European Network of
Transmission System Operators
for Electricity

All TSOs' Common Grid Model Alignment Methodology in accordance with Article 24(3)(c) of the Common Grid Model Methodology

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1 Introduction

One of the key inputs for any individual grid model ("IGM") of a bidding zone (or control area[1]) is that bidding zone's net position for the corresponding market time unit. Article 2(5) of Regulation 2015/1222[2] defines net position as "the netted sum of electricity exports and imports for each market time unit for a bidding zone"[3]. In other words, the net position (typically measured in the unit "MW") is a number that states whether a bidding zone is a (net) exporter or (net) importer of electricity. If the net position is positive, the bidding zone is a net exporter; if the net position is negative, the bidding zone is a net importer[4].

When no market schedules are available TSOs will typically base their IGM on an estimate of the net position which, in the first instance, they are free to determine by themselves. However, TSOs collectively have to respect a critical consistency requirement: <u>all</u> net positions within an interconnected system have to sum to zero because the sum of exports has to be equal to the sum of imports. When this consistency requirement is met, the net positions are referred to as "balanced" and the IGMs are said to be "aligned". Unless this condition is fulfilled, it is not possible to merge the IGMs from all TSOs into the Common Grid Model ("CGM").

Establishing balanced net positions is, in principle, straightforward for those time frames for which schedule data are available (i.e., day-ahead and intraday). However, for time frames for which schedules are not available; specifically, the

- (D-2) (two days ahead),
- (W-1) (week-ahead),
- (M-1) (month-ahead), and
- (Y-1) (year-ahead)

time frames; balanced net positions have to be established via a process known as "Common Grid Model Alignment" ("CGMA"). The CGMA process consists of a set of procedures by which the initial (preliminary) estimates of net positions are revised such that the resulting set of net positions is balanced. The present CGMA Methodology ("CGMAM") collects these procedures into a single document and describes them in detail.

The CGMA approach supersedes the practice of using net positions for a historical reference timestamp. Since net positions for any historical reference timestamp have to be balanced by definition, if all TSOs use their net position during that historical reference timestamp in a model to be built for a future timestamp, the net positions will be balanced. However, since the

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[1] Where a control area comprises more than one bidding zone, the TSO may provide a single IGM for the whole control area, cf. Chapter VI. For the sake of simplicity, the present document does not distinguish between the two cases and uses the term "bidding zone" only. Note, too, that "bidding zone" in the sense in which the term is used in the present document does not refer to internal bidding zones within a control area such as exist in Italy, Norway, or Sweden. Since in mathematical terms the CGMA algorithm represents a constrained optimisation, the bidding zones are also referred to as "optimisation areas."

[2] Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management

[3] A more precise way of referring to net positions in the sense in which the term is used in the present document would be to refer to "aggregate AC/DC net positions". However, the simpler (and slightly less accurate) term "net position" is used in order to be consistent with the terminology in Regulation 2015/1222.

[4] In CGMES grid models, the converse sign convention is used.

future target timestamp is likely to differ from the historical reference timestamp, use of historical net positions is not likely to provide a best estimate. The introduction of the CGMA approach thus gives TSOs much more freedom in defining the scenarios for which they build their models. In fact, as long as the requirements with respect to the input data are respected, the CGMA approach will be able to accomodate any scenario.

Flows on direct current ("DC") lines linking different bidding zones are, of course, taken into account when computing net positions if the DC line links different CGMA optimisation areas. However, they impose special constraints with respect to the CGMA process. The CGMAM addresses this challenge, too, and ensures that flows on DC lines are also consistent. The flows thus established are referred to as "balanced flows on DC lines".

The remainder of the present introduction provides an overview of the document which is being prepared on the basis of the Common Grid Model Methodology ("CGMM"). The CGMM exists in three versions and was drafted by all TSOs just like the present document. The CGMM-v1-plus (pursuant to Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management - the "CACM Guideline") covers the day-ahead and intraday capacity calculation time frames and was approved by all NRAs in May 2017. The CGMM-v2 (pursuant to Commission Regulation (EU) 2016/1719 of 26 September 2016 establishing a guideline on forward capacity allocation - the "FCA Guideline") covers the month-ahead and year-ahead time frames and was submitted to all NRAs for approval in July 2017. Finally, at the time of revision in November 2017 the CGMM-v3 was being drafted pursuant to Commission Regulation (EU) 2017/1485 of 02 August 2017 establishing a guideline on electricity transmission system operation (the "SO Guideline"). The relevant legal background is explained in Chapter 2. The CGMAM is a more flexible document than the CGMM in that the latter requires regulatory approval whereas the former does not. It is thus expected that the CGMAM will be revised more frequently. However, each revision needs to be backed by a positive "All TSOs" vote.

Chapter 3 explains the CGMA algorithm. As will be explained below, the CGMA algorithm is crucial in ensuring that the preliminary net positions can be transformed into balanced net positions. The application of the CGMA algorithm is integrated into the overall CGMA business processes which are described in Chapter 4.

Chapter 5 is dedicated to the reporting of key performance and quality indicators. CGMA being a crucial starting point for processes such as capacity calculation, TSOs need to ensure that they monitor it in a robust manner and make relevant data available for checking by external stakeholders, too.

The last chapter in the body of the CGMAM, Chapter 6, provides an overview of the IT arrangements required to implement the CGMA process.

The annexes contain in-depth descriptions of a number of rather technical topics. Annex I summarises the results of two rounds of comprehensive tests used to gauge the performance of the CGMA algorithm. The pre-processing approaches proposed by Regional Security Coordinators and / or TSOs are the subject of Annex II. Pre-processing approaches aim at minimising the adjustments required in order to compute balanced net positions, so three of the future "alignment agents[5]" have taken it upon themselves to develop strategies in this regard. A summary of the parameters referenced in the CGMAM and on the data formats to be used as part of the IT set-up are appended as Annexes III and IV, respectively.

Annex V contains a glossary. This also serves as a correspondence table which for a number of important terms used in the present document states the equivalent terms used in related documents. The last two annexes of the document, Annexes VI and VII, provide a list of the bidding zones to be included in the CGMA process and a list of the optimisation areas and DC lines used by the CGMA algorithm, respectively.

It should be noted that the material provided in this version of the CGMAM – especially the descriptions of the algorithm, the processes and associated performance indicators, as well as the IT setup – reflect the design envisaged as of the summer of 2017. TSOs are planning to organise a parallel run ("dry run") towards the end of 2017 during which all aspects of this design will be tested in practice. If during the parallel run additional adjustments to the algorithm, processes, IT setup, etc. seem called for, these can still be specified and implemented in advance of the go-live of the overall CGM process planned for June 2018 at the time of revision.

Note to readers not associated with an ENTSO-E member organisation:
The present document is made available to stakeholders not associated with ENTSO-E member organisations for the purpose of increasing transparency about TSOs' procedures and in order to meet the legal requirement set out in Article 24(3)(c) of the Common Grid Model Methodology.

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[5] The role of "alignment agent" will be handled by Regional Security Coordinators (RSCs).

2 Legal background

The present chapter describes the legal framework for the CGMAM. The need for the CGMA process is recognised in European legislation; specifically, Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management ("Regulation 2015/1222"). The TSOs have transposed the requirements set out in Regulation 2015/1222 into their "All TSOs’ proposal for a common grid model methodology in accordance with Article 17 of Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management" ("Common Grid Model Methodology" or "CGMM"). While Regulation 2015/1222 is the only item of European legislation that explicitly refers to the CGMA process, this process is implicitly required by other items of legislation stipulating that TSOs prepare CGMs for time frames for which schedules are not available.

2.1 Regulation 2015/1222

The most important passage in this Regulation is the following Article 18(3) which explicitly requires TSOs to prepare the CGMAM:

> For each scenario, all TSOs shall jointly draw up common rules for determining the net position in each bidding zone and the flow for each direct current line. These common rules shall be based on the best forecast of the net position for each bidding zone and on the best forecast of the flows on each direct current line for each scenario and shall include the overall balance between load and generation for the transmission system in the Union. There shall be no undue discrimination between internal and cross-zonal exchanges when defining scenarios, in line with point 1.7 of Annex I to Regulation (EC) No 714/2009.

In addition, Article 19(4) is relevant:

> All TSOs shall harmonise to the maximum possible extent the way in which individual grid models are built.

Along with the other requirements set out in Regulation 2015/1222 relating to the Common Grid Model, these provisions have been transposed into the CGMM by the TSOs.

2.2 Other European legislation

Two other European Regulations – the Commission Regulation (EU) 2016/1719 of 26 September 2016 establishing a guideline on forward capacity allocation ("FCA Guideline") and the Commission Regulation (EU) 2017/1485 of 02 August 2017 establishing a guideline on electricity transmission system operation ("SO Guideline") – also require TSOs to build a CGM for time frames at which schedules are not available.

Specifically, Article 22 of the FCA Guideline stipulates that "*The process and requirements set in Article 28 of Regulation (EU) 2015/1222 for creating a common grid model shall apply when creating the common grid model for long-term capacity calculation time frames in capacity calculation regions, where security analysis based on multiple scenarios pursuant to Article 10 is applied.*" In practical terms, this applies to year-ahead and month-ahead CGMs.

The SO Guideline requires TSOs to build year-ahead CGMs for the purpose of performing operational security analysis. Week-ahead CGMs are not mandatory at pan-European level. In the case of the week-ahead CGM, Article 69(1) of the SO Guideline makes it clear that this applies to TSOs "coordinating the operational security analysis of their transmission system for the week-ahead timeframe": "*Where two or more TSOs consider it necessary, they shall determine the most representative scenarios for coordinating the operational security analysis of their transmission system for the week-ahead timeframe and shall develop a methodology for merging the individual grid models analogous to the methodology for building the year-ahead common grid model from year-ahead individual grid models in accordance with Article 67(1).*"

Note, however, that neither Regulation addresses the topic of CGM alignment explicitly.

While only the year-ahead and the two-days ahead CGMs are mandatory at pan-European level, the CGMAM covers all time-frames for which CGMs are required, but schedules are not available. Therefore although the different Regulations cited above cover different time frames only a single CGMAM is required.

2.3 Common Grid Model Methodology ("CGMM")

Regulation 2015/1222 requires TSOs to jointly prepare a Common Grid Model Methodology ("CGMM") that "*enable[s] a common grid model to be established*." (Article 17(2) of Regulation 2015/1222). The CGMM sets out the TSOs' rules for preparing the Common Grid Model (required by Regulation 2015/1222 as well as other items of European legislation; see above) and was approved by NRAs in May 2017. Given the crucial importance of CGM alignment in the preparation of both IGMs and CGMs, the CGMM contains detailed requirements in this regard.

As was noted in the introduction, there are actually three different versions of the CGMM. However, the provisions regarding Common Grid Model Alignment are consistent across the three versions. For the avoidance of doubt, references to the CGMM denote references to the CGMM prepared pursuant to Regulation 2015/1222 (CGMM-v1-plus).

Specifically, Article 4(2)(e) and (f) of the CGMM oblige TSOs to complete the following tasks when building their IGM:

> e. apply the common rules for determining the net position in each bidding zone and the flow for each direct current line set out in Articles 18 and 19;
> f. ensure that the model is consistent with the net positions and flows on direct current lines established in accordance with Articles 18 and 19;

Articles 18 and 19 of the CGMM read as follows:

> **Article 18**
>
> **Net positions and flows on direct current lines**
>
> 1. For all scenarios for the day-ahead capacity calculation time-frame pursuant to Article 3, each TSO shall follow the CGM alignment procedure described in Article 19 in order to comply with Article 18(3) of Regulation 2015/1222.
> 2. For all scenarios for the intraday capacity calculation time-frame pursuant to Article 3, in order to comply with Article 18(3) of Regulation 2015/1222
>   a. the best forecast of the net position for each bidding zone and of the flow on each direct current line shall be based on verified matched scheduled exchanges;
>   b. each TSO shall share with all other TSOs the net position for its bidding zone(s) and the values for the flow on each direct current line used in its IGM via the information platform described in Article 21 in accordance with the CGM process described in Article 22.
> 3. For all scenarios pursuant to Article 3 in case of bidding zones connected by more than one direct current line, in order to comply with Article 18(3) of Regulation 2015/1222 the TSOs concerned shall agree on consistent values for the flows on direct current lines to be used in each TSO's IGM. These shall also be the values that the TSOs make available to all other TSOs.

Article 19 covers CGM alignment proper; i.e., addresses the case where schedules are not available at the two-days ahead time horizon:

> **Article 19**
>
> **CGM alignment**
>
> 1. For each scenario for the day-ahead capacity calculation time-frame pursuant to Article 3, each TSO shall prepare and share with all other TSOs via the information platform referred to in Article 21 in accordance with the CGM process description set out in Article 22 its best forecast of
>   a. the net position for its bidding zone, being its preliminary net position;
>   b. the flow on each direct current line connected to its bidding zone being the preliminary flows on each direct current line;
>   c. any other input data required by the algorithm pursuant to paragraph 2.
> 2. All TSOs shall jointly define an algorithm which for each scenario and for all bidding zones aligns the preliminary net positions and preliminary flows on each direct current line in such a way that following the adjustment by the algorithm
>   a. the sum of adjusted net positions for all bidding zones in the CGM area balances the targeted net position for the CGM area;
>   b. for all bidding zones connected by at least one direct current line the sum of

flows on all direct current lines is mutually consistent for both bidding zones concerned.

3. The algorithm shall have the following properties or features in order to ensure that in accordance with Article 18(3) of Regulation 2015/1222 there is no undue discrimination between internal and cross-zonal exchanges:
   a. the alignments of preliminary net positions and preliminary flows on each direct current line shall be spread across all bidding zones and no bidding zone shall benefit from any preferential treatment or privileged status with respect to the operation of the algorithm;
   b. in its objective function the algorithm shall give appropriate weight to the following when determining the adjustments required:
      i. the size of the adjustments required to each preliminary net position and the preliminary flows on each direct current line, which shall be minimised;
      ii. the ability of a bidding zone to adjust its preliminary net position and the preliminary flows on each direct current line, based on objective and transparent criteria;
   c. the algorithm shall specify objective and transparent consistency and quality criteria which the input data required from each TSO shall meet;
   d. the algorithm shall be robust enough to provide the results pursuant to paragraph 2 in all circumstances given the input data provided to it.
4. TSOs shall agree on procedures
   a. to reduce the absolute value of the sum of preliminary net positions for all bidding zones in the CGM area; and
   b. to provide updated input data if necessary; and
   c. to take into account reserve capacity and stability limits if it becomes necessary to update input data.
5. TSOs shall regularly review and, if appropriate, improve the algorithm.
6. TSOs shall publish the algorithm as part of the data to be provided pursuant to Article 31(3) of Regulation 2015/1222. If the algorithm was modified during the reporting period, TSOs shall clearly state which algorithm was in use during which period and they shall explain the reasons for modifying the algorithm.
7. All TSOs shall jointly ensure that the algorithm is accessible to the relevant parties via the information platform referred to in Article 21.
8. In accordance with Article 81 of Regulation 2015/1222 each TSO shall designate an alignment agent who shall perform, on behalf of the TSO, the following tasks in accordance with the process described in Article 22:
   a. check the completeness and quality of the input data provided pursuant to paragraph 1 and, if necessary, replace missing data or data of insufficient quality with substitute data;
   b. apply the algorithm in order to compute for each scenario and each bidding zone aligned net positions and aligned flows on all direct current lines that meet the requirements set out in paragraph 2 and make these available to all TSOs via the information platform referred to in Article 21;

> c. ensure that the results obtained are consistent with those obtained by all other alignment agents (if any).
>
> **9.** Pursuant to Article 4(2)(f), each TSO shall ensure that its IGM is consistent with the aligned net position and aligned flows on direct current lines provided by the alignment agent.

The provisions in the CGMM Articles cited above outline the essential features of the CGMA Methodology; these are explained in more detail in the present document.

Article 21 of the CGMM on the "Information platform" (known as the Operational Planning Data Environment or "OPDE") also contains a number of provisions that are relevant for the CGMA process:

> **Article 21**
>
> **Information platform**
>
> 1. All TSOs shall delegate the task of implementing and administering a joint information platform that provides at least the services described in paragraph 2 in accordance with Article 81 of Regulation 2015/1222.
> 2. The information platform shall at a minimum support the CGM process in the following ways and it shall have all the features required to this end:
>   a. intraday capacity calculation time-frame - each TSO shall be able to use the information platform in order to share with all other TSOs the net position for its bidding zone(s) and the values for the flow on each direct current line used in its IGM pursuant to the CGM process described in Article 22;
>   b. (...)
>   c. day-ahead capacity calculation time-frame - each TSO shall be able to use the information platform in order to share with all other TSOs pursuant to the CGM process described in Article 22 its best forecast of
>   i. the net position for its bidding zone, comprising its preliminary net position;
>   ii. the flow on each direct current line connected to its bidding zone comprising the preliminary flows on each direct current line;
>   iii. any other input data required by the algorithm further to Article 19(2);
>   d. the algorithm pursuant to Article 19(2) shall be accessible via the information platform;
>   e. the alignment agent(s) shall be able to make the aligned net positions and aligned flows on direct current lines that meet the requirements set out in Article 19(2) available to all TSOs via the information platform;
>   (...)

The most important process steps applicable to the two-days ahead CGMA process are set out in Article 22 of the CGMM:

> **Article 22**
> **CGM process**
>
> 1. When preparing the CGM for the day-ahead capacity calculation time-frame, all TSOs, merging agents and alignment agents shall complete the following steps:
>   a. each TSO shall make preliminary net positions, preliminary flows on direct current lines as well as any other input data required for the CGM alignment process available to all TSOs via the information platform referred to in Article 21;
>   b. the alignment agent(s) shall check the completeness and quality of the input data provided pursuant to Article 19(1) and, if necessary, replace missing data or data of insufficient quality with substitute data;
>   c. the alignment agent(s) shall apply the algorithm in order to compute for each scenario and each bidding zone aligned net positions and aligned flows on direct current lines that meet the requirements set out in Article 19(2);
>   d. the alignment agent(s) shall make these aligned net positions and aligned flows on direct current lines available to all TSOs via the information platform referred to in Article 21;
>
> (...)
>
> 2. When preparing the CGM for the intraday capacity calculation time-frame, all TSOs, merging agents, and alignment agents shall complete the following steps:
>   a. each TSO shall make its net position and flows on direct current lines for each scenario for the intraday capacity calculation time-frame available to all TSOs via the information platform referred to in Article 21. TSOs in bidding zones where the cross-zonal intraday market for the following day opens before 16:30h shall use the data as of 16:00h;
>
> (...)

Article 23 of the CGMM on "Quality monitoring" addresses the need for TSOs to provide high-quality input data for the CGMA process and to be transparent about how well the CGMA process is functioning. In particular, as will be stressed throughout the present document, TSOs shall publish data that make it possible to assess whether the "no undue discrimination" requirement set out in Article 18(3) of Regulation 2015/1222 is being respected.

Article 23
Quality monitoring

(...)

3. All TSOs shall jointly define criteria that the preliminary net positions and preliminary flows on direct current lines as well as the other input data required for the CGM alignment process pursuant to Article 19 have to meet. Data sets that do not meet these criteria shall be replaced by substitute data.
4. All TSOs shall jointly define quality indicators that make it possible to assess all stages of the CGM process including, in particular, the CGM alignment process described in Article 19. They shall monitor these quality indicators and publish the indicators and the results of the monitoring as part of the data to be provided pursuant to Article 31(3) of Regulation 2015/1222.

Finally, the obligation to prepare the present CGMAM is – in addition to the corresponding requirement in Regulation 2015/1222 - restated in Article 24 of the CGMM in somewhat greater detail:

Article 24
Timescale for implementation

(...)

3. By six months after the approval of the present methodology (...)
    b. each TSO shall formalise the delegation agreement with the alignment agent referred to in Article 19. In devising this agreement each TSO shall respect the provisions on delegation set out in Article 81 of Regulation 2015/1222;
    c. all TSOs shall jointly specify and develop the algorithm referenced in Article 19 and shall also specify the rules and process associated with the said algorithm. All TSOs will publish on the internet the specifications, rules and process associated with the algorithm referenced in Article 19;
    d. all TSOs shall jointly define the quality criteria and quality indicators referred to in Article 23;

(...)

6. All TSOs shall jointly prepare the available data related to quality monitoring in a sufficiently timely manner to allow these to be included in the first report referred to in Article 31 of Regulation 2015/1222 due by 14 August 2017. They shall prepare these data in subsequent years as required.

One additional task set out in Article 24 of the CGMM is the drafting of a governance framework for the information platform referred to in Article 21 above by all TSOs. Since this information platform – the Operational Planning Data Environment ("OPDE") – plays a very important role in the CGMA process, that governance framework will have considerable implications for the CGMA process, too.

In summary, the CGMM provisions relating to the CGMA process provide the framework for the CGMAM, all major elements of which are addressed in the CGMM. The present document provides the details required in order to make the CGMA process operational.

3 CGMA Algorithm

The present chapter describes the CGMA algorithm referred to in, inter alia, Article 19(2) of the CGMM. This description, together with the description of the CGMA processes in Chapter 4, reflects the requirements with respect to the algorithm set out in Article 19(3) and 19(4) of the CGMM.

3.1 The three phases of the CGMA process

The CGMA process can be subdivided into three phases:

- Pre-processing phase
- Processing phase
- Post-processing phase

During the pre-processing phase each TSO provides its pre-processing data ("PPD") to the CGMA IT platform which is operated by one or more alignment agents. The alignment agents – which in practice will be Regional Security Coordinators ("RSCs") – are responsible for completing a number of tasks related to the CGMA process on behalf of the TSO. These tasks are described in more detail below.

The PPD consist of

- the preliminary net position (PNP)
- the feasibility range (FR) for the adjustment of the preliminary net position
- preliminary flows on DC lines
- maximum import and maximum export flows on DC lines

The following additional data can be optionally submitted as part of the PPD:

- absolute minimum and maximum net position (ABS_NP_MIN, ABS_NP_MAX)

The feasibility range is described by an interval $[FR_{neg}, FR_{pos}]$ such that under normal circumstances the TSO expects its balanced (as opposed to preliminary) net position to be inside the interval $[PNP + FR_{neg}, PNP + FR_{pos}]$. In practical terms, the feasibility range is a proxy for flexibility and the ability of a bidding zone to accommodate different net positions.

As far as (both preliminary and balanced) DC flows are concerned, three points are worth noting:

- DC flows may refer to both a single DC line or to an aggregate of DC lines. For the time being, if DC lines on a DC border (i.e., two bidding zones linked by one or more DC lines) are aggregated, then they are aggregated into a single DC connection. However, it would also be possible to aggregate them into more than one DC connection. To give an example, DC lines Skagerrak 1 to 4 could be modelled as any number of DC connections between 1 and 4. The splitting / aggregation of DC flows is determined as part of a separate sub-process referred to as "DC pole splitting and loss calculation" (DC PSLC) that is not within scope of the CGMAM.

- Both within-synchronous area DC lines and across-synchronous area DC lines are included if they connect different CGMA optimisation areas. The differences between the two types of DC connections and the implications of this for the CGMA process are explained below.
- Unless the flow on a DC line is zero there is always one exporting and one importing end. The flow at the importing end is always equal to the flow at the exporting end minus the losses on the line resp. the converters. The handling of DC losses in the context of the CGMA process is not explained in the CGMAM, since it is part of the DC PSLC sub-process referred to above.

The absolute minimum and maximum net position and their use in the process will be explained in connection with the process descriptions in Chapter 4.

Note that these PPD need to be provided for each of the scenarios for which an IGM / CGM is being prepared (and for which market schedules are not available). In the case of the two-days ahead CGM this will typically correspond to 24 scenarios (one scenario per market time unit which, in practical terms, will be one hour). In the case of the year-ahead CGM the expectation is that eight scenarios will be used; one peak and one trough scenario for each season. All scenarios that are mandatory at pan-European level are or will be described in the various versions of the CGMM. The annotated version of the CGMM will feature descriptions of all scenarios, whether mandatory at pan-European level or not.

In line with the requirement in Article 18(3) of Regulation 2015/1222, the PPD have to correspond to the TSO's best forecast. It is rather intuitive that by estimating the PPD on a regional basis in a coordinated manner the precision of the estimates ought to increase. The more precise the estimates the smaller the adjustments required in order to obtain balanced net positions. A number of parties are therefore developing methods for estimating PPD on a regional basis. These so-called coordinated pre-processing approaches are presented in Annex II. While these regional, coordinated approaches offer improvements relative to estimates prepared by an individual TSO, there is no obligation for a TSO to prepare its PPD on the basis of a regional approach. Each TSO's obligation is to provide PPD such that these meet the quality standards set out in Chapter 3 on the algorithm. In line with Article 81 of Regulation 2015/1222, a TSO can, of course, delegate this task to an RSC. Delegation to an RSC seems a particularly relevant option for those TSOs that join a coordinated approach.

During the processing phase, the CGMA algorithm will use the PPD in order to compute the variables of interest, namely

- balanced net positions
- balanced flows on DC lines

Also computed are AC-only net positions per bidding zone as well as indicative flows per AC border. The AC-only net position is simply the balanced net position adjusted, where applicable, for the balanced flows on DC lines. As for indicative flows per AC border, any two bidding zones have an AC border if they are linked by one or more AC tie lines. In other words, an AC border represents an aggregate of these tie lines. As a by-product of the computation, the CGMA algorithm also computes, for each AC border, an indicative flow figure which is provided along with the other CGMA results. These indicative AC flow figures do not have any bearing on actual physical flows, so any ex post comparison against realised flows would be meaningless. To see this, consider the example of three bidding zones all mutually linked via AC borders: an infinite number of combinations of AC flows could be determined that are all consistent with a given set of balanced net positions. By default the CGMA algorithm computes AC flows in such a way that these flows are minimised.

The accompanying CGMA Data Exchanges Implementation Guide refers to "CGMA results" as the set of balanced net positions, balanced flows on DC lines, AC-only net positions, and indicative AC flows. Together with the set of pre-processing data originally provided to the CGMA IT platform and any substituted or modified pre-processing data, the CGMA results constitute the "CGMA output data". The term "CGMA input data" used in the CGMA Data Exchanges Implementation Guide, however, is fully equivalent to "pre-processing data".

During the post-processing phase the balanced net positions and the balanced flows on DC lines will be used to adjust each TSO's IGM(s). The post-processing phase is mentioned for the sake of completeness, but the tasks that are part of this process phase are not part of the CGMA process.

The three phases can be illustrated as follows:

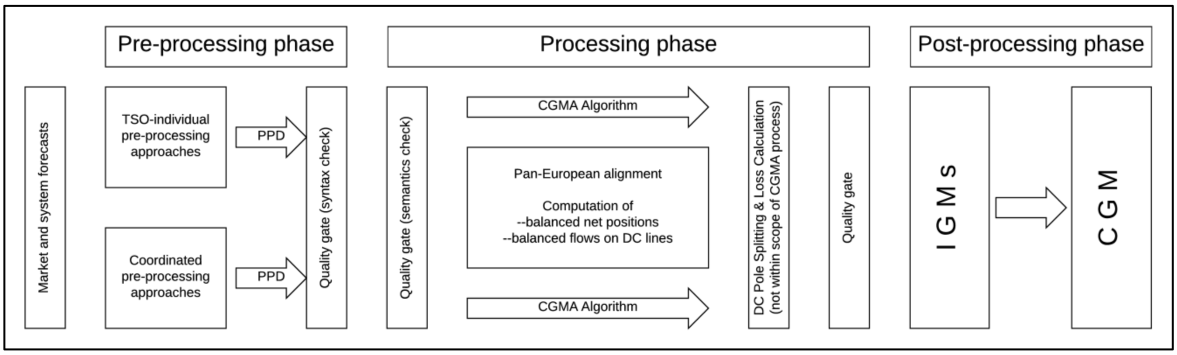

Figure 1: Phases of CGMA process

The present chapter is primarily about the processing phase and, in particular, the CGMA algorithm.

3.2 Requirements with respect to the PPD

In the processing phase, the CGMA algorithm uses the PPD in order to compute balanced net positions and balanced flows on DC lines. That requires adjusting the preliminary net positions as well as the preliminary flows on DC lines. However, the range of possible adjustments is limited by the feasibility range (in the case of the net position) and the maximum permissible import flow and maximum permissible export flows on DC lines (in the case of the preliminary DC flows). Section 3.3 explains how losses on DC lines are taken into account. Clearly, if the scope for adjustments is insufficient, it might not be possible to obtain balanced net positions and balanced flows on DC lines.

To avoid the problem of non-convergence, the feasibility ranges have to be "of meaningful magnitude".[6] The "meaningful magnitude" requirement is a quality criterion that is checked at the CGMA quality gate (to be described in more detail in Section 4.4 as well as Chapter 6 on IT implementation). In the case of the (D-2) CGMA process time is of the essence, so data that do not meet the quality requirements will be rejected and replaced by default data. This ensures that the CGMA process can run nevertheless.

What, in concrete terms, does it mean for the data to be "of meaningful magnitude"? In the case of the feasibility range for the adjustment of the preliminary net position, the answer to this question is based on the concept of a weighting factor.

The weighting factor ("WF") is an indicator of the ease with which a given bidding zone should be able to implement an adjustment of its net position of a given size. The intuition behind this concept is that, holding everything else constant, it should be easier for a large system such as France or Germany to adjust its net position by, for example, 500 MW than for a smaller system such as Portugal or Slovenia. Thus the "meaningful magnitude" requirement can be expressed in terms of the weighting factor; the larger the weighting factor, the larger the required feasibility range.

After reviewing several candidates it was agreed to use "instantaneous peak load" as the weighting factor. The instantaneous peak load for all relevant bidding zones is provided in the "ENTSO-E Yearly Statistics & Adequacy Retrospect" (which, as the title suggests, is updated every year with the previous year's data). Using this weighting factor as the reference, the feasibility range for a bidding zone needs to exceed 2*β % of the weighting factor (instantaneous peak load) in absolute terms in order for the corresponding set of PPD to pass the quality gate. The TSO can shift this feasibility range around its PNP as it sees fit. The interval

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[6] For DC lines the maximum permissible import and maximum permissible export flows reflect the technical cable capabilities (excluding losses). Note that these may differ by direction of flow. If actual restrictions are more constraining than the technical cable capabilities, the TSOs can indicate this by providing suitably adjusted values for the maximum import and maximum export flows on the corresponding DC lines as part of the PPD (see above). This implies that with respect to DC flows there is no equivalent of the "meaningful magnitude" requirement that is applicable to net positions. This is explained in more detail below.

for the feasibility range could thus be symmetric about the PNP [PNP – β % * IPL, PNP + β % * IPL] or the PNP could be at the top or bottom end of the interval: [PNP – 2*β % * IPL, PNP] or [PNP, PNP + 2*β % * IPL], respectively. "β" is a parameter that can be modified so as to widen or narrow the minimum feasibility range required. The initial proposal for "β" is 1 which corresponds to a minimum feasibility range of 2 % of IPL. The test results reported in Annex I suggest that this feasibility range ought to be sufficient in order for the CGMA algorithm to find a solution.

The weighting factor and the "β" percentage will be reviewed periodically. Even if the WF as such were not changed, the parameters will be updated on a yearly basis (when the new version of the "ENTSO-E Yearly Statistics & Adequacy Retrospect" is released).

The following Table 1 presents the latest available data (for 2016 unless otherwise noted). Note that the figures below refer to the national level whereas in the case of some countries (e.g., Germany) the IGMs and thus PPDs are provided on the level of control areas that do not cover the entire country. In these cases, the figures below shall be pro-rated in proportion to the instantaneous peak load on the level of the control area or an alternative suitable statistic (with all data being properly documented). In a similar vein, where a relevant bidding zone or control area is not (yet) included in the "ENTSO-E Yearly Statistics & Adequacy Retrospect" a suitable alternative set of statistics shall be used in order to establish instantaneous peak load for that area. Annex 0 provides additional detail.

