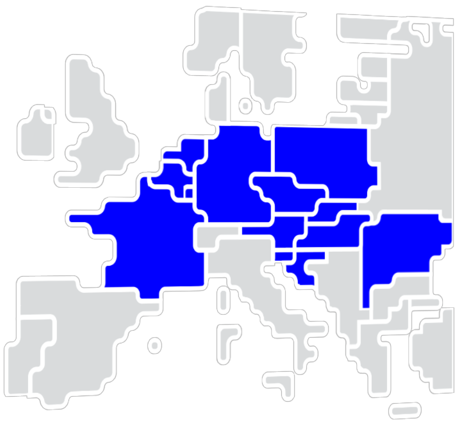
Explanatory document to the common methodology for redispatching and countertrading cost-sharing for single day-ahead and intraday coupling for Capacity Calculation Region Core in accordance with Article 74 of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a Guideline on Capacity Allocation and Congestion Management

22 February 2019



Disclaimer*:*
This document is released on behalf of the transmission system operators ("TSOs") of the Capacity Calculation Region Core solely for the purpose of providing additional information on the methodology for redispatching and countertrading cost sharing in accordance with Article 74 of Commission Regulation (EU) No 2015/1222 of 24th of July 2015 establishing a guideline on capacity allocation and congestion management ("CACM guideline"). This version is a draft and does not constitute a firm, binding or definitive TSOs' position on the content. It reflects the current status quo of the TSOs discussions and TSOs are further working on the details of the cost sharing methodology. In particular, the document describes different options for the design of the cost sharing methodology. A former version of this document was submitted to Core NRAs end of 2018 in order to get their shadow opinion on former cost sharing methodology.

Content

INTRODUCTION

In accordance with Article 74 of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a Guideline on Capacity Allocation and Congestion Management (hereafter referred to as the "CACM guideline") the Core Transmission System Operators (hereafter referred to as "Core TSOs") are working on the Common Methodology for Redispatching and Countertrading Cost-sharing for the Core Capacity Calculation Region (hereafter referred to as "CCR"). This methodology aims at defining the costs induced by congestion management in the Core CCR, as well as the related sharing dispositions between Core TSOs.

The determination of the costs eligible for sharing amongst Core TSOs is considered, and as a general approach causation principle is used to assign the costs to TSOs. This requires sub-steps that are further described in this methodology, such as the flow decomposition methodology, the transformation and the mapping.

The aim of this explanatory note is to provide additional information with regard to the Common Methodology for Redispatching and Countertrading Cost-sharing for the Core CCR (hereafter referred to as "Cost Sharing Methodology"). In particular, it provides insight on open points of the methodology on the following aspects, which are still being assessed and discussed between Core TSOs such as flow decomposition, mapping of the costs to the congested elements, socialization of the costs due to non-Core contributions, prioritization of the flow types, netting of the burdening and relieving flows, consideration of multiple contingencies on a given critical network element, treatment of the PST flows and deviation from RSC recommendation. This paper considers the main elements of the relevant legal framework (i.e. CACM guideline, Regulation (EC) 714/2009, Commission Regulation (EU) 543/2013), and is provided for additional insight on the methodology only.

1. OVERVIEW ON COST SHARING CALCULATION PROCESS

The following chart serves as an introduction and overview to the cost sharing calculation process.

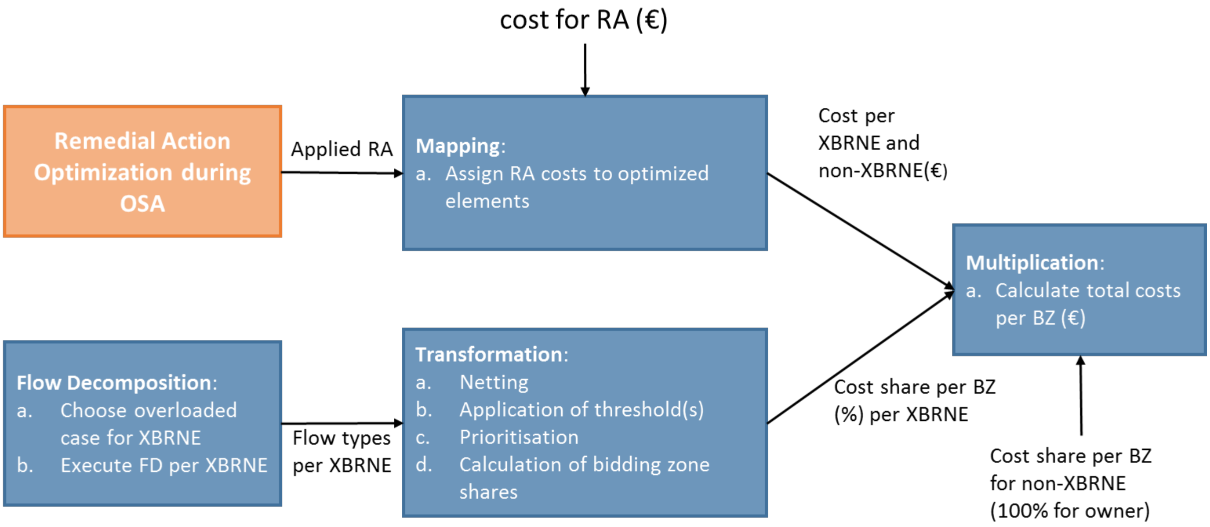


Figure 1: Overview on cost sharing calculation

The calculation process starts after the remedial action optimization during OSA. It consists of the four steps (still open to discussion): flow decomposition, transformation, mapping and multiplication. The Figure 1 gives some insight on the details of each step as well as on the output information. Further explanation is contained in the corresponding chapters below.

2. INTERACTIONS WITH OTHER METHODOLOGIES

Based on the current analysis, Core TSOs identified the following interactions with the other methodologies

Table 1: interactions with other methodologies

Input or Output interface?	Parameter	Used by module / description	Interaction with other methodology
Input	XBRNE	CB Labeling (Flow decomposition): used for the determination of elements on which partial flows are to be determined	Article 35(2) CACM guideline (Definition of the cross-border relevance for the cost-sharing process) Comment: currently
Input	GSKs[1] (optional)	Flow decomposition	CACM Article 21 CACM guideline (Capacity Calculation)

[1] Please note that Core TSOs did not conclude whether or not to use GSKs for cost-sharing process

Input	RAO	Mapping: how to allocated total eligible costs for cost-sharing to the different elements (XBRNE and non-XBRNE) Used input: activated resources with its volume and costs, tap positions (before/after), relieved grid elements (before/after)	Article 76 SO guideline (Optimization of remedial actions) / Article 35 CACM guideline (information about the prices of resources)
Input	CGM	Flow decomposition	Articles 67(1), 70(1), and Art.76(1) SO guideline (Common Grid Model)
Output	Cost per Core BZ, Cost per non-Core BZ	-	Tbd: used for the reporting and monitoring obligations out of Article 74 CACM guideline

3. CALCULATION OF COSTS FOR SETTLEMENT

The calculation of the total cost of a redispatching and countertrading action is described in Article 14 of the methodology required by Article 35 of the CACM guideline (hereafter referred to as "Core RD and CT Methodology"). The total cost includes all eligible costs for cost sharing according to Title 2 of the Cost Sharing Methodology. Eligible costs do not include capacity costs, which consist, among others, of costs incurred by contracting redispatching and countertrading assets for congestion management and/or balancing. The basis for this calculation is the incurred costs invoiced or credited by the providers of redispatching involved in the redispatching and countertrading action. It may include ramping costs, costs/revenues for balancing where applicable, start-up costs and shut-down costs where Core TSOs agree to start or stop a generating asset to solve congestion on a critical network element.

The total cost is not necessarily identical to the costs resulting from the remedial action optimization process (in accordance with the methodology required by Article 76 of the Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Electricity Transmission System Operation (hereafter referred to as "SO guideline"), which is the basis for the activation of the redispatching and countertrading action. Deviation between total cost and optimization result can be explained with the following two causes.

Price changes

As explained in Article 11 (2) of the Core RD and CT Methodology, in case a cost related pricing mechanism is used for redispatching and countertrading, the costs are known only ex-post. The TSOs can declare indicative prices/costs for the optimization but the costs can be strongly influenced by market prices which can change between start of the optimization and activation of the redispatching and countertrading action. There could be a remaining deviation (positive or negative) between optimization results and total cost. Any deviations and reasoning of the deviation will be clearly communicated to Core TSOs and Regional Security Coordinators (hereafter referred to as “RSCs”) and reported by RSCs on the frequency and size of the deviations.

This deviation must not mean that the optimization would lead to a different set of redispatching and countertrading actions, as the influencing factors like electricity market prices affect different kind of generators in a similar manner. It also depends on the Remedial Action Optimizer (hereafter referred to as “RAO”) to determine the most efficient set of remedial actions: changing between the sharing of redispatching offers by TSOs to RSCs and results from the RAO.

Balancing activity

Several TSOs use a combined approach for balancing and congestion management. Redispatching and countertrading is basically a balanced activity. However, some TSOs might use it in a non-balanced way. In this case the imbalance in the system (which shall be compensated by the balancing activity) and the deviation between upward and downward redispatching and countertrading result in total in a fully balanced situation. This can be used, when the use of redispatching and countertrading and balancing sources can be reduced at the same time (see Figure 2). This action always leads to the reduction of the total cost and cannot be predicted at the time of the optimization process.

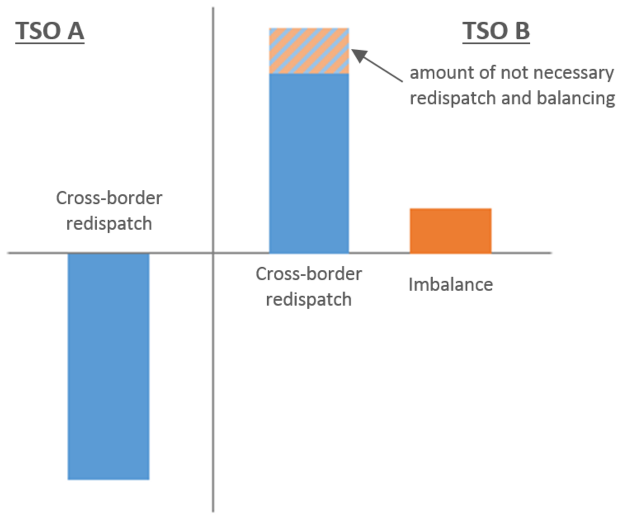


Figure 2: Combined approach for congestion management and balancing

4. EXPLANATION OF OPEN-POINTS IN COST SHARING METHODOLOGY

4.1. Flow Decomposition Methodologies

The main pre-requisite for the application of the causation principle is the identification of partial flows on a congested Cross-border Relevant Network Element (hereafter referred to as “XBRNE”). So far, there are three different methodologies under discussion in Core region in order to identify the different categories of flows:

1. Power Flow Colouring Decomposition Method with and without consideration of electrical distances for market flows (hereafter referred to as “PFC”)
2. Full Line Decomposition Method (hereafter referred to as “FLD”)
3. Multi-stage Full Line Decomposition Method (hereafter referred to as “MFLD”)

The three methodologies identify loop flows, transit flows, import/export flows, internal flows and Phase Shifting Transformer (hereafter referred to as “PST”) flows. The description of PFC has been delivered by APG, the description of FLD by TenneT NL and the description of MFLD by Elia.

4.1.1 Power Flow Colouring Decomposition Method (“PFC”)

Main features of PFC method

The Power Flow Colouring (PFC) method for the decomposition of flows has been developed with the main goal to stay consistent with the European zonal market model and, at the same time, to allow for a complete partitioning of the power flow for each network element of the power system. The technical concept has been drafted within the Horizon 2020 research project FutureFlow[2] (financed by EC) on which four (4) TSOs from the Core CCR (ELES, MAVIR, APG and Transelectrica) are involved.

The main basis for the development of PFC decomposition method was the agreement between ACER and ENTSO-E on the definition of allocated flow (exchange flows), i.e. a flow that originates from market coupling process and is consisted of transit and export/import flows. In that light, total flow over a network element is a sum of allocated flows and flows that do not result from the capacity allocation mechanism. The flows that “do not result from the capacity allocation mechanism” and remain are internal flows (in case of an internal network element) and loop flows (in case of a cross-border network element or of an internal element of another zone).

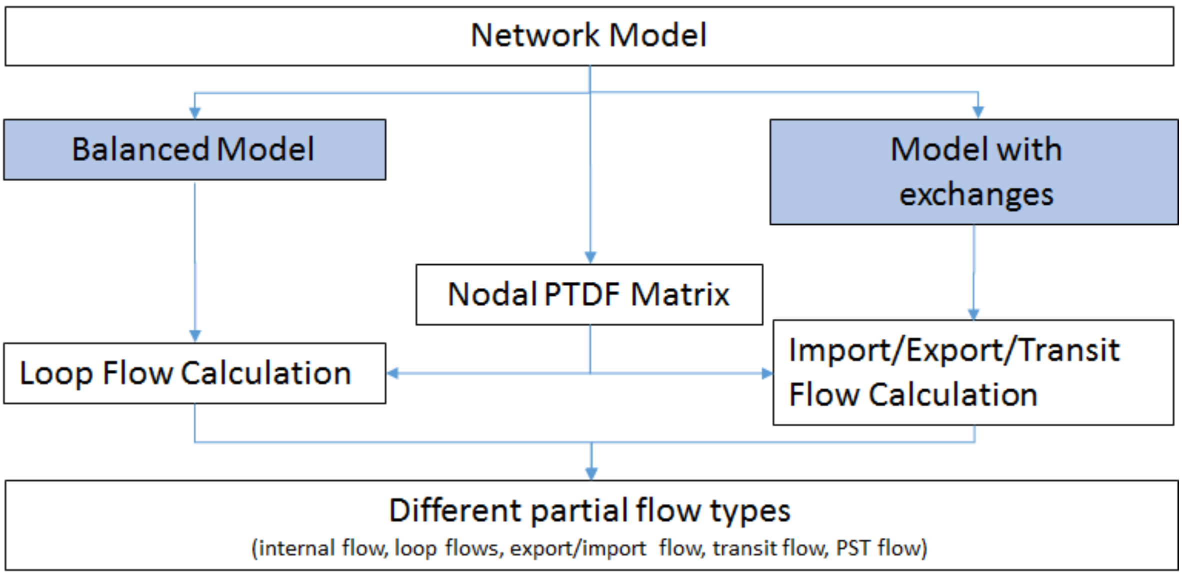


Figure 3: PFC calculation process

[2] FutureFlow description: Four TSOs of Central-Eastern Europe (Austria, Hungary, Romania, Slovenia), associated with power system experts, electricity retailers, IT providers and renewable electricity providers, propose to design a unique regional cooperation scheme: it aims at opening Balancing and Redispatching markets to new sources of flexibility and supporting such sources to act on such markets competitively. Project duration is four years (2016-2020), with funding of 13 million of Euros. http://www.futureflow.eu

The main idea behind PFC decomposition method is to apply a superposition principle **on two zonal models,** namely on the one balanced model **without** commercial cross-zonal energy exchanges, (each zone could cover its own energy needs) and one **with** commercial energy exchange (either includes the results of day-ahead market coupling or intraday net positions). Out of those two decomposition steps, it is possible to obtain all partial flow types:

- Loop flows and Internal flows (using balanced model)
- Exchange Flows - Transit flows, Export/Import flows (using model with exchanges)

If deemed necessary, with the method it is also feasible to clearly separate flows that are shifted by a particular phase-shifting transformer (PST) compared to the case when it is in its neutral position.

Methodological approach

Initial load flow calculation

As a starting point of PFC calculation, initial load flow calculation is performed.

- Determining nodal injections and flows per each branch
- Determining losses per each branch (in case of AC calculation)
- Determining Area net positions
  - Obtaining initial net positions from AC/DC load flow calculation
  - Division of losses between the adjacent nodes and their addition to the load of these nodes (in case of AC calculation)
  - Determining new net positions by adding losses to the load of a particular node (in case of AC calculation)

Node-to-node PTDFs

For the calculation of different type of flows nodal Power Flow Distribution Factor (hereafter referred to as "PTDF") matrix has been used. For the calculation of PTDF matrix only network topology and the parameters of network elements, such as lines and transformers, are necessary as an input. In addition to nodal injection (generation/load), influence of PSTs is also included through Phase Shifter Distribution Factor (hereafter referred to as "PSDF") matrix and considered in the total flow calculation.

Balanced model – general concept for calculation

Balanced model is created out of the initial model by balancing each zone.

