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Background

In the beginning of the 20th century, when electricity started to be produced seriously, the government-owned producers were the only ones that were allowed to provide energy to consumers. But in the beginning of the 90th, a new sort of revolution started in Europe: The Deregulated Electricity Market. It started in England in 1989[1] and from that moment on, it have been more and more countries that have followed the same example. Finland, Norway and Sweden are countries that have today a well developed deregulated energy system, with Nordpool as market place.

But the effects of deregulation have not always been as expected. Experience has shown that deregulation produces unexpected outcomes. In some countries the results are excellent and in others, chaotic and destabilising as in Germany and California. In general, the prices have fallen and in some cases so dramatically that the stability of the industry is threatened[2].

Deregulation is nowadays introduced in many countries and makes it possible for producers and consumers to sell and buy their energy from each other. As in all other markets, the price is determined by the demand and supply, and it is also possible to have transactions between countries. In some countries the development has reached a point where you can go to your supermarket and buy your energy.

Even though the implementation of an electricity market can be done in many different ways, the creation of a centralised marketplace for the sale and purchase of electric power is important to:

- Facilitate the establishment of a competitive, transparent and non-discriminatory wholesale market for electric power,
- Reduce the cost of trading electric power, and
- Establish reliable reference prices for the wholesale market.

This increasing in liberalisation and deregulation in the electrical sectors across Europe, together with the creation of the EU Electricity Directive[3] in February 1999, are obliging successively many countries to create companies and incorporate systems that allow the new situation. With the help from the European Union, many east-European countries are starting to leave the old, government-owned and controlled system, to convert to this new and modern method of buying and selling electricity.
Aim of Project

As being applying to become a member of the European Union, Romania must, among many other things, accept the EU Electricity Directive from 1999 that stipulates how the energy shall be treated within the Union. In this Directive, it is clearly stated that all the countries within the European Union have to have a deregulated electricity market. The main objective of deregulating the wholesale electricity market around the world is to improve the efficiency of the electric power industry by encouraging competition. Or as it is written in the Directive;

“To ensure the free movement of electricity while improving the security of supply and the competitiveness of the European economy.” [4]

To be able to fulfil this mandatory task, the Romanian Market Operator OPCOM, has today contracted the French company AREVA T&D, who is in charge of the implementation of a new deregulated electricity market, with its main function being the Day-Ahead Market infrastructure (web-based bidding interface with market participants, matching process and settlement). This market is supposed to be taking into action during the summer of 2005.

The scope of this training can be summarized in the following points,

- Analyse the proposed national market rules of Romania. These rules integrate a Day-Ahead Market, a Balancing Market and Imbalance Calculation.
- Analyze the formulation of the Settlement of these markets. The Settlement has the object to determine the payments for transactions made under the different markets by the market actors.
- Develop a prototype / simulator of these Settlement rules that will allow verifying their consistence and that will be used in testing and demonstration environment.

It is important to mention that the analyses above will be a theoretical analysis on the rules since the project is still in a developing phase and has not been tested in a real environment.

The prototype / simulator will be implemented using AIMMS mathematical modelling language, where all settlement rules have to be implemented. The idea of the prototype is to simulate how the rules will behave and if the results are credible. To verify that the rules have been implemented in the right manners, the results given by AIMMS will then be compared with the results from the AREVAS’s e-terra settlement products, which is the simulator that is going to be used in the future market.

Except for the settlement rules, the developed prototype will also include the matching process with its offer-acceptance algorithm to determine the cleared energy and price for each trading interval, and will serve to give feedback to the future matching process. It aims also to validate the results provided by the delivered algorithm.

To be able to get a full vision, and as well to understand their implementation, the three different notions, Day-Ahead Market, Balancing Market and Imbalance Calculations studied under this project will be explained in detail, the role they play and why they are needed in a deregulated environment.
Summarizing, this report will treat the following markets and areas:

- Day-Ahead Market
- Balancing Market
- Imbalance Calculation
- Settlement of these three processes

Finally, some screenshot will be shown to visualise the prototype and how the results are presented to the customer together with some conclusions and the future work that can be done.
1. Day-Ahead Market (DAM)

1.1 Introduction

The objective with the Day-Ahead Market is to match the sell offers, send from producers to the Market Operator, together with the buy offers send from suppliers. The Market Operator has then the task to perform the matching process to determine the market clearing price and the amount of energy that shall be cleared for each one-hour interval. Before the transition from the old system to the new one takes place, ANRE has determined special rules, called transition rules, which shall be applied during the transition period and shall cease to apply afterwards. During this period, the participation in the DAM is mandatory for all suppliers and producers. Producers must submit sell offers for their entire available production capacity and planned imports, while suppliers must submit buy offers for their entire expected demand and planned exports. The total sale and purchase quantities will then be determined from their net physical position and the preliminary transaction quantities, terms which are explained in detail in chapter 1.5.3.

During the transition phase, the demand is estimated by the Market Operator, represented by OPCOM. For the estimation of this demand, OPCOM will use its own external forecast module, which among other inputs, considers the competitive bids of purchase that the participant have carried out as additional information. The transition period, can be seen as a training period for trading participant buying energy from the DAM. When these participants have consolidated their participation in the market, the demand can be establish as an aggregation of the consumption bids.

The settlement shall be carried out by the Settlement Administrator, which has been established to avoid that the party handling the market also takes care of the payments and invoicing. To be able to perform his task, the Market Operator must provide all needed information. Since ANRE has decided that the Day-Ahead Market shall adopt a “system marginal price”, also known as market clearing price for all trades, the settlement calculation shall be based on this price and the quantity cleared in the DAM. The Settlement Administrator shall calculate the final amounts to pay or to get paid for each market participant that have concluded a transaction in the DAM.

1.2 Submission of Offers

All participants that have been approved by the Market Operator can send offers to the DAM. Depending on the type of participants, the offers can be sell offers or buy offers. With buy offers, it is meant bids to purchase electric power from the DAM while sell offers are offers to sell electric power to the DAM. Each offer may contain up to twenty-five price-quantity pairs. For buy offers, the price-quantity pairs defines the maximum price that the participant is willing to pay for an amount of electric power not exceeding the quantity quoted in the price-quantity pair. In the same manner, the price-quantity pair for sell offers is the minimum price at which a trading

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1 ANRE is an autonomous public institution of national interest whose mission is to create and implement fair and independent regulation. Also known as the Romanian Regulator.
participant is willing to sell an amount of electric power not exceeding the quantity quoted in the price-quantity pair. All prices shall be within the price scale for the DAM that shall be established by the Market Operator and validated by the regulator. The price scale is limited by a price of zero and a highest price, for which an offer can be submitted. The highest price shall at all time be higher than the expected market price.

Except for price and quantity of the offers, the trading participant shall provide the following information to the Market Operator when submitting an offer:

- DAM Identification Code of the Trading Participant
- Delivery Day, which the offer applies to
- Trading Interval, which the offer applies to
- Trading Zone, which the offer applies to
- Type of offer, i.e. buy or sell offer

All markets have usually two trading zones, referred to as the national trading zone and the border trading zone(s). As the names stipulates, the national trading zone is the part of the national power system to which producers and consumers are connected to, in this case Romania, whilst the border trading zone(s) are the neighbouring countries around.

The trading participant shall also verify, that the following conditions are met before submitting the offer to the Market Operator,

- In the case of buy offers, all prices shall be listed in a decreasing order
- In the case of sell offers, all prices shall be listed in an increasing order

The trading participants must submit offers for each interval of the day and also separately for each trading zone. In the Romanian market, each interval is one hour, while most of the countries have chosen 15- minutes interval.

The fact of having new bids each hour of the day can create problems for slow production units, as nuclear power plants. Imagine that a unit is selected to produce a given quantity of energy the first hour. For the second hour, the unit has been selected for an amount of energy much greater than the hour before, or even worse, he has not been selected at all. Since the unit is slow, this change in output may not be done during the required time. This problem is up to every producer to handle and can be done by avoiding large differences in the price-quantity pairs given in each offer.

1.3 Market Clearing Price

Market Clearing Price is the price at which supply equals demand. Since it is this price that is going to be used when performing the settlement, it is very important to have well-defined rules for its determination. Graphically, the market clearing price is the point of intersection between the market supply and demand curves. This point represents also the equilibrium between buy and sell offers. Strictly speaking, it is intended to mean the price for a given commodity that insures that all available supply is sold and all available demand is met. This definition is valid for the Romanian market, while other market defines the Market Clearing Price as the total cost deviation in case it is necessary to provide one more unit (i.e. MW).
In an energy market, there are four types of intersection that can occur,

![Diagram](image)

**Figure 1.1a-c.** The four types of intersection that can occur between demand and supply curve.

If there is a unique point of intersection like figure a, b or if all points of intersection have the same price (figure c), the price at the point of intersection shall become the market clearing price.

