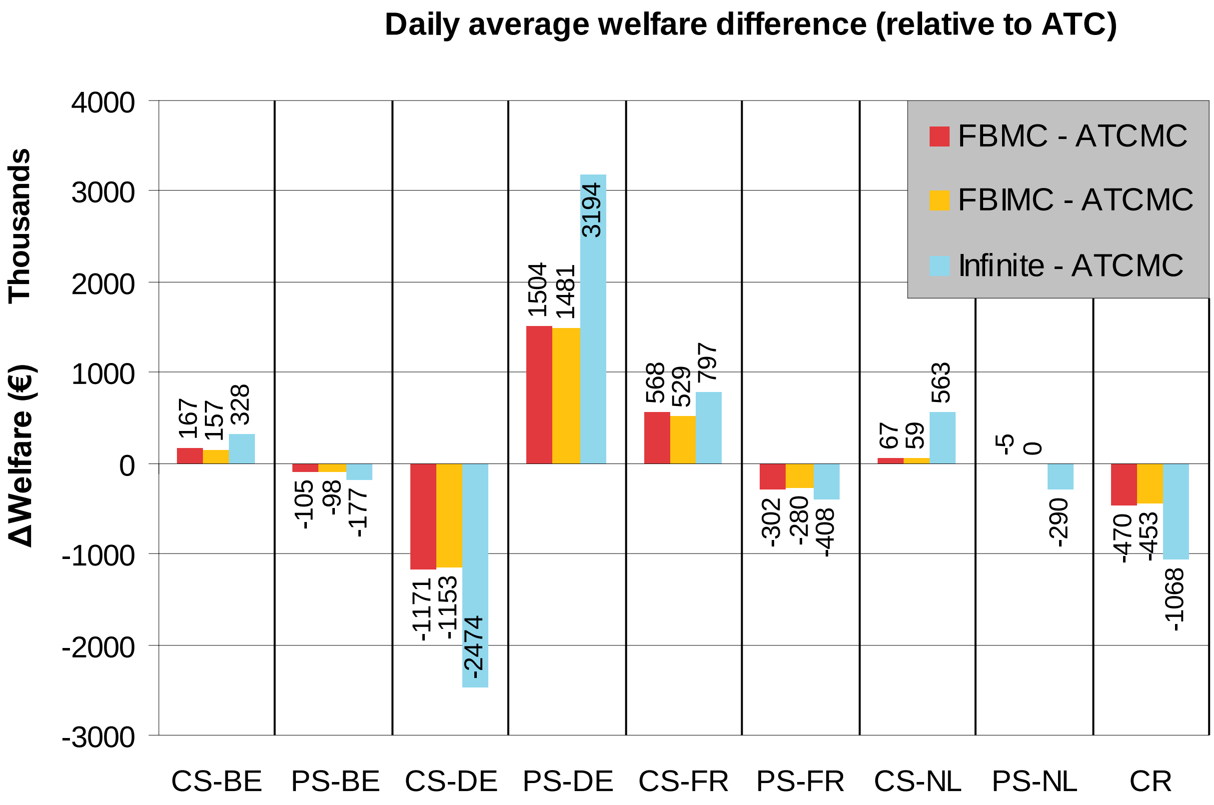


Figure 6: Daily average welfare difference relative to ATCMC split by area and by actor in k€/day

1.4.3 Market clearing volumes

Here are the definitions of the 4 clearing volume indicators used:

- Supply Clearing Volume (SCV): the sum over the whole period of the supply volume in a bidding area (volume of accepted supply bids);
- Demand Clearing Volume (DCV): the sum over the whole period of the demand volume in a bidding area (volume of accepted demand bids);
- Market Clearing Volume (MCV): the sum over the whole period of the maximum per hour of the Demand and Supply Clearing Volumes. It is this indicator that is usually reported by the PXs. Note that the MCV of a set of bidding areas considered as one area is not equal to the sum of the MCV of the bidding areas because the exchanges are counted twice: once in the MCV of the exporting area and once in the MCV of the importing area.
- Total Clearing Volume (TCV): the sum over the whole period of the Demand Clearing Volume and of the Supply Clearing Volume. The sum over several areas of the TCV is the TCV of the set of these areas.

Figure 7 and Figure 8 show the change in clearing volumes per bidding area in FBMC relative to ATCMC (DCV, SCV and TCV on Figure 7 and MCV on Figure 8). FBIMC results are similar and thus not shown. Three observations can be made:

- The main change is the increased export from Germany to France;
- The TCV over all bidding areas increases: Overall, the increase of demand in areas in which the prices decreased is larger than the decrease of demand in areas in which the prices increased. However, no definitive conclusion can be made;
- All areas see an increase of the MCV. The high increase of the sum of MCV over all bidding areas is linked to the fact that exchange are counted twice: once in the exporting area, once in the importing area, therefore, as FBMC globally increases the exchanges, the total MCV significantly increases contrary to the total TCV that remains almost unchanged.

Figure 9 shows the detail of MCV per day and per area. Note that for missing days the values are interpolated between the adjacent days. It illustrates that FBMC and FBIMC most of the time lead to the same market clearing volume. Significant differences with ATCMC occur.

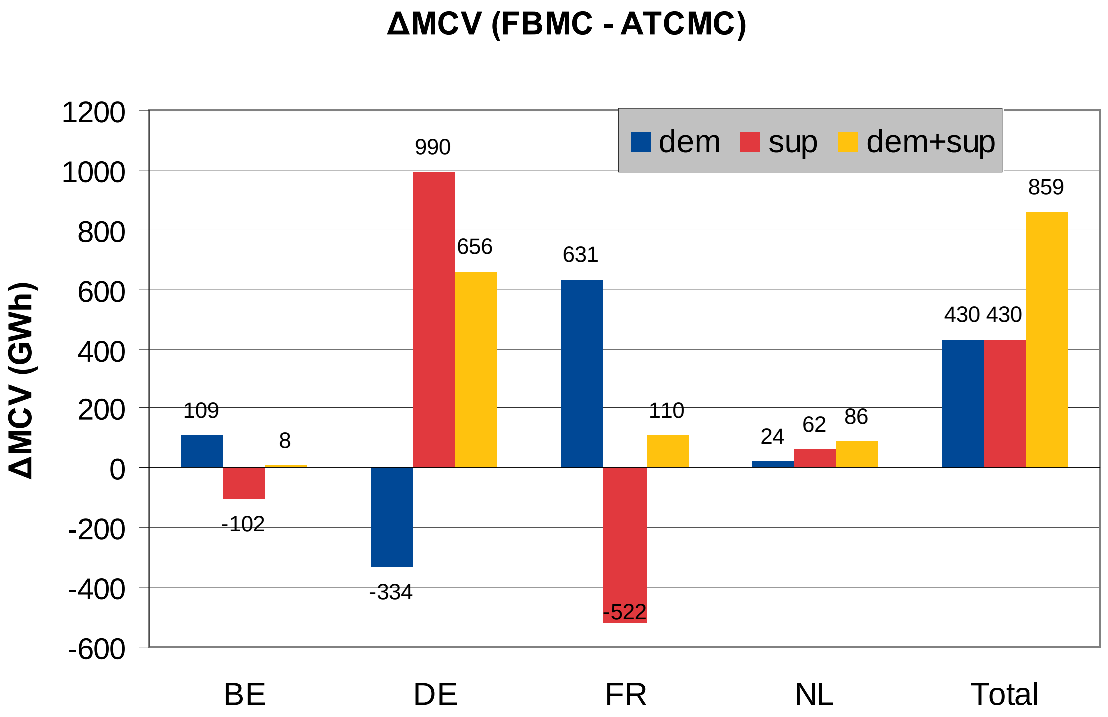


Figure 7: Sum of Demand, Supply and Total Clearing Volumes by area over all the simulation period

