

EMCC – Market Coupling Company

EMCC optimizer

Version	2.0
Status	Final
Document ID	EMCC optimizer 2.0
Date	13.05.2009
Printed	6.11.2009

Table of Contents

1	Management Summary	3
1.1	Abstract	3
1.2	Document Content	3
1.3	Definitions and Abbreviations	4
2	Market Coupling Overview	6
3	Functional Overview	6
3.1	Motivation	7
3.2	Calculation Input	7
3.2.1	Order Book Data	7
3.2.2	Available Transfer Capacity	7
3.2.3	Ramp Rates	7
3.2.4	EPEX Products	8
3.2.4.1	Single Hourly Bids	8
3.2.4.2	Block Contracts	8
3.2.5	Nord Pool Products	8
3.2.5.1	Single Hourly Bids	9
3.2.5.2	Flexible Hourly (Sales) Bids	9
3.2.5.3	Fixed Block Bids	9
3.2.5.4	User-defined block bids	10
3.2.5.5	Linked Block Bids	10
3.2.5.6	Convertible Block Bids	10
4	Market Coupling Calculation	11
4.1	Method	11
4.2	Model	12
4.2.1	Optimization goal	12
4.2.2	Handling the products	12
4.2.2.1	Hourly bids	12
4.2.2.2	Block bids	12
4.2.2.3	Flexible hourly sales bids	13
4.2.2.4	Linked Blocks	13
4.2.3	Handling cross-border flow and its restrictions	13
4.2.3.1	ATC	13
4.2.3.2	Ramping	13
4.2.4	Balancing of purchase and sales	14
4.2.5	Objective function	14
4.3	Solving the Problem	14
4.3.1	Algorithm overview	14
4.3.2	Algorithm phases	14
4.3.3	Special Cases	15
4.3.4	Curtailement	15
4.3.5	Choosing minimum prices (“vertical overlaps”)	15

1 MANAGEMENT SUMMARY

1.1 Abstract

Five project initiators (TPS transpower stromübertragungsnetz gmbh, Energinet.dk, Vattenfall Europe Transmission GmbH, Nord Pool Spot AS and European Energy Exchange AG) introduce a new market scheme for coupling the Nordic and German power markets.

The goal of this initiative is the improved utilization of day-ahead cross border capacity between Germany and Denmark on the interconnectors:

- TPS transpower stromübertragungs gmbh and Energinet.dk (DK West)
- Vattenfall Europe Transmission GmbH and Energinet.dk (“Kontek”)

EMCC has contracted DBS as its IT-Service provider. DBS provides EMCC with an IT-Service for linking the Nordic (NPS) and German (EPEX) Day-Ahead power auctions via an implicit auction. This implicit auction will coordinate and merge the trading of the commodity (electricity) and the acquisition of transmission capacity rights into a single operation.

1.2 Document Content

This document contains the description of the EMCC Market Coupling calculation.

- Section 2 provides a general overview
- Section 3 provides a functional description including the necessary input
- Section 4 provides a description of the market coupling calculation

1.3 Definitions and Abbreviations

Term/Abbreviation	Explanation
ATC	Available Transmission Capacity; is the part of NTC that remains available, after each phase of the allocation procedure (after day-ahead trading), for further commercial activity.
Aggregated Bid Curve	Aggregation of the individual hourly bid curves.
Bid	A bid is a request for purchase or sale of electricity. A bid is given by an electricity/power trader.
Block Bid	The block bid is an aggregated bid for several hours, with a fixed price and volume throughout these hours. The market participants can freely pick the start and stop hour of a block.
CBF	Cross Boarder Flow.
CAS	Control Area Schedules
Congestion	Congestion Management means to manage surplus.
Curtailment	The minimum or maximum technical price limits are reached in a particular bidding area and hour.
DBS	Deutsche Börse Systems AG
EMCC	European Market Coupling Company GmbH
EMCC IT-Service	Refers to the ASP Service requested by the EPEX for purposes of German – Denmark Market Coupling pursuant to the functional realization concept as agreed in SA001
Energinet.dk	Energinet.dk (TSO)
EPEX	European Power Exchange EPEX Spot SE (PX)
ESS	ETSO Scheduling System
ETSO	European Transmission System Operators
Explicit Auction	Traders buy capacity between areas and decide the daily use. The auctions of power and capacity are independent of each other; they are not coordinated into one activity. Market participants buy or sell capacity between areas independently of their physical power purchases or sales.
Flexible Hour Bid	The flexible hourly bid is a sales bid for a single hour with a fixed price and volume. The hour is not specified, but instead the bid will be accepted in the hour with the highest price in the calculation, given that the price is higher than the limit set in the bid.
FI	Finland.
GUI	Graphical User Interface.
Hourly Bid	The hourly bid is the basic type of a market order for a single hour. Each market participant selects the range of price steps for the Hourly Bid individually.
Implicit Auction	The common term for market splitting and market coupling. The auctions of power and capacity are coordinated into one activity.

