Consultation document for CWE capacity calculation for ID timeframe

1. **Methodology for capacity calculation for ID timeframe (Technical Paper)**

2. **Context paper**

Methodology for capacity calculation for ID timeframe

For NRA approval

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Contents

1 Management summary

The purpose of this technical paper is to provide all Regulators of the CWE region with a description of the Flow-Based Intraday Capacity Calculation (FB ID CC) methodology, in order for them to approve it in the framework of the Regulation 714/2009. This document is considered as a follow up of the CWE Flow-Based Day Ahead (FB DA) approval package dated August 1st, 2014 and in particular of the "*Position Paper of CWE NRAs on Flow-Based Market Coupling*" of March 2015, as well as the approval package on the methodology for capacity calculation for the ID timeframe submitted to NRAs on November 9th 2015. The present FB IDCC methodology is therefore to be seen as a third implementation step for the calculation of ID capacity after CWE FB DA market coupling and will include an enriched version of the coordinated increase/decrease process applied since March 30th of 2016.

For the avoidance of any doubts, this document does not cover FB ID allocation. For the purpose of the allocation of capacity, Available Transfer Capacities (ATC) (extracted from the FB domain) will be used.

The remainder of the document is structured as follows: chapter two contains the glossary with the acronyms used in this paper. The FB ID CC methodology including a description of the inputs, the process and the outputs is presented in chapter three. The next chapter describes the back-up procedures and chapter five includes transparency procedures.

2 Glossary

- **ATC provided to the market**: The ATC values resulting from the re-assessment of the ATC values for allocation that will be provided to the market.
- **DC calculations:** Direct current calculations. Calculations of unidirectional flow of electric charge.
- **CACM:** Regulation 1222/2015 - Capacity allocation and congestion management guideline
- **CMT**: Central Matching Tool. Central tool used for intraday increase/decrease process to consolidate the increase requests and the decrease notifications.
- **DA CGMs & ID CGMs**: Day Ahead & Intraday Common Grid Models which are the result of the merging of the Individual Grid Models provided by TSOs in day-ahead or in intraday as their best forecast of the topology, generation and load for a given hour of the Day D.
- **Day D**: Delivery day for which capacity increases or rejection are considered.
- **DACF**: Day-Ahead Congestion Forecast.
- **Explicit remedial actions**: Remedial actions taken into account in the capacity calculation process.
- **ID ATC**: Intraday Available Transfer Capacity.
- **IGM**: Individual grid models
- **FB DA ATC**: The left-over ATC values extracted from the FB DA domain.
- **FB ID ATC**: The ATC values extracted from the FB ID capacity calculation domain.
- **MCP**: Market Clearing Point.
- **MTP**: Market Time Period. A group of consecutive hours within the Day D.
- **Net exchange program**: Netto exchanges in terms of cross-zonal flows between different bidding zones.
- **Net position**: netted sum of electricity exports and imports for each market time unit for a bidding zone.
- **Partial acceptance**: Situation in ID ATC after FBMC process when a TSO will partially accept the requested increase on the borders on a non-discriminatory basis. This occurs when the requested capacity increases on different borders compete for available margin on the same network element.
- **PTDF**: Power Transfer Distribution Factor.
- **RA**: Remedial action. Measure applied to modify (increase) the FB domain in order to support the market, while respecting security of supply.
- **RCS**: Regional security coordinator.
- **RAM**: Remaining available margins on critical network elements.
- **Rejection**: Situation in ID ATC after FBMC process when a TSO will reject the increase requested because the consequences of the request cannot be fully nor partially accepted by the TSO.
- **Zone-to-hub PTDF**: Represent the variation of the physical flow on a critical branch induced by the variation of the net position of each hub
- **Zone-to-zone PTDF**: The impact in terms of flows of a power exchange between two zones on a given critical network element.

3 Flow Based Intraday capacity calculation Methodology

3.1 Inputs

To calculate the Flow Based capacity domain for one timestamp of the business day, TSOs have to assess the following items which are used as inputs into the model:

- Critical Network Elements (CNEs)
- Contigency (C)
- Maximum current on a Critical Network Element (Imax) / Maximum allowable power flow (Fmax)
- Final Adjustment Value (FAV)
- DA Common Grid Model (CGM) and reference Programs
- Remedial Actions (RAs)
- Generation Shift Key (GSK)
- Flow Reliability Margin (FRM)
- Allocation/external constraints: specific limitations not associated with Critical Network Elements
- Data from previous Flow based capacity computations

3.1.1 Critical Network Element (CNE) and Contingency (C)

3.1.1.1 Definitions

Definition of a Critical Network Element

A Critical Network Element (CNE) is a network element significantly impacted by CWE cross-border trades and/or by RAs. A CNE has the following parameters:

- An element: a line (tie-line or internal line) or a transformer
- An "operational situation": normal (N) or contingency cases (N-1, N-2 or busbar faults, depending on the applicable TSO risk policies). (See below for link between CNE and Cs)
- A set of Imax (See 3.1.2)
- A FAV (See 3.1.5)
- A FRM (See 3.1.7)

Definition of a Contingency

A Contingency (C) is an event that can occur in the network that will be monitored in the process. A C can be:

- Trip of a line, cable or transformer,
- Trip of a busbar,
- Trip of a generating unit,
- Trip of a (significant) load,
- Trip of several elements.

Definition of the Critical Network Element and Contingency (CNEC)

A CNEC (combination of Critical Network Element and Contingency) is defined by each CWE TSO who links one of his CNEs with one of the Cs.

3.1.1.2 CNEC list for Remdial Action Optimization

The Remedial Action Optimization is used to find a set of Remedial Actions (RA) that will be applied in the FB computation. Therefore, RAO must take into account at least all CNECs that will also be taken into account during FB computation (see section 3.1.1.3). The TSO may specify CNECs to be only taken into account during Remedial Action Optimization. This can be required in order to avoid Security of Supply effects on CNECs that are strongly influenced by RAs albeit only weakly influenced by cross-border exchanges. Consequently, the CNECs considered in the RAO can be a superset of the CNECs used in the FB computation and thus CNECs are not checked for their sensitivity to exchanges.

3.1.1.3 CNEC list for the FB computation

The CNECs with the agreed set of RAs that are monitored in the FB computation should be significantly impacted by CWE cross-border trades. This selection approach is identical to the approved and applied process for the day ahead flow-based capacity calculation.[1]

A set of PTDFs is associated to every CNEC after each Flow Based parameter calculation, and gives the influence of the change of the net position of any bidding zone on the CNEC.

A CNE is considered to be significantly impacted by CWE cross-border trade, if its maximum CWE zone-to-zone PTDF is larger than a threshold value that is currently set at 5%.

For each CNEC, the following sensitivity value is calculated:

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

If the sensitivity is above the threshold value of 5%, then the CNEC is said to be significant for CWE trade. If a CNEC does not meet the pre-defined conditions, the concerned TSO then has to decide whether to keep the CNEC or to exclude it from the CNEC list.

Although the general rule is to exclude any CNEC which does not meet the threshold on sensitivity, exceptions on the rule are allowed: if a TSO decides to keep the CNEC in the CNE list, it has to justify this decision to the other TSOs, furthermore it will be systematically monitored by the NRAs as it is done today in the day ahead process.

3.1.2 Maximum current on a Critical Network Element (Imax) and Maximum allowable power flow (Fmax)

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

As the thermal limit and relay setting can vary in function of weather conditions, Imax is usually defined at least per season.

When the Imax value depends on the outside temperature or wind conditions, its value can be reviewed by the concerned TSO if outside temperature or wind forecast is announced to be much higher or lower compared to the seasonal values.

Imax is not reduced by any security margin, as all margins have been covered by the calculation of the contingency by the Flow Reliability Margin (FRM, c.f. chapter 3.1.7) and Final Adjustment Value (FAV, c.f. chapter 3.1.5).

Some TSOs allow to overload lines after a contingency up to a temporary limit for a limited amount of time. As a result, two Imax values will be provided for one CNE.

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[1] "Documentation of the CWE FB MC solution as basis for the formal approval-request", Brussels, 1st August 2014, http://jao.eu/support/resourcecenter/overview?parameters=%7B%22IsCWEFBMC%22%3A%22True%22%7D, pp. 18ff

- Temporary Imax
- Permanent Imax

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

Fmax = $\sqrt{3}$ * Imax * U * cos(φ) / 1000 [MW],

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

As several Imax may be provided for one CNE, several Fmax may exist for a CNEC.

3.1.3 Day ahead Common Grid Model

The day ahead Common Grid Model (DA CGM) is created by merging all individual Grid Models (IGMs) from all TSOs of continental Europe and is based on data from DA market coupling and a security assessment of the grid.

For intraday capacity calculation the latest available version of the day ahead Congestion Forecast process (DACF) will be used at the moment the capacity calculation process is initiated. This includes, according to the methodology developed in line with Regulation 1222/2015 Article 16 and 17 (CACM):

- Best estimation of Net exchange program
- Best estimation exchange program on DC cables
- Best estimation for the planned grid outages, including tie-lines and the topology of the grid
- Best estimation for the forecasted load and its pattern
- If applicable best estimation for the forecasted renewable energy generation, e.g. wind and solar generation
- Best estimation for the outages of generating units
- Best estimation of the production of generating units
- All agreed remedial actions during regional security analysis.

3.1.4 Remedial Actions (RA)

During Flow Based parameter calculation CWE TSOs take Remedial Actions (RA) into account to improve the Flow Based domain where possible while ensuring a secure power system operation, i.e. N-1/N-k criterion fulfillment.

Remedial Actions used in capacity calculation can embrace the following measures a.o.:

- 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.
- Redispatching: changing the output of generators by ramping up and down certain power units.

The effect of these RAs on the CWE CNEs is directly determined in the calculation process to monitor the shift of load flow in the entire CWE grid.

There are several types of RAs, differentiated by the way they are used in the optimization of the domain.

