Annex 5: The MC algorithm requirements

In this annex we describe the list of requirements that a market coupling algorithm which must calculate the optimised market results (volumes and prices), from an input consisting of information from the PXs' order books and network parameters provided by the TSOs, must fulfil.

These requirements relate:

- either to the strict framework of the CWE project, i.e. they are considered as necessary to couple the four CWE exchanges through scheduled electrical energy transfers using electric networks of the seven TSOs existing in the five CWE countries ("mandatory requirements"),

- or - as a second priority- to potential extensions of the CWE project, for instance the coupling of the CWE regions with other PXs belonging to other regions ("additional requirements").

The latter "additional" requirements, if not strictly necessary for the success of the CWE project, will undoubtedly be highly useful, notably in the already planned multi-regional extensions. Therefore, one of the evaluation criteria for the CWE algorithm is its flexibility: the algorithm must be relatively easily adaptable to fulfil additional requirements.

1   Mandatory Functional requirements

1.1   Objective

The MC algorithm refers to the full solution, including elements that may be undertaken locally or centrally. The algorithm takes as input all necessary information[1] from all local orders submitted by the participants of the power exchanges and the parameters of the network constraints.

The MC Results, output of the algorithm, are:

- for each bidding area:

  - the area net position for each hour (exporting or importing),
  - the Market Clearing Price (MCP) for each hour,
  - the set of accepted and rejected, block orders;

- for each constraint in the network representation:
  - the shadow[2] price associated with the network constraint for each hour.

The algorithm must determine the best MC results under the exchanges' constraints, the network constraints and the high level properties (see below) and in this way optimize the economical usage of the cross border day ahead transmission capacity in the CWE region.[3]

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[1] Minimum information to be provided includes volume and price of all individual but anonymised block orders and so called Net Export Curves, provision of more detailed information like all anonymised individual orders should also be supported by the algorithm but is not required
[2] a "shadow" price associated to a constraint is the increase of the objective function resulting from relaxing this constraint by one unit
[3] In the MoU the goal of the flow based market coupling is expressed as 'to increase economic efficiency for the region'.

1.2 Types of Market Coupling

There are two possible MC algorithm types:

- "tight coupling" refers to the method which incorporates the entire set of necessary data (orders aggregation and static information) and all matching rules of the coupled markets. This information (market data and rules) is then used in its entirety to calculate the MC results. The method thus aims at finding feasible[4] and as optimal market results as possible. In any case, these MC results are acceptable as such for all parties (which thus allows volume and price coupling mechanisms, see further)
- "loose coupling" is a general term which describe a coupling method that does not necessarily incorporate all local information or matching rules. In this case, only the calculated exchange volumes between the loosely coupled markets can be used from the algorithm output[5]. Loose coupling is thus only applicable with volume coupling mechanisms.

These MC methods thus distinguish on the level of information (data and rules) which is shared in order to couple the markets.

When considering the coupling of results with the local market results, different methods then exist:

- "price coupling": in this mode, the net export positions, prices and list of selected block orders that are determined centrally are transferred to the exchanges which use this information to compute individual positions of their market participants. This type of coupling requires necessarily a tight coupling method.

- "volume coupling": in this mode, only the net export positions computed by a central unit[6] are transferred to the exchanges which incorporate them as price acceptant bids into their local system. The exchanges thus locally calculate their prices on their own in a second step. This type of coupling can use a tight coupling method (this combination is referred to as "tight volume coupling") or loose coupling method (this combination is referred to as "loose volume coupling").

The algorithm must be able to perform each of these MC types. Since the requirements of tight coupling algorithms encompass the requirements of all other MC types, this type is assumed in the rest of this document.

1.3 Order types
The different order types that are used within the CWE region today, are considered mandatory. Therefore, the algorithm must be able to handle the following order types:

1.3.1 Hourly Orders

- An Hourly Order can be an offer (sale) or a bid (purchase).
- An Hourly Order can be Stepwise or Linear.
    - Stepwise Hourly Orders are defined by one volume limit and one price limit for one given hour in one given bidding area.
    - Linear Hourly Orders are defined by one volume limit and two price limits (one upper and one lower limit) for one particular hour in one bidding area.

The fixing of hourly orders satisfies the following constraints:

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[4] i.e. in the sense that all market rules are respected

[5] as the complete set of market results might not be feasible in the sense that they might not completely obey the local market rules

[6] The same algorithm can be used for price and tight volume coupling, requiring few modifications knowing that in volume coupling, the prices and the selected block orders are calculated by a central unit and then recomputed by the PXs.

- An Hourly Offer is rejected when the Market Clearing Price is lower than the offer (lowest) price limit.
- An Hourly Bid is rejected when the Market Clearing Price is higher than the bid (highest) price limit.
- An Hourly Offer is accepted when the Market Clearing Price is higher than the offer (highest) price limit.
- An Hourly Bid is accepted when the Market Clearing Price is lower than the bid (lowest) price limit.
- An Hourly Order may be partially accepted if and only if the Market Price is equal to the price limit of that order / is between the two price limits of that order.
- An Hourly Order is not accepted for a quantity in excess of the volume limit specified in the Order.