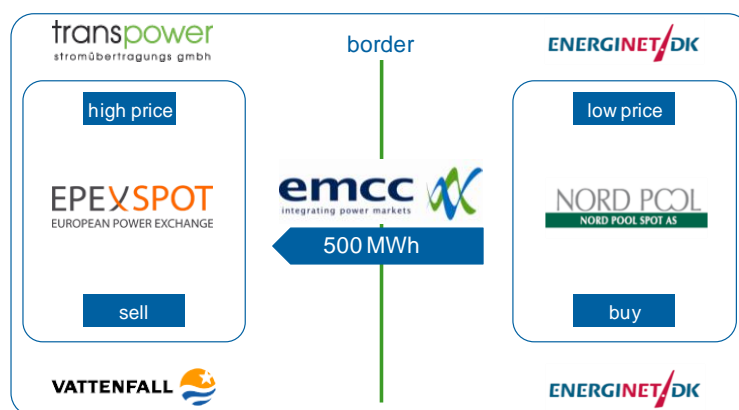
Market Area	A price zone within a region and not identical with a TSO-Area, e.g. Denmark: 1 TSO - 2 price zones; Norway 1 TSO – 4 price zones, Germany 4 TSOs – 1 price zone
Market Clearing Price, MCP	Per area and hour prices calculated by the EMCC IT-Services auction algorithm
Market Coupling	When two power exchanges manage the cross-border flow between two separate price areas.
MILP	Mixed Integer Linear Program
Market Splitting	When one power exchange manages the cross-border flow between two or more separate bidding areas. A price area may consist of one or more bidding areas with one common price.
NTC	Net Transfer Capacity Corresponds to the maximum exchange between two areas compatible with security standards applicable in both areas and taking into account the technical uncertainties on future network conditions.
NPS	Nord Pool Spot AS (PX)
NO	Norway.
PTDF	Power Transfer Distribution Factors The PTDFs are the contributions of commercial electricity exchange between two market areas, to the power flows over each electrical border, expressed in percentage.
Price Steps	Execution prices are determined in accordance with pre-defined price increments (also referred to as "minimum ticks").
Project Initiators	Refers to the Market Coupling initiating companies: E.ON Netz, Energinet.dk, Vattenfall Europe Transmission, Nord Pool Spot and the European Energy Exchange.
Profile Blocks	A block with variable volume for different segments of the block period but a fixed price limit
PX	Power Exchange
QP	Quadratic Program
Ramp Rates	Ramping is the term used for increasing or decreasing the amount of electricity flowing through the power grid. A ramping limit may be placed on one connection alone and/or on several connections collectively. As with transmission capacities the ramping limits are defined by the TSO's.
RCA	Reserved/restricted Capacity Allocation.
SE	Sweden.
Territory	Is defined as the Kingdom of Denmark and the Federal Republic of Germany.
TPS	transpower stromübertragungs gmbh (TSO)
TSO	Transmission System Operator
Vattenfall	Vattenfall Europe Transmission GmbH (TSO)
XML	Extensible Mark-up Language

2 MARKET COUPLING OVERVIEW

Market coupling allows two or more independent power exchanges to manage the cross-border power flow between separate price areas via the calculation of cross-border market coupling bids.