- Preventive (pre-fault) and curative (post-fault) RAs: While preventive RAs are applied before any fault occurs, and thus to all CNECs of the flow based domain, curative RAs are only used after a fault occurred. As such the latter RAs are only applied to those CNECs associated with this contingency. Curative RAs allow for a temporary overload of grid elements and reduce the load below the permanent threshold.
- Shared and non-shared RAs: Each TSO can define whether he wants to share the RA provided for capacity calculation or not. In case a RA is shared, it can be applied to increase the Remaining Available Margin (RAM) on ALL relevant CNEs. If it is a non-shared RA, the TSO shall determine the CNEs for which the RA can be triggered in the capacity optimization.

Each CWE TSO defines and checks the availability of the available RAs in its responsibility area according to his operational principles. At least all RAs used for the DA capacity calculation and still available at the time of the ID capacity calculation have to be considered.

The CWE TSOs commit to include the DA MCP in the FB ID CC domain up to the FRM value – except in case of force-majeure. In order to do so CWE TSOs foresee to include costly remedial actions to avoid automatic DA MCP inclusion. CWE TSOs will work on developing, testing and implementing this and seek for intermediate steps to reach this commonly agreed target with limited DA MCP inclusion.

Automatic DA MCP inclusion for values higher than FRM should only occur in very exceptional cases (aim to reach a pre-defined threshold).

3.1.5 Final Adjustment Value (FAV)

With the Final Adjustment Value (FAV), operational skills and experience that cannot be introduced into the Flow Based-system can find a way into the Flow Based-approach by increasing or decreasing the remaining available margin (RAM) on a CNE for very specific reasons which are described below. Positive values of FAV in MW reduce the available margin on a CNE while negative values increase it. The FAV can be applied by the responsible TSO during the validation phase to reduce the margin on a dedicated CNE, since the process is expected to be highly automated. 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 thus calculated in the Flow Based parameter calculation.
- A positive value for FAV as a consequence of the validation phase of the Flow Based domain, leading to the need to reduce the margin on one or more CNEs for system security reasons. The overload detected on a CNE during the validation phase is the value which will be put in FAV for this CNE in order to eliminate the risk of overload on the particular CNE.

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

3.1.6 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 zone. Therefore, it contains the relation between the change in net position of the market area and the change in output of every generating unit inside the same market area.

Due to convexity pre-requisite of the Flow Based domain, the GSK must be linear and items of the GSK cannot consider minimum or maximum values.

A GSK aims to deliver the best forecast of the impact on CNE of a net position change, taking into account on one hand the operational feasibility of the reference production program, projected market impact on units, market/system risk assessment and the characteristics of the grid; and on the other hand the model limitations.

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.

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 do not 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).

3.1.7 Flow Reliability Margin (FRM)

For each CNE, a Flow Reliability Margin (FRM) has to be defined, that quantifies at least how the uncertainty impacts the flow on the CNE. Inevitably, the FRM reduces the remaining available margin (RAM) on the CNE 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.

The basic idea behind the FRM determination is to quantify the uncertainty by comparing the Flow Based model to the observation of the corresponding timestamp in real time. More precisely, the base case, which is the basis of the Flow Based parameters computation, is compared with a snapshot of the transmission system on the respective day D. A snapshot is like a photo of a TSO's transmission system, showing the voltages, currents and power flows in the grid at the time of taking the photo. This basic idea is illustrated in the figure 1.

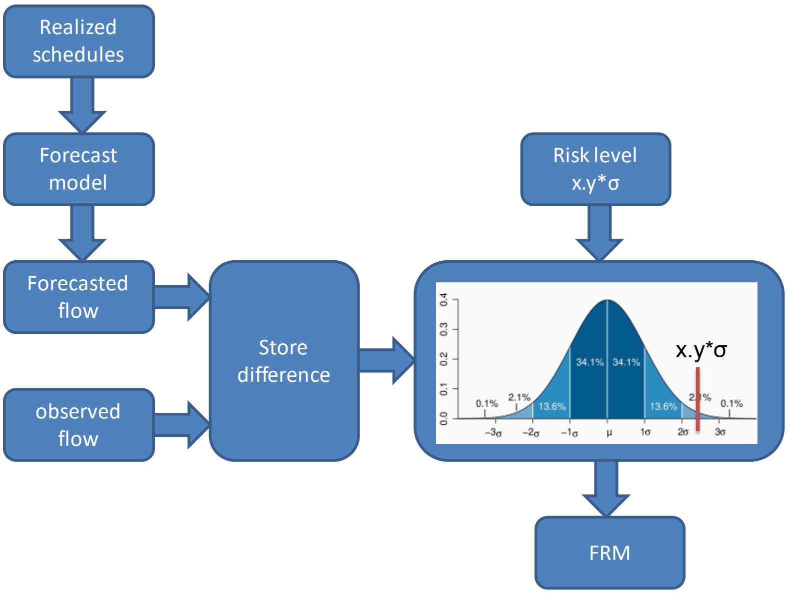

Figure 1: FRM Assessment Principle

The differences between the observed and predicted flows 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
- 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 CNE definition. The rationale behind this is that TSOs remain critical towards the outcome of the pure theoretical approach in order to ensure the implementation of

[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. This risk level is a fixed, reference that each TSO has to respect globally in all questions related to congestion management and security of supply. This risk level is a pillar of each TSO's risk policies.

parameters which make sense operationally. For any reason (e.g.: data quality issue), it can occur that the "theoretical FRM" is not consistent with the TSO's experience on a specific CNE. Should this case arise, the TSO will proceed to an adjustment.

The differences between operationally adjusted and theoretical values shall be systematically monitored and justified, which will be formalized in a dedicated report.

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

The general FRM computation process can then be summarized by figure 2.

Figure 2: FRM computation process

Step 1: Elaboration of statistical distributions, for all CNE, in N and N-1 situations.

Step 2: Computation of theoretical (or reference) FRM by applying of a risk level on the statistical distributions.

Step 3: Validation and potentially operational adjustment. The operational adjustment is meant to be used sporadically, only once per CNE, and systematically justified and documented after bilateral agreement.

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 re-computing FRM values, following the same principles but using updated input data, on a regular basis.

3.1.8 External constraints (EC)

Besides the limitations on CNEs, other specific limitations may be necessary to guarantee a secure grid operation. Import/Export limits for bidding zones declared by TSOs are taken into account as "special" constraints, in order to guarantee that the market outcome does not exceed these limits. For these constraints the term "external constraints" was introduced in the days of implementing DA FB in CWE. In CACM guidelines the term "allocation constraints" is introduced, meaning constraints that need "to be respected during capacity allocation to maintain the transmission system within operational security limits and have not been translated into cross-zonal capacity or that are needed to increase the efficiency of capacity allocation". These allocation constraints are a superset of the external constraints used in CWE as they may also contain other constraints such as technology-driven ramping constraints on HVDC connections. For intraday capacity calculation in CWE the use of the well-known external constraints is deemed sufficient. Therefore, the respective terminology will be used in the remainder of this document.

External constraints can be used for two different reasons. Firstly, they can be justified if market results beyond such constraints would lead to stability problems. Such stability issues have to be detected via system dynamics studies. Secondly, market results which are too far from reference flows, and might have unexpected impact due to linearization errors, can be avoided by the external constraints. This aspect is of particular importance during the introduction of FB allocation because new flow patterns may arise. The definition of external constraints is a responsibility of each individual TSO. It is important to understand that these constraints do not limit transit flows.

TSOs remind here that these constraints are not new, since they are already being successfully applied in DA FB capacity calculation. As the physics behind the external constraints remain the same irrespective of the market time period under investigation, the same constraints in the intraday stage as in the day ahead allocation shall be applied in the intraday allocation. This is also in line with the TSC concept on coordinated intraday capacity calculation.

3.2 FB Intraday Capacity Calculation

3.2.1 Operational process

Figure 3 illustrates an overview of the process divided in several steps. Each step is described in the next paragraphs.

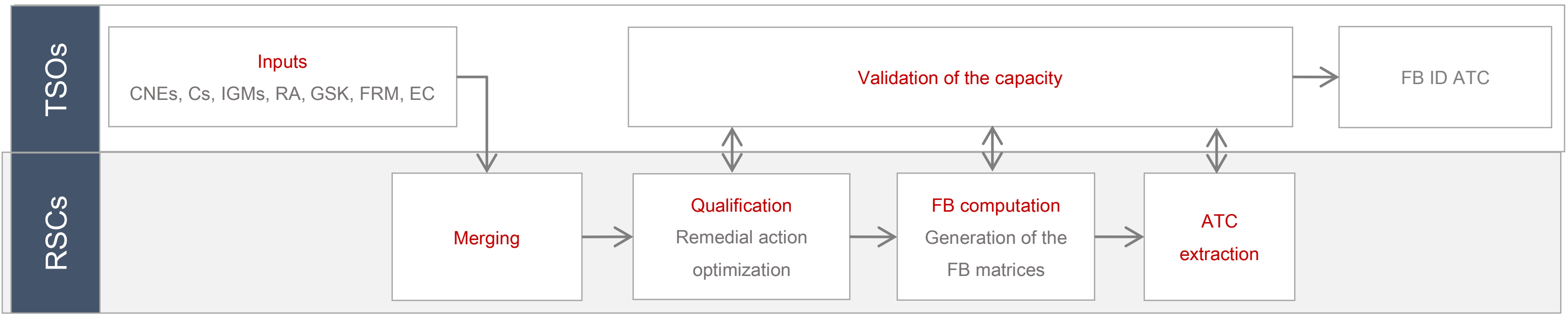

Figure 3: Operational process for FB IDCC.

3.2.2 Inputs

The aim of the input phase is to gather all the necessary inputs decribed in the previous section. The responsibility of the delivery and the quality of the inputs lies with the TSOs.

3.2.3 Merging

The aim of the merging process is to define a common set of data based on the data provided by the TSOs. During this merging process, quality checks are performed.
Concerning the grid model, the merging entity will be in charge to generate the common grid model (CGM) reflecting the best forecast of infeeds, flows and topology of continental Europe at the time of the merge.