Creation of "Balanced model"

- Area balancing is performed according to predefined Generation Shift Key (hereafter referred to as "GSK") / Load Shift Key (hereafter referred to as "LSK"):
  - Exporting area (Area net position > 0): Decreasing total generation to the level of total load of an area based on:
    1. "Neutral approach": proportionally to initial model generation (prop-to-gen). Explicit GSK is not required for area balancing
    2. "GSK approach": model is balanced using the defined GSK file[3]

[3] Could be enlarged with a "market approach" where the net positions of all zones equal to zero are obtained (e.g. using an optimisation with market model and with the predefined constraints)

Excess generation is considered only in the model with exchanges

- Importing area (Area net position <0): Decreasing total load to the level of total generation of an area based on:
    i. "Neutral approach": proportionally to initial model load (prop-to-load). Explicit LSK is not required for area balancing
    ii. "GSK approach": model is balanced using the defined LSK file

  Excess load is considered only in the model with exchanges

- Determining "balanced" nodal injections (generation and load)
- Obtaining Loop flows/Internal flows of each area/subarea/TSO per defined XBRNE/Critical Outage by multiplying node to reference PTDF matrix with balanced nodal injections

This way each area will first supply local load centres, and only afterwards other nodes in the surrounding areas. Possible usage of GSK approach allows consistency with the other processes already in place, such as capacity calculation and market coupling (zonal export/imports and bidding zone day-ahead energy prices are dependent on the GSKs). Shift keys allow for the modelling of market behaviour within a bidding zone, i.e. give the information which power plant should deliver an additional MW that is to be exported from this zone.

Model with exchanges – general concept for calculation

Model with exchanges contains only imports and exports of all areas (left after balancing) with residual injections/load in each node obtained as a difference between initial model and balanced model injections.

Creation of "Model with exchanges"

- Determination of "exchange" nodal injections as a difference between nodal injections from the initial model and balanced nodal injections.
- Determination of particular generator-load exchanges by applying the following methodology on the zonal level:
    - *Net position approach without consideration of geographical proximity:* Each remaining generation (nodal generation in the "model with exchanges") feeds in each remaining load (nodal load in the "model with exchanges") proportionally to all the remaining loads in the network[4]
    - *Net position approach with consideration of geographical proximity (perfect-mixer[5]):* Each exporting zone feeds in each importing zone by considering the distance among them over a perfect-mixer approach.

- Calculation of exchange flows (exports/imports-transits) of each area/subarea/TSO per defined XBRNE by multiplying node to node PTDF matrix with previously determined generator-load exchanges.

4 An alternative implementation concept known as ePFC (Exchange Power Flow Colouring) applies multiplication of zone to zone PTDF matrix (per bidding zone border) with previously determined schedule exchanges. Beforehand, net positions are decomposed into the schedule exchange.

5 P. Kattuman, R. Green, J.W. Bialek: A tracing method for allocating the cost of interarea electricity transmission"

The proportional method for determination of source-sink pairs or a perfect-mixer approach is used for allocation on the zonal level. The responsibility of an exchange is divided equally (50/50) between the involved parties. Transit flows and Export/Import flows are obtained from the exchanges flows by considering a location of zones as well as the location of a network element.

Model with exchanges – consideration of satellite region

One or more network elements that connect one participating country with the satellite region and which are not "breathing" with the continental Europe (such as the connection with Turkey, Spain or UK) are considered as fix injections/withdrawals towards the meshed European grid. For the proportional net position approach, exporters and importers of such regions are firstly paired among themselves and, only afterwards, remaining export/import is considered towards the central calculation region (in this case Core). In such a way, the model ensures that external influence is properly taken into account, but at the same time, that PFC model could be applied in the different European CCRs (Capacity Calculation Regions).

Granularity of calculation

All calculations are performed at nodal level but with a consideration of bidding zones[6] **in each step** of calculation. As the location of each node is clearly known, the results are shown on the zonal level. In such a way, a consistence with the ENTSO-E definition and European zonal market design is ensured.

The application of the method is to be done on the level of **bidding zones** as capacity calculation is also performed with such granularity.

PFC – main characteristics

The main features of methodology include:

4. Usage of the physical reality (network model);
5. Consideration of European zonal market model and linkage with the market coupling and capacity calculation;
6. Consideration of the proportional and/or perfect-mixer sharing principle for exchange model as it is in general not possible to uniquely allocate origin of the source/sink exchanges to the particular nodes (proportional share split 50/50 between export and import zones);
7. Calculation is independent of slack bus location;
8. Both partial flows identified, relieving and burdening ones;
9. Consideration of losses by using AC load flow approximation method;
10. Automatic determination of a partial flows over any network element:
11. In the base case without any outage
12. In the contingency case with an outage
13. Determination of PST influence on the total flow.

By the application of the PFC decomposition method, it is ensured that:

1. Total flow over an element is a sum of all partial flows, both relieving and burdening ones;
2. Total flow is decomposed into internal flow, loop flow, export/import flow and transit flows (according to ENTSO-E definition);

[6] Zones could be defined as control areas, control blocks, bidding zones etc.

3. In case export/import of a zone is zero (net position = 0) this zone produces only internal flows over an own element and loop flows over the elements of the other zone(s). It means that there are no export/import or transit flows created by this zone.

PFC module is already a part of an industrialized software solution called TNA[7] which in use by some Regional Security Coordinators (TSCNET, SCC) as well as ACER.

4.1.2 Full Line Decomposition Method (“FLD”)

The full line decomposition has been developed in order to calculate the various flow types. FLD allows a complete partitioning of the power flow for each network element [1] in N-0 and/or N-1 situations and produces unambiguous results for each network model, independent of slack bus location and GSKs. FLD is a further development of the Simple Tie-line Decomposition (hereafter referred to as “STD”) method that was proposed in [2].

Definitions

The physical flow in a network element is the flow that results from a load flow calculation. The used network may represent a forecast or scheduled scenario or any other scenario. The physical flow is decomposed into flow types. The definitions of the flow types are based on the ENTSO-E definitions, as agreed in September 2014. The ENTSO-E definitions are adapted to accommodate for 4 types of network elements:

- Network elements that are completely in one zone
- Network elements that connect to an X-node at the border between two zones
- Network elements that cross the border between two zones
- Network elements that connect to HVDC nodes

The flow types depend on whether the network element, the generator and the load are located in the same or in different zones. Five flow types are distinguished:

- Internal flows (I)
- Loop flows (L)
- Import and/or export flows (Im, E, I/E)
- Transit flows (T)
- Phase shifter flows (PhS/PST)

The flow types are defined in the following four diagrams. These diagrams show the connected zones "A", "B", "C" and/or "DC". All combinations of zonal locations for the network element, the generator and the load are shown in Figure 4 to Figure 7.

The X-nodes in the network models in the first diagram split the border-crossing elements into two network elements and a flow type is defined for each of these two elements. Network elements that connect to X-nodes are treated as elements that are completely in one zone. The flow type definitions for the first two types of elements are shown inFigure 4.

[7] Transmission Network Analyzer (TNA) is a software developed in cooperation of Electricity Coordinating Center (EKC) and Schneider Electric DMS NS

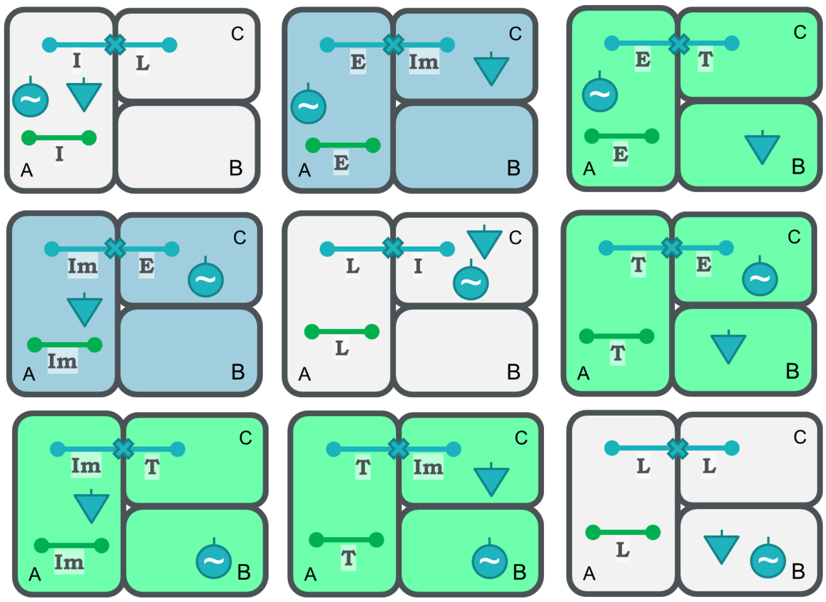


Figure 4: Flow Types for network elements completely inside one zone.

For network elements that cross a border, the Import & Export flow types are taken together. The definitions of flow types for cross border elements are shown inFigure 5. In the UCTE-DEF network model, tie-lines generally are connected to an X-node, so in this case Figure 4 applies as definition. However, for reasons of flexibility, the FLD method can also be applied to networks where the tie-lines are directly connecting two zones, without a connection with an X node. For example the numerical examples in Section 4.1.5 have tie-lines without X-nodes, and the FLD method can be applied to this network.

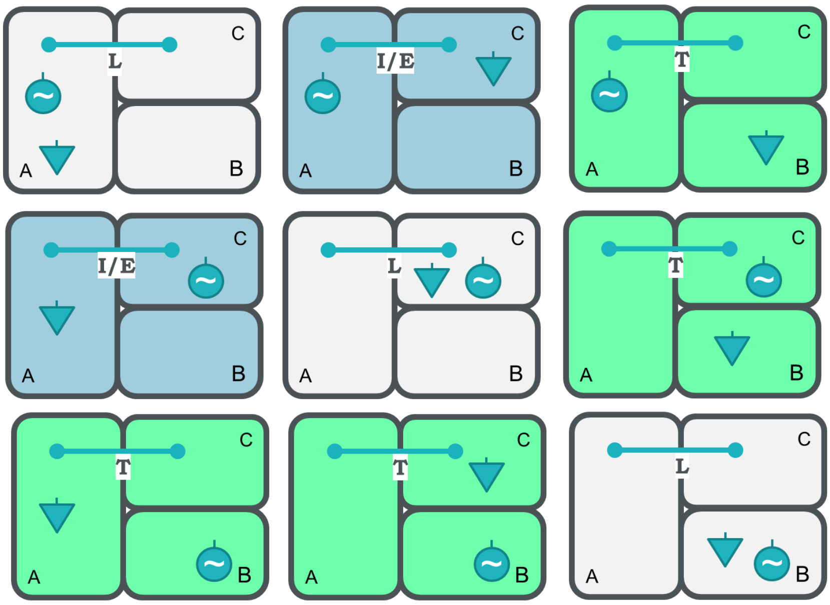


Figure 5: Flow Types for border-crossing network elements. L=Loop, I/E=Import/Export, T=Transit

The HVDC nodes can be treated as internal nodes, like an internal generator or load, in which case the flow type definitions for internal elements apply for the connecting elements. The HVDC may also be placed in a "DC zone", in which case the connecting elements become border crossing elements. The definitions of flow types for elements crossing the border to DC zones are shown inFigure 6. It can be defined in the beginning of the calculation how HVDC links will be treated.

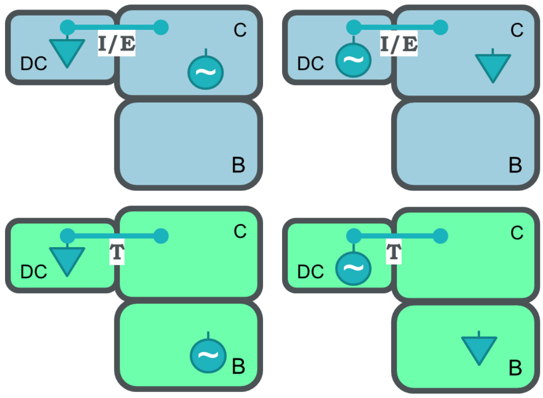


Figure 6: Flow Types for HVDC connections. I/E=Import/Export, T=Transit

The flows resulting from off-nominal phase shifting transformers are cyclic and cannot be related to a source or a sink. The definition is equal for all types of network elements, as shown inFigure 7.

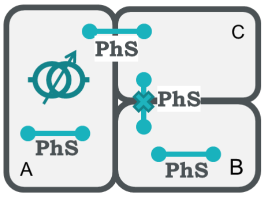


Figure 7: Flow Types for Phase Shifters. PhS=Phase Shifter

In addition to the flow type definitions, the following flow attributes are defined:

- **Burdening flow** is a component of the physical flow on a specific line which flows in the same direction as the whole physical flow.
- **Relieving flow** is a component of the physical flow on a specific line which flows in the opposite direction as the whole physical flow.

Calculation of flow types

FLD is a mathematical method that calculates the flow types in any network element by calculating:

- The AC load flow (or DC load flow when AC load flow does not converge)
- The nodal Power Transfer Distribution Factors (hereafter referred to as "PTDFs")
- The nodal Power Exchange matrix (hereafter referred to as "PEX")
- The Power Flow Partitioning matrix (hereafter referred to as "PFP")

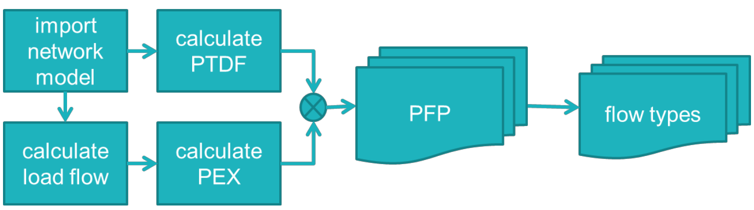


Figure 8: FLD method

The PFP matrix is obtained by multiplying PTDF and PEX values. The flow types for individual network elements are calculated from the PFP matrices by filtering and summing the PFP values according to the flow type definitions.

Load flow

The AC load flow is calculated and the branch losses are transferred to the adjacent nodes. If the AC load flow cannot be made to converge, then a DC load flow is calculated where the losses are calculated iteratively from the active power flows.

It is assumed that the imported network model is completely balanced as it will be created and analysed in preceding processes. In case the leftover imbalance after importing the network, a 'generator spread' method is applied that shifts all generators that are active (in service and connected) by the unbalance, by ratio of their dispatch. In formula:

$$ShiftFactor = \frac{\sum_{i \in A} G_{loadflow,i}}{\sum_{i \in A} G_{ini,i}}$$

$$G_{new,i} = G_{ini,i} \cdot ShiftFactor$$

Where A is the set of all active generators, including the slack node, $G_{ini,i}$ is the initial dispatch of generator i, $G_{loadflow,i}$ is the calculated power flow of generator i and finally $G_{new,i}$ is the shifted dispatch of generator i.

PTDF

The nodal PTDF matrix is calculated directly from the network topology and impedances. The PTDFs describe the linear relation between the active power of generators and loads and the active power flows in the network elements.
Node-to-node PTDFs results from subtracting the nodal PTDFs of two specific nodes. The bilateral exchange of power between these two nodes (ΔBE_{n2n}) will change the flow in the network elements (ΔP_l) according to:

$$\Delta P_l = PTDF_{l,n2n} \cdot \Delta BE_{n2n}$$

A balanced power exchange between two nodes does not lead to a change at the slack node. The dependency on the slack node location is therefore cancelled out in the node-to-node PTDF.

PEX

For a network consisting of N buses and L lines:

- P_G is the vector of N nodal generations
- P_D is the vector of N nodal demands
- F is the vector of L branch flows

The incidence (or connectivity) matrix C is a LxN matrix describing the topology of a network, i.e. which lines are connected to which nodes. The incidence matrix C is split into the matrix C_d that contains the 1's of C and a matrix C_u that contains the -1's, such that $C = C_d + C_u$.
The matrix F_d is defined such that $F_{d_{ij}}$ is equal to the flow on branch i-j towards node j:

$$F_d = - C_d^T \, diag(F) \, C_u$$

Where the operator diag() denotes a diagonal matrix constructed from a vector.
The nodal power P of a bus is defined as the sum of nodal inflows and local generation, which is equal to the sum of nodal outflows and local demand:

$$P = P_D + F_d e \quad \text{or} \quad P = P_G + F_d^T e$$

Where “e” is the Nx1 identity vector of ones.

The A_d and A_u matrices are referred to as the downstream and upstream distribution matrices. They allow relating the vectors of power demands and power generations to the vector of nodal powers. They can be derived directly from the line flows and the nodal power, as:

$$A_{d_{ij}} = \begin{cases} 1 & \text{for } i = j \\ -\dfrac{|P_{ji}|}{P_j} & \text{for } j \in \alpha_i^d \end{cases}$$

$$A_{u_{ij}} = \begin{cases} 1 & \text{for } i = j \\ -\dfrac{|P_{ji}|}{P_j} & \text{for } j \in \alpha_i^u \end{cases}$$

Where P_{ji} is the flow on the line from node i to node j, P_j is the nodal power at node j, α_i^d is the set of downstream nodes directly supplied from node i and α_i^u is the set of upstream nodes directly supplying node i.

It can be shown that A_d and A_u are invertible [3]. The contribution to the power flows in the network, due to individual generators and loads can now be calculated by either

$$P = A_d^{-1} P_D$$

or, equivalently,

$$P = A_u^{-1} P_G$$

An element (i,j) of A_d^{-1} shows the share of the nodal power at node j that is supplied from node i, whereas an element (i,j) of A_u^{-1} shows the share of the nodal power at node j that supplies node i. The element (i,j) of the PEX matrix can now be expressed as follows:

$$PEX_{ij} = P_{D_j} \frac{P_{G_i} A_{d_{ij}}^{-1}}{P_i}$$

In which $\frac{P_{G_i}}{P_i}$ is the proportion of the nodal power P_i coming from the local generation P_{G_i}.
The same result is obtained by using the inverse of the upstream distribution matrix:

$$PEX_{ij} = P_{G_i} \frac{P_{D_j} A_{u_{ji}}^{-1}}{P_j}$$

The PEX matrix contains the power that is exchanged between each generator node and each load node. PEX_{ij} is the power produced in node *i* for the load in node *j*. The calculation of the PEX matrix only requires the active power flow in the network model.