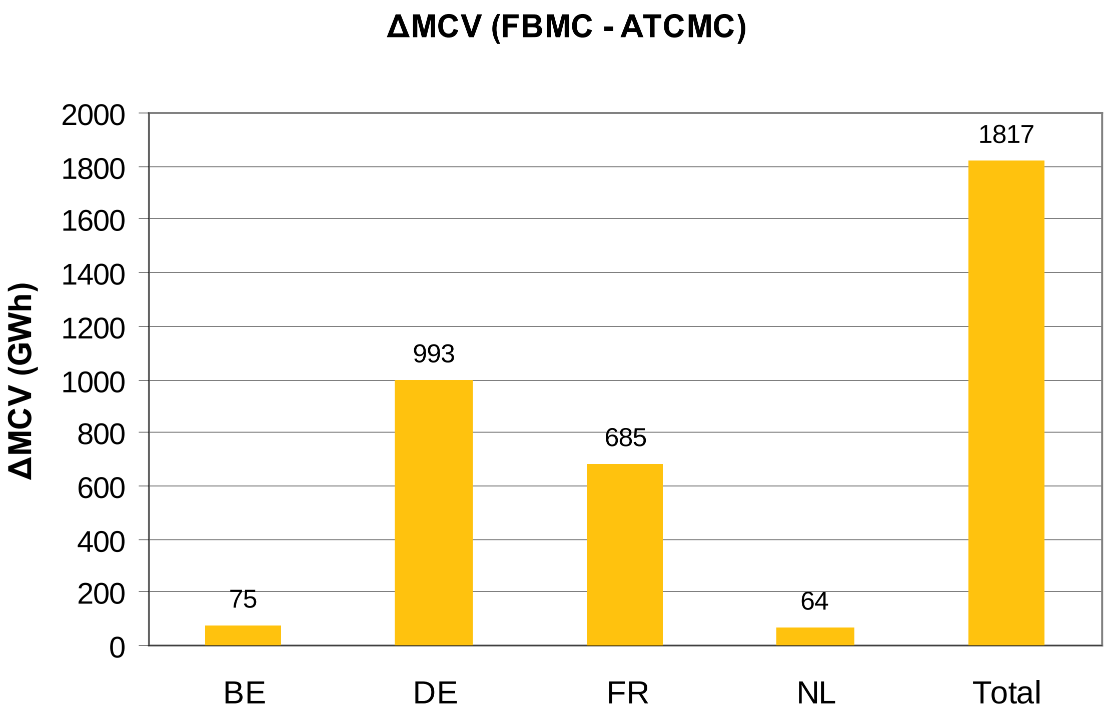
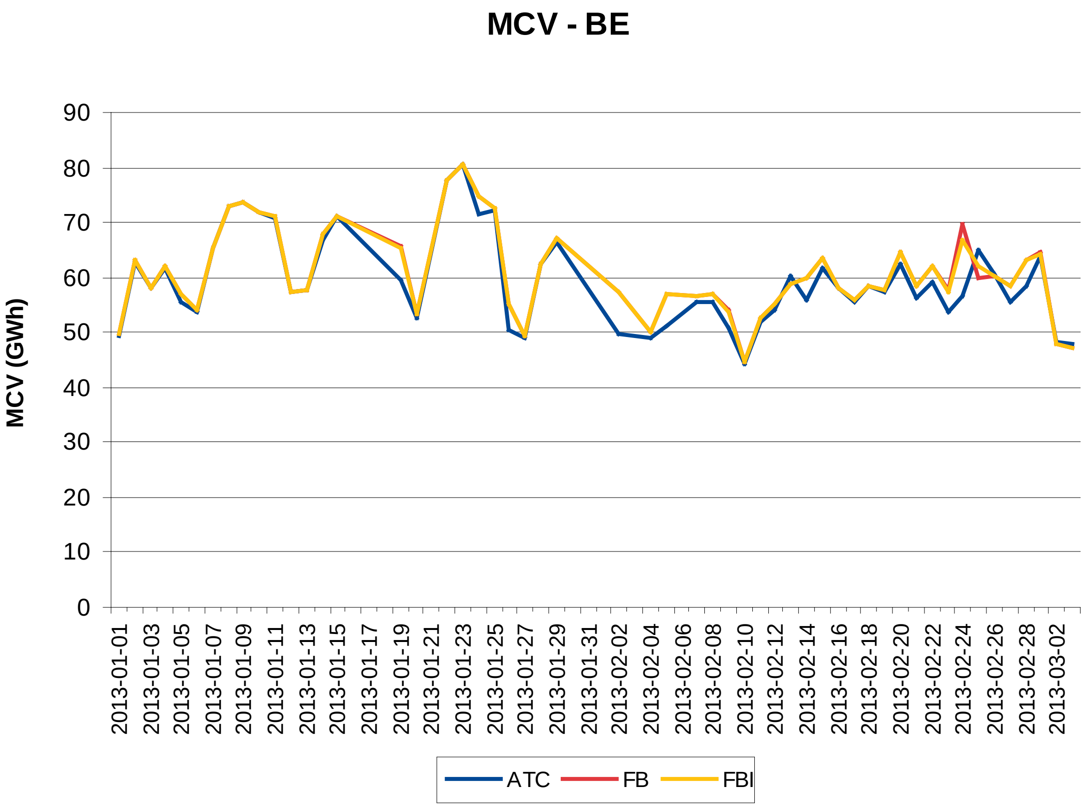
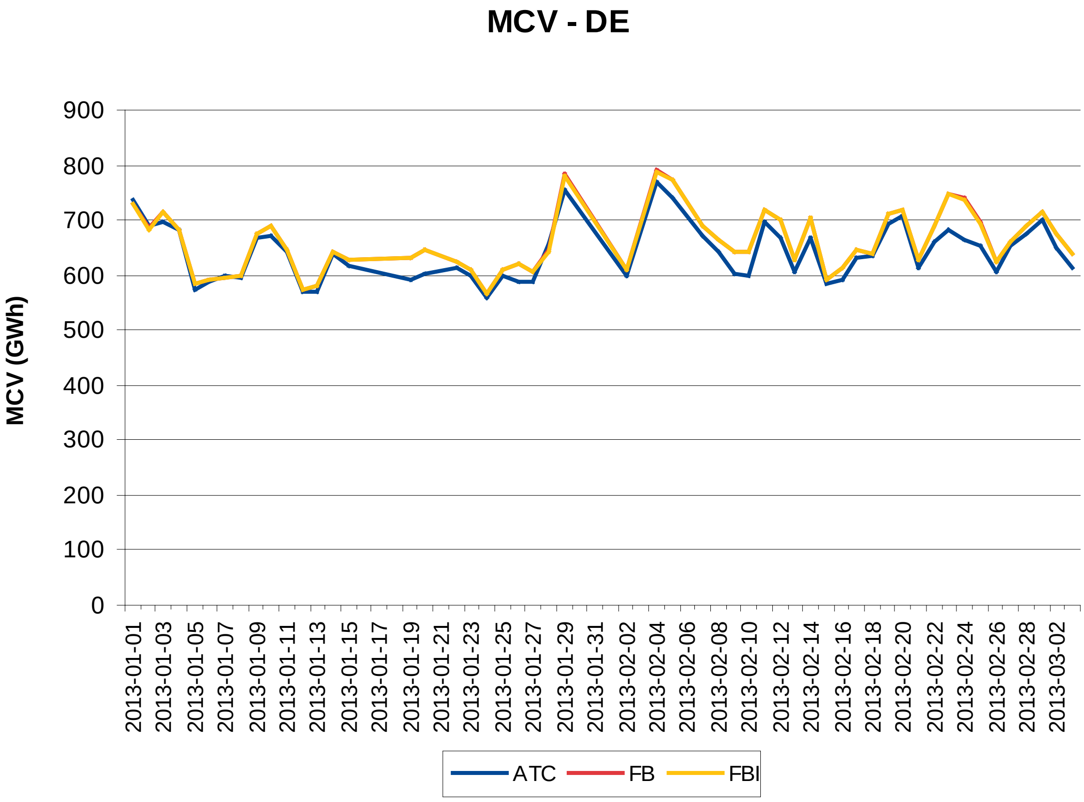
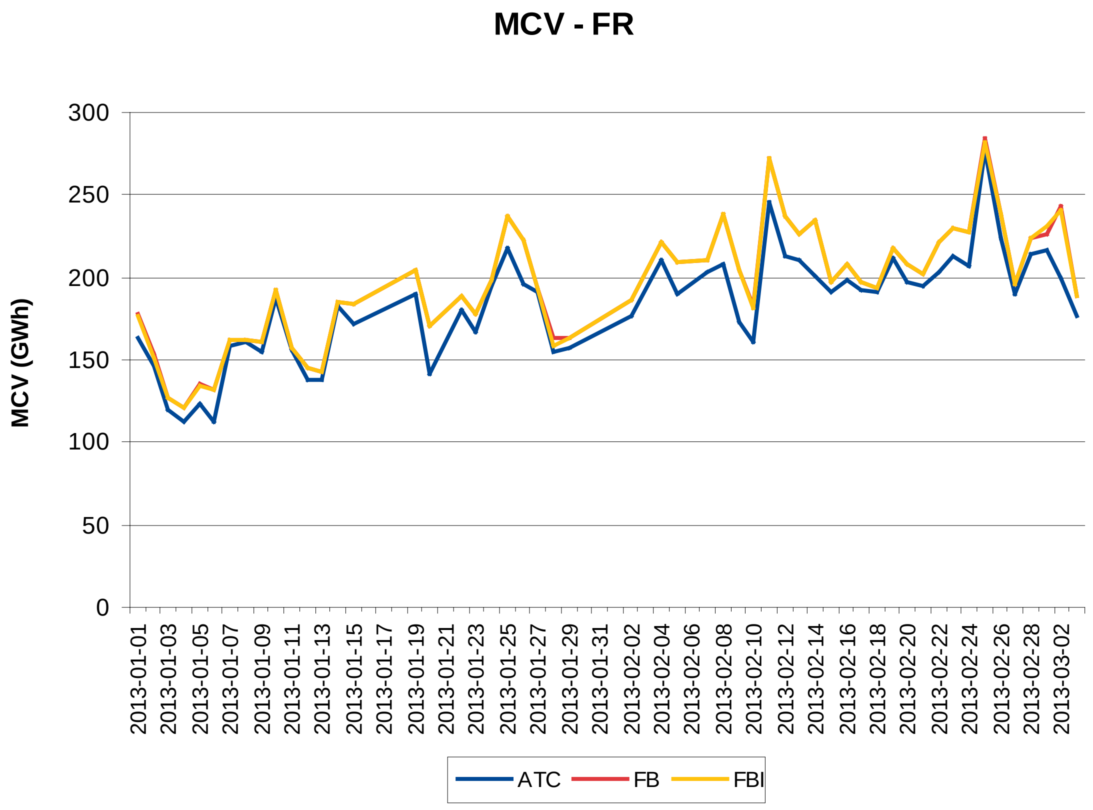


Figure 8: Sum of Market Clearing Volume by area over all the simulation period


MCV - BE
MCV (GWh)
0
10
20
30
40
50
60
70
80
90
2013-01-01
2013-01-03
2013-01-05
2013-01-07
2013-01-09
2013-01-11
2013-01-13
2013-01-15
2013-01-17
2013-01-19
2013-01-21
2013-01-23
2013-01-25
2013-01-27
2013-01-29
2013-01-31
2013-02-02
2013-02-04
2013-02-06
2013-02-08
2013-02-10
2013-02-12
2013-02-14
2013-02-16
2013-02-18
2013-02-20
2013-02-22
2013-02-24
2013-02-26
2013-02-28
2013-03-02
ATC
FB
FBI


MCV - DE
MCV (GWh)
0
100
200
300
400
500
600
700
800
900
2013-01-01
2013-01-03
2013-01-05
2013-01-07
2013-01-09
2013-01-11
2013-01-13
2013-01-15
2013-01-17
2013-01-19
2013-01-21
2013-01-23
2013-01-25
2013-01-27
2013-01-29
2013-01-31
2013-02-02
2013-02-04
2013-02-06
2013-02-08
2013-02-10
2013-02-12
2013-02-14
2013-02-16
2013-02-18
2013-02-20
2013-02-22
2013-02-24
2013-02-26
2013-02-28
2013-03-02
ATC
FB
FBI



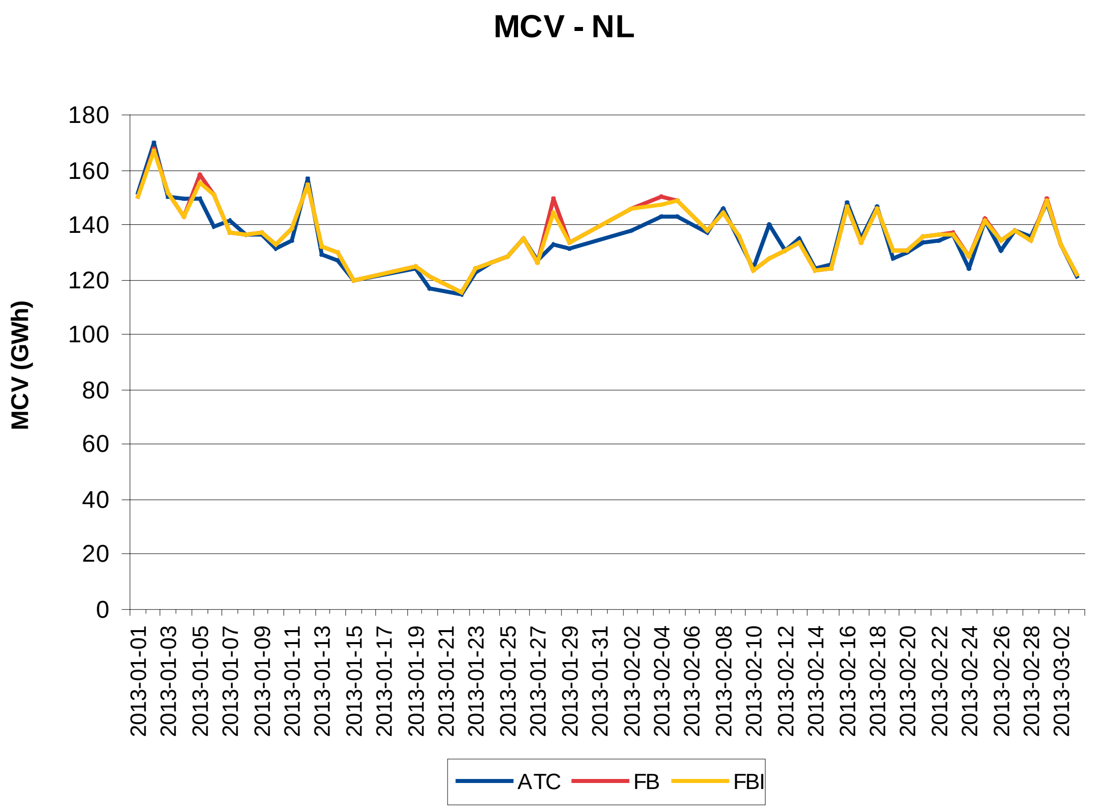


Figure 9: Daily MCV per area

1.4.4 Flow Pattern

Finally, to give an idea of the changes in flow patterns, some clearings are presented below. They are selected among those with the largest changes between ATCMC and FBMC.

Situations where the exchanges are significantly increased

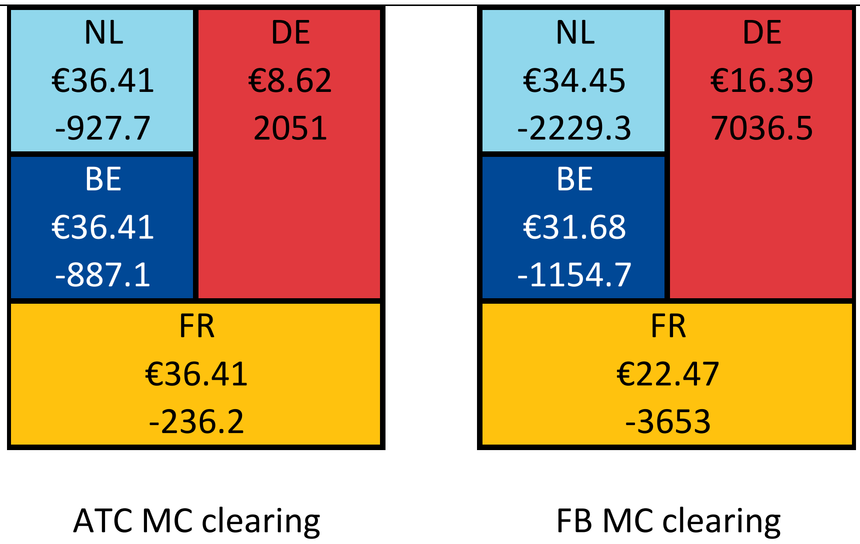


Figure 10: February 5th, 2013, 03:00 clearings

Figure 10 illustrates a situation where DE is exporting almost 5000 MW more.