The output of the merging process is a clean merged dataset to be used in the next steps:

- Common list of CNECs with associated parameters (Fmax, FRM…),
- Common list of remedial actions and condition of use,
- Common grid model,
- Merged GSK file.

3.2.4 Qualification

The aim of the qualification phase is first to include the already allocated capacity and second to increase the capacity around the already allocated capacity.
In order to achieve this goal, a branch-and-bound optimizer is used in order to associate remedial actions to constraints creating an additional margin that can be offered to the market participants. The risk policy of each TSO has to be respected during the association and the impact of the RA on CNEC has also to be assessed in order not to create unsecure grid situations.

The output of this part of the process is:

- A coordinated set of preventive remedial actions,
- A coordinated set of curative remedial actions for contingencies.

3.2.5 FB computation

The aim of the FB computation is to deliver the flow based matrix. The Flow Based parameters computation is a centralized computation.

The outputs of the FB computation process are:

1. PTDF for each hub of the CWE area

The PTDFs are calculated by varying the exchange of a zone, taking the zonal GSK into account. For every single zone-variation the effect on the load of every CNE is monitored and the effect on the loadflow is calculated in percent (e.g. additional export of BE of 100 MW has an effect of 10 MW on a certain CNE => PTDF = 10%).
The 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 CNEs by multiplication with the PTDFs.

2. Margin for each considered CNEC (RAM)

As the reference flow (Fref) is the physical flow computed from the common base case, it reflects the loading of the CNE. Out of the formula:
RAM = Fmax – Fref – FRM - FAV
The calculation delivers, with respect to the other parameters, the free margin for every CNE. This RAM is one of the inputs for the subsequent process steps.

3. List of CNEC limiting the domain

Not all CNEC are relevant for the market as only a few ones limit the exchanges. The pre-solve sub-process removes the redundant CNEC to create the pre-solved domain.

4. Power Shift Distribution Factors for special grid element

These PSDFs aim at representing the influence of special grid elements on CNEC like cross zonal HVDC links in a Capacity Calcualtion Region which may be used to redistribute the flows in the region.

3.2.6 Validation of capacity

The aim of validation is to verify whether the computed flow based domains are secure. For example, the TSOs can verify voltage/transient stability and perform AC load flows. In case the TSOs are detecting a constraint, they have several instruments at their disposal to reduce the flow based domains:

- Providing one or more additional CNEs, to be taken into account
- Editing or adding external constraints
- Using FAV on a specific CNE
- Updating the availability status of the RAs

The use of any of the above mentioned instruments has to be monitored. The output of this process is the amended FB domain.

3.3 Outputs

3.3.1 ATC extraction from Flow Based computation

The output of FB capacity calculation for the intraday timeframe can be separated in two parts:

- A FB domain resulting from the capacity calculation which can be described by domain indicators;
- Intraday ATCs extracted from the FB domain, as long as the capacity allocation for the intraday market is based on ATC.

Both kinds of output are briefly discussed in the two subsequent subsections.

3.3.1.1 Flow Based capacity domain

The Flow Based parameters that have been computed indicate which net positions, given the CNEs that are specified by the TSOs in CWE, can be facilitated under the continuous intraday trading without endangering the grid security. As such, the Flow Based parameters are able to act as constraints in the allocation of cross-zonal capacity. Only those Flow Based constraints that are most limiting to the net positions need to be respected in the capacity allocation: the non-redundant constraints. The redundant constraints are identified and removed by the TSOs by means of the so-called pre-solve. This pre-solve step is schematically illustrated in the two-dimensional example in Figure 4 below.

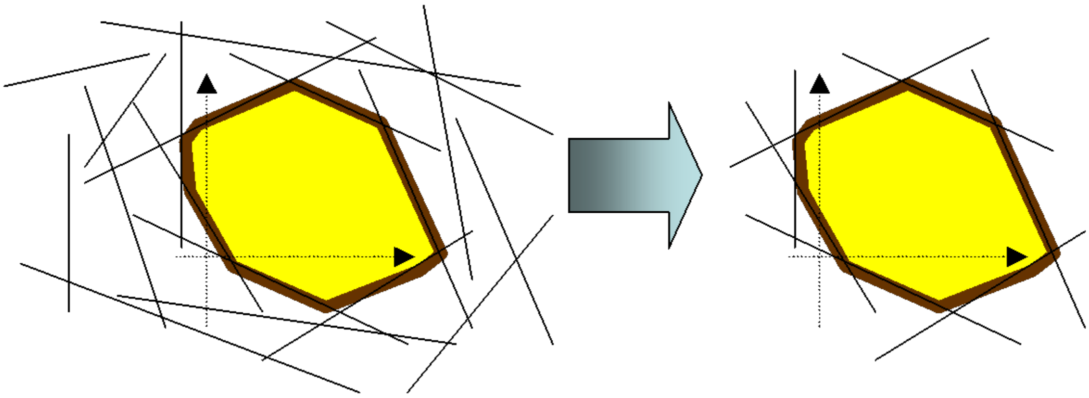

Figure 4: Pre-solve illustration

In the two-dimensional example shown in Figure 4, each straight line in the graph reflects the Flow Based parameters of one CNE. A line indicates for a specific CNE 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 CNE and endanger the grid security. As such, the non-redundant, or pre-solved, Flow Based parameters define the Flow Based capacity domain that is indicated by the yellow region in the two-dimensional figure above.

3.3.1.2 ID ATC

As described above the following procedure is an intermediate step to make the ID Flow Based method compatible with the current ID ATC process for capacity allocation. The aim is to assess ID ATC values deduced from the Flow Based parameters. The ID ATCs can be considered as a coordinated ATC model of the FB capacity domain. The procedure of ATC computation equals the approved methodology for computing leftover ATCs from FB DA. As a result a set of ATC for each border in each direction is given.

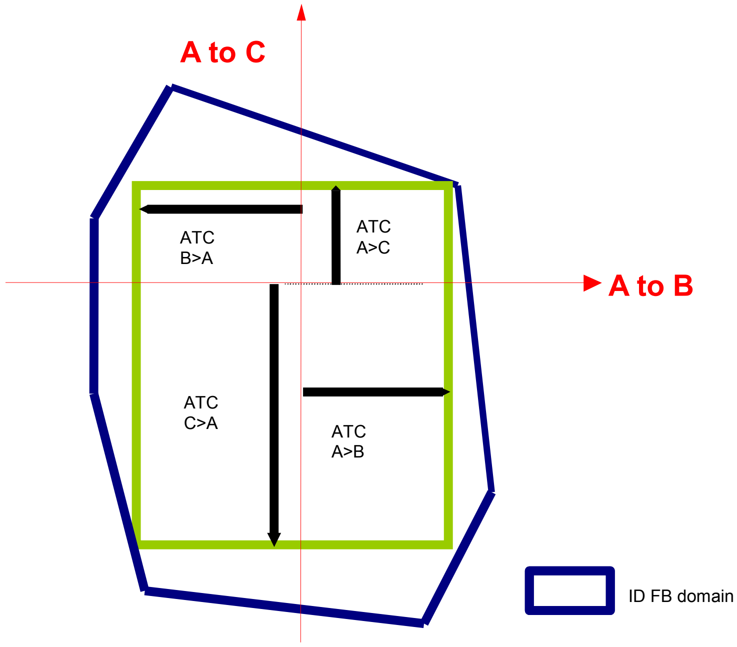

Figure 5: Illustration of ID ATC computation

In the following paragraphs the input and output parameters are described and the iterative method is explained using a pseudo-code and an example calculation.

Input data

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

- Already allocated capacities
- Pre-solved Flow Based parameters

Output data

The calculation leads to the following outputs for each timestamp:

- ID ATC
- Number of iterations that were needed for the ID ATC computation
- Branches with zero margin after the ID ATC calculation

Algorithm

The ID ATC calculation is an iterative procedure. First, the remaining available margins (RAM) of the pre-solved CNEs have to be adjusted to the net positions at the time of computation. In other words, the ΔID nominations, being the ID nominations between creation of the network model for ID capacity calculation and the timestamp where the ATCs are computed, need to be reflected in the FB domain. The adjustment is performed using the net position shift between both timestamps and the corresponding zone-to-hub PTDFs.

The resulting margins serve as a starting point for the iteration (step i=0) and represent an updated Flow Based domain from which the ID ATC domain is determined.

From the non-anonymized pre-solved zone-to-hub PTDFs ($PTDF_{z2h}$), zone-to-zone PTDFs ($pPTDF_{z2z}$) are computed, where only the positive numbers are stored[3]:

$$pPTDF_{z2z}(A > B) = \max(0, PTDF_{z2h}(A) - PTDF_{z2h}(B))$$

with $A, B = DE, FR, NL, BE$ at the moment. Only zone-to-zone PTDFs of neighboring market area pairs are needed (e.g. $pPTDF_{z2z}(DE > BE)$ will not be used until the first interconnection of these bidding zones has been commissioned).

The iterative method applied to compute the ID ATCs in short comes down to the following actions for each iteration step i:

1. For each CNEC, the remaining margin is equally shared between the CWE internal borders that are positively influenced.
2. From those shares of margin, maximum bilateral exchanges are computed by dividing each share by the positive zone-to-zone PTDF.
3. The bilateral exchanges are updated by adding the minimum values obtained over all CNECs.
4. Update the margins on the CNECs using new bilateral exchanges from step 3 and go back to step 1.

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

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

After algorithm execution, there are some CNEs with no remaining available margin left. These are the limiting elements of the ID ATC computation.

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

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

[3]Negative PTDFs would relieve CBs, which cannot be anticipated for the ID ATC computation

```
        End for
        For each ContractPath
                MaxBilExchange = min(MaxBilExchanges)
        End for
        For each CNE
                margin(i+1) = margin(i) – pPTDF_z2z * MaxBilExchange
        End for
End While
ID_ATCs = Integer(MaxBilExchanges)
```

Configurable parameters:

- StopCriterionIDATC (stop criterion); recommended value is 1.E-3.
- NbShares (number of CWE internal commercial borders); current value is 4.