Full Line Decomposition

The PEX matrix contains the power that is exchanged between nodes. The node-to-node PTDF describe the effects of these power exchanges in the network element. The flow on line *l* due to the exchange of power from node *i* to node *j* can thus be calculated as:

$$PFP_{l,ij} = PTDF_{l,ij} \cdot PEX_{ij}$$

The PFP matrix can be calculated for each individual network element, and has the same format as the PEX. The PFP, however, does not contain the power exchange between each two nodes, but the resulting MW flow on the network element, for each of these two nodes.

The flow types can then be calculated by filtering and summing the cells of the PFP matrix. If, for instance, the network element for which the PFP was calculated is in zone A, then the sum of all PFP values for generator nodes in zone A and load nodes in zone A will sum up to the total internal flow.
All other flow types can be calculated like-wise, except for the phase-shifting flow because that flow is part of the PEX and thus not part of the PFP matrices.

Phase Shifter Flows

The effect of a phase shifting transformer (PST) is linearized by using the phase shifter distribution factors (PSDFs). The PSDF expresses the change of MW flow in a network element for a change of the tap of a PST:

$$PSDF_{CB,i} = {}^{\Delta P_{CBCO}}\!/_{\Delta TAP_i}$$

for PST number *i*.

The PSDFs can be directly calculated from the nodal PTDF matrix by:

$$PSDF_{branch,pst} = B_d - PTDF_{branch,n} \cdot (B_d \cdot C)^{\mathrm{T}}$$

Where $\mathrm{B_d}$ is the susceptance matrix and C is the connectivity matrix, which are both created during the calculation of the PTDF matrix.

The Phase Shifter flow types are calculated for each network element by multiplication of the corresponding PSDF values by the actual TAP positions. This also allows to calculate the flow contribution of PSTs from each specific zone.

Options of the FLD app

The FLD app has some settings which can be adjusted by the user.

1. The user can choose whether the areas D1, D2, etc. should be considered as separate zones, aggregated to a DE zone or aggregated to the zones DE, DK and LU;
2. The user can choose whether HVDC interconnections should be treated as internal loads, to aggregate all DC-connected areas to a "DC"-zone or assign to for each zone with HVDC-interconnections a corresponding country-DC zone;

Configurable CBCO file which can have separately or combined following inputs

1. Definition of critical branches/XBRNE to calculate N-0 cases;
2. Definition of critical branches/XBRNE with Critical outages to calculate N-1 cases;
3. Results filter by defining a line Outage Distribution Factors (LODF)

Main characteristics of FLD

The FLD method has the following characteristics:

1. It agrees with the commonly accepted proportional sharing principle, according to perfect-mixer;
2. It can be applied to any network model;
3. It is independent of slack bus location;
4. It is independent of GSK;
5. It is robust and fast;
6. Its results are compliant with the physical properties of the network;
7. The sum of all flow types for each network element exactly equals the total physical flow;
8. It identifies relieving and burdening flows;
9. It is able to identify Phase Shifter flows;
10. It is able to identify HVDC flows.

Further developments

FLD can be further developed.

4. PST cycle flows can then <u>be or not integrated into</u> the existing ENTSO-E flow types.

- The results of the FLD method could be further processed, in order to relabel the resulting flows for cost-sharing purposes. This post-processing occurs after the FLD calculation and offers the possibility to incorporate high-level assumptions (e.g. related to the net-position of a bidding zone) in the FLD results and, consequently, reflect them in the cost-sharing figures.

References

1. Marco Pavesi, Partitioning the Power Flow in the ENTSO-E Transmission Network, M.Sc. thesis, TU Eindhoven, August 2017.
2. P. Hoffmann, S. A. de Graaff, J. Bammert, “The simple tie-line decomposition method - a new approach for a causation based cost-sharing key,” *Cigre Science & Engineering,* pp. 119-125, June 2016.
3. C. Achayuthakan, C. J. Dent, J. W. Bialek, W. Ongsakul, “Electricity Tracing in Systems With and Without Circulating Flows: Physical Insights and Mathematical Proofs,” *IEEE Transactions on Power Systems,* vol. 25, no. 2, pp. 1078-1087, May 2010.

4.1.3 Multi-stage Full Line Decomposition methodology (“MFLD”)

The meshed structure of high-voltage transmission networks provides many possible routes by which electrical power can flow from generators to loads. Therefore, partitioning the power flow into individual component flows represents a challenging task, with the impossibility to determine and trace each MW of power flowing from any generator to any load.

In this section, a concept from Elia for the partition the power flow on any network element according to ENTSO-E flow definitions is described. First, ENTSO-E flow definitions are presented. Subsequently, the approach used in Flow Based Market Coupling (FBMC) for calculating market flows and, accordingly, zero-balance flows is presented. Lastly, the methodology for allocating the identified flow components to the causing bidding zones is described and its main features highlighted.

ENTSO-E flow definitions

According to ENTSO-E flow definitions, the total flow over a network element is the sum of allocated flows (flows that result from the capacity allocation mechanism) and unallocated flows. The flows that do not result from the capacity allocation mechanism are internal flows (in case of an internal network element) and loop flows (in case of a cross-border network element or an internal element of another zone), which together are also called zero-balance flows. The “zero-balance” definition is because those flow components are only attributable to the geographical location of generation and consumption within each bidding zone and do not depend on market exchanges. On the other hand, allocated flows are also named market flows and they can be divided into import/export flows and transit flows. In Figure 9, the different flow contributions are visualised for a network with three bidding zones A, B and C.

Source	Sink	Line	Flow Type
A	A	A	Internal Flow
A	B	A or B	Import/Export Flow
A	A	B or C	Loop Flow
A	B	C	Transit Flow

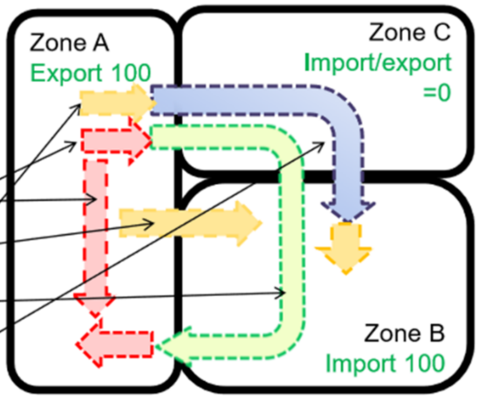


Figure 9: ENTSO-E flow definitions

FBMC: Calculation of market flows and zero-balance flows

In FBMC, zonal PTDFs are used by the market algorithm to assess whether zone-to-zone exchanges respect the grid constraints. These PTDFs describe the relation between a zone and a line, where a change in the Net Position (NP) of bidding zones directly produces the change of the flow in particular lines. The zonal PTDFs are calculated from the nodal PTDFs by aggregation. In order to aggregate the nodal PTDFs into zonal PTDFs, the contribution of each generating node in a zone needs to be weighed. FBMC makes use of Generator Shift Keys (GSKs) to describe how the injection of one generating node changes with the net position of the zone it is part of. These GSKs express the fraction of power that each unit will contribute to a power shift of the total zone and therefore define how a change in the NP is to be mapped to the individual generating units in a bidding zone. Since GSKs are only applied to a selection of generating nodes, a reduction of the nodal PTDF matrix is introduced. This matrix is called PGDF (Power Generating Distribution Factor) and it contains the same rows as the nodal PTDF, but only the generating nodes with non-zero GSK values as columns. The introduction of GSKs allows to calculate the zonal PTDFs (zPTDFs) as follows:

$$zPTDF_l^A = \sum_{i \in A} GSK_i^A * PGDF_l^i \qquad (1)$$

The physical flows in the network can be separated into the zero balance flows due to the generators feeding the loads in the same zone (when NP=0) and into the market flows due to the exchange of power between zones (for NP ≠0). From the zPTDF, the market flow on each line l can be calculated as follows:

$$Market\ flow_l = \sum_{A \in zones} zPTDF_l^A * NP_A \qquad (2)$$

The zero-balance flow on line l is then obtained by subtracting the above-calculated market flow from the total physical flow, as follows:

$$Zero - balance\ flow_l = Physical\ flow_l - \sum_{A \in zones} zPTDF_l^A * NP_A \qquad (3)$$

Multi-stage FLD

Based on Equation (2) and (3), a distinction between market flows and zero-balance flows can be made on any network element according to FBMC principles. The next step is now the allocation of those flows to the causing bidding zones.

The solution proposed in this document consists of applying the so-called Full Line Decomposition (FLD) method, described in [1], to market flows and zero-balance flows separately. FLD is a methodology that allows to find the contribution of each generator to each load on any network element by making use of a matrix approach where network topology and physics of power flows are taken into account.

FLD is a mathematical method that calculates the flow types in any network element by calculating:

- a load flow
- the nodal Power Transfer Distribution Factors (PTDFs)
- the nodal Power Exchange matrix (PEX)
- the Power Flow Partitioning matrix (PFP)

The workflow of FLD is displayed in Figure 10.

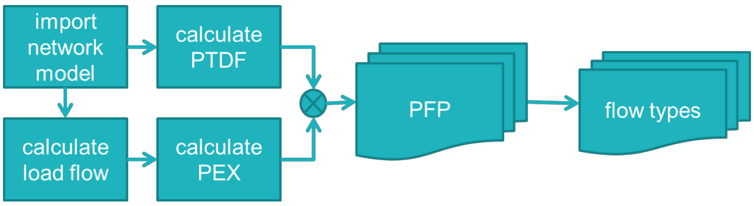


Figure 10: FLD method

The PFP matrix is obtained by multiplying PTDF and PEX values. The flow types for individual network elements are calculated from the PFP matrix by filtering and summing the PFP values according to the flow type definitions.

The main difference between the FLD method as reported in [1] and the proposed multi-stage FLD lies in network model that is provided as input to the calculation. The network model used in FLD, for a network consisting of N nodes and L lines, comprises a vector P_G (Nx1) of nodal generations, a vector P_D (Nx1) of nodal demands and a vector F (Lx1) of branch flows. Conversely, the proposed solution entails a multi-step approach where only the nodal generation and demand (and consequently the resulting branch flows) responsible for market flows and zero-balance flows are separately provided as input for the computation.

In Figure 11, the workflow of the multi-stage FLD approach is presented.

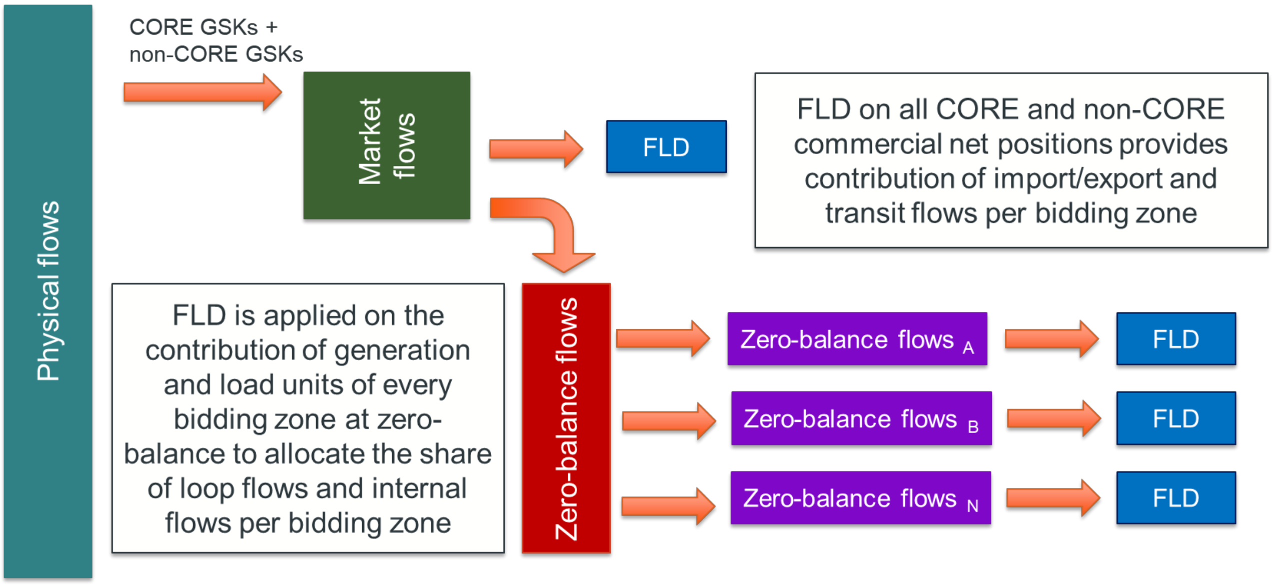


Figure 11: Multi-stage FLD

More specifically, the following procedure is suggested for the allocation of import/export flows and transit flows to the contributing bidding zones:

- The Market Nodal Injection (MNI) of each node is computed by multiplying the NP of the bidding zone to which each node belongs to with its GSK value, as follows:

$$MNI_j = GSK_j * NP_J \quad (4)$$

Where node j belongs to bidding zone J

- With these market nodal injections, a load flow on the full network model is run
- FLD method is then applied on these load flow results

This procedure provides as output the contribution of each bidding zone to the market flow on any network element. In case a bidding zone does not belong to the Core region, its contribution may be labelled as “non-Core” market flow.

Analogously, FLD is applied on the Balanced Nodal Injections (BNI) of the nodes belonging to each bidding zone separately. The BNI of node j is obtained by subtracting its MNI from the original Nodal Net Injection (NNI), as follows:

$$BNI_j = NNI_j - MNI_j \quad (5)$$

Moreover, for each network element, the difference between the physical flow and the market flow previously calculated consitutes the input to the FLD in terms of branch flow (vector F). The application of FLD on those branch flows allows calculating the nodal PEX matrix of each bidding zone and, consequently, to determine the contribution of every power exchange between generators and loads within the same bidding zone to any network element, independently on the slack bus location.

As already mentioned, the significant modification of the newly introduced methodology with respect to the original FLD method is represented by the split between market flows and zero-balance flows that is done at the beginning of the procedure based on FBMC principles. While FLD allocates zero-balance flows and market flows at once starting from the full physical flow, the proposed solution takes into account the principles of a zonal market model in determining market flows and, consequently, zero-balance flows. Nevertheless, starting from a full load flow calculation entails that all the different flow contributions are inter-twined: the resulting physical flow is, in most cases, obtained by flow contributions which partially cancel each other. Therefore, it is expected that the results obtained with multi-stage FLD approach would generally be different than the ones obtained by applying the standard FLD. In other words, the following inequality holds:

$$FLD(Physical\ flows) \neq FLD(Market\ flows) + \sum_{A \in zones} FLD(Zero - balance\ flows_A) \quad (6)$$

Multi-stage FLD: Main features

The multi-stage FLD method presents the following advantages:

- Results compliant with the physical properties of the network
- Proper consideration of European zonal market model and linkage with the market coupling and capacity calculation by means of GSKs
- Clear distinction between Core and non-Core flow contributions
- Possibility to estimate the influence of PST tap change on flows
- Calculation is independent of slack bus location
- Both partial flows identified, relieving and burdening ones
- Total flow over an element is the sum of all partial flows
- In case export/import of a bidding zone is zero (NP = 0), this zone produces only internal flows over an own element and loop flows over the elements of the other zone(s)

References

[1] M. Pavesi, J. van Casteren, S. A. De Graaff, "The full line decomposition method – a further development for causation-based cost sharing", Cigre Science & Engineering N°9, October 2017

4.1.4 High-level comparison of the method features

The following table shows a high-level technical comparison of PFC and FLD.

Table 2: High-level technical characteristics of FLD, PFC and MFLD methods

Feature of a decomposition method	**Full line decomposition (FLD) method**	**Power Flow Colouring (PFC) decomposition method**	**Multi-stage Full Line Decomposition (MFLD) method**
Granularity of calculation?	Zonal (starting from the nodal level and afterwards for the flow decomposition, aggregating the nodes per zone)	Zonal (starting from the nodal level by considering zones in all decomposition steps)	Zonal (starting from the nodal level by considering zones in all decomposition steps)

Zonal granularity	Control area, control block, bidding zone	Control area, control block, bidding zone	Control area, control block, bidding zone
Dependency on slack node during the decomposition	No	No	No
AC/DC load flow calculation?	AC load flow with losses (DC load flow with losses when AC cannot be made to converge)	AC with losses approx. (DC also possible)	AC load flow with losses (DC load flow with losses when AC cannot be made to converge)
Calculation possible for base case and contingency case?	Yes, both (n-0) base case and (n-1) contingency case	Yes, both (n-0) base case and (n-x) contingency case	Yes, both (n-0) base case and (n-1) contingency case
Possibility to estimate the influence of PST tap change on flows (difference to neutral position)?	Yes	Yes	Yes
Sum of all decomposed flows per element is equal to **the total flow** over element?	Yes	Yes	Yes
Comparison of technical features related to different flow-types			
Internal flows and loop flows	FLD results are according to the flows in the network model, independent from net position.	If a zone has zero net position, this zone produces only internal and loop flows (no export/import or transit flows created by this zone)	If a zone has zero net position, this zone produces only internal and loop flows (no export/import or transit flows created by this zone)
Export and import flows	The flow on a line is a combination of all exchanges between all nodes in the network model.	If a zone exports x MW (net position x>0), it can not produce export flows higher than x MW over an element	If a zone exports x MW (net position x>0), it can not produce export flows higher than x MW over an element Remaining available margin (RAM) on each line is in full accordance with FBMC results.