With the market coupling procedure an implicit auction coordinates and merges the trading of the commodity (electricity) and the acquisition of transmission capacity rights into a single operation. In such an implicit auction the highest purchase orders and lowest sales orders are executed while taking into account the available daily interconnection capacities.

EMCC will use the available daily capacity data and the anonymous order book data to calculate the cross-border flow, or the market coupling bids. These market coupling bids will be forwarded to the respective power exchange (NPS / EPEX) for execution in the day-ahead power auctions of each exchange.

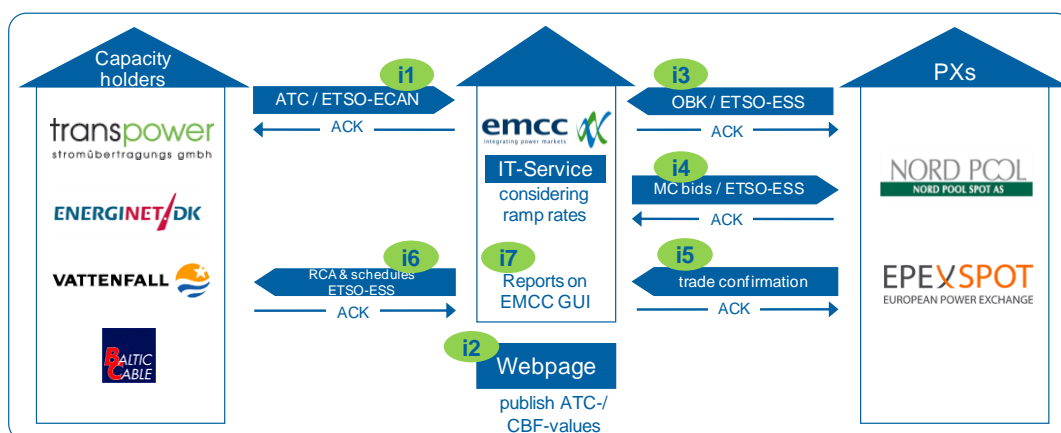


3 FUNCTIONAL OVERVIEW

The primary function of the EMCC IT-system is the improved utilization of day-ahead cross border capacity between Germany and Denmark and Germany and Sweden on the interconnectors:

- TPS transpower stromübertragungs gmbh and Energinet.dk (DK West)
- Vattenfall Europe Transmission GmbH and Energinet.dk ("Kontek")

based on order book (OBK) data and transmission capacity information received from the PXs and the TSOs, respectively.



3.1 Motivation

The goal of the optimization calculation is to determine the cross-border flow which leads to a levelling of market prices in the price areas and, therefore, power flowing from areas with a lower price to areas with a higher price.

The calculation will be done based on the complete, anonymous order book information received from the power exchanges EPEX and NPS (as can be seen in 3.2.1, 3.2.4 and 3.2.5) and the transfer restrictions (ATC, ramping) on the interconnections as received from the TSOs directly through NPS.

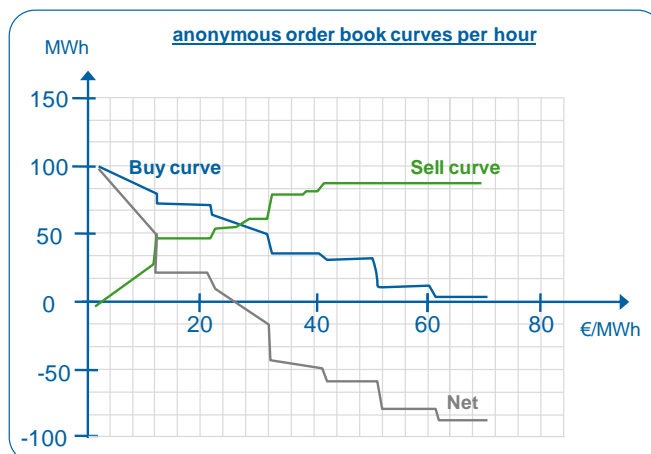
In order to find a robust solution the problem will be solved in a staged approach. DBS internal investigations have proven that the chosen approach yields acceptable solutions in a reasonable time.