Special cases

In case the already allocated capacity is not included in the flow based domain, the algorithm of market clearing point coverage is used to include the already allocated capacity. The algorithm of capacity extraction can then be performed. In any case the necessity and extent of Market Clearing Point (MCP) inclusion will be tracked in order to allow for potential counter measures.

3.4 Re-assessment of ID ATCs for allocation

After the first computation, all TSOs[4] have the possibility to locally re-assess the extracted ATCs. This re-assessment is necessary to prevent a large risk on the Security of Supply, due to possible unforseen grid situations which can occur during the day and which cannot be fully mitigated by implementation of additional security margins in the FlowBased methodology (e.g. increasing the FRM or FAV).The new re-assessed ID ATC are provided to the market in a stepwise approach.

3.4.1 Preparing the possible increase of ID ATC on all borders

The possible additional ID ATCs will be provided to the market during the day per Market Time Period (MTP[5]), for all borders. During the day, for each MTP, the process described below will be performed.

3.4.1.1 Determination of initial ATC and increase proposal

In case the FB DA ATC (from FB DA CC) is lower than the FB ID ATC (from FB ID CC) an increase request of ATC up to the FB ID ATC will be prepared by the Common Matching Tool (CMT), for those hours of the Day D of the next MTP, for each border.

In case the FB DA ATC is higher than the FB ID ATC, the ATC provided to the market will be set to the FB ID ATC, for those hours of the Day D of the next MTP, for each border.

For all remaining hours of the Day D, and for all borders, the ATC will be limited to the minimum of the FB DA ATC and the FB ID ATC, for each particular hour.

3.4.1.2 Assessing the feasibility of the increase proposal

After the increase proposal is prepared, the TSOs have to assess locally the feasibility of the proposals in order to consider the impact on the security of supply within their control area due to potential unforeseen intraday system/grid changes or automatic MCP inclusion. An increase proposal can be:

[4] APG is not part of the ID ATC after FBMC process. As for APG it isn't necessary to reduce the FB IDCC capacities throughout the day, there is no need for APG to be part of the ID ATC after FBMC process.

[5] This is a group of consecutive hours within the Day D. The foreseen MTPs per border/direction for this process are equal to the MTPs used in operation at the moment.

- Fully accepted
- Partially accepted
  If based on a local assessment of a TSO, the full intended increase can not be provided to the market, the TSO can decide to only partially accept the increase of ID ATC.
- Rejected in case the consequences of the proposals cannot be fully nor partially accepted by the TSO.

After the assessment, the TSO will notify the CMT with the status of each increase proposal for each MTP, including, in case of partial acceptance or rejection, the motivation in terms of limiting CNEC(s). In case of an emergency situation, TSOs will have to safeguard the system which could lead to reducuction of the ATCs to zero.

3.4.2 Consolidation of acceptances/rejections

When a deadline for feedback on a request for increase is reached, the CMT will immediatly proceed for each hour of the applicable MTP with the consolidation per border and direction of the received information respecting the following rule:

- In case justified rejections are received, the CMT will consider the lowest value as the result of the applicable increase.

The CMT will then send for each hour of the Day D and for each CWE border and direction to the CWE TSOs the resulting ID ATCs/NTCs for the applicable MTP.

3.4.3 Providing ID ATCs for allocation

After receiving the updated capacity from the CMT, the responsible TSOs provide the capacity to the available allocation platform.

4 Back-up procedures

The back-up process has to be reliable in order to ensure that capacity will always be delivered to the market players. In case the process fails, the last computed capacity will be provided to the allocation platform. For example, in case the intraday capacity calculation fails, the TSOs will provide to the allocation platforms the leftover of the day ahead capacity.

5 Transparency

The level of transparency of the process will be at least the transparency decided for the CWE day ahead process.

Context Paper for capacity calculation for ID timeframe

For additional information

Version	for consultation	
Date	27-02-2017	
Status	☒ For consultation	☐ Final

Contents

1 Management summary

1.1 Purpose of the document

The purpose of this context paper is to describe the concept of the Flow-Based Intraday Capacity Calculation (FB IDCC) and thereby to complete the Methodology for capacity calculation for intraday timeframe that is provided for approval to the CWE NRAs in the framework of Regulation 714/2009. It provides in particular a more detailed explanation of the methodology, the experimentation results and the further improvements foreseen.

In order to ensure a manageable implementation of the FB IDCC within a reasonable timeframe, TSOs focused on a set of requirements to be covered by the present concept as a first step towards a CACM enduring solution. . These are the following:

- At least one FB ID computation should be performed for each time stamp (TS).
- Concerning the network model, focus is mainly on DA CGM, possibility of the applicability of ID CGM will be analysed and potentially implemented.
- For the remaining inputs, the methodology should be close to the day ahead (DA) method.
- All remedial actions coordinated in DA should be considered if still available, and possible additional remedial actions should be considered.
- In order to increase the coordination and ease the operational process, taking into account the time constraints, an optimizer will be developed to link remedial actions to CNECs in a way to optimize capacities.
- At the end of the capacity calculation process, ATCs will be extracted from the flow-based domains.

This paper provides a detailed description of the inputs and processes. The major changes compared to the FB DA method relate to Critical Network Element Contingency (CNEC) creation and Remedial Action (RA) Optimization. Due to the time constraints in intraday, a highly automated process is needed.

Particular attention has been taken in order to provide a clear objective function and ensure that the inputs allow to apply this new methodology. The other needed inputs, processes and outputs are also described in a similar way as in the FB DA approval package.

The remainder of this document is structured as follows: chapter two an introduction. A description of the FB IDCC process is defined in chapter three and the experimentation results with the first assessments and learnings are presented in chapter four. The next chapter describes the improvements on the inputs and the process for the future FB IDCC and chapter six provides technical and quality criteria for the parallel run.

2 Introduction

2.1 Background of FB IDCC

2.1.1 Recalculation of the existing Flow-Based Day-Ahead Capacity Values

Due to the structural change in the electricity sector, mainly due to the increase of intermittent renewable energy sources, liquid and efficient intraday markets become more and more important. Cross border capacities are of major importance for the liquidity by increasing trade and balancing opportunities for the market players between market areas. While guarantying security of supply, TSOs have the obligation to deliver to the market as much available capacity as possible.

With the implementation of the Flow Based Market Coupling, CWE TSOs developed a flow based capacity calculation for the day ahead timeframe. Using the latest available information on grid, demand and supply TSOs compute the available capacity before the day ahead allocation (12 am D-1). As this information is supposed to change over time, a recalculation of the available capacity after the day ahead timeframe might lead to additional capacity for the intraday allocation, supporting cross border trade and balancing opportunities for market parties. However, it has to be noted that a recalculation taking into account the latest available information on grid, demand and supply could also result in less available capacity for the intraday timeframe. In any case, the already allocated capacity will be ensured.

According to the CACM Guideline the target model used in the capacity calculation methodologies shall be a flow-based approach and should ensure that cross-zonal capacity is recalculated within the intraday market timeframe based on the latest available information. Moreover, the frequency of this recalculation shall take into consideration efficiency and operational security. On the way towards a CACM compliant capacity calculation methodology CWE TSOs will apply a step-wise approach on the basis of the current intraday ATC solution and under consideration of the target model to be developed and implemented in the Core region.

2.1.2 Current solution is an ID ATC calculation after FBMC process

The current capacity calculation methodology for the intraday timeframe is based on an ATC approach (intraday ATC calculation). This solution is an outcome of a step-wise evolution from a bilateral increase/decrease process to a coordinated increase/decrease process.

The intraday ATC calculation process was inspired by the process that was implemented before FB Go Live on the DE-NL and BE-NL borders and the CWE ATC day ahead process, which also combined different local processes with coordination on CWE level in consecutive steps. Starting point for the intraday ATC calculation methodology are the initial intraday ATC values, which result from the Flow Based day ahead process. The initial intraday ATC is computed out of the day ahead FB domain around the day ahead market clearing point and is the result of a unique and common centralized computation. The first step is followed by a local assessment by CWE TSOs evaluating a possible increase or decrease on their own borders. The third step is a merging step by a common system. A Central Matching Tool (CMT) consolidates the increase requests and the decrease notifications. Based on this consolidated input, all CWE TSOs perform a local analysis that enables them to accept, partially accept or reject the requested capacity increases in a justified manner. Finally, the acceptance or rejection messages are handled in a common way by the CMT.

2.2 Context of FB IDCC

2.2.1 Request from CWE NRAs to design a Flow-Based IDCC process

According to Regulation EC 714/2009, TSOs shall establish a congestion management method for the different timeframes taking into account the electrical and physical realities of the network.

After receiving the "Position Paper of CWE NRAs on Flow-Based Market Coupling" of March 2015, CWE TSOs implemented a bilateral increase/decrease process starting from initial intraday ATC values, which was extended to a coordinated increase/decrease process by November 2015. This process allows for more capacity at the intraday timeframe, taking stock of recent information on grid, consumption, generation parameters and renewables.
In February 2016 CWE NRAs communicated their position regarding the implementation of the coordinated intraday ATC calculation to CWE TSOs. CWE NRAs stressed that the proposed method is not in line with the request made in the Position Paper, since the proposed method is seen as a reassessment but not as a recalculation of the intraday ATC values by CWE NRAs.

CWE NRAs and TSOs discussed the development of a Flow based capacity calculation for the intraday timeframe during 2016. In May 2016 a workshop was held in order to discuss the FB IDCC concept foreseen to be implemented in CWE, the challenges compared to FB day ahead and the implementation approach. Also the aim of the workshop was to provide detailed explanations and receive direct feedback from the regulators.

After the decision taken by ACER on CCRs on November 17th 2016, CWE NRAs have communicated to CWE TSOs on January 4th 2017 a letter officially requesting CWE TSOs to continue with the development and implementation of a Flow-Based Intraday Capacity Calculation Methodology in CWE, as an extension of the original and already approved CWE FB DA MC. This letter also reminds that the Flow-Based Intraday Methodology has to be compliant with the general and content-related objectives of the CACM Regulation.