If there is no unique point of intersection and if different points of intersection have different prices (figure d), the rules stipulates that the market clearing price shall be determined as,

$$MCP = \frac{P_{\text{max}} + P_{\text{min}}}{2},$$  \hspace{1cm} (1)

where $P_{\text{max}}$ denotes the highest price where the market supply curve and the market demand curve intersect, and $P_{\text{min}}$ denotes the lowest price where the market supply curve and the market demand intersect. It is easy to understand that the equation given above is a compromise between choosing one of the two extremities and thereby giving the preference for either the sellers or the buyers.

Like the market clearing price, the cleared energy is also determined by the intersection of the two curves. For figure a and b, where we have only one point of intersection, the cleared energy shall become the energy at this point. Figure d has several points of intersection with the same quantity, which shall also be the cleared quantity. If a situation like figure c occurs, the cleared quantity shall be the highest possible.

It is worth mentioning that the situation as figure 1.1 c-d shows, can only occur if the market rules allows vertically and horizontal so called ‘staircases’ with no inclination, given that we can have several points of intersection between the two curves. Other markets, like Nordpool, don’t allow this and therefore the intersection between the curves always occurs in one point only.
1.4 Matching Process

1.4.1 Introduction

The Matching Process\(^{[6]}\) is one of the most important procedures in an electricity market and especially for the Day-Ahead Market. It is from this process that the total amount of energy which is going to be produced and later on sell is going to be determined. It is important to know that not all energy in a country comes from the Day-Ahead Market and that in some countries this energy represents not more than 10\% of the total energy consumed.

In Romania, the energy sold in the Day-Ahead Market is the difference of what a producer can produce and the bilateral contracts that he has undergone with a consumer. In the same manner, the energy bought at the Day-Ahead Market by a consumer, is the difference between the quantity that this consumer is going to consume and the bilateral transactions that this consumer has undergone with a producer.

The aim of the matching process is to determine the price of energy for the interval and zone in question. This will eventually lead to a selection and acceptance of offers omitted to the market. In the next chapters, the matching process will be explained in detail and comments will be done, explaining the different steps. At the end, an example will be given, to better show this important procedure.

As mentioned in earlier chapters, the Romanian market has two trading zones, referred to as the national trading zone and the border trading zone(s). As the names stipulates, the national trading zone is the part of the national power system to which producers and consumers are connected to, in this case Romania, whilst the border trading zone(s) are the neighbouring countries around. When executing the matching process, it is considered that congestion can only occur in the lines connecting the national trading zone with the border trading zones and that the capacity of the lines in the national trading zone are much greater than the power transmitted on them. This is equivalent to say that congestion is only due to offers coming from abroad.

Figure 1.2 Congestion can only occur in the lines connecting Romania with its neighbouring countries.
1.4.2 Merit Order

After the market closing time, which is the time when the Market Operator stops to receive buy and sell offers, the Market Operator has to create the merit order for all the sell and buy offers received for the day and interval in question. For sell offers, the offer with the lowest price shall have the priority and therefore be placed first on the merit order for sell offers before the next lowest bid. The bid with the highest price shall then be placed last on this list. For buy offers, the offer with the highest price shall have the priority and therefore shall be place first on the list. The last offer in the merit order for buy offers shall be the one with the lowest price.

Graphically, the merit order list for both type of offers, can be represented as figure 1.

1.4.3 Extension of Merit Order

If the most expensive sell offer has a price which is below the maximum value of the reference level called price scale, then the rules stipules that the merit order for sell offers shall be extended by the creation of a fictive bid with a price equal to the maximum price of the reference level and with a quantity of zero. In the same manners, if the price of the cheapest buy offer is above the minimum value of the reference value, normally set to zero, then the merit order for buy offers shall be extended by the creation of a fictive bid which has a price equal to this minimum price and with a quantity equal to zero. To understand the purpose of this, figure 1.3 shows the merit order list for two sell offers and three buy offers. As figure 1.3 is drawn, we can not find an intersection between the two curves and therefore we can’t determine the market clearing price and no energy will be cleared, even though it is obvious that all the supply can be met. After the extension of the two merit order list with the fictive bids, we can see in figure 1.4 that the determination of the market clearing price and the energy cleared is now possible, since we have an intersection.

It is important to remember that the two fictive bids created by the Market Operator are there only to find the intersection of the two curves, and can never be interpreted as real offers.
After the creation of the Merit Order lists, the initial market clearing price shall be determined as to section 1.3.

1.4.4 Acceptance of offers

After the determination of the initial market clearing price, the matching process shall preliminary accept offers. Graphically, the preliminary accepted sell offers are the ones that are placed at the same level and below, as the point of intersection that leads to the determination of the initial price. For buy offers, the preliminary accepted offers are the ones placed at the same level and above, as the point of intersection. It is important to remember that for offers, placed graphically at the same level as the point of intersection, only a part of the offered quantity can be accepted (see figure 1.4). This quantity is strictly determined by the matching process and is done to maintain the energy balance in the national power system.

1.4.5 Determination of the Supply and Demand Volume.

After the determination of the initial price and the preliminary acceptance of offers, the matching process shall determine the supply and demand volume separately for each zone. For the supply volume, this is done by summarizing the quantity of all the preliminary accepted sell offers, taking into account the zone that they belong to. In the same manner, the demand volume is the total quantity of the preliminary accepted buy offers, taking into account the zone that they belong to. Having the preliminary volumes for each zone, the matching process shall determine the contractual exchanges as the difference between the supply volume and demand volume for each zone, not being the national trading zone. This is done to be able to see the amount of electric power that is going to transit on the lines between the national trading zone and each border trading zone. These contractual exchanges shall then be compared to the maximum value allowed, also called ATC²-value, for each border trading zone. All zones where the transit of power is greater than its ATC limit shall be named as congested zone and the market splitting procedure shall be applied. The notation ‘congested zone’ is not quite right, since congestion can only occur between zones due to the physical limits of the transmission lines that interconnect the zones. Therefore, with the term congestion zone it is meant that we have congestion between a border trading zone and the national trading zone and that the ‘congested zone’ is the border trading zone.

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² Available Transfer Capacity
The ATC values shall be provided by the Transmission System Operator (TSO), who determines the values for each interval during the day and also for each direction (i.e. export to and import from the national trading zone). This means that a transmission line doesn’t necessarily have the same ATC value for imports as exports. This depends on many factors and among them a phenomenon called wheeling, which is the term used to describe the free movement of electricity along interconnected transmission lines. This phenomenon has become more common today in a deregulated energy environment, which encourages the communication and cooperation between the TSOs of neighbouring countries.

1.4.6 Market Splitting – Congestion Management

When a zone has been found congested, the matching process shall determine the merit order list for this zone, taking only into account the offers that applies to the zone in question. This shall be done for all the congested zones separately but also for the uncongested zones. Afterwards, the matching process shall determine the initial market clearing price for all congested zones and for the uncongested zone. The price at each congested zone shall then be compared with the price in the uncongested zone. The congested zone with the largest difference in price shall become the selected zone and shall be treated first. All other congested zones, shall be considered as uncongested since when releasing the congestion in the selected zone, the transit of power will be modified and a zone that was congested before can now become uncongested.

If the contractual exchange of the selected zone is positive and larger than its ATC value, the matching process shall extend the merit order list for the congested zone by an offer with a price equal to zero and with a quantity equal to the ATC value. In addition, an offer shall be added to the merit order list of the national trading zone, with a price equal to the maximum price of the price scale and with a quantity equal to the ATC value.

If the contractual exchange is negative and its absolute value is larger than the ATC value, then the matching process shall extend the merit order list of the congested zone by an offer with a price equal to zero and with a quantity equal to the ATC value. In addition, an offer shall be added to the merit order list of the national trading zone, with a price equal to the maximum price of the price scale and with a quantity equal to the ATC value.

This will create two fictive bids, one in the congested zone and one in the national trading zone that will force the transit of power between the selected zone and the national trading zone to be equal to the maximum limit of the line that connects them together. At the end of this chapter, an example is given to show this mechanism.