Country	Value [MW]
AL	1552[7]
AT	11728
BA	2142
BE	13147
BG	7105
CH	10178
CZ	10512
DE	81945
DK	6115
EE	1538
ES	40144
FI	15177
FR	88571
GB	60133[8]
GR	9207
HR	2869
HU	6437
IE	4737
IT	53748
LT	1979
LU	1025
LV	1300
ME	576
MK	1457
NI	1758 [see FN 8]
NL	18243
NO	24485
PL	23779
PT	8139
RO	8752
RS	6958
SE	26576
SI	2144
SK	4360
TR	2217[9]
UA_W	1145[10]
XK	1160[11]

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[7] Not yet included in ENTSO-E document; 2016 figure obtained directly from OST by the drafting team

[8] 2015 figure obtained from ENTSO-E Yearly Statistics and Adequacy Retrospect as the Statistical Factsheet does not provide a breakdown into GB and NI

[9] 5 % of 44341 MW (the 2016 IPL figure for all of Turkey) which corresponds to the share of the European part of Turkey in the overall area of the country. This is used as a proxy for the actual interconnection capacity which is disproportionately low given the large size of the Turkish power system and of the remainder of the Continental Europe power system.

[10] Figure for 2014; source: ENTSO-E Yearly Statistics and Adequacy Retrospect 2015. An updated figure for Ukraine (UA_W) is no longer included in the 2016 edition (reporting on 2015 data). The drafting team has attempted to obtain an updated figure directly from Ukrenergo.

[11] Not yet included in ENTSO-E document; 2016 figure obtained directly from KOSTT by the drafting team

Source: ENTSO-E Statistical Factsheet 2016[12]

Table 1: Instantaneous peak load 2016

Note that the "meaningful magnitude" for the feasibility range is defined in terms of an absolute value. However, each TSO is still required to provide two values – one for the maximum negative adjustment (FR_{neg}) and one for the maximum positive adjustment (FR_{pos}) of the preliminary net position.

To give an example, if Belgium (with an absolute minimum feasibility range of 263 MW; i.e., 2% of 13,147 MW where 13,147 MW represents the 2016 WF and 2% follows from a value of β of 1) declares a preliminary net position of PNP = +500 MW (i.e., an expected export of 500 MW), the following feasibility ranges would all be just accepted by the CGMA Quality Gate:

- $[FR_{neg} = -263\,MW, FR_{pos} = 0\,MW]$ which results in a net position range of $[NP_{min} = PNP + FR_{neg} = +500\,MW - 263\,MW = +237\,MW, NP_{max} = PNP + FR_{pos} = +500\,MW + 0 = +500\,MW]$
- $[FR_{neg} = -132\,MW, FR_{pos} = +132\,MW]$ which results in a net position range of $[NP_{min} = PNP + FR_{neg} = +500\,MW - 132\,MW = +368\,MW, NP_{max} = PNP + FR_{pos} = +500\,MW + 132\,MW = +632\,MW]$
- $[FR_{neg} = 0\,MW, FR_{pos} = +263\,MW]$ which results in a net position range of $[NP_{min} = PNP + FR_{neg} = +500\,MW + 0\,MW = +500\,MW, NP_{max} = PNP + FR_{pos} = +500\,MW + 263\,MW = +763\,MW]$.

The equivalent weighting factor for DC lines is, in principle, given by the maximum technical capacity of the line. If permanent or semi-permanent constraints (e.g., outages) restrict the capacity that is actually available, the DC weighting factor can be reduced accordingly by the relevant TSOs. The DC weighting factor is required as an input for the CGMA algorithm as will be explained below. However, the "meaningful magnitude" for maximum permissible import and maximum permissible export DC flows is not defined with respect to the DC weighting factor, but is simply the largest maximum import and the largest maximum export flow consistent with the technical design of the cable and operational requirements.

Note that each TSO can set specific maximum import and maximum export flows on each of its DC lines for each individual scenario if necessary (i.e., in the case of the (D-2) time horizon for each individual hour). These values can reflect, for example, ramping constraints or other technical restrictions. The values specified will be checked against the maximum technical capacity; if values are specified that exceed the technical maximum these will be rejected. However, there is no problem in specifying values less than the maximum technical capacity.

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[12] For the 2017 revision of the Common Grid Model Alignment Methodology and on an exceptional basis, the ENTSO-E Statistical Factsheet was used as the principal source. This made it possible to include - albeit provisional - 2016 data as opposed to 2015 data). The ENTSO-E Yearly Statistics & Adequacy Retrospect will remain the principal reference in future updates.

In summary, the data provided by each TSO need to meet the following requirements in order to pass the CGMA Quality Gate:

- the feasibility range needs to be wider than or at least equal to 2*β % of the bidding zone's weighting factor (the bidding zone's instantaneous peak load, typically relating to the previous year or the year before that; "β" being a parameter used to determine the width of the feasibility range)
- the maximum permissible import and maximum permissible export flows given for each of the DC lines must be the largest maximum import and the largest maximum export flows consistent with the technical design of the cable and operational requirements.

The next section describes how the CGMA algorithm uses the data provided by TSOs in the pre-processing phase in order to obtain, inter alia, balanced net positions.

3.3 Processing phase: the CGMA algorithm

Objectives for this phase

The objectives for the processing phase are best illustrated by use of a diagram. Figure 2 shows the situation at the start of the processing phase when all bidding zones have submitted their preliminary net positions and preliminary DC flows. For the sake of clarity, preliminary AC-only net positions and preliminary DC flows are depicted separately. Bidding zones are indexed i and numbered from 1 to n; DC lines are labelled with capital letters. Since a DC line always connects exactly two bidding zones each DC line appears in the diagram exactly twice. In principle this diagram relates to the pan-European level and encompasses all the bidding zones that take part in the CGM (and thus CGMA) process.

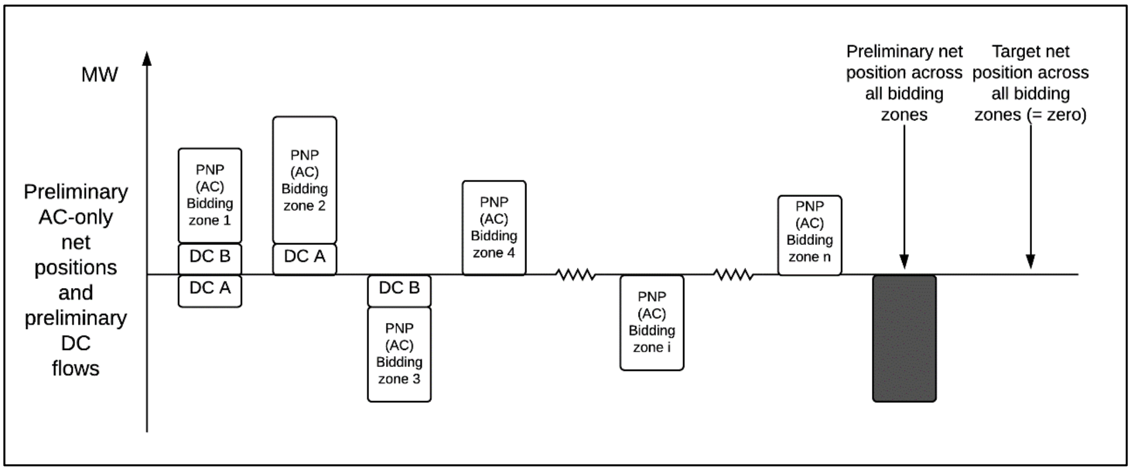

Figure 2: Unbalanced preliminary AC-only net positions and preliminary DC flows at the start of the processing phase

The diagram shows that there is a problem with the preliminary net positions – the problem that is to be solved in the processing phase. The "Preliminary net position across all bidding zones" – the dark grey bar on the right-hand side of the diagram - is not equal to the "target net position" (cf. far right of Figure 2). The latter quantity is always zero on the level of the CGM area. Planned exchanges with "external" bidding zones (i.e., bidding zones that are not included in the CGM and CGMA processes) have to be incorporated into the net position of that bidding zone within the CGM area that is linked to them (e.g., an export to or import from Morocco would be included in the net position of Spain). This discrepancy (i.e., the preliminary net position across all bidding zones not being equal to the target) implies that TSOs' expectations (which aim to reflect market participants' expectations to the extent possible) are not consistent: in this particular illustration, TSOs expect market participants in aggregate to consume more power than they plan to generate. Clearly that is not possible. The objective of the processing phase is to determine a balanced net position for each TSO such that the net position across all bidding zones is equal to the target (i.e., zero). In terms of the diagram, this means making the grey bar disappear by adjusting the preliminary net position for each of the bidding zones.

In practical terms, if the "preliminary net position across all bidding zones" is negative (excess load), it is necessary to increase total expected generation (i.e., the individual preliminary net positions). The converse is the case when the "preliminary net position across all bidding zones" is positive (excess generation). The objective of the processing phase is to determine what exactly (in terms of MW) this adjustment should be for each of the bidding zones.

The present section describes how, for each of the bidding zones, the adjustment required to the (unbalanced) preliminary net position is calculated; i.e., how the "preliminary net position across all bidding zones" (the grey bar in Figure 2) is to be redistributed.

Expressing this in terms of Figure 3, for our example distribution of preliminary net positions, the objective of the processing phase is to compute the size of the black boxes (making a positive PNP more positive) and the boxes with dotted lines (making a negative PNP less negative).

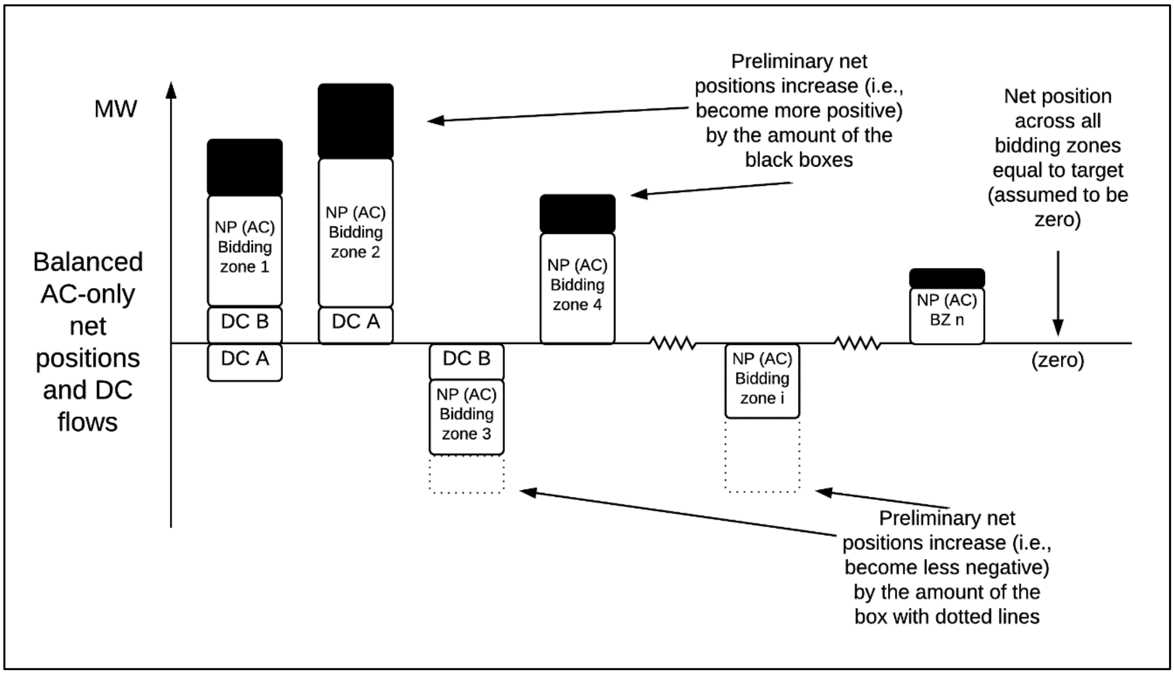

Figure 3: Balanced AC-only net positions and balanced DC flows at the end of the processing phase

It is quite intuitive that there is an infinite number of ways of redistributing the "preliminary net position across all bidding zones". For example, one could use simple rules such as assigning the complete adjustment to a single bidding zone (with bidding zones taking turns to adjust their preliminary net position accordingly) or simply dividing the adjustment required by the number of bidding zones and asking each bidding zone to make the same adjustment.

The technique used for computing the adjustments required in the present CGMAM is more sophisticated than the simple rules sketched out above. That technique builds on an algorithm – the CGMA algorithm – developed as part of the preparation of the CGMAM. Both the algorithm and how it is to be implemented are explained next.

By way of background, note that when the preliminary net positions are adjusted, the flows on DC lines have to be adjusted, too. Before the balanced net positions can be computed, the data relating to a DC line linking any two TSOs need to be preliminarily balanced. The maximum import and maximum export flows for each link also need to be consistent. In practice, the CGMA process does not consider DC flows at the level of individual lines, but rather aggregates the possibly multiple DC lines linking two optimisation areas across a DC border. The splitting of the aggregate flows across the different DC lines happens as part of the DC pole splitting and loss calculation sub-process which is out of scope of the CGMA process.

To summarise: the objectives of the processing phase are to obtain

- balanced net positions (one per bidding zone)
- balanced flows on DC lines (one flow figure per DC border)

by applying the CGMA algorithm. As a prerequisite for the computation, the following values are also established:

- adjusted[13] maximum import and maximum export flows per DC border (if applicable)

The CGMA algorithm: notation

This sub-section explains the notation for the CGMA algorithm and how it is to be applied to the input data. The basic idea behind the algorithm is straightforward: given the objective of obtaining balanced net positions and DC flows, minimize the adjustments required. "Adjustments" are measured by the weighted sum of the squared differences between the preliminary net position and the balanced net position; a similar criterion is applied to the adjustments required with respect to DC flows.

The input data are the pre-processing data; i.e.,

(i) preliminary net position,
(ii) the feasibility range for the adjustment of the preliminary net position,
(iii) preliminary flows on DC lines, and
(iv) maximum import and maximum export flows on DC lines

in the resolution of one hour. Each hour is processed separately and independently of all other hours (i.e., twenty-four independent calculation processes for the (D-2) time frame). In order to use consistent notation throughout, the following symbols are introduced:

(i) preliminary net position,

- bidding zones are indexed i; i runs from 1 to n
- n is the number of bidding zones covered by the algorithm; i.e., the total number of bidding zones included in the pan-European CGM
- the preliminary net position forecast for bidding zone i is denoted PNP_i

(ii) the feasibility range for the adjustment of the preliminary net position,

- there is one feasibility range per bidding zone, so feasibility ranges are also indexed i with i running from 1 to n
- the feasibility range is formed by two values:
  - the maximum negative adjustment FR_{neg} with $FR_{neg} \leq 0$ and
  - the maximum positive adjustment FR_{pos} with $FR_{pos} \geq 0$;
- the resulting range is $\left[FR_{neg}; FR_{pos}\right]$
- the feasibility range for bidding zone i is denoted $\left[FR_{neg,i}; FR_{pos,i}\right]$
- the resulting minimum and maximum net positions are
  - $NP_{min,i} = PNP_i + FR_{neg,i}$
  - $NP_{max,i} = PNP_i + FR_{pos,i}$;
  - in summary $\left[NP_{min,i}; NP_{max,i}\right]$

(iii) preliminary flows on DC lines (per DC border),

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[13] "adjusted": consistent with the maximum import and maximum export flows given by both TSOs (which need not be the same); the adjustment is described in more detail below

- K is the set of all connections (AC and DC links) between bidding zones in Europe[14]
- a single connection k has a defined direction from bidding zone i to bidding zone j[15]
  $k \in K, k = (i, j)$
- flows from and to bidding zones belong to the set of all defined connections between bidding zones
  $K_{from,i} \subseteq K \quad k \in K_{from,i} :\Leftrightarrow k \in K, k = (i, j)$
  $K_{to,i} \subseteq K \quad k \in K_{to,i} :\Leftrightarrow k \in K, k = (h, i)$

Because both TSOs connected by a DC line will typically declare a preliminary flow for the same link each, it must be possible to distinguish the two declarants

- in summary, the preliminary flow on DC connection k forecast by TSO i is given by $IPFlow_{k,i}$
- the "I" in the term denotes the fact that this is the TSO's "Individual" forecast

(iv) maximum import and maximum export flows on DC lines

- maximum import flow on DC line k declared by TSO i (which corresponds to the maximum export on DC line k in the opposite direction) is given by $IFlow_{min,k,i}$
- maximum export flow on DC line k declared by TSO i (which corresponds to the maximum import on DC line k in the opposite direction) is given by $IFlow_{max,k,i}$
- where $IFlow_{min,k,i} \leq 0$ and $IFlow_{max,k,i} \geq 0$
- once again, an "I" is included in the designation in order to make it clear that these are values given by an "Individual" TSO

In addition to the input data from the pre-processing phase, a number of additional parameters need to be defined; these are:

(v) weighting factors

- there is one weighting factor per bidding zone for the adjustment of the net position: $NP_{weight,i}$
- there is one weighting factor per connection: $F_{weight,k}$

Some additional notation is introduced below; it makes sense to explain it first.

<u>Applying the algorithm: overview</u>

This section gives a brief overview of the various steps in the process. In step 0, the target net position across all bidding zones is established. Since the target net position is always set equal to zero, this is not considered as a proper "step" and so is referred to as "step 0". Given input variables (including the target net position across all bidding zones of zero), in the first step - step 1 - the different values relating to DC lines (typically submitted by two declarants; i.e. two TSOs) are provisionally balanced. In other words, rules are defined that ensure that two possibly

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[14] Multiple AC links between the same bidding zones will be aggregated into a single virtual link. DC links between the same bidding zones are also aggregated at this stage of the process.

[15] Flows in the opposite direction will be represented by negative values.

different values for preliminary, minimum, and maximum flows (on the level of DC borders) can be mapped into single ones. In step 2 of the process, the algorithm is applied in order to obtain balanced net positions at pan-European level and to calculate balanced DC flows. Step 3 ensures that, given the model parameters and input data, a solution is found. At the conclusion of step 3 all preparations for the DC pole splitting and loss calculation sub-process have been completed. Following the computation of adjusted output variables during the DC PSLC sub-process; the results computed will be provided and can be used in order to adjust individual grid models in the post-processing phase.

Applying the algorithm: Step 0 – establishing the target net position across all bidding zones

In order to determine the target net position across all bidding zones, in principle the planned exchanges with external bidding zones (i.e., bidding zones that are not part of the CGM area) need to be known and netted. For example, if the planned net exchange with the relevant bidding zones is an import by these external bidding zones (i.e., an export by the CGM area) of 1000 MW, then the target net position across all bidding zones is + 1000 MW.

In practice, however, the target net position across all bidding zones is always set equal to zero for computational reasons. Therefore, in the example the planned export of +1000 MW from the CGM area would be taken into account by including it in the PNPs of those bidding zones planning to exchange power "externally". Take the case of Spain and Morocco as an example. Spain and Morocco are linked by an AC connection. Assume that Spain is expecting to export 100 MW to Morocco. If this is the only external flow, then the CGM area as a whole needs to export 100 MW and the target net position across all bidding zones could be thought to be + 100 MW. However, since the target net position across all bidding zones is zero by convention, REE needs to take into account the planned export to Morocco in its preliminary net position. The declared net position for Spain would thus be reduced by 100 MW (the power that is planned to be exported to Morocco).

Applying the algorithm: Step 1 – obtaining preliminary balance on DC lines

Recall that, if both TSOs connected by DC connection (DC border) k provide data, the following variables need to be reconciled:

- TSO i forecasts the flow to be $IPFlow_{k,i}$
- TSO j forecasts the flow to be $IPFlow_{k,j}$
- individually declared maximum import flows are
    - $IFlow_{min,k,i}$
    - $IFlow_{min,k,j}$
- individually declared maximum export flows are
    - $IFlow_{max,k,i}$
    - $IFlow_{max,k,j}$

As for the forecast flow, the rule is to use the simple arithmetic average as the provisionally balanced flow (and, of course, to drop the subscript for the declarant): $PFlow_k = \frac{IPFlow_{k,i}+IPFlow_{k,j}}{2}$

Maximum import and maximum export flows are computed as follows: $Flow_{min,k} = max\left(IFlow_{min,k,i}; IFlow_{min,k,j}\right)$ $Flow_{max,k} = \min\left(IFlow_{max,k,i}; IFlow_{max,k,j}\right)$

Recall that "*a single connection k has a defined direction from bidding zone i to bidding zone j*". This direction is set as a matter of convention – either of the two possibilities is fine, but the convention has to be respected consistently. Given this convention, knowing the value of both of the $IPFlow_{k,*}$ means knowing $PFlow_k$ which, in turn, means knowing the direction of the flow on connection k. To make this more concrete, consider the example of the SwePol cable linking Poland and Sweden (SE4). All flows on this cable will be expressed in terms of either an export from Poland to Sweden or an export from Sweden to Poland. In the former case, an import into Poland from Sweden would be expressed as a negative number. In the latter case, an import into Sweden from Poland would be expressed as a negative number. Which of the two options is chosen does not matter at all provided that the same convention known to (i.e., programmed into) the CGMA algorithm is applied by all other parties involved in the process.

In the definition of $PFlow_k$ it is important to note that the TSO-individual estimates have to be expressed as expected flows that refer to the same end of the DC link. In other words, the provisionally balanced flow is not obtained as the average of what TSO i (by assumption) expects to export on link k and what TSO j (by assumption) expects to import on link k. These two quantities cannot be properly compared because one of them (implicitly) takes losses into consideration (namely what TSO j expects to import; i.e., import = export minus losses) and the other (namely what TSO i expects to export) does not. Thus if the two forecasts are provided in this way one of the values has to be corrected for the losses. In order to make the two forecasts compatible such that they can be used in the above formula, either the losses have to be added back at the importing end's estimate or the losses have to be deducted at the exporting end's estimate. In practice, however, DC losses will be taken into account in a sub-process referred to as DC PSLC (pole splitting and loss calculation). The convention is therefore that both TSOs provide gross values (that have not been adjusted for losses) at this stage of the CGMA process. In other words, DC borders will be treated as if there no losses on these.

Applying the algorithm: Step 2 – obtaining balanced net positions and DC flows

The CGMA algorithm is formulated as a weighted least squares optimisation problem with both equality and inequality constraints. The different components of the least squares programme are now introduced one by one.

There are two objective functions, one objective function for the minimisation of the adjustment of the net positions and one objective function for the minimisation of the adjustment of the DC flows.

The first objective function is given by

$$\min_{BNP_i} \sum_{i \in N} \frac{1}{NP_{weight,i}} (PNP_i - BNP_i)^2$$

This objective function minimises the aggregated adjustment of the preliminary net positions. BNP_i is a new variable that has not yet been defined. It denotes the "balanced net position" for bidding zone i. The BNP_i are the control variables. The objective function aims to minimize the weighted squared deviations of the balanced net position from the preliminary net position. The reason for trying to minimise the difference between the BNP and the PNP is that the larger that difference, the more extensive the changes required to the underlying IGM.

The weighting factor $NP_{weight,i}$ also deserves additional explanation in the context of the objective function. Because the inverse of the weighting factor is used in the objective function, a large value of $NP_{weight,i}$ means that the weight given to $(PNP_i - BNP_i)^2$ in the minimisation is low. That is just another way of saying that relatively larger adjustments are acceptable for bidding zone i than for another bidding zone with a lower weighting factor. As was noted above, the weighting factor is a proxy for how easily a bidding zone can accommodate a given adjustment of the net position. To restate the earlier example, surely a 500 MW adjustment should be easier to accomplish for a bidding zone such as France than for, say, Portugal.

The second objective function is given by

$$\min_{BFlow_k} \sum_{k \in K} \frac{1}{F_{weight,k}} (PFlow_k - BFlow_k)^2$$

This objective function minimises the aggregated adjustment of the preliminary DC flows as well as preliminary AC flows (explained below). Recall that K is the set of all connections between bidding zones, whether DC or AC, and that k is an index referring to both DC and AC connections. The control variables here are $BFlow_k$; i.e., balanced flows per DC border or AC connection. The objective function is conceptually the same as that used for determining balanced net positions. Note that this function is defined with respect to the preliminarily balanced DC flows (not the initial forecasts provided by TSOs individually) as well as the preliminarily balanced AC flows (simply zero by definition as explained below). The weighting factor $F_{weight,k}$ ensures that the adjustment falls more heavily on DC lines with higher capacity and most heavily on AC connections.

Thus far, in contrast to DC lines which were discussed in some detail in the preceding section, AC connections were hardly mentioned in the present document. However, they do need to be included in the optimisation, too, for otherwise it would not be possible to model flows between bidding zones that are not connected by DC lines. The following paragraphs explain the way in which AC connections are incorporated.

Flows on DC lines (or "DC flows") are defined as the values at the exporting and at the importing ends of a DC line (DC border) which really exists as a physical asset. The difference between the two values is made up by losses which, in the case of DC lines (DC borders), are taken into account via the DC PSLC sub-process.

In contrast to this, the flow values assigned to an AC connection included in the CGMA algorithm represent a flow of electricity from an exporting bidding zone to an importing bidding zone; they do not correspond to physical flows and no losses on such connections are being considered. This is because, in the context of the CGMA algorithm, an AC connection does not correspond to a specific physical asset; it is merely a virtual connection between two bidding zones. It is virtual, for example, in the sense that regardless of the actual number of tie lines linking the two bidding zones, only a single AC connection is modelled in the CGMA algorithm. Conversely, each pair of bidding zones is linked by at most one AC connection in the CGMA algorithm. Further note that in the context of the CGMA algorithm the value of an AC flow cannot be interpreted as the sum of the physical flows on the tie lines that it represents; the AC flows are artefacts of the computation.

In the case of DC flows we speak of "preliminarily balanced DC flows" because the two TSOs might not provide consistent data. Once the averaging rule described in the document has made the data consistent, the DC flows are described as "preliminarily balanced".

For AC flows a similar procedure is not required in order to obtain the equivalent of "preliminarily balanced" values. The reason for this is that TSOs do not provide preliminary AC flow data that might be inconsistent with each other. Preliminary AC flows are set equal to zero by default for all bidding zones, so that any two corresponding flows (i.e., the values for the flow on a particular virtual AC connection) are always consistent; i.e., preliminarily balanced by definition.

In the optimisation model there is no mathematical distinction between AC and DC connections and between AC and DC flows. But for the AC connections and AC flows fixed rules are defined:

- The connection weighting factor for all AC connections is set to a very high value for higher priority in adjustment. The objective is the adjustment of AC connections before the adjustment of DC connections where it is applicable:[16]
  $F_{weight,\hat{k}} \gg \sum_{k \in K_{DC}} F_{weight,k} \; \forall \hat{k} \in K_{AC}$
- The preliminary flow for each AC connection is set to zero:
  $PFlow_{\hat{k}} = 0 \;\; \forall \hat{k} \in K_{AC}$
- The maximum import and maximum export flow for each AC connection is unlimited by default:
  $Flow_{min,\hat{k}} = -\infty \;\; \forall \hat{k} \in K_{AC}$
  $Flow_{max,\hat{k}} = +\infty \;\; \forall \hat{k} \in K_{AC}$

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[16] The concrete value will be defined in the implementation of the algorithm.

The advantage of this approach is a very sizeable reduction in the pre-processing data required. In concrete terms, neither preliminary AC flows (per virtual AC connection) nor capacity restrictions for the latter will have to be provided. In fact, it will not be possible for TSOs to provide these data which will greatly simplify the IT implementation.

One special case needs to be mentioned in connection with the modelling of AC lines. This special case concerns DC lines linking two bidding zones within the same synchronous area if such a DC line is actually operated as a DC line (and not operated in AC-simulated mode) and if, in addition to the DC connection (operated as a genuine DC line), these two bidding zones are also linked by one or more AC connections. Note that it does not matter whether the (single or more than one) AC connection parallels the DC line directly or via a detour (i.e., indirectly via additional bidding zones). At the time of writing (in November 2017) this applied to

- Fennoskan 1 and 2 (operational DC lines linking bidding zones FI and SE3 which are also linked by AC via FI – SE1 – SE2 – SE3)
- GRITA (operational DC connection linking bidding zone IT6 (BRNN) in Italy with Greece (GR) with Italy and Greece also being indirectly linked by numerous AC connections)
- Sweden's planned Southwest Link (DC line linking bidding zones SE3 and SE4 which are also linked by AC)
- ALEGrO – a planned DC line connecting Belgium and the Amprion control area in DE (both of which are indirectly linked in parallel by a number of AC connections)
- COBRA – a planned DC line connecting bidding zone DK1 with bidding zone NL (both of which are also linked indirectly by AC connections)

If the process is not modified for these special cases, the result will be that the preliminary DC flows will hardly be modified (if at all). In other words, the balanced flow values for the DC lines would likely be identical to the preliminary flows. The reason for this is the very large weighting factor that is applied to standard AC connections as well as the lack of a capacity restriction for the latter. The entire adjustment required would effectively be made via the AC connection(s), not the DC line.

For the time being, the preliminary DC flows on such lines will be made consistent in the way described above.

There are a number of constraints that need to be respected. The first constraint

$$\sum_{i=1}^{n} BNP_i = 0$$

is the most straightforward one. It says that the balanced net positions need to sum to zero. That, of course, is the point of computing balanced net positions. Note, however, that the right-hand side of this constraint is zero as a matter of notational convention – because the target net position will always be set equal to zero.

The next set of constraints is a set of inequality constraints which restrict the balanced net position BNP_i to feasible values; i.e.,

$BNP_i \geq NP_{min,i} \forall i \in N$

and

$BNP_i \leq NP_{max,i} \forall i \in N$

Given the extensive discussion of the need for establishing a feasibility range, these constraints also should not be surprising. If one of these constraints becomes binding, the corresponding BNP_i is set equal to the constraint. Holding everything else equal, in that case the adjustment required in other bidding zones increases.

The next set of constraints relates to the flows on DC lines.

Balanced flows must be within the min/max range for every connection (border) between bidding zones:

$$BFlow_k \geq Flow_{min,k} \forall k \in K$$

and

$$BFlow_k \leq Flow_{max,k} \forall k \in K$$

The balanced net positions of each bidding zone must be equal to the aggregated balanced AC and DC flows from and to this bidding zone:

$$BNP_i = \sum_{k \in K_{from,i}} BFlow_k - \sum_{k \in K_{to,i}} BFlow_k \quad \forall i \in N$$

The numerical solution of this optimisation problem requires some customisations.

The two objective functions will be optimised at the same time to ensure the fulfilment of all constraints and to find a combined solution. So the two objective functions must be transformed into a single function:

$$\min_{BNP_i, BFlow_k} W \sum_{i \in N} \frac{1}{NP_{weight,i}} (PNP_i - BNP_i)^2 + \sum_{k \in K} \frac{1}{F_{weight,k}} (PFlow_k - BFlow_k)^2$$

The global weighting factor W is introduced in order to prioritise the first term of the objective function (net positions). Hence W must have a high value:[17]

$W \gg 1$

Additional constraints (e.g., ramping) are not being taken into account. The CGMA process is not intended to give the allocation results; i.e., it does not predetermine the capacity calculation. Instead it serves as an input for the capacity calculation which treats each synchronous area as a copperplate; it is thus “unlimited” (i.e. allocation constraint free).

As far as ramping constraints specifically are concerned, the principal justification for not including these is that the initial forecasts of DC flows are expected to be of sufficiently high quality such that the relevant constraints have already been taken into account in the preliminary DC flows provided. The relevance of concerns in this respect will, of course, be reviewed as part of the CGMA dry run planned for the fourth quarter of 2017.

Applying the algorithm: Step 3 – scenarios without solutions

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[17] The concrete value will be defined in the implementation of the algorithm.

The task of this step is to ensure that a solution for the given model parameters always exists as required by Article 19(3)(d) of the CGMM. Note that the present step only concerns the operation of the algorithm, not the CGMA process. The CGMA process and, in particular, the Active Quality Management Process (AQMP) that is part of the CGMA process complement the operation of the algorithm described here. The AQMP also addresses the problem of non-convergence (i.e., the CGMA algorithm not finding a solution); it is described in detail in the following chapter on the business processes.

As far as the CGMA algorithm is concerned, for unsolvable situations methodology enhancements are needed. To all intents and purposes, the only relevant reason for the non-existence of a solution is a feasibility range for net positions that is too restrictive. Increasing the feasibility range for certain bidding zones can solve this problem. However, if feasibility ranges are to be extended, two questions have to be answered:

1. How exactly (i.e., according to which rules or principles) should feasibility ranges be adjusted?
2. How is it ensured that the extension of the feasibility ranges does not cause problems – after all, the feasibility ranges have been set by TSOs for a reason. If a TSO did not care about the feasibility range, it would presumably have specified a (wider) feasibility range in the first place.