2.2.2 Planning for implementation

The TSOs aim at implementing a solution in the short term in order to replace the current coordinated bilateral increase/decrease process (see Figure 1 for the implementation planning).

The next steps of the project will be an internal parallel run followed by an external parallel run beginning of 2018. The launch of the process is foreseen in the second semester of 2018.

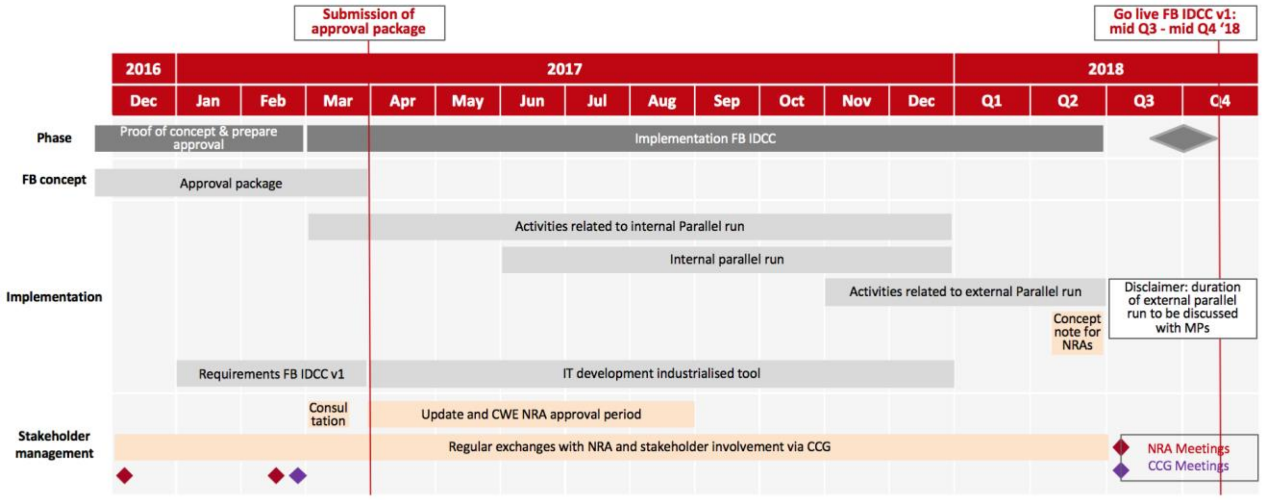

Figure 1: Planning for implementation FB IDCC.

In parallel of the TSO activity, stakeholders will be consulted on the method beginning of 2017. During the CCG meeting, the project will inform the stakeholders of the updates and next steps.

3 General principles of Flow-Based Intraday Capacity Calculation

3.1 Inputs

Each time intraday capacity will be computed, the TSOs will have first to provide all the required input data: Individual Grid Models (IGMs) aiming at representing the best forecast of his control area for the computed timestamps, the list of Critical Network Elements (CNEs), Contingencies (Cs), Flow Reliability Margins (FRMs),available Remedial Actions (RAs), the Generation Shift Key (GSK) and the External Constraints (ECs). These inputs will be provided for each remaining hour of the day.

3.1.1 GSKs

In order to take into account the characteristics of each TSO's network, individual GSKs are defined for each bidding zone.

3.1.1.1 GSK for the German-Austrian bidding zone

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

Every German TSO as well as APG provides one file per business day. If one TSO does not provide a new GSK file for a business day the replacement strategy will take the latest valid file for working day, bank holiday or weekend day. Within this GSK file, the generators are listed with their estimated share within the specific control area for the different time-periods. Therefore, every German TSO as well as APG provides within this GSK file the generators, according to TSO´s estimation, that participate to a net-position shift of the German/Austrian hub. The generation-distribution among the defined generators inside its grid must sum up to 1.

In the process of the German/Austrian merging, the FB ID system creates out of these five individual GSK-files, depending on the target day (working day / week-end or bank holiday), a specific GSK-file. The German TSOs and APG defined generation share keys which represent the share of available power in a control area. The content of the individual GSK-files will be multiplied with the individual share of each TSO. This is done for all TSOs with the usage of the different share keys for the different target times. In that way a Common GSK file for German/Austrian bidding zones is created on daily basis.

With this method, the knowledge and experience of each German TSO and APG is incorporated in the process to obtain a representative GSK. With this structure, the generators named in the GSK are distributed over the whole German-Austrian bidding zone in a realistic way, and the individual factor is relatively small.

The Generation Share Key for the individual control areas i is calculated according to the reported available market driven power plant potential of each TSO, divided by the sum of market driven power plant potential in the bidding zone.

$$GShK\ TSO_i = \frac{Available\ power\ in\ control\ area\ of\ TSO_i}{\sum_{k=1}^{5}(Available\ power\ in\ control\ area\ of\ TSO_k)}$$

Where k is the index for the five individual TSOs.

With this approach the share factors could be determined based on regular generation forecasts and will sum up to 1 forming the input for the common merging of individual GSKs.

TransnetBW

To determine relevant generation units TransnetBW takes into account most recent available information at the time when individual GSK-files are generated:

- Power plant availability
- Planned production

The GSK for every power plant i is determined as:

$$GSK_i = \frac{P_{max,i} - P_{min,i}}{\sum_{i=1}^{n}(P_{max,i} - P_{min,i})}$$

Where n is the number of power plants, which are considered for the GSK in the TransnetBWcontrol area.

The following types of generation units connected to the transmission grid can be considered in the GSK:

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

Nuclear power plants as baseload units are excluded upfront because of their constant power output that does not change during normal operation.

Amprion

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

In general Amprion only considers middle and peak load power plants as GSK relevant. With other words basic load power plants like nuclear and lignite power plants are excluded to be a GSK relevant node.

From this it follows that Amprion only takes the following types of power plants: hard coal, gas and hydro power plants. In the view of Amprion only these types of power plants are taking part in changes in the production.

TenneT Germany

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

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

APG

APG's method to select GSK nodes is the same as for the other German TSOs. So only market driven power plants are considered in the GSK file which was done with statistical analysis of the market behaviour of the power plants. In the case of APG pump storage and thermal units are considered. Power plants which produce band energy (river power plants) are not considered. Only river plants with daily water storage are also considered in the GSK file. The list of relevant power plants is updated regularly in order to consider maintenance or outages. Furthermore will the GSK file be also updated seasonally because in the summer period the thermal units will be out of operation.

3.1.1.2 GSK for the Dutch bidding zone

The Dutch GSK will dispatch the main generators in a manner which avoids extensive and unrealistic under- and overloading of the units for extreme import or export scenarios. The GSK is directly adjusted in case of new power plants. Also unavailability of generators due to outages are considered in the GSK.

All GSK units are re-dispatched pro rata on the basis of predefined maximum and minimum production levels for each active unit. The total production level remains the same.

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

For the intraday timeframe, a proportional GSK based on the results of FB DA CC will be used using the same set of GSK units. It is to be expected that, for relatively small volumes of additional capacity given in intraday, this will not result in less reliable results.

3.1.1.3 GSK for the Belgian bidding zone

Elia will use in its GSK a fixed list of nodes based on the locations where most relevant flexible and controllable production units (market oriented generating units) are connected. This list will be determined in order to limit as much as possible the impact of model limitations on the loading of the CNEs.
The variation of the generation pattern inside the GSK is the following: For each of these nodes, the sum of the generation which are in operations in the base case of each of these nodes will follow the change of the Belgian net position on a pro-rata basis. That means, if for instance one node is representing n% of the sum of the generation on all these nodes, n% of the shift of the Belgian net position will be attributed to this node.

3.1.1.4 GSK for the French bidding zone

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

3.1.2 ECs

The following sections will depict in detail the method used by each TSO[1] to design and implement external constrains. These methods were already approved together with the DA FB methodology.

3.1.2.1 German External Constraint

Amprion, TransnetBW and TenneT Germany determine the external constraints for the German CWE net position in order to limit the German export and import in interdependence with the day ahead market clearing point. As such, the deviation from expected flows can be restricted to avoid flows in real-time that are too far from the expected flows going through Germany and therefore, cannot be verified as safe during the flow based process. As a consequence, the external constraint is set to a value in a certain range around the day ahead market clearing point. The magnitude of this range is based on offline studies.
Under extreme grid conditions it can further be necessary to reduce the external constraint in order to ensure security of supply.

3.1.2.2 Dutch External Constraint

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

3.1.2.3 Belgian External Constraint

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

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

3.1.2.4 French External Constraint

RTE will not use any External Constraint in most cases.
In some specific cases (cold front for example) though, RTE could use an import/export limit constraint related to the voltage control and dynamic stability of the network. If required, these limitations will be calculated with a dynamic study performed on the afternoon of D-1. The use of External Constraints will be systematically reported to the NRA.

3.2 FB ID CC Process

On an abstract level, the Flow-based Intraday Capacity Calculation process can be described by the following flow chart in Figure 2.

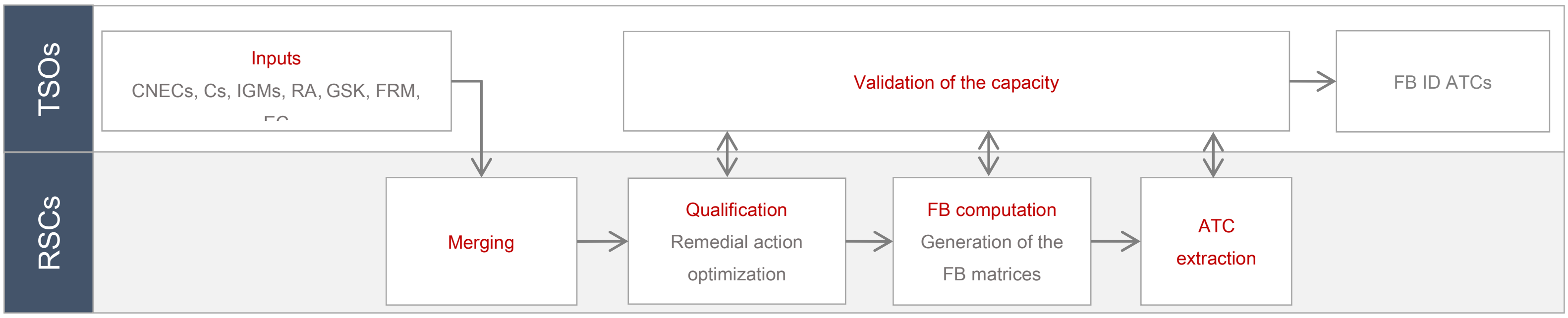

Figure 2: FB IDCC process

Once the inputs have been provided, the Regional Security Coordinators (RSCs) in charge of the merging and computation will merge the IGMs. The aim of the merging process is to define a common set of data based on the data provided by the TSOs. This will result in Common Grid Models (CGMs). During the merging process quality checks are performed.
For the construction of the CGMs the IGMs of CWE TSOs but also of every continental European TSO will be used. At the time of the merge this CGM is the best forecast of the infeeds and flows in Continental Europe.