4.1.5 Basic examples for PFC and FLD methodologies

The following three basic examples illustrate different principles and assumptions applied by the FLD and PFC methodologies. As the MFLD was recently proposed, there are no consideration of this methodology in the examples below. For both methodologies, the source and sink pairing is a major step to identify the exchanges between zones. Depending on the assumptions chosen, the results of exchange flows attributed to the different zones vary significantly, as shown in these examples. As a result, different results are obtained by FLD and PFC when decomposing flows into partial flows in a pan-European network model.

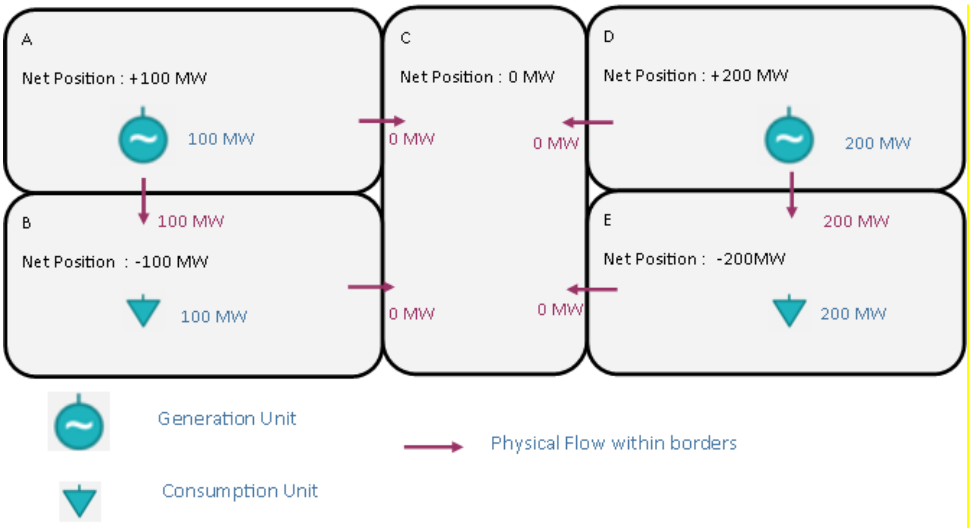


Figure 12: Example 1 - Source and Sink Pairing with PFC and FLD Methodologies

- PFC

PFC Methodology without consideration of geographical proximity considers that each generator supplies each load proportionally to the load in each node in the system.

$$A \rightarrow B = P_A \times \frac{P_B}{\sum_{network} P_{load}} = 100 \times \frac{100}{100+200} = 33\ MW$$

$$D \rightarrow E = P_D \times \frac{P_E}{\sum_{network} P_{load}} = 200 \times \frac{200}{100+200} = 133\ MW$$

$$A \rightarrow E = P_A \times \frac{P_E}{\sum_{network} P_{load}} = 100 \times \frac{200}{100+200} = 66\ MW$$

$$D \rightarrow B = P_D \times \frac{P_B}{\sum_{network} P_{load}} = 200 \times \frac{100}{100+200} = 66\ MW$$

- FLD

Based on the physical flows on the network, a PEX matrix containing the power that is exchanged between each generator node and each load node is built. In our basic example, generation in zone A only feeds consumption in zone B and generation in zone D only feeds consumption in zone E. There are no flows between zone C and another zone.

Table 3: Source-sink paring in PFC and FLD methodology for Example 1

	A-> B	D->E	A->E	D->B
PFC without consideration of geog. proximity	33 MW	133 MW	66 MW	66 MW

PFC with consideration of geog. proximity	100 MW	200 MW	0 MW	0MW
FLD	100 MW	200 MW	0 MW	0MW

Comments

In PFC Methodology without consideration of geographical proximity, the pairing of sources and sinks for export/import and transit flow is done proportionally to the Net Position, without taking into account geographical proximity. As a result, even if a zone D is much further from B than A, the flows feeding B are in majority attributed to D because of its net position higher than A. In PFC Methodology with application of geographical proximity on the zonal level this is no more the case.

In FLD Methodology, the source and sink paring is computed based on physical flows. As a result, the only exchange flows are flows from A to B and D to E.

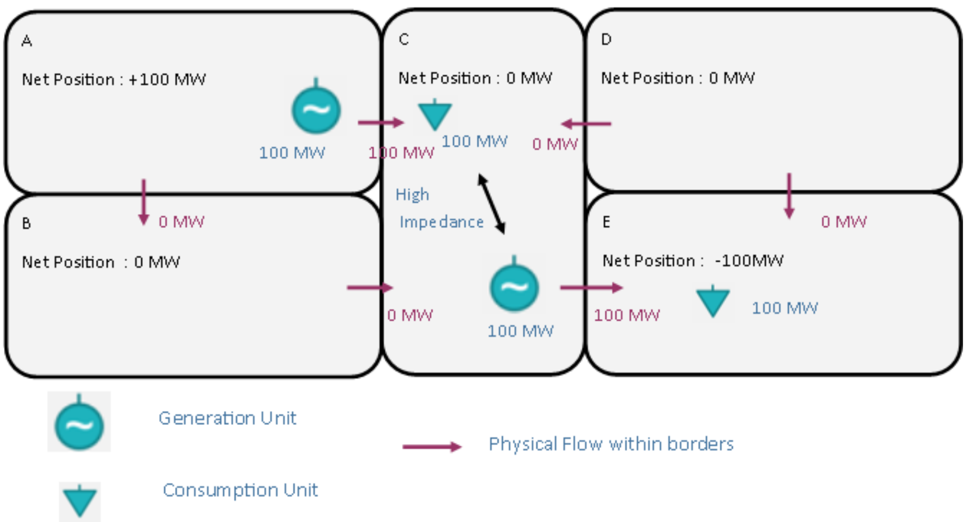


Figure 13: Example 2 - Source and Sink Pairing with PFC and FLD Methodologies

Table 4: Source-sink paring in PFC and FLD methodology for Example 2

	A-> C	C->E	A->E
PFC	0 MW	0 MW	100 MW
FLD	100 MW	100 MW	0 MW

Comments

Due to its net position equal to 0, with PFC Method, no exchange flows (import/export or transit) are attributed to zone C on any element of the zone. Even if bilateral and explicit transactions between A & B, B & C and between C & E have been scheduled, with different prices.

With FLD Method, C imports from A and exports to E. Exchange flows are attributed to C even if its net position is equal to 0 and if the flows on borders may be caused by implicit transactions between A and E.

Only physical flows are taking into account when pairing source and sinks in the FLD method. Bidding zones are used in a second step when flows are aggregated.

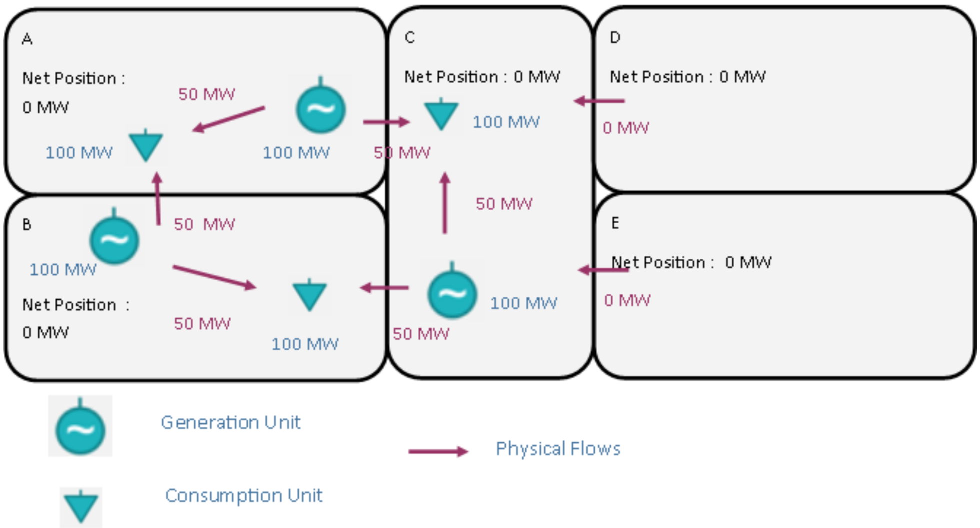


Figure 14: Example 3 - Source and Sink Pairing with PFC and FLD Methodologies

Table 5: Source-sink paring in PFC and FLD methodology for Example 3

	A-> C	C->B	B->A
PFC	0 MW	0 MW	0 MW
FLD	50 MW	50 MW	50 MW

Comments

According to PFC Methodology, as all zones have a Net Position equal to 0, there are only internal and loop flows. Internal flows and loop flows on elements are attributed per zone by multiplying nodal injections by a node to reference PTDF matrix. The example 3 also covers the case when all bilateral Net Transfer Capacity (hereafter referred to as “NTC”) on borders are set to zero for both, export and import direction (no matching of bid/ask offers between the different zones in the market coupling).

According to FLD Methodology, regardless of net position, a physical flow from one source to one sink between different areas is identified as an import export flow.

4.2. Mapping

4.2.1 Description of mapping of costs to relieved network elements

A costly remedial action within Core’s meshed network can relieve several network elements at the same time. In addition, a measure can last for several hours, such that the list of relieved network elements can change between the hours. As the discussed cost-sharing methodology is based on a flow decomposition approach for individual network elements, it is necessary to split the total costs of costly remedial actions by assigning a share to the corresponding network elements. This step is called ‘Mapping of costs’. Core TSOs are investigating four different mapping methodologies which are described in the following.

In addition, Core TSOs will define how to handle so-called “bridge-shares”. It might happen that during Redispatching optimisation some generation units are re-dispatched for a few hours although there is no overloaded network element detected during these hours at the RAO process. Such redispatching might still be necessary in order to keep slow and efficient generating units up and running for sub-sequent hours, where further overloads are detected. The corresponding costs will be re-allocated to hours, where overloads were detected, if feasible.

4.2.2 Option “Volume-based mapping” (VBM)

Description

The volume-based mapping (hereafter referred to as “VBM”) consists of the following steps:

- First, the total netted costs are distributed[8] to each hour of the remedial action according to the relative redispatching volume-share of the concerned hour (e.g. 100 MW for hour 1 out of 1000 MWh in total -> 10% to hour 1). This results in “hourly-shares”. This step is necessary only in case that the hourly costs/revenues of remedial actions are not known beforehand. If there was no overload for intermediate hours, the share of this intermediate hour will be redistributed and the methodology for this redistribution is under discussion.
- Second, the hourly-shares are assigned to the relevant network elements of each hour based on the load flows before and after the remedial action (hereafter referred to as “cb-share”). For each overloaded element, the “relative relieve” is determined according to:

$$r(i) = \frac{F_{before} - F_{max}}{F_{before} - F_{after}}$$

The cb-shares are then calculated according to:

$$c(i) = \frac{r(i)}{\sum_j r(j)}$$

VBM is already established for the settlement of multilateral remedial actions within the TSC cooperation. It requires a few information taken from grid models and a simple script (e.g. Excel Macro).

[8] Where possible if hourly costs are available then it can go straight to step 2

Table 6: Example for VBM

Mapping					
Basis	Total Costs	1.000 €			
	Hour	1	2	3	4
	MRA [MW]	100	300	200	100
	Overload	y	y	y	y
Hourly-Shares	Share per hour (after remapping)	14%	43%	29%	14%
	Costs per hour	143 €	429 €	286 €	143 €
CB-Shares	Load Element 1 before MRA	1.210	1.220	1.310	1.250
	Load Element 2 before MRA		880	890	900
	Fmax Element 1	1.200	1.200	1.190	1.180
	Fmax Element 2	840	840	840	840
	Load element 1 after MRA	1.190	1.180	1.170	1.180
	Load element 2 after MRA		830	840	840
	Relief element 1	20	40	140	70
	Relief element 2	-	50	50	60
	Required relief element 1	10	20	120	70
	Required relief element 2	-	40	50	60
	MRA efficiency element 1	50%	50%	86%	100%
	MRA efficiency element 2	0%	80%	100%	100%
	Mapping key Element 1	100%	38%	46%	50%
	Mapping key Element 2	0%	62%	54%	50%
	Total costs element 1	143 €	165 €	132 €	71 €
	Total costs element 2	0 €	264 €	154 €	

The optimization result is a set of remedial actions (costly and non-costly), which could be differentiated with respect to their impact on the network element, when applying the mapping of costs. This can be done using a sensitivity filter for each RA.

4.2.3 Option “Individual-optimisation based mapping” (IOBM)

Description

The Individual-optimisation based mapping (hereafter referred to as “IOBM”) methodology reflects the possible increase of costs for individual TSO due to a regional optimization. It is an incentive for TSOs to share as much as possible non-costly remedial action or competitive costly remedial action. With VBM, a TSO that maximizes the availability of its non-costly remedial action can be penalized by its neighbouring TSOs if they are not doing the same. The pre-requisite for IOBM is to define the remedial actions to be used for an individual congestion without creating an overload in a neighbouring area and the availability of a Remedial Action Optimization tool.

IOBM consists of the following steps:

- First, the total netted costs are distributed to each hour of the remedial action according to the relative redispatching volume-share of the concerned hour (e.g. 100MW for hour 1 out of 1000 MWh in total -> 10% to hour 1). This step is necessary only in case that the hourly costs/revenues of remedial actions are not known beforehand.
- In a second step, a "what-if" analysis is performed with the goal to determine the individual contribution of each overloaded element (i=1…I) on total hourly costs (GKj). This is ensured by running a remedial actions optimisation algorithm that solves overload over each overloaded network element individually and isolated from the other ones[9]. In such a way, specific redispatching costs per hour and per element (TKj,i) are obtained.
- At the end, total redispatching costs per hour (GKj) are allocated to the overloaded network element (i) proportionally to the ratio (pro-rata) of specific redispatching costs of this element per hour (Tkj,i) and sum of all specific hourly redispatching costs for all overloaded network elements.

Possible consideration of PSTs

If deemed necessary, with the deployment of IOBM it is even possible to consider non-costly remedial actions (network reconfiguration, PST taps…). For example, it could be possible to take into account a variation of PST positions, at least in a specific range around optimal PST-setting that is obtained from the global optimisation of non-costly and costly remedial actions (=basis for the activations of remedial actions). The concept also works if some (and not all) congestions could be relieved only via non-costly measures. In such a case, zero costs are allocated to such measures.
Special case: if **all** congestions could be relieved individually via non-costly measures and costly are needed due to the interference of the individual actions, total costs shall be shared proportionally among them.

Numerical example[10]

Assume that there are two overloads on DE-PL and DE-CZ profiles, which have the n-1 flow limits of 1200 MW and 1500 MW respectively (as presented in the picture below).

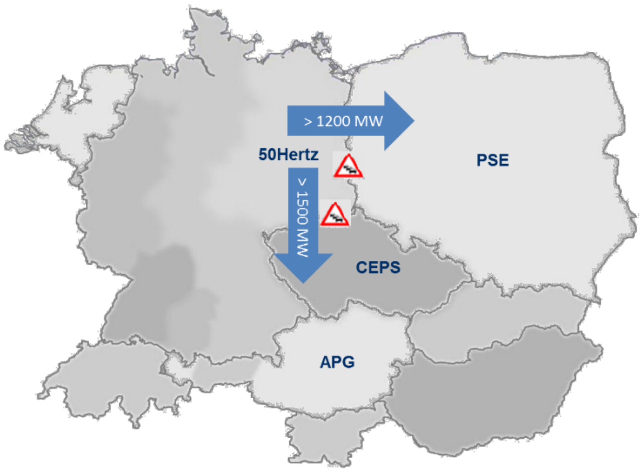


Figure 15: Overloads – example

[9] During this individual optimisation a side condition (constraint) for the other overloaded lines could be defined (for other overloaded lines: F_{after} <= F_{before}, and for other non-congested lines: F_{after} <= F_{max}).

[10] The principle described in the Cost Sharing Methodology Article 8.2 still needs to be integrated into this numerical example.