On 1., note that the question of how to relax constraints when an algorithm does not find a solution is a very general one that is well understood and for which various mathematical techniques have been developed and implemented in software programs. The CGMA algorithm makes use of a standard toolkit originally developed by IBM in order to compute the feasibility range adjustments. Following some general background material the explanations below give the intuition behind the adjustment rules used by the CGMA algorithm.

Because of its quadratic objective function, the CGMA optimisation model falls into the general class of quadratic programming problems[18]. The CGMA algorithm can thus make use of the CPLEX solver - part of a software program developed by IBM (IBM ILOG CPLEX Optimisation Studio[19]) - in order to apply a set of standard techniques for solving such quadratic problems. The solver distinguishes between convex and nonconvex quadratic programs. Convex problems are not typically a challenge for the solver – in mathematical parlance it solves these efficiently in polynomial time. Nonconvex quadratic problems are much harder to solve than convex problems; in theoretical terms these are characterized as "NP-hard" (non-deterministic polynomial-time hard). The CPLEX solver is able to use a number of different approaches to solving such problems such as, for example, barrier algorithms and branch and bound algorithms. The default approach used by the CPLEX solver is the barrier optimizer.

Using the CPLEX solver entails a certain approach to relaxing the feasibility ranges which from a mathematical point of view are simply constraints. Specifically, the CPLEX solver uses an

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[18] For an explanation of quadratic programming see Gill, Philip E., Walter Murray, and Margaret H. Wright, Practical Optimization. New York: Academic Press, 1982 reprint edition.
[19] See http://www-03.ibm.com/software/products/en/ibmilogcpleoptistud for additional information

optimisation algorithm analogous to phase I of the simplex algorithm. The solver thus takes a model for which a solution does not exist initially and relaxes the constraints in order to obtain a solution. It does so in two phases and in a way that minimises a weighted penalty function. In the first phase it attempts to find a feasible solution that requires minimum change of constraints; i.e., it minimizes the sum of all feasibility range extensions required by, inter alia, using the slack variables. In the second phase, it finds an optimal solution (with respect to the objective function) among all those solutions which require only as much extension of feasibility ranges (= relaxation of constraints) as was found to be necessary in the first phase.

In other words, the solver has to analyse the influence of different feasibility ranges with respect to the quality of the optimisation results; the extent of the adjustment of the feasibility ranges must minimise the objective function and consider the other constraints. The CGMA algorithm is programmed such that it is able to make these adjustments to feasibility ranges automatically by following the steps described below. The actual operation of the CGMA algorithm is much more complicated, of course, but the description below covers the principal steps and it provides some intuition for the very abstract description above:

The following method will be used to distribute the extensions of feasibility ranges required among the affected bidding zones with respect to (especially but not only) the weighting factors:

1. Try to calculate a solution for the optimisation problem

In case the solver finds no solution:

2. Analyse utilisation of constraint variables
3. Detect binding constraints[20] (where variable value is on border of constraint)
4. Calculate sensitivity of binding constraints with respect to objective function
5. Determine changeable binding constraints with highest impact on objective function
6. Extend constraints so as to achieve maximum impact with respect to the objective function result

→ this leads to a new optimisation model with different constraints

7. Recalculate the optimisation model and find a solution
8. If necessary, the algorithm will repeat steps 2-7 above until it has found a solution.

To make this more concrete, consider the following illustration: Assume that 1500 MW of additional feasibility range in one direction are required. In the first step, this additional adjustment of feasibility ranges will be assigned to the different bidding zones in proportion to their weighting factors. In the example, let us say that there are five bidding zones and that their WFs are 10000 MW, 20000 MW, 30000 MW, 40000 MW, 50000 MW, respectively. The sum of the weighting factors is 150000 MW, so the relative weights of the bidding zones are 1/15 (=10000MW/150000MW), 2/15, ..., 5/15. Therefore, the adjustments for the five BZs would be (1/15)*1500 MW = 100 MW, (2/15)*1500 MW = 200 MW, etc. and the adjustments in total would sum to the 1500 MW that are required.

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[20] A distinction has to be made regarding constraints that can be changed (net position feasibility ranges) and that cannot be changed (DC capacity based maximum import and maximum export flows).

Unfortunately, this distribution may not be possible due to DC line restrictions - there is no point changing the net position feasibility range if a DC line is the limiting factor! In this case the DC line flow will be set equal to its capacity and the "leftovers" require a new calculation. This is where the cleverness of the algorithm outlined above comes in which aims at finding a solution quickly.

To summarise, if the CGMA algorithm finds a solution for given input data, all is well. If there is no solution the algorithm then automatically adjusts (i.e., extends) feasibility ranges as outlined above until it finds a solution. Since no restrictions are imposed upon the feasibility ranges, the existence of a solution is ensured.

However, this leads to the second question stated above: Following the adjustment of feasibility ranges by the algorithm, the resulting feasibility ranges by definition exceed those originally stated by TSOs. In other words, a solution may have been found, but it remains to be confirmed that this solution is realistic in the sense that the TSOs concerned agree with the extension. This is what the Active Quality Management Process (AQMP) described in Chapter 4 aims at.

In step 1, the AQMP tries to ensure that the changes to feasibility ranges are validated by the TSOs concerned. If this cannot be achieved in time (i.e., before the relevant CGM process deadline), step 2 kicks in. Since step 2 leads to a change in the optimisation model, it is described below.

In the light of the explanations above the algorithm will always find a solution. However, it may have to extend feasibility ranges in order to do so. If it is not possible to agree on the extension to feasibility ranges under step 1 of the AQMP, a different approach is needed. In step 2 of the AQMP, the CGMA algorithm will thus be augmented with a set of additional constraints, the absolute minimum and/or maximum net positions (ABS_NP_MIN / ABS_NP_MAX). These constraints will be respected by the algorithm by definition. However, all feasibility ranges not affected by such an additional constraint may be modified by the algorithm in a manner similar to the approach outlined above.

Absolute minimum and/or maximum net positions signal that a TSO would not be able to build an IGM based upon a net position above or below the absolute net position, respectively. Absolute minimum and/or maximum net positions are to be used with great caution as they make TSOs vulnerable to the accusation that the "no undue discrimination" requirement set out in Article 18(3) of Regulation 2015/1222 is not respected.

This concludes the discussion of how the CGMA algorithm deals with situations in which there is not, at first, a solution given the input data provided. The process aspects of such a situation are discussed in more detail in Chapter 4.

DC losses did not feature in the discussion above. The DC losses are to be determined (and net positions are to be adjusted accordingly) as part of the DC PSLC (pole splitting and loss calculation) sub-process which is out of scope of the CGMA process. The CGMA IT Platform will merely check the results of the PSLC sub-process for consistency as part of a quality check.

Applying the algorithm: Outputs

The purpose of the CGMA process is to provide to TSOs data that are inputs of critical importance in the preparation of IGMs (and thus CGMs), namely

- balanced net positions
- balanced flows on DC lines (borders)

The output variables determined by the CGMA algorithm have the same granularity as the input variables. For example, if a TSO who has several bidding zones in its control area provides a single preliminary net position covering the entire control area, the CGMA algorithm will compute a single balanced net position.

The CGMA output data will be used by the DC PSLC sub-process in order to compute flows per individual DC line as well as losses. The results of the DC PSLC sub-process are fed back to the CGMA IT Platform.

As the final step in the CGMA process, the CGMA output data computed by the CGMA algorithm as well as those computed by the DC PSLC sub-process are provided to TSOs (and other relevant parties such as RSCs).

Applying the algorithm: summary

A brief summary concludes the description of the processing phase. First the target net position is established (even though for ease of processing this is always set equal to zero and a non-zero target is taken into account indirectly). Provisionally balanced DC flows and associated minimum and maximum flows per DC line are obtained. In the subsequent step, applying the CGMA algorithm yields balanced net positions (balanced at pan-European level) and DC flows (per DC border). For situations where no solution exists, another process step modifies the optimisation model by extending the net position feasibility ranges. Following the algorithm run, the DC PSLC sub-process (which is not part of the CGMA process) determines DC flows per DC line as well as losses. The results can then be used in order to update the individual grid models.

The following section briefly discusses the post-processing phase.

3.4 Post-processing phase

The post-processing phase entails a number of tasks most of which (specifically the publishing of individual grid models as well as subsequent steps: merging of individual grid models etc.) are not within scope of the present document. A general description of the post-processing phase is provided in the annotated CGMM. As far as the CGMA process is concerned, the question is only how the results of the processing phase are to be used. Application of the CGMA algorithm in the processing phase yields balanced net positions as well as balanced flows on DC lines (borders).

4 Business processes

The present chapter describes the CGMA business processes and the various steps within these processes. This description, together with the description of the CGMA algorithm in Chapter 3, reflects the requirements with respect to the algorithm set out in Article 19(3) and 19(4) of the CGMM.

4.1 CGMA business processes overview

Regardless of the time horizon for which balanced net positions and balanced flows on DC lines are being computed, the steps in the CGMA process are essentially the same (although the deadlines by which the different steps need to have been completed differ, of course).

However, it should be noted that the deadlines for completing the various steps are much more constraining in the case of the (D-2) process than for the other time frames. This creates a special challenge in case the CGMA algorithm cannot find a solution immediately. The options for dealing with this problem are discussed in detail. First, however, the common CGMA process steps are outlined. Following the description of the process steps the deadlines applicable to each step are stated.

Most of the process steps have one or more (performance) indicators associated with them. These indicators are explained in more detail in the CGMA IT specification ("Common Grid Model Alignment Requirements and Technical Specification") described in chapter 6. However, it is useful to reference them in the description of the process steps already as this provides for a more detailed view of the process. The indicators described in the present version of the CGMAM should be thought of as a minimum; it is likely that as implementation progresses and, especially, as lessons are learnt from the parallel run ("dry run") of the CGMA process planned for 2017-Q4, additional indicators may be included.

4.2 Summary of the three phases

As was noted at the very beginning of Chapter 3, the CGMA process consists of three distinct phases. The various steps of the processing phase will be discussed in detail below. The description of the pre-processing and post-processing phases, however, will be kept brief and will serve primarily to clearly delineate the interfaces and the associated responsibilities. The reasons for this are as follows:

- Pre-processing phase: The CGMAM aims to leave TSOs as much freedom as possible and to be only as prescriptive as necessary. With respect to the pre-processing phase, a TSO's only firm obligation is to provide its PPD on time and in the right quality. How TSOs obtain these PPD is entirely their own choice although from the point of view of the overall process the preference is clearly for coordinated approaches. The latter ought to reduce the total adjustment required, so the CGMAM provides guidance by outlining coordinated pre-processing approaches under development (cf. Annex II). These descriptions are meant to be helpful, but it is by no means mandatory for any TSO to adopt either of these or any other particular approach.

- Post-processing phase: The post-processing phase is referred to in the CGMAM (and, in this sense, included in the CGMA process) for the sake of completeness. The output of the CGMA process, the balanced net positions and balanced flows on DC lines, are a critical input for the preparation of IGMs and their subsequent merging into CGMs. All of the latter tasks are part of the post-processing phase. However, the CGMA process proper ends with the provision of the balanced net positions and balanced flows on DC lines to TSOs.

It is helpful to provide an outline of each of the three phases before describing the individual steps within each phase. The different steps are labelled with a code (reference) which makes it easy to refer to them and the indicators associated with each of them. The first element of the codes used is a symbol relating to the process phase:

- A – Pre-processing phase
- B – Processing phase
- C – Post-processing phase

An identifier for the time horizon could be added; e.g., (D-2), (W-1), etc. However, in line with the introductory explanations it does not seem particularly helpful to make that distinction except when defining the deadlines.

Reference	**What happens in this step**
A_*	TSOs prepare their PPD either by themselves (TSO-individual approach) or in coordination with other TSOs (coordinated approach). Alignment agents (RSCs) will likely play an important role in the coordinated approaches. When the PPD have been computed, TSOs provide their PPD to the CGMA IT platform via the OPDE. The pre-processing phase ends when the PPD have successfully passed the syntax check aimed at ensuring that the TSO's submission can be processed by the CGMA IT platform. (The content is assessed during the processing phase; see below.)

Reference	What happens in this step
B_*	The processing phase begins with a semantics check of the PPD provided to the CGMA IT platform. In other words, the content will be checked with respect to a number of quality criteria. In the case of the (D-2) time frame, missing or poor-quality data may be substituted by the CGMA IT platform. Once a full set of PPD is available, the CGMA algorithm described in the preceding chapter establishes balanced net positions and balanced flows on DC lines (borders). If convergence cannot be achieved immediately, a work-around procedure ensures that a solution can nevertheless be found. Balanced net positions and balanced flows on DC lines (per border) are then further adjusted by the separate DC PSLC sub-process (not part of CGMA): flows are computed for individual DC lines and DC losses are determined and the results of this sub-process are fed back to the CGMA IT platform. The processing phase ends when balanced net positions and balanced flows on DC lines have been made available to all participating TSOs.
C_*	In the post-processing phase each TSO by default adjusts its IGM by using the balanced net positions and balanced flows on DC lines as input data. The IGM adjustment may optionally be delegated to the alignment agent (RSC).

As part of this overview, the principal roles and parties involved should be explained. First of all, there are the TSOs with clearly defined responsibilities related to the provision of PPD. Pursuant to Article 19(8) of the CGMM, each TSO has to designate an alignment agent. It is expected that all alignment agents will be RSCs. However, the converse is not necessarily true in that some RSCs may decide not to offer the services described below. Article 19(8)(c) of the CGMM assigns to alignment agents the responsibility for ensuring that the CGMA "*results obtained are consistent with those obtained by all other alignment agents (if any)*." This task as well as the tasks related to the Active Quality Management Process described below clearly require some measure of cooperation between RSCs. It may be the case that this cooperation will be facilitated by a coordinator (i.e., an RSC with a coordinating function) and that this coordinator role will rotate among different alignment agents / RSCs. The cooperation between different alignment agents (roles, responsibilities etc.) and, in particular, the tasks and responsibilities of the coordinator are clearly topics to be addressed in the "Inter RSCI Agreement on Coordination and Minimum Standards of Regional Security Coordination Initiatives" envisaged in the "Multilateral Agreement on Participation in Regional Security Coordination Initiatives". In line with the deadline stated in Annex 3 of the Multilateral Agreement, the relevant provisions need to have been agreed and included in the Inter-RSC Agreement by the end of 2017. Future versions of the present CGMAM will be updated in the light of the Inter-RSC Agreement.

Finally, two optional elements of the pre-processing data mentioned at the very beginning of the preceding chapter, the absolute minimum net position (ABS_NP_MIN) and the absolute maximum net position (ABS_NP_MAX), should be explained in more detail here as they will be of considerable importance in this chapter.

If a TSO's balanced net position may under no circumstances be lower than a certain value, that TSO is facing a stability threat and can set an ABS_NP_MIN in line with this restriction. Conversely, if a TSO's balanced net position may under no circumstances exceed a certain value, that TSO's constraint is referred to as an adequacy threat and the TSO can set an ABS_NP_MAX. A TSO could theoretically even set both constraints; however, it still needs to respect the requirement for a minimum feasibility range of 2*β*WF%. Note, however, that the ABS_NP_* are meant to be used on an exceptional basis only and they have to respect consistency requirements: ABS_NP_MIN has to be less than or, at most, equal to (PNP + FR_neg); ABS_NP_MAX has to be greater than or, at most, equal to (PNP + FR_pos). The following diagram illustrates the concept of absolute minimum and maximum net positions:

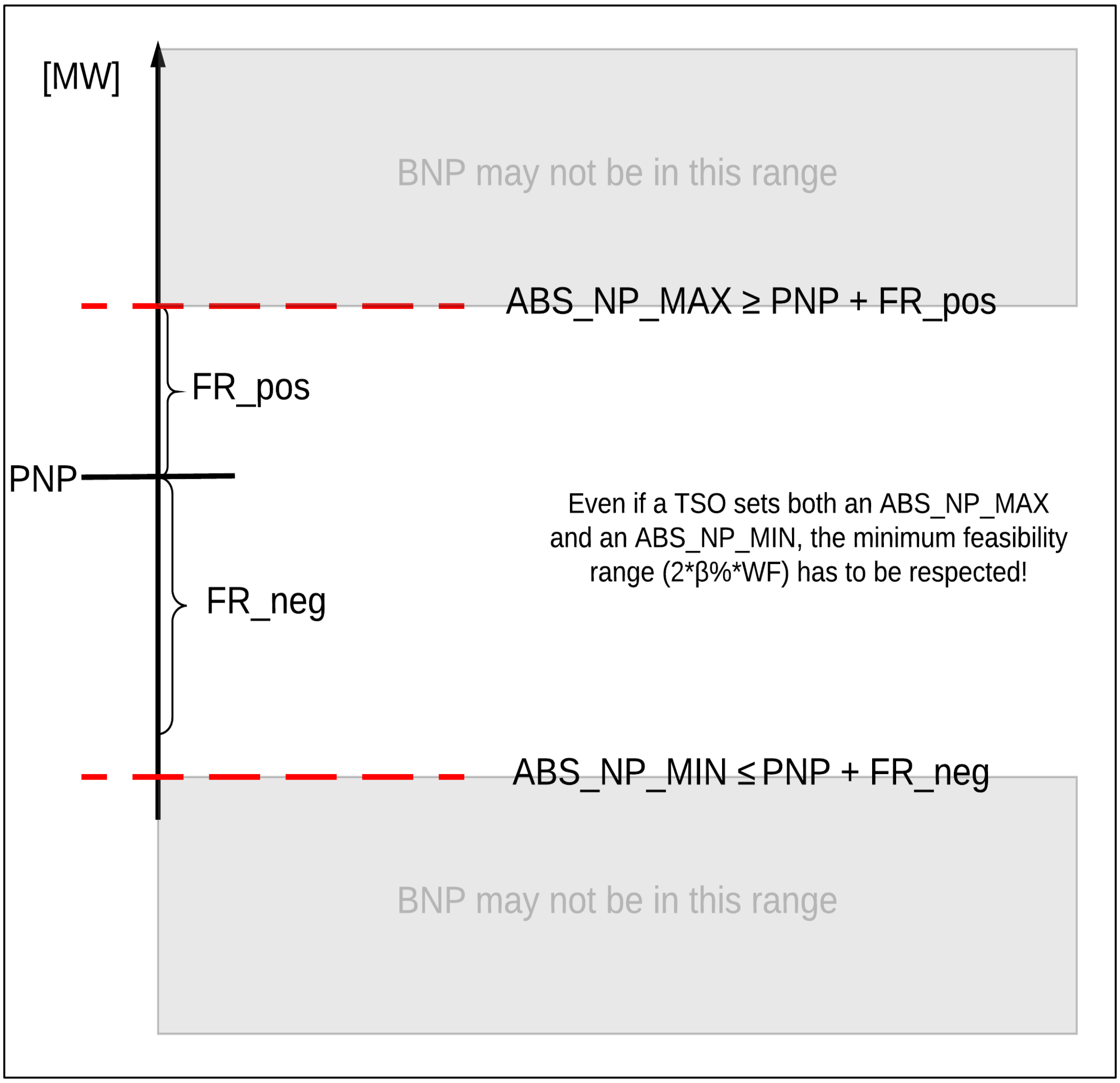

Figure 4: Absolute minimum and maximum net positions

4.3 Pre-processing phase process steps

Reference	What happens in this step
A_010	Determination of PPD
A_020	PPD made available by TSOs
A_030	CGMA syntax check
A_040	End of pre-processing phase

These process steps and the associated (performance) indicators are described in more detail in the following table.

Default rule used in the tables in this chapter:

- References to IT systems involved are meant to be comprehensive; i.e., if, for example, an indicator refers to the "CGMA IT platform" but does not refer to, say, the Quality Portal (QAS), then the data relating to that indicator will not be accessible via the QAS, they will only be available via the CGMA IT platform

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
A_010	TSOs determine their PPD either on an individual or coordinated basis	(no relevant indicators at European level)		TSOs and / or RSCs may want to define their own (performance) indicators; however, as the process by which TSOs establish their PPD is out of scope of the CGMAM, no relevant indicators can be set at pan-European level
A_020	TSOs provide their PPD to the CGMA IT platform via the OPDE..			Provision of PPD by TSOs may, where agreed, be delegated to RSCs. This is especially relevant in case of a coordinated approach (RSC would then provide PPDs on behalf of all involved TSOs). It means that this RSC is the party with which the alignment agent will communicate instead of the TSO(s) in the rest of the process, especially for quality gate issues. RSC and alignment agent may be the same party, which favours this approach.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		A_020_010	General OPDE syntax check passed? Per TSO All time frames Each submission OPDE	This indicator has been added for the sake of completeness. It is expected that all data submitted to the OPDE will have to pass a general OPDE syntax check, so this step is included here for the PPD as well. Data that do not pass the OPDE syntax check will be rejected and TSOs will be informed about the rejection. However, this indicator is not expected to be analysed as part of the CGMA process.
		A_020_020	Time of submission of PPD Per TSO All time frames Each submission CGMA IT platform	As noted, applies to all PPD submissions whether (ultimately) successful or not
		A_020_030	Data format used for submission of PPD Per TSO All time frames Each submission CGMA IT platform	Each TSO was originally expected to choose and then continue to use one of two data formats for providing its PPD to the CGMA IT platform. However, given that at least for the foreseeable future only a single data format will be used, this indicator could be left out for the time being.
A_030	During the CGMA syntax check the CGMA IT platform verifies compliance with the format (and related) requirements of the CGMA IT platform; a submission that does not meet the requirements is rejected and the TSO concerned is informed accordingly.			
		A_030_010	CGMA syntax check successful? Per TSO All time frames Each submission CGMA IT platform	In order for the CGMA IT platform to be able to work with the PPD, the PPD submissions need to be in a format that the CGMA IT platform can understand. This is what is checked in this process step.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		A_030_020	PPD successfully submitted ? Per TSO All time frames Each submission CGMA IT platform	This particular indicator refers to the syntax only; "successfully" does not refer to the contents.
A_040	At this point the pre-processing phase has been completed. In the subsequent step (i.e., during the processing phase) the PPD will be checked with respect to their content.	(no relevant indicators at European level)		

4.4 Processing phase process steps

Reference	What happens in this step
B_010	Quality gate (CGMA semantics check)
B_020	Availability of a full set of PPD is ensured
B_030	First run of CGMA algorithm
B_040	Active quality management process (AQMP) – step 1: validation of adapted FRs
B_050	Active quality management process (AQMP) – step 2 [(D-2) only]: augmented CGMA algorithm
B_060	Ensure consistency of results obtained by different alignment agents (if any)
B_070	CGMA process results available
B_080	End of processing phase

These process steps and the associated (performance) indicators are described in more detail in the following table:

B_010 - Quality gate (CGMA semantics check)

At the beginning of the processing phase the PPD submitted are checked for "quality" in the sense of "content" as opposed to "format". That part of the process is also referred to as the "quality gate". The quality gate basically consists of a series of checks and tests that each TSO's PPD have to pass in order to be considered to be of sufficient quality. "Of sufficient quality" means that the PPD can be used by the CGMA algorithm without any adjustment, resubmission of data, or substitution. Such adjustments or substitutions are made as part of the subsequent process step. In order to ensure that the deadline for the submission of PPD is respected, the CGMA IT platform stops accepting PPD when the corresponding deadline has been reached. The submission of data after the deadline has to be especially authorised by an alignment agent and is logged.

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Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
B_010	As PPD are submitted, the CGMA IT platform --runs a number of checks on the PPD submitted (see below), --adjusts the data as needed, and --informs the TSO concerned about the results. At the agreed cut-off time, the CGMA IT platform blocks further PPD submissions.			
		B_010_010	Are minimum requirements with respect to FRs respected? Per TSO All time frames Each submission CGMA IT platform	This concerns the agreed minimum range (which is determined by the WF). The FR is defined relative to the PNP so it is in principle always consistent with the PNP. An insufficiently wide FR does not lead to the PPD being rejected (see next line)

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_010_020	Adjustments to insufficiently wide FRs (including a special mention if ABS_NP_* had to be exceeded)? Per TSO All time frames Each submission CGMA IT platform	The CGMA IT platform automatically adjusts an insufficient FR and informs the TSO concerned about the new values used. This approach makes it possible to retain the remainder of the PPD, notably the PNP, rather than substitute the complete set of PPD. Default adjustment: FRneg and FRpos are each increased by half of what is still needed in order to reach the minimum required If the default adjustment were to lead to one of the ABS_NP_* (if any) being exceeded, the constraining FR would be set to equal the corresponding ABS_NP_* and the remainder of the adjustment needed would be made to the other FR. If following the above procedure were to lead to both ABS_NP_* being exceeded, then in the first instance both FRs would be set to equal the corresponding ABS_NP_*. The remaining adjustment needed would then, once again, be assigned to both FRs equally such that both ABS_NP_* would be exceeded by the same absolute amount in terms of MW. Of course, the TSO is alerted to this modification and invited to resubmit the PPD (see B_020)

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_010_030	Where applicable: are DC data complete (expected flows; as well as $IFlow_{max,k,i}$ and $IFlow_{min,k,i}$)? Per TSO All time frames Each submission CGMA IT platform	Adjustments to the DC FRs are not mentioned, because the DC FRs are, in principle, given by the maximum permissible import and export flows which are equal to the technical capacity. As noted in the description of the CGMA algorithm, TSOs can specify a narrower DC FR due to operational requirements (see below).
		B_010_035	Where applicable, adjust DC data Per TSO All time frames Each submission CGMA IT platform	This step generally refers to the preparation of preliminarily balanced DC flows as well as consistent maximum import and export flows. If data from one TSO are missing, data from the other TSO are used. If data from the TSOs are inconsistent, they are consolidated according to agreed rules. The TSOs concerned are informed who are allowed to upload new data if feasible within the deadline.
		B_010_040	Are ABS_NP_* provided? Per TSO All time frames Each submission CGMA IT platform	All values set shall be reported per TSO. As these are entirely optional data, PPD not containing ABS_NP_* will not be rejected. ABS_NP_MIN corresponds to a stability threat ABS_NP_MAX corresponds to an adequacy threat It is also possible to specify both; however, the minimum FR has to be respected.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_010_045	Where applicable (i.e., where $IFlow_{max,k,i}$ and $IFlow_{min,k,i}$ for a DC cable have been provided), are $IFlow_{max,k,i}$ and $IFlow_{min,k,i}$ consistent with the technical limits of the DC line? Per TSO All time frames Each submission CGMA IT platform	Values per TSO. These values could be said to be a DC equivalent of ABS_NP_*. They cannot, of course, exceed the technical limits of the cable. The CGMA IT platform will therefore adjust the data provided if necessary.
		B_010_050	Are consistency requirements with respect to ABS_NP_* respected? Per TSO All time frames Each submission CGMA IT platform	The ABS_NP_* have to be consistent with the other PPD provided (e.g., ABS_NP_MAX of + 500 MW is not consistent with a PNP of + 1000 MW). The data are consistent if the following formulae hold: ABS_NP_MAX ≥ PNP + FRpos ABS_NP_MIN ≤ PNP + FRneg (Note the sign convention.) If this is not the case, the PPD should be rejected and the TSO should be informed accordingly.
		B_010_055	Are consistency requirements with respect to IFlow (*,k,i) respected? Per TSO All time frames Each submission CGMA IT platform	The IFlow(*,k,i) have to be consistent with the other PPD provided. The corresponding tests are equivalent to those for the ABS_NP_*. If the data are not consistent, the PPD should be rejected and the TSO should be informed accordingly.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_010_060	Are general consistency requirements met? Per TSO All time frames Each submission CGMA IT platform	This is about plausibility checks such as reasonable limits – e.g., a "small" bidding zone should not have a PNP of 10000 MW etc. However, a reference to such plausibility checks is recorded here primarily as a reminder. It will be rather difficult to define sensible tests in the first place and even if and when such tests have been included in the checking routine in the light of operational experience it is not at all clear whether PPD could or should be rejected on the basis of such tests. A more likely function is that such plausibility checks will serve as a warning that, for example, flags PPD for manual checking.
		B_010_070	Have PPD successfully passed the Quality Gate? Per TSO All time frames Each submission CGMA IT platform	This particular indicator refers to the content only; "successfully" does not refer to the syntax (which is checked in a preceding step)

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_010_080	Time of submission of all sets of PPD that have successfully passed the Quality Gate? Per TSO All time frames Each submission CGMA IT platform	The relevant criterion is the dispatch of the corresponding ACK file; the time at which that file is dispatched is recorded. The most important question, of course, is whether the associated deadline has been met? Note that if, upon request of the TSO, the CGMA IT platform is reopened for submission of revised / updated PPD, this indicator would also need to be recorded at a later stage in the process. However, for the time being an explicit reference has not been included a second time below.
		B_010_090	Logging of PPD-related ACK files Per TSO All time frames Each submission CGMA IT platform	

B_020 - Availability of a full set of PPD is ensured

The CGMA IT platform subsequently ensures the availability of a full set of PPD; regardless of whether all TSOs have submitted their PPD in time and regardless of the quality of the PPD submitted. In other words, if data are missing the CGMA IT platform substitutes these data; limiting the substitution to those data that are missing.
The substitution rules used are similar to those defined for the overall CGM process and described in the annotated CGMM. For the year-ahead time frame, no substitution rules are defined because, given the time available, substitution is to be strictly avoided. The month-ahead and the week-ahead time frame are not mandatory at pan-European level. If all relevant regions agree on a common approach, this common approach could be documented in a future version of the CGMAM. For the time being, no substitution rules are included for these time frames.

As for the (D-2) time frame, one analogy with the substitution rules for IGMs referred to above is that both pre-processing data for the same day of delivery (the equivalent of IGMs for the same day of delivery) and CGMA results for the complete history of prior algorithm runs (the equivalent of archived IGMs for days of delivery in the past) may be available as substitute data.

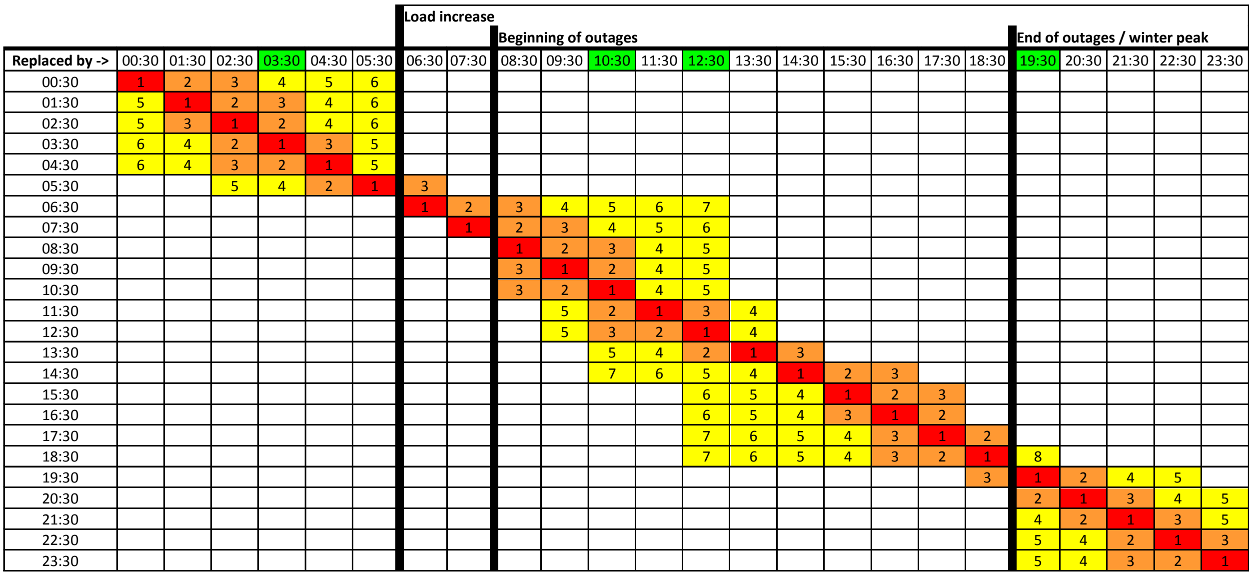
In the case of the CGMA process, substitute data would, in principle, be required for the full set of those pre-processing data that are mandatory, i.e.,

- preliminary net position;
- feasibility range for the adjustment of the preliminary net position;
- preliminary flows on DC lines;
- maximum import and maximum export flows on DC lines

However, no genuine substitution will be carried out in the case of the feasibility range for the adjustment of the preliminary net position and in the case of the maximum import and maximum export flows on DC lines. If these data are not available, they will always be replaced with the minimum feasibility range, placed symmetrically around the preliminary net position, and the technical capacity limits of the DC line, respectively.