Once the CGMs are generated the qualification phase starts. The aim of the qualification phase is first to include the already allocated capacity and second to increase the capacity around the already allocated capacity.
In order to achieve this goal, a branch-and-bound optimizer is used in order to associate remedial actions to constraints creating an additional margin that can be offered to the market participants. The objective of the optimization is to maximize the margin of the CNEC that has the lowest relative margin, which means to optimize those margins that yield the highest impact on capacities. The relative margin is the absolute margin divided by the absolute sum of the four bilateral CWE zone to zone PTDF.The aim is to introduce a gain in terms of capacity and not absolute Ampere. Presently the PTDFs are computed before and after the choice of the preventive remedial actions. The risk policy of each TSO has to be respected during the association and the impact of the RA on CNECs has also to be assessed in order not to create an insecure grid situation. The outputs of this part of the process is, for each remaining hour of the day:

- A coordinated set of preventive remedial actions,
- A coordinated set of curative remedial actions for contingencies.

Based on these outputs, the FB computation will be performed with the aim to deliver the flow based parameters just like in the DA FB computation.
The outputs of the FB computation process are for each remaining hour of the day:

- a PDTF per hub and CNEC
- a margin per CNEC
- a list of limiting CNEC (pre-solved domain)
- and, optionally, Power Shift Distribution Factors (including virtual hubs) per special grid element (Eg. HVDC links)

In case the day ahead market clearing point is not included in the FB domain (at least one CNEC has negative margin after the Remedial Action Optimization and flow based computation), the day ahead market clearing point will be automatically included in the domain (Annex 7.1).

The resulting FB domain will then be used to extract the available transfer capacities (ATCs) for each remaining hour of the day, for each border and direction. Remedial Action Optimization, FB computation and ATC extraction will be performed in a central place by RSCs.

3.3 Validation of ID ATCs

The results of Remedial Action Optimization, FB computation and ATC extraction will be subject to validation by TSOs. The aim of this validation is to verify if the computed flow based domains and extracted ATCs are secured at the moment of computation. The proposed methodology foresees different ways to perform a validation after Remedial Action Optimization and FB computation like using FAV, changing EC, modifying CNECs or applied RAs. However, it has to be noticed that for the time being no TSO intends to use one of these possibilities. Currently, only a validation after ATC extraction is foreseen to be used by performing a local re-assessment.

On an abstract level the local re-assessment process can be described by the following flow chart (see Figure 3). After the FB ID computation & ID ATC extraction (step 1), The Central Matching Tool (CMT) prepares an initial ATC, for all borders, for each MTP of the following day (step 2). This initial ATC will be the minimum of the extracted FB ID ATC and the (remaining) FB DA ATC.

An increase proposal will also be prepared for all hours of the day, based on the extracted FB ID ATC, for each border (step 3). During the day for each MTP each TSO has the possibility to assess, by means of local tools, the feasibility of the increase proposal in order to consider the impact on the security of supply within their control area due to potential unforeseen intraday system/grid changes or automatic MCP inclusion (step 4). The information on (partial) acceptance or rejection is sent back to the CMT and consolidated (step 5). The consolidated increase of capacity is then sent to the TSOs who provide them to the available allocation platform (step 6). If no objections are put out by any TSO until a certain deadline is reached, the ATCs calculated in the intraday process are sent to the allocation platform. It has to be noted that step 3 to 6 are repeated during the day for each MTP for each border.

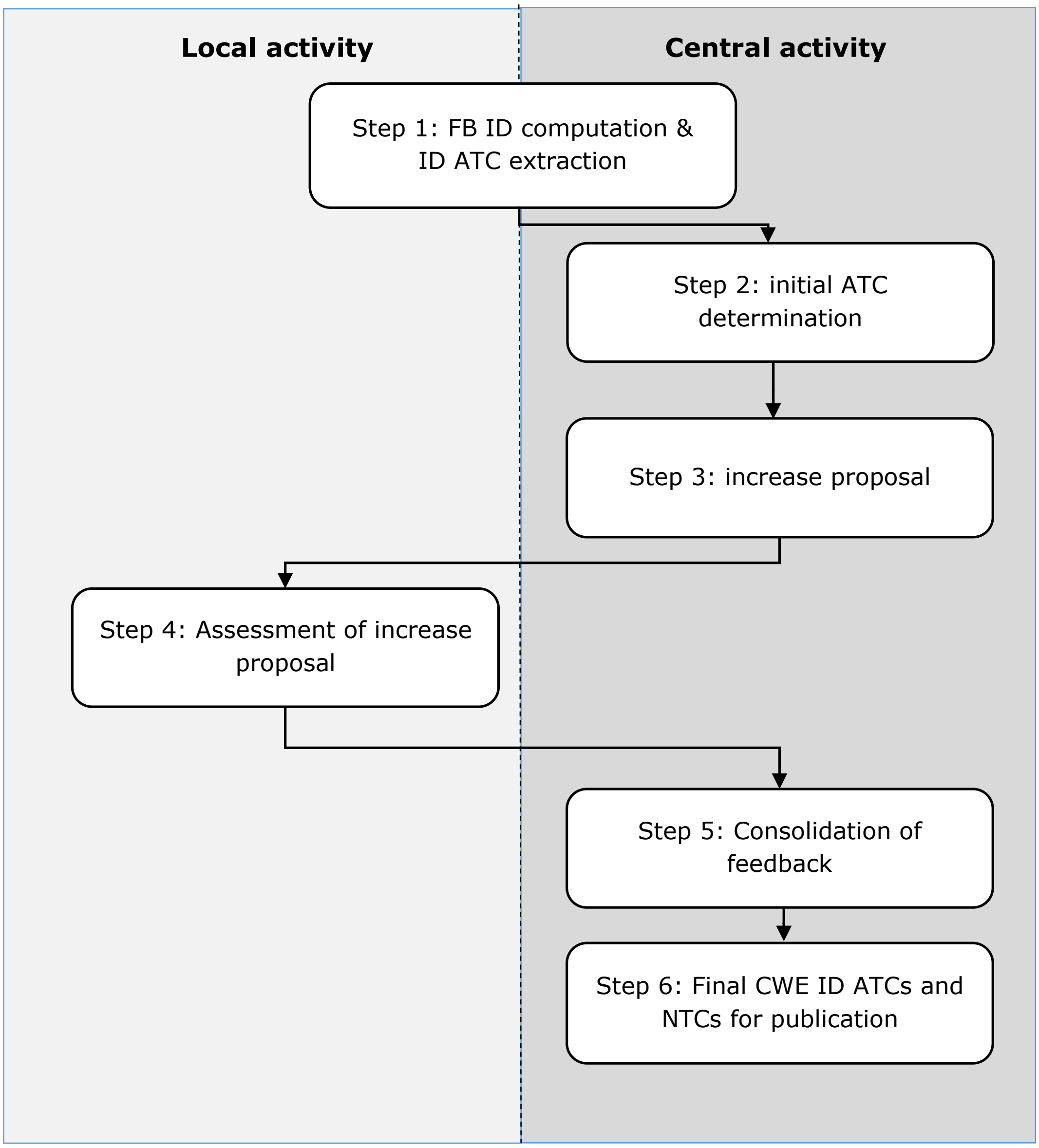

Figure 3: Process for validation of ID ATCs

4 Flow-Based IDCC Experimentation Results

4.1 Approach of the experimentation

TSOs in collaboration with RSCs performed an experimentation in several phases in order to develop the capacity calculation process. The core of the experimentation has been the development of a Remedial Action Optimizer (RAO) in accordance with TSO's business requirements.

For each of the phases an experimentation goal was defined and lessons learned from previous phase(s) were directly used in next phase(s) in order to constantly improve the development of the process.

Experimentation process

The experimentation process is different from the general Flow Based process in order to avoid unnecessary actions as much as possible.

Three main steps in the experimentation process can be identified:

- Initial data preparation, mapping & checks
- Baseline computation (without RA)
- Remedial Action Optimization

1. **Initial data preparation, mapping & checks**

   The main objective is to prepare the input for baseline computation and RA optimization. The following input is required:
   - Initial DA CGM (containing corrections on tie-lines inconsistencies, balance mismatch, correction of loadflow parameters etc.)
   - Reference program
   - Critical Network Elements, Contingencies and Remedial Actions (CNE, C, RA)
   - Generation Shift Key (GSK)
   - External Constraints (EC)
   - Initial and increased ID ATC domain (for comparison)

2. **Baseline computation**

   The main objective of the baseline computation is to perform a FB computation excluding Remedial Action Optimization in order to assess the added value of the RA optimization on the provided ID capacity.

3. **Remedial Action Optimization**

   In this step ID capacities are optimized by applying a certain set of shared remedial actions. TSOs define the remedial actions available for the Remedial Action Optimization and the set of monitored CNECs.

4.2 Experimentation Results

4.2.1 Phase 1: first step to define an intraday process[2]

In phase 1, experimentation was performed on four runs of one time stamp (TS) each. In this phase, the objective function was to maximize the minimum absolute margin of all CNECs that constitute the FB domain. The aim was to test the first version of the process including the use of a Remedial Action Optimization algorithm and analyse first timestamps.