The matching process shall now continue, by the determination of the new market clearing price for the selected congested zone, taking into account the fictive bid from the congestion management. A determination of the initial market clearing price shall also be done for the uncongested zone, taking into account the new bid from the congestion management but also taking into account the bids from the all the other congested zones which have not been selected for congestion management. The market clearing price for the selected zone shall become the final price and this zone, together with its offers, shall not be taken into further account. The matching process shall, one more time calculate the supply and demand volume for the border trading zones in the uncongested zone and verify congestion. While the matching process finds congested zones, the congestion management shall be repeated until there are no more congested zones left.
1.4.7 Selection of Offer and Trade Confirmation

Since the congestion management is an iteration process, we are going to have several market clearing prices during the execution of the matching process before arriving to the required
situation where we have no congestion. Therefore, the final selection of offers shall be done accordingly to the merit order that leads to the final market clearing price. Seen from a general perspective, it is important that the demand volume is equal to the supply volume to have equilibrium in the power grid. Meanwhile, this does not mean that the equilibrium shall be maintained within a zone, since energy can transmit between different zones. After the final selection of offers, the Market Operator shall create a trade confirmation for each market participant, which shall contain at least the following information:

- Name and Identification code of the market participant in question
- Delivery day and trading interval
- Trading zone
- Quantity sold respectively purchased by this market participant
- Price of the transaction, which is the market clearing price for the zone in question

The quantity and price stipulated in the trade confirmation shall later be used when performing the settlement calculations. Therefore, the Market Operator must provide a copy of the trading confirmation to the Settlement Administrator when sending it to each trading participant that has undergone a transaction in the DAM.

In order to better understand the matching process, in appendix B a simple matching process example can be found.
1.5 Settlement - DAM

1.5.1 Introduction

As mentioned in the aim of the project, the settlement has the object to determine the payments for transactions made under the different markets by the market actors. The daily settlement is run every trading day by the Settlement Administrator, who is responsible for this task. The Market Operator has to provide all necessary information to the Settlement Administrator, so that he can be able to perform the calculation and the invoicing correctly. The information required, and provided by the Market Operator through the trading confirmation is:

- Identification code of the trading participant
- Delivery day in question
- Trading interval in question
- Trading zone
- Transaction quantity, and
- Transaction price (i.e. market clearing price)

On the other hand the Settlement Administrator shall provide,

- Market operator fees
- All applicable taxes

The Settlement Administrator shall provide each trading participant with a daily statement. This statement includes:

- The daily settlement amount for the delivery day in question
- The total volume and amounts of all sales by the trading participant to the Market Operator
- The total volume and amount of all purchases by the trading participant from the Market Operator
- The amount resulting from any applicable Market Operator fees
- The amount resulting from taxes
- The total amount to be debited or credited to this party’s account.

Each Trading Participant shall create a market clearing account, that the Settlement Administrator shall have total access to. This shall be used when distributing the payments for transaction undergone in the DAM.

1.5.2 Daily Settlement Calculation

The Settlement Administrator shall determine for each trading participant the daily settlement amount, by aggregating the product of the quantity and the price of all transaction that this participant has undergone with the Market Operator in the DAM for the day in question. Mathematically, this can be expressed as,
\[ DSA = \sum_{t} \sum_{z} Q_{t,z} \cdot P_{t,z}, \]

where \( DSA \) is the daily settlement amount, \( Q_{t,z} \) is the quantity of the transaction and \( P_{t,z} \) is the price of the transaction for the \( t \)-th trading interval and for trading zone \( z \). As mentioned before, the price of the transaction is the market clearing price for the interval and zone in question. The sum shall be done for all the zones and for all the intervals during the day in question. To separate buy and sell transactions, the quantities of purchases shall be expressed with a negative sign and all sale transactions shall be expressed with a positive sign.

Since a trading participant can be both a producer and a supplier, which means that he can buy and sell energy to the DAM, the equation above can be written as,

\[ DSA = \sum_{t} \sum_{z} (PTQ_{t,z} \cdot MCP_{t,z} + STQ_{t,z} \cdot MCP_{t,z}), \]

where \( DSA \) is the daily settlement amount, \( PTQ_{t,z} \) stands for the purchased quantity (with a negative sign), \( STQ_{t,z} \) for the sale quantity and \( MCP_{t,z} \) is the price of the transaction for the \( t \)-th trading interval and for trading zone \( z \).

For each transacted MWh, each market participant must pay a fee to the Market Operator which can be expressed as,

\[ DAMOF = MOF \cdot \sum_{t,z} (STQ_{t,z} - PTQ_{t,z}), \]

where \( MOF \) is the market operator fee and is a constant determined by the Settlement Administrator.

The total amount to be debit, in case of a negative value, or credit, in case of a positive value, to the market clearing account of the corresponding trading participant, is then,

\[ DTSA = DSA - DSA \cdot TDAM - DAMOF, \]

where \( DTSA \) stands for daily total settlement amount and \( TDAM \) is the Day-Ahead Market taxes applied to the daily settlement value.

### 1.5.3 Daily Settlement during Transition phase

The settlement performed during the transition phase, is quite different from the settlement performed during the final phase. The biggest difference is that the settlement must be corrected at the end of the day, due to the fact that during the transition phase the consumption is based on estimations. Another difference is that during the final phase, the settlement is based on the quantities that each participant has been selected for and nothing more (see equation 1-4), while during the transition phase other terms will also intervene as we shall later see.

At the end of each day during the transition phase, when receiving the metered values from the different metering points placed in the national power system, the Settlement Administrator must calculate the compensation payments for the difference between the
preliminary settlement, based on the estimated consumption and the final settlement, based on the metered consumption for each interval.

During the transition phase, as mentioned in section 1.1, a net physical position is determined for each trading participant being a producer while a preliminary transaction quantity is to be calculated for suppliers. This information is going to determine the quantity that a producer / supplier is going to deliver, respectively buy from the DAM.

Mathematically, these two expressions can be written as,

$$NPP = STQ - \sum_{TP} \frac{ESTC}{ESTC} \cdot CDF - PTQ + RBE - DBE + IMP - EXP,$$  \hspace{1cm} (6)

where STQ is the cleared energy in the DAM corresponding to the trading participant in question, EST is the consumption estimation for the trading participant TP in question, CDF is the centralised demand forecast determined by the Market Operator, PTQ is the purchased energy, RBE is the net bilateral exchange received by the trading participant, DBE is the net bilateral exchange delivered by the trading participant, IMP is the import nominated by the trading participant and EXP is the import nominated by the trading participant. The difference between $\sum_{TP} ESTC$ and CDF, is that in CDF the network losses are included. This means that it is the consumers that have to pay for the losses that occur in the National Power System. This turns out to be natural, knowing that the Market Operator is a non-profit company.

If the net physical position has a negative sign, then it is known as the preliminary transaction quantity PRTQ.

All participants having a positive net physical position are deemed to have sold energy to the DAM, while all participants having a negative net physical position are deemed to have bought energy from the DAM.

The total sale transaction amount (TSTA) and total purchased transaction amount (TPTA), shall then be based on the quantities given above together with the market clearing price for the interval and zone in question.

Mathematically this can be written as,

$$TSTA = \sum_{t} \sum_{z} NPP_{t,z} \cdot MCP_{t,z}, \hspace{0.5cm} NPP > 0,$$  \hspace{1cm} (7)

$$TPTA = \sum_{t} \sum_{z} NPP_{t,z} \cdot MCP_{t,z}, \hspace{0.5cm} NPP < 0,$$  \hspace{1cm} (8)

The following example given below will help to understand the two terms and their settlement.

**Example 1.1:**

Let’s assume that a producer, called P1, has undergone a contract with a consumer for the delivery of 1000 MWh at a price of 25 € /MWh. Let’s also assume that P1’s total production
capacity is 1100 MWh. As explained before, all producers are obliged to submit sell offer to
the DAM for their entire production capacity during the transition period. Let’s assume that
he distributes his offers in the following way for a given dispatch interval:

Offer 1: 900 MW @ 15 €/MWh
Offer 2: 200 MW @ 25 €/MWh

At the same time another producer, P2, has submitted the following offer:

Offer 3: 300 MW @ 19 €/MWh

Due to the transition period, the Market Operator sets the load forecast to 1100 MW.

All this gives the following situation,

After running the matching process, the accepted offer will be;

Offer 1: 900 MW that will be paid at a price of 19 €/MWh (MCP) for the trading interval of
one hour.
Offer 3: 200 MW that will be paid at a price of 19 €/MWh (MCP) for the trading interval of
one hour.

P1 has a production obligation of 900 MW, while he is going to get paid for 1000 MW
accordingly to the contract. This means that P1, is earning 2500 € (100*25 €) for the
additional 100 MWh that he does not produce. But who will produce the additional 100 MW
(1000-900=100), which is the difference between P1’s contracted value and the value that he
has been selected for by the market?

Accordingly to equation (6), the expression for P1’s net physical position is,

\[ NPP = STQ - \sum_{tp} \frac{ESTC}{ESTC} \cdot CDF - PTQ + RBE - DBE + IMP - EXP \]

Since we are here considering the simplest case, meaning that P1 is a simple producer who is
selling its energy to another participant and doesn’t export nor import energy, the terms
ESTC, CDF, PTQ, RBE, IMP and EXP are all zero. This leaves the reduced equation,

\[ NPP = STQ - DBE, \quad (9) \]

with STQ and DBE defined as above.
Using the numbers given in the example, we find

\[ NPP = 900 - 1000 = -100 \]

which defines the amount that P1 has to buy from the DAM. The amount to pay the Market Operator can now be determined by equation (8),

\[ TPTA=100*19 = 1900 \text{ €}, \]

containing one element since we are only considering one dispatch interval.