As for the preliminary net position and the preliminary flows on DC lines, the basic principle is to use substitute data that are as representative of the given scenario as possible.

Step 1: Use values for different timestamps from the same set of PPD (i.e., the same day of delivery) by applying the order of substitution indicated in the matrix below (Figure 5).



							Load increase		**Beginning of outages**											**End of outages / winter peak**				
Replaced by ->	00:30	01:30	02:30	03:30	04:30	05:30	06:30	07:30	08:30	09:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30
00:30	1	2	3	4	5	6																		
01:30	5	1	2	3	4	6																		
02:30	5	3	1	2	4	6																		
03:30	6	4	2	1	3	5																		
04:30	6	4	3	2	1	5																		
05:30			5	4	2	1	3																	
06:30							1	2	3	4	5	6	7											
07:30								1	2	3	4	5	6											
08:30									1	2	3	4	5											
09:30									3	1	2	4	5											
10:30									3	2	1	4	5											
11:30										5	2	1	3	4										
12:30										5	3	2	1	4										
13:30											5	4	2	1	3									
14:30											7	6	5	4	1	2	3							
15:30													6	5	4	1	2	3						
16:30													6	5	4	3	1	2						
17:30													7	6	5	4	3	1	2					
18:30													7	6	5	4	3	2	1	8				
19:30																			3	1	2	4	5	
20:30																				2	1	3	4	5
21:30																				4	2	1	3	5
22:30																				5	4	2	1	3
23:30																				5	4	3	2	1

Figure 5: Substitution matrix

For example, for the 11:30 timestamp the substitution order would be:

1 – 11:30 (no substitution)

2 – 10:30

3 – 12:30
4 – 13:30
5 – 9:30

Step 2: If step 1 does not succeed (for example, because the entire file with PPD has not been received by the CGMA IT Platform), substitute data will be obtained from the Pan-European Verification Platform (PEVF) in the form of matched schedules relating to the same timestamp for a previous day of the same type. The PEVF is an application linked to the OPDE just like the CGMA IT platform and will be briefly illustrated in chapter 6. Three types of days are distinguished: working day, Saturday, Sunday. (A calendar of bank holidays etc will not be maintained by the CGMA IT platform.) In step 2, the CGMA IT platform will go back at most five days. If no substitute data can be obtained in this manner, the system moves on to step 3.

Step 3: In step 3, substitute data would once again be obtained from the PEVF in the form of matched schedules related to different timestamps for a previous day of the same type by applying the above substitution matrix. As in step 2, the CGMA IT platform will go back at most five days. If no substitute data can be obtained in this manner, the system moves on to step 4.

Step 4: In step 4, the PEVF would continue to be the source of the substitute data. The data to be used in step 4 are matched schedules relating to the same timestamp on a past day of a different type. The system would go back at most five days.

If steps 1 to 4 do not yield usable substitute data, default values of zero for both the preliminary net position and the preliminary flows on DC lines are used.

Note that if PPD are substituted, all PPD will be substituted. For example, if only the preliminary net position is missing the system will nevertheless substitute the preliminary net position and (if applicable) the DC-related pre-processing data.

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Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
B_020	(D-2) time frame: At the agreed cut-off time, the CGMA IT platform ensures the availability of suitable PPD for each bidding zone by --replacing missing data with substitute data --modifying low-quality data (e.g., insufficient feasibility ranges) --informing the TSOs concerned about the substitution and by reopening, upon request, the CGMA IT platform for submission of (updated) PPD --TSOs are also informed about adjustments to FRs and invited to resubmit new PPD with updated FRs themselves; upon request the CGMA IT platform can be reopened for submission of (updated) PPD (W-1) / (M-1): Not pan-European time frames; may be added at a later time (Y-1): Substitution of flawed or missing data is not acceptable for this time horizon; the alignment agents are responsible for obtaining a suitable set of PPD from their TSOs			
		B_020_010	PPD substituted because of (...) Per TSO All time frames Each submission CGMA IT platform	The indicator should distinguish between substitutions due to poor quality data and substitutions necessary because no data were submitted.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_020_020	Preliminary net position across all bidding zones For the CGM area All time frames Each submission CGMA IT platform	The CGMA IT platform would, by default, aggregate across the entire CGM area. This indicator does not, in principle, allow making inferences with respect to individual synchronous areas.
		B_020_030	Aggregate FR For the CGM area All time frames Each submission CGMA IT platform	The CGMA IT platform would, by default, aggregate across the entire CGM area. This indicator does not, in principle, allow making inferences with respect to individual synchronous areas. Specifically, the aggregate FR exceeding the aggregate PNP in the opposite direction as the aggregate deviation from the target net position is a necessary (but not sufficient) condition for achieving convergence.

B_030 – First run of CGMA algorithm

The CGMA algorithm will take whatever input data are available from the CGMA IT platform following the cut-off time and possible substitution of missing or poor-quality data and attempt to obtain a solution; i.e., a set of balanced net positions and balanced flows on DC lines (borders).

- The (optional) absolute net positions (ABS_NP_MAX and ABS_NP_MIN) are not used as constraints in the first run of the algorithm. TSOs can provide these additional constraints if the net position based upon which they build their IGM may not, under any circumstances, be lower (ABS_NP_MIN is a lower bound for permissible BNP) or higher (ABS_NP_MAX is an upper bound for permissible BNP) than a certain value.
- If the algorithm finds a solution in the first run without adapting feasibility ranges, that solution is the default solution. The CGMA algorithm may be run again at a later time, but the first solution will be retained as the default solution.
  - At the (D-2) time horizon, the first run of the CGMA algorithm is to be completed just after 16:35h. (16:35h is the (D-2) deadline for all input data to be available, by substitution if necessary.)
  - PI: "Solution obtained without modification of FRs"
  - Note that since no feasibility ranges have been adapted, the absolute net positions (ABS_NP_*) cannot have been exceeded.

- If the algorithm cannot find a solution without adapting feasibility ranges, it will extend the feasibility ranges by using the approach described at the very end of the chapter on the CGMA algorithm ("Applying the algorithm: Step 3 – scenarios without solutions").
  - PI: "No convergence without adaptation of FRs; FRs extended by a total of X MW / Y %"
  - Since no restrictions are imposed upon the extent to which the FRs may be extended, the existence of a solution is guaranteed from a mathematical point of view. Whether the solution obtained is meaningful / relevant in practical terms will be assessed in the subsequent step ("Validation of adapted FRs")

Reference	**Description (responsible party; input / starting point; output / results)**	**Indicator ref.**	**Indicator description (incl. destination)**	**Comments**
B_030	First run of CGMA algorithm as described above			
		B_030_010	Time at which first algo run was completed One value per CGMA process Applies to all time frames CGMA IT platform	Completion of algorithm run means that the previous step has to have been completed. Checking on the algorithm run thus provides a simple means of checking whether the earlier CGMM deadline was respected if the algo run is completed at or before 16:35h (D-2).
		B_030_020	Solution obtained without modification of FRs? One value per CGMA process Applies to all time frames CGMA IT platform	
		B_030_030	No convergence without adaptation of FRs; FRs extended by a total of X MW / Y % One value per CGMA process Applies to all time frames CGMA IT platform	This indicator, in principle, only becomes relevant if the value of indicator B_030_020 above is "No". If a solution is found without adapting FRs, the value of indicator B_030_030 becomes "Not applicable" (an even simpler solution would be to provide no value in that case).

B_040 – Active quality management process (AQMP) – step 1: validation of adapted FRs

(NB: This process step is not relevant if the CGMA algorithm has managed to find a solution without adapting FRs.)

If, in the first run, the CGMA algorithm had to adapt the FRs in order to obtain a solution, that solution remains to be confirmed. The confirmation entails validating the adapted (extended) FRs. In other words, if it can be shown that the adjustment of the FRs was acceptable to all TSOs, then the solution obtained is a valid solution.

This first step of the AQMP makes use of the fact that within a synchronous area it does not matter mathematically where (in which bidding zone or zones) the FRs are extended. In particular, within a synchronous area the extension of one or two sets of FRs by a large amount is equivalent to the extension of many FRs by a small amount. The latter kind of adjustment is the adjustment made by the CGMA algorithm. However, in a synchronous area with many TSOs such as Continental Europe it would be very time-consuming to contact each and every TSO and obtain permission for extending the FRs. Also, if even one TSO refused the adjustment, other TSOs' FRs would have to be extended by an even larger amount. Therefore, it would be much easier to validate the extended FRs if the corresponding commitments could be obtained from a small number of TSOs.

All TSOs and their alignment agents are therefore encouraged to pre-agree on mutual assistance arrangements by which they commit to help each other by extending their feasibility ranges if necessary. Such arrangements are all the more valuable in cases where a TSO knows that it will occasionally have to specify absolute minimum or maximum net positions. Note that all TSOs will, at any rate, have to enter into contractual agreements with their alignment agents (RSCs). Such contractual agreements should be tailored to the specific needs of each region or group of TSOs and might very well include operational agreements such as provisions on mutual assistance in the CGMA process.

Before outlining how this approach would be implemented in practical terms, note that step 2 of the AQMP provides for a fall-back procedure that essentially works as follows: The CGMA algorithm is re-run with an additional set of constraints. These additional constraints – the ABS_NP_* - guarantee that, for example, a TSO that knows that its imports of electricity exceeding a certain value would lead to a stability threat can ensure that such constraints will be respected; i.e., that its feasibility ranges will not be involuntarily expanded beyond the constraint (in this case ABS_NP_MIN). Of course, such constraints could be used to address other types of restrictions in addition to import restrictions such as a minimum import or maximum export value in case of an adequacy threat. To the extent that such constraints are set and prevent the corresponding TSOs' feasibility range(s) from being adjusted, all other TSOs' feasibility ranges have to be adjusted by a commensurately larger amount. Note, however, that making use of such ABS_NP_* constraints in the computation of the results is to be avoided as much as possible. Therefore, the fall-back procedure is preceded by step 1; an alternative approach during which the ABS_NP_* constraints do not have to be explicitly included in the calculation of the results, but the requirement in Article 19(4)(c) of the Common Grid Model Methodology is respected nonetheless.

In practical terms, the CGMA algorithm will aggregate the FR adjustments it has made by alignment agent. Each alignment agent thus knows the total amount of the FR adjustments (in terms of MW) that it needs its TSOs to agree to. In particular, if a single TSO were to agree to accept the entire adjustment that would ensure that this alignment agent has made the contribution expected from it.

As far as the process is concerned, the alignment agents might agree for one of their number to act as coordinator. Note, however, that these details of implementation have not yet been discussed and are unlikely to be resolved before the dry run envisaged for 2017-Q4. If the CGMA algorithm has to extend the FRs, this is signalled to all alignment agents (and all TSOs) in a suitable manner; the details of this alert mechanism remain to be determined. One option might be for alignment agents to organise a conference call at a certain time during which alignment agents unable to provide their assigned contribution in terms of extended FRs can ask other alignment agents for assistance. As for whether a conference call is the most suitable means of communication, further trials and testing can be conducted during the dry run in 2017-Q4. Nothing hinges on using this or an alternative means of communication.

In practical terms, each alignment agent would (likely based on the above-mentioned pre-agreements) contact one or more of its TSOs with a view to obtaining agreement to extend the TSO's (TSOs') FR (typically by the maximum amount acceptable) until the total amount of adjustment of FRs required from that alignment agent has been obtained. Either the TSOs concerned would send updated PPD (in which case TSOs need to be allowed to provide these data even after the usual cut-off time) or the alignment agent makes these modifications manually via the CGMA application GUI. In the latter case, a means of ensuring that TSOs' agreement is documented in a robust manner needs to be found. For example, if the alignment agent establishes contact by telephone and their (telephone) lines are recorded anyway, the documentation required would be ensured without any additional preparations. TSOs would also need to receive an acknowledgement via a suitable mechanism (to be determined).

When all alignment agents have provided their assigned share of the adjustments required, the CGMA algorithm can be manually restarted using the updated PPD / FRs as input. If there were to be a coordinating RSC, for example, that coordinator could trigger this re-calculation. Under the assumptions made, a solution would be guaranteed to exist and would have the property that (i) all (updated) FRs are respected and (ii) none of the ABS_NP_* are violated.

Step 1 of the active quality management process, if successful, ensures that a solution is found without including another set of constraints in the algorithm. No involuntary changes to FRs are required.

- "successful completion of algo run following voluntary modification of FRs by X MW" is registered (PI)

- FR adjustments accepted are to be reported per TSO

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
B_040	Solution requires adjustment of FRs (i.e., confirmation that these FR adjustments were acceptable)			
		B_040_010	Total adjustment requested per alignment agent Per alignment agent All time frames CGMA IT platform	
		B_040_020	Total adjustment provided per alignment agent and per TSO Per alignment agent; per TSO All time frames CGMA IT platform	Note that agreeing to an adjustment is equivalent to providing updated PPD and is recorded accordingly
		B_040_030	Manual algorithm runs Per CGMA process All time frames CGMA IT platform	Also applies to manual algorithm runs triggered in subsequent steps
		B_040_040	Computation time required for all manual algorithm runs Per CGMA process All time frames CGMA IT platform	
		B_040_050	Time of last PPD adjustment Per CGMA process All time frames CGMA IT platform	
		B_040_060	Computation time required for final run of CGMA algorithm Per CGMA process (if applicable) All time frames CGMA IT platform	

B_050 – Active quality management process (AQMP) – step 2 [(D-2) only]: augmented CGMA algorithm

If step 1 of the AQMP is not successful (i.e., no solution is found) by the cut-off time (17:05h in the case of the (D-2) process), the CGMA algorithm is automatically restarted. However, under step 2 of the AQMP the CGMA algorithm is augmented with an additional set of constraints, namely the absolute net positions (ABS_NP_MIN and ABS_NP_MAX).

Note that the alignment agent shall have the ability to try out the procedure described in this step earlier in the process (i.e., before the 17:05h deadline) for trial and testing purposes without the results being used automatically ("dry run").

As the augmented CGMA algorithm is run, three outcomes are possible:

- The algorithm finds a solution and none of the additional constraints become binding.
    - PI: "No convergence without adaptation of FRs; augmented CGMA algorithm run; none of the ABS_NP_* binding; solution obtained; FRs extended by a total of X MW"
- The algorithm finds a solution and one or more of the additional constraints become binding.
    - PI: "No convergence without adaptation of FRs; augmented CGMA algorithm run; one or more of the ABS_NP_* binding; solution obtained; FRs extended by a total of X MW" is registered (PI) and published to QAS
    - Those ABS_NP_* constraints that were binding are reported to all TSOs
- There is no solution. This outcome is exceedingly unlikely in that it requires all TSOs to set additional constraints in the form of absolute net positions. For the sake of completeness, if that outcome should materialise the solution obtained during step 1 (guaranteed to exist because the FRs are extended as necessary) is retained as the solution. In this case TSOs would have to be informed about the outcome via a suitable alert mechanism.
    - PI: "No convergence without adaptation of FRs; augmented CGMA algorithm run; all of the ABS_NP_* binding; no solution obtained; FRs extended by a total of X MW / fall-back to default solution" is registered (PI) and published to QAS and sent to TSOs as an alert (means of communication to be determined)

To repeat, if the augmented CGMA algorithm finds a solution by extending feasibility ranges involuntarily, this can be done in the following way: Feasibility ranges can be extended on both sides for those TSOs who have not set any ABS_NP_*. If a TSO has set an ABS_NP_MAX, the balanced net position for that TSO shall not exceed the value of ABS_NP_MAX. If a TSO has set an ABS_NP_MIN, the balanced net position for the TSO shall not be less than the value of ABS_NP_MIN.

With respect to step 2 of the AQMP, the more ABS_NP_* conditions are set and the more constraining these are, the more the FRs of TSOs without such ABS_NP_* conditions will have to be adjusted.

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Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
B_050	Augmented CGMA algorithm is run			
		B_050_010	No convergence without adaptation of FRs; augmented CGMA algorithm run; none of the ABS_NP_* binding; solution obtained; FRs extended by a total of X MW Per CGMA process All time frames CGMA IT platform	
		B_050_020	No convergence without adaptation of FRs; augmented CGMA algorithm run; one or more of the ABS_NP_* binding; solution obtained; FRs extended by a total of X MW Per CGMA process All time frames CGMA IT platform	
		B_050_030	Binding ABS_NP_* constraints Per CGMA process per TSO All time frames CGMA IT platform	
		B_050_040	No convergence without adaptation of FRs; augmented CGMA algorithm run; all of the ABS_NP_* binding; no solution obtained; FRs extended by a total of X MW / fall-back to default solution Per CGMA process All time frames CGMA IT platform	

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B_060 Ensure consistency of results obtained by different alignment agents (if any)

This task is recorded here for the sake of completeness; it is not expected to be of practical relevance. However, by way of background note that since all alignment agents are using the same CGMA IT platform, they must logically be producing identical (i.e., consistent) results if and only if their computations are based upon the same input data. The only way in which inconsistencies might thus be introduced would be for alignment agents to use different sets of input data. The latter scenario is avoided by imposing the simple rule that the CGMA results to be used in the later stages of the process are to be those based upon the definitive run of the CGMA algorithm (in the case of the (D-2) time horizon this is to be the run starting at or just after 17:05h).

B_070 - CGMA process results available

The CGMA IT platform makes the results of the CGMA process available to all TSOs and RSCs via the OPDE in a CIM-based format and also publishes the results of the CGMA process via the quality portal. The CGMA results (output data) are, for each scenario and each TSO:

- balanced net position
- where applicable, balanced flows on DC lines (borders)

The granularity of the output data corresponds to the granularity of the input data. For example, if a TSO provides a single PNP for a control area covering more than one bidding zone, that TSO will receive a single balanced net position in return.

Reference	**Description (responsible party; input / starting point; output / results)**	**Indicator ref.**	**Indicator description (incl. destination)**	**Comments**
B_070	CGMA output available			
		B_070_010	CGMA results incl. time-stamp of delivery provided to primary users (i.e., the users who provided the PPD) Per CGMA process; per TSO All time frames CGMA IT platform	

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
		B_070_020	CGMA results incl. time-stamp of delivery provided to secondary users (i.e., other users who have a use for the results, if any) Per CGMA process; per TSO All time frames CGMA IT platform	

Not covered in this process description is the separate DC PSLC (pole splitting and loss calculation) sub-process, as part of which balanced flows are computed for individual DC lines, losses are calculated, and balanced net positions are adjusted accordingly.

B_080 - End of processing phase

The processing phase ends when balanced net positions and balanced flows on DC lines have been made available to all participating TSOs.

4.5 Post-processing phase process steps

Reference	What happens in this step
C_010	Data for checking for compliance with CGMA results available
C_020	Data for checking for compliance with "best forecast" criterion available
	The following steps are mentioned for the sake of completeness, but are no longer part of the CGMA process:
	Each TSO adjusts its IGM based on its balanced net position and (if applicable) balanced flows on DC lines
	Each TSO provides the aligned IGM for merging into the CGM

These process steps and the associated (performance) indicators are described in more detail in the following table:

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
C_010	Data for checking for compliance with CGMA results available	C_010	Data for checking for compliance with CGMA results available Per CGMA process; per TSO All time frames This indicator is expected to be computed by QAS	"Compliance check" refers to checking whether the updated IGMs are indeed consistent with the CGMA output data provided. The CGMA process provides the raw data. However, the compliance check as such is no longer part of the CGMA process.
C_015		C_015	Data for checking for compliance with CGMA results available Per CGMA process; per TSO All time frames This indicator is expected to be computed by QAS	This indicator aims at obtaining a list of delta values; i.e., not just a "Yes or No?" answer to the question of whether an IGM is consistent with the CGMA output, but a list of deviations measured in MW per optimisation area and for all relevant data (net positions; flows on DC lines).
C_020	Data for checking for compliance with "best forecast" criterion available	C_020	Data for checking for compliance with "best forecast" criterion available Per CGMA process; per TSO (D-2) time horizon CGMA IT platform	This "compliance check" refers to checking whether the PNPs and expected flows on DC lines can be said to constitute "best forecasts" as required by Article 18(3) of Regulation 2015/1222. The CGMA process provides the raw data to be compared to PEVF data. However, the compliance check as such is no longer part of the CGMA process.

Reference	Description (responsible party; input / starting point; output / results)	Indicator ref.	Indicator description (incl. destination)	Comments
C_025	Aligned forecast quality	C_025	Data for checking on the added value of the CGMA process Per CGMA process; per TSO (D-2) time horizon CGMA IT platform	This "compliance check" refers to checking how good a predictor of realised physical flows the CGMA results were and, in particular, whether the CGMA results managed to improve upon the PPD. The CGMA process provides the raw data to be compared to PEVF data. However, the compliance check as such is no longer part of the CGMA process.
C_030		C_030	Assessment of overall robustness of CGMA algorithm and process	Not part of the CGMA process

4.6 Deadlines for all process steps and all time frames

The deadlines in the following table[21] refer to the time by which the corresponding step has to have been completed. Where a deadline refers to a certain date and not time, the deadline corresponds to 23:59h on the date given.

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[21] Please note that while the heading of this section refers to "all time frames", the time frames which are not mandatory at pan-European level; i.e., (W-1) and (M-1); are (for the time being) included as placeholders only. The relevant deadlines would have to be agreed on regional level. If all regions concerned can agree on common deadlines it would be possible to include these in a future update of the present document. Otherwise the reference in the present document serves as a reminder of the need for agreeing on common deadlines for each of the relevant regions.

Reference	**(D-2)**	**(W-1)**	**(M-1)**	**(Y-1)**	**Comments**
A_010	Before 16:30h				
A_020	16:30h			15 July plus three business days	
A_030	16:30h plus ca. 5 seconds				
A_040	16:30h plus ca. 10 seconds				
B_010	~ 16:31h				
B_020	16:35h				
B_030	16:35h plus a few seconds				
B_040	Shortly before 17:05h at the very latest				
B_050	17:15h minutes two minutes or so				
B_060	17:15h minus one minute or so				
B_070	17:15h			15 July plus nine business days	
B_080	Just after 17:15h				
IGM update	Well before 19:00h				

5 Reporting

Three types of reporting will be implemented under the CGMAM:

- Operational reporting
- TSO-individual reporting via QAS
- Regulatory reporting

The operational reporting is targeted at the alignment agents (RSCs). The key conduit for the operational reporting is the GUI of the CGMA IT platform from which the time series with data on all the performance indicators described in the the CGMA IT specification will be available for analysis. The primary data themselves (PNPs, expected flows on DC lines, FRs, BNPs, balanced flows on DC lines etc.) will also be available.

TSO-individual reporting via QAS is meant for TSOs and will encompass the data of most relevance to a TSO's participation in the CGMA process; in particular the primary data referred to above (PNPs, expected flows on DC lines, FRs, BNPs, balanced flows on DC lines etc.).

Regulatory reporting is modelled on the biennial reporting under Article 31(3) of Regulation 2015/1222 and will, in fact, use the report on capacity calculation and allocation as the reporting channel. In other words, CGMA performance indicators will be included in the biennial report under Article 31(3). The first of these reports was due on 14 August 2017; with additional reports to be provided upon explicit request of ACER every two years thereafter. By default all performance indicators will be included. However, in light of the volume of information already being submitted as part of the report on capacity calculation and allocation it may be sensible to restrict the CGMA-related data to a subset of the performance indicators.

6 IT implementation

The present chapter explains the CGMA IT implementation in four distinct sections. The first section describes the work streams into which the IT-implementation-related work has been summarised. The second section explains the integration of the CGMA IT platform into the overall IT architecture built on and around the Operational Planning Data Environment (OPDE; an IT infrastructure supporting the CGM and other processes being developed by ENTSO-E). The details of the CGMA IT platform setup are described in the "Common Grid Model Alignment Requirements and Technical Specification" (or "CGMA IT specs"). Because of the importance of that material for the present CGMAM, the subsequent section provides an extensive summary of that document. Some of the technical aspects of CGMA-related data exchanges are covered in the "CGMA Data Exchanges Implementation Guide" prepared by ENTSO-E WG EDI on behalf of the CGMA project. In order to complete the present chapter, the fourth and final section gives an overview of the contents of the CGMA Data Exchanges Implementation Guide.

6.1 CGMA IT platform within the overall IT architecture

As illustrated by Figure 6 the CGMA application is one of the applications that are part of the Operational Planning Data Environment (OPDE) – in Article 21 of the CGMM referred to as "information platform".

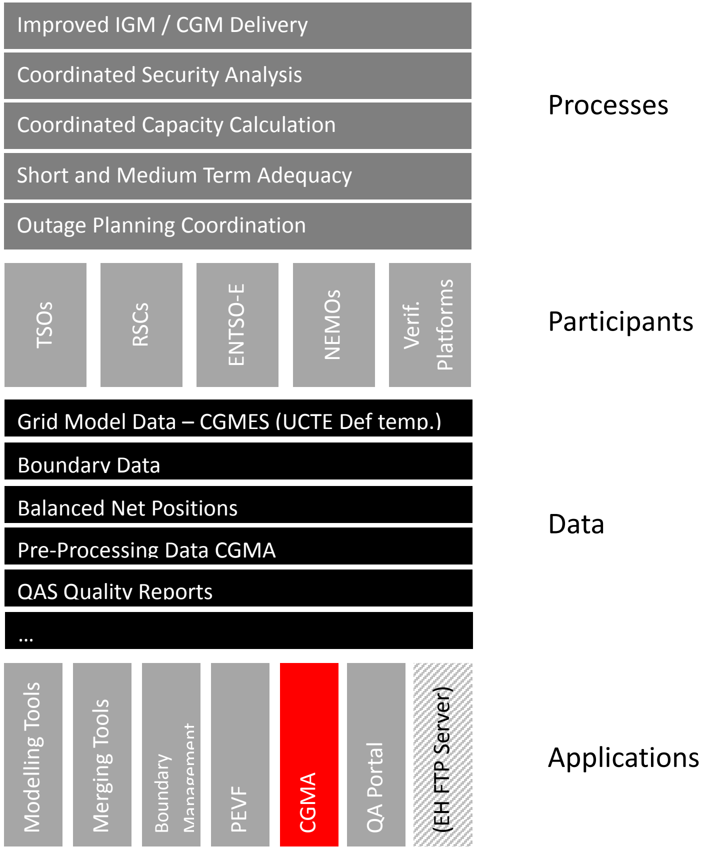

Figure 6: Operational Planning Data Environment (stylised representation)

The following Figure 7 provides some additional technical context for the OPDE applications:

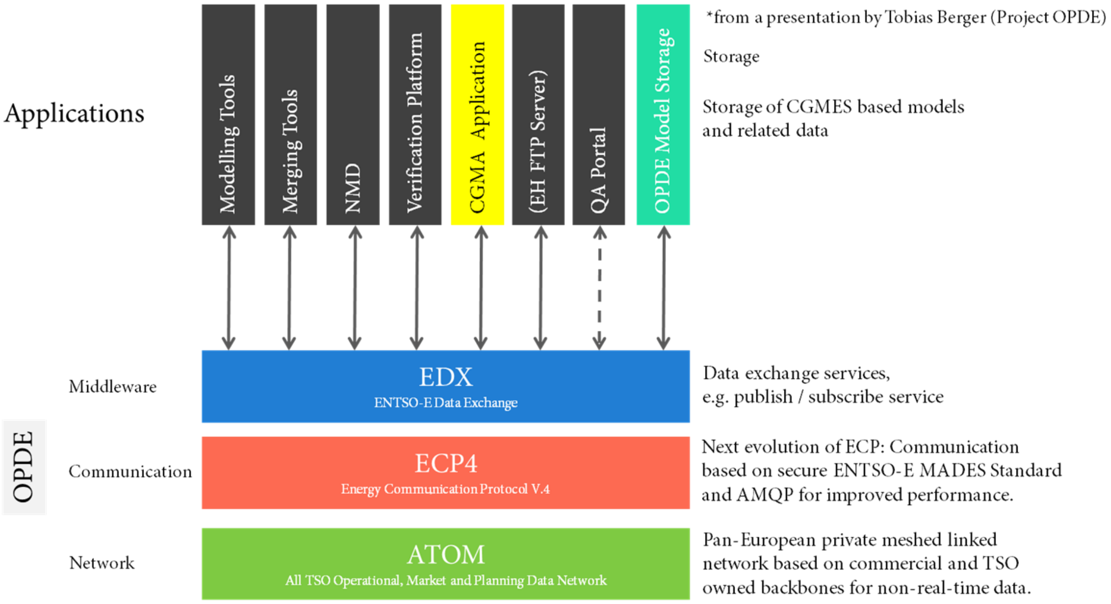

Figure 7: Operational Planning Data Environment (stylised architecture)

The following section describes the CGMA IT specification proper.

6.2 The CGMA IT specification

The requirements with respect to the (central) CGMA IT platform are described in detail in the "Common Grid Model Alignment Requirements and Technical Specification" (or "CGMA IT specs"). While the primary addressees of that document are the developers of the CGMA IT platform, some passages of the CGMA IT specs will also be relevant for the vendors who adapt TSOs' IT systems as required as well as the TSOs themselves. The vendors will, in particular, find the chapters on the external data exchange as well as the chapter on the Quality Gate to be of interest whereas the chapter on master data will be important for TSOs. Apart from this target audience, the CGMA IT specs should be considered background material for the present CGMAM. Knowing and understanding the CGMA IT specs is therefore not a prerequisite for understanding the present document. However, since many readers of the CGMAM will be very interested in the CGMA IT specs, an extensive summary is provided below.

Following a description of the scope of the CGMA IT specs and the material covered therein (chapter 01), chapter 02 explains the various components of the CGMA IT platform and how these are linked to external applications within the OPDE (Operational Planning Data Environment). The following Figure 8 provides an overview.

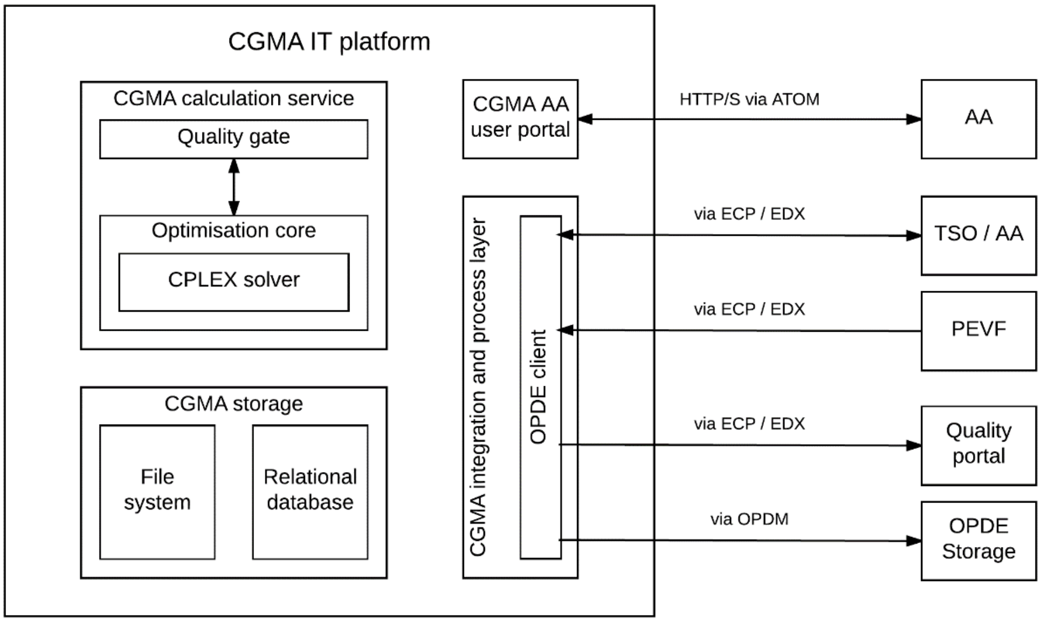

Figure 8: CGMA IT platform architecture

The integration and process layer will provide transparent access to the OPDE and connect all CGMA application modules internally via web services. It is able to read and write all required data formats. The process engine is shown as part of the integration and process layer. This component will guard and control the optimisation service shown on the left-hand side of the diagram; it will schedule automatic and manual jobs, and gather process-related quality and performance indicators.