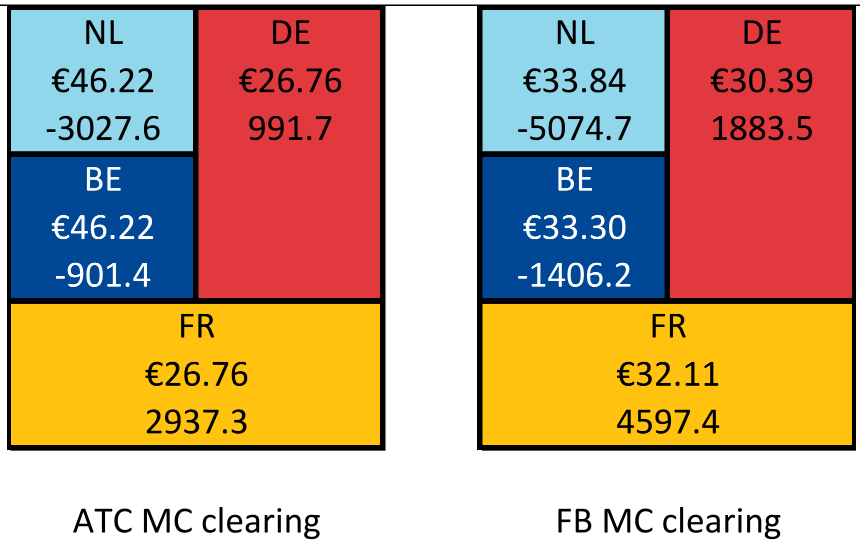


Figure 11: January 6th, 2013, 17:00 clearings

Figure 11 illustrates a situation where FR is exporting 1650 MW more.

Situations where the maximum net export over the simulated period are reached

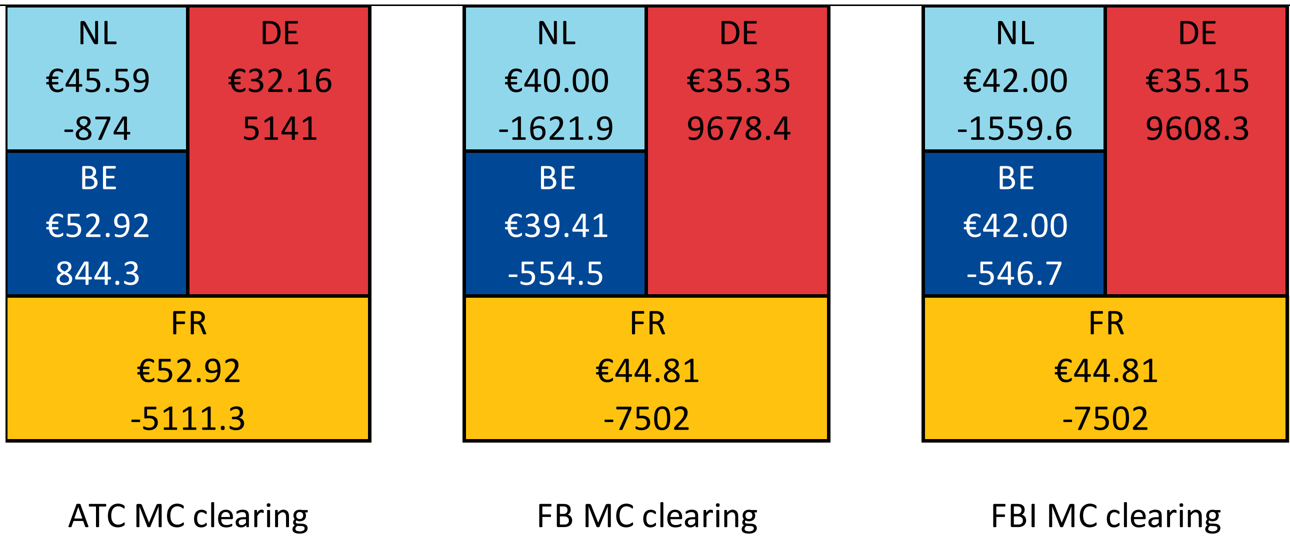


Figure 12: February 23rd, 2013, 07:00 clearings: maximum DE export in FBMC

Figure 12 illustrates the situation where the maximum DE export is reached. For BE, the situation is non-intuitive because BE imports whereas FR and NL both have higher prices. In FBIMC a partial price convergence is created between BE and NL

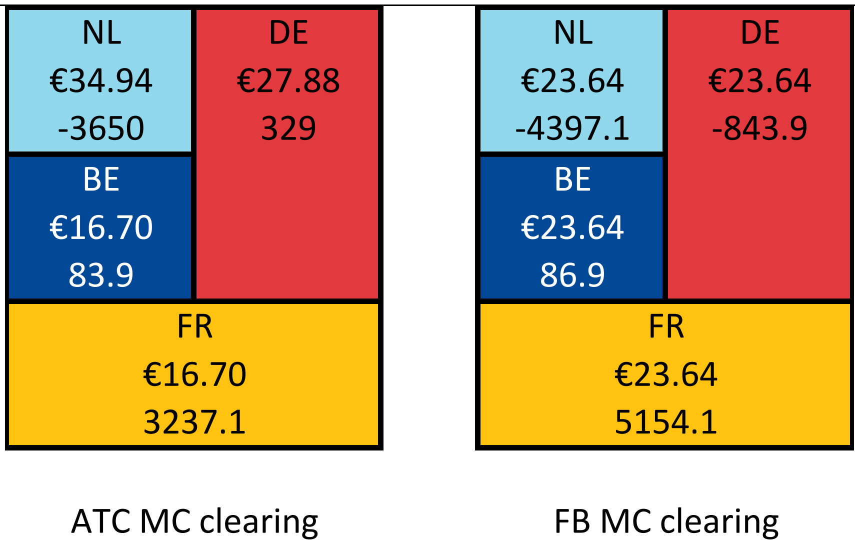


Figure 13: January 1st, 2013, 17:00 clearings: maximum FR export in FBMC

Figure 13 illustrates the situation where the maximum FR export is reached. For FR, full convergence is reached whereas a divergence between the highest priced (NL) and lowest priced (FR) markets of 18 €/MWh existed in ATCMC.

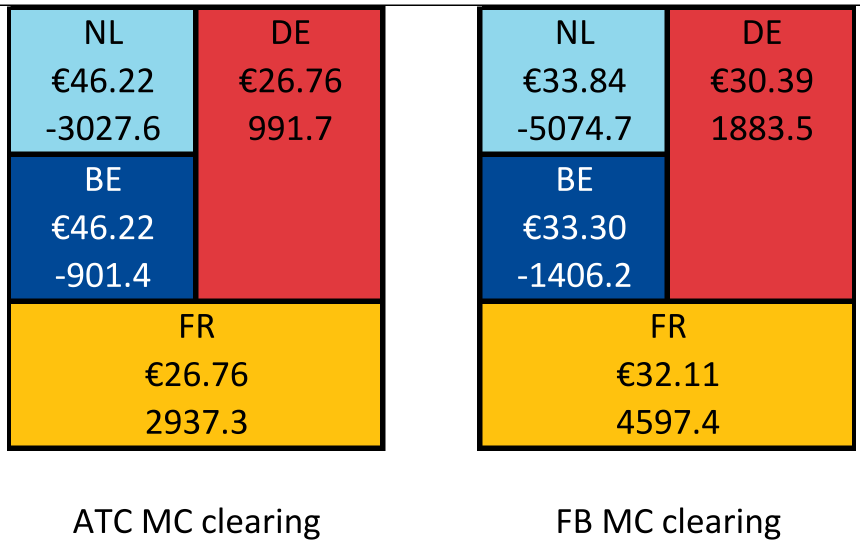


Figure 14: January 6th, 2013, 17:00 clearings: maximum NL import in FBMC

Figure 14 illustrates the situation where the maximum NL import is reached. Under ATCMC an NL-BE and DE-FR partial convergence was reached, but between them a spread of € 19.46 remained. FBMC results in full price divergence, however the overall spread is down to € 3.45.

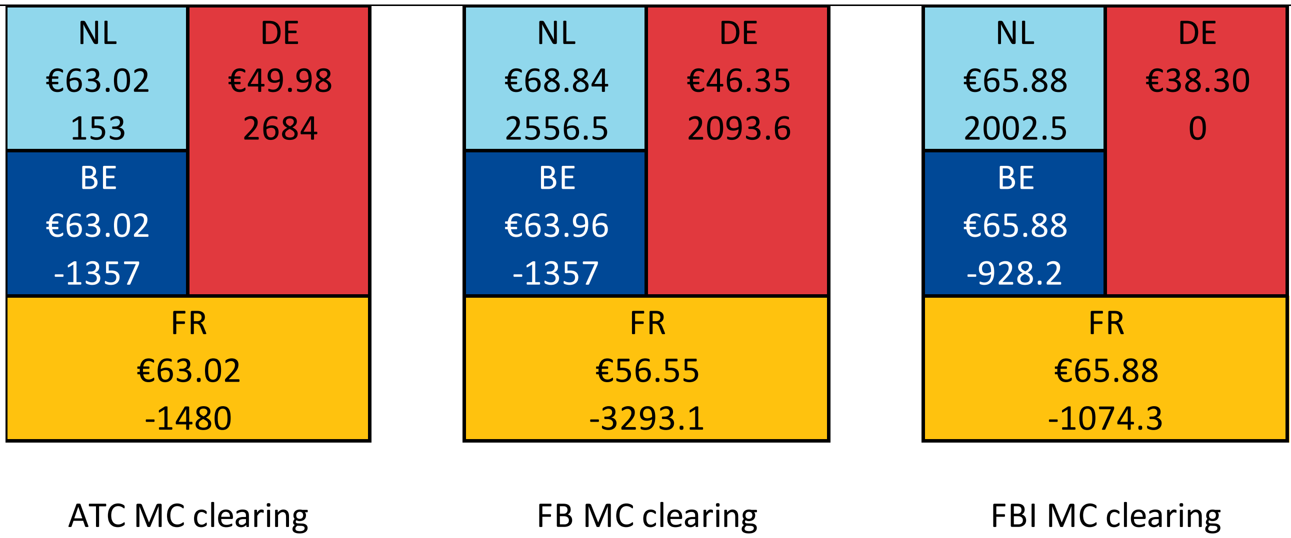


Figure 15: January 28th, 2013, 20:00 clearings: maximum NL export in FBMC

Figure 15 illustrates the situation where the maximum NL import is reached. The FBMC clearing forces NL to non-intuitively export. In the intuitive FB clearing this is "fixed" by reducing the DE export to 0, and simultaneously creating a partial convergence between BE, FR and NL

Similar figures are not shown for Belgium because the maximum export and the maximum import do not change significantly with the switch to FBMC.

1.4.5 Price convergence

Full price convergence ("Copper plate") is achieved when the price in all areas is equal. Partial convergence is reached when at least 2 areas have the same price. Full divergence means that all areas have different prices.

Figure 16 represents the proportion of time for which the situation was either "fully converged", "partially converged", or "fully diverged".

As, most of the time, the ATC domain is included in the FB domain, an increase of convergence was expected and is observed.