3.2 Calculation Input

3.2.1 Order Book Data

EPEX and Nord Pool will send their respective anonymous order book data at the end of the day-ahead auction call phase. This anonymous order book data includes the

- aggregated single hourly buy and sell curves and
- block bids and flexible hourly bids for the respective market areas



A buy and sell curve will be received for each hour of the day and each price zone.

The aggregated buy and sell curves consist of price steps and the quantity in MW. As the gaps between these points are interpolated linearly the resulting curves are piecewise linear.

The net curve shows sales orders as negative values and purchase orders as positive values.

3.2.2 Available Transmission Capacity

Available Transmission Capacity is the portion of the NTC which is available for commercial activity; it is the portion of the NTC that remains available after each phase of the allocation procedure (e.g. before day-ahead trading). The “ATC files” are to be sent to the EMCC IT-Service by the responsible TSO or Power Exchange (see 3.1).

3.2.3 Ramp Rates

Ramping is the term used for increasing or decreasing the amount of electricity flowing through the power grid for successive hours. A ramping limit may be placed on any connection. As with transmission capacities, the ramping limits are defined by the TSOs.

For the EMCC MC-calculation, ramp rates can be configured via the GUI. As specified, hard-coded ramping override the GUI settings for the interconnector DK1A / DK1. There, the ramping rate is currently

equivalent to 600 MW. This setting is consistent with the current values applied in the NPS auction.

3.2.4 EPEX Products

On the Spot Market of EPEX hour contracts for every hour of the day are traded. This means there are 24 different hour contracts for every day.

On Sundays on which the switch from wintertime to summertime takes place there are 23 different hour contracts. Therefore, the hour contract for the hour from 2:00 am until 3:00 am cannot be traded on these Sundays.

On Sundays, with the switch from summertime to wintertime 24 different hour contracts can be traded; however, the hour contract for the hour from 2:00 am until 3.00 am comprises in total 2 time hours, i.e. 120 min, for these Sundays.

EPEX distinguishes between the instrument groups hourly bids and block bids.

Product	Minimum Steps		Hours	Comments
	Price	Volume		
Single Hourly Bid	0.01 €	0.1 MW	Single hours from 0:00 - 24:00	Any combination of valid price and Volume possible. Bid and Ask different contracts. No partial execution possible.
Hourly Block	0.01 €	0.1 MW	Any combination of hours from 0:00-24:00	Same quantity for each requested hour. Execution all or nothing.

3.2.4.1 Single Hourly Bids

A single hourly bid is a sequence of price/volume pairs for each specified bidding hour in a given bidding area.

Each price/volume pair states a point on a piecewise linear curve, i.e. the bid is regarded as having straight lines between each price/volume pair. The system will then make a linear interpolation using the price/volume pairs to calculate prices and the contract volume for each participant. Single Hourly Bids must extend from the minimum to the maximum price. Consequently, they are always executed at some price in or at the min/max bounds.

3.2.4.2 Block Contracts

Block contracts can be trades at a user defined number of hours (block-bid hours) on an all-or nothing basis. If selected, they are executed with the given block bid quantity in each of the defined hours. A necessary condition for execution is that the price of the block bid must be better than the average market clearing price in the selected block bid hours.

3.2.5 Nord Pool Products

The following products can be traded in the NPS Day-Ahead Auction and are relevant for the EMCC IT-Service:

- single hourly bids
- flexible hourly bids
- fixed block bids
- user defined block bids
- linked block bids
- convertible block bids

3.2.5.1 Single Hourly Bids

A single hourly bid is a sequence of price/volume pairs for each specified bid period in a given bidding area.

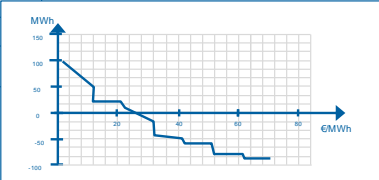
Each price/volume pair states a point on a piecewise linear curve, i.e. the bid is regarded as having straight lines between each price/volume pair. The system will then make a linear interpolation using the price/volume pairs to calculate prices and the contract volume for each participant.