The distinct areas in the above diagram correspond to the principal modules of the CGMA IT platform. The CGMA calculation module includes GAMS (General Algebraic Modeling System) with CPLEX (commercial software integrated via an API); the optimisation core (a service running optimisation tasks); and the quality gate which – as was described in detail in Chapter 4 – validates all CGMA input data, contributes the substitution data if necessary (via the verification platform which is the ultimate source for these data), and gathers the various indicators (KPIs) also described in Chapter 4 and the CGMA IT specs. The web-based user portal makes it possible for alignment agents to actually use the CGMA application. Finally, the CGMA system needs a storage module that provides a file system and relational database.

Anyone interested in learning more about the different modules should refer to the detailed explanations in the CGMA IT specs.

Chapter 03 of the CGMA IT specs sets out the requirements with respect to hosting. These should be read in conjunction with additional and more detailed requirements described in the annex of the "Minimum Viable Solution Agreement" which, at the time at which the present document was being prepared, was the principal contract describing the cooperation of ENTSO-E and TSOs in setting up the OPDE and associated IT infrastructure. The hosting requirements include, inter alia, a description of the types and number of servers to be provided by the hosting entity. In addition to the hardware requirements, the functionalities required are outlined.

The description of the CGMA business processes in chapter 04 of the CGMA IT specs is largely equivalent to the description in the corresponding chapter in the present document. However, the description in the CGMA IT specs is limited to the (D-2) time frame, whereas the present document covers all time frames for which the CGMA process is used; i.e., all time frames for which market schedules are not available.

External data exchange - i.e., the exchange of data between the CGMA IT platform on one end and TSOs or external OPDE applications such as the PEVF on the other end - is covered in chapter 05 of the CGMA IT specs. The CGMA IT platform makes use of four different document types maintained by ENTSO-E WG EDI (plus Common Grid Model Exchange Standard (CGMES) files) in order to enable the data exchanges required. These data exchanges are represented for the (D-2) case in the sequence diagram in Figure 9:

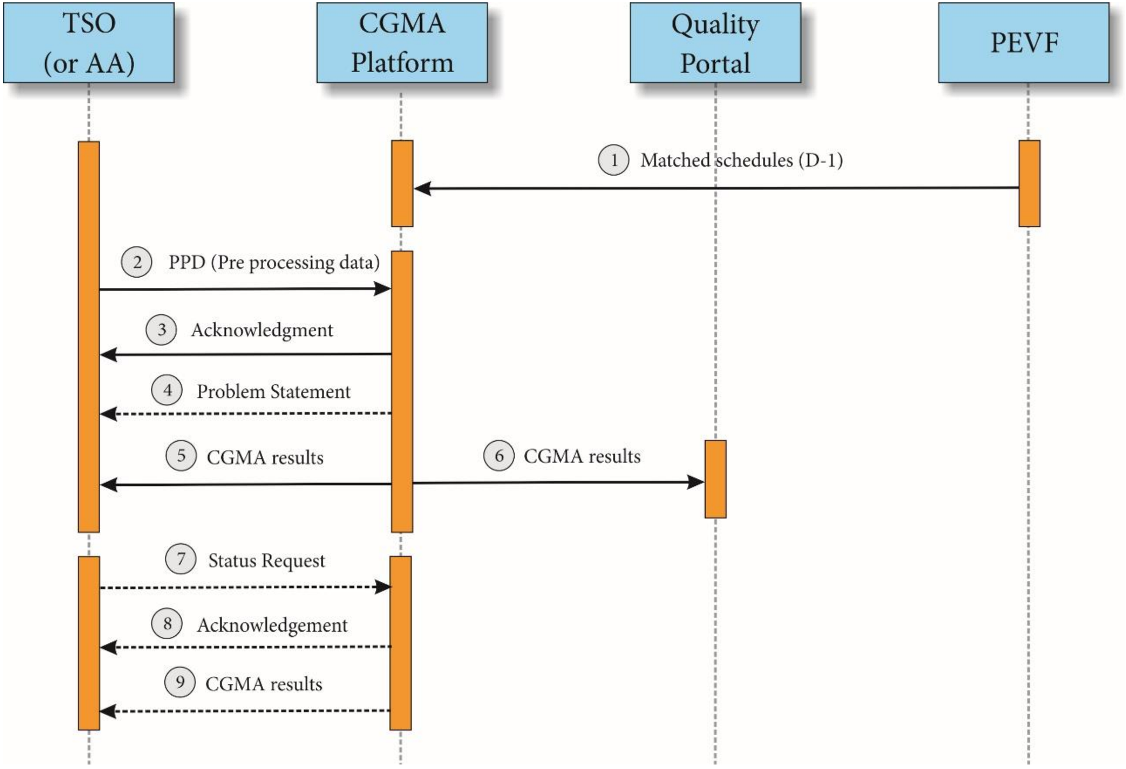

Figure 9: CGMA external data exchanges (D-2) excluding DC PSLC sub-process

For each of the data exchanges numbered 1 to 9 above, the CGMA IT specs state the associated document type and, for each type, the recommended (non-mandatory) file naming convention.

Three application interfaces to and / or from external systems are depicted in the above diagram. Optional data flows are represented by dotted lines. First of all, there is a bilateral connection with individual TSOs. This connection is used to send PPD from the TSO to the CGMA IT platform whereas the CGMA IT platform sends the CGMA output data (results) and error or status messages the other way. The data format used is explained in more detail in Annex IV. The same format is used for providing input data to the CGMA IT platform and for sending CGMA output data back (Reporting Information Market Document). Acknowledgement messages have a format of their own. All of these data are exchanged via the OPDE and delivered automatically.

The exchange of data with the Quality Portal is unilateral in the sense that the CGMA IT platform provides data to the Quality Portal but not conversely. The data being exchanged are the optimisation results. A CIM-based format, the Reporting Information Market Document (RIMD), will be used to transfer the CGMA output (i.e., the results of the optimisation) via the OPDE and automatic delivery.

Data exchange with the Verification Platform (PEVF) is bilateral (i.e., two-way). The CGMA system obtains substitution data (in the form of (D-1) matched schedules provided by the Verification Platform) from the OPDE using the CIM RIMD format. Data may be provided via automatic daily delivery or upon request by the CGMA platform.

Chapter 05 of the CGMA IT specs also references an additional document, the CGMA Data Exchanges Implementation Guide, as well as an associated set of XML schema definition files (XSDs) available from the WG EDI page on the ENTSO-E website. A summary of the CGMA Data Exchanges Implementation Guide is provided below. The XSDs and the information contained in the CGMA Data Exchanges Implementation Guide are very important for vendors working to adapt TSO systems such that these are able to communicate with the CGMA IT platform.

Chapter 06 of the CGMA IT specs on data storage provides details on the CGMA IT platform's database, more specifically on each of the tables in the data model (see diagram of the CGMA data model in the CGMA IT specs; the diagram is not included in the present document). Internal data storage and internal archiving arrangements as well as the possible use of OPDM data stores are also described in the chapter.

The (initial) master data used are listed in chapter 07. There is some overlap between these data and information included in the present document; where this duplication exists it is deliberate. For example, the list of optimisation areas is included both in the CGMA IT specs and in the present CGMAM. With two exceptions there is a one-to-one mapping between optimisation areas and TSOs - the exception being Eirgrid and SONI (two TSOs who will jointly provide one IGM and thus one set of PPD for the CGMA process) and Energinet.dk (which, as a single TSO, will be managing the two optimisation areas of DK1 / Denmark-West and DK2 / Denmark-East each of which will be providing a separate IGM and thus a separate set of PPD to the CGMA process). Noting the two exceptions, the CGMA IT specs provide the list of TSOs whereas the CGMAM provides the list of optimisation areas.

The CGMA IT specs, in addition, also list the Alignment Agents and the TSOs preliminarily associated with each of them. The present CGMAM only assigns Alignment Agents to a TSO where the appointment has been explicitly confirmed.

For those master data included both in the present document and the CGMA IT specs, there are some differences in the details provided. For example, the CGMA IT specs contain, for each optimisation area, both the EIC for the area and the EIC for the associated TSO whereas these data are not felt to be relevant for the CGMAM. Both documents contain a list of individual DC lines included in the CGMA algorithm; the CGMA IT specs also include the corresponding EIC code and the linear factor in the losses polynomial (which can be specified separately for each DC line).

Understanding the meaning of the detailed master data related to DC lines and the discussion thereof in the CGMA IT specs requires a good grasp of the underlying conceptual questions. The CGMAM provides these explanations in chapter 03 on the CGMA algorithm.

Both the CGMA IT specs and the present CGMAM include information on the DC and virtual AC links in the form of a stylized map of the European grid. These maps are equivalent.

Chapter 07 of the CGMA IT specs also includes a list of the business types that are supported. Since some of these terms are equivalent but not identical to terms used in the present CGMAM, a correspondence table is included in the Glossary in Annex V.

The way that the algorithm described in chapter 3 of the present CGMAM has been implemented in the CGMA IT platform and transposed into the modelling language used by GAMS is described in chapter 08 of the CGMA IT specs. Terminology and symbols/notation used differ somewhat from those used in the present CGMAM; however, in terms of content there are no inconsistencies.

Chapter 09 of the CGMA IT specs covers the internal data exchange between the different modules of the CGMA IT platform and notably also describes a dedicated XML data format used for this purpose.

The interfaces of the CGMA IT platform are described in chapter 10 of the CGMA IT specs. The first section addresses internal interfaces and the various web service operations provided for these internal exchanges. External interfaces (specifically those between the CGMA IT platform on one end and the PEVF or QAS - both modules hosted on the OPDE - on the other end) are addressed in the second section. That section describes the specific adjustments required in order to allow the CGMA IT platform to exchange data with these other two applications. For example, the PEVF will not be able to provide aggregate AC and DC net positions because such a time series does not exist. The CGMA IT platform will therefore have to compute the aggregate values from the separate values for the AC net position and DC flows provided by the PEVF. The third and final section of that chapter addresses message exchange via the OPDE. It describes the preparations that the hosting entity has to complete in order to allow the CGMA IT platform to communicate via the ATOM network and it outlines the "receive" and "send" operations available as well as the EDX businessTypes associated with each of the four WG-EDI-maintained document types.

Chapter 11 on the Quality Gate describes in detail the various checks performed by the CGMA IT platform in order to ensure that the input data used meet the requirements. These checks are referred to in the description of the various process steps in chapter 4 of the present document. Chapter 11 of the CGMA IT specs also covers the subjects of substitution and modification, respectively, of input data which includes, for example, the rules applied by the CGMA IT platform in order to ensure that inadequate feasibility ranges are increased. As chapter 4 would suggest, the checks described in the CGMA IT specs can be grouped into (A) checks on individual TSO PPD: A1 syntax check; A2 semantic check; and (B) checks on the complete set of PPD in order to check consistency of, inter alia, data related to DC lines.

As there was very considerable overlap between the contents of chapter 12 of the CGMA IT specs and the previous chapter 5 on "Key performance and quality indicators" in the present CGMAM, the latter chapter was essentially removed. However, these indicators are described in detail in the CGMA IT specs.

Chapter 13 of the CGMA IT specs describes the web portal which allows the Alignment Agents to actually use the CGMA IT platform. Aside from pure administration tasks such as the management of the master data this chapter also explains how the web portal will make it possible for Alignment Agents to perform the tasks also described in the present CGMAM such as the manual modification of input data (including as part of the AQMP), the manual triggering of optimisation runs, or the review and exporting of data on performance indicators.

Chapter 14 concludes by summarising all requirements into a single chapter in the form of a table.

This completes the summary of the CGMA IT specs.

6.3 Summary of CGMA Data Exchanges Implementation Guide

The CGMA Data Exchanges Implementation Guide was prepared by ENTSO-E WG EDI on behalf of the CGMA project. The Implementation Guide follows a standard format / outline for such documents and provides a description of the CGMA business processes and document exchange processes as well as general rules for document exchange. While the other three formats used for CGMA-related data exchanges - the Acknowledgement Market Document, the Problem Statement Market Document, and the Status Request Market Document - are not modified for the specific CGMA use cases, this is different for the fourth format, the Reporting Information Market Document (RIMD). The Implementation Guide therefore provides detailed information on how the RIMD format is to be used in the context of the CGMA process. This information is highly technical and would be very useful for, inter alia, a vendor supporting a TSO in setting up the CGMA process and data exchanges. The EDI Library on the ENTSO-E website provides detailed information on the RIMD as well as associated XSDs (see https://www.entsoe.eu/Documents/EDI/Library/cim_based/schema/Reporting%20information%20document%20and%20schema%20v1.pdf).

Annex

I. ANNEX – Test Results

The CGMA algorithm described in Chapter 3 of the present document is not based on theoretical considerations alone. In fact, the algorithm was developed over a period of about two years and was rigorously tested against data at every step of its development. The tests themselves have evolved in parallel with the algorithm and have gone through a number of versions. The two most recent series of tests, referred to as “CGMA Testing 2017”, included both challenges deliberately designed to (stress-) test the algorithm for robustness and realistic test scenarios. More specifically, TSOs were invited to provide "real" input data (i.e., PPD) in order to make it possible to test the performance of the algorithm against the sort of challenges expected to be encountered in daily operation[22].

Both the robustness checks and the tests against regular data were successful. No problems with the algorithm were identified. The minimum feasibility range of 2 % of instantaneous peak load was shown to be generally sufficient to ensure the existence of a solution. In those instances in which the feasibility range provided was not sufficient, the algorithm managed to find a solution based on the approach outlined at the end of Chapter 3 ("Applying the algorithm: Step 3 – scenarios without solutions"). In summary, these test results were very encouraging and suggest that the CGMA algorithm will perform very well.

Even though the tests thus far have not identified any shortcomings, a parallel run of the CGMA algorithm and CGMA process is scheduled to start in January 2018. This parallel run is basically a long-term test under highly realistic conditions. It will provide the definitive reassurance that the CGMA algorithm can successfully handle all the challenges that arise in daily operations.

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[22] All test results from 2015 onwards can be found at: https://extra.entsoe.eu/SOC/IT/SitePages/WP-5%20Common%20Grid%20Model%20Alignment.aspx
However, please note that TSO-individual results are only made available to the corresponding TSOs and that individuals not associated with an ENTSO-E member organisation will not be provided with access rights.

II. ANNEX - Coordinated Pre-processing Approaches

The present annex serves to outline four coordinated pre-processing strategies currently under development by designated alignment agents. The first, referred to as "INPROVE" (Identification of Net Positions Representative of the OVerall Electrical evolution), is being developed by Coreso. The second contribution – which encompasses several methodological approaches – is being developed by the Nordic RSC. The third contribution outlines the approach envisaged in the Baltic RSC. The fourth contribution outlines the approach being developed by SCC.

Note that the development of pre-processing approaches is at a very early stage and that additional attempts are under way to develop suitable strategies in this respect. In particular, it is also too early to say what exactly these strategies will aim at. However, this should become progressively clearer based on the parallel run in 2018.

Before presenting this material in detail, a reminder of the rationale for such coordinated pre-processing approaches is helpful. Holding everything else constant, the difficulty of finding balanced net positions and balanced flows on DC lines increases in proportion to the "preliminary net position across all bidding zones" (illustrated, for example, in Figure 2). The "preliminary net position across all bidding zones" is simply the sum of individual preliminary net positions. As such it is a measure of the aggregate forecast error – "error" because in equilibrium, exports have to exactly equal imports and the net position across all bidding zones has to be zero.

In order to obtain the balanced net positions needed for the subsequent stages of the CGM process, the CGMA algorithm has to redistribute the "preliminary net position across all bidding zones" (the aggregate forecast error) across bidding zones (ideally respecting the feasibility ranges set by each TSO). In other words, the preliminary net positions have to be adjusted until, post-adjustment, they sum to zero (at which point they are referred to as balanced net positions).

It is intuitively plausible that the latter task is much easier when the volume of redistribution required (i.e., the aggregate forecast error) is 500 MW rather than, say, 5000 MW. The coordinated pre-processing strategies outlined in this chapter aim at precisely this reduction in the size of the adjustment required. Under a coordinated (regional) approach, several individual preliminary net positions are forecast jointly, and, if the technique works as intended, the sum of the individual preliminary net positions estimated in this way is smaller (in absolute terms) than if the preliminary net positions had been estimated by each TSO individually. Note that this does not entail reducing the absolute size of each individual preliminary net position; it is the aggregate that matters from the point of view of the overall CGMA process.

Finally, note that the strategies outlined below are still under active development. In that sense the material presented here provides a snapshot of the current state of development and does not purport to be definitive.

II (i) Pre-processing approach of CORESO

Coordinated pre-processing approach under investigation by Central European TSOs

iNProve: Identification of Net Positions Representative of the OVerall Electrical evolution

(contribution kindly provided by Coreso)

General Principles

The regional statistical approach intends to build a coordinated forecast of net positions for a set of bidding zones located in the same "electrical region" of the system (like capacity calculation regions (Core, CSE, SWE, etc. …)), or the entire Continental Europe synchronous area. This approach consists of establishing a linear relationship between net position(s) and a set of input variables representative of the situation of the electrical market and the electrical grid in the chosen market area as well as neighbouring bidding zones. Coefficients of the linear models are trained and fitted by learning on past realisations or forecasts of these variables. At the time of writing the regional statistical approach was solely focused on the former CWE CCR.

Choice of input data

Data analysis

The more relevant the information provided to the forecasting models, the better the quality of the forecast. In order to guide the choice of input data, an analysis was conducted in order to identify the possible links between the net position of different bidding zones and different types of input data

A data analysis made on past market realisations showed that:

- Net positions of certain bidding zones are strongly correlated with net positions of other bidding zones (when Germany exports, clear tendency of import in Switzerland, Austria, and France)
- The net position of a particular bidding zone is highly correlated with the net position of this same bidding zone during the preceding hour.

This indicates that feeding the forecasting engine with past market realisations already provides a significant and relevant amount of information for the forecast.

Further analysis also using data on load, renewable infeed and cumulated unavailability of generation units showed that for certain bidding zones, these types of data were particularly relevant (for small electrical countries like Belgium, the unavailability of production, the load for thermo-sensitive countries like France, or renewable infeed for Germany or Spain and Portugal).

Input data for the forecasting models

Two types of data were chosen as inputs:

- Past commercial data: realised net positions of the entire Continental Europe synchronous area for the week preceding the target scenario (the time stamp for which preliminary net positions are being forecast)
- Forecast of exogenous data such as load, must-run production and renewables infeed.

For each type of data, not only values corresponding to the target bidding zone are provided but also values corresponding to neighbouring bidding zones (if not all European bidding zones). This has two advantages:

- data collection, storage, and management for all individual forecasts can be centralised, and
- the interdependencies between the different connected bidding zones can be captured to the maximum extent.

However, this also increases the number of input variables and the volume of data.

Output Data (hourly resolution)

- (Aggregate AC/DC) Net position per bidding zone

- DC flows per interconnector

  The approach of net position forecasting is easily extensible to different timeframes, or regions. The target net position can correspond to the full aggregate AC/DC net position of a bidding zone (considering all borders) or to aggregation in a specific capacity calculation region.

  For example, the two following models could be built for the net position of Germany: one considering only the borders with France and Benelux (CWE), and another model taking into account the borders with France, Benelux, Denmark, Poland, the Czech Republic, Austria, and Switzerland; i.e., all of Germany's relevant electrical borders.

  The DC flow per interconnector can be predicted using the same methodology. For this forecast, the availability and capacity of the link will be key input data.

Learning market behaviour or market tendencies through history

Structure of the forecasting models

The statistical approach tries to learn and reproduce the market behaviour within a region of the system. During learning, the forecasting engine identifies correlations between the net position and the set of input variables in the history, and determines appropriate weights and coefficients for each of the relevant predictors to be applied for forecasting future values of the net position.

The final forecasting model is a linear function with adapted weights on each of the input variables considered relevant during learning.

Implicit or explicit coupling of net positions

The past market outcomes based on which the forecasting model learns are coupled: the sum of past hourly net positions of the bidding zones participating in the Continental Europe synchronous area equals zero.

The forecasted net positions can be pre-coupled (implicit condition in the input variables of a single-component linear model) or exactly coupled (explicit condition in a multi-component linear model)

Workflow for daily forecasting.

Once the model has been trained on historical data, forecasts can be made for future target dates. In the target workflow, every day the latest market results as well as the most recent forecasts are added to the data available to the forecasting model. The forecast can then be made by applying the linear function to the provided input data.

Every day, models could be also re-trained with the last day of observations. However, as the structure of the market is not expected to change drastically from one day to the next, the coefficients of the models should be stable over a certain period of time. Thus, re-training should be performed less frequently than every day; e.g., every two or three months.

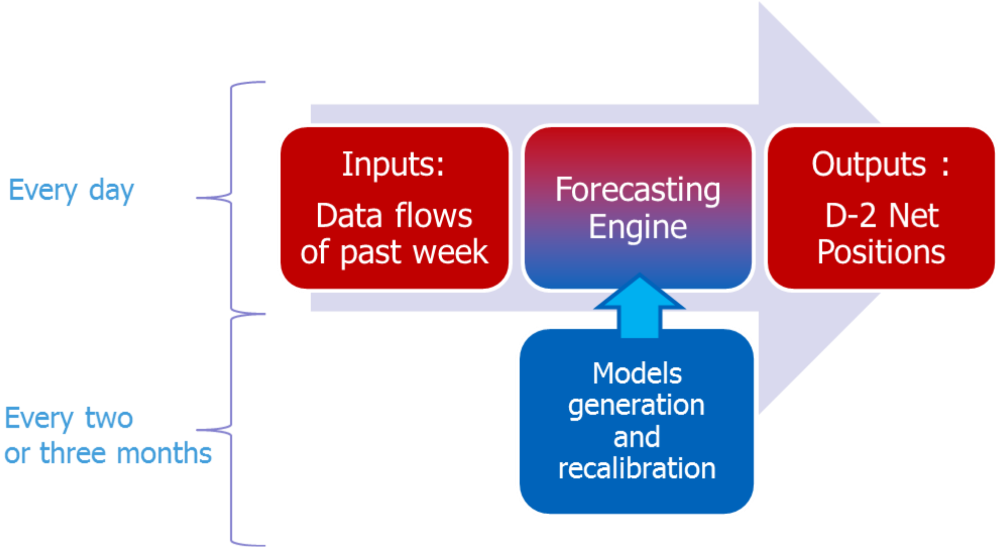

Figure 10: Retraining frequency (illustration)

Data Analysis

The correlation coefficient between two variables measures the intensity of the numerical and statistical link between these variables. It does not prove a cause-and-effect relationship, however it indicates tendencies in a dataset. This value consists of the ratio between the co-variance between the two variables divided by the product of the standard deviations:

$$Cor(X,Y) = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$$

The coefficient value is between -1 and 1. If close to 1, the two variables tend to be strongly linked. If the value is close to -1, the variables are also strongly linked but in opposite ways. If close to zero, the variables tend to have no relation.

NP autocorrelation

This study has no clear-cut conclusions except that the correlations between different bidding zones' net positions are limited, such that it is difficult to forecast one net position based upon the net position of another bidding zone.

Hourly coefficient correlation

This study had the following objective: separate the different hours of the days into several groups, to have a specific model depending on the period of the day. The analysis showed a strong correlation between hours during the day and hours at night in general.

NP vs. load correlation

Load is one of the (largely) exogenous variables the correlation of which with net positions was studied. Clearly, as suggested by intuition, load is highly correlated with net positions.

NP vs. renewable correlation

Wind forecast

The correlation between the forecast wind infeed in Germany and European net positions is as one would expect, and there is a very high correlation between the forecast wind infeed in Spain and Portugal with these bidding zones' own net positions.

Solar forecast

As solar power is less important in Europe than wind power, the correlation is less strong, but we observe that for some countries like Germany, Italy or Switzerland, this variable is important.

NP vs. unavailability of production units

Clearly, unavailability of production units has a high impact in net positions. And beyond the intuitive impact on small countries like Belgium, we have other countries like Germany for which this variable is important.

Basic description of the mathematics structure of the forecasting models

The approach consists of a penalized linear regression after a variable selection, to model the behaviour of net positions from input data, based on previous months or years.

The mathematical principles of statistical algorithms used are based on:

- An historical period of realized net positions
- An historical period of variables that can be used to forecast net positions: previous net positions, forecast data such as wind infeed, solar infeed, load, generation…
- A linear algorithm

⇨ The linear algorithm will model the linear relationship between the variables and the realized net positions, by minimizing the error between the model and the target.

⇨ Finally, the result is a linear formula sum(Ai*Xi) with Xi variables and Ai coefficients, that represents in the best way the historical relationship between the net position and the input variables.

Errors out of range [-[$-\in,\in$] are highly penalized.

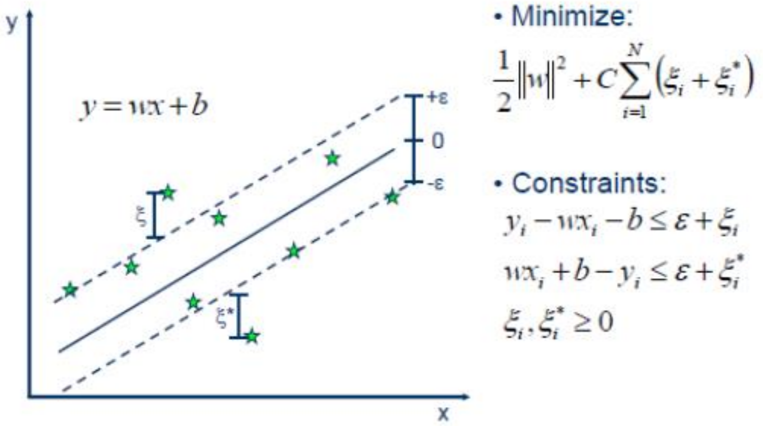

Figure 11: Principle of the Support Vector Machine (SVM) algorithm

In the figure above, it leads to penalize the regression with the sum of distances of exterior points to a regression range (penalized term by the C factor). The introduced penalization makes the regression particularly robust and provides especially a strong resilience to correlation issues between regressors and a good stability to the problem dimension. This property is in particular interesting in a context of net positions modelization since we use numerous regressors, strongly correlated.

II (ii) Pre-processing approach of Nordic RSC

Coordinated pre-processing approaches under investigation by the Nordic TSOs

(contribution kindly provided by the Nordic RSC)

Disclaimer

This section presents preliminary results of common Nordic work on determination of net positions for the D-2 process as required by Regulation (EU) 2015/1222. The objective of this document is mutual information between TSOs on approach and algorithm. Work is still ongoing and the approach may be modified or completely changed. This document does not in any way constrain the Nordic TSOs in their final approach to provide input to the CGMA algorithm.

(1) Introduction

The All TSOs' Proposal for a Common Grid Model Methodology of May 2016 requires the TSOs to provide their preliminary net positions to the CGM Alignment (CGMA) procedure. The input to this procedure will be preliminary net positions and DC flows from the individual TSOs.

The Nordic TSOs are of the opinion that their net positions are closely related, and that they preferably should be determined in one comprehensive procedure. Initially the following approaches were discussed:

- Reference Day
- Regression against a number of relevant variables
- Similar Net Demand
- Euphemia based

The Reference day approach is the base line against which the other approaches will be evaluated.

Regression based approaches were seen as quite relevant, but also requiring significant effort to develop to a satisfactory level.

Instead, a rather simple method, Net Demand Similarity, was developed and compared with the Reference Day approach. It turned out that the proposed approach in fact leads to a significant improvement in the estimated net positions.

The Euphemia based approach was tested on historical data in a master's thesis that presently is being finalized. Results so far also are promising as a "proof of concept".

This section describes the Similar Net Demand approach in the following sub-section. In the subsequent sub-section initial test results using historical data from 2015 are presented. The following sub-section describes various potential improvements that were tested, but did not lead to better results. It was nevertheless seen as useful to include this as documentation. The last-but-one sub-section describes the Euphemia based approach, while the final sub-section concludes and sums up further work envisaged by the Nordic TSOs.

(2) Net Demand Similarity: the method

The method is based on estimating "net demand", given by the difference between the forecasts of demand and of non-dispatchable generation[23]. This difference must either be produced within the area by dispatchable generation, or imported, respectively exported if negative. The idea is then to find "similar hours" with respect to net demand in recent history. "Similar" is based on a sum of least squares of the deviations. The hypothesis is that hours with similar net demand for all areas, also would have similar net positions.

Historical hours should not be taken too far in the past, as the water values (and prices in general) change over time, altering the patterns of dispatchable generation. On the other hand, taking too few hours in the past gives only a limited statistical basis and reduces the likelihood of finding comparable cases.

Basic approach

The approach is as follows:

1) Calculate net demand for all areas and all hours for target day

$$DN_{i,t}^{target} = D_{i,t}^{target} - PNC_{i,t}^{target} \qquad (0)$$

where D^{target} is the demand forecast for the target day, PNC^{target} the sum of the non-controllable generation, and i and t indices for area (bidding zone) and hour respectively.

"Net demand" may be negative, indicating an area where non-controllable generation exceeds demand.

2) Determine reference hours

---

[23] One might think of intermittent renewable energy, but the scope may be wider. The important point is to include generation that will not be influenced by prices within the time horizon of the analysis. In this context, nuclear is also seen as non-dispatchable.

For a historical period before the present day, find one or several combinations of net demand in all areas that matches the combination of net demand for the target day as closely as possible. In order to find the best matches, calculate the deviation with the net demand of the forecast target hour for all areas and each hour of the historical period:

$$\alpha_{t,s} = \sum_{i \in A} w_i \cdot \left(DN_{i,t}^{target} - DN_{i,s} \right)^2 \qquad (0)$$

where s is the index of an hour in the selected historical period. w_i is a suitable weighting factor representing the size of the area.

We then choose a number of hours that have the lowest $\alpha_{t,x}$ and use these as the reference hours:

$$s_{t,ref} = \underset{s}{\operatorname{argmin}}\, \alpha_{t,s} \qquad (0)$$

3) Determine net positions

The net positions are taken as the average net positions of each area in the identified reference hours, i.e. the n hours with lowest $\alpha_{t,s.}$

The net positions must be checked against and possibly constrained by the possible range of net positions, determined by the forecast physical interconnection capacities and available generation capacity. Note that this does not interfere with the ultimate goal of the whole process, i.e. to determine the trading capacities, as the physical capacities in any case will be the upper limit to the trading capacities.

The opposite problem occurs if the reference hour is more constrained. E.g. area x has a maximum net position +1000 MW in the reference hours, and the actual net position in that hour is equal to this value, but the maximum physical net position in this hour is 2000 MW. This might for example happen when the reference hours occurred during a long maintenance period. In such cases, the net position could have been higher in that hour if the maximum value would have been higher.

These issues will be further discussed below

Calculation of flows

Flows between bidding zones are of interest for two reasons:

1) An estimation of the DC flows between synchronous areas is a requirement of the CGMA methodology
2) On the borders between IGMs, injections are needed for each interconnection in order to represent import/export to neighbouring countries.

Although the AC injections may be obtained by other means, the present approach could be used if it yields good results.

For this purpose, the algorithm was extended in order to find the flows. Firstly, an external area was added. The net position of each area then includes the flow to the external area. After the estimation of the net positions as described in the previous section, the flows are estimated by solving for each time step *t* the optimization problem:

$$\min_{\mathbf{y}_t} \sum_i \left(a_i y_{i,t}^2 + b_i \left| y_{i,t} \right| \right)^2$$

subject to

$$A\mathbf{y}_t = \mathbf{PN}_t \qquad \forall i$$

$$lb_{i,t} \le y_{i,t} \le ub_{i,t} \qquad \forall i$$

Here $\mathbf{y}_t$ is the vector of the flows to be found at time *t*, $\mathbf{PN}_t$ is the vector of the net positions found for time *t* and **A** is the matrix that defines the couplings between the bidding zones. Moreover, lb_{it} and ub_{it} are the lower and upper flow limits on the interconnections. By minimizing the flows, loop flows are avoided in this formulation. **a** and **b** are vectors of suitable weights.