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[2] During experimentation phase 1 APG was not fully integrated in all technical CWE processes yet. Therefore it was not possible to consider APG CNECs already in this phase. However APG was fully involved in the subsequent phases 2 and 3.

The main results of this phase are:

- Improved understanding of Remedial Action Optimization and impact of prepared inputs;
- Improvements on Remedial Action Optimization objective function were identified.

4.2.2 Phase 2: experience over one day computation

In phase 2, Remedial Action Optimization experimentation was performed on five runs of one full business day (24 TS) each. In this phase Remedial Action Optimization was perfomed only for a few TSs per day and afterwards the resulting RAs were extrapolated on the neighbouring hours. The Remedial Action Optimization was performed with the previous objective function and also with the new one to maximize the minimum relative margin.
The objective was to fine-tune and finalize the methodology and to prepare phase 3 activities in terms of tools and organisation on TSO and RSC level.

The main results of the second phase are:

- Improved objective function gives better results from capacity perspective as the algorithm focusses more on the elements that are sensitive to the cross border exchanges instead of only the elements with absolute low margin;
- Extrapolation of Remedial Action Optimization results does not give satisfying results and the extracted ATCs are low.

4.2.3 Phase 3: gaining confidence to launch a parallel run

In phase 3, Remedial Action Optimization experimentation was performed on four runs of five full business days (24 TS each). The optimization is performed for every hour only with the updated (new) objective function.

The objective was to perform recurrent FB ID computations in order to develop a quantitative assessment of the proposed concept / methodology that can be approved by CWE NRAs.

During this phase 3 experimentation, additional indicators have been developed to monitor

- The DA Market Clearing Point (MCP) Inclusion: The indicator will look after Remedial Action Optimization to the minimum absolute margin on the CNECs that will be monitored during the FB computation. If this value is below 0, the MCP is considered as non-included and is marked as red.
- ATC indicators: the resulting ATCs per border and direction extracted from the ID FB domain are compared to the initial ATCs extracted from the DA FB domain and a reference ATC obtained from a statistical analysis on the intraday behaviour of the market participants' cross border nominations. For each hour, these differences are summed. If the sum is below 0, then the value is marked as red.

The main results of the last phase are:

- 3 runs out of 4 (run 1 to 3) have very limited FB domain, except during weekends. This is illustrated in table 1 below, which provides the value of the above indicators for each hour of the business days simulated in run 1. Reasons are:
    - MCP non inclusion
    - High congestions in the used grid models
    - Lack of available/efficient RA in some congested areas
    - Usage of lower Imax (in run 4 higher Imax values have been used for some lines)

	10/10/2016		11/10/2016		12/10/2016		13/10/2016		15/10/2016	
	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion
Hours	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin
H01	-2006	-179	-1220	-149	1953	107	-107	-89	2159	65
H02	-1339	-250	-1013	-252	171	-194	1	-84	1517	51
H03	-1337	-264	-1606	-324	196	-234	-1173	-195	2013	109
H04	-1337	-283	-1532	-346	432	-251	-1174	-250	1545	42
H05	-1165	-310	-1532	-383	553	-287	-1146	-292	-444	23
H06	-1174	-343	-862	-347	375	-312	-1485	-248	-179	15
H07	-1773	-456	-1174	-420	-1174	-454	-1175	-432	1365	58
H08	-1936	-379	-1975	-356	-2006	-329	-1695	-314	-670	-12
H09	-1773	-333	-1898	-293	-1531	-238	-1979	-198	-1461	-66
H10	-1936	-386	-2006	-318	-1936	-210	-2006	-162	-1461	-45
H11	-1936	-428	-2074	-350	-1778	-211	-1532	-197	-2451	-37
H12	-599	-419	-1937	-373	-1739	-174	-1532	-171	-2564	-43
H13	-762	-429	-1984	-369	-1704	-179	-1779	-120	-2191	-4
H14	-1936	-489	-1834	-455	-1475	-244	-1953	-107	-2123	-1
H15	-1773	-513	-1806	-463	-1532	-324	-2006	-101	-338	26
H16	-1773	-537	-1918	-474	-1174	-298	-2006	-133	-1841	-16
H17	-1797	-612	-1810	-423	-1843	-281	-2006	-179	-1627	-78
H18	-1843	-364	-1889	-400	-1843	-320	-1532	-249	-1347	-89
H19	-3243	-244	-1677	-363	-1620	-273	-1753	-222	-1832	-20
H20	-2297	-345	-2034	-305	-1948	-410	-1558	-278	-352	39
H21	-2006	-473	-1678	-373	-1987	-336	-1696	-173	-1092	10
H22	-1843	-355	-2017	-321	-1532	-539	-1799	-106	-1936	-31
H23	-1442	-320	-1459	-208	-1751	-491	-2006	-86	-1765	-40
H24	-1576	-439	-1383	-285	-1971	-326	1032	52	-1696	-12

Table 1: Experimentation results for phase 3 run 1.

- Only run 4 provides interesting results in terms of FB domain to be compared with initial ATC domain for normal business days. But even during this run, it can be noticed, as illustrated in the table 2 below, that non-inclusion of the MCP generally leads to negative results in terms of FB domain and related ID ATCs.

	1/11/2016		2/11/2016		3/11/2016		4/11/2016		6/11/2016	
	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion
Hours	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin
H01	1475	333	1003	66	1221	33	1843	191	1931	302
H02	1015	215	1047	63	895	56	1544	172	2845	445
H03	1463	283	-74	21	686	43	1821	141	2601	198
H04	1513	131	-2266	-41	787	44	1984	122	2263	497
H05	1408	122	-2293	-40	175	23	1900	65	1269	
H06	1095	243	-570	10	763	15	2005	149	1340	547
H07	756	75	190	45	-1489	-355	2156	112	204	455
H08	1123	114	-1761	-135	-120	-65	-1514	-64	174	358
H09	1137	283	-1531	-70	-343	-10	138	0	97	119
H10	1265	281	-1576	-42	-350	-136	934	52	1128	302
H11	1154	276	-1513	-4	-209	-153	908	108	179	203
H12	1193	271	464	45	-1421	-200	1297	81	207	203
H13	1193	225	427	42	-587	-189	700	112	174	112
H14	1283	136	981	45	-330	-168	1223	114	173	165
H15	1393	130	1456	119	-1827	-215	866	98	174	289
H16	1605	136	1680	92	-862	-185	1226	70	130	376
H17	1000	116	1665	60	-1173	-132	1828	113	127	425
H18	1120	83	212	-31	-1486	-135	2013	278	1563	308
H19	637	69	-633	15	-1843	-38	1545	92	1983	253
H20	1107	93	-494	0	-2002	-180	1798	137	1766	187
H21	1588	43	1048	30	-1689	-146	1667	343	1571	158
H22	1232	64	778	92	-121	17	2000	128	1128	251
H23	1195	82	1362	58	1095	10	2013	171	1128	72
H24	1705	145	1435	65	-1174	-48	1611	565	1128	77

Table 2: Experimentation results for phase 3 run 4.

4.3 Assessment results and learnings

Despite the suboptimal results of experimentation phase 1-3, there has been a significant improvement of the method and the RAO tool (as described in the sections above). The proper functioning of the proposed concept based on an optimizer has been verified as well.

As illustrated in the table 1 and 2 above and the table 3 and 4 in chapter 7.2 the quantitative assessment performed in phase 3 shows limited results in terms of available ID capacity. Only in the last run of phase 3, results comparable with the initial ATC domain have been obtained. Qualitative assessment of these results shows however that MCP inclusion after Remedial Action Optimization generally leads to positive results in term of resulting ATCs compared to the initial ones. Based on this correlation, better fine-tuning of the inputs data and Remedial Action Optimization parameters as well as provision of additional RA for the Remedial Action Optimization with the objective to significantly reduce the use of automatic MCP inclusion have been identified as important improvements that would be implemented in further experimentation and parallel runs.

More capacities for all directions compared to FB DA and the ATC increase/decrease process cannot be guaranteed with the new process. Optimization of FB domains can benefit the likely market directions at the cost of capacity in the opposite directions.

New calculated FB IDCC domains reflect better the expected real-time situation which improves security of supply.

Further improvements of the FB IDCC methodology, and especially the Remedial Action Optimization, have been identified as well. After the analysis of parallel run results quick wins will be implemented if possible.

The CWE TSOs commit to include the DA MCP in the FB ID CC domain up to the FRM value – except in case of force-majeure. In order to do so CWE TSOs foresee to include costly remedial actions to avoid automatic DA MCP inclusion. CWE TSOs will work on developing, testing and implementing this and seek for intermediate steps to reach this commonly agreed target with limited DA MCP inclusion. Automatic DA MCP inclusion for values higher than FRM should only occur in very exceptional cases (aim to reach a pre-defined threshold).

5 Developments for future FB IDCC

The current FB IDCC method has been developed in the CWE area. The new capacity calculation region is now the Core CCR and subsequently a FB IDCC method will be developed in that CCRs as set forth in CACM. The following improvements of the CWE FB IDCC methodology will therefore need to be coordinated at Core level. Hereafter is a list of possible future improvements to be implemented in that context:

5.1 Additional recomputation in ID

In the current process, only one recomputation is coordinated with all TSOs. This recomputation is performed in the evening of the D-1. In the future, additional recomputations could be implemented based on the updated set of data: IGMs, but also remedial actions, in order to assess more efficiently the capacity that can be provided to the market players.

5.2 Improvements of the tools

In the current version, the tools used are based on existing tools. In the future, new methods will be developed to focus the remedial action optimizer even more on the elements that will provide additional capacity by not optimizing the margin on all elements but only on the elements that limit the flow based domain and thereafter the capacity that provided to the market players.