The picture below shows basic criteria/limits for hourly bids.

An effective product for optimisation of a physical power portfolio that is fairly easily regulated (flexible) on an hourly basis or which is fixed, e.g. purchase bids based solely on coverage of load prognosis.

from hour	to hour	price													
		0	10	11	50	51	200	201	300	301	2000				
1	1														
2	2														
9	9	300	300	150	150	0	-100	-100	-300	-300	-300				
24	24														
Sum	24hours														

Bid shall be given within technical price limits. Volume must be stated at min/max limit and in between at least 62 price steps shall be possible to enter for each individual hour



Note: The bid form is treated with linear interpolation. This means that at a price of 50,50 €/MWh, the participant buys 75 MW and at 300,50 €/MWh the participant sells 200 MW.

Buying volume is reflected with a positive sign and selling with a negative sign. One single hourly bid can show both buying and selling, e.g. buying at “low” prices and selling at “higher” prices. The volume at each price step shows the volume to be bought / sold at the indicated price limit, thus not the net change from the previous price step.

The number of allowed price-steps is 64; however, can be extended to at least 200.

3.2.5.2 Flexible Hourly (Sales) Bids

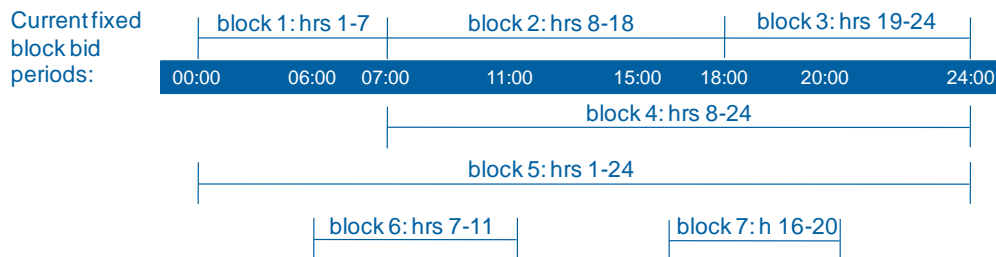
A flexible hourly bid consists of a fixed price limit and volume (“all or nothing”). Activation, if any, will only occur in one hour, but the hour is flexible, thus not defined by the participant. Currently, only sales bids are entered in the Nord Pool system. The hour, in which a flexible hourly bid is executed - if at all - is implicitly calculated by the auction algorithm (see 4.3.1) and cannot be deduced in a straightforward way from the market clearing prices.

3.2.5.3 Fixed Block Bids

A fixed block bid consists of a fixed price limit (min for sales and max for buying) and volume for a number of consecutive hours.

Fixed block bids are accepted or rejected in their entirety (“all or nothing”), depending on the average hourly market clearing price within the actual block period.

An effective way to, together with hourly bids, optimise a portfolio with units (production, consumption or contracts) that are not very flexible on an hourly basis. It is possible to use both fixed block periods and user defined periods.



Example:

period	price	volume
hrs 1-24	40 €	-200 MW
hrs 8-12	50 €	- 50 MW

3.2.5.4 User-defined block bids

User-defined block bids allow Traders to define their own block bid periods, e.g. the start and stop hour of blocks. All other criteria/limits for User Defined Block Bids are identical with Fixed Block Bids.

3.2.5.5 Linked Block Bids

Activation of Linked Block Bids requires as precondition that other blocks have been accepted or not. In other words, a participant is able to state that block C is only to be tested for activation if blocks A and B have been activated and block B only if block A has been accepted. In case the calculation system has found that a block with higher priority in a given chain of linked block bids shall be rejected, then all the linked blocks with lower priority will not be accepted.

At least five block bids can be linked, e.g. five levels of prioritisation. Furthermore, it is possible to allow two blocks on each prioritisation level. The linking option is limited to blocks within one Bidding Area and for a combination of either only sales Blocks or purchase Blocks. All other criteria/limits for Linked Block Bids shall be identical with Fixed and User Defined Block Bids.