The optimization thus solves a minimum-cost-of-flow problem that satisfies the net positions and avoids loop flows. A similar problem is used by Nordpool to calculate the market flows. Main focus is on the calculation of the DC flows, as these are required by the CGMA algorithm. In addition, it is necessary to split up the external (HVDC) flow from SE4 into flows to Germany, Poland and the Baltics. A simple approach is to use the ratios between these flows in the same reference hours as a basis to distribute the total flow.

(3) Initial results on net positions

Case description and assumptions

The approach was tested on data for 2015. The following historical data are required for all Nordic bidding zones and all hours:

- Demand forecasts
- Forecasts of non-controllable generation
- Historical net positions
- Physical import and export capacities

As several of the required D-2 forecasts are presently not available, the tests use the real or market data instead of forecasts, i.e. "perfect foresight". Note that the market data are used, not metered data. Use of forecasts will reduce the quality of the results, but the market result is based on the market participants' forecasts, and this may reduce the deteriorating effect of using forecasts instead of market results in the algorithm. This needs to be tested once such data become available.

Net positions are calculated from the difference between total export and total import for each bidding zone, taken from the Nordpool web site.

For "non-controllable generation", only wind production was included initially, while nuclear production was added subsequently. Solar PV was not considered significant yet. The Nordic system also includes significant volumes of non-controllable hydro generation. However, little or no data on this are available. It is a complicated issue, as the extent to which hydro generation is controllable is highly dependent on the reservoir and inflow situation. Preparing forecasts for this is an area for potential future improvement of the methodology.

The algorithm uses bidding zones, even though the input to the CGMA algorithm will be on a country basis. There are two reasons for this:

- The bidding zone results may subsequently be used as a basis for use of the GSKs within each bidding zone instead of country-wide
- The bidding zone errors are not fully correlated, and the hypothesis is thus that adding the results for the bidding zones gives a better result than estimating the country net position directly. This hypothesis needs to be tested.

To document the quality of the results, the main indicator used is the Mean Absolute Error, defined as:

$$MAE = \frac{\sum_{i=1}^{n} \left| NP_{est} - NP_{real} \right|}{n}$$

Results net positions

The results are shown in the table below. The results are compared with an approach where the net positions are copied from a reference day[24].

---

[24] Tuesday-Friday: the day before. Monday: Friday. Saturday and Sunday: same day one week earlier.

Bidding Zone	MAE (MWh/h)		Improvement (%)	MAE (% of Mean Absolute Net Position – MAN)		MAN (MWh/h)
	Net Demand Similarity	Reference Day		Net Demand Similarity	Reference Day	
SE1	282	327	14 %	20	23	1440
SE2	326	439	26 %	9	12	3585
SE3	329	587	44 %	26	46	1282
SE4	175	323	46 %	10	18	1789
NO1	174	189	8 %	10	10	1824
NO2	409	630	35 %	19	30	2100
NO3	151	204	26 %	19	26	799
NO4	158	258	39 %	29	48	542
NO5	273	429	36 %	14	22	1952
FI	272	264	-3 %	17	17	1570
DK1	309	685	55 %	41	92	747
DK2	145	226	36 %	23	35	641

Table 2: Test case results, bidding zones

Bidding Zone	MAE (MW)		Improvement (%)	MAE (% of Mean Absolute Net Position – MAN)		MAN (MW)
	Net Demand Similarity	Reference Day		Net Demand Similarity	Reference Day	
Denmark	381	867	56 %	33	74	1168
Finland	272	264	-3 %	17	17	1570
Norway	714	1273	44 %	30	54	2360
Sweden	588	830	29 %	22	31	2641

Table 3: Test case results, countries

The columns MAE (MW) show the average absolute deviation in MW between the estimated net position and the net position resulting from the market clearing for the Net Demand Similarity and the Reference Day approaches respectively. The next column shows the improvement in percent. The next two columns show the same deviations in percent of the mean average net position, indicating the relative error. These numbers should be handled with some care, because if the net positions normally are small or often have opposite signs, the relative error may be large, even though this may not be large e.g. compared with the total demand and/or production of the area. The last column shows the actual net positions, i.e. the reference for the percentages in the two columns before. All these net positions are rather high, so the percentages give a reasonable indication, but this can be problematic for shorter periods.

Compared with the reference day approach, significant improvement is obtained for SE3 and SE4 in Southern Sweden, NO2, NO4 and NO5 (West and Northern Norway) and the Danish bidding zones. SE3 and SE4 together with the Danish areas are the major wind areas, which is probably an important part of the explanation. The Norwegian areas are the most flexible hydro areas, which would react on the changes in wind production. Only for Finland, the proposed approach results in a slight deterioration.

On a country basis, the improvements for especially Denmark and Norway are impressive. The relative errors for these countries are still around 30 % of the average flows. It should however be taken into account that the maximum net positions of both Denmark and Norway are well above 6000 MW, and in this perspective the deviations look more acceptable.

As part of the test, the optimal length of the historical period and the number of reference hours were determined empirically. A longer historical period increases the probability of finding hours with similar net positions, but at the same time they become less representative because of changes in prices and water values. Similarly, having more reference hours smooths out special situations, but makes it necessary to include less representative hours. So for both parameters there will be an optimum number. In the present tests, the following parameters were used:

Historical period:	4 days back in time
Number of reference hours:	2

The weighting factors w_i were all equal to 1.

Results net flows

It appears possible to estimate the flows, initial results indicate MAEs of the order of 10 to 25 % of the cable capacities, cf. the table below.

Interconnection		MAE (MWh/h)	MAE (% of capacity)
NorNed	NO2-Netherlands	107	15
Skagerrak	NO2-DK1	163	10
Storebælt	DK1-DK2	111	19
Kontiskan	SE3-DK1	128	18
Fenno-Skan	SE3-Finland	207	17
Kontek	DK2-Germany	119	20
Baltic Cable	SE4-Germany	46	??
SwePol	SE4-Poland		
NordBalt	SE4-Lithuania	n/a	n/a
Estlink	Finland-Estonia	n/a	n/a

Table 4: Test case results, HVDC flows

(4) Potential improvements

Historical period and number of hours

In the tests referred to above, the optimal number of historical days was found to be equal to four, and the number of reference hours used equal to two. Earlier tests on a country basis yielded a much longer period (13 days) and a larger number of hours (10). More testing is needed to find the optimal numbers. They might also be state dependent, e.g. during stable periods in winter a longer period may be better than during snow melting. The optimal numbers may also depend on some of the other options below.

Weighting factors

In the initial test case described above, the weights w_i for all bidding zones were all set equal to 1. This means that the bidding zones with the largest exchange flows dominate the sum in Equation (0), which again might mean that areas with smaller exchange flows get relatively larger deviations. On the other hand, areas with large exchange flows are also the largest areas in terms of demand and/or production, and therefore dominate the Nordic exchange pattern overall. So it might be that when the net positions of these bidding zones are close to their correct values, the smaller areas follow. On the other hand, it might be that the influence of the areas with large exchange flows becomes too large, resulting in unacceptable deviations for the smaller areas.

An alternative calculation was therefore done with weighting factors equal to the inverse of the bidding zones' net average demand. This may be expected to change the results somewhat in favour of the smaller areas. An initial test confirmed this assumption, but gave slightly worse results on a country basis. This also needs to be tested more.

Constraints on minimum and maximum net positions

In general, bidding zones' export and/or import is often constrained by physical limitations on their export respectively import capacities. Consequently, these limitations will also constrain maximum and minimum net positions of the bidding zones. However, it turns out that the relations between the limited import and export capacities on the one hand and the limitations on the bidding zones' net positions are not straightforward.

The obvious relations are given by the fact that a bidding zone's net position cannot be larger than the sum of the export capacities of its interconnections with other bidding zones, and not be less than the sum of the corresponding import capacities. However, for the Nordic system in 2015 it turns out that these constraints are never binding. The figure below illustrates this for bidding zone SE1:

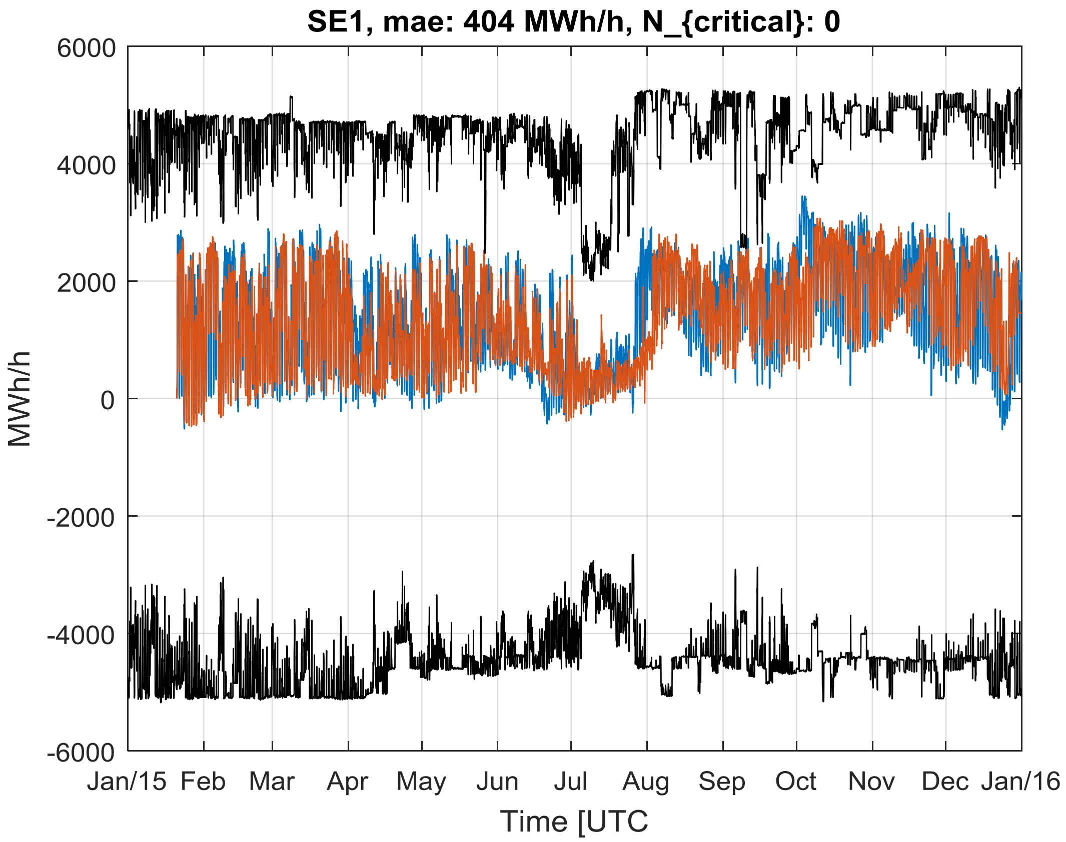

Figure 12: Example of estimated (brown) and market (blue) flows and the minimum and maximum net positions for SE1.

This is also clearly illustrated in the next figure that shows the minimum and maximum net positions during 2015 for all Nordic bidding zones, as well as the physical maximum capacity in

MW. Although the latter naturally varies somewhat during the year, it is obvious that the physical maximum is seldom a binding constraint.

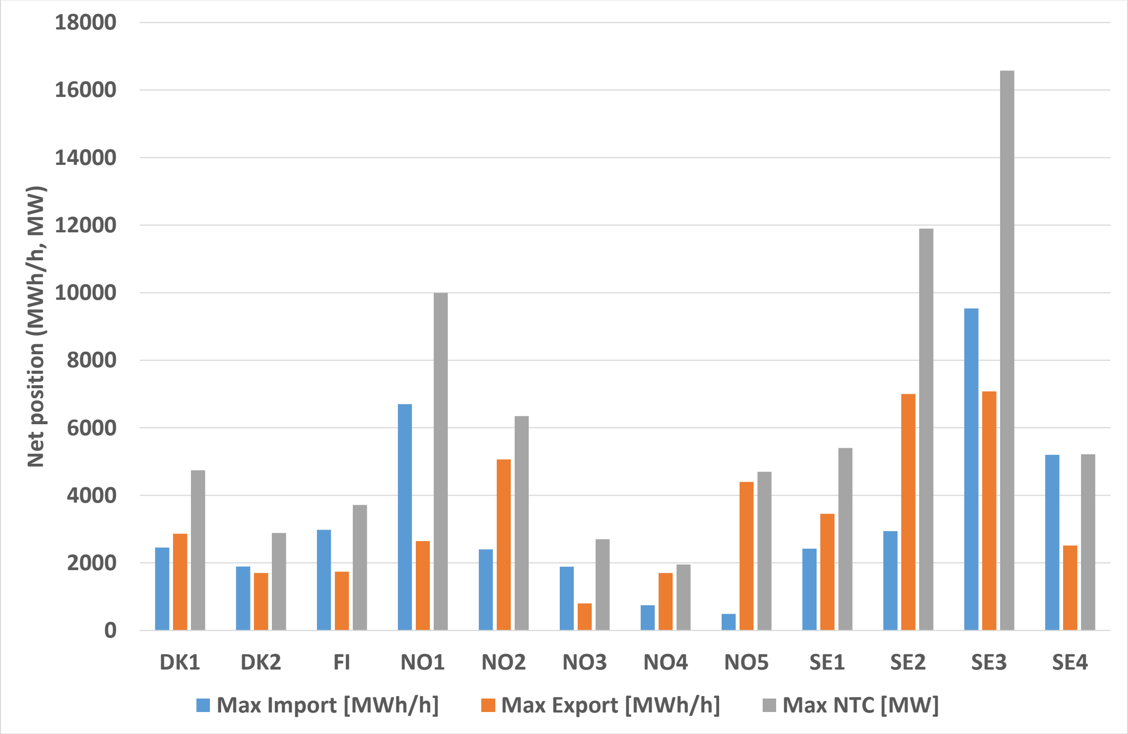

Figure 13: Lowest and highest maximum positions in 2015 and physical maximum.

The reason for this behaviour is that most bidding zones have a transit function in addition to being dominated by import or export. When the maximum net position of a normally exporting bidding zone is calculated, the export capacities of the normally importing lines are included, even though they in reality do not contribute to the zone's export capacity. The maximum net position will then not be a binding constraint in the net position estimation, even though the capacities of the exporting lines in reality may constrain the maximum net position. The situation is illustrated in the figure below:

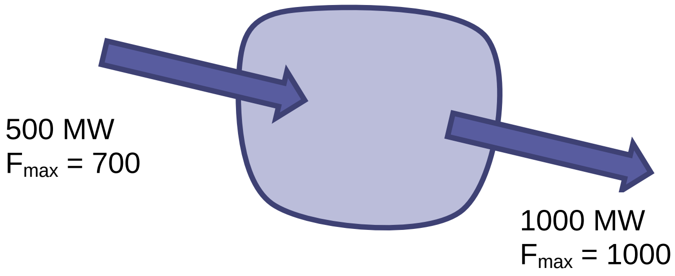

Figure 14: Bidding zone with transfer flow

The bidding zone has a theoretical maximum net position of 700 + 1000 = 1700 MW. Its actual net position is 1000 – 500 = 500 MW, and the maximum net position is far from being a binding constraint. However, the capacity of the exporting line in reality probably limits the net position in the given situation (this is not certain, depending on the conditions for the import – reduced import also results in an increased net position).

It is not straightforward to constrain the net positions based on assumptions on transit. Firstly, most bidding zones have a somewhat dynamic behaviour, e.g. even if they are normally exporting, they may sometimes have net import, cf. the figure for SE2 above. It is also hard to know how to treat the transit flows. E.g. in the figure above, should the import be assumed to be always at least 500 or could it be reduced to zero, resulting in a maximum net position of 500 or 1000 MW respectively. Secondly, making assumptions on this to some extent pre-empts the capacity calculation itself, which should be avoided.

Several tests were done with various assumptions on the transit. However, this did not lead to a significant number of hours where the maximum or minimum net positions became constrained, and moreover it did not improve the overall results.

However, the physical constraints of the interconnections obviously do have an impact on the maximum and minimum net positions. In periods where these capacities change frequently due to maintenance, including the impact of such changes could potentially improve the result. In addition to this, availability of generation capacity also constrains the possible net positions, and should be taken into account. This has not been considered and needs to be analysed in further work.

Inclusion of German net demand

The total flow into or out of the Nordic area will be influenced by German renewable generation or German net demand. An illustration is given in the figure below which depicts data for 2015.

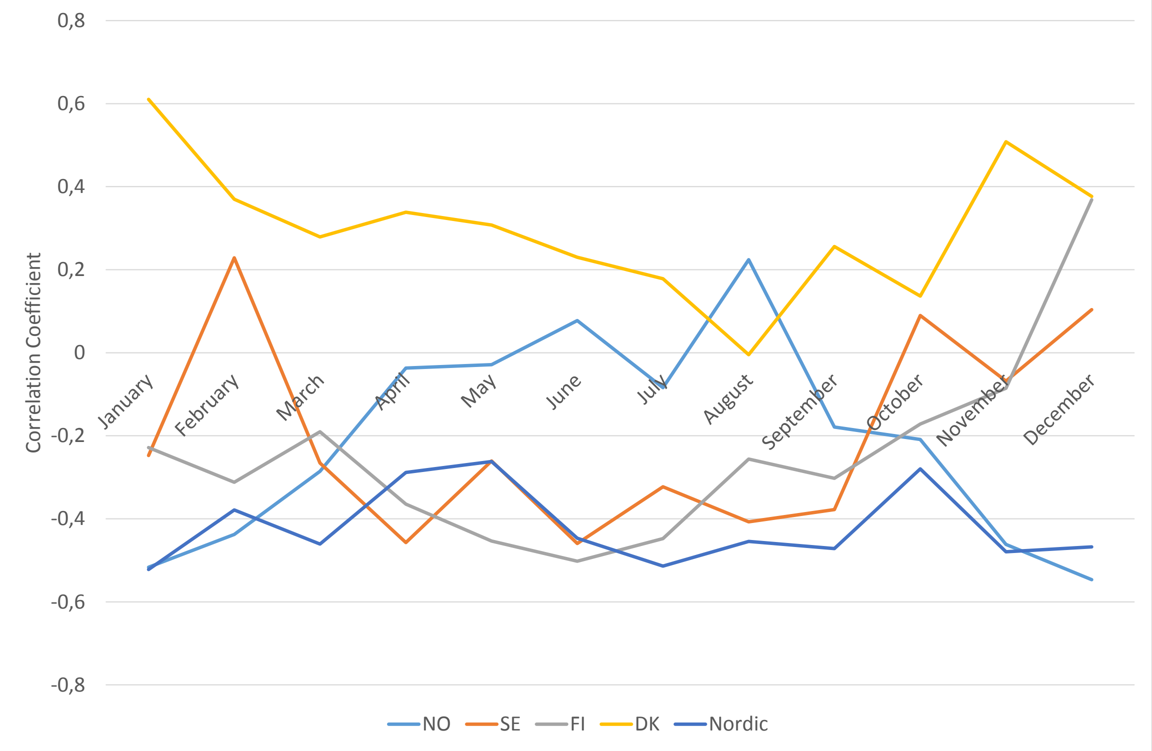

Figure 15: Correlations between German renewable generation and Nordic net positions

The figure to some extent confirms the hypothesis, but is still ambiguous:

- The Danish net position is normally positively correlated with German RE generation. This is assumed to be caused by the positive correlation between Danish and German wind generation.
- Norwegian hydro production is negatively correlated with German RE production in winter, but hardly at all during summer. The probable explanation is that the hydro generation is the most flexible production in the area, and will react on changes in RE production. However, in summer when there is much water in the reservoirs, hydro generation is less flexible and more controlled by the hydrological situation. Moreover, 2015 was a very wet year.
- The Swedish and Finnish patterns have less obvious explanations.

All in all, the Nordic net position clearly has a negative correlation with the German RE production, and including this in the model might improve the results.

German net demand was therefore included in the sum (0), and different weighting factors were tested. The following figure shows the change in result as a function of the weight of the German net demand. A weight of zero corresponds to German net demand not being included.

The numbers differ somewhat from those in , because the tests were done with slightly different assumptions.

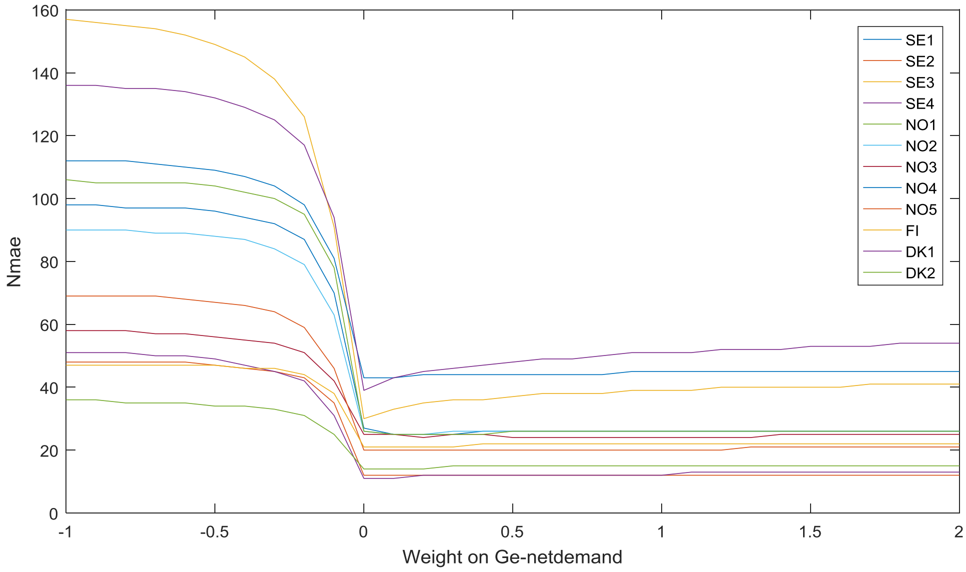

Figure 16: Effect of including German net demand in the calculation of the sum of squared net demands

The expected weight should be positive, i.e. the German net demand is used in a similar way as the Nordic net demand in order to find the best reference hours. As could be expected, using a negative weight gives significantly worse results. However, using a positive weight initially does not have a large effect, though somewhat negative. For larger values, the effect becomes increasingly negative.

So far, a good explanation for this unexpected behaviour has not been found, and further testing is needed.

Including only similar hours

The search for the best reference hours purely focuses on the best α's in Equation (0) without considering time of day. It might be that using only hours from a similar time of day could give better results. A test was therefore done using weighting factors measuring the distance to the actual hour of the day.

It turned out that this did not improve the results. This might be because the selected days mostly already were "similar", which was not verified.

Distribution functions

Apart from the average errors, it is also of interest to look at the distribution of the errors. In general a narrow distribution is preferable to a wide distribution, indicating that large errors sometime occur.

A preliminary picture of the distribution of errors is show below.

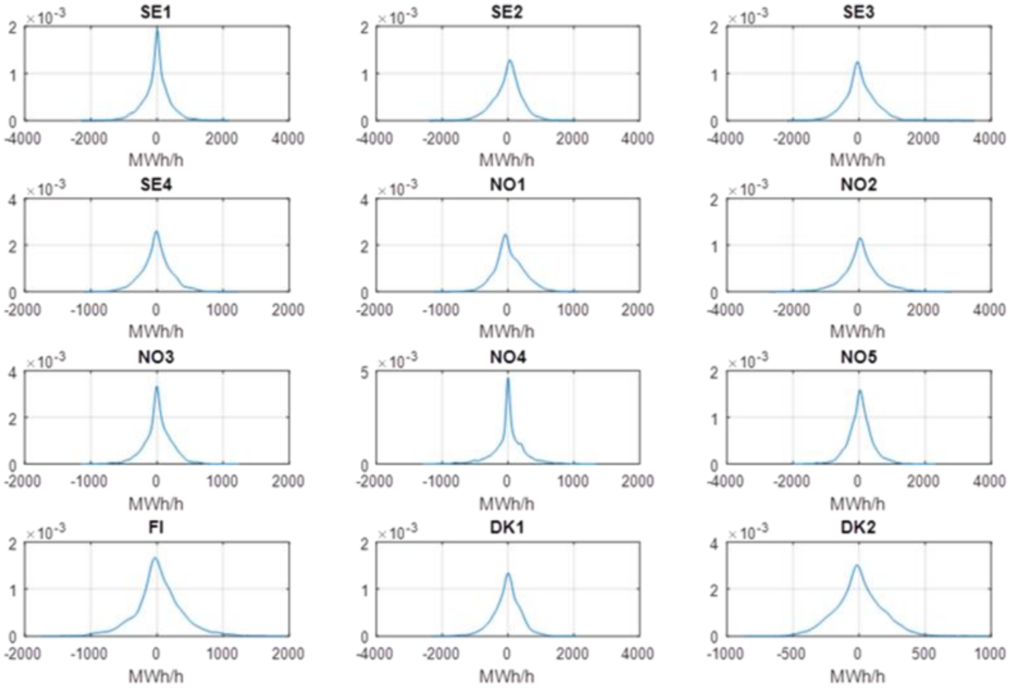

Figure 17: Preliminary distribution functions of the flow errors

The pictures suggest that the average errors are close to zero, indicating that the estimations have the correct expectation. For many areas, the distribution function seems to resemble normal distributions (to be verified), but this is clearly not the case for NO1, NO3, NO4 and DK1.

The distribution functions are of particular interest when comparing different approaches, as reducing the large errors is more important than minimizing the average error.

(5) Euphemia based approach

Description

The approach based on the Price Coupling of Regions (Euphemia) is based on the idea that on D-2 (after the clearing of the market), the best available information for the business day D is contained in the bid curves of the PXs for D-1. Of course, the market participants can change their bids from D-1 to D, but such changes cannot reasonably be foreseen in any approach. However, what changes and can be forecast is:

- Inelastic (price insensitive) demand
- RES production
- Outages of network elements
- Topology

With access to the PXs' clearing function and the possibility to change these parameters, it is then in principle possible to estimate new net positions.

The principal shape of the bid and offer curves in each bidding zone is as shown in the figure below:

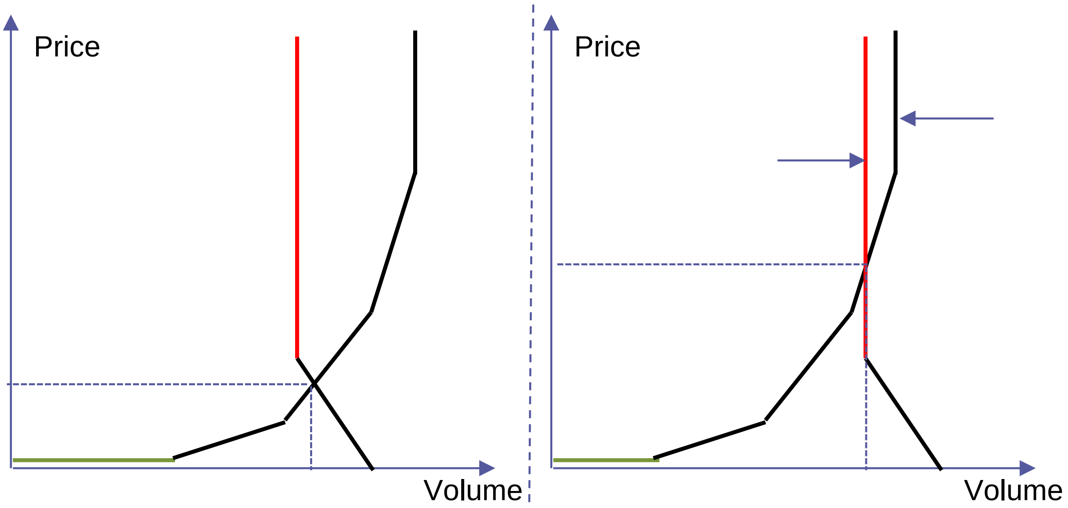

Figure 18: Supply and demand curves for one area, original (to the left) and modified (to the right)

The left hand panel shows assumed supply and demand curves for D-1 (or any other appropriate reference), resulting in a particular market solution with a price and a cleared volume. Importantly, the **brown** part of the supply curve represents renewable (or rather: non-controllable) production, while the **red** part of the demand curve represents inelastic (non price-sensitive demand). These parts of the curves would in a perfect market not be influenced by prices. The brown part of the supply curve should in theory lie at zero, but at least parts of it may be assumed to be slightly positive due to e.g. maintenance costs.

Assume that for the same hour of the business day D, the forecast of non-controllable power is lower than for D-1. This shifts the whole supply curve to the left. Moreover, assume that demand is higher than for D-1. This shifts the demand curve to the right. For the area in consideration we get a new market balance with increased price and volume. In a market with multiple zones, the result will naturally be influenced by the imports and exports between the areas, but the principal shifts of the supply and demand curves are the same.

So on D-2 forecasts must be prepared for:

- non-controllable production
- inelastic demand

for each bidding zone.

Although the principle shown in Figure 18 is straight forward, there are challenges in practice:

Which parts of the bid- and offer curves are determined by non-controllable generation and inelastic demand?

As an example, the curves for Germany/Austria for 24.06.2014 are shown below:

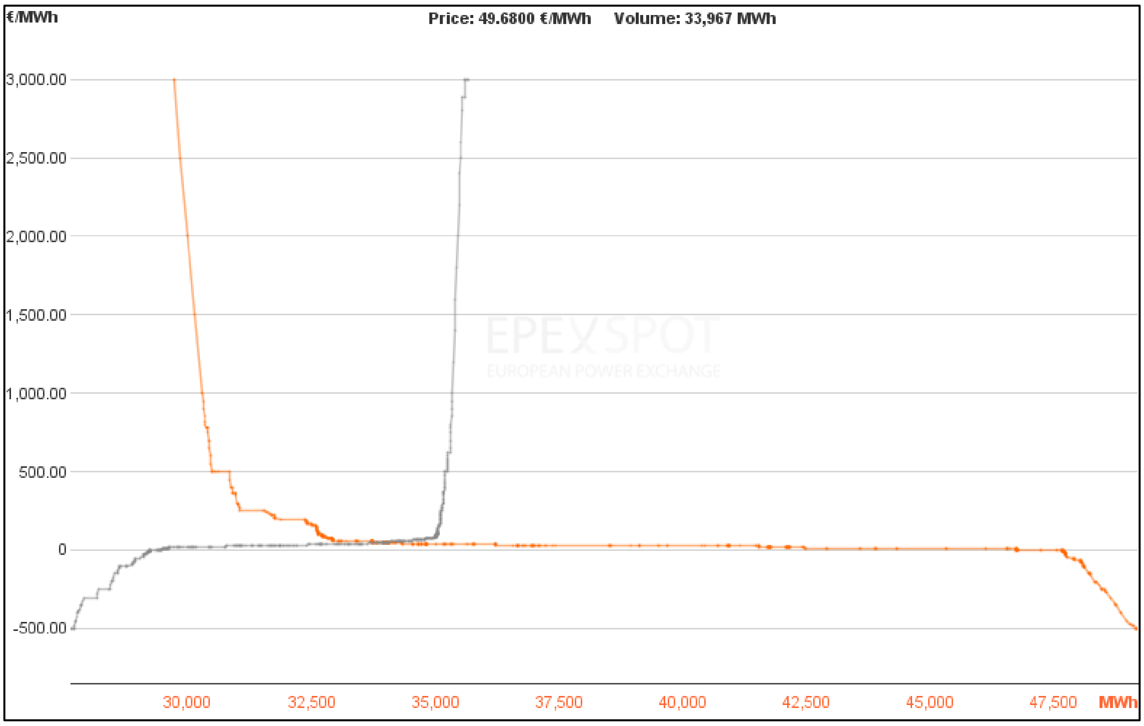

Figure 19: Supply and demand curves German/Austria (source: EPEX)

Although the principal shapes from Figure 18 can be recognized, we observe among other features negative bids. The crucial question is, however, which part of these bid curves must be substituted with the RES and demand forecasts. A possible option is to base this on the forecast from the day before, but this needs to be further explored.