Due to the nature of FB constraints, less partial convergence (measured as the number of hours with at least partial convergence) was expected and is also observed (cf annex 5.11.3 of the CWE FBMC feasibilty report[2]). The small increase of partial convergence in FBIMC compared to FBMC is directly linked with the intuitiveness constraints on prices[3]. The partial convergences under FBMC correspond to situations where import constraints are met: special FB constraints with a factor "1" for the market for which the constraint applies, and "0" for the others[4]. In the price formation it means that the markets with a "0" factor (i.e. all have the same factor) will share a price: partial convergence. Note that a full divergence is not necessarily worse than a partial convergence. For example, let's consider a partial convergence of 2 areas with 40 €/MWh and 2 zones with 80 €/MWh, and a full divergence in FB with prices equal to 40.1 €/MWh - 40.2 €/MWh – 40.30 €/MWh – 40.4 €/MWh. Therefore, the analysis of other indicators like the price divergence (cf paragraph 1.4.6) is needed to assess the importance of the observed decreased partial convergence.

Overall, on the simulation period, FB allowed full convergence on 47% of hours instead of 23% in ATC.

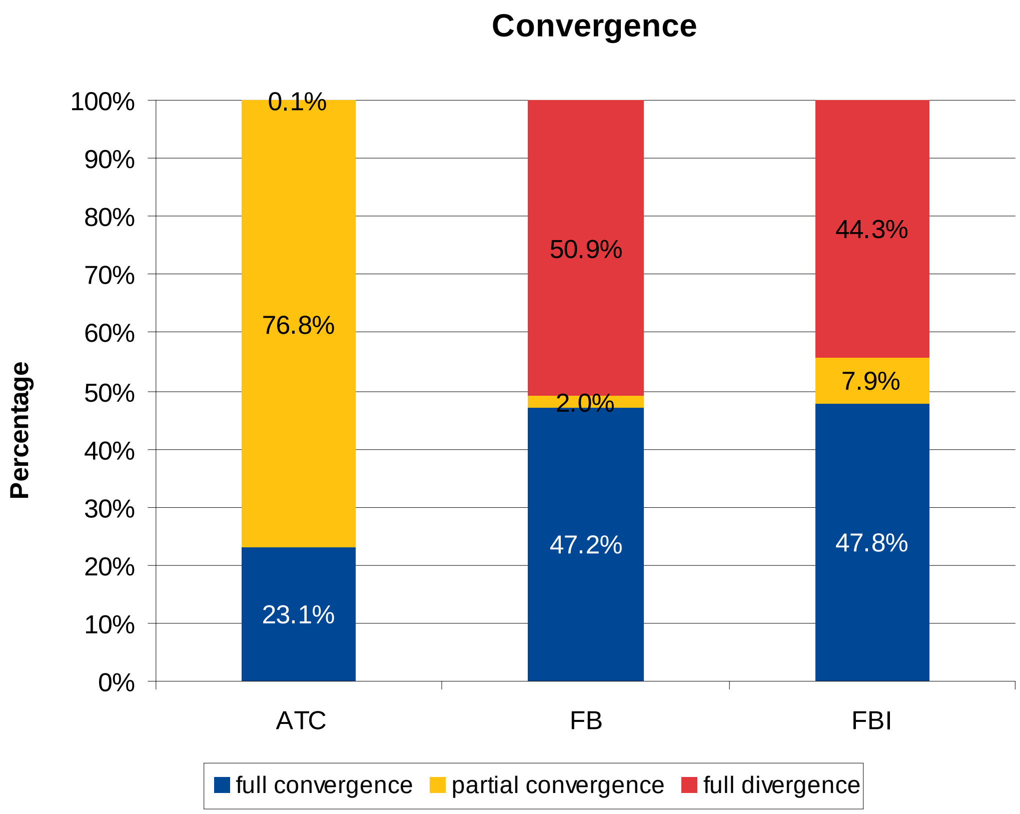


Figure 16: Convergence of price difference between areas in proportion of the number of situations (tolerance: 0.005 €/MWh)

As the FB domain usually includes the ATC domain, it is expected that FBMC results in full convergence when ATCMC results in full convergence. Although this typically is the case, there are some exceptions (for 25 hours out of the 1272 of this study ATC resulted in full convergence, whereas FB did not). For these periods either the FB domain does not contain the ATC domain or a different block selection caused a congestion. Hence the 25 hours in an upper bound on the number of hours for which the FB domain did not contain the ATC domain.

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[2] Published on all project partners websites, e.g. http://static.epexspot.com/document/14533/CWE_FB-MC_feasibility_report_2.0_19102011.pdf

[3] Indeed, when intuitiveness is enforced, it generally results in limiting the non-intuitive exchange between areas up to the point where these areas have the same clearing price so that the remaining exchange between them is allowed. Then, the exchange between these areas becomes compatible with the prices so that the situation becomes intuitive. See Section 1.4.87 for more details.

[4] This kind of constraints may have to be added by TSOs because the FB parameters computations are using a DC (direct current) model, not taking into account voltage stability problems.

These observations are summed up in the table below:

		FBMC		
		no full convergence	full convergence	Total
ATCMC	no full convergence	50.8%	26.1%	76.9%
	full convergence	2.0%	21.1%	23.1%
	Total	52.8%	47.2%	100.0%

Full convergence results are typically similar to FBIMC. For 7 hours this however is not the case. For instance January 5th, h2): full convergence is reached in FBIMC and a price divergence of 5.61 €/MWh is observed in FBMC. This situation is illustrated in Figure 17. In the FBIMC result 98MWh of block buy volume is is no longer accepted in NL. This reduces the need for import and relieves the congestion. For the other situations it also has been checked that these unexpected effects are all linked to block orders. Indeed, without such block order effects, enforcing intuitiveness cannot remove a congestion.

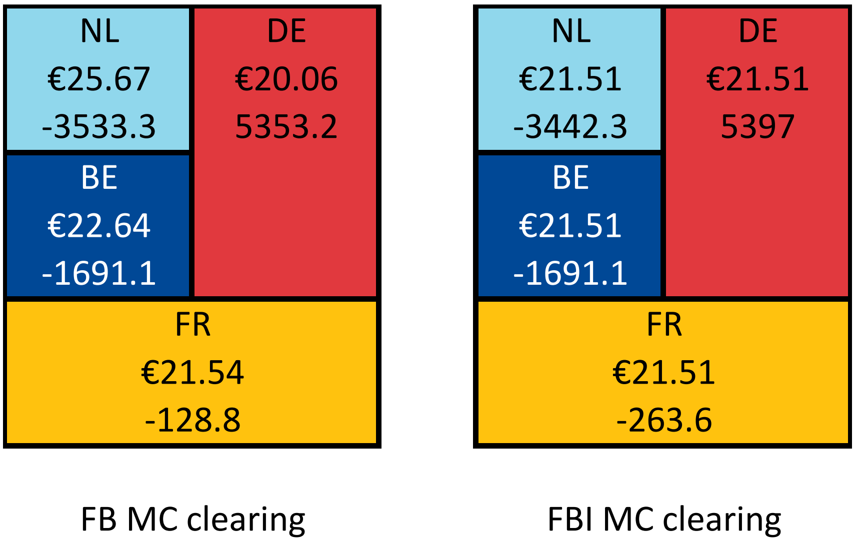


Figure 17: January 5th, 2013, h2 clearings: no convergence in FBMC and convergence in FBIMC

Occasionnally, due the interaction of block orders and capacity parameters over several hours, the convergence is reached in both ATC MC and FB MC but with a significantly different clearing, as on January 28th, 2013, h10.

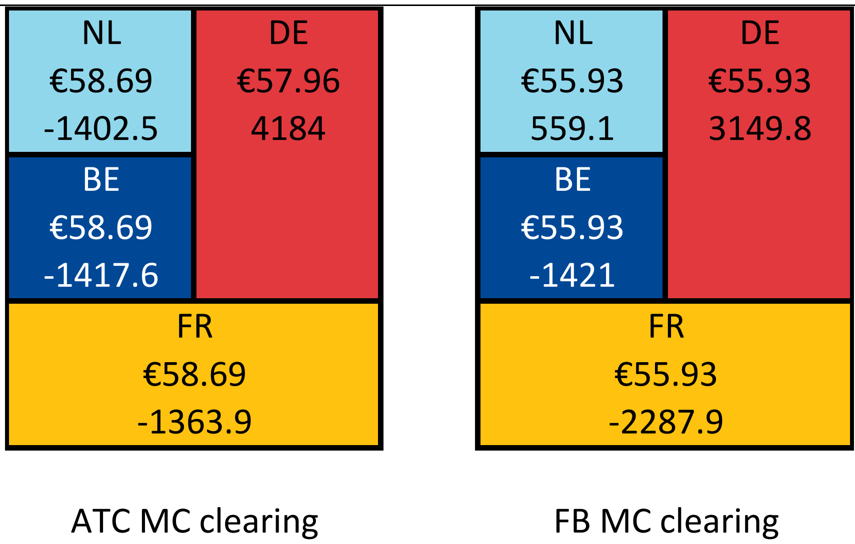


Figure 18: January 28th, 2013, h10 clearings

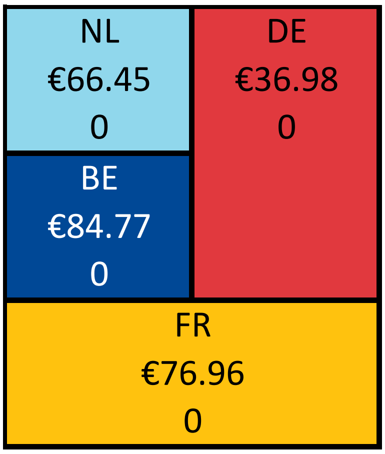
1.4.6 Price divergence

The graphs (Figure 19 and Figure 20) show the hourly difference between the highest and the lowest price among all areas, i.e. the maximum price difference, ranked in decreasing order for the different methods.

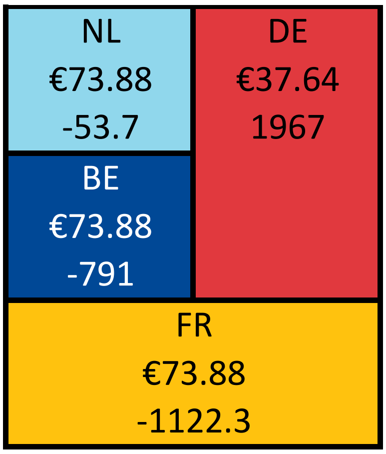
As observed for the convergence, the divergence is lower with FBMC than with ATCMC for most . However, the zoom on the first hours (Figure 20) shows that there are some situations for which the maximum price difference is larger in FBMC (and FBIMC) than in ATCMC. The most severe of these situations is February 4th, h19 and is analysed thoroughly in the frame below. Note that the fact that a price divergence distribution is below another one does not mean that the price divergence is always lower.

February 4th 2013. h19

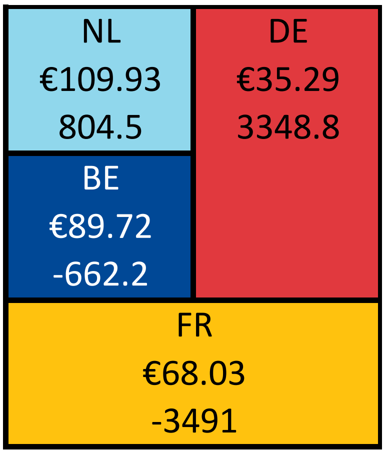
The clearing situations in isolated mode, ATCMC and FBMC on February 4th, 2013, h19 are depicted below:



Isolated Clearing



ATC MC clearing

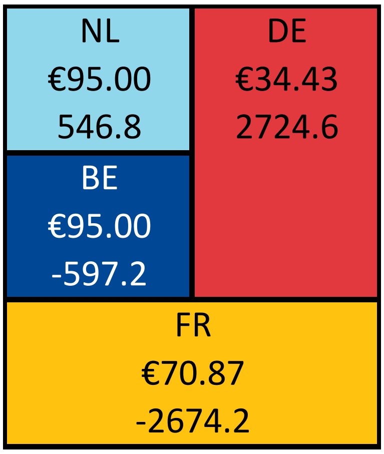


FB MC clearing

This situation is analysed in somewhat more detail, since contrary to what one might expect this situation illustrates how under FBMC the spread between the low and high priced markets actually increases (ATCMC: 36.24€/MWh, FBMC: 74.64€/MWh). This is linked to a higher price in NL and a lower price for DE in FBMC compared to ATCMC.