1.3.2 Block Orders (profile)

- A Block Order can be an offer (sale) or a bid (purchase).
- A Block Order is defined by one volume limit at each hour and one price limit, in one bidding area

The fixing of block orders satisfies the following constraints:

- A Block Offer is not accepted when the average of the rounded Market Clearing Prices over the relevant hours and weighted by the corresponding volume limits is lower than the price limit of this order.
- A Block Bid is not accepted when the average of the rounded Market Clearing Prices over the relevant hours and weighted by the corresponding volume limits is higher than the price limit of this order.
- A Block Order can only be accepted at all hour simultaneously, for a quantity equal to the hourly volume limits specified in the order.

1.4 Network constraints

The algorithm must be able to handle the network constraints expressed in two network representations:

1.4.1 Flow-Based representation

In Flow-based representations of the network, the set of feasible solutions is defined externally by a set of hourly linear inequality constraints, as defined in Chapter 3 of this report.

As such, the link between the provided parameters and the physical reality is left out of the scope of the algorithm, as it accommodates either with an advanced network representation as described in Chapter 3, or with a more simplified flow-based model such as the ETSO flow-based model.

1.4.2 Less sophisticated representations

In addition, the algorithm should also be in condition to operate with the well-known ATC values methodology, independent from any underlying FB modelling of the grid. With ATC-based network constraints, the areas' net positions are only limited by a provided capacity value for each interconnection.

Also, it is highly desirable as an optional requirement that the algorithm is able to support a full flow-based model for the CWE region and less sophisticated representations including a normal ATC-based approach for other regions simultaneously.

1.4.3 Balancing constraint

With both network representations, the sum of the areas' net position is equal to zero[7] (subjected to a predefined tolerance).

1.5 High Level Properties

The MC Results comply with the following High Level Properties (HLP):

- Market prices are within pre-defined price boundaries per market, subject to a predefined tolerance.
- Whenever a network constraint i is not binding, the shadow price[8] μ_i of this constraint is null, subject to a predefined tolerance.

  $(PTDF_{i\,*}\,b - f_i).\mu_i = 0$ for all flow based-constraints i

- In flow-based models, the difference between Market Clearing Prices of area z and z' equals the average of the μ_i weighted by the difference of PTDF coefficients related to area z and z', subject to a predefined tolerance:

$$P_z - P_{z'} = \sum_i (PTDF_{z',i} - PTDF_{z,i})\,\mu_i \text{ for all bidding areas z, z'}$$

In ATC models, this condition would become: The shadow price $\mu_{z\text{->}z'}$ of an (unidirectional) interconnector bringing power from area z to area z' is the positive difference between the market Clearing Prices of areas z' and z if $Flow_{z\text{->}z''} = ATC_{z\text{->}z'}$ and zero otherwise:

$$(Flow_{z\text{->}z'} - ATC_{z\text{->}z'}).\,\mu_{z\text{->}z'} = 0 \text{ for all bidding areas[9] z, z'}$$

$$P_{z'} - P_z = \mu_{z\text{->}z'} - \mu_{z'\text{->}z} \text{ for all bidding areas z, z'}$$

Note: these High Level Properties are similar to the ones currently used in the TLC, except the HLP meaning that the less expensive markets should export towards the more expensive markets, since the validity of this condition is not certain any more with flow-based constraints (see Chapter 3).

1.6 Performance requirements

The algorithm must fulfil the following mandatory requirements:

1.6.1 Reliability

The algorithm is robust, reliable, and is resilient to unexpected data configuration, i.e. it provides satisfying results in all cases, including in all special situations such as orders curtailment, max/min prices, price and volume indeterminacy, etc. Note: the solution should always produce a unique result – i.e., price and volume indeterminacy must be resolved.

1.6.2 Computing time

Generally speaking, the total processing time should be optimised and strongly under control (e.g. guarantee to provide solutions within a limited time).The maximum limit is fixed to 10 minutes. Performance evaluation in this respect is part of the algorithmic targets!

1.6.3 Fairness

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[7] If considering future extensions that are DC lines (e.g. BritNed), the algorithm is able as an additional requirement to take losses for such cables into account (see §2.2).
[8] i.e. a shadow price is the maximum price for an extra unit of a given limited resource, this latter being in this specific case the constrained transmission capacity of a specific transmission element.
[9] This implies ATC = 0 for all pairs of non-connected bidding areas.

Generally speaking, the algorithm is fair, meaning that there is no discrimination between market participants (for example between sellers and buyers) or between bidding areas (for example between "stepwise" and "linear" markets).

1.7 Varia

The following requirements are also mandatory:

1.7.1 Winter and Summer Time

The algorithm is able to deal with clock changes related to winter and summer time changes (supports 23, 24 or 25 hours).

1.7.2 Price boundaries

The algorithm is able to support different price boundaries (Pmin & Pmax) for each bidding area[10]. Price boundaries can possibly be negative.