How to set the exchange capacities in the market clearing?
To get reasonable net positions, realistic exchange capacities must be used in the market clearing. However, setting these capacities is the purpose of the D-2 calculations.
Setting infinite capacities is not a solution: this will in many cases lead to net positions that are unrealistic.

For the *Flow Based* approach this is probably not problematic: the inputs to the FB algorithm are mainly physical limits of the interconnections and the Critical Network Elements (CNE). So changes in the availability of assets will mostly translate directly into the capacities of interconnections and CNEs.

For the *ATC* approach this is more challenging. Setting the capacities will to some extent pre-determine the result. Still the TSOs have significant experience in how outages will affect the interconnections. Moreover, the result is not final, but only establishes a base case from which to calculate the final capacities. In any case this must be studied more closely if the FB approach is not the final choice for the market clearing.

Handling of reservation of physical transmission capacity
If physical reservations for bilateral trade are made this needs to be reflected correctly in the calculations.

Preliminary results
The preliminary results for the Euphemia based approach for 2015 are shown in , together with the results for the other methods discussed in this section.

	Euphemia	Net Demand Similarity	Reference Day
SE1	257	282	327
SE2	285	326	439
SE3	354	329	587
SE4	171	175	323
NO1	114	174	189
NO2	319	409	630
NO3	129	151	204
NO4	138	158	258
NO5	259	273	429
FI	201	272	264
DK1	244	309	685
DK2	93	145	226

Table 5: Mean Average Error per bidding zone in MW for the Euphemia based approach, compared with alternatives

The last two columns in the table are identical to those in . The country results are shown below.

	Euphemia	Net Demand Similarity	Reference Day
Denmark	278	381	867
Finland	201	272	264
Norway	539	714	1273
Sweden	512	588	830

Table 6: Mean Average Error per country in MW for the Euphemia based approach, compared with alternatives

All results are summed up in the following figure.

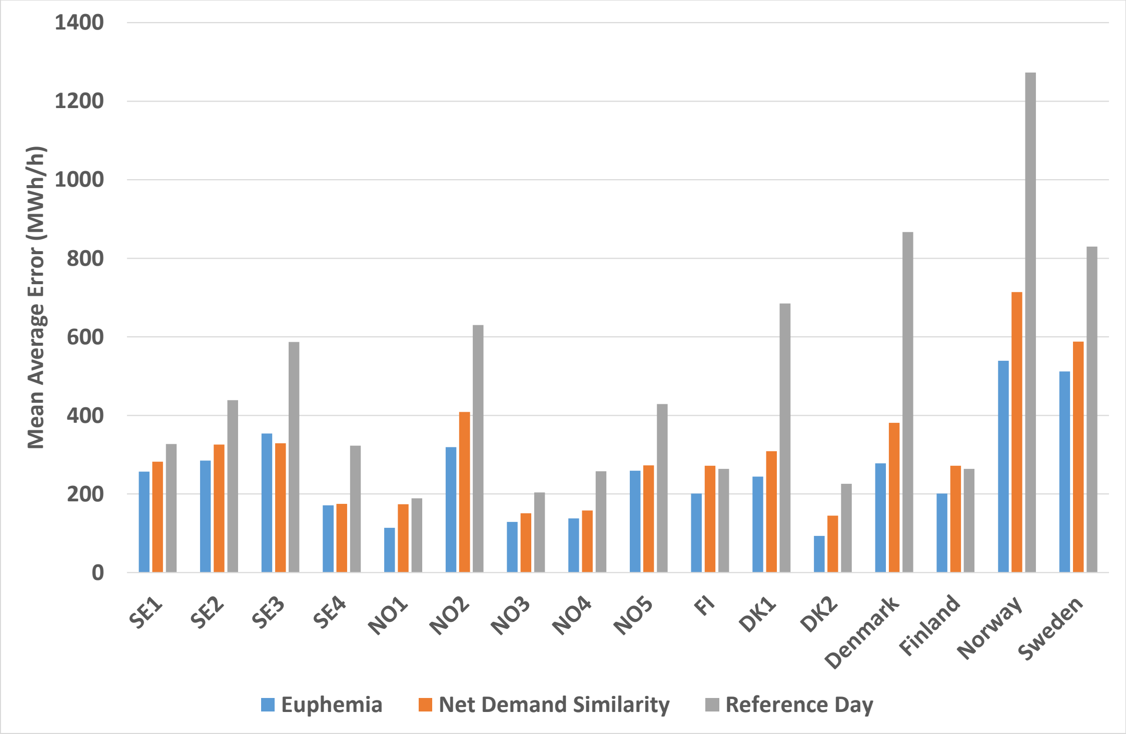

Figure 20: Comparison of MAEs for three approaches

Preliminary conclusions:

- The Euphemia based approach is better than the Net Demand Similarity approach for all bidding zones and countries, except SE3.
- Improvements are significant for NO1, NO2 and the Danish bidding zones.

At the present stage, it is not obvious what is "good enough". This must be analysed further once the processes are up and running. It should also be noted that both approaches use perfect foresight forecasts, and that using real forecasts may worsen the results.

For the Euphemia based approach, it should further be considered that the need for alignment is reduced and may ultimately be avoided when more (all) involved countries are included, as the result of the market clearing already will be balanced.

(6) Conclusions and further work

The work done so far indicates that an approach based on finding recent hours with similar net demand results in preliminary net positions that are significantly closer to real values than a simple reference day approach for almost all Nordic bidding zones. This result is obtained with a conceptually simple algorithm that is easy to implement. As forecast data were not sufficiently available, real market results were used instead of forecasts, and this may have influenced the result in a positive direction. However, the project group does not think the effect should be very large, as also the market results are based on forecasts.

An additional simple algorithm for the estimation of the flows was also tested and initial results look somewhat promising. More analysis is however needed on the flows.

A number of potential improvements to the base algorithm were tested, but none of these so far gave better results.

In addition to the main analysis using the Net Demand Similarity methodology, an approach based on the use of Euphemia data was also tested in a master's thesis at NTNU in Trondheim, using the Euphemia Simulation Facility. This approach showed additional improvements, especially for Denmark and some of the Norwegian bidding zones. These are promising results, and the work that was done is certainly a proof of concept for this approach. It may be the best option for Europe in the long run. However, a number of hurdles must be passed before the Euphemia approach can be realized in practice.

At this stage of the implementation of the capacity calculation process, it is not possible to know what is required for the preliminary net positions to be "good enough", meaning that they provide a sufficient basis for capacity calculations. This must be tested thoroughly when all required procedures are established, and this may confirm that e.g. the Net Demand Similarity approach is good enough, or that improved methods need to be developed. The improvements obtained with the Net Demand Similarity approach certainly seem to be worth the rather limited additional efforts compared with the Reference Day approach.

Further work will include:

- testing with forecast data instead of market results
- establishment of reasonable minimum and maximum values
- analysis of the variability of the results
- if possible a structured comparison of alternative approaches

In the longer term, preparing forecasts of non-controllable hydro may have a potential of improving the results.

II (iii) Pre-processing approach of Baltic RSC

Coordinated pre-processing approach under investigation by Baltic TSOs

(contribution kindly provided by the Baltic RSC)

In providing pre-processing data to the CGMA process, the three TSOs of the Baltic region – Elering AS, Augstsprieguma tīkls AS, Litgrid AB – are planning to cooperate on a regional level. The process currently envisaged is summarised in the following Figure 21 which is explained in more detail below. Note that:

- This cooperation is building on the existing coordination of the forecasting of AC-only net positions, HVDC flows, consumption and production data. The objective is to follow existing processes as closely as possible so as to not set up parallel processes.
- This is an initial draft vision developed by Elering and a later detailed version may deviate from the description below.

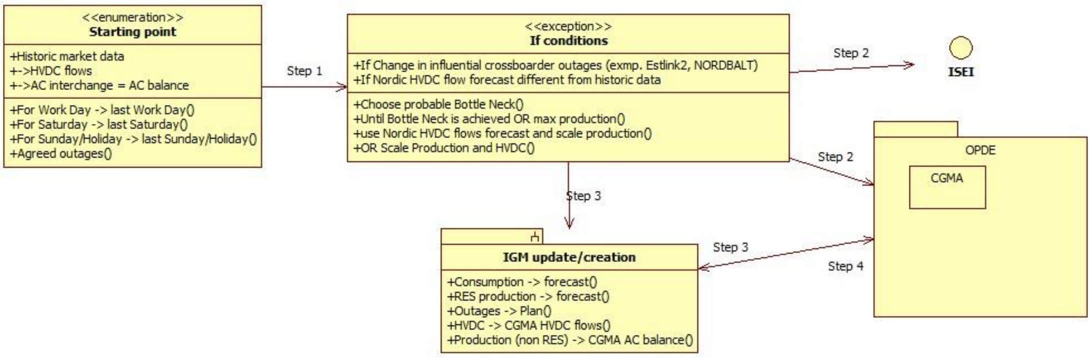

Figure 21: Overview of pre-processing approach envisaged in Baltic region

First, note that the pre-processing cooperation outlined above applies to those time frames for which the CGMA process is required; i.e., those time frames for which there are no market schedules (from (D-2) up to and including (Y-1). The relevant market time unit is one hour; i.e., all data will be provided with a resolution of one hour. One abbreviation in the above figure that deserves to be explained is "ISEI" – this is a web portal for exchange planning data used by the BRELL organisation (BRELL: Belarus, Russia, Estonia, Latvia and Lithuania).

In step 1 of the process, each TSO provides schedules for a reference day (i.e., a day with characteristics similar to those expected for the relevant energy delivery day). The data provided include preliminary AC-only net positions and associated feasibility ranges as well as preliminary DC flow data including DC feasibility ranges. The schedules provided will be adjusted if congestion is expected (which will typically be driven by the outage of important cross-border connections including both HVDC links and AC tie lines). Where the HVDC flow forecasts from the Nordic region are not consistent with the initial forecasts, the latter may also be modified.

In step 2 of the process, the matched schedules for the (historic) reference day will be used as the basis of the forecast. If no congestion is expected they will be used without modification; if congestion is to be expected, for each time-stamp the congested border will be identified and HVDC and conventional production will be scaled until allowed cross-border flow at forecasted congestion is achieved. If an HVDC forecast from the Nordic region is available, the target day DC schedules will be replaced with the Nordic forecast. The pre-processing data based on the matched schedules are then uploaded to both the ISEI platform as well as the CGMA system via the OPDE.

In step 3 of the process (no longer part of the pre-processing phase), the CGMA output data are obtained from the CGMA system and the IGMs are built (or updated) based on these balanced net positions and balanced flows on DC lines. The IGMs are then uploaded to the OPDE in turn.

II (iv) Pre-processing approach of SCC

Coordinated pre-processing approach under investigation by SEE TSOs

(contribution kindly provided by SCC)

1. The pre-processing phase of CGMA methodology for SEE region

In the pre-processing phase of the CGMA process, coordination of TSOs that choose SCC as Alignment Agent (AA), is planned. Pre-processing data will be prepared using the same methodology for those TSOs that delegated this task to SCC. Pre-processing cooperation procedure will be applied to those time horizons for which there are no market schedules, from D-2 up to W-1.

Forecast will be performed separately per TSO, since it is very hard to detect high correlation between net positions of neighboring TSOs in SEE region. Input data for prediction of TSOs PNPs are: net positions, generation and load. Each type of data will be provided on hourly time resolution. Forecast of PNPs will be determined on the basis of historical data, realized in the past (minimum) two years for the corresponding timestamps.
In the networks of TSOs that currently use SCC AA services, there are no HVDC links for now. HVDC link between CGES and TERNA is under construction, but it will not be in operation for the next two or three years. Therefore, predictions of flows on HVDC links is out of scope for the time being.

2. SCC method for net position forecasting

In contrast to the complex models, simple statistical method is proposed by SCC. The SCC method for forecasting PNPs is based on a pattern recognition and linear regression in the neighborhood of similar data. The number of parameters here is small and they can be estimated using simple least squares approach. The key element of the proposed method is data pre-processing – defining patterns of seasonal cycles. This simplifies the short-term net position forecast problem eliminating non-stationarity in mean and variance, and filtering out the trend and seasonal cycles on periods longer than the daily one.

The algorithm of the proposed pattern-based linear regression is presented and summarized in the following steps:

1. Mapping the original time series elements to patterns **x** and **y**;
2. Selection of the k nearest neighbors of the net position query pattern **x*** and creation of the training set **Φ**;
3. Construction of the linear regression model M mapping $\mathbf{X}^{\Phi} \rightarrow \mathrm{y}_{\mathrm{t}}^{\Phi}$ based on **Φ**;
4. Determination of the forecasted $\mathbf{y}^{\mathbf{f}}$ value for **x*** using M;
5. Decoding $\mathbf{y}^{\mathbf{f}}$ to get the forecast values of net positions.

Next subchapters will describe each of these steps with more details.

2.1 Determination of patterns from the original times series variables

Data pre-processing, based on patterns, simplifies the forecasting time series with multiple seasonal cycles. In our case, patterns of the daily cycles are introduced – the input patterns **x** and output ones **y**.

Vector of input variables $\mathbf{v_i} = \left[v_{i,1}\ v_{i,2}\ \dots\ v_{i,n} \right]^T$, where $n = 24$ for hourly data time series, and $i = 1, 2, \dots, N$ is the daily period number (*N* is the number of days in the time series), represents historical data of net positions $(V = NP)$, generation $(V = G)$ and load $(V = L)$. Therefore, using label $\mathbf{v_i}$, three input time series will be represented in following equations (1) and (2).

The input pattern is a vector $\mathbf{x_i} = \left[x_{i,1}\ x_{i,2}\ \dots\ x_{i,n} \right]^T$, representing the vector of input variables in successive time points of the daily period $\mathbf{v_i}$. Functions of mapping the time series elements **V** into patterns should maximize the model quality. In this study, the input pattern $x_{i,t}^{V}$, representing the $i-th$ daily period and $t-th$ hour, calculated for input variable **V**, is defined as follows:

$$x_{i,t}^{V} = \frac{V_{i,t} - \overline{V}_i}{\sqrt{\sum_{k=1}^{n} \left(V_{i,k} - \overline{V}_i \right)^2}} \qquad (1)$$

, where:

$k = 1, 2, \dots, n = 24$ is the time series element number in the daily period i,

$V_{i,t}$ is the $t-th$ time series element in the period i,

$\overline{V}_i$ is the mean value of input variables in the period i.

Whilst **x**-vectors represent input patterns (i.e. normalized values of input variables for the day i), **y**-vectors represent output patterns (i.e. the forecasted values of input variables for the day $i + \tau$, where τ is a forecast horizon stated in days). Components of the n-dimensional output pattern $\mathbf{y_i} = \left[y_{i,1}\ y_{i,2}\ \dots\ y_{i,n} \right]^T$, representing the input variable vector $\mathbf{v_{i+\tau}}$, are defined as follows:

$$y_{i,t}^{V} = \frac{V_{i+\tau,t} - \overline{V_i}}{\sqrt{\sum_{k=1}^{n}\left(V_{i,k} - \overline{V_i}\right)^2}} \qquad (2)$$

, where $i = 1, 2, \dots, N-\tau$. This is the similar equation to (1), but in this case, we do not use the mean of input variable on the day $i+\tau$ $\left(\overline{V_{i+t}}\right)$ in the numerator and $\sqrt{\sum_{k=1}^{n}\left(V_{i+\tau,k} - \overline{V_{i+\tau}}\right)^2}$ in the denominator, because these values are not known in the moment of forecasting. We use known values of $\overline{V_i}$ and $\sqrt{\sum_{k=1}^{n}\left(V_{i,k} - \overline{V_i}\right)^2}$ instead.

Using equations (1) and (2), we can calculate input ($\boldsymbol{X}$) and output ($\boldsymbol{Y}$) pattern matrices for all three input variables: net positions, generation and load.

2.2 Creation of the training set Φ

The relationship between **x** and **y**-patterns of net positions can be nonlinear. In our approach, this function is approximated locally in the neighborhood around the current input pattern for which we want to get the forecast of net positions (we call this pattern a net position query pattern **x***). By the neighborhood of **x*,** in the simplest case, we consider the set of k nearest neighbors, defined as the k net position **x**-patterns from the history which are closest to **x*** in terms of total Euclidean distance.

Total Euclidean distance quantifies the resemblance between current day and rest of the days from the history, taking into account their combined similarity of net positions, generation and load, using the equation:

$$TED_i = ED_i^{NP} + ED_i^{G} + ED_i^{L} \qquad (3)$$

, where ED_i^{NP}, ED_i^{G}, ED_i^{L} are Euclidean distances for net position, generation and load time series, respectively. Euclidean distance for input variable V could be calculated using equation:

$$ED_i^{V} = \sqrt{\left(x_{i,1}^{V} - x_1^{*V}\right)^2 + \left(x_{i,2}^{V} - x_2^{*V}\right)^2 + \dots + \left(x_{i,n}^{V} - x_n^{*V}\right)^2} \qquad (4)$$

Sorting TED_i in descending order, we could find k smallest values and then include their appropriate **x** and **y**-patterns of net positions into the training set **Φ**:

$$\Phi = \left\{ \begin{array}{cccc} x_1^{NP} & x_2^{NP} & \dots & x_k^{NP} \\ \Downarrow & \Downarrow & \vdots & \Downarrow \\ y_1^{NP} & y_2^{NP} & \dots & y_k^{NP} \end{array} \right. = \left\{ \begin{array}{c} X^{\Phi} \\ \Downarrow \\ Y^{\Phi} \end{array} \right. \qquad (5)$$

2.3 Construction of the linear regression model M using PLSR method

In the neighborhood of **x*** the target function mapping **x**-patterns to **y**-patterns is less complex than in the entire range of **x** variation of net positions. It is assumed that for small set of **Φ** this function can be approximated locally using linear regression.

To simplify the regression model the problem of approximating the vector-valued function g: $\boldsymbol{X}^{\Phi} \to \boldsymbol{Y}^{\Phi}$ is decomposed into a set of problems of approximating the scalar-valued functions g_t: $\boldsymbol{X}^{\Phi} \to \mathbf{y}_{\mathbf{t}}^{\mathbf{\Phi}}$, $t = 1, 2, ..., n = 24$. Now instead of multivariate linear regression model the multiple linear regression models can be used, one for each component of $\mathbf{y}^{\mathbf{f}}$.

The multiple linear regression model for forecasting net positions is in the form of:

$$y_t = \beta_0 + \beta_1 \cdot x_1 + \beta_2 \cdot x_2 + ... + \beta_n \cdot x_n \quad (6)$$

, where $\beta_0, \beta_1, \beta_2, ..., \beta_n$ are coefficients. Coefficients could be estimated using least-squares fit. However, notice that in the local approach the number of points used to build a model (k) can be less than their dimensionality and the number of free parameters of the model ($m = n + 1$). In such case the model is oversized – it has too many degrees of freedom in relation to the problem complexity expressed by only a few training points. In m-dimensional space, we need at least m points to define a hyper plane. When $m > k$, we get an infinite number of solutions of regression model (6), i.e. the least squares coefficients β_j are not uniquely defined.

Also, it is worth mentioning that components of **x**-patterns representing subsequent elements of time series are usually strongly correlated. Correlations between predictors indicate that some of them are linear combination of others (multicollinearity). Building model on collinear predictors leads to imprecise estimation of coefficients and missing importance of predictors. If predictors carry similar information about the response variable, some of them can be ignored. One way to deal with collinearity and excessive dimensionality is the creation of new predictors combining the original ones.

Partial least-squares regression (PLSR) produces new predictors (latent variables) which are linear combinations of the original ones and are linearly uncorrelated. The first latent variable has the largest sample variance. Subsequent latent variables have the highest variances possible under the constraint that they are orthogonal to the preceding components. The latent variables are used in place of the original predictors in the regression model:

$$y_t = \beta_0 + \beta_1 \cdot z_1 + \beta_2 \cdot z_2 + ... + \beta_c \cdot z_c \quad (7)$$

, where z_j is the $j - th$ latent variable, $c < n$ is the number of components included into the model. There is no need to use all latent variables in the model, but only the first few ones (c), because usually they explain most of the variability in the response variable. So, components with the lowest variance can be discarded. PLSR searches for such orthogonal directions to project **x**-points that have the highest variance and highest correlation with the response. The number of predictors used in the final model is a parameter of PLSR.

Based on a training set **Φ**, linear regression model could be described using equation:

$$y_t^{\Phi} = B_0 + B \cdot X^{\Phi} \qquad (8)$$

, where matrices of coefficients $\mathbf{B}_0$ and $\mathbf{B}$ are determined, for every $\mathbf{y}_t^{\Phi}$, using PLSR.

2.4 Determination of the forecasted y_t^f value

Using constructed linear regression model M (used to calculate coefficient matrices $\mathbf{B}_0$ and $\mathbf{B}$ in previous step) and query pattern **x***, $t-th$ component of forecasted net position **y**-pattern (y_t^f) can be calculated using equation:

$$y_t^f = B_0 + B \cdot x^* \qquad (9)$$

2.5 Decoding y_t^f to get the forecast values of net positions

In final step, to get the forecasted net position at hour t for τ days ahead, we decode y_t^f according to equation (2), which now can be represented as:

$$NP_t^f = y_t^f \cdot \sqrt{\sum_{k=1}^{n}(NP_k^* - \overline{NP^*})^2} + \overline{NP^*} \qquad (10)$$

3. Simulation results

In our example, the proposed linear models were examined in tasks of net position forecasting of Serbian TSO (EMS) power system for two days ahead $(\tau = 2)$. The hourly input variable (net positions, generation and load) time series are from the period August 2015 – June 2017. The test samples are from January 2016 up to January 2017, i.e. we forecast net positions in the successive 365 days. Total Euclidean distance is used to select the nearest net position **x**-patterns. For each hour of the day of forecast a separate model M is built. So, for our test samples 365·24 = 8760 models were constructed.

In order to find best values of PLSR parameters k and c, that provide the smallest root mean square error of net positions for test period, sensitivity analysis of net position forecast is implemented. Result of this analysis showed that the root mean square error decrease when the number of elements in set **Φ** (k) increase and the number of predictors (c) decrease. Based on that conclusion, models are constructed using 80 nearest neighbors of the net position query point **x*** from the history (i.e. they are selected from the period from 1^{st} August 2015 until the day before the day of the forecast) and only 1 predictor (one new latent variable compresses information extracted from all original predictors). In such case, for some query pattern **x*** we get the forecast as: $y_t = \beta_0 + \beta_1 \cdot z_1$. It means that y-values of the nearest neighbors of **x*** are similar to each other. Remember that this liner model is valid only for this query point. For another query point we determine another set of neighbors and the hyper plane changes.

As relative indicator for estimating quality of prediction of net positions forecasting methods, we calculated percent value of mean absolute error (MAE):

$$MAE = \frac{BIAS}{MAN} = \frac{\frac{\sum_{t=1}^{H} \left| NP_t^f - NP_t^r \right|}{H}}{\frac{\sum_{t=1}^{H} \left| NP_t^r \right|}{H}} = \frac{\sum_{t=1}^{H} \left| NP_t^f - NP_t^r \right|}{\sum_{t=1}^{H} \left| NP_t^r \right|} \qquad (11)$$

, where:

NP_t^f are forecasted net positions for $t-th$ hour during test period,

NP_t^r are realized net positions for $t-th$ hour during test period ,

$H = 24 \cdot N$ is total number of hours in test period.

Calculation has showed that percentage MAE value for EMS is 19% for testing period. Distribution of errors is displayed on Figure 22, where each bar represents number of errors that had a value within specific range, also known as bin. Width of every bin is 10MW. In this case, borders of bins are 1, 10, 20,…, 1000MW in positive direction, and same negative values in opposite direction. The majority of errors is located around zero, indicating that the forecast has the correct expectation. Also, it is noticeable that distribution is not symmetrical around mean value, yet that negative errors are more dominant then positive ones, which means that our methodology usually forecast smaller net positions, than realized ones.

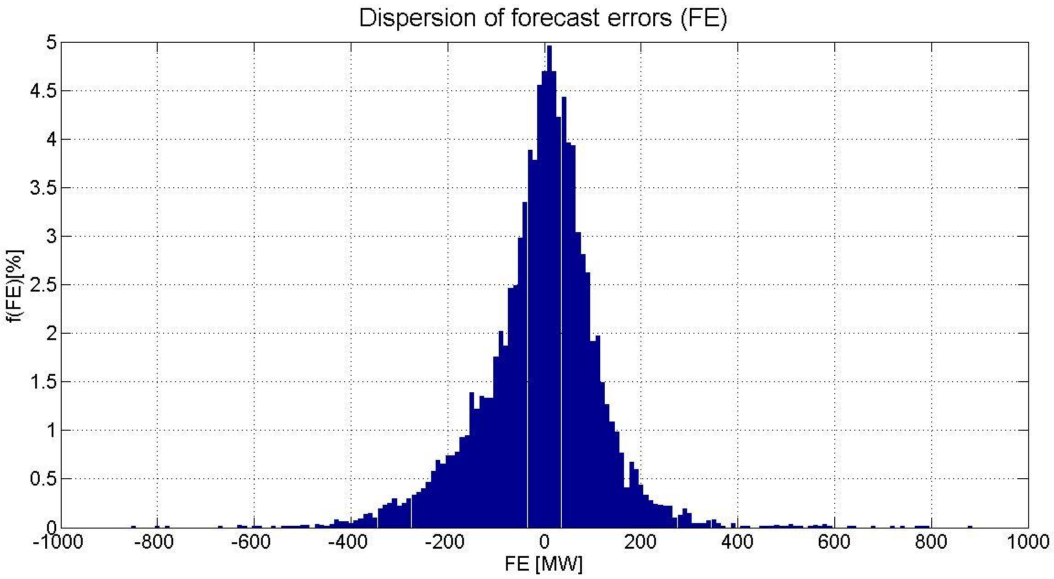

Figure 22: Dispersion of deviation between forecasted net position and realized net positions for EMS, for test period of one year

Finally, Figure 23 displays absolute forecast errors in decending order, for all 8760 hours from test period. Calculating feasibility range (FR) as 2% of instantaneous peak load of TSO, for

EMS we get value $FR \approx 150MW$ (based on instantaneous peak load for 2014). Errors smaller than 150MW occure 89% of a time, which means that majority of errors fall within feasibility range.

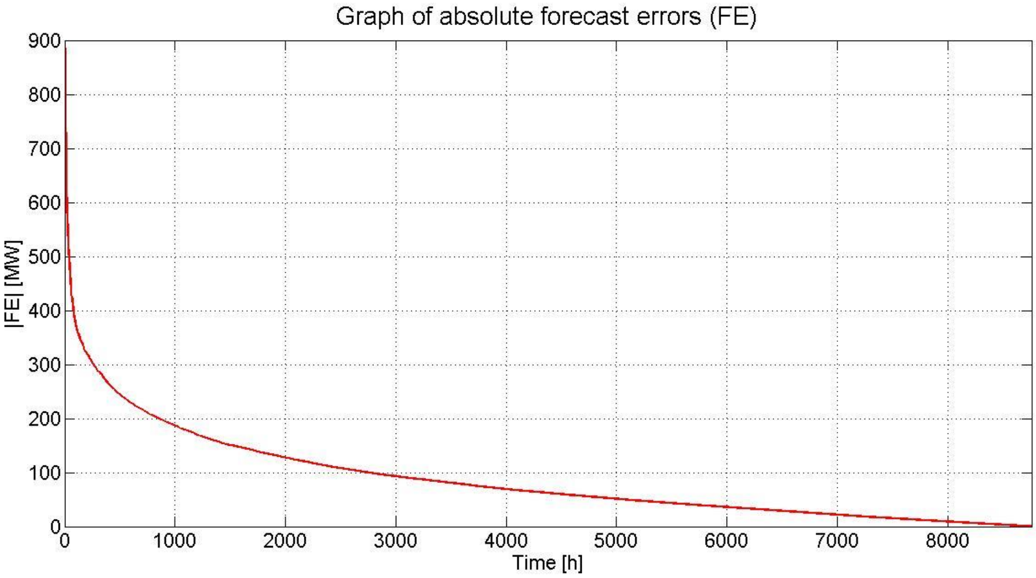

Figure 23: Absolute forecast errors for all test hours

III. ANNEX – Summary of parameters used

The present annex provides a list of the principal parameters used for easy reference.

Symbol	Parameter / Variable	Explanations
PPD	Pre-processing data	PPD for each scenario consist of --preliminary net position --feasibility range --expected flows on DC lines --maximum import and export flows per DC line The PPD may optionally include the absolute minimum and/or maximum net position.
PNP_i	Preliminary net position for bidding zone i	In accordance with Article 18(3) of Regulation 2015/1222, this has to be a TSO's "best forecast".
FR_{pos}	Positive feasibility range	$FR_{pos} \geq 0$
FR_{neg}	Negative feasibility range	$FR_{neg} \leq 0$
$[FR_{neg}; FR_{pos}]$	Feasibility range	This interval has be at least equal to 2*β*WF*% (minimum feasibility range).
$[FR_{neg,i}; FR_{pos,i}]$	Feasibility range for bidding zone i	This interval has be at least equal to 2*β*WF*% (minimum feasibility range).
$[PNP_i + FR_{neg,i};\ PNP_i + FR_{pos,i}] = [NP_{min,i}; NP_{max,i}]$	Minimum and maximum net positions (= end points of the range of acceptable balanced net positions around the preliminary net position for bidding zone i)	This interval has be at least equal to 2*β*WF*% (minimum feasibility range). The preliminary net position has to be inside the feasibility range.
$IPFlow_{k,i}$	Flow expected by TSO i on (DC) connection k	In accordance with Article 18(3) of Regulation 2015/1222, this has to be a TSO's "best forecast". Connection k has a defined direction from bidding zone i to bidding zone j
$IFlow_{min,k,i}$	Maximum import flow on (DC) connection k specified by TSO i	Has to respect the technical capacity of the connection. Sign convention: $IFlow_{min,k,i} \leq 0$
$IFlow_{max,k,i}$	Maximum export flow on (DC) connection k specified by TSO i	Has to respect the technical capacity of the connection. Sign convention: $IFlow_{max,k,i} \geq 0$
$PFlow_k$	Preliminarily balanced flow on (DC) connection k	$PFlow_k = \frac{IPFlow_{k,i} + IPFlow_{k,j}}{2}$
$Flow_{min,k}$	Maximum import flow on (DC) connection k	$Flow_{min,k} = \max(IFlow_{min,k,i}; IFlow_{min,k,j})$
$Flow_{max,k}$	Maximum export flow on (DC) connection k	$Flow_{max,k} = \min(IFlow_{max,k,i}; IFlow_{max,k,j})$
ABS_NP_MIN	Absolute minimum net position	Optional element of the PPD The balanced net position for a bidding zone must not be lower than the ABS_NP_MIN (if specified). The ABS_NP_MIN must respect the requirement that ABS_NP_MIN ≤ $PNP_i + FR_{neg}$
ABS_NP_MAX	Absolute maximum net position	Optional element of the PPD The balanced net position for a bidding zone must not be greater than the ABS_NP_MAX (if specified). The ABS_NP_MAX must respect the requirement that ABS_NP_MAX ≥ $PNP_i + FR_{pos}$
WF	Weighting factor	Provides a proxy for the ability of a bidding zone to accommodate a change in the (preliminary) net position of a given size. Is currently defined in terms of the instantaneous peak load of a bidding zone.

Symbol	Parameter / Variable	Explanations
$NP_{weight,i}$	Weighting factor for the adjustment of the net position of bidding zone i	
$F_{weight,k}$	Weighting factor for the adjustment of the flow on (DC) connection k	
β	Minimum feasibility range modifier	The minimum feasibility range is currently set at 2*β*WF*%. The β thus varies the width of the minimum feasibility range; the larger β, the larger the feasibility range required. The initial value for β is 1.
$\sum_i PNP_i$	Preliminary net position across all bidding zones	Sum of PNPs; corresponds to the aggregate forecast error
BNP_i	Balanced net position for bidding zone i	
$BFlow_k$	Balanced flow on connection k	

IV. ANNEX – Data Formats

As of the summer of 2017, the question of which data formats will be used by the CGMA process has been resolved in principle. Contrary to the initial expectation, only one data format will be available for sending input data (the PPD) to the CGMA IT platform: CGMES – at least in version 2.4.15 – will not be suitable for transferring the PPD to the CGMA IT platform. However, a CIM-based format, the Reporting Information Market Document, is available for transferring the PPD to the CGMA IT platform and for sending the CGMA output data (balanced net positions and balanced flows on DC lines) back to TSOs and other relevant parties.