Here are some observations and analysis:

- A block effect caused the NL price to rise in the ATCMC scenarion, even though energy is now being imported;
- The ATCMC clearing point is within the FB domain;
- Consequently DAMW increased from ATCMC to FBMC. Indeed the objective of COSMOS is to maximize DAMW, not to minimize price divergence;
- Price convergence for FR and DE is slightly improved, whereas BE and NL are increasingly diverged, compared to the partial convergence obtained in the ATCMC;
- The solution under FBMC is non-intuitive: NL has the highest price and is exporting energy;
- Applying the intuitive patch in this specific instance therefore somewhat mitigates the observed increase in overall price divergence (at the cost of both welfare and the FR-DE price convergence):



FBI MC clearing

-

Overall, it is not possible to draw conclusions from only one exceptional situation. In following simulations, the number of hours with an increase of price divergence will be closely monitored.

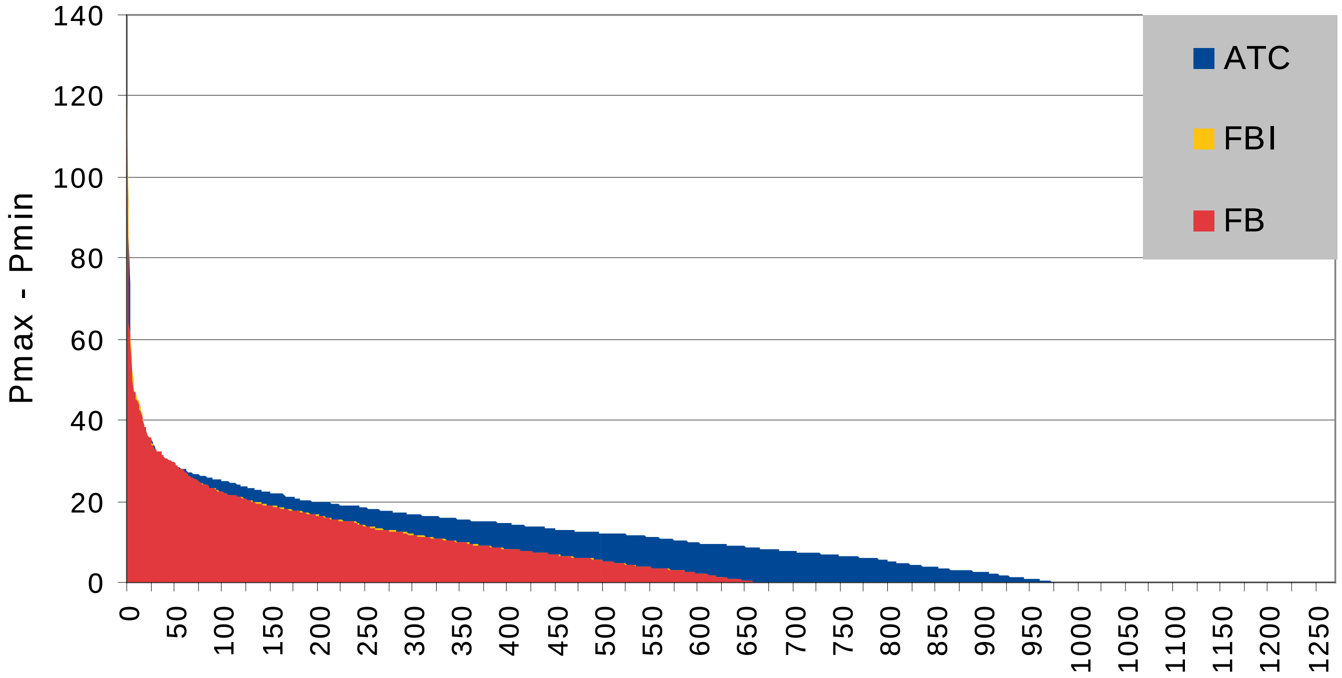


Figure 19: Maximum price difference distributions

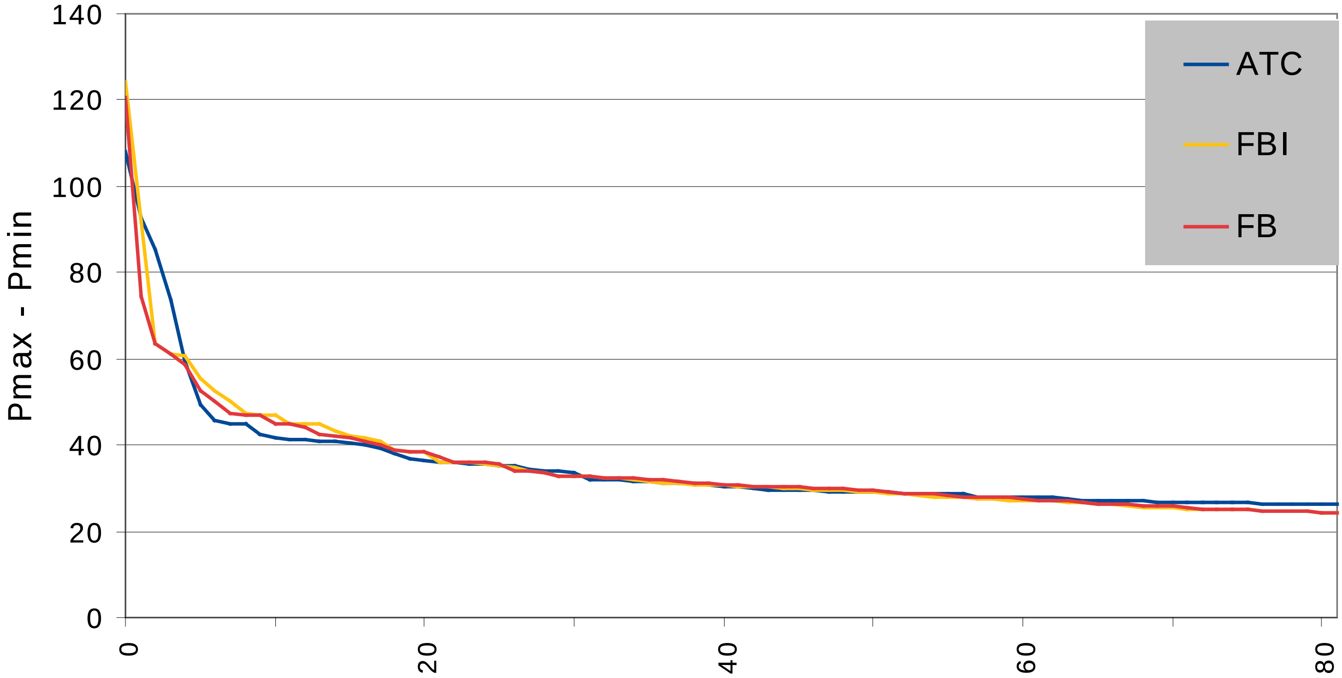


Figure 20: Maximum price difference distributions (zoom)

Flow pattern – results leading to full price convergence

Finally, in order to give a feeling of the changes from ATCMC to FBMC, the 3 next figures are the 3 situations with price divergence in ATCMC while no congestion occurs in FBMC (and, as expected, in FBIMC).

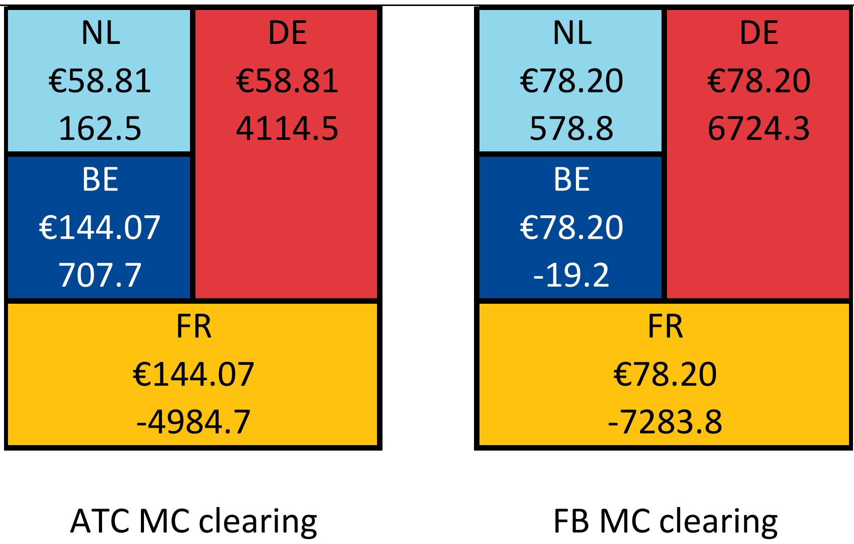


Figure 21: February 25th, 2013, h20 clearings

Figure 21 illustrates a situation where a partial convergence BE+FR vs DE+NL existed. Under FBMC more energy can be exchanged between these regions and full convergence results.

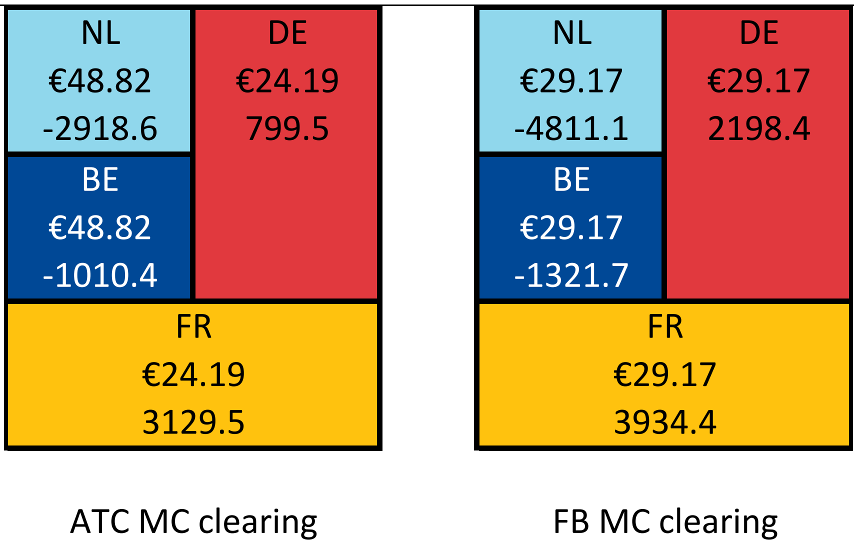


Figure 22: January 6th, 2013, h16 clearings

Figure 22 illustrates a situation where a partial convergence BE+NL vs DE+FR existed. Under FBMC more energy between these regions can be exchanged and full convergence results.

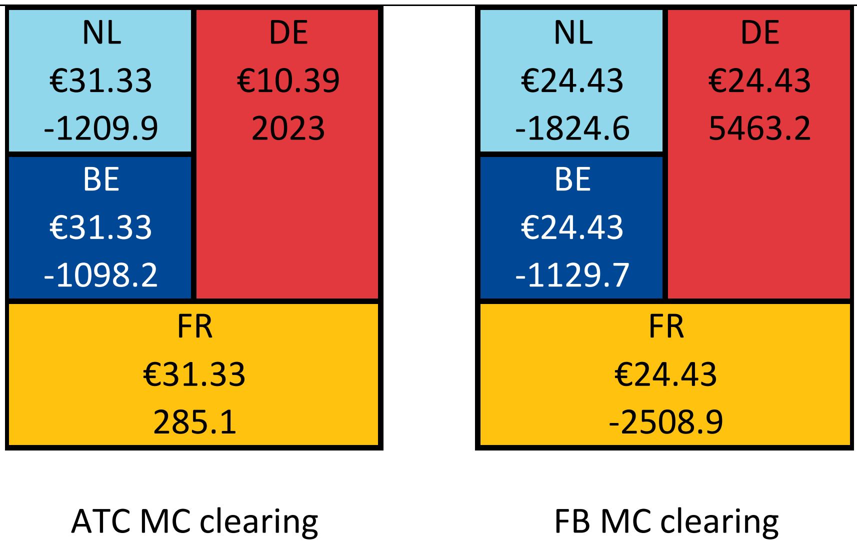


Figure 23: January 29th, 2013, h6

Figure 23 illustrates a situation where a partial convergence betwee BE+FR+NL vs DE existed. Under FBMC DE can export more energy and full convergence results.