The concept of linked block bids is based on the standard block bids, but activation of one block bid is made dependent on if other block(s) have been removed or not, thus enables better ability to properly reflect complex portfolios.

Example:

Block bid combination 1

block bid	priority order	price	volume (=-sell)
"what if block"	block 5 (01-24)	385 NOK	-200 MW
	block 4 (08-24)	400 NOK	-200 MW
	block 2 (08-18)	410 NOK	-200 MW

Alternative 3
test only if alt. 1 and 2 have been accepted and accept if block price \geq 410

Alternative 2
test only if alt. 1 has been accepted and accept if block price \geq 400

Alternative 1
if block price \geq 385

hour 1 hour 24

3.2.5.6 Convertible Block Bids

When submitting block bids it should be possible for the participant to allow that the block bid is converted in to a single hourly bid in case it is not accepted as a block. To enable conversion of a given

block into an hourly bid the participant states – in addition to the basic properties of volume, time period, block price and bid area –

- that the block bid is convertible
- the price-step from which the volume in the hourly bid linearly interpolated shall shift from zero to the volume limit given in the block. The linearly interpolated increase/decrease of volume shall be applied automatically based on the smallest allowed difference between subsequent steps starting from the given conversion.

If a block bid is converted, the created hourly bid is applied equally for all hours included in the specified block period. It is only possible to allow conversion in case the maximum technical price limit has been reached in at least one hour in the specified block bid period.

Block bid conversion generates temporary hourly bids. The temporary bids are linked to the actual block bids to keep track on the relation of the converted block bids and created single hourly bids. The algorithm to convert block bids goes as follows:

1. Check if the auction runs into curtailment in certain hours and areas. If not the calculation process is finished.
2. Choose list of block bids to convert: Take all convertible block bids in the bid areas with curtailment that
 - have not been activated in the preceding calculation and
 - contain hours in the block period where curtailment takes place.
3. If no block bids can be found for conversion, the calculation process is finished.
4. Convert all chosen block bids per given bid area and “participant” to one converted hourly bid that reflect the volume of the block bids in all the corresponding hours with price steps as this example shows:

Sales Block1 of -500 MW at 540 EUR for hours 8-24 and Sales Block2 of -135 MW at 615 EUR for hours 8-24.

Converted sales block into hourly for hours 8-24:

Price steps	0	54	540.1	615	615.1	2000
Vol. 8-24 h	0	0	-500	-500	-635	-635

E.g. the minimum price step is used in the hourly bid to activate the individual block bid volumes and all the relevant blocks are added together from lowest price to highest price with two such new price steps per block bid (block price, block price + smallest currency increment). For sales block bids the example states clearly how the minimum price step is applied. For purchase block bids the smallest price step increment is subtracted rather than added.

5. Run a new price calculation with the relevant block bids converted. Continue with step 1.

4 MARKET COUPLING CALCULATION

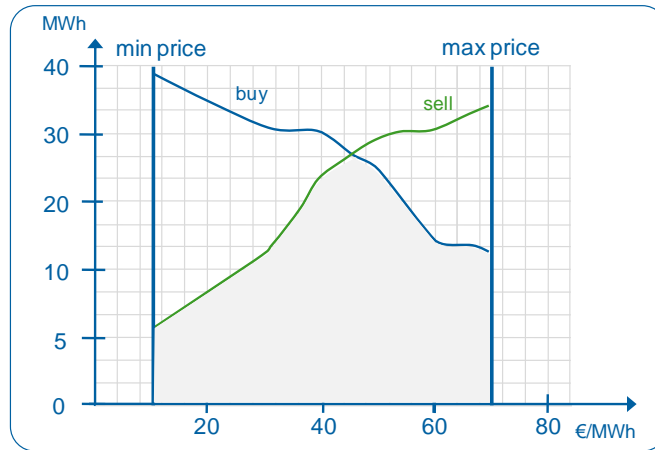
4.1 Method

The aim is to balance market prices by volume coupling. The problem can be mathematically formulated as a quadratic optimization problem. The model consists of integer as well as continuous variables, a quadratic objective function and linear side constraints. The goal is to find the optimum (maximum) of the objective function respecting a set of conditions, i.e. to find a configuration of variables that fits into the constraints and optimizes the value of the objective function. To achieve this, a model is built up by the EMCC IT-System and solved by third party optimization software (CPLEX from ILOG) The numerical solution can then be interpreted and processed by the EMCC IT-System in order to send Market Coupling Bids to the PXs and allocate capacity at the TSOs that administrate cross-border capacity.