RIMD is building on existing formats developed for similar transfer purposes; specifically the data exchange with the Pan-European Verification Function (PEVF). These formats are similar to scheduling formats and, simplifying somewhat, may be thought of as all-purpose vehicles for transferring time series.

Sample files and xsd files have also been made available to CGM SPOCs shortly upon the release of the Implementation Guide.

As for the data to be transferred, the table below summarises the input data (as discussed in the present document):

No.	Data	Source	Originator	Format
1	Bidding Zone (known to the CGMA algorithm as "Optimisation Area")	CGMA user portal	AA	internal
2	AC Link	CGMA user portal	AA	Internal
3	DC Line	CGMA user portal	AA	internal
4	DC Max Flow (in)	OPDE	TSO	RIMD
5	DC Max Flow (out)	OPDE	TSO	RIMD
6	Weighting Factor for Bidding Zone (Optimization Area)	CGMA user portal	AA	Internal
7	Weighting Factor for DC line	CGMA user portal	AA	Internal
8	Preliminary Net Position (PNPs)	OPDE	TSO	RIMD
9	Preliminary DC Flow	OPDE	TSO	RIMD
10	Positive Feasibility Range for Adjustment of PNPs	OPDE	TSO	RIMD
11	Negative Feasibility Range for Adjustment of PNPs	OPDE	TSO	RIMD
12	ABS_NP_MIN and / or ABS_NP_MAX	OPDE	TSO	RIMD
13	Substitution values from verification platform (PEVF) for missing values	PEVF	PEVF	RIMD

Table 7: CGMA input data

With respect to the column "Originator", note that in many cases the information could also be provided by a party other than the party listed here. This is of particular relevance with respect to the possible delegation to RSCs of the provision of PPD by the individual TSOs (whose obligation it is to provide these data).

The output data to be provided are the following:

No.	Data	Source	Format
1	Quality Gate Check Results	Quality Gate	Acknowledgement Problem Statement
2	Balanced Net Position	CGMA Algorithm	RIMD
3	Balanced DC Flow	CGMA Algorithm	RIMD
4	Indicative AC Flows	CGMA Algorithm	RIMD
5	Status Information from Optimization Run	CGMA Algorithm	internal
6	KPIs (Key Performance Indicators)	CGMA Algorithm / Quality Gate	proprietary XML

Table 8: CGMA output data[25]

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[25] In addition to these output data narrowly defined, the CGMA IT platform also provides information on revised / substituted input data

2979
V. ANNEX - Glossary

2980

Term/Abbreviation	Definition	Source/Reference
Across-synchronous area DC line	DC line connecting different synchronous areas (and therefore different CGMA optimization areas)	
DC flows	Equivalent of "flows on DC lines" The terms "flows on DC lines" and "DC flows" are used interchangeably in the various CGMA-related documents (the present CGMAM, the CGMA IT specification, the CGMA Data Exchanges Implementation Guide). All documents make use of both terms which are equivalent.	
Minimum feasibility range	Currently set at 2*β*%*WF; i.e., the interval [FR_neg, FR_pos] has to be wider than or equal to 2*β*%*WF	PT CGM WP-5
Net position	the netted sum of electricity exports and imports for each market time unit for a bidding zone A more precise way of referring to net positions in the sense in which the term is used in the CGMAM would be to refer to "aggregate AC/DC net positions". However, the simpler (and slightly less accurate) term "net position" is used in the CGMAM in order to be consistent with the terminology in Regulation 2015/1222.	Article 2(5) of Regulation 2015/1222
Netted area position	Equivalent of "net position" The CGMA DExIG uses the term "netted area position" as this is consistent with an already existing business type (B65).	
Netted area AC position	Equivalent of "AC-only net position" Also see above	
Optimisation area	In connection with the CGMA algorithm, bidding zones (control areas) are referred to as "optimisation areas".	

Term/Abbreviation	Definition	Source/Reference
Pre-processing data (PPD)	The PPD consist of • the preliminary net position (PNP) • the feasibility range (FR) for the adjustment of the preliminary net position (FR_neg; FR_pos) • expected flows on DC lines • maximum import and maximum export flows on DC lines The following additional data can be optionally submitted along with the PPD: • absolute minimum and maximum net position (ABS_NP_MIN, ABS_NP_MAX)	PT CGM WP-5
Weighting factor	CGMA-related parameter currently defined as a bidding zone's instantaneous peak load (IPL)	PT CGM WP-5
Within-synchronous area DC line	DC line fully within a synchronous area that connects different CGMA optimization areas	

VI. ANNEX - CGM area in terms of coverage of bidding zones (as of 2017-07) as well as DC lines

The following table comprehensively describes the geographical coverage of the CGM on the level of bidding zones. It should be read in conjunction with the annotations related to Article 1 of the CGMM. Unless noted otherwise, the bidding zones listed below are part of the CGM area.

In the case of TSOs managing more than one bidding zone, the TSO may provide a single IGM for the whole control area (although the information on the DC lines need not be included in the IGM and can be provided via an alternative route) and the TSO's website provides additional information about the composition of the bidding zones. A TSO managing several control areas, may, of course, provide several IGMs in line with the provision in Article 19 of Regulation 2015/1222.

Additional information of interest may also be found in the "All TSOs’ proposal for Capacity Calculation Regions (CCRs) in accordance with Article 15(1) of the Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a Guideline on Capacity Allocation and Congestion Management" published on the ENTSO-E website.

In multiple-TSO jurisdictions, Member States may have assigned responsibilities among the TSOs in a particular manner. The present overview table does not aim to provide details on this. It also does not provide information on EICs which may, however, be found in the CGMA IT specs.

Where TSOs have appointed Alignment Agents (RSCs), the name of the AA/RSC is added in square brackets as, for example, [Baltic RSC].

SUB-LINE	**Synch. Area**	**Bidding zone**	**TSO(s)**	**EU member?**	**ENTSO-E member?**	**Comments**
01	CE	AL	Operatori i Sistemit të Transmetimit (OST)	No, but Energy Community member	Yes	Albania provides its IGM and is part of the CGM area. [SCC]
02	CE	AT / DE / LU	Austrian Power Grid AG Vorarlberger Übertragungsnetz GmbH Eneco Valcanale S.r.l. 50Hertz Transmission GmbH Amprion GmbH TenneT TSO GmbH TransnetBW GmbH Creos Luxembourg S.A.	Yes	Yes (except Eneco Valcanale S.r.l.)	This bidding zone composition reflects the bidding zone configuration as of 2017-07. [TSCNET]
03	CE	BA	Nezavisni operator sustava u Bosni i Hercegovini (NOS BiH)	No, but Energy Community member	Yes	[SCC]
04	CE	BE	Elia System Operator SA	Yes	Yes	[CORESO]
05	CE	BG	Electroenergien Sistemen Operator EAD (ESO)	Yes	Yes	[SCC]
06	Baltic	BY	Belenergo Holding / Belarus TSO	No	No	Belarus not part of CGM area; interconnections to Belarus to be incorporated as injections by the TSOs of Lithuania and Poland

SUB-LINE	**Synch. Area**	**Bidding zone**	**TSO(s)**	**EU member?**	**ENTSO-E member?**	**Comments**
07	CE	CH	Swissgrid AG	No	Yes	Switzerland is part of the CGM area; legal questions related to Article 1 (4) and (5) of Regulation 2015/1222 are out of scope of the present document [TSCNET]
08	CE	CZ	ČEPS a.s.	Yes	Yes	[TSCNET]
09	CE	DK1	Energinet.dk	Yes	Yes	[Nordic RSC]
10	Nordic	DK2	Energinet.dk	Yes	Yes	[Nordic RSC]
11	Baltic	EE	Elering AS	Yes	Yes	[Baltic RSC]
12	CE	ES	Red Eléctrica de España S.A.	Yes	Yes	[CORESO]
13	Nordic	FI	Fingrid Oyj	Yes	Yes	[Nordic RSC]
14	CE	FR	Réseau de Transport d'Electricité	Yes	Yes	[CORESO]
15	GB	GB	National Grid Electricity Transmission plc Scottish Hydro Electric Transmission plc Scottish Power Transmission plc BritNed National Grid Interconnectors Ltd. Moyle Interconnector Ltd. Offshore Transmission Owners (OFTOs – not individually listed)	Yes	Yes Yes Yes No No No No	[CORESO]
16	CE	GR	Independent Power Transmission Operator S.A.	Yes	Yes	

SUB-LINE	**Synch. Area**	**Bidding zone**	**TSO(s)**	**EU member?**	**ENTSO-E member?**	**Comments**
17	CE	HR	HOPS d.o.o.	Yes	Yes	[TSCNET]
18	CE	HU	MAVIR Magyar Villamosenergia-ipari Átviteli Rendszerirányító Zártkörűen Működő Részvénytársaság	Yes	Yes	[TSCNET]
19	IE / NI	IE/NI	EirGrid plc System Operator for Northern Ireland Ltd Moyle Interconnector Ltd.	Yes	Yes Yes No	[CORESO]
20	CE	IT1 (NORD)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
21	CE	IT2 (CNOR)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
22	CE	IT3 (CSUD)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
23	CE	IT4 (SUD)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
24	CE	IT5 (FOGN)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
25	CE	IT6 (BRNN)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
26	CE	IT7 (ROSN)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
27	CE	IT8 (SICI)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]
28	CE	IT9 (PRGP)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	[CORESO]

SUB-LINE	**Synch. Area**	**Bidding zone**	**TSO(s)**	**EU member?**	**ENTSO-E member?**	**Comments**
29	CE	IT10 (SARD)	Terna - Rete Elettrica Nazionale SpA	Yes	Yes	Not included in CGM according to Terna (not relevant from a technical point of view)
30	Baltic	LT	Litgrid AB	Yes	Yes	[Baltic RSC]
31	Baltic	LV	AS Augstsprieguma tÏkls	Yes	Yes	[Baltic RSC]
32	CE	MA	ONEE	No	No	Morocco not part of CGM area; interconnection to Morocco to be incorporated as injection by the TSO of Spain
33	CE	MD	Moldelectrica	No, but Energy Community member	No	Moldova not part of CGM area
34	CE	ME	Crnogorski elektroprenosni sistem AD	No, but Energy Community member	Yes	[SCC]
35	CE	MK	Macedonian Transmission System Operator AD	No, but Energy Community member	Yes	
36	CE	MT	Enemalta	Yes	No	Malta is not part of the CGM area as it only has a distribution network, not a transmission network. Following the commissioning of the interconnection linking Malta with Sicily, Malta is incorporated in the IGM of Terna, the Italian TSO, as an injection.
37	CE	NL	TenneT TSO B.V. BritNed	Yes	Yes No	[TSCNET]
38	Nordic	NO1	Statnett SF	No	Yes	Norway is part of the CGM area. One IGM is submitted for the combined Norwegian
39	Nordic	NO2	Statnett SF	No	Yes	
40	Nordic	NO3	Statnett SF	No	Yes	
41	Nordic	NO4	Statnett SF	No	Yes	

SUB-LINE	Synch. Area	Bidding zone	TSO(s)	EU member?	ENTSO-E member?	Comments
42	Nordic	NO5	Statnett SF	No	Yes	bidding zones. [Nordic RSC]
43	CE	PL	Polskie Sieci Elektroenergetyczne S.A.	Yes	Yes	[TSCNET]
44	CE	PT	Rede Eléctrica Nacional, S.A.	Yes	Yes	[CORESO]
45	CE	RO	C.N. Transelectrica S.A.	Yes	Yes	[TSCNET]
46	CE	RS	JP Elektromreža Srbije	No, but Energy Community member	Yes	[SCC]
47	Baltic	RU	FGC	No	No	Russia not part of CGM area; interconnections to Russia to be incorporated as injections by the TSOs of Finland, Estonia, Latvia, Lithuania, and Norway.
48	Nordic	SE1	Svenska Kraftnät	Yes	Yes	[Nordic RSC]
49	Nordic	SE2	Svenska Kraftnät	Yes	Yes	[Nordic RSC]
50	Nordic	SE3	Svenska Kraftnät	Yes	Yes	[Nordic RSC]
51	Nordic	SE4	Svenska Kraftnät	Yes	Yes	[Nordic RSC]
52	CE	SI	ELES, d.o.o.	Yes	Yes	[TSCNET]
53	CE	SK	Slovenská elektrizačná prenosová sústava, a.s.	Yes	Yes	
54	CE	TR	TEIAS	No	No	Turkey provides its IGM and is part of the CGM area.
55	CE	UA_W	WPS	No, but Energy Community member	No	Western Ukraine provides its IGM (six timestamps) and is part of the CGM area
56	CE	XK	KOSTT	No, but Energy Community member	No	Kosovo provides its IGM and is part of the CGM area

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VII. ANNEX - CGM area in terms of coverage of CGMA algorithm optimisation areas (as of 2017-07) as well as DC lines

The present annex describes the composition of the CGM area in terms of CGMA optimisation areas; i.e., those areas for which PPD are provided and for which balanced net positions etc. are computed. Since the optimisation areas correspond to those areas for which IGMs are contributed to the CGM process - i.e., do not correspond one-to-one to the bidding zones listed in the preceding Annex VI - it seemed advisable to include a separate list of optimisation areas in the present document.

Note that, as far as the CGMA algorithm and the CGMA IT platform are concerned, it will always be possible (even at a later stage) to adjust the configuration of optimisation areas; i.e., their number and how they are linked. It will also be possible to set "valid from" dates (differentiated by time horizon) in the CGMA IT platform such that for non-EU TSOs there is some flexibility with respect to when they join the CGMA process.

Sub-line	Synch. Area	"Area" (ISO code)	IGM / PPD on the level of CA vs BZ	Comments (incl. on IPL availability)
01	CE	AL	IGM = CA = BZ = PPD	IPL figure not yet included in ENTSO-E document but obtained directly from OST
02	CE	AT	IGM = CA = PPD At present the AT control area is part of the wider AT-DE-LU bidding zone. The splitting up of the AT-DE-LU bidding zone into an AT BZ on the one hand and a DE-LU BZ on the other hand is under way. As far as the CGMA process is concerned that question is irrelevant in the sense that it is certain that --AT will provide an IGM on the level of its control area --AT will provide PPD on the level of its control area	IPL figure available
03	CE	BA	IGM = CA = BZ = PPD	IPL figure available
04	CE	BE	IGM = CA = BZ = PPD	IPL figure available
05	CE	BG	IGM = CA = BZ = PPD	IPL figure available
06	Baltic	BY	Belarus is not part of the CGM Area and does not constitute a CGMA optimisation area	(N.A.: not applicable)

Sub-line	Synch. Area	"Area" (ISO code)	IGM / PPD on the level of CA vs BZ	Comments (incl. on IPL availability)
07	CE	CH	IGM = CA = BZ = PPD	IPL figure available
08	CE	CZ	IGM = CA = BZ = PPD	IPL figure available
09	CE	DE_50Hz	IGM = CA = PPD At present all four German control areas are part of the wider AT-DE-LU bidding zone the breaking up of which is currently under way. As far as the CGMA process is concerned that question is irrelevant in the sense that it is certain that each of the DE TSOs will provide an IGM and PPD on the level of its control area. The IPL figure for Germany in the ENTSO-E Yearly Statistics & Adequacy Retrospect needs to be pro-rated in proportion to "vertikale Netzlast" (which DE TSOs are required to publish by law); see below for additional explanations.	IPL figure for all of DE available; this has been pro-rated in proportion to maximum "vertikale Netzlast" (see below for explanations)
10	CE	DE_Amprion	IGM = CA = PPD (see explanations above)	(see above)
11	CE	DE_TenneT	IGM = CA = PPD (see explanations above)	(see above)
12	CE	DE_TransnetBW	IGM = CA = PPD (see explanations above)	(see above)
13	CE	DK1	IGM = CA = BZ = PPD Denmark does not pose any particular conceptual challenges as far as the CGMA process is concerned. Denmark is modelled as two control areas which each correspond to a bidding zone. Denmark will thus provide two IGMs and two sets of PPD. The only remaining task is to split the DK weighting factor (available from the ENTSO-E document only on the level of the entire country) across the two CAs/BZs. The notes below explain how this pro-rating was done in proportion to yearly consumption.	IPL figure available; see below for additional explanations
14	Nordic	DK2	IGM = CA = BZ = PPD (see comment / explanation above)	(see above)
15	Baltic	EE	IGM = CA = BZ = PPD	IPL figure available
16	CE	ES	IGM = CA = BZ = PPD	IPL figure available
17	Nordic	FI	IGM = CA = BZ = PPD	IPL figure available
18	CE	FR	IGM = CA = BZ = PPD	IPL figure available

Sub-line	Synch. Area	"Area" (ISO code)	IGM / PPD on the level of CA vs BZ	Comments (incl. on IPL availability)
19	GB	GB	IGM = CA = BZ = PPD As far as the CGMA process is concerned, the United Kingdom consists of GB (England, Wales, Scotland) and NI (Northern Ireland). This subdivision is well established and, as far as GB is concerned, does not raise any particular questions.	IPL figure available
20	CE	GR	IGM = CA = BZ = PPD	IPL figure available
21	CE	HR	IGM = CA = BZ = PPD	IPL figure available
22	CE	HU	IGM = CA = BZ = PPD	IPL figure available
23	IE/NI	IE AND NI	The key to understanding how Ireland (Eirgrid) and Northern Ireland (SONI) are taken into account in the CGMA process is the observation that IE and NI will jointly provide an IGM which corresponds to their joint bidding zone and that they will also provide a single set of PPD for the CGMA process. They also jointly constitute a single LFC area/block. However, the Eirgrid and SONI grids do not constitute a single control area, but rather two separate control areas.	IPL figures available for both TSOs; the figures will be summed up in order to obtain the (single) weighting factor for the combined PPD
24	CE	IT	IGM = CA = PPD (CA does not correspond to BZ) Italy consists of a total of ten bidding zones. However, Terna submits a single IGM on the level of the control area which is also the relevant area with respect to the CGMA process.	IPL figure available
25	Baltic	LT	IGM = CA = BZ = PPD	IPL figure available

Sub-line	Synch. Area	"Area" (ISO code)	IGM / PPD on the level of CA vs BZ	Comments (incl. on IPL availability)
26	CE	LU	IGM = CA = PPD At present LU and all four German control areas are part of the wider AT-DE-LU bidding zone (the breaking up of which is currently under way). At the time of writing (July 2017) the LU IGM is contained in the IGM provided by DE TSO Amprion. Creos is expecting to provide an IGM fully of its own in future although a timetable for this has not yet been set. This means that Creos will also have to join the CGMA process and provide PPD and LU will become one of the optimisation areas for the CGMA algorithm. As for the control area / bidding zone status of LU, LU constitutes a control area. LU and DE will continue to constitute a joint / common bidding zone.	IPL figure available
27	Baltic	LV	IGM = CA = BZ = PPD	IPL figure available
28	CE	MA	Morocco is not part of the CGM Area and does not constitute a CGMA optimisation area	(N.A.: not applicable)
29	CE	MD	Moldova is not part of the CGM Area and does not constitute a CGMA optimisation area	(N.A.: not applicable)
30	CE	ME	IGM = CA = BZ = PPD	IPL figure available
31	CE	MK	IGM = CA = BZ = PPD	IPL figure available
32	CE	MT	In terms of the practical handling envisaged for the time being, Malta will not provide an IGM to the CGM and will instead be incorporated into Terna's IGM as an injection. It would appear that Malta does not have a TSO nor a transmission system and that the requirements set out in Regulation 2015/1222 are not applicable. Article 1(2) of that Regulation stipulates that "This Regulation shall apply to all transmission systems and interconnections in the Union except the transmission systems on islands which are not connected with other transmission systems via interconnections."	(N.A.: not applicable)
33	CE	NL	IGM = CA = BZ = PPD	IPL figure available
34	Nordic	NO	IGM = CA = PPD (CA does not correspond to BZ) Norway consists of a total of five bidding zones. However, Statnett submits a single IGM on the level of the control area which is also the relevant area with respect to the CGMA process.	IPL figure available

Sub-line	Synch. Area	"Area" (ISO code)	IGM / PPD on the level of CA vs BZ	Comments (incl. on IPL availability)
35	CE	PL	IGM = CA = BZ = PPD	IPL figure available
36	CE	PT	IGM = CA = BZ = PPD	IPL figure available
37	CE	RO	IGM = CA = BZ = PPD	IPL figure available
38	CE	RS	IGM = CA = BZ = PPD	IPL figure available
39	Baltic	RU	Russia is not part of the CGM Area and does not constitute a CGMA optimisation area	(N.A.: not applicable)
40	Nordic	SE	IGM = CA = PPD (CA does not correspond to BZ) Sweden consists of a total of four bidding zones. However, SvK submits a single IGM on the level of the control area which is also the relevant area with respect to the CGMA process.	IPL figure available
41	CE	SI	IGM = CA = BZ = PPD	IPL figure available
42	CE	SK	IGM = CA = BZ = PPD	IPL figure available
43	CE	TR	IGM = CA = BZ = PPD	IPL figure available
44	CE	UA_W	IGM = CA = BZ = PPD	IPL figure no longer included in ENTSO-E document
45	CE	XK	IGM = CA = BZ = PPD	IPL figure not yet included in ENTSO-E document but obtained directly from KOSTT

Notes:

Link to list of EIC approved Y (area) codes:
https://www.entsoe.eu/fileadmin/user_upload/edi/library/eic/ars/area.htm

As a general rule whenever the IPL values (or other data required) cannot be obtained from the ENTSO-E Yearly Statistics and Adequacy Retrospect the relevant RSC shall be responsible for ensuring that the data are available.

Notes on Denmark:

Figures (approximately) corresponding to instantaneous peak load are not easily available separately for the two Danish control areas. The 2016 IPL figure for all of Denmark [6115 MW] was therefore pro-rated in proportion to yearly total consumption of electricity (in 2015). The resulting weighting factors for each of the Danish control areas are shown in the table below:

Consumption in MWh				
(Source: NPS website)	**DK1**	**DK2**	**DK**	
2015	19768527	13039599	32808126	
Share in 2015 [%]	60.3%	39.7%		
Pro-rated IPL 2016 [MW]	3687	2428	6115	

(For future – internal – reference: data sources and computations have been documented in file DK-pro-rating-IPL-in-proportion-to-consumption-2015.doc. Note that the consumption figures were not updated with figures for 2016 as the consumption shares of the two control areas were likely to have remained approximately constant.)

Notes on Germany:

The table below shows weighting factors for each of the four DE control areas obtained by pro-rating the 2016 IPL figure for all of Germany [81945 MW] in proportion to the maximum value of "vertikale Netzlast" in 2015. (For future – internal – reference: data sources and computations have been documented in file DE-weighting-factors-as-of-2016-09-26-1700h.xls. Note that the "vertikale Netzlast" figures were not updated with figures for 2016 although the figure for maximum instantaneous peak load for Germany as a whole was.)

Maximum "Vertikale Netzlast" [MW]	Share [%]	Year	DE IPL share [MW]	TSO
9268	17.6%	2015	14422	50Hertz
19312	36.6%	2015	29992	Amprion
16233	30.8%	2015	25239	TenneT
7907	15.0%	2015	12292	TransnetBW
52720			81945	

Notes on Ireland:

IPL 2015 IE [MW]	IPL 2015 NI [MW]	IPL 2015 IE/NI [MW]
4704	1758	6462

The source for the above data on IE and NI is the 2016 edition of ENTSO-E's Yearly Statistics and Adequacy Retrospect (for internal reference: entsoe-2017-05-29-yearly-statistics-and-adequacy-retrospect-2015.pdf) featuring data for calendar year 2015. The ENTSO-E Statistical Factsheet with data for 2016 (cover-dated 04 May 2017) does not contain a breakdown for the UK figure into separate GB and NI figures.

The following table summarises the DC lines that need to be included in the CGMA process. The figures in highlighted cells have not yet been reconfirmed by at least one of the TSOs:

No. in map	Name	Synchro-nous Area 1	Synchro-nous Area 2	TSO 1	TSO 2	Bidding Zone 1	Bidding Zone 2	Country 1	Country 2	Max. export when TSO 1 is exporting [MW]	Max. export when TSO 2 is exporting [MW]	DC weighting factor [MW]
1	Moyle Interconnector	IE/NI	GB	SONI	National Grid	IE/NI	GB	UK	UK	300 (due to voltage stability issues)	500	300
2	East West Interconnector	IE/NI	GB	EirGrid	National Grid	IE/NI	GB	IE	UK	525	525	525
3	Britned	GB	Continental Europe	National Grid	TenneT NL	GB	NL	UK	NL	1000	1000	1000
4	IFA (Cross-Channel Interconnector linking GB and FR)	GB	Continental Europe	National Grid	RTE	GB	FR	UK	FR	2000	2000	2000
5	Norned	Nordic	Continental Europe	Statnett	TenneT NL	NO2	NL	NO	NL	723	723	723
6	Skagerrak (1-4; total of four cables)	Nordic	Continental Europe	Statnett	ENDK	NO2	DK1	NO	DK	1700	1700	1700
6-1	Skagerrak 1	Nordic	Continental Europe	Statnett	ENDK	NO2	DK1	NO	DK	250	250	250
6-2	Skagerrak 2	Nordic	Continental Europe	Statnett	ENDK	NO2	DK1	NO	DK	250	250	250
6-3	Skagerrak 3	Nordic	Continental Europe	Statnett	ENDK	NO2	DK1	NO	DK	500	500	500

No. in map	**Name**	**Synchro-nous Area 1**	**Synchro-nous Area 2**	**TSO 1**	**TSO 2**	**Bidding Zone 1**	**Bidding Zone 2**	**Country 1**	**Country 2**	**Max. export when TSO 1 is exporting [MW]**	**Max. export when TSO 2 is exporting [MW]**	**DC weighting factor [MW]**
6-4	Skagerrak 4	Nordic	Continental Europe	Statnett	ENDK	NO2	DK1	NO	DK	700	700	700
7	KontiSkan (1-2; total of two cables)	Nordic	Continental Europe	SvK	ENDK	SE3	DK1	SE	DK	720	720	720
7-1	KontiSkan 1	Nordic	Continental Europe	SvK	ENDK	SE3	DK1	SE	DK	360	360	360
7-2	KontiSkan 2	Nordic	Continental Europe	SvK	ENDK	SE3	DK1	SE	DK	360	360	360
8	StoreBælt	Nordic	Continental Europe	ENDK	ENDK	DK2	DK1	DK	DK	600	600	600
9	NordBalt	Nordic	Baltic	SvK	Litgrid	SE4	LT	SE	LT	738	738	738
10	SwePol	Nordic	Continental Europe	SVK	PSE	SE4	PL	SE	PL	600	600	600
11	Baltic Cable	Nordic	Continental Europe	SVK	TenneT DE	SE4	AT / DE / LU	SE	DE	600	600	600
12	Kontek	Nordic	Continental Europe	ENDK	50Hertz	DK2	AT / DE / LU	DK	DE	600	600	600
13-1	Estlink 1	Nordic	Baltic	Fingrid	Elering	FI	EE	FI	EE	366	366	366
13-2	Estlink 2	Nordic	Baltic	Fingrid	Elering	FI	EE	FI	EE	666	666	666
14	LitPol (back-to-back converter)	Baltic	Continental Europe	Litgrid	PSE	LT	PL	LT	PL	500	500	500

No. in map	**Name**	**Synchro-nous Area 1**	**Synchro-nous Area 2**	**TSO 1**	**TSO 2**	**Bidding Zone 1**	**Bidding Zone 2**	**Country 1**	**Country 2**	**Max. export when TSO 1 is exporting [MW]**	**Max. export when TSO 2 is exporting [MW]**	**DC weighting factor [MW]**
15*	Fenno-Skan (1-2; total of two cables)	Nordic	Nordic	SvK	Fingrid	SE3	FI	SE	FI	1229	1229	1229
15-1	Fenno-Skan 1	Nordic	Nordic	SvK	Fingrid	SE3	FI	SE	FI	410	410	410
15-2	Fenno-Skan 2	Nordic	Nordic	SvK	Fingrid	SE3	FI	SE	FI	819	819	819
16*	GRITA	Continental Europe	Continental Europe	Terna	ADMIE	IT6	GR	IT	GR	500	500	500

*: DC lines fully within synchronous areas; the preliminary DC flows on these lines are made consistent by the Quality Gate; however, for the time being these preliminary DC flows are not being modified as part of the operation of the CGMA algorithm. As of July 2017, these are the only operational DC lines within synchronous areas also operated as such.

Table 9: DC lines to be included in CGMA process (as of 2017-07)

The following map provides a stylized topology of the CGMA optimisation areas:

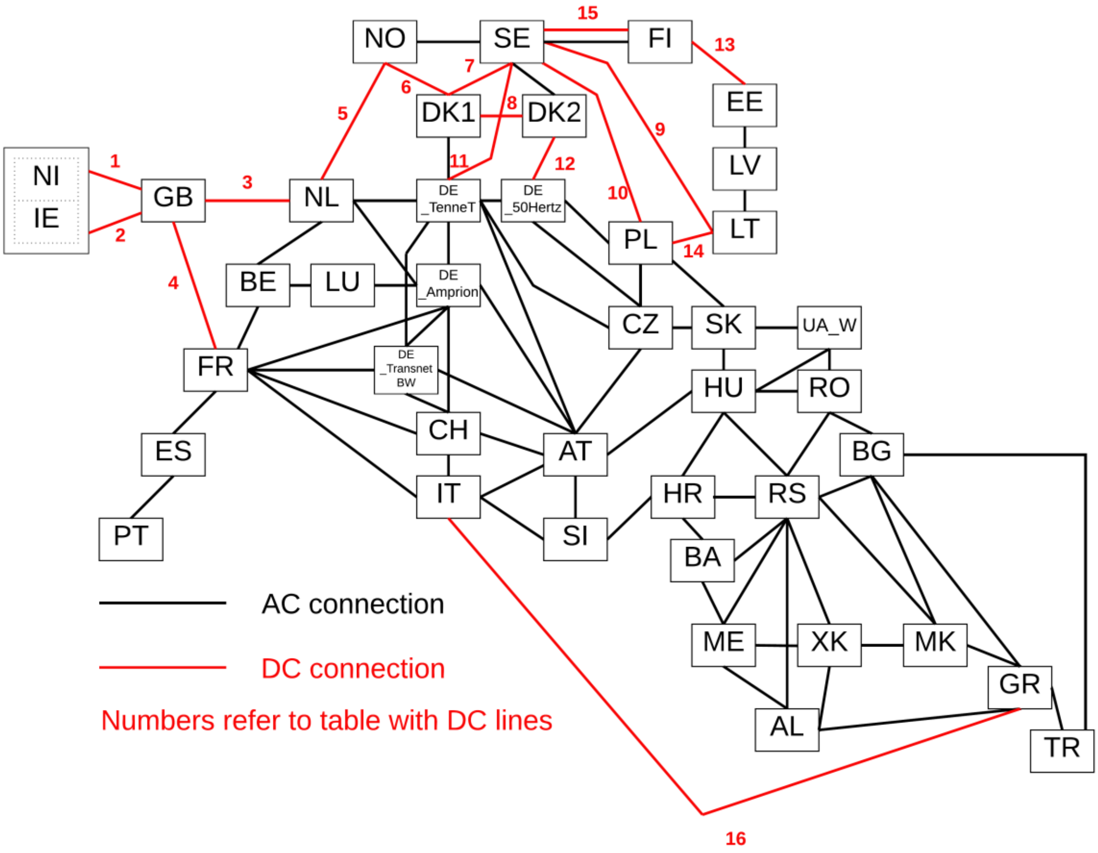

Figure 24: Stylised topology of CGMA optimisation areas