1.7.3 Rounding

The algorithm is able to tackle different price and volume ticks (a small tolerance level on the some constraints might therefore be allowed / necessary in some cases).

2 Additional requirements

The algorithm should, inasmuch as this does not create delays or substantial additional costs, be able to handle other features (instruments, network constraints,…) which, while not required by the isolated CWE project, are necessary when used in the coupling with neighbouring regions. In particular:

2.1 Additional Order types

The algorithm should be able to handle the following additional order types:

2.1.1 Flexible Hourly Orders

- A Flexible Hourly Order can be an Offer (sale) or a Bid (purchase).
- A Flexible Hourly Order is defined by one volume limit and one price limit in one bidding area (the hour in which to accept it is not specified).

The fixing of flexible hourly orders satisfies the following constraints:

- A Flexible Hourly Bid is not accepted in one hour when the Market Clearing Price of this hour is higher than the price limit of the order.
- A Flexible Hourly Offer is not accepted in one hour when the Market Clearing Price of this hour is lower than the price limit of the order.
- A Flexible Hourly Order is not accepted for a quantity in excess of the volume limit specified in the Order.
- A Flexible Hourly Order is not accepted partially.
- A Flexible Hourly Order is not accepted at more than one hour.

2.1.2 Linked Block Orders

- Linked Block Orders are defined by priority lists of Block Orders for each bidding area.
- A priority list can contain one or more offers and bids.

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[10] Handling different min / max prices in the market coupling system is however not desired as it could yield to anti-economic outcomes and robustness of the algorithm is then more difficult to ensure. Also, price boundaries can normally be harmonized relatively easily (except when considering negative prices). This does not mean that harmonizing the price boundaries is unnecessary.

The fixing of linked block orders satisfies the following constraints:

- The acceptance of a Block Order is subject to the acceptance of all Block Orders with higher priority.
- Linked Block Orders satisfy all other "normal" Block Order constraints.

2.1.3 Other order types

Potential additional order types are:

- Volume Flexible Block Orders are Block Orders for which the "fill or kill" condition has been replaced by a "fill at least x% or kill" (with x defined by the submitting participant). Such orders could be useful to ensure start-up cost recovery or to model technical minimal production limits with additional flexibility in comparison to normal Block Orders.
- Flexible Energy Orders are Flexible Hourly Orders which can be accepted partially and/or accepted at more than one hour (with optionally an hourly volume limit). They might be useful to model generation units limited by their total energy (e.g. dams) with additional flexibility.

2.2 Network constraints

The algorithm should be able to handle the following transmission constraints:

- Ramping constraints that limit the change in flow from one hour to the next:
  - in the flow of some particular network element (i.e. single ramping),
  - in the sum of the flows of several network elements (i.e. cumulative ramping),
  - in an area net position (i.e. internal cuts);

- Losses might be taken into account for some particular network elements (e.g. cables to UK) as a fixed proportion of the flows over these network elements requiring a balancing of overall physical and financial flows.
- Charges are applied to use certain network elements (cables to UK). As a result, a constraint enforces that the hourly price differences over the interconnector (i.e. CR) at least compensates for the hourly charges to be paid.

2.3 Currencies

The coupling system supports different currencies to be used simultaneously as long as one unique exchange rate is to be considered during calculations (all orders are then converted in Euros during price calculation and converted back to local currency afterwards).

3 Algorithmic behaviour

This section describes the "targets" of the algorithm and presents insight on the qualitative aspects expected for the algorithm.

3.1 Methodology

Several methodologies may be considered with respect to the desired market results properties:

- On the one hand, the algorithm must provide an optimal solution in terms of total Net Utility (Total surplus = consumer surplus + producer surplus + congestion revenue); failing that, the algorithm provides a suboptimal solution accompanied by an upper bound to its difference with the optimal solution, in terms of Net Utility.
- On the other hand, the algorithm must also provide a minimal number of PRBs in particular avoiding PRBs with large price deltas.

Optimality (in terms of Net Utility) and Quality (in terms of PRB minimisation) are two different criteria and the balance between them will have to be weighed.

3.2 Simplicity

The algorithm must be easy to implement. The complexity of the algorithm does not prevent its efficient implementation.

3.3 Performance

The total processing time should be optimised, so that the solution is compatible with the harmonisation of the gate closure times of the power exchanges at 12:00 and with the new daily schedule.

3.4 Scalability

A system whose performance improves after adding hardware, proportionally to the capacity added, is said to be a scalable system.
In the context of CWE market coupling, this means that the algorithm, if the computer hardware is improved (more working memory, more processors, faster processors).
- produces better solutions in the same amount of computing time and/or
- produces a similarly good solution in a smaller amount of computing time

3.5 Robustness

The algorithm can be easily maintained.

3.6 Reliability

The algorithm uses proven technology (e.g. open software standards, proven third party software).

3.7 Transparency

Non-expert parties need to understand how the algorithm calculates prices and capacity allocations, and be able to satisfy themselves that it is operating correctly.
The calculation process, as well as prices and allocated capacities resulting from this process, have to be transparent, auditable, explainable and understandable.