1.4.7 Base load price

The base load price is the price of selling/buying 1 MW during each hour of all the period. It is the average of the clearing price. Figure 24 shows this daily average and its standard deviation (the standard deviation of daily averages, not the standard deviation of hourly prices). The standard deviation illustrates the range of the daily price average. Assuming a normal distribution of the daily price average, the probability that the base load price of a given day is in the plotted interval is 68%.

Globally, the price increases in areas exporting more and decreases in areas importing more. For Belgium and for France, the standard deviation is lower in FB than in ATC, meaning that the volatility on the base load price is reduced. For the Netherlands, the standard deviation is higher in FBMC, indicating a slightly higher volatility of the base price, probably linked to the fact that the partial convergence between NL and DE that anchored the NL price to DE during this period in ATCMC disappears in FB[5].

[5] For example, see slide 11 of the presentation shown at CWE Market Coupling Flow-Based Forum on June 1st, 2011. http://clients.rte-france.com/htm/fr/offre/telecharge/CWE_Flow_Based_Forum_1st_June_2011_presentation.pdf

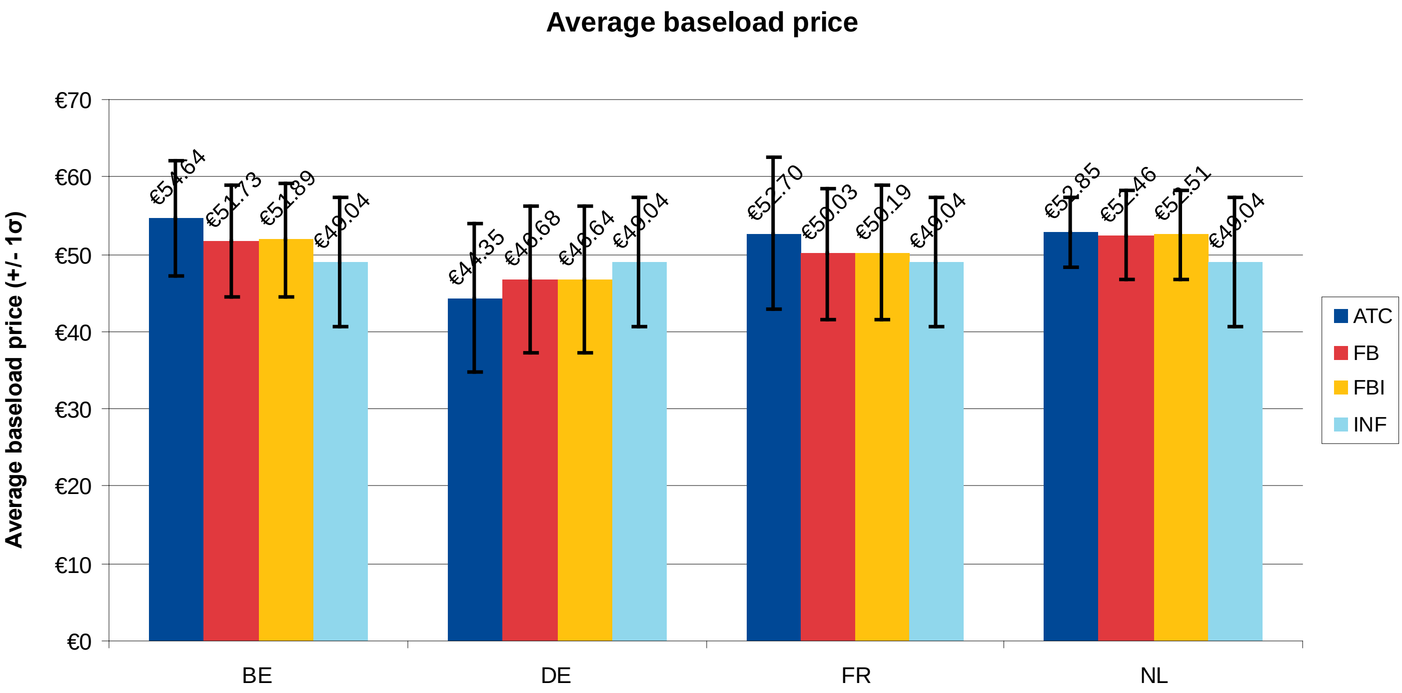
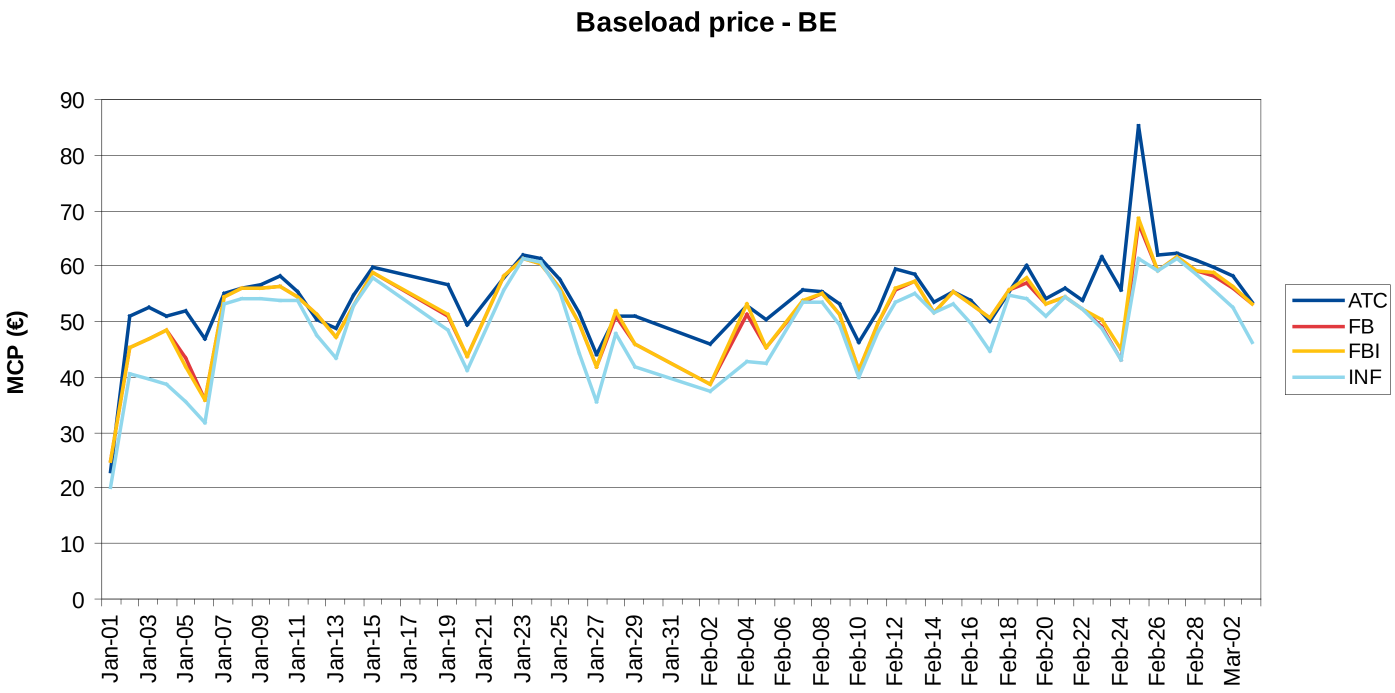
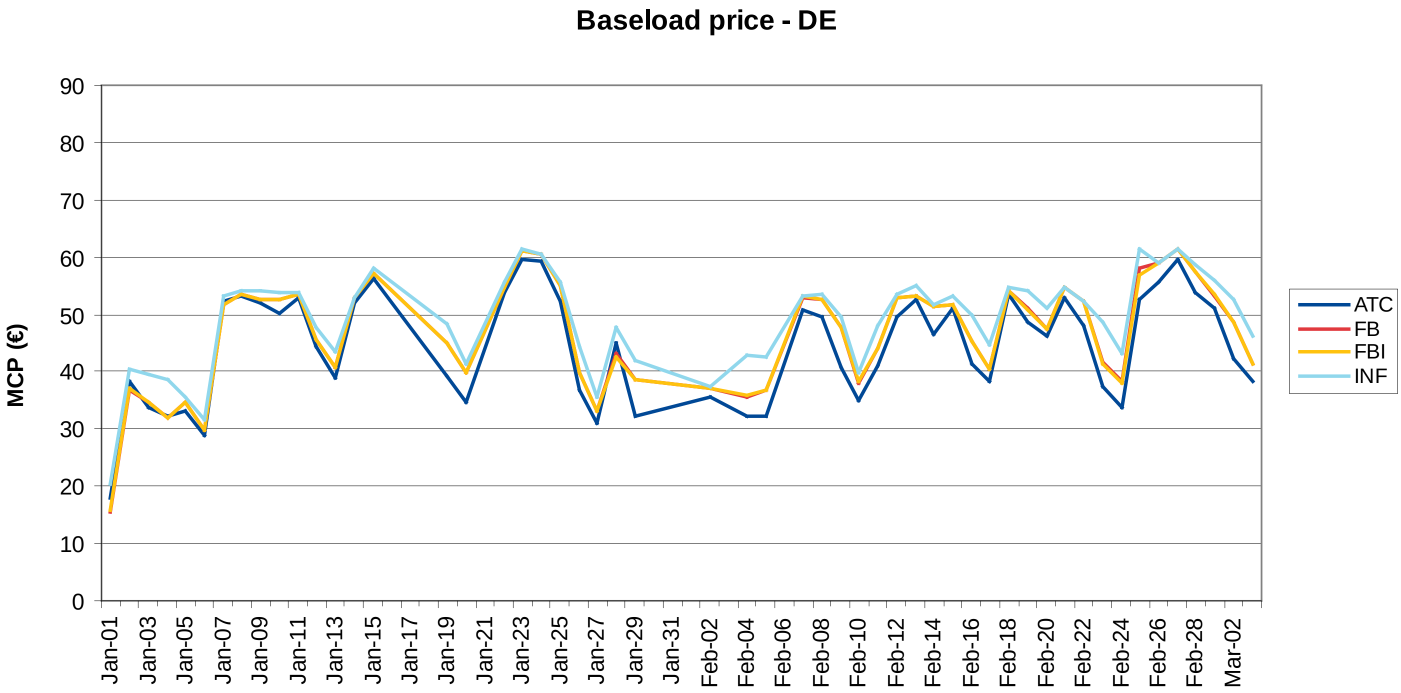


Figure 24: Average baseload price in €/MWh

The simulation period is short enough to plot the daily baseload price per area in Figure 25 representing the hourly clearing price per areas. Both Figure 24 and Figure 25 show that the difference between FBMC and FBIMC is small even on an hourly basis.

The daily baseload price for BE under FB tend to be reduced (in the direction of the INF scenario), whereas for DE the situation is reversed (but still closer to INF scenario). For FR and mainly NL both situations occur.