The total amount that P1 is going to receive is therefore, \( 1000*25 – 1900 = 23100 \text{ €} \).

1.5.4 Compensation payments

At the end of each trading interval, the Settlement Administrator will receive the metered values for each participant who is registered as a supplier. This involves that the values and naturally the amounts, are going to be modified. The compensation made after each trading interval, is determined accordingly to,

\[ DCOP = (TMC - \sum_{TP} ESTC \cdot CDF) \cdot MCP, \]

where TMC is the total metered consumption, ESTC is the estimated consumption for trading participant TP in question, CDF is the centralized demand forecast and MCP is the market clearing price.

1.5.4 Distribution of payments – Transition rules

The Settlement Administrator can, during the final settlement rules, demand trading participant to provide an amount of economical security before being entitled to commit transaction in the DAM. This amount will then limit the total financial volume that a trading participant can submit to the DAM. By this, the Market Operator is always sure of receiving payments for transactions. This option doesn’t exist during the transition period and other measurements must be taken to avoid that the Market Operator is affected economically, since he is a non-profit company.

To protect the Market Operator from the risk of non–payments from any trading participant, and to distribute the associated risk and losses to all trading participant, the Settlement Administrator shall make sure that the Market Operator always pays all owned amounts, upon the reception of payments from other participants owning money. The amount received by the Market Operator shall then be distributed in portions, which depend on the total amount received and the amount that he should have received, to each trading participant.

Mathematically this can be written as,
Having this form of distribution, the payments performed by the Market Operator can never be greater than the amount that he has received.

Trading participants are not allowed to reclaim any outstanding payments to the Market Operator. The only way for a trading participant to take legal action against another participant, who for some reason doesn’t pay, is by choosing to be settled bilaterally. This means that all amounts that a participant owes to the Market Operator, shall be proportionally owed to all participants that have to get paid.

Mathematically, this can be written as

\[
P_{\text{distr amount to } TP_i} = A_{\text{owned amount by } M\text{.O to } TP_i} \cdot \frac{A_{\text{received amount by } M\text{.O}}}{\sum_i A_{\text{owned amount by } M\text{.O to } TP_i}},
\]

(11)

Mathematically, this can be written as

\[
PA_{i,j} = PA_i \cdot \frac{RA_j}{TRA},
\]

(12)

In the same manner, all amount that a participant is owed by the Market Operator, shall be proportionally owed to all participants,

Mathematically this can be written as,

\[
RA_{i,j} = RA_j \cdot \frac{PA_i}{TPA},
\]

(13)

Now, each participant can easily verify which participant is responsible for the outstanding payment, and can decide to start a legal procedure. To better understand this, the following example is given:

**Example 1.2:**

Let’s assume that we have a market situation with six participants. Three of them are buyer and three of them are seller. The amount that each participant must pay, respectively get paid are shown in the figure below.

![Figure 1.6 Market situation](image)

To prevent non-payments, let’s assume that all sellers chose to be settled bilaterally. This means that the Settlement Administrator will determined the amount that each of this sellers must received from each of the buyers.

Using equation (12) and (13), we can determine the corresponding amounts, which can be summarized in the table below.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP4</td>
<td>44.4</td>
</tr>
<tr>
<td>TP5</td>
<td>33.3</td>
</tr>
<tr>
<td>TP6</td>
<td>22.2</td>
</tr>
</tbody>
</table>

Table 1.1 Distributed amounts
Let’s now assume that trading participant TP6 does not pay the amount that he owns. The distribution will then be as to table 1.1 and each seller can verify that the outstanding amounts are due to TP6’s non-payment and can take legal actions without involving the Market Operator.

As shown, the Settlement Administrator shall make sure that the Market Operator only distributes the amount that he has received.

Figure 1.7 Distribution payments for Example 1.2
2. Balancing Market

2.1 Introduction

As all offers to the Day-Ahead Market must be submitted before 5 p.m. local time the day before the trading day, this means that the market is not organised for handling offers in real-time. To be able to maintain the load equal production at all time in the national grid and thereby being able to handle unexpected changes that can occur during the trading day, another market must be created that selects offers in advance and later call up on them in real time when needed. This market is known under the name of Balancing Market\(^8\) and is very important in order to prevent a collapse in the national power system.

It is the Transmission System Operator (TSO) represented by the Romanian Power Grid company Transelectrica S.A\(^3\) that has the total responsibility of the balancing market and is therefore the balancing market operator. His task is to ensure that the security is maintained for each time interval during the day, by buying or selling energy at the balancing market.

The balancing market, which covers this purpose, has three types of balancing energy;

- Secondary Regulation
- Fast Tertiary Regulation
- Slow Tertiary Regulation

and involves the followings participants,

- The TSO
- All producers that operate dispatchable units
- All consumers that operates dispatchable loads, mostly pump-storage plants.

During the following chapters, we will see how the balancing market is used by the TSO and the balancing participants. We will also see how balancing energy is used when solving network constraints, which sometimes are due to the use of balancing energy itself. Terms like down and up-regulation will be explained and finally we will deal with the settlement formulation.

---

\(^3\) Transelectrica is responsible for sale and efficient operations of the power system and the whole electric market.
2.2 Balancing Energy

Balancing energy shall be used for either upward or downward regulation. The term upward regulation means that a producer increases his production or that a consumer with a dispatchable load, reduces its consumption. In the same manner, with downward regulation it is meant a producer who reduces its production or a consumer that increases its consumption. To ensure the security of the system, all licensed parties that operates dispatchable loads and units, must sign up as balancing market participant and shall be authorized for the delivery of secondary, fast tertiary and/or slow tertiary regulation depending on the type of unit / load that this participant owns (standing data as ramp-time, cool down time etc, are taken into account). If a unit or a load has not been authorized for the delivery of fast tertiary, then it is deemed that this participant is authorized for the delivery of slow tertiary regulation.

2.2.1 Primary and Secondary Regulation

The power balance is first maintained by using primary regulation and secondary regulation. It is the deviation in frequency that is going to activate the primary regulation, since the frequency in the power system indicates the balance between electricity production and consumption. If the frequency decreases from its nominal value, 50.0 Hz, then consumption is higher than production. In the same manner, production is greater than consumption when the frequency of the grid increases from the nominal value.

Primary regulation is completely automatic and can be mobilised within 30 seconds and maintain for a period of 15 minutes. With automatically, it is meant that no physical person must activate the regulation after a given order. In Romania, all trading participants providing electrical energy must also provide some kind of primary regulation. If they can’t manage to do this all by them self, they are allowed to pay a third party that can provide primary regulation instead. The primary regulation is part of the Ancillary Services Market, and therefore out of the scope of this report and project.

Since the primary regulation causes the frequency to either descend or to increase, this solution can not be used in a longer time frame since the system must maintain the nominal frequency. To solve this problem, the TSO shall call upon the use of secondary regulation, which function is:

- Restore the frequency to 50.0 Hz
- Substitute the primary regulation, in order to have primary regulation available in case a new, unexpected load or production change occurs.

To be able to provide secondary regulation, the providing party must be registered and authorised by the TSO for this purpose. The secondary regulation must be mobilised within a maximum of 15 minutes, starting after no more than 30 seconds after a corresponding instruction has been issued by the TSO. Unlike primary regulation, which the TSO has no control over, secondary regulation is controlled automatically by a device called Automatic Generation Control (AGC) and a participation factor. The participation factor is calculated by the TSO and decides the part of the total amount of balancing energy that each generator providing secondary regulation, must deliver. The Romanian regulator ANRE, has until today
not chosen how often this participation factor will change. The most probable solution is to have a participation factor that changes each day. Another possible solution is having participation factors that follows the on-peak and off-peak periods. A system that changes its participation factor each trading interval is not to recommend, since this can give reliability problems and jeopardize the system’s security.

It is worth mentioning that some countries have decided that their secondary regulation, or secondary control as it also can be called, shall not be automatically and instead manually. This is the case in the Nordic power grid, where the secondary regulation is started manually by a technician in the control room of each production unit after a given order from the TSO\(^9\).

### 2.2.2 Tertiary Regulation

If the TSO expect that balancing energy will be needed during a longer time period, he shall try to replace the secondary regulation with tertiary regulation in order to have secondary regulation available in case of new, unexpected production changes occurs. This tertiary regulation is divided into two sections:

- Fast Tertiary Regulation – can be fully provided within 15 minutes after instruction from TSO.
- Slow Tertiary Regulation – can be provided after more than 15 minutes after instruction from TSO.