To solve the overloads, with the least costly remedial action set, the optimizer of 5 RAs is used (see the picture below). The RAs are:

- RA1: PST in Mikulowa, with full taps range: from -32 to +32
- RA2: PST in Hradec, with the full taps range: from -32 to +32
- RA3: cross-border PSE-50Hz redispatching, with potential up to 1000 MW, and cost 32 EUR/MW
- RA4: cross-border CEPS-50Hz redispatching, with potential up to 500 MW, and cost 32 EUR/MW
- RA5: Multilateral remedial action (hereafter referred to as “MRA”) from APG to 50Hz, with unlimited potential, and cost 81 EUR/MW

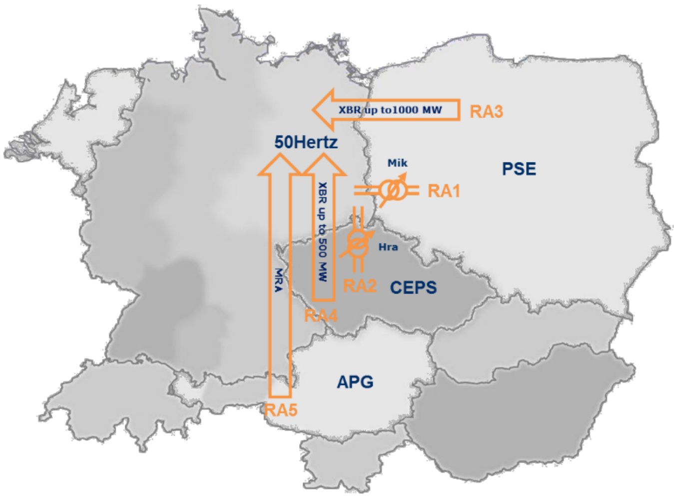


Figure 16: Remedial actions - example

The input data for the optimiser, are the sensitivities of the border flows to all of the RAs, which are:

5. RA1 on DE->PL flow: +25,6 MW/tap
6. RA1 on DE->CZ flow: -8,1 MW/tap
7. RA2 on DE->PL flow: -3,7 MW/tap
8. RA2 on DE->CZ flow: +30,0 MW/tap
9. RA3 on DE->PL flow: -0,429 MW/MW
10. RA3 on DE->CZ flow: -0,157 MW/MW
11. RA4 on DE->PL flow: -0,192 MW/MW
12. RA4 on DE->CZ flow: -0,265 MW/MW
13. RA5 on DE->PL flow: -0,224 MW/MW
14. RA5 on DE->CZ flow: -0,201 MW/M

Example 1 (both individually optimized congestion requires RD)

$F_{DE\text{->}PL,\ before}$ = 2200 MW (i.e. 1000 MW overload)

$F_{DE\text{->}CZ,\ before}$ = 3200 MW (i.e. 1700 MW overload)

Optimal solution for relieving both overloads:

RA1 = -5 tap, RA2 = -32 tap, RA3 = 1000 MW, RA4= 500 MW, RA5 = 2268 MW,

$F_{DE\text{->}PL,\ after}$ = 1174 MW, $F_{DE\text{->}CZ,\ after}$ = 1500 MW, TotalCost = 231 kEUR

Optimal solution for relieving only DE-PL overload:

RA1 = -32 tap, RA2 = 32 tap, RA3 = 145 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 4391 MW, $TotalCost_{DE\text{-}PL}$ = 4.6 kEUR

Optimal solution for relieving only DE-PL overload (while not increasing DE-CZ overload):
RA1 = -32 tap, RA2 = -6 tap, RA3 = 473 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 3188 MW, $TotalCost_{DE\text{-}PL}$ = 15.1 kEUR

Optimal solution for relieving only DE-CZ overload:
RA1 = 32 tap, RA2 = -32 tap, RA3 = 1000 MW, RA4= 500 MW, RA5 = 778 MW,
$F_{DE\text{->}PL,\ after}$ = 2455 MW, $F_{DE\text{->}CZ,\ after}$ = 1500 MW, $TotalCost_{DE\text{-}CZ}$ = 111 kEUR

Optimal solution for relieving only DE-CZ overload (while not increasing DE-PL overload):
RA1 = 24 tap, RA2 = -32 tap, RA3 = 1000 MW, RA4= 500 MW, RA5 = 1100 MW,
$F_{DE\text{->}PL,\ after}$ = 2178 MW, $F_{DE\text{->}CZ,\ after}$ = 1500 MW, $TotalCost_{DE\text{-}CZ}$ = 137 kEUR

Mapping by VBM (volume based mapping) method:
$r_{DE\text{-}PL} = (F_{DE\text{->}PL,\ before} - F_{DE\text{->}PL}, \text{limit}) / (F_{DE\text{->}PL,\ before} - F_{DE\text{->}PL,\ after}) = (2200\text{-}1200)/(2200\text{-}1174) = 0.9747$
$r_{DE\text{-}CZ} = (F_{DE\text{->}CZ,\ before} - F_{DE\text{->}CZ}, \text{limit}) / (F_{DE\text{->}CZ,\ before} - F_{DE\text{->}CZ,\ after}) = (3200\text{-}1500)/(3200\text{-}1500) = 1.0000$
$BorderCost_{DE\text{-}PL} = TotalCost * r_{DE\text{-}PL} / (r_{DE\text{-}PL} + r_{DE\text{-}CZ}) = 231*0.9747/(0.9747+1) = 114$ kEUR
$BorderCost_{DE\text{-}CZ} = TotalCost * r_{DE\text{-}CZ} / (r_{DE\text{-}PL} + r_{DE\text{-}CZ}) = 231*1.0000/(0.9747+1) = 117$ kEUR

Mapping by IOBMa (individual optimization based mapping) method:
$BorderCost_{DE\text{-}PL} = TotalCost * TotalCost_{DE\text{-}PL} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 231*4.6/(4.6+111) = 9$ kEUR
$BorderCost_{DE\text{-}CZ} = TotalCost * TotalCost_{DE\text{-}CZ} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 231*111/(4.6+111) = 222$ kEUR

Mapping by IOBMb (individual optimization based mapping) method (while not increasing the other congestion):
$BorderCost_{DE\text{-}PL} = TotalCost * TotalCost_{DE\text{-}PL} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 231*15.1/(15.1+137) = 23$ kEUR
$BorderCost_{DE\text{-}CZ} = TotalCost * TotalCost_{DE\text{-}CZ} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 231*137/(15.1+137) = 208$ kEUR

Example 2 (one of individually optimized congestion requires RD)

$F_{DE\text{->}PL,\ before}$ = 2200 MW (i.e. 1000 MW overload)
$F_{DE\text{->}CZ,\ before}$ = 1600 MW (i.e. 100 MW overload)

Optimal solution for relieving both overloads:
RA1 = -32 tap, RA2 = -9 tap, RA3 = 499 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 1493 MW, TotalCost = 15.9 kEUR

Optimal solution for relieving only DE-PL overload:
RA1 = -32 tap, RA2 = 32 tap, RA3 = 145 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 2791 MW, $TotalCost_{DE\text{-}PL}$ = 4.7 kEUR

Optimal solution for relieving only DE-PL overload (while not increasing DE-CZ overload):
RA1 = -32 tap, RA2 = -6 tap, RA3 = 473 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 1588 MW, $TotalCost_{DE\text{-}PL}$ = 15.1 kEUR

Optimal solution for relieving only DE-CZ overload:
RA1 = 2 tap, RA2 = -3 tap, RA3 = 0 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 2262 MW, $F_{DE\text{->}CZ,\ after}$ = 1494 MW, $TotalCost_{DE\text{-}CZ}$ = 0 kEUR

Optimal solution for relieving only DE-CZ overload (while not increasing DE-PL overload):
RA1 = -1 tap, RA2 = -4 tap, RA3 = 0 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 2189 MW, $F_{DE\text{->}CZ,\ after}$ = 1488 MW, $TotalCost_{DE\text{-}CZ}$ = 0 kEUR

Mapping by VBM (volume based mapping) method:
$r_{DE\text{-}PL}$ = ($F_{DE\text{->}PL,\ before}$ - $F_{DE\text{->}PL}$, limit) / ($F_{DE\text{->}PL,\ before}$ - $F_{DE\text{->}PL,\ after}$) = (2200-1200)/(2200-1200) = 1.0000
$r_{DE\text{-}CZ}$ = ($F_{DE\text{->}CZ,\ before}$ - $F_{DE\text{->}CZ}$, limit) / ($F_{DE\text{->}CZ,\ before}$ - $F_{DE\text{->}CZ,\ after}$) = (1600-1500)/(1600-1494) = 0.9434
$BorderCost_{DE\text{-}PL}$ = TotalCost * $r_{DE\text{-}PL}$ / ($r_{DE\text{-}PL}$ + $r_{DE\text{-}CZ}$) = 15.9*1.0000/(1+0.9434) = 8.2 kEUR
$BorderCost_{DE\text{-}CZ}$ = TotalCost * $r_{DE\text{-}CZ}$ / ($r_{DE\text{-}PL}$ + $r_{DE\text{-}CZ}$) = 15.9*1.0000/(1+0.9434) = 7.7 kEUR

Mapping by IOBMa (individual optimization based mapping) method:
$BorderCost_{DE\text{-}PL}$ = TotalCost * $TotalCost_{DE\text{-}PL}$ / ($TotalCost_{DE\text{-}PL}$+$TotalCost_{DE\text{-}CZ}$) = 15.9*4.7/(4.7+0) = 15.9 kEUR
$BorderCost_{DE\text{-}CZ}$ = TotalCost * $TotalCost_{DE\text{-}CZ}$ / ($TotalCost_{DE\text{-}PL}$+$TotalCost_{DE\text{-}CZ}$) = 15.9*0/(4.7+0) = 0 kEUR

Mapping by IOBMb (individual optimization based mapping) method (while not increasing the other congestion):
$BorderCost_{DE\text{-}PL}$ = TotalCost * $TotalCost_{DE\text{-}PL}$ / ($TotalCost_{DE\text{-}PL}$+$TotalCost_{DE\text{-}CZ}$) = 15.9*15.1/(15.1+0) = 15.9 kEUR
$BorderCost_{DE\text{-}CZ}$ = TotalCost * $TotalCost_{DE\text{-}CZ}$ / ($TotalCost_{DE\text{-}PL}$+$TotalCost_{DE\text{-}CZ}$) = 15.9*0/(15.1+0) = 0 kEUR

Example 3 (none of individually optimized congestion requires RD)

$F_{DE\text{->}PL,\ before}$ = 2100 MW (i.e. 900 MW overload)
$F_{DE\text{->}CZ,\ before}$ = 1600 MW (i.e. 100 MW overload)

Optimal solution for relieving both overloads:
RA1 = -32 tap, RA2 = -11 tap, RA3 = 283 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 1475 MW, TotalCost = 9 kEUR

Optimal solution for relieving only DE-PL overload:
RA1 = -32 tap, RA2 = 22 tap, RA3 = 0 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1199 MW, $F_{DE\text{->}CZ,\ after}$ = 2519 MW, $TotalCost_{DE\text{-}PL}$ = 0 kEUR

Optimal solution for relieving only DE-PL overload (while not increasing DE-CZ overload):
RA1 = -32 tap, RA2 = -7 tap, RA3 = 246 MW, RA4= 7.4 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 1200 MW, $F_{DE\text{->}CZ,\ after}$ = 1600 MW, $TotalCost_{DE\text{-}PL}$ = 8 kEUR

Optimal solution for relieving only DE-CZ overload:
RA1 = 2 tap, RA2 = -3 tap, RA3 = 0 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 2162 MW, $F_{DE\text{->}CZ,\ after}$ = 1494 MW, $TotalCost_{DE\text{-}CZ}$ = 0 kEUR

Optimal solution for relieving only DE-CZ overload (while not increasing DE-PL overload):
RA1 = -1 tap, RA2 = -4 tap, RA3 = 0 MW, RA4= 0 MW, RA5 = 0 MW,
$F_{DE\text{->}PL,\ after}$ = 2089 MW, $F_{DE\text{->}CZ,\ after}$ = 1488 MW, $TotalCost_{DE\text{-}CZ}$ = 0 kEUR

Mapping by VBM (volume based mapping) method:
$r_{DE\text{-}PL} = (F_{DE\text{->}PL,\ before} - F_{DE\text{->}PL}, \text{limit}) / (F_{DE\text{->}PL,\ before} - F_{DE\text{->}PL,\ after}) = (2100\text{-}1200)/(2100\text{-}1200) = 1.0000$
$r_{DE\text{-}CZ} = (F_{DE\text{->}CZ,\ before} - F_{DE\text{->}CZ}, \text{limit}) / (F_{DE\text{->}CZ,\ before} - F_{DE\text{->}CZ,\ after}) = (1600\text{-}1500)/(1600\text{-}1475) = 0.8000$
$BorderCost_{DE\text{-}PL} = TotalCost * r_{DE\text{-}PL} / (r_{DE\text{-}PL} + r_{DE\text{-}CZ}) = 9*1.0000/(1+0.8) = 5$ kEUR
$BorderCost_{DE\text{-}CZ} = TotalCost * r_{DE\text{-}CZ} / (r_{DE\text{-}PL} + r_{DE\text{-}CZ}) = 9*1.0000/(1+0.8) = 4$ kEUR

Mapping by IOBMa (individual optimization based mapping) method:
Because all individual costs are equal to 0 then the TotalCost is divided equally:
$BorderCost_{DE\text{-}PL}$ = TotalCost / 2 = 9/2 = 4.5 kEUR
$BorderCost_{DE\text{-}CZ}$ = TotalCost / 2 = 9/2 = 4.5 kEUR

Mapping by IOBMb (individual optimization based mapping) method (while not increasing the other congestion):
$BorderCost_{DE\text{-}PL} = TotalCost * TotalCost_{DE\text{-}PL} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 9*8/(8+0) = 9$ kEUR
$BorderCost_{DE\text{-}CZ} = TotalCost * TotalCost_{DE\text{-}CZ} / (TotalCost_{DE\text{-}PL}+TotalCost_{DE\text{-}CZ}) = 9*0/(9+0) = 0$ kEUR

4.2.4 Option “improved Volume Based Mapping”

VBM mapping does not allow to take into consideration the impact of each individual RA on the congestions. Therefore counter intuitive results can happen. iVBM intends to solve these issues according to the following principles. Basically, iVBM allows to map each RA one by one, and therefore to avoid these effects.

iVBM: mapping RA individually

the global iVBM flowchart is the following:

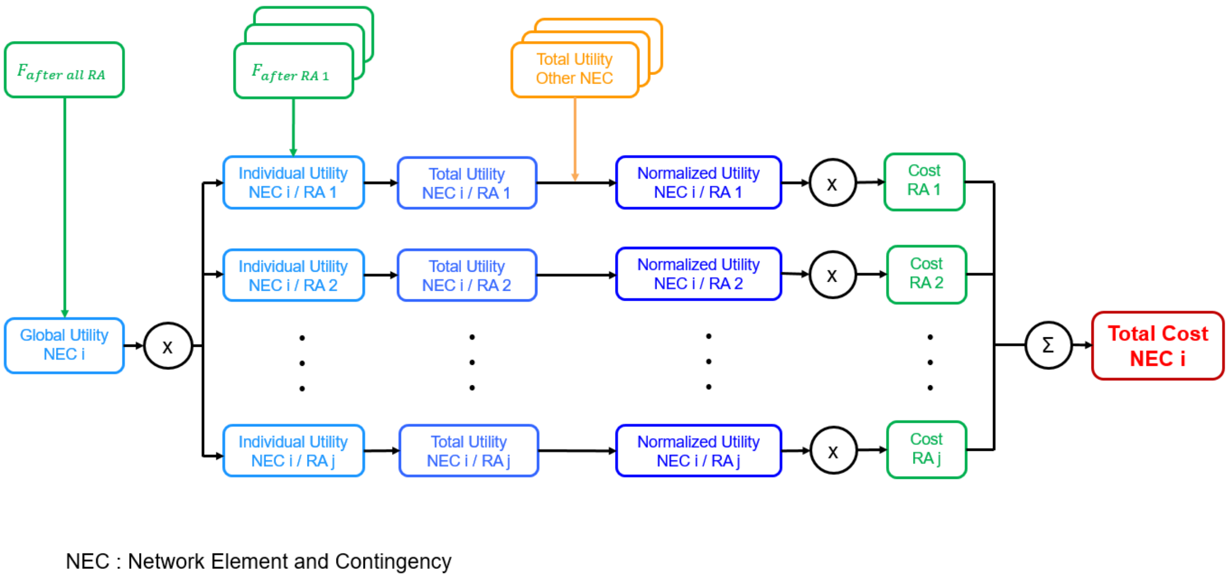


Figure 17: iVBM flowchart

The corresponding formulas are presented below.

Individual RA utility function

In order to quantify the utility of an individual RA on a congestion, it is needed to define a utility function that depends on the power flow before (F_{before}) and after ($F_{after\ RA}$) applying the individual RA.

$$individual\ utility_{NEC\ RA}(F_{before}, F_{after\ RA})$$

This utility function should model, in a consistent way, the individual utility of a RA on a congestion.