4.2 Model

4.2.1 Optimization goal

The optimization goal is to maximize social welfare, i.e. to maximize the difference between producers' utility and consumers' cost. Without block bids, flexible hourly bids, cross area flows and other constraints, this corresponds to maximizing the area below the minimum of the purchase bid curve and the sales bid curve:



4.2.2 Handling the products

This section shows how the PXs' products are handled. For each type of product some decision variables and restricting constraints are needed.

4.2.2.1 Hourly bids

For each market area and each contract the aggregated single hourly purchase and the aggregated single hourly sales bid curve are put together to an aggregated single hourly net bid curve, which is a non-increasing, piecewise linear function of the price.

4.2.2.2 Block bids

Block bids are modelled as profile bids, i.e. any combination of hours and quantities is possible as long as all quantities are non-negative (purchase block bids) or non-positive (sales block bids). A purchase block bid must not be executed if its price per quantity is above or equal to the calculated average market clearing price per unit (MW) over the hours (out of the money).

Defining

$b_B \in \{0,1\}$ as binary execution variable where
 $b_B = 1$ if the block bid is executed, and
 $b_B = 0$ otherwise

$x_{i,t}$ as the market clearing price in area i and hour t

p_B as the given maximum purchase price and

$q_{B,t}$ is the bidden quantity for Block B in hour t

this leads to the following constraint for purchase block bids that are executed:

$$p_B \sum_t q_{B,t} - \sum_t x_{i,t} q_{B,t} \geq 0 \text{ if } b_B = 1$$

No constraint must be implemented if the block is not executed. The modelling of sales block bids works analogously.

4.2.2.3 Flexible hourly sales bids

Definition:

x_t to indicate the calculated price in hour t ,
 p_l for the minimum execution price given for the flexible hourly bid with index l , and
 $\beta_{l,t} \in \{0,1\}$, a binary execution variable where
 $\beta_{l,t} = 1$, if flexible hourly sales bid l is executed in hour t and
 $\beta_{l,t} = 0$, otherwise.

Flexible hourly sales bids can only be executed in one hour only. So for all flexible sales bids l

$$\sum_t \beta_{l,t} \leq 1$$

If the flexible bid is executed, it has to be ensured that the bid is not executed if the bid price exceeds the clearing price.

$$x_t \geq p_l \sum_t \beta_{l,t}$$

4.2.2.4 Linked Blocks

If Block A is linked to Block B it means that A can only be executed if B is executed which is a simple additional constraint on the block decision variables:

$$b_A \leq b_B$$

4.2.3 Handling cross-border flow and its restrictions

In order to post market coupling bids to the PXs the estimated cross-border flow has to be computed. It follows two restrictions, ATC and ramping.

4.2.3.1 ATC

For each interconnection the cross-border flow must not exceed the available transmission capacity. Positive ATC values act as upper bounds for the inter-area flows. Denoting

$f_{i,j,t}$ as flow from price area i to price area j in hour t and

$c_{i,j,t}$ as available capacity from area i to price area j in hour t

the following restriction applies

$$f_{i,j,t} \leq c_{i,j,t}, \quad \text{if } c_{i,j,t} \geq 0$$

Negative ATC values from area i to area j define minimal flows in the opposite direction, i.e.

$$f_{j,i,t} \geq -c_{i,j,t}, \quad \text{if } c_{i,j,t} \leq 0$$

4.2.3.2 Ramping

There are some interconnections with ramping limits, i.e. the flow in two consecutive hours may not differ by more than the amount $r_{i,j}$. This gives the constraint

$$|f_{i,j,t} - f_{j,i,t} - f_{i,j,t+1} + f_{j,i,t+1}| \leq r_{ij}$$

where $r_{i,j} = r_{j,i}$ is the given ramp rate between areas i and j .