As the names clearly states, the first one is the faster one of the two. Technically this means that a generator that provides fast tertiary regulation, is synchronised with the national power system, but does not inject any electrical power into the net until he is told to. Normally, this kind of regulation is provided by thermal power plants that are kept in the right temperature. Slow tertiary regulation is provided by generators that are not synchronised with the national power system, and therefore takes longer time for them to start up and get synchronised with the national power system.

### 2.3 Submission of offers

All trading participants that have been signed up as balancing market participants must submit daily offers for their entire capacity of a dispatchable unit/load that has been declared available. This daily offers shall contain the price and the amount of balancing energy that this participant is willing to make available for up and down regulation, but not contain the type of balancing energy as to which the offer applies to, as many other markets requires. The price given for upward regulation is the minimum unit price for which this participant is willing to provide the energy offered. In addition, the price given for downward regulation is the maximum unit price that a participant is willing to pay when providing downward regulation. In other words, it can be said that upward regulation is selling energy to the balancing market while downward regulation is buying energy from the balancing market.

Unlike offers omitted to the Day-Ahead Market, each daily offer can only contain up to ten price-quantity pairs. In the case of a dispatchable unit, all offers with the lowest prices and a total quantity below the scheduled production shall be considered as offers for downward
regulation. In the same manner, all offers with the highest prices and a total quantity above the scheduled value shall be deemed to be offers for upward regulation. For a dispatch load, the first price-quantity pair is considered to be the minimum consumption of this load and the energy that the participant don’t want to do available for balancing energy. All quantities that are between the scheduled value and this minimum consumption shall be deemed as quantities for upward regulation and all other shall be considered for downward regulation.

![Figure 2.1 Daily offers omitted by a production unit.](image)

In addition to the daily offers, all participants that are entitle to provide slow tertiary regulation shall also submit standing offers, which shall contain two components:

- Standing Offers for Start-up, and
- Standing Offers for Stand-by

Each standing offer for start-up defines the price at which a participant is willing to start his production unit that is not synchronised with the national power system. For a consumer, this means the price at which he is ready to start the reduction of consumption of his dispatchable load. Each standing offer for stand-by defines the price per hour that a participant is willing to let his production unit be in a state that allows it to be synchronised with the national power system on instruction of the TSO. For a dispatchable load the stand-by price is, for natural reasons, considered to be zero.

2.3.1 Available Balancing Capacities

After the reception of all offers and following the approval of the physical notification, which determines the scheduled for a given unit/load, the TSO shall determine the available balancing capacities, which is the total balancing energy that can be made available by a unit / load during each interval and the distribution of this energy in the different types of balancing energy. The TSO shall determine the available balancing capacities separately for:

- Each dispatchable unit / load
- Each dispatch interval
- Each type of balancing energy, i.e. secondary, fast and slow tertiary
- Up and downward regulation

This calculation shall maximise the availability of secondary regulation, before fast tertiary regulation and slow tertiary regulation taking into account technical constraints as max and min generation, ramp rates, start-up time, cooling down time, stand-by possibilities/constraints etc. This selection can be illustrated, with the same production unit as above, in the following figure,

Figure 2.2 Available balancing capacities

As the figure shows, a range around the scheduled production is made available for secondary regulation, and then an additional amount as fast tertiary and the remaining capacity is made available for slow tertiary regulation. However, if the scheduled production is changed due to the use of balancing energy, i.e. the production unit provides downward or upward regulation, the situation may change. Therefore, the TSO shall verify after a given instruction for the delivery of balancing energy to the providing party, that the limits are still valid and change them if necessary.

2.4 Selection of offers

For the selection of offers in the Balancing Market, three different timeframes are used as illustrated by the figure below. Each dispatch interval is split into four 15 minutes intervals, which are again divided into three 5- minutes balancing intervals, ensuring in this way that there is no conflict between the use of the same offer for one of the three types of balancing energy.
At least 20 minutes before the start of each balancing interval, the TSO shall have completed its selection of offers for secondary regulation for the interval in question. This is done by collecting all offers made available for secondary regulation accordingly to figure 2.2, and listing them by price, i.e. determining the merit order list, separately for upward and downward regulation. Thereafter, the TSO shall accept offers so that the following points are satisfied:

- The aggregated quantity of all accepted price-quantity pairs for upward and downward regulation is equal to the required margin.
- The accepted upward regulation quantity for a dispatch unit shall be equal to the downward accepted quantity.

Right after the selection, the TSO must inform all participants about the quantity that they have been selected for. After the reception of this information, the participants shall set the regulating band of the unit, given the TSO fully access to it. In case the TSO considers it necessary, he will send signals in real time from the central secondary controller to the AGC and start the delivery of balancing energy of this unit. Upon the reception of a signal, a transaction is deemed to take place between the TSO and the providing unit at a price of the most expensive offer accepted by the TSO. In the same manner, the price when providing downward regulation shall be the price of the cheapest offer that the TSO has accepted for downward regulation. It shall be précised that only selected offers will be paid, in difference from some markets that also pay just for submitting offers.

Unlike secondary regulation, where the selection of offers is done even though the need of balancing energy has not yet been determined, the selection of fast tertiary is done when the TSO expects a continuous need of balancing energy. He shall then determine the time intervals were balancing energy will be required and select offers that are within this interval. This is done since the control of fast tertiary regulation is a decentralised manoeuvre that takes place at the central command room of each unit, given the TSO no control over it. When doing the selection, the TSO shall verify that the required margin for secondary regulation is maintained at all time.

In the same manners, the TSO shall use slow tertiary regulation if he expects a continuous need for balancing energy during one or more dispatch intervals. After determining the dispatch interval(s) were balancing energy will be required and the amount, the TSO shall accept offers. This selection is done in the same manners as the selection for the other types of regulation. The TSO can also accept the standing offers that have been submitted to the
balancing market. All standing offers for start-up that are accepted by the TSO and that lead to an additional start-up, establish a transaction between the TSO and the providing party at the time instructed by the TSO and shall be paid at the offered price. All standing offers for stand-by that have been accepted, establish a transaction between the TSO and the providing party during the time specified by the TSO and for the price offered.

To avoid an inefficient reservation of offers for a certain type of regulation, all offers for secondary regulation are also made available as fast and slow tertiary regulation, and all offers for fast tertiary are made available as slow tertiary regulation. It is though very important that the TSO has enough secondary and/or fast tertiary regulation available at all times. Therefore the TSO must calculate for all balancing intervals, a certain minimum amount, called required regulation, of secondary respectively fast tertiary regulation that must be kept at all time and therefore reserved.

For better understand the use of the three timeframes, let’s assume a major production outage, expected to continue for several hours. The use of secondary regulation is determined for the current balancing interval. At the same time, the TSO already decides on the use of fast tertiary regulation. But the use of fast tertiary regulation is only beginning with the first 15-minutes interval starting at least 15- minutes after the end of the current balancing interval, i.e. in this case by the beginning of the fourth 15–minutes interval of the current dispatch interval. Similarly, the use of slow tertiary regulation is only beginning with the first dispatch interval starting at least 1 hour after the end of the current balancing interval, i.e. in this case by the beginning of dispatch interval 2.

By this procedure, the rules avoid any conflict due to the simultaneous use of any offers for secondary, fast tertiary and / or slow tertiary regulation. In essence, any imbalance is thus first solved by secondary regulation, which can be replaced by fast tertiary regulation within 15 - 30 minutes. The use of fast tertiary regulation may in turn be replaced by slow tertiary regulation after a minimum of 60- 105 minutes. This structure therefore tries to find a suitable compromise between allowing determining an “optimal” solution and limiting the complexity of the selection mechanism.

As all the balancing market participants are obliged to submit daily offers to the market, the TSO is always sure of having sufficient balancing energy. To control this, the TSO must

![Diagram](image-url)
verify that each participant has submitted valid offers for all its units. If the TSO determines that a participant has failed to submit an offer, it shall inform the participant giving the information of the missing unit. At the reception of such information, the participant has 30 minutes for sending the missing offer. If the participant doesn’t response to this call, then the TSO will create the missing offer based on the standing technical data and the approved physical notification for the corresponding unit. The price of all price-quantity pairs in such an offer shall be equal to the market clearing price of the Day-Ahead Market applying to the delivery day and dispatch interval in question.

2.5 Congestion Management

If a transaction concluded by the TSO would result in a congestion that can endanger the security of the national power system, he shall immediately cancel this transaction by marking it as cancelled in the balancing market system. Thereafter, he shall replace this cancelled transaction by accepting an equal amount of balancing energy but at the same time making sure that this new acceptance doesn’t lead to new congestion. This new accepted offer shall then be marked as used for congestion management in the balancing market system.