Baseload price - BE
MCP (€)
90
80
70
60
50
40
30
20
10
0
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Jan-27
Jan-29
Jan-31
Feb-02
Feb-04
Feb-06
Feb-08
Feb-10
Feb-12
Feb-14
Feb-16
Feb-18
Feb-20
Feb-22
Feb-24
Feb-26
Feb-28
Mar-02
ATC
FB
FBI
INF


Baseload price - DE
MCP (€)
90
80
70
60
50
40
30
20
10
0
Jan-01
Jan-03
Jan-05
Jan-07
Jan-09
Jan-11
Jan-13
Jan-15
Jan-17
Jan-19
Jan-21
Jan-23
Jan-25
Jan-27
Jan-29
Jan-31
Feb-02
Feb-04
Feb-06
Feb-08
Feb-10
Feb-12
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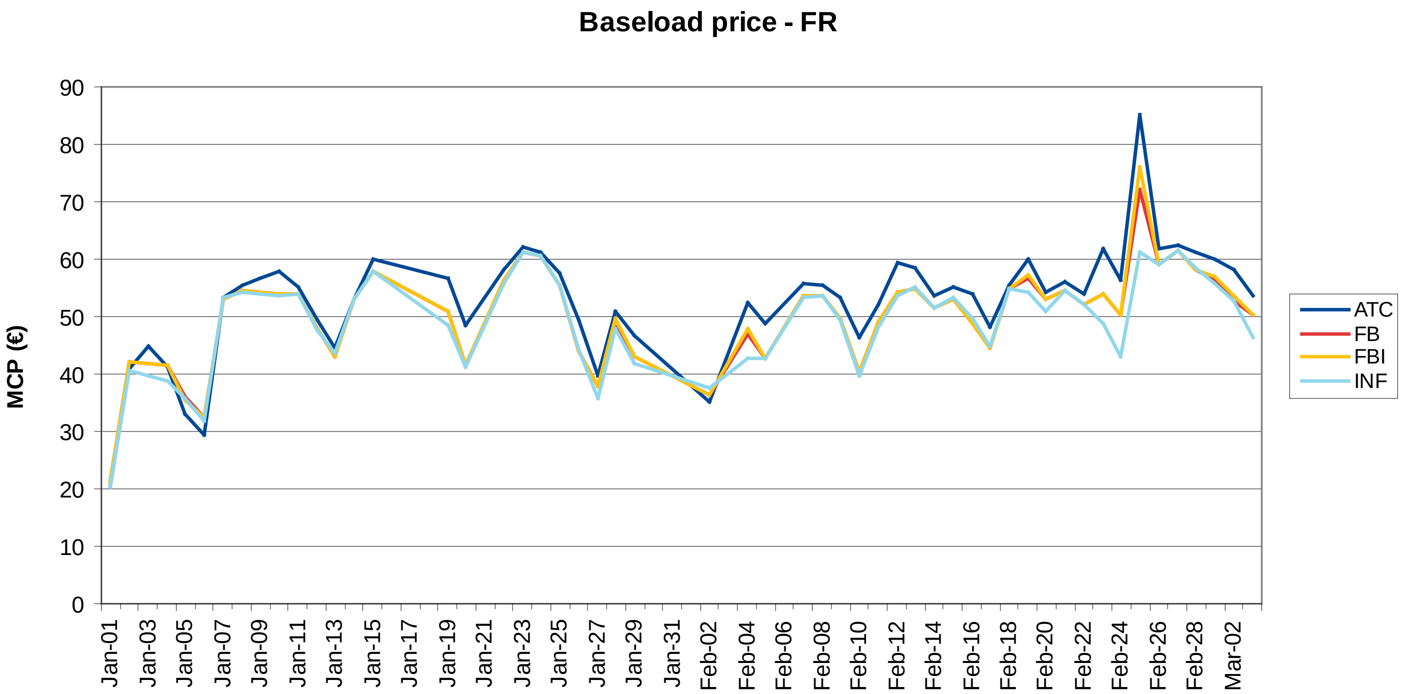
Feb-18
Feb-20
Feb-22
Feb-24
Feb-26
Feb-28
Mar-02
ATC
FB
FBI
INF



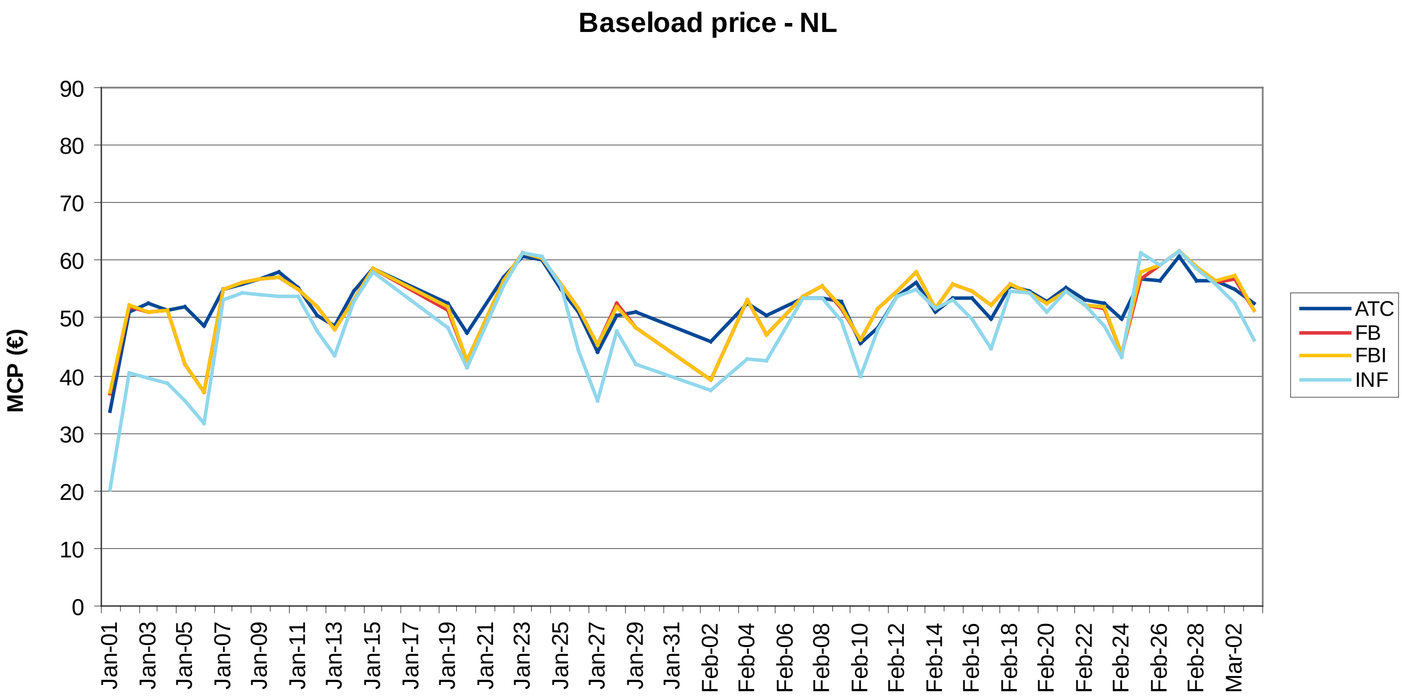


Figure 25: Daily baseload price per area

1.4.8 Frequency of non-intuitive situations

In Section 1.3.1, we define a situation as being “bilateral intuitive” (or just “intuitive”) if it exists at least one set of intuitive direct bilateral exchanges (from the cheapest bidding area to the most expensive one).

Out of 1272 hours there are 95 non-intuitive ones in FBMC. As expected, none are observed in FBIMC and ATCMC.

(tol. 0.005 €/MWh on rounded prices)	Number of hours where situations are bilateral non-intuitive	Proportion of hours where situations are bilateral non-intuitive	Proportion of hours where situations are bilateral non-intuitive among

			congested hours
ATCMC	0	0 %	0 %
FBMC	95	7.5 %	14.2 %
FBIMC	0	0.0 %	0.0 %
ISO	0	0 %	0 %

1.4.8.1 Description of non-intuitive situations

The non-intuitive situations occured during the days shown in the table below[6].

Wed	Thu	Fri	Sat	Sun	Mon	Tue
						2013-01-01
2013-01-02	2013-01-03	2013-01-04	2013-01-05	2013-01-06	2013-01-07	2013-01-08
2013-01-09	2013-01-10	2013-01-11	2013-01-12	2013-01-13	2013-01-14	2013-01-15
2013-01-16	2013-01-17	2013-01-18	2013-01-19	2013-01-20	2013-01-21	2013-01-22
2013-01-23	2013-01-24	2013-01-25	2013-01-26	2013-01-27	2013-01-28	2013-01-29
2013-01-30	2013-01-31	2013-02-01	2013-02-02	2013-02-03	2013-02-04	2013-02-05
2013-02-06	2013-02-07	2013-02-08	2013-02-09	2013-02-10	2013-02-11	2013-02-12
2013-02-13	2013-02-14	2013-02-15	2013-02-16	2013-02-17	2013-02-18	2013-02-19
2013-02-20	2013-02-21	2013-02-22	2013-02-23	2013-02-24	2013-02-25	2013-02-26
2013-02-27	2013-02-28	2013-03-01	2013-03-02	2013-03-03	2013-03-04	2013-03-05

On February 24th 18 hours resulted in non-intuitive situations, hence non-intuitiveness situations are over represented on this day. The non-intuitive situations are scattered all throughout the day. Only hours 3, 5, 7, 8, 10 and 18 resulted in intuitive clearings.

For this day for 16 out of 18 hours the non-intuitiveness of the situations stems from the fact that BE has a price lower than FR and NL, and only DE has an even lower price. But since no BE-DE connection exists, the situation is considered bilaterally non-intuitive.

For the 2 remaining non-intuitive hours (23 and 24) NL has the lowest price and is obliged to import, to facilitate a larger exchange from DE to FR.

Schematically, non-intuitiveness is solved by the combination of 2 effects that occurs when increasing the NEX of the bidding areas with the lowest price:

- As imports decrease, price increases so that the area price is not the lowest anymore: in FBIMC the prices of the 2 areas partially converge
- Imports may decrease up to the point that the area exports, so that the fact that the area has the lowest price is not non-intuitive anymore.

Experimentally, both effects are observed and combined on this specific day:

- In 16 situations out of 18, partial convergence is observed: in FBIMC, the prices of the 2 areas with the lowest prices are equal. Usually, it means that the BE price is aligned with the NL price (when the BE price is the lowest) or the NL price is aligned with the DE price (when the NL price is the lowest).
- In 4 situations, the NEX sign changes (in 2 situations, it occurs together with price convergence). It always concerns NL. In 2 situations, the new NL NEX is 0 MW. In 2 situations, the new NL NEX is strictly positive (154.5 MW –cf. Figure 27- and 358.9 MW –cf. Figure 28-: this effect is due to block orders which do not allow a continuous variation of NEX.

Below some typical non-intuitive situations are described and how FBIMC “solves” the non-intuitiveness. In the diagrams below, green squares emphasize partial convergences or net export position sign change.

[6] Font size gives an idea of the occurrence of non-intuitive situations for a particular day.

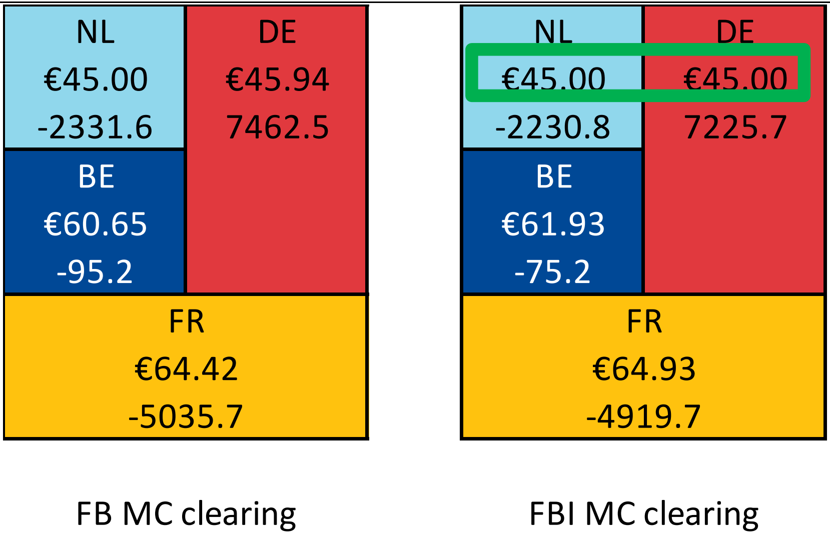


Figure 26: February 24th, h23 FBMC and FBIMC clearings

Figure 26 illustrates a timestamp in which NL was in a non-intuitive situation that was "solved" by creating partial convergence with DE.