4.2.4 Balancing of purchase and sales

An important condition that has to be fulfilled is that the sum of all purchase and all sales bids (including PXs' bids as well as market coupling bids) has to be zero:

$$y_{i,t}^b - y_{i,t}^s + \sum_B q_{B,t} * b_B + \sum_{l \in FB} \beta_{l,t} * q_l - \sum_{j \in A} f_{j,i,t} + \sum_{j \in A} f_{i,j,t} = 0, \forall i \in A, t \in C, \text{ where } y_{i,t}^b \text{ is the}$$

aggregated purchase bid quantity and $y_{i,t}^s$ is the aggregated sales bid quantity at the determined price.

4.2.5 Objective function

The objective function is the generated social welfare summed over all areas and hours, and bid types, resp. Depending on the bid type, it is composed of the following contributions.

1. Hourly bids:

The executed social welfare of purchase hourly bids is the area below the bid curve, starting at the market clearing price up to the maximal price. For sales bids, the area integral extends from the minimum price to the market clearing price.

2. Block bids:

Executed purchase and sales block bids contribute to the objective by the amount $p_B \sum_t q_{B,t}$.

3. Flexible hourly bids:

Executed flexible hourly bids contribute $p_l q_l$.

4. Flows:

Flows contribute via the implicitly included quantities of the generated market coupling bids. Per hour and area, a social welfare of $\sum_j f_{i,j,t} x_{i,t}$ adds to the objective function.

4.3 Solving the Problem

4.3.1 Algorithm overview

The algorithm calculates the following quantities

- The market clearing prices per area and hour
- The flows between connected areas per hour
- The execution of block bids and flexible hourly bids.

The goal of the EMCC Market Coupling is the maximization of social welfare. Generally, this results in power flowing from the low price area to the high price area and the levelling of market prices. The EMCC IT-Service Flow Control prevents market coupling flows from a high price region to a low price region based on price and flow results as calculated by the EMCC IT-Service, except in cases where ramping or negative ATC values force minimal flow from a high to a low price area. The EMCC IT-Service Flow Control mechanism aims to equalize prices between flow-connected areas. If a price cannot be determined uniquely by varying flows (vertical overlaps), the minimum possible price is selected.

4.3.2 Algorithm phases

In particular, the algorithm is divided into phases.

1. The quadratic problem is approximated by solving a linearized MILP, i.e. the social welfare is approximated by a piecewise linear function. The approximation includes all ATC and ramping constraints, as well as block and flexible bid price conditions and block link conditions. The result serves as an approximation for the block and flexible bid selection.

2. Using the selection of (1), a QP without block and flexible bid price constraints is solved. If an included block or flexible bid is incompatible with the calculated prices, it is removed from the selection, and the problem is resolved. This is repeated until all included block and flexible bids are compatible with the market prices. The step returns a valid solution in the sense that all capacity and price conditions are satisfied.
3. The exact solution of step (2) is improved by successively including formerly excluded block bids. At each step, the corresponding QP is solved to verify if the inclusion still is a valid solution.
4. Finally, the prices in the welfare maximal solution of (3) are adjusted according to the rules for dealing with “vertical overlaps”. Flows remain unchanged in that step.
5. If curtailment is encountered, after step (4), corresponding convertible block bids are converted and added to the hourly bid curves. The process with the modified input is repeated starting from (1) (see 3.2.5.6).

4.3.3 Special Cases

The following special cases have to be taken into consideration when solving the problem.

4.3.4 Curtailment

In case of a surplus of purchase bids and a shortage of sales bids the maximum price shall be reached and the purchase bids shall be curtailed.

4.3.5 Choosing minimum prices (“vertical overlaps”)

In case the intersection of the purchase bid curve and the sales bid curve is not a single point, but an interval the minimum price for which equality is guaranteed is chosen. The price correction does not influence the calculated flows, nor the social welfare objective. The price correction is done such it does not violate price conditions of included block and flexible hourly bids.