Balancing energy shall also be used to treat unexpected congestion that can occur during the day. The TSO shall solve congestion by selecting an equal amount of upward and downward regulation in the respective parts of the system where congestion is due to take place. In addition, the TSO shall specify:

- The time at which the congestion is expected to start and how long is its expected duration
- The required reduction of the power flow between the two parts in the system where the congestion is going to take place.
- Where in the national power system the congestion is situated.

The TSO shall try as far as possible to solve all congestion with the use of slow tertiary regulation and if this is not possible, the use of fast tertiary regulation. All the transaction that takes places after a given order from the TSO for taking care of congestion shall be marked as used for congestion management in the balancing market system. The first reason for this is that from a settlement point of view, there is a difference done between the costs for system balancing, meaning the transactions used to keep the balance, and the costs for congestion management, meaning the transactions used to avoid congestion in the system. The second reason is that the transactions for congestion management are not taken into account when determining the penalty that each participant must pay for imbalance. This will be further explained in chapter 2.6.
To understand how balancing energy can be used to solve network constraints, let’s look at the following example.

**Example 2.1:**

Let’s assume that the TSO becomes aware of the following situation that is going to take place in a couple of hours,

![Diagram of power flow](image)

To solve this problem, the TSO shall order the delivery of 50 MW downward regulation in the border trading zone and 50 MW upward regulation in the national trading zone. By doing this, the transit of power will be decreased to the allowed amount of 200 MW, and the congestion is solved.

![Diagram with 50 MW flow](image)

It is important to understand that this example is extremely simplified since in reality we have many more factors that come into play, but the principle stays the same.

**2.6 Settlement – Balancing Market**

**2.6.1 Introduction**

As in the Day-Ahead market, the TSO shall prepare trade confirmation for all the transaction concluded during the day in the balancing market and that have not been cancelled due to congestion. Each trading confirmation shall contain the accepted quantities and price for each type of balancing energy and for upward and downward regulation. This trade confirmation shall be send to all participants that the TSO has undergone a transaction with and one copy shall be send to the settlement administrator.

At the end of each month, the metering operator must send all metered values [MWh] to the TSO. Upon the reception of this information, the TSO shall create the monthly balancing market statement separately for each balancing market participant. This statement shall summarize, as the trade confirmation, all monthly amounts of balancing energy delivered and actually delivered, by the participant in question together with its prices. This monthly statement shall be send to the corresponding balancing market participant and to the Settlement Administrator.
2.6.2 Daily Settlement Calculation

Upon the reception of the monthly statement, the settlement administrator shall perform the settlement calculation, separately for each participant and day, accordingly to the equation

\[ BMDSA = \sum_i (AQ_{up,i} \cdot P_i) - \sum_i (AQ_{down,i} \cdot P_i), \]  

(14)

where BMDSA is the balancing market daily settlement amount, \( AQ_i \) is the quantity actually delivered in interval \( i \) and \( P_i \) is the price of this transaction. As mentioned in earlier chapters, the price for secondary regulation shall be the lowest accepted price for downward regulation and the highest accepted price for upward regulation. For tertiary regulation, the price is the offered price. It shall though be mentioned that if the amount of upward regulation actually delivered is less than the amount to be delivered, only those transactions for the delivery of upward regulation with the lowest prices and with an aggregated quantity equal to the amount of upward regulation actually delivered shall be deemed to have been delivered. In the same manners, if the amount of downward regulation actually delivered is less than the amount to be delivered, only those transactions for the delivery of downward regulation with the highest prices and with an aggregated quantity equal to the amount of downward regulation actually delivered shall be deemed to have been delivered.

All participant that has not fulfilled to deliver the amount of energy that they have contracted with the TSO as to the trade confirmation, will be penalized for each MWh that he has not delivered. Mathematically this can be written as,

\[ (CQ - AQ_{up,i}) + (CQ_{down,i} - AQ_{down,i}) \cdot K, \]  

(15)

where BMP is the balancing market penalty, \( CQ \) is the contracted quantity, \( AQ \) is the actually delivered quantity and the constant \( K \) is the specific penalty for under-delivery of balancing energy for interval \( i \). As the name of the constant tells us, a participant can only be penalised for the under-delivery of power and not for delivering more than he has contracted. It shall also be mentioned that the standing transactions, i.e. the start-up and standby transaction, are not taken into account in the calculation of the balancing market penalties. This is due to the fact that a standing offer does only contain a price and not a quantity and therefore can’t be penalized.

The constant \( K \), which has the unit [Lei / MWh]

\(^4\), is determined for each dispatch interval during the day as,

\[ K_i = a + b \cdot MCP_i + c \cdot IMBDP_i + d \cdot IMBSP_i, \]  

(16)

where \( a, b, c \) and \( d \) are constants determined by ANRE. The constant \( a \), shall be expressed in Lei, and constants \( b, c \) and \( d \) shall be expressed as percentages. The term \( IMBDP \) is called imbalance deficit price and \( IMBSP \) is called imbalance surplus price which is the average cost of upward respectively downward regulation that has been used in the corresponding dispatch interval \( i \). These two terms are calculated accordingly to the equations.

\(^4\) Lei is the national currency if Romania.
\[
IMBDP_i = \frac{\sum_j (AQ_{up,bal,j} \cdot P_j) + \sum_j (AQ_{up,can,j} \cdot P_j)}{\sum_j AQ_{up,bal,j} + \sum_k AQ_{up,can,k}},
\]

(17)

\[
IMBSP_i = \frac{\sum_j (AQ_{down,bal,j} \cdot P_j) + \sum_j (AQ_{down,can,j} \cdot P_j)}{\sum_j AQ_{up,bal,j} + \sum_k AQ_{up,can,k}},
\]

(18)

where the index ‘bal’ stands for balancing, and the index ‘can’ stands for cancelled.

From this two equations, we can see that the average price of imbalance only takes into account all transactions that have been initially chosen for providing balance energy, even if they later have been cancelled due to congestion.

If the TSO has not ordered any balancing energy, or if the only balancing energy order is for congestion management, then both the imbalance surplus price and imbalance deficit price shall be set equal to the market clearing price from the Day-Ahead Market for the corresponding dispatch interval.

2.6.3 Cost of System Balancing and Congestion Management

The settlement administrator, which is the one responsible for determining all the amounts that shall be paid or received by each participant in the Day-Ahead Market and the Balancing Market, shall also calculate the total cost of system balancing and congestion management. The cost of system balancing includes:

- The cost of transactions that have been concluded in the balancing market, and that are not marked as used for congestion management in the balancing market system. The quantity shall be the actually delivered quantity and not the contracted quantity.
- The cost of transactions that have been concluded in the balancing market and that have been cancelled due to congestion.

This can be divided in two terms, the payment for system balancing and the income from system balancing. Putting this into equations gives,

\[
PSB_i = \sum_j (AQ_{up,bal,j} \cdot P_{ij}) + \sum_k (AQ_{up,can,i,k} \cdot P_{ik}),
\]

(19)

\[
ISB_i = \sum_j (AQ_{down,bal,j} \cdot P_{ij}) + \sum_k (AQ_{down,can,i,k} \cdot P_{ik}),
\]

(20)

where \( P_{ij} \) and \( P_{ik} \) are the prices for the \( j \)-th respectively \( k \)-th transaction in interval \( i \). Putting this two equations together gives the cost for system balancing as,

\[
CSB_i = PSB_i - ISB_i,
\]

(21)

The costs for congestion are equal to:
- The cost of transaction that have been concluded in the balancing market and that have been marked as used for congestion management in the balancing market system. The quantity shall be the actually delivered quantity.
- Minus the avoided costs of transaction that have been concluded in the balancing market and that have been cancelled due to congestion.

As the cost for system balancing, this can also be divided in the payment for congestion management and the income for congestion management,

\[
P_{\text{con,}j} = \sum_{j} (AQ_{\text{up,con,}i,j} \cdot P_{i,j}) - \sum_{k} (AQ_{\text{up,can,}i,k} \cdot P_{i,k}), \quad (22)
\]

\[
I_{\text{con,}j} = \sum_{j} (AQ_{\text{down,con,}i,j} \cdot P_{i,j}) - \sum_{k} (AQ_{\text{down,can,}i,k} \cdot P_{i,k}), \quad (23)
\]

The cost for congestion can then be expressed as,

\[
C_{\text{con,}j} = P_{\text{con,}j} - I_{\text{con,}j}, \quad (24)
\]

The Settlement Administrator shall send the invoice for the cost of congestion to the TSO, who will charge this to all the consumers in the national power grid indirectly as taxes or charges.
3. Imbalance Calculation

3.1 Introduction

As seen in the previous chapter, it is important that the balance is maintained during the day. But who is responsible for this imbalances and who has to pay the cost of imbalances? Is it the producers, the consumers or is it the TSO? And what is the definition of imbalance? In this chapter, the answer to the questions above will be given, starting with the definitions of the BRP and ending with the BRP imbalance calculation\(^{[10]}\) and information imbalance.