This function is defined as follows:

$$If\ F_{after\ RA} \leq F_{max}: individual\ utility = \frac{|F_{after\ RAj}| + |F_{before}| - F_{max}}{|F_{before}|}$$

$$If\ F_{max} \leq F_{after\ RA} \leq F_{before}: individual\ utility = \frac{|F_{before}| - |F_{after\ RA}|}{|F_{before}| - F_{max}}$$

$$If\ F_{after\ RA} \geq F_{before}: individual\ utility = \frac{|F_{before}| - |F_{after\ RA}|}{|F_{after\ RA}| - F_{max}}$$

Global utility

And additional utility to be computed is the global utility of RA set with a Volume Based approach:

$$global\,utility\ (NEC_i) = \frac{F_{before} - F_{max}}{F_{before} - F_{after\ all\ RA}}$$

Total utility coefficient

The total utility coefficient is then computed:

$$total\,utility(NEC_i, RA_j) = r(i,j)$$

$$r(i,j) = global\,utility(NEC_i) \times individual\,utility(NEC_i, RA_j)$$

Normalized coefficients

The coefficient of the total utility formula should be normalized to allow for the cost sharing, according to the following formulae:

$$normalized\ coefficient\big(NEC_i, RA_j\big) = c(i,j)$$

If a particular RAj individually worsens all the constraints, only negative utilities are mapped and the normalization formula should be in the following form:

$$If\ \forall NEC_i\quad r(i,j) \le 0, then\ \ c(i,j) = \frac{1 + r(i,j)}{\sum_i (1 + r(i,j))}$$

Otherwise:

$$If\ r(i,j) \le 0 : c(i,j) = \frac{r(i,j)}{\sum_i |r(i,j)|}$$

$$If\ r(i,j) > 0 : c(i,j) = \frac{r(i,j)}{\sum_{i\ if\ r(i,j)>0} r(i,j)} \times (1 + \frac{\sum_{i\ if\ r(i,j)<0} |r(i,j)|}{\sum_i |r(i,j)|})$$

Calculation of the costs mapped to each congestion

$$costs\ mapped\ to\ NEC_i = \sum_{RA_j} c(i,j) \times cost\big(RA_j\big)$$

4.2.5 Shadow-price mapping concept SBM

The starting point of this concept is an algorithm that determines binding constraint(s) (along with its/their shadow price) which need to be relieved. In the next step, the side conditions would be relaxed by increasing thermal limit only on this binding element(s) for x[11] MW and the initial optimisation would be

[11] x would need to be small enough to properly consider change of binding constraint but, at the same time, high enough that the calculation time is considered as realistic

repeated with the new parameters. Delta in the total cost calculated between two optimisation rounds is allocated to the current binding constraint(s). The iteration steps need to be repeated until there is no more costly remedial actions applied (= means that the remaining constraints could be solved by non-costly measures only). One of the main advantages of this concept is a possibility to properly consider both, non-costly and costly remedial action when allocation costs to the binding constraints.

4.2.6 Technical comparison of the both mapping options

Table 7: Table Technical comparison of mapping options

Feature	VBM	iVBM	IOBM	SBM
Usage of PTDF matrix	No	No	Yes	Yes
Usage of remedial optimisation function	No	Yes	Yes	Yes
Dependence of slack node	No	No	No	No
Possible consideration of non-costly remedial	No	Yes (Non costly RA can either be mapped individually (at zero costs) or can be included in the CGM before mapping costly RA)	Yes	Yes
Calculation	simple formula (e.g. Excel macro)	load flow calculation	load flow calculation / optimization	load flow calculation / optimization
Input data	load flow of each relevant element before and after redispatching	Output from the Remedial action optimisation performed in accordance with the methodology pursuant to article 76(1) SO guideline	Input parameters of the regional optimization performed in accordance with Article 76 SO guideline	Input parameters of the regional optimization performed in accordance with Article 76 SO guideline

4.3. Socialization principles

The following flows are considered as they might appear in the flow decomposition of a Core CCR network element and as they concern at least one non-Core bidding zone:

1. Loop flows caused by a non-Core bidding zone;
2. PST flows caused by a non-Core bidding zone;
3. Transit flows between two non-Core bidding zone;
4. Transit flows between a Core bidding zone and a non-Core bidding zone;
5. Import/Export flows between a Core bidding zone and a non-Core bidding zone.

4.3.1 Socialization

According to the proposed Core RD and CT Methodology, the sharing costs of RAs, used for solving congestions in Core region, are allocated to some of the decomposed flows on congested critical network elements. It may happen that the particular partial flow, to which some costs are assigned, is caused partly or fully by non-Core bidding zone(s). In such cases these costs should be partly or fully socialized among Core bidding zones.

Fully socialized costs should apply to transits, loop flows and PST flows which are exclusively caused by non-Core bidding zone(s).

Partially socialized costs should apply to import/exports and transits when the cause of such flow is due to exchanges between a non-Core bidding zone and a Core bidding zone. In such situation following potential options can be applied:

- Option 1: full cost is covered by the causing Core bidding zone, i.e. no socialization[12]
- Option 2: 50% of cost is covered by the causing Core bidding zone, 50% are socialized among all Core bidding zones <u>including</u> the causing Core bidding zone(s) that already covers 50%
- Option 3: 50% of cost is covered by the causing Core bidding zone, 50% are socialized among all Core bidding zones <u>excluding</u> the causing Core bidding zone(s) that already covers 50%
- Option 4: full cost is socialized among all Core bidding zones[13]

Any socialised costs from bidding zones outside the Core region will be reported to NRAs for monitoring purposes.

Once the total costs for socialization is determined, the following socialization principles can be applied:

Option 1: "Pro Rata"

This option comprises the proportional sharing of the socialization costs among Core bidding zones according to the directly assigned costs of used RAs for solving congestions on critical network elements.

Option 2: "Equal Share"

Each Core bidding zone covers the same amount of costs equal to total socialization cost divided by number of Core bidding zones.

Option 3: "Proportional to energy consumption"

Each Core bidding zone covers the socialization costs of non-Core bidding zones proportionally to its yearly energy consumption in the Core CCR.

Option 4: "Congestion Rent dependent"

This option comprises the proportional sharing of the socialization costs among Core bidding zones according to the received congestion rent.

[12] This should not prevent the causing Core bidding zone to have bilateral agreement with the non-Core bidding zone

[13] Recommendation in ENTSO-E paper Cost Sharing Principles for Remedial actions

4.3.2 No socialization (Owner-Pays)

The costs allocated to bidding zone(s) outside of the Core CCR are borne by the Core bidding zone owning the congested element unless there is an agreement with a non-Core bidding zone.

4.4. Netting and scaling of flows

Flow decomposition methods will identify both relieving and burdening flows. Before flows are being prioritised, there are several options to net burdening flows with relieving flows. According to the causation principle based on the prioritisation of flows, flows are netted per category[14]. There is however an issue using this principle in case there is no burdening flow type available to net against a relieving flow. In case netting per category would be used, it would mean that an additional method should always be available to handle the relieving flows which cannot be netted immediately. In total 6 different options have been identified and these are displayed in Table 8.

Table 8: Netting options

Number	Name	Type	Description
1	Proportional netting per category	Netting per category	Net the flows per category proportionally. Relieving flows are distributed proportional with burdening flows within each category, without distinction between bidding zones.
2	Equal netting per category	Netting per category	Net the flows per category equally. Relieving flows are distributed equally to burdening flows without distinction between bidding zones
3	Proportional netting	Netting proportional	Proportional netting without taking into account the categories
4	Proportional netting per category with credit	Netting per category and bidding zone	Netting of flows per category which reward bidding zones causing relieving flows
5	Vertical shift	Netting related to prioritisation	Relieving flows lower the flow on an element. Based on the prioritisation principle the remaining burdening flows above the Fmax are punished

4.4.1 Proportional netting per category

With proportional netting per category the different flow categories with burdening and relieving flows are proportionally netted. In this option there is no distinction made if a bidding zone is creating burdening and/or relieving flows. In the netting principle the prioritisations of the flow types are taken into account. Following steps are taken:

1. Net overload percentage is determined;
2. Share per flow category is calculated, starting with flow with highest priority. This will be done for every category causing the overload and will not exceed the total overload percentage. This will happen according to following equation:

[14] Cost Sharing Principles for Remedial Actions

$$\%\text{share}_{\text{flow } x} = \frac{\%\text{overload}_{\text{flow x}}}{\%\text{overload}}$$

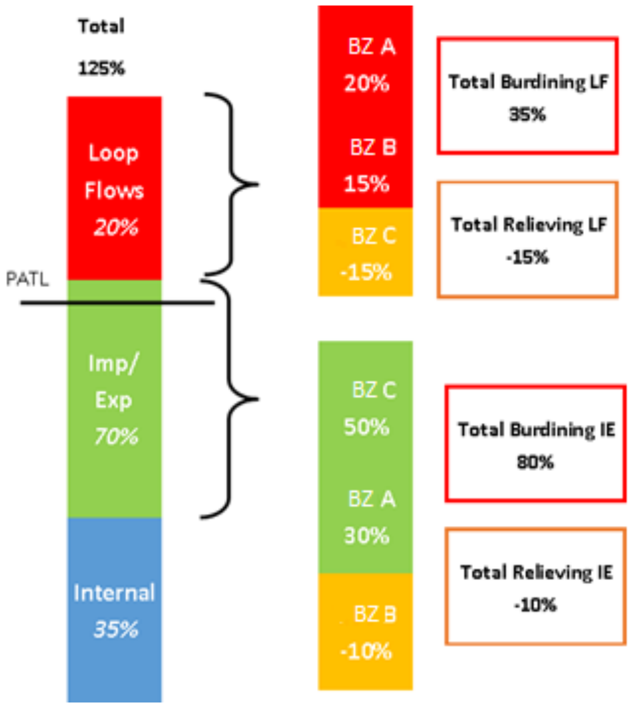
In case the share of the flow category exceeds the (remaining) overload, the $\%\text{overload}_{\text{flow x}}$ is set equal to the (remaining) overload;

3. Per overload category the share per bidding zone (hereafter referred to as "BZ") is calculated according to following equation:

$$\%\text{BZ} = \left(\frac{\text{BZ}_{\text{burdening flow x}}}{\text{Tot}_{\text{Burdening}_{flow\ x}}}\right) \times \%\text{share}_{\text{flow x}}$$

4. The total share of costs is calculated per bidding zone by summing up the calculated bidding zone shares from previous step 3.

In Figure 18 is an example of the proportional netting principle presented.



Loop Flows and Imp/Exp Flows Penalized

Share for Loop Flows: 20%/25%= 80%

- BZ A: (20%/35%)*80%=46%
- BZ B: (15%/35%)*80%=34%

Share for Import/Export: 5%/25%= 20%

- BZ A: (30%/80%)*20%=7.5%
- BZ C: (50%/80%)*20%=12.5%

Total:

- BZ A: 53.5%
- BZ B: 34%
- BZ C: 12.5%

Figure 18: Proportional netting per category

4.4.2 Equal netting per category

With equal netting per category the different flow categories with burdening and relieving flows are equally netted. In this option there is similar as in the proportional netting principle no distinction made if a TSO is creating burdening and/or relieving flows. All bidding zones creating burdening flows get an equal share from the relieving flow. In the netting principle the prioritisations of the flow types are taken into account. Following steps are taken:

1. Net overload percentage is determined;
2. Share per flow category is calculated, starting with flow with highest priority. This will be done for every category causing the overload and will not exceed the total overload percentage. This will happen according to following equation:

$$\%\mathrm{share}_{\mathrm{flow}\ x} = \frac{\%\mathrm{overload}_{\mathrm{flow\ x}}}{\%\mathrm{overload}}$$

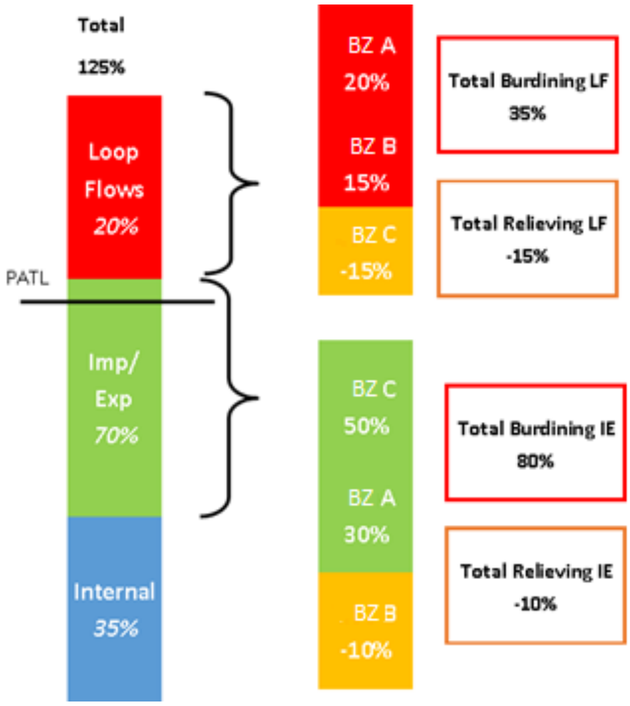
In case the share of the flow category exceeds the (remaining) overload, the $\%\mathrm{overload}_{\mathrm{flow\ x}}$ is set equal to the (remaining) overload;

3. Per overload category the share per bidding zone is calculated according to following equation:

$$\%\mathrm{BZ} = \left(\frac{\left(\mathrm{BZ}_{\mathrm{burdening\ flow\ x}} - \frac{\mathrm{Tot}_{Relieving_{flow\ x}}}{\mathrm{Involved\ BZs}}\right)}{\mathrm{Net}_{\mathrm{Burdening}_{flow\ x}}}\right) \times \%\mathrm{share}_{\mathrm{flow\ x}}$$

4. The total share of costs is calculated per bidding zone by summing up the calculated bidding zone shares from previous step 3.

In Figure 19is an example of the equal netting principle presented.



Loop Flows and Imp/Exp Flows Penalized

Share for Loop Flows: 20%/25%= 80%

- BZ A: ((20%-15%/2)/20%)*80%=50%
- BZ B: ((15%-15%/2)/20%)*80%=30%

Share for Import Export: 5%/25%= 20%

- BZ A: ((30%-10%/2)/70%)*20%=7.1%
- BZ C: ((50%-10%/2)/70%)*20%=12.9%

Total:

- BZ A: 57.1%
- BZ B: 30%
- BZ C: 12.9%

Figure 19: Equal netting per category

4.4.3 Proportional netting

With proportional netting the sum of the relieving flows is proportional netted with the different categories of burdening flows. According to this principle all burdening flows types get relieved by the relieving flows, without taking into consideration the categories and creators of the relieving flows. Following steps are taken:

1. Net overload percentage is determined;
2. The flow after netting per burdening category is calculated via following equation:

$$\text{Flow after netting } = \text{Gross Flow } - \frac{Gross\ Flow}{Total\ \ Burdening\ Flows} \times Total\ Relieving\ Flows$$

   The same formula can be used to calculate the flow share for an individual bidding zone after netting;

3. Share per flow category is calculated, starting with flow with highest priority. This will be done for every category causing the overload and will not exceed the total overload percentage. This will happen according to following equation:

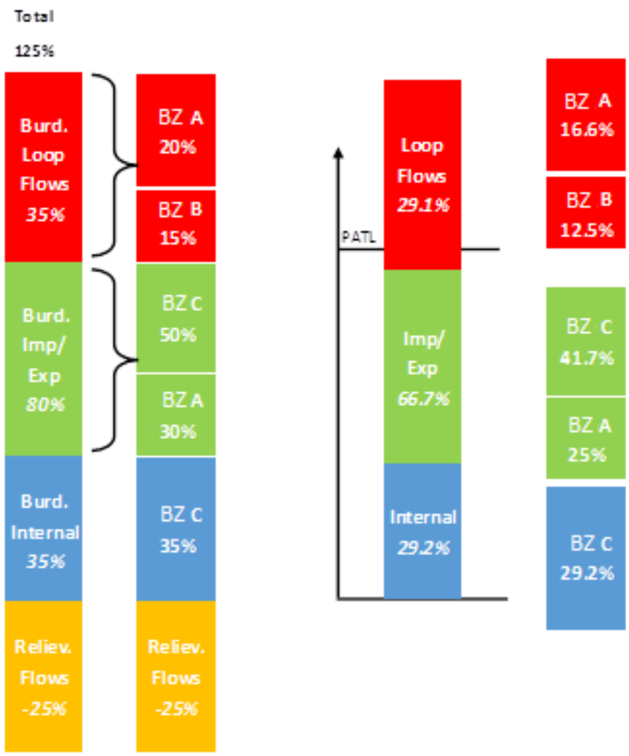
$$\%\text{share}_{\text{flow } x} = \frac{\%\text{overload}_{\text{flow x}}}{\%\text{overload}}$$

   In case the share of the flow category exceeds the (remaining) overload, the $\%\text{overload}_{\text{flow x}}$ is set equal to the (remaining) overload;

4. Per overload category the share per bidding zone is calculated according to following equation:

$$\%\text{BZ} = (\frac{\text{BZ}_{\text{burdening flow x}}}{\text{Tot}_{\text{Burdening}_{flow\ x}}}) \times \%\text{share}_{\text{flow x}}$$

The total share of costs is calculated per bidding zone (when applicable) by summing up the calculated bidding zone shares from previous step 4.