5.3 Developments foreseen in order to cope with the evolution of the system in the region

In the case of new HVDC interconnectors within the CWE area that will be operated in parallel with the AC system, the following is presenting possible adaptations to the capacity calculation process which would allow considering the influence of this grid element:

The impact of an exchange over the HVDC is considered for all relevant Critical Network Elements Contingencies (CNECs)

The outage of the HVDC interconnector is considered as a contingency for all relevant CNEs in order to simulate a zero flow over the interconnector, since this is becoming the n-1 state.

In order to achieve the integration of the HVDC interconnector into the FB process, two “virtual hubs” at the converter stations of the HVDC are added. These hubs represent the impact of an exchange over the HVDC interconnector on the relevant CNE/Contingency combinations. By placing a GSK value of 1 at the location of each converter station the impact of a commercial exchange can be translated into an equivalent PTDF value which will be called PSDF for Power Shift Distribution Factor. This action adds two columns to the existing PTDF matrix.

6 Criteria for an operational process

6.1 Criteria for the process operation

The first criteria is to have a reliable process that can produce results everyday. The number of process fails will be monitored.

6.2 Criteria for the released capacity

The second criteria will monitor the output of the process:

- The already allocated capacity should be included in the domain with explicit remedial actions.
- The capacity computed with the new process will be compared to the results of the coordinated bilateral increase/decrease process.

The percentage of automatic DA MCP inclusion for values higher than the FRM values will be monitored separately.

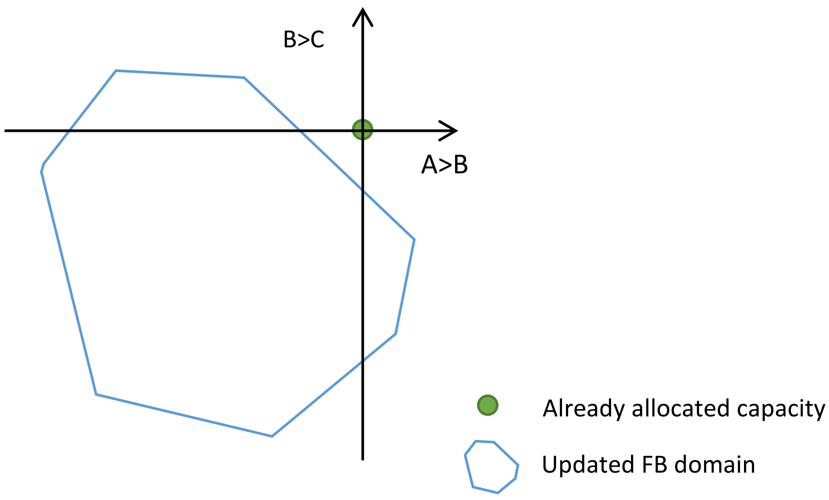
6.3 Criteria for the market

The updated capacity should provide more flexibility to the market players:

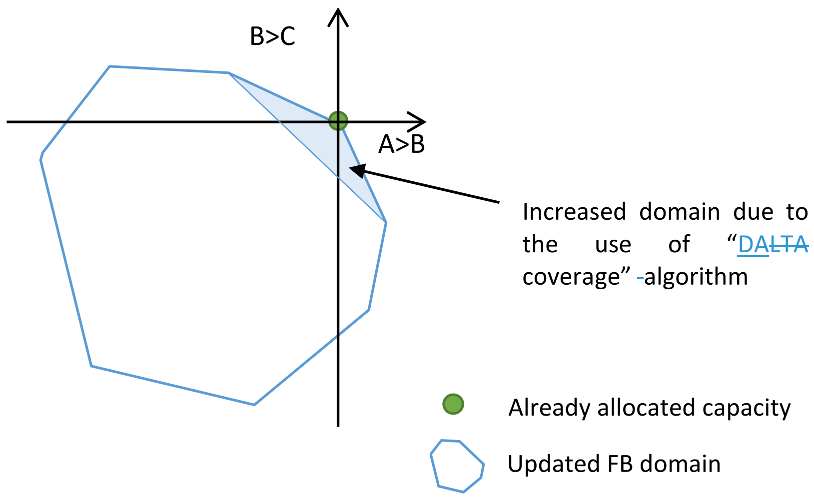
- The updated capacity will be compared to the current behaviour of the market players in the market direction and in the opposite market direction.
- The additional capacity that can be provided in the market direction will be monitored.

7 Annexes

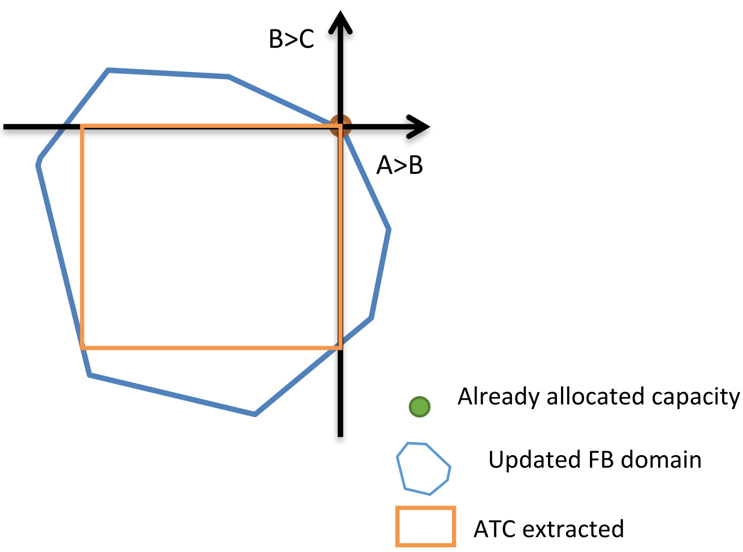
7.1 Example for automatic market clearing inclusion



Step 1: Shift the FB domain according to the market clearing point



Step 2: Add the origin (zero NPs) as a vertex when it is not part of the FB domain



Step 3: Run the ATC extraction module to assess the ID ATCs

7.2 Experimentation results for phase 3 run 2 and 3

	17/10/2016		18/10/2016		19/10/2016		20/10/2016		23/10/2016	
	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion
Hours	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin
H01	862	42	-669	-157	-1693	-33	1713	127	2012	466
H02	-1459	-9	-669	-64	443	37	1306	66	2013	238
H03	-1773	-61	-1870	-107	-2006	-20	1426	94	2013	241
H04	66	70	-1927	-90	-2006	-112	1746	96	2013	296
H05	-1115	38	-2027	-146	-1870	-164	1848	95	1084	281
H06	-2223	-286	-1588	-184	-1924	-107	809	42	2013	267
H07	-1773	-595	-1174	-308	-1337	-282	-680	-348	2013	268
H08	-1877	-685	-2236	-241	-1843	-301	-841	-532	2013	247
H09	-1969	-714	-1399	-313	-2007	-343	-1268	-434	2013	294
H10	-1053	-614	-1873	-278	-1935	-330	-311	-441	2013	570
H11	-1334	-606	-1831	-302	-2009	-396	-439	-284	2013	432
H12	-1283	-539	-1486	-346	-1850	-379	-977	-227	2013	589
H13	-1174	-529	-1662	-377	-1843	-323	-1057	-220	2013	501
H14	-1337	-664	-1648	-373	-1843	-251	-598	-201	2074	415
H15	-1174	-580	-1534	-448	-1843	-181	-681	-178	1640	459
H16	-1629	-693	-1612	-452	-1843	-195	-1703	-170	617	432
H17	-1174	-648	-1792	-462	-2065	-268	-1485	-243	578	432
H18	-1291	-600	-2069	-460	-1956	-393	-1772	-245	1522	300
H19	-640	-342	-1909	-283	-1888	-340	-2328	-220	1548	728
H20	-1014	-279	-1285	-273	-1121	-336	-868	-251	2261	449
H21	-389	-408	-1915	-327	-1950	-480	-287	-296	2381	339
H22	-1843	-395	-1958	-388	-1843	-436	-1143	-212	1597	131
H23	-1624	-625	-1263	-198	-1674	-203	-570	-58	2138	486
H24	-450	-398	-1843	-338	293	33	1235	70	2532	212

Table 3: Experimentation results for phase 3 run 2.

	24/10/2016		26/10/2016		27/10/2016		28/10/2016		29/10/2016	
	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion	ATC indicator	MCP inclusion
Hours	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin	Total Sum	Minimum Margin
H01	2013	211	259	25	978	-18	1015	45	1514	174
H02	2013	216	233	27	2013	279	-1316	-75	1287	180
H03	2013	418	1365	36	2013	279	-2006	-132	1416	221
H04	2013	202	1319	28	2013	97	-2006	-139	1494	188
H05	2013	157	743	12	2013	97	-2006	-111	1319	320
H06	1992	159	-780	-2	1717	222	-2008	-122	1440	207
H07	-27	-69	71	-76	1174	69	-1531	-52	1161	194
H08	311	-141	357	-77	-961	-103	-1472	-215	1065	199
H09	-8	-134	-6	-16	427	15	-2010	-211	1234	280
H10	-158	-123	-262	-71	802	23	-1928	-118	1651	195
H11	177	-43	-240	-132	938	29	-2130	-119	2707	214
H12	662	-39	-595	-154	-746	-3	-1973	-153	2488	170
H13	308	-71	-697	-228	-968	-22	-2070	-31	2410	112
H14	-330	-80	-1567	-249	-964	-28	824	51	2196	82
H15	-825	-121	-650	-295	-954	-17	1062	48	1794	30
H16	-1073	-178	-1773	-345	-1004	-49	1322	65	973	106
H17	-369	-240	-1563	-411	-2192	-87	1291	65	1281	232
H18	-1140	-251	-1641	-385	-1223	-207	630	23	1985	207
H19	-599	-219	-1174	-410	-2011	-299	1221	24	1192	179
H20	-762	-204	-220	-381	-2204	-321	174	6	2186	69
H21	-98	-240	-1	-390	-2131	-38	804	25	769	76
H22	-635	-147	-1309	-219	-1531	-19	-1340	-256	1219	186
H23	312	-137	-862	-195	-1537	-21	-887	-4	1227	427
H24	1665	41	583	37	-1651	-17	-204	-20	1078	62

Table 4: Experimentation results for phase 3 run 3.