3.2 Balance Responsibility Party – BRP

Before any participant is allowed by the Romanian regulator ANRE to participate in any of the two markets mentioned earlier, special applications must be filled out and send. Different criteria must be fulfilled depending if the application comes for a producer or a consumer. One criteria in common, is that each applicant must nominate someone who will assume the responsibility if he doesn’t fulfil his tasks. The party can provide such responsibility is called Balance Responsibility Party (BRP).

The establishment of a BRP is important to:

- Enable the execution of electric power transaction in the national electricity market in an orderly fashion.
- Help establish a priori the electric power balance of the national power system.
- Unlink financial transactions from physical delivery.
- Ensure correct settlement of electric power transaction in the national electricity market.

The concept of balance responsibility provides for a compromise between assigning the financial responsibility for imbalance between planned and actual production, consumption and exchange of electric power and avoiding any undue punishment of individual market parties, by allowing market parties to combine their aggregate imbalances. This means that a BRP can have the responsibility for several production units and consumers at the same time and by combining their imbalance try to achieve its responsibility at each dispatch interval. Assume for instance that a BRP’s costumers, has a total consumption of 1500 MW the first half hour and that the consumption is 2500 MW during the second half hour. If the production units that this BRP has responsibility for has a total production of 2000 MW during the whole hour, then this BRP has achieved to maintain his balance.

Each BRP obliges itself for this purpose, to plan for each dispatch interval, in such a way that the production and purchasing, including imports, of electric power correspond to the anticipated consumption and sales, including exports, of electric power by all market parties, including itself, that this BRP has the balance responsibility for.

The invoice for the energy that the TSO must purchase at the balancing market is going to be sent to the BRPs with negative imbalances which together have made upward regulation.
necessary. In the same manners, if the TSO sells energy to the balancing market, i.e. downward regulation, then the revenues from this sale is passed on to the BRPs with positive imbalance which together have made downward regulation necessary.

All licensed parties can become BRPs. They have to do a written appliance to the TSO, providing the following information:

- Full name, legal address and contact details of the licensed party
- Type and number of the licensed party’s license
- Names and contact details of all persons being entitle to act on behalf of the licensed party
- Aggregate installed capacity of all production set for which the applicant would like to assume the balance responsibility for
- Aggregate capacity of all consumers for which the applicant would like to assume the balance responsibility for.

Since the responsibility is financial and not technical, all BRPs must also provide a financial guarantee, showing that they are able to assume the responsibility for the capacity that they have applied for.

### 3.3 Net contractual position and net metered position

To be able to determine if a BRP has had imbalances during a dispatch interval, the calculation are going to be based on different information provided from several involved actors, mainly BRP, the TSO and the Meter Operator. To enable the determination of the imbalances, it is very important to have the,

- Net contractual position, and
- Net metered position

The net contractual position of each BRP is based on all contractual deliveries (production, consumption, exports and imports) of electric power with other BRPs, for which he is responsible for, including those transactions entered into the DAM and the balancing market. The net metered position of each BRP is based on all metered deliveries of electric power from or to the nation power system, or between the different parts of the national power system. All the metered values are provided by the meter operator that is in charge of all the metering points that are placed throughout the national grid.

The simplest example is a supplier who simple supplies customers and purchases all its need in the market, without selling to anybody else. The net metered position would then be equal to the demand of its costumers and the net contractual position equal to its purchases in the market, and the imbalance equal to the difference between the demand of its costumers and its purchases in the market.

For the net contractual position the corresponding equation is then,

\[
NCP = \sum \text{Prod} - \sum \text{Cons} + \sum \text{EXP} - \sum \text{IMP} + B.E, \quad (25)
\]
where Prod is the production, Cons is the consumption, EXP is the contractual exports and IMP is the contractual imports that this BRP has the responsibility for. B.E is the total balancing energy that this BRP has undertaken the responsibility to deliver to the TSO.

For the net metered position, the corresponding equation is,

\[ NMP = TMG - TMC, \quad (26) \]

where TMG is the total metered generation and TMC is the total metered consumptions, both values given by the meter operator. It should be mentioned that this equation is valid only if the BRP is not a network operator. If the BRP is a network operator then the equation is,

\[ NMP = TME - TMI, \quad (27) \]

where TME is the total metered exports and TMI is the total metered imports. This is done, since the losses in the system are taken into account in the imbalances of the network operator.

Having these two equations, the BRP imbalance can be calculated as,

\[ BRPI = NMP - NCP, \quad (28) \]

which will give that the amount to pay or to receive for each BRP is,

\[ BEA = BRPI \cdot IMBSP, \quad \text{for } BRPI > 0, \quad (29) \]
\[ BEA = BRPI \cdot IMBDP, \quad \text{for } BRPI < 0. \quad (30) \]

In both equation (29) and (30), the imbalance prices are the same as determined in the previous chapter. This means that we now can give a more correct definition of the imbalance deficit price, as the unit price that a BRP has to pay to the TSO for negative imbalance and imbalance surplus price as the unit price that a BRP receives from the TSO for positive imbalance. To this amount, the settlement administrator must also apply the corresponding taxes and send the invoice to the corresponding BRP.

### 3.4 Information Imbalance

The information imbalance is a measure of a power plant’s deviation from its scheduled output. In other words, this means the difference between the actual and planned production of a dispatch unit. As in the balancing market, each unit has to pay a penalty fee for this deviation. The amount to pay is based on the information imbalance quantity and the imbalance information charges. The later one can be compared with the constant K in the balancing market, since it is determined by the same equation,

\[ IIIC_i = a + b \cdot MCP_i + c \cdot IMBDP_i + d \cdot IMBSP_i, \quad (31) \]

but where the constant a, b, c and d can have different values to the constants in the balancing market.
The penalty amount that each producer has to pay at each dispatch interval \( i \), is determined by the equation,

\[
IIA_i = \left| IIB_{\text{non},i} \right| + \sum_{\text{outage}} \left| IIB_{\text{not},i,\text{outage}} \right| \cdot \left( 1 - \frac{T_{\text{not, outage}}}{T_{\text{ref}, i}} \right)^2 \cdot IIC_i,
\]

where \( IIB_{\text{non}} \) is the non-notified information imbalance quantity in MWh, \( IIB_{\text{not},i,\text{outage}} \) is the notified information imbalance quantity for an unexpected outage in MWh, \( T \) is the time in minutes between the start of the dispatch interval and when the outage was informed to the TSO, \( T_{\text{ref}} \) is the time in minutes between the scheduled submission time and the start of the dispatch interval where the outage has occur and \( IIC_i \) is the information imbalance charge [Lei/MWh] for dispatch interval \( i \).

It shall be mentioned that a unit can only send a notice for reduction of outputs, not for increases and that the only time when a producer is allowed to change its initial schedule, and therefore will not get penalised, is if he suffers from an unexpected outages due to technical failure which he has to be able to prove.

To better understand the information imbalance and equation (32), let’s study the following example.

**Example 3.1:**

Assume that a producer has the schedule and his actual output as figure 3.1 for the first dispatch interval of the day, i.e. between 00:00 a.m. and 01:00 a.m. Let’s now assume that an unexpected outage occurs at 00:30 and that the unit gives a notice to the TSO at 00:35 that his scheduled output will change.

![Information Imbalance](image)

After the reception of the metered values at the end of the dispatch interval, the TSO and the settlement administrator are going to base their calculations on the average output that this value gives. Here, the average output (i.e. the metered value of the whole interval) is therefore,
\[ \text{Metered} = \frac{130 \cdot 30 + 120 \cdot 30}{60} = 125 \text{ MW}, \quad (33) \]

This will then give us the following graph,

The determination of the imbalance information quantities \( \text{IIB}_{\text{non}} \) and \( \text{IIB}_{\text{not}} \) is now done by taking into account the time when the unit notified the change to the TSO. The difference between the metered and scheduled values up to the notice time shall become the non-notified information imbalance and the rest shall become the notified information imbalance.