Loop flow BZ A after netting:
20% - (20%/150%) * 25% = 16.6%
Loop flow BZ B after netting:
15% - (15%/150%) * 25% = 12.5%

Total loop flow share after netting
35% - (35%/150%) * 25% = 29.17%

Loop Flows Penalized
Share for Loop Flows: As the total loop flow share (29.1%) is > overload (25%), the loop flow share is 100% (25%/25%=100%)

- BZ A: (16.6%/29.1%) * 100% =57%
- BZ B: (12.5%/29.1%) * 100% =43%

Total:

- BZ A: 57%
- BZ B: 43%

Figure 20: Proportional netting principle

4.4.4 Proportional netting per category and bidding zone with credit

With proportional netting per category the causers of relieving flows get a 'credit', which is used to lower the share of burdening flows. The credit which is built up for one category, can be used for lowering the share of burdening flow in a different category. This cross-subsidising principle is a combination of netting per category and netting per bidding zone. Following steps are taken:

1. Net overload percentage is determined;
2. Share per flow category is calculated, starting with flow with highest priority. This will be done for every category causing the overload and will not exceed the total overload percentage. This will happen according to following equation:

$$\%\text{share}_{\text{flow}\ x} = \frac{\%\text{overload}_{\text{flow x}}}{\%\text{overload}}$$

In case the share of the flow category exceeds the (remaining) overload, the $\%\text{overload}_{\text{flow x}}$ is set equal to the (remaining) overload;

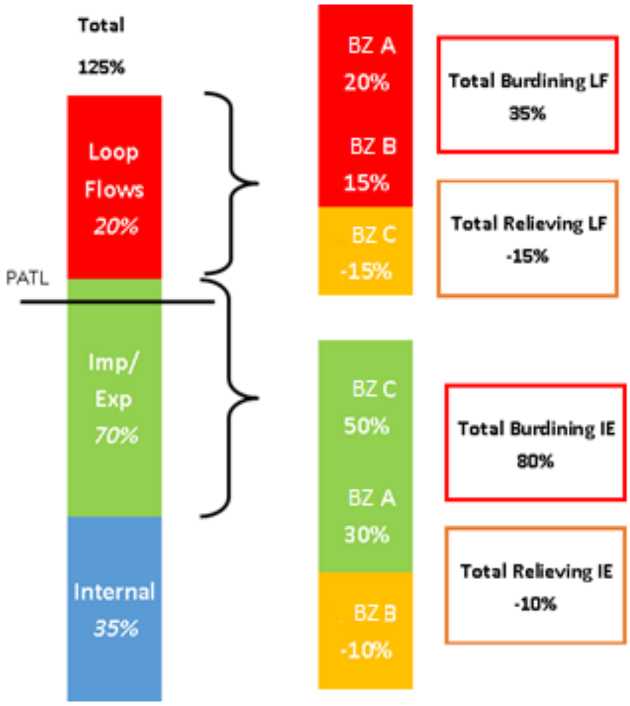
3. Per overload category the share per bidding zone is calculated according to following equation:

$$\%\text{BZ} = \frac{\text{BZ}_{\text{burdening flow x}}}{\text{Tot}_{\text{Burdening}_{flow\ x}}} \times \%\text{share}_{\text{flow x}}$$

4. The total share of costs is calculated per bidding zone by summing up the calculated bidding zone shares from previous step 3. This presents the subtotal of the netting on category per bidding zone;

5. As last step the credit of a bidding zone is used and a recalculating of the bidding zone shares is made. The sum of the negative bidding zone shares will be proportional divided between the bidding zones with a positive share, according to following formula:

$$\%BZ_{\text{Total}} = \%BZA + \frac{\%BZA}{\%BZA + \%BZB + \cdots} \times (\%BZC + \%BZD \ldots.)$$



Loop Flows and Imp/Exp Flows Penalised

Share for Loop Flows: $\frac{20\%}{25\%} = 80\%$

- BZ A: $S_{\text{LF A}} = \frac{20\%}{20\%} \cdot 80\% = 80\%$
- BZ B: $S_{\text{LF B}} = \frac{15\%}{20\%} \cdot 80\% = 60\%$
- BZ C: $S_{\text{LF C}} = \frac{-15\%}{20\%} \cdot 80\% = -60\%$

Share for Import Export: $S_{\text{IE}} = \frac{5\%}{25\%} = 20\%$

- BZ A: $S_{\text{IE A}} = \frac{30\%}{70\%} \cdot 20\% = 8{,}57\%$
- BZ B: $S_{\text{IE B}} = \frac{-10\%}{70\%} \cdot 20\% = -2.857\%$
- BZ C: $S_{\text{IE C}} = \frac{50\%}{70\%} \cdot 20\% = 14.286\%$

Subtotal:

- BZ A: $S_{\text{A}} = 80\% + 8.57\% = \mathbf{88.57\%}$
- BZ B: $S_{B} = 60\% + (-2.857\%) = \mathbf{57.143\%}$
- BZ C: $S_{\text{C}} = -60\% + 14.286\% = \mathbf{-45.714\%}$

Figure 21: Proportional netting per category and bidding zone with credit

The credit (negative share) which is built up by bidding zone C will be divided proportionally between the other bidding zones to calculate the final total share per bidding zone.

- $\%BZA_{\text{Total}} = 88.57\% + \frac{88.57\%}{88.57\% + 57.143\%} \cdot (-45.714\%) = \mathbf{60.78\%}$
- $\%BZB_{\text{Total}} = 57.143\% + \frac{57.143\%}{88.57\% + 57.143\%} \cdot (-45.714\%) = \mathbf{39.22\%}$
- $S_{\text{C Total}} = \mathbf{0\%}$

4.4.5 Vertical shift

With Vertical shift there is no netting applied between the categories of relieving and burdening flows. For the burdening flows the flow types are split up into defined categories and prioritised. The relieving flows lower the total flow. The same calculation steps are taken as in the described principle for Proportional netting per category. However the burdening flows are not lowered per category. Following steps are taken:

1. Net overload percentage is determined;
2. Share per flow category is calculated, starting with flow with highest priority. This will be done for every category causing the overload and will not exceed the total overload percentage. This will happen according to following equation:

$$\%\text{share}_{\text{flow } x} = \frac{\%\text{overload}_{\text{flow x}}}{\%\text{overload}}$$

In case the share of the flow category exceeds the (remaining) overload, the $\%\text{overload}_{\text{flow x}}$ is set equal to the (remaining) overload;

3. Per overload category the share per bidding zone is calculated according to following equation:

$$\%\mathrm{BZ} = \left(\frac{\mathrm{BZ}_{\mathrm{burdening\ flow\ x}}}{\mathrm{Tot}_{\mathrm{Burdening}_{flow\ x}}}\right) \times \%\mathrm{share}_{\mathrm{flow\ x}}$$

4. The total share of costs is calculated per bidding zone by summing up the calculated bidding zone shares from previous step 3.

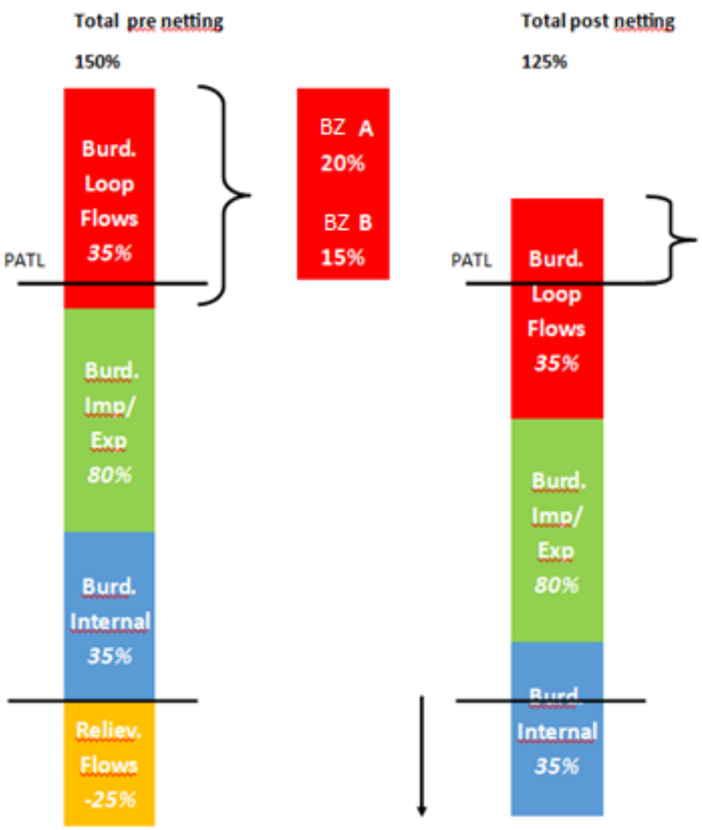


Figure 22: Vertical shift

Loop Flows Penalized

Share for Loop Flows: as the loop flows exceed the overload percentage, the loop flow share is 100%

- BZ A: (20%/35%)*100%=57%
- BZ B: (15%/35%)*100%=44%

Total:

- BZ A: 57%
- BZ B: 43%

4.5. Complete prioritization and threshold

Flow decomposition methods will identify the types of flows on each network element that is considered for cost sharing. The question is how to allocate the costs related to a costly RA to the TSOs that contribute to the overload via the different flows (and their different treatment). There are several possibilities, but those will be reduced by the following statements:

1. Polluter-pays principle should be applied;
2. Burdening Loop flows should be prioritized, optionally with a threshold.

The polluter-pays principle leads first of all to the identification of the polluters. The answer is partially given by the second statement but not entirely.

In a zonal approach like the one used for the Day-ahead capacity calculation, the Market Flows (Import, Export and Transit) are flows that compete for the cross-border capacity on a level playing field. They are scheduled and are not considered as polluters.

4.5.1 Treatment of loop flow

Loop flows are unscheduled flows and make use of cross-border capacity (indirectly) prior to the Market Flows. For the prioritisation of the different flows identified by the flow decomposition methodology, burdening loop flows are seen as the most critical flows. In accordance with the ACER recommendation and to avoid free-riding of neighbouring countries, those flows should be penalised in the first place in case a XBRNE is overloaded[15]. Therefore loop flows are considered as polluters. They are also, individually, associated with only one bidding zone.

The electricity network of the Core CCR is highly meshed and in combination with the zonal design of the EU Internal Energy Market a certain level of loop flows is therefore inevitable, even with the most ambitious grid investments. Indeed, such a goal could lead to the target which could be opposite to the goals of internal electricity market (lower investments in cross-border lines). Due to these reasons a threshold for the loop flows could be considered. The consequence of applying a threshold is that a part of the loop flows gets accepted and gets less highly prioritised as the remaining bigger share. This option leads to the following questions:

On what parameter does the threshold apply?

(For the sake of clarity, please find an example in order to grasp the difference between the two possible options or parameters.)

15. On each loop flow contributor proportionally:

The proportionality allows the BZs to have a specific proportional share of a reference value, e.g. 10% of Fmax, according to the amount of loop flows they create. Thus, the larger the loop flow produced by the BZ the higher the absolute amount they have below the threshold. The rationale of a proportional approach is to reflect the different structure of bidding zones in Europe.

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Example

To illustrate this example, the following assumptions will be taken:

- Relative value of Fmax of 10%
- Fmax: 2GW
- Loop flow:800MW

These LFs are created by 5 BZs with the respective amount below.

- BZ A: 400MW
- BZ B: 300MW
- BZ C: 70MW
- BZ D: 20MW
- BZ E: 10MW

Therefore, the loop flow threshold is 200MW.

Loop flow credit is an amount of MW which will be deprioritized and considered as loop flow below threshold.

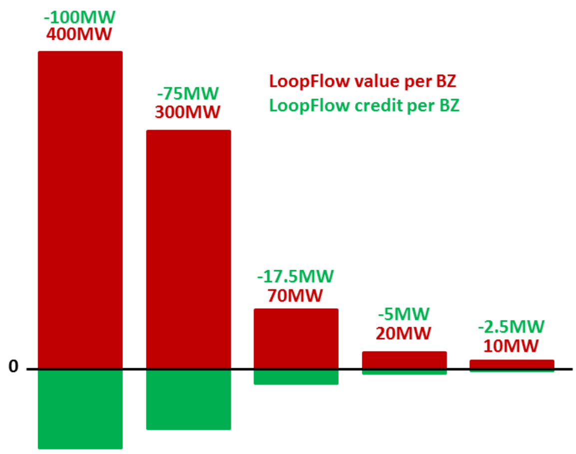

Figure 23: Proportional threshold application

16. On each loop flow contributor equally (with credit):

The equality allows the BZs to have an equal value of the loop flows which will be below the threshold. This approach ensures that small LF contributors are not penalized if they do not reach the allowable loop flows. The remaining amount of allowable loop flow unused by each BZ is shared equally with the BZs still having loop flow above threshold. The rationale for an equality approach is to give all contributors identical access to a threshold and to reduce risk of penalizing small loop flow contributors.

Example (continued based on the setting of the previous example)

Step 1: Equal sharing

As a first step, the amount of capacity reserved for the loop flow below threshold called loop flow credit is divided among all the BZs equally.

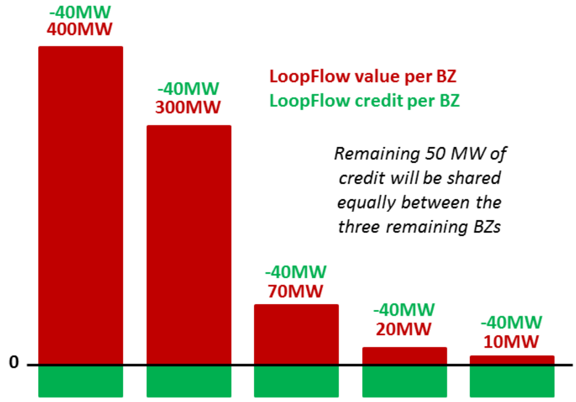

Figure 24: Equal threshold application

Step 2: Sharing of the unused allowable loop flow
As a second step, the credits not used by the BZs producing low amount of loop flows will be shared equally among the BZs which still have loop flows not covered by their credits.

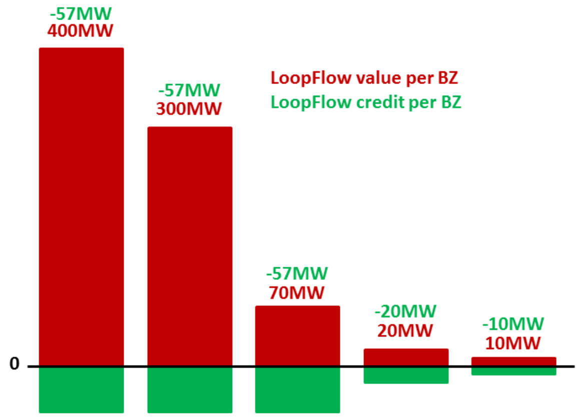

Figure 25: Sharing of the unused allowable loop flow

a. On each loop flow contributor equally (without credit):

An alternative to option b (i.e. equal with credit) is to split loop flow threshold equally among all BZs but without possibility to re-allocate the amount of unused loop flow threshold further among the rest of BZs still having loop flows above the threshold. With this option the risk of penalizing BZs with loop flows below the allowed threshold due to re-allocation of credits (i.e. unused loop flow threshold) to other TSOs is avoided. This approach ensures equal treatment of all BZs, especially when allocating LF thresholds and provides sufficient incentive for keeping loop flows closer to the allowed threshold. The intention of separating loop flows above and below threshold is to penalize those above the threshold with higher priority than those below.

Example (continued based on the previous example)
In this option c the amount of allowed loop flow threshold is divided equally among all the BZs and only loop flows below the threshold are considered as allowed. The remaining loop flow threshold (in this case 50 MW unused by the last two BZs) is not shared further among the rest of BZs still having loop flows above threshold.

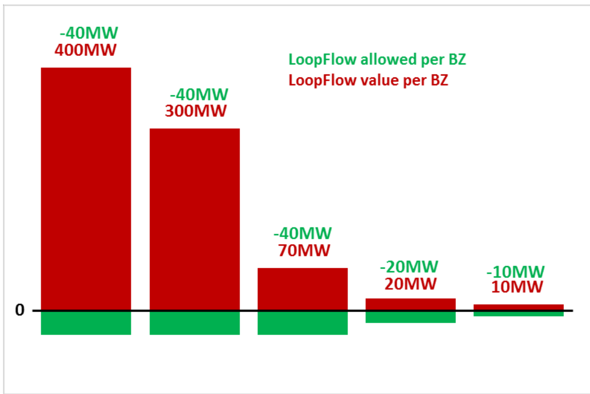

Figure 26: Equal threshold application (without credit)

Table 9: Comparison of loop flows above or below threshold in the example

		BZ A	BZ B	BZ C	BZ D	BZ E
Loop flow above threshold (Highly prioritized)	Proportional	300	225	52.5	15	7.5
	Equal (with credit)	343	243	13	0	0
	Equal (without credit)	360	260	30	0	0
Loop flow below threshold (Less prioritized)	Proportional	100	75	17.5	5	2.5
	Equal (with credit)	57	57	57	20	10
	Equal (without credit)	40	40	40	20	10

Is the threshold an absolute or a relative value?

The threshold can be defined as an absolute value, e.g. x MW, or a relative value of a specified reference, e.g. x % of Fmax. In case of a relative value, the reference needs to be defined to receive a line-specific value of the threshold. If an absolute value, the threshold can be defined uniformly for all lines independently of their technical characteristics or needs to define individually for each line.

If the threshold is a relative value, what would be the reference?

17. Fmax of the congested line
18. Sum of LF over the congested line
19. Total physical flow over the congested line
20. Fmax of the congested line under consideration of FRM

Would it be the same threshold for all types of lines (internal vs. cross-border)?