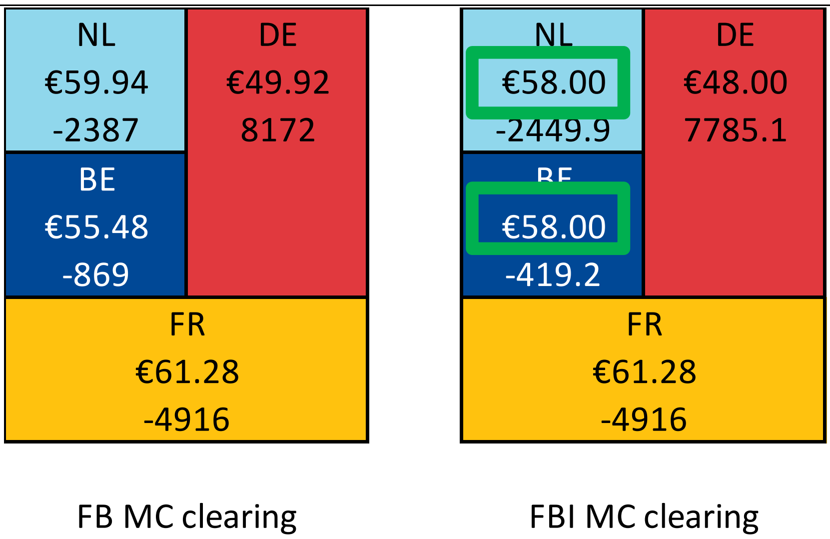


Figure 27: February 24th, h19 FBMC and FBIMC clearings

Figure 27 illustrates a timestamp in which BE was a non-intuitive situation that was "solved" by creating partial convergence with NL.

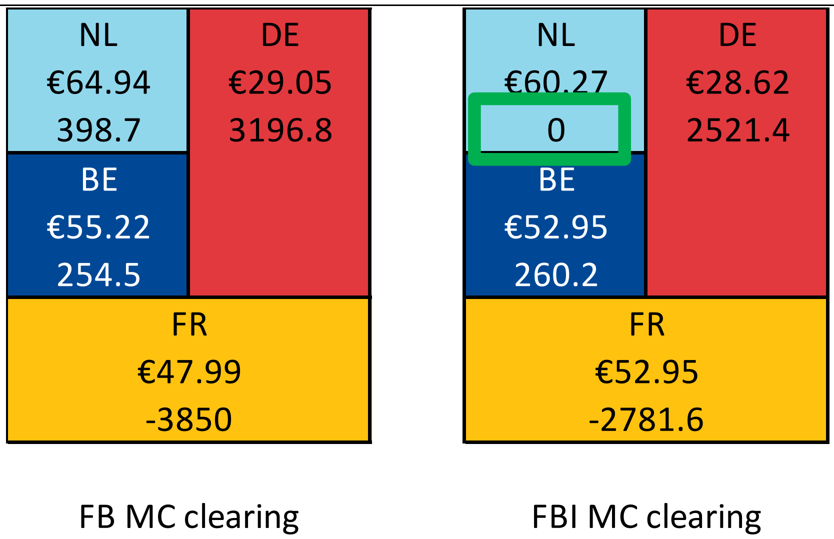


Figure 28: February 4th, h21 FBMC and FBIMC clearings

Figure 28 illustrates a timestamp where a non-intuitive situation in NL is "solved" by changing the sign of NL NEX.

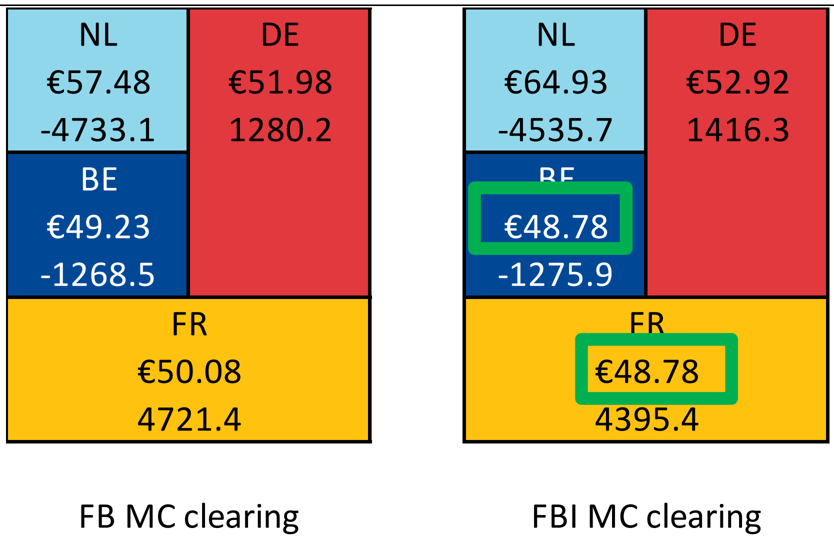


Figure 29: January 5th, h18 FBMC and FBIMC clearings

Figure 29 illustrates a timestamp in which a partial convergence between FR and BE is created to "solve" the non-intuitiveness in Belgium.

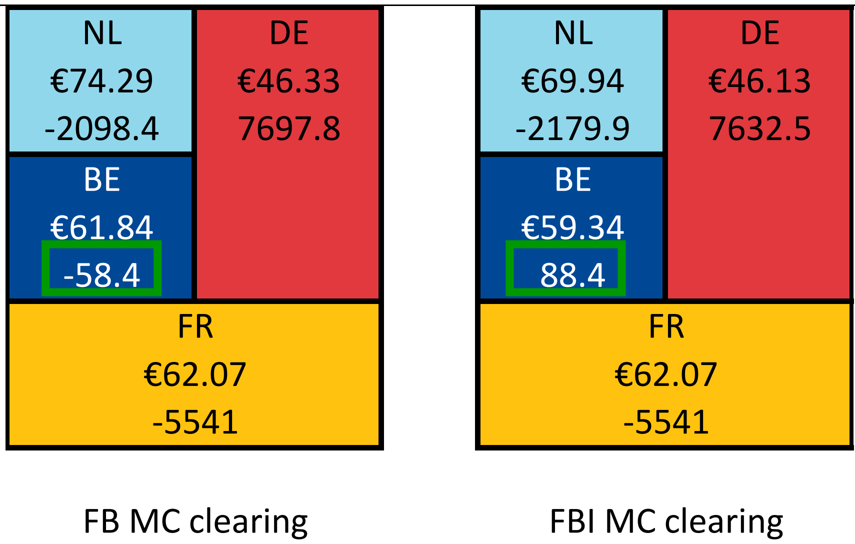


Figure 30: February 24th, h21 FBMC and FBIMC clearings

Figure 30 illustrates a timestamp where a non-intuitive situation in BE is "solved" by changing the sign of BE NEX. The fact that BE position becomes strictly positive, while 0 MW was enough, is due to the impossibility of a continuous variation of the NEX linked with block orders. In fact this block effect is cleary visible, since the BE price actually goes down when moving from an import to an export position. The missing import is fully offset by buy blocks that no longer are active in the FBI solution.

1.4.9 Comparison of isolated prices vs coupled prices

As coupling markets usually increases price convergence, situations in which one of the market clearing prices is higher than the highest price of all markets in isolated mode or in which one of the market clearing prices is lower than the lowest price of all markets in isolated mode are monitored.

For these two scenarios the tables below register the number of hours where each of the markets sees it price above the highest isolated price or below the lowest isolated price. Note that (partial) convergence leads to situations where more than one markets have prices above or below the isolated extreme price. The totals in these table therefore do not correspond to the sums of the rows: hours for which more than one market is impacted are only counted as one occurrence.

	# hours most expensive coupled market price > most expensive ISO market price				
	BE	DE	FR	NL	Σ
ATCMC	0	0	0	0	0
FBMC	6	0	0	11	12
FBIMC	5	0	0	8	9

	# hours cheapest coupled market price < cheapest ISO market price				
	BE	DE	FR	NL	Σ
ATCMC	1	3	1	1	3
FBMC	1	16	1	1	16
FBIMC	1	17	1	1	17

Prices under FBMC and FBIMC can both decrease below the lowest islolated price and increase beyond the highest isolated price. Both occur more frequently than under ATCMC. The amount by which prices drop below the lowest ISO price are limited to:
ATCMC: 1.48 €/MWh;
FBMC: 2.87 €/MWh;
FBIMC: 3.74 €/MWh;

Perhaps more concerning are the price rises beyond the highest isolated price. Under ATC this was not observed. Under FBMC this goes up to 25.16 €/MWh, for FBIMC up to 10.23 €/MWh;

This worst case for both FBMC and FBIMC is illustrated in Figure 31. NL non-intuitively exports, raising its price beyond the highest isolated price (BE).

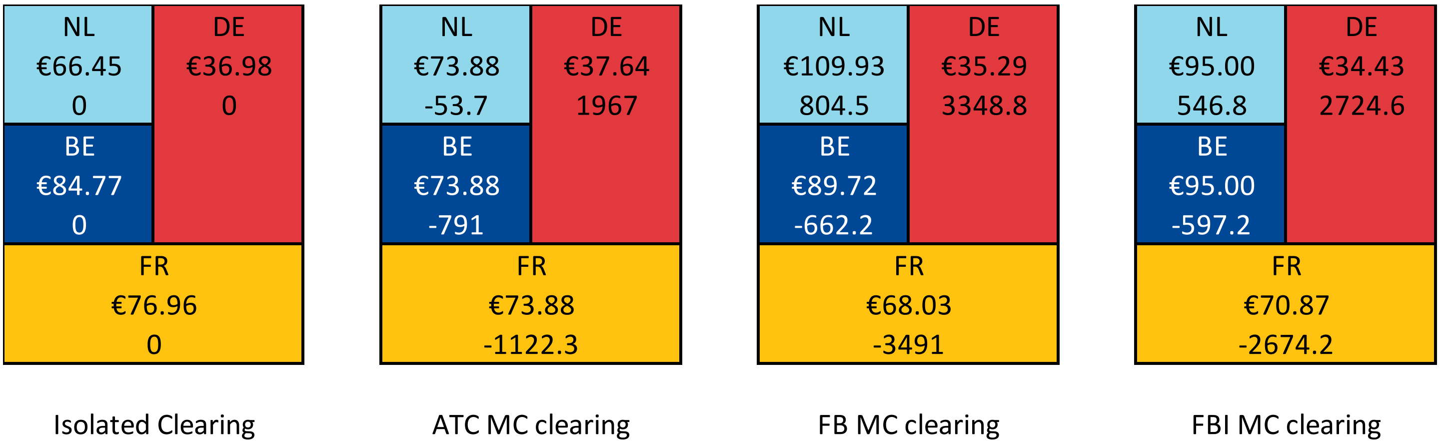


Figure 31 February 4th 2013, h10 different clearings

1.4.10 Paradoxically rejected blocks

Paradoxically rejected blocks (PRB) are block orders that are rejected while they are “in the price” (below the price for sell bids and above it for buy bids). Overall, as shown in the table below, the number of rejected blocks and the associated welfare loss (for the owner of the bid) decrease when the capacity available and the convergence increase.

	Number of PRBs	PRB Welfare Loss
ATCMC	402	275,151 €
FBMC	266	184,171 €
FBIMC	270	215,393 €
Isolated	864	4,204,020 €
Infinite cap. MC	140	56,873 €

Therefore, the conclusion is that FBMC and FBIMC have a positive impact on the PRB issue because they increase the convergence compared to ATCMC. Of course it should be noted that since under FBMC and FBIMC prices have changed, it might be that blocks (provided they were submitted around the anticipated ATC clearing price) now are well in- or out-of-price. Hence the conclusion could be premature.

1.4.11 Computation time

The computation time is an indicator of the complexity of the market clearing problem. The table below shows that the number of times that the algorithm reaches the time limit of 600s is not significantly larger in FBMC and FBIMC than in ATCMC.

	Number of runs reaching time limit (600 s)
ATCMC	22 (42%)
FBMC	17 (32%)
FBIMC	19 (36%)
Isolated	51 (96%)
Infinite cap. MC	5 (9%)

Therefore, the conclusion is that the computation time for FBMC and FBIMC is not a problem.

1.5 Conclusions

Simulations comparing ATC, FBMC and FBIMC on the first 9 weeks of the parallel run gave the following results:

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

Notwithstanding the limitations mentioned in section 1.2.2, the market impact analysis concludes that FBMC and FBIMC have a positive impact on the market compared to ATCMC.