Whereas lines internal to a BZ can face all flow types, cross-border lines can only carry import/export flows, transit flows and loop flows. Therefore, a threshold can have different implications on internal or cross-border lines. Consequently, the options of a uniform threshold, i.e. independent of the type of line, or differentiated thresholds for internal and cross-border lines are of relevance.

What would be the value of the threshold?

Depending on the defined characteristics of the threshold definition, a non-negative value of the threshold needs to be specified.

4.5.2 Treatment of internal flows

No Threshold

All the internal flows are considered as one and there is no differentiation within them.

Application of a threshold

The Internal Flows are per definition not using capacity on cross-border lines but have an access to internal capacity prior to the market flows (and together with the loop flows). This internal capacity is translated via the CNEC and contributes to the FB calculation and has therefore an impact on the flow-based domain. It has been proposed to apply the minRAM20 concept to internal lines (and cross-border lines) in order to make at least 20% of Fmax available for market flows (RAM at least equal to 20% of Fmax). Nevertheless for cost sharing, it has to be clarified what that means in terms of constraint on the internal flows. A minimum RAM of 20% of Fmax means that a minimum of 20% of Fmax is available for Core market flows.

4.5.3 Prioritization

The final prioritisation principles depend on the decisions made on other topics. The aspects of prioritization which are taken into consideration are as following and not final:

- Loop flows above potential threshold are to be penalized first
- Coordinated market flows are to be penalized with low priority
- Penalization of the other flows (listed in the flow decomposition) is still to be determined

Only flow types above the technical limit are penalized. This goes along with a strict ordering of the flow types, which includes the reasoning that there are "good" and "bad" flow types. The following sketch illustrates the idea:

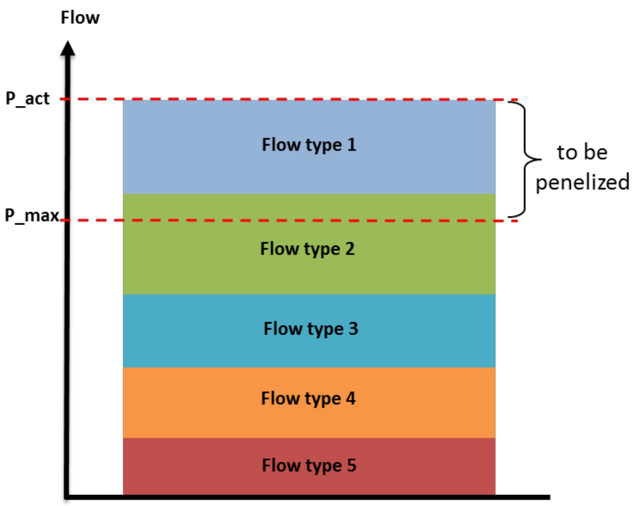

Figure 27: prioritization principle

The concrete ordering of the flows types should be based on a proper and agreed reasoning. This is a complex task and under discussion at the moment.

4.6. Cost allocation principles

In order to allocate the costs to BZs, different options are possible:

- Loop flows above the threshold should be associated to the BZ that create the loop flows
- PST flows should be associated to the owner of the PST or to the owner of the line
- Internal flows (whatever there is a threshold or not) should be associated to the BZ owning the congested element. For internal flows, the owner of the congested element is also the causer of the flow

- Loop flows below the threshold should be associated to the BZ that creates the loop flow or the BZ owning the congested element
- Market flows (Import/Export/Transit) should be either associated to the BZ(s) owning the congested element as this one made the XB capacity available to the market or to the sources and sinks (by applying 50/50 split).

4.7. Contingencies on the same XBRNEs

Most of congestions are detected in N-1, rarely in the base case (N) situation. In case multiple contingencies create an overload on the same XBRNE it has to be agreed which situation is taken for the power flow decomposition on that particular XBRNE. The following options are identified:

1. Use N-1 grid model:
    a. Highest overload before applying the RA
    b. Highest overload after applying the RA;
2. Average flows from all contingencies;
3. Use N situation for flow decomposition;
4. All overloads in N and N-1 situations.

Option (1a) and (1b) propose to use the N-1 grid model situation with the highest overload either before (1a) or after (1b) applying remedial action. Although in both options all contingencies are simulated and only the highest overload is considered this significantly ease and simplify the calculation process. Option (1a) takes contingency situation where the highest initial overload is occurred without considering the amount of redispatched energy needed to relieve congestion of all other contingencies, while option (1b) consider exactly this but neglecting situation with the highest initial overload. In most cases both options will identify flow from the same contingency because the amount of redispatched energy is usually determined with the highest initial overload. Majority of TSOs think that flow decomposition on XBRNE can be sufficiently represented only with one contingency. For the rough study more TSOs give support to option (1b) than (1a).

Option (2) propose to use an average flows from all contingencies from N-1 situations. The calculation is done in a way that firstly flows per bidding zone are identified for each contingency and secondly the flows used for cost-sharing are calculated as the weighted average per overload volumes. This option is more complex while it requires an ex-post processing of every contingency and without proper tool this calculation process can last more time while it depends on number of identified contingencies which cannot be eliminated during calculation. Mainly due to these two drawbacks no one voted for this option for the rough study.

Option (3) proposes to take for the power flow decomposition on XBRNE only the flow from N state. This option clearly simplifies the process in a way that selection of contingencies is not needed but on other side requires an additional clarification on how these flows are penalized, especially in cases when overload is identified only in N-1 situation. In such case the flow in N state will be lower than 100% (i.e. no overload) and consequently prioritization of flows will not be possible to perform. Due to lack of support on side of TSOs this option also will not be analysed for the rough study.

Option (4) proposes to treat all overloads detected in N and N-1 situations equally. The calculation is done in a way that for each overload situation the flow decomposition, prioritization and cost allocation for each bidding zone is performed. This option is even more complex and time-consuming than any other option while it requires to perform for every contingency also prioritization of flows and assignment of costs per bidding zone. Due to lack of support on side of TSOs this option also will not be analysed for the rough study.

TSOs will try to converge between option 1a and 1b while all other options require much more effort and time to perform all those calculations. It is assumed that performing much more calculations do not necessarily bring much different results than with simplified solutions. Automatized tool for any of these options could speed up calculation process but cannot be expected to be available for the rough study. During experimentation phase TSOs will try to analyse if volatility of decomposed flows on XBRNE is significantly changing between these options and if one contingency could replace all other contingencies.

4.8. PST flows treatment

Flows within a region can be changed by using active elements such as phase shifting transformers (PSTs). By tapping a PST, a circular flow is generated which starts and ends at that particular PST[16]. The flows created by a PST depend on the voltage level and tap settings and superimposes the existing flows caused by generation and load in the grid. While in general the majority of the PST flows are relieving congestion as intended, burdening PST flows can remain. Some PSTs are also used not only to reduce loop flows, but are used to maximise capacity in the most-likely market direction, i.e. to increase export/import possibilities on the zonal level.

When using flow decomposition, both methodologies, FLD and PFC, can identify the PST flows. As a result five different categories of flows can be directly identified:

- Internal flows,
- Loop flows,
- Import/Export flow,
- Transit flows, and
- PST flows.

The flows of all five categories, resulting from the flow decomposition calculation, sum up to the total flow on a line. PST flows are not easy to be treated regarding cost sharing. In contrast to all other flows, not only they are influenced by the market but also by the tap position. Therefore they could also be regarded as a topological measure just like any other switching operation in the grid. Since topological measures are currently sovereign decisions by the grid-owning TSO, this could also be applied to PST taps. By ignoring PST flows, the overload of a line in an N or N-1 situation cannot be fully explained.

Just like market flows can stem from coordinated or uncoordinated capacity calculation, PST flows can result from coordinated or uncoordinated decisions. Currently PSTs are mainly used to protect the grid of the PST owner from unscheduled flows, esp. loop flows, and to avoid redispatching costs caused by these loop flows. In a coordinated remedial action optimization the optimizer will instead try to maximize welfare. This means the optimizer will redirect any overloads to areas where inexpensive remedial actions can be disposed. In such a case, neither the owner of the PST nor the owner of the residual overloaded element can be held accountable for the costs. Unfortunately the detection of the original causer is mathematically challenging. There might also be cases, where a large part of the congestion is solved by the PST. Not considering PST flows in this case could lead to a bias in cost allocation. It needs to be taken into

[16] Circular flows differ from loop flows as loop flow have different start and end points within one bidding zone.

consideration that PSTs are also used to solve internal congestions within a bidding zone and that they are used to maximise transmission capacity in the most-likely direction of the market.

The PST flows are considered on a similar level than the Market Flows in the prioritization.

4.9. Cost sharing for deviation from RSC advice

4.9.1 The coordination process

The Core RD and CT Methodology focuses, among other things, at cooperation of the TSOs within Core CCR with RSCs. According to SO guideline, coordination of the remedial actions such as redispatching and countertrading is needed. The activation of these costly remedial actions can be applied only as described in the Core RD and CT Methodology. Both measures are applied exclusively with an aim to ensure firmness of already allocated cross-zonal capacities during D-1 and ID timeframe in the Core CCR.

As mentioned, coordination is done during different timeframes. Preparing of redispatching and countertrading actions starts at D-1, i.e. the day before the day of delivery. At first, TSOs shall individually assess possible redispatching and countertrading actions and supply a list of these actions, including their provisional costs, to the RSC. The RSC needs such a list, amongst other data such as common grid models, the contingency list and the operational security limits, in order to carry out a coordinated regional operational security assessment. The RSC then delivers the results of the coordinated regional operational security assessment to the Core TSOs. In case of detected constraint RSC will recommend to the relevant TSOs the most effective and economically efficient redispatching and countertrading actions. This recommendation is the result of coordination within Core CCR.

Any recommendation received from the RSC for a particular redispatching or countertrading action shall be evaluated by the TSO with regard to the elements involved in that action and located in its control area. The decision-making right on the implementation of a redispatching or countertrading action remains with the TSOs but there is a duty to inform and explain its decision to the RSC in case the recommendation by the RSC for a particular action is not accepted. The accepted recommended actions shall be included by the TSOs in the upcoming individual grid models (hereafter referred to as “IGM”).

The process described leads to a considerable degree of coordination of redispatching and countertrading actions, as assessment for needed actions on a regional level will be performed by a third party, the RSC. Thus, this neutral entity will ensure more efficient dispatching of relevant resources on a regional level in comparison to the current situation where congestion is relieved bilaterally by involved TSOs.

Closer to real time there will be less possibilities for regional coordination via the RSC. In order to ensure coordination of unforeseen events causing physical congestions happening after the last relevant coordinated operational security analysis and until real time, the TSOs shall coordinate bilaterally with neighbouring TSO(s) in order to plan and carry out redispatching and countertrading. These TSOs will inform directly impacted TSOs in Core CCR as well as the Core CCR-appointed RSC. Lastly, TSOs will take into account the bilaterally agreed countertrading and redispatching actions in the next relevant IGMs.

4.9.2 Proposed cost sharing principles in relation to the RSC advice

Considering above described coordination process, in general all the TSOs within the Core CCR commit themselves to coordinate between each other when planning and activating remedial actions in an enduring coordination process which goes from capacity calculation, through operational planning, till real time. It is therefore taken as a basic assumption that TSOs shall act by respecting what was agreed in the previous phases of this coordination process and by following the coordination principles. Thus, each TSO breaching the above-mentioned coordination process shall bear responsibility for covering the possible additional costs which may arise.

Even close to real-time, cross-border relevant remedial action shall be coordinated (Article 74 (1) SO guideline). Each TSO shall abstain from unilateral or uncoordinated redispatching and countertrading measures of cross-border relevance (Article 35 (4) CACM guideline). The coordination for bilateral/multilateral restoring remedial actions is made between two or more affected TSOs in real time, with possible support of RSCs.

Following principles can be applied depending on TSO approach to RSC advice:

A: Cost sharing principle in case of coordinated actions according to RSC advice

In case of coordinated measures, the costs related to remedial actions will be shared according to cost sharing arrangements defined in Cost Sharing Methodology.

B: Cost sharing principle in case of uncoordinated actions deviating from RSC advice

If TSO decides unilaterally to execute costly remedial actions, deviating from the recommendation of RSCs defined in accordance with the methodology of Article 76 of SO guideline, one option is that the TSO shall bear just the additional costs of the uncoordinated remedial action, over costs estimated according to RSC advice, otherwise, if there is no additional costs, the remedial action offer will be subject of cost sharing arrangements defined in Cost Sharing Methodology.

4.10. Interdependence of cost sharing with coordinated security analysis performed in different timeframes

Because the activation of RAs (for a given operational hour) takes place in different timeframes, it is important to determine how and based on which model the calculation and sharing of those RAs costs are performed in each timeframe.

For example, as presented in the picture below three coordinated security analyses (hereafter referred to as “CSA”) will be performed (i.e. in DACF, IDCF1, and IDCF2 timeframes).

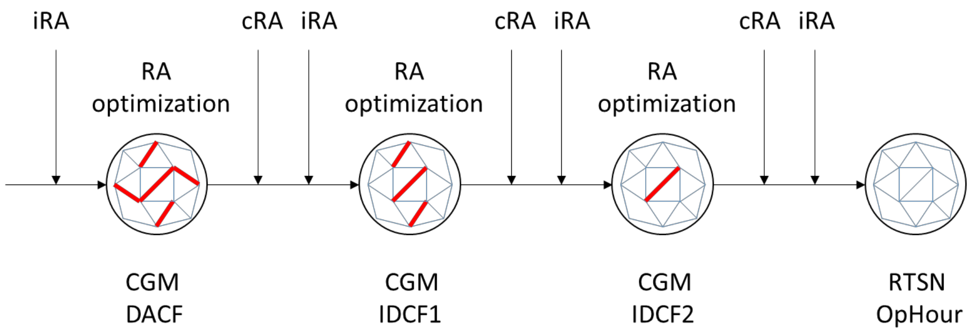

Figure 28: Timeframes

To receive N-1 secure grid (no congestions in n and N-1 states) in real time (RT) many coordinated RAs (cRA) and individual non-coordinated RAs (iRA) are applied throughout the whole process.

Different approaches for cost sharing among different timeframes are possible. They will mainly depend on the chosen RAs coordination process, which will finally be defined in the methodology required by Article 76 of the SO guideline (e.g. will all RAs that make common grid model (hereafter referred to as “CGM”) congestion free be applied in each timeframes or a part of them which have too long lead time to be considered in optimization during the next timeframe CSA or only a part of them that clears congestion but only to certain level?). Also the proper choice has to be taken on which models the cost sharing calculations will be performed (e.g. on each timeframe model based on which the decision about applied RAs within this timeframe is taken or on only one model (for example real-time snapshot (RTSN) or last IDCF after removal of all applied cRAs), on congested CGM before optimization or on CGM after optimization with removal of only costly cRAs?). The above mentioned issues require further investigation.

5. COMMITMENTS OF THE CORE TSOS RELATED TO THE IMPLEMENTATION OF THE METHODOLOGY

In article 14 of the submitted methodology, Core TSOs commit themselves to submit an amended version of this methodology, no later than 12 months after its approval or after an agreement is reached on the details of the cost sharing application (whichever happens earlier).

The decisions on the different parameters is to be supported by an experimentation phase, for which Core TSOs are already actively working.

This experimentation cannot support all possible scenarios. Indeed, the multiplicity of the above described options is likely to lead to a number of different scenarios so high that they could not reasonably be computed.

Core TSOs intend to investigate the different possibilities that can be used to apply the polluter pays principle via the experimentation. This experimentation will explore several ways of applying the methodology, by varying its parameters. These scenarios are the following[17]:

Table 10: scenarios for the experimentation

OPTIONS	GREEN	YELLOW	BLUE
Netting	Equal per category with credit	Equal per category with credit	proportional per category
Internal Flow threshold	Not applicable (no threshold for internal flows)	Common threshold of 20%	Y = 30%
Loop Flow threshold (5-10% already agreed in PT)	X = 10%		X = 0%
Cost allocation Market Flows	Owner of the line	Owner of the line	50:50 source-sink
Cost allocation for LF<x%	Owner of the line	Owner of the line	Causer pays
Order-stack	LF>x% (polluter) Internal flow (owner) LF<x% (owner) Market + PST (owner of the line)	LFs>th (polluter) and IFs (owner) LFs<th (owner) MFs and PST	LF> x% (polluter) IF> y% (owner) Market + PST (same level, polluter) LF < x% (polluter) IF < y% (owner)
Application LF threshold	Equal with credit	Equal with credit	Proportional split / Equal with credit (no NRs Agreement: 2 views)
Non-Core TSO costs	Owner of the line (no socialization)	Owner of the line	Equal share
XB relevance definition	CNECs considered in CCM (with at least 10% PTDF threshold)	Tie line + directly connected line	CNECs considered in CCM with PTDF >= 5%

Core TSOs are convinced that these scenarios, even if they do not allow to fully assess all the parameters presented in this document, will greatly help to further understand their impact on the cost distribution.

Ongoing discussions between Core NRAs and Core TSOs might result in refinements of the scenarios.

[17] Different options for the definition of Cross border relevance will be included in the scenario choices, to allow Core TSOs and Core NRA to gain broader insight on the application of different PTDF-thresholds. For further details on the cross-border relevance, please refer to the methodology according to Art 35 CACM guideline and the corresponding explanatory document.