Mathematically, this can be expressed as,

\[ \text{IIB}_{\text{non},i} = \frac{(130 - 125) \cdot 35}{60} = 2.92 \text{ MWh}, \quad (34) \]

and

\[ \text{IIB}_{\text{not},i,\text{outage}} = \frac{(130 - 125) \cdot 25}{60} = 2.08 \text{ MWh}, \quad (35) \]

Using equation (32), (34), (35) and assuming that \( T_{\text{ref}} \) is 420 minutes (corresponding to the time in minutes between the scheduled submission time 17:00 and the start of the dispatch interval), gives the total quantity that this unit is penalised for as,
\[ HIA_i = \left[ 2.92 + \sum_{\text{outage}} 2.08 \cdot \left( 1 - \frac{35}{420} \right)^2 \right] \cdot ICC_i, \]  

As seen, the information imbalance is to oblige each production unit to respect their schedule. In reality, the information imbalance is to prevent the BRP from changing dispatch instruction during the day. Take for instance a BRP that has two production units under his responsibility, one located geographically in a southern border trading zone and one in the northern part of the national trading zone. The one in the national trading zone has been scheduled for 100 MW, and the one in the border trading zone has been scheduled for 200 MW. This BRP has then a total balance responsibility of 300 MW which he has to fulfil. Imagine now, that the BRP considers that it is more economical from his point of view, to produce 100 MW in the BTZ and 200 MW in the NTZ. This solution means that he is still going to keep his balance in the dispatch interval, but the geographical change in production can eventually lead to congestion and therefore is not the most economical solution for the TSO.
4. Implementation

4.1 Introduction

As seen throughout this report, the flow of information in an electricity market is very complex and indeed important, which requires well-defined structures of databases and information flow. With the modern communication systems that we have today, all communication between the different market actors is going to be done through Internet. Trade confirmations, submission of offers etc. is relevant market information that is required to be stored in a central database and were relevant parties can have access to. The primary sources of published market information for the public, is the respective web-sites of the market operator, the settlement administrator and the TSO, were it shall be possible to download certain information.

Since the practical part of this project, is the creation of a prototype for the settlement calculation, this chapter is going to focus on the information flow that is necessary to have for the settlement. A short description of the program AIMMS\textsuperscript{[11]}, were the prototype has been developed, is going to be given together with some screen-shots showing the user-interface of the prototype.

4.2 Information flow and AIMMS

As in all electronic system, the information has to be stored in a central database. This central database is, in the case of the Romanian electricity market, composed by the information send from one market participant to another, mainly by the TSO (ATC-values, matching process results, etc.), trading participants (offers) and the settlement administrator. The contribution from the settlement administrator is the calculation of payments in the Day-Ahead Market, the Balancing Market and the Imbalance calculation. To be able to perform the settlement in an orderly fashion, the settlement administrator must have a fully access to this central database. The general structure of the connection with the database can be presented as in the figure below,

![Diagram](image-url)

Figure 1.1 The information flow between the market actors and the central database.
Here, it can be seen that all market actors have access to the central database. Some restrictions must though exist for preventing that sensible information gets in the wrong hands. For instances, a trading participant shall not be able to see the price of offers send by another participant, since this wouldn’t be competitive.

All rules have been implemented in AIMMS which is a multi-dimensional modelling language, who has a powerful index notation enabling to capture the complexity of problems as the occur in real life situation. It also provides the ability to express very complex calculations in a compact manner without the need to worry about memory or sparse data storage. AIMMS provides also a powerful combination of automatically updated multidimensional definitions and procedural execution. The definitions allow to globally specifying unique relationships between entities in the model without having to worry about the order of execution. In addition, the procedures provide the total control over the precise order in which particular computation has to be performed. This is especially necessary, when one calculation depends on other calculated input data. AIMMS provides also a rich set of mathematical, statistical and financial functions and also gives the opportunity to express time-based models through the use of calendar, which in the core of this project and that can easily be used.

Thanks to the existents of an integrated tool for the construction of graphical user interface, called GUI, the creation of ends-user screens are done in an easy point – and click manner. Here, the results can be visualised as tables, charts and curves, all linked to the multi-dimensional identifiers in the model.

An ODBC\textsuperscript{5}- connection is used to communicate with the database, which makes it possible to access any data from any application, regardless of which database management system (DBMS) is handling the data.

### 4.3 Prototype

The prototype, as today, is created so that a user can easily navigate between the different markets thanks to a menu. After having selected the trading date, which can indeed be several dates at the same time, he can choose the results that shall be visualised. The results can be displayed for each day, months or weeks that are within the selected dates. For the Day-Ahead Market, it exist a checkbox called ‘transitions rules’, that a user can select when the chosen dates are within the transition period. This will lead to a change in the results that can be displayed, since accordingly to chapter 1, we have different equation during this phase.

\begin{footnote}
\textsuperscript{5} Open DataBase Connectivity
\end{footnote}
When pressing the ‘READ’ button, the program will get the information that he needs from the central database. This process can be shown in the following figure,
This figure shows what the trajectory would have been if this prototype would be used as the settlement calculator in the Romanian market. Since this prototype is created to verify the rules, the results are not going to be written in the central database as it would otherwise. Instead, the results are shown directly in the screen, which means that the trajectory is the one with the black arrow. If the button ‘CLEAR DATA’ is pushed, then all information is going to disappear, and a new run must be performed to get the data back.

The user interface for the matching process is similar to the settlement calculation. Here, the user must type the date together with the dispatch interval for which he wishes to see the matching results. Furthermore, the user must also check that the time of the computer is set on the Romanian time zone and type in the date in standard time, i.e. not in daylight saving time DST. This means that if a user wants to check the result for, let’s say 8-april- 2004, he has to enter the start date, 7-april-2004 23:00, and the end date 8-april-2003 23:00 and also precise the interval.

As for the run of the matching process, the same procedure as in figure 4.3 takes place when the button ‘READ DATA’ is pushed.

![Figure 4.4 Screen shot showing the matching process.](image)

### 4.4 Conclusions and future work

This project has analysed the proposed market rules in Romania for the Day-Ahead Market, Balancing Market and the Imbalance Calculation. The rules have also been explained why they are needed and the role they play in the market. A prototype has been created in AIMMS, where the settlement rules for the Day-Ahead Market, as well as the Matching Process, have been implemented and where the results have been checked and found satisfactory. But there
are many more markets that have to be implemented and many more rules that have to be analysed before having a completely deregulated market. Ancillary Services (for the management of the reserves, reactive power and losses), Scheduling rules, Hydro Optimization rules and Metering rules are just a few of the items that have to be in a deregulated energy market. It is therefore natural to encourage such analysis for the remaining markets and rules but also the creation of a similar document in order to better understand the deregulated market.
APPENDIX A. Flow Chart of Matching Process

Start: Market closing time

1. Creation of merit order

2. Determination of initial market clearing price.

3. Preliminary acceptance of offers

4. Computing of Contractual Exchanges (C.E) for border trading zones

5. C.E - ATC > 0
   - Yes
   - No

   6. Initial MCP, becomes the final MCP

   7. Preliminary accepted offers, becomes final accepted offers

   8. Creation of the merit order separately for each congested zone and for the uncongested zone

   9. Determination of initial MCP, separately for congested zone and for the uncongested zone

10. Determination of Selected zone

11. Extention of the merit order list for the selected zone and the national trading zone

12. Computing final MCP the for selected zone and initial MCP for the uncongested zone

13. Final acceptance of offers for the selected zone
    Preliminary acceptance of offers for the uncongested zone

Stop: Trade confirmation
APPENDIX B. Matching Process - Example

To better understand the Matching Procedure given in section 1.4, the following example consists of a set of offers for three trading zones. One of them is of course the National Trading Zone, called NTZ, and the other two are Border Trading Zones, called BTZ1 and BTZ2. For each of the Border Trading Zone, only one sell offer has been proposed. The offer configuration is the following:

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Buy</th>
<th>Sell</th>
<th>Trading Zone</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>X</td>
<td>NTZ</td>
<td>125 MWh / 5 €</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>X</td>
<td>NTZ</td>
<td>200 MWh / 20 €</td>
</tr>
<tr>
<td>C</td>
<td>X</td>
<td></td>
<td>NTZ</td>
<td>300 MWh / 50 €</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>X</td>
<td>BTZ1</td>
<td>100 MWh / 10 €</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>X</td>
<td>BTZ2</td>
<td>100 MWh / 15 €</td>
</tr>
</tbody>
</table>

The ATC-limits are the following:
Import from BTZ1 limited to 50 MWh and import from BTZ2 is limited to 50 MWh. Let’s also assume that the maximum price of the price scale is 60 €.

Step 1. Creation of merit order

<table>
<thead>
<tr>
<th>Sell</th>
<th>Trading Participant</th>
<th>Price / Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>125 MWh / 5 €</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>100 MWh / 10 €</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>100 MWh / 15 €</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>200 MWh / 20 €</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>0 MWh / 60 €</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Buy</th>
<th>Trading Participant</th>
<th>Price / Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td>300 MWh / 50 €</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>0 MWh / 0 €</td>
</tr>
</tbody>
</table>

The Trading Participant F stands for the two fictive bids created by the Market Operator in order to fulfil the requirements given by the Matching Process above.

Step 2 and 3:

This two Merit Order list can then be resumed in the following figure below.

The figure shows that the Market Clearing Price is 15 € and that the preliminary selected offers are,
Step 4:

The determination of the contractual exchanges, is here very simple to calculate. The equation given in section 1.4.4 is,

\[
C.E = \text{Supply} - \text{Demand}
\]

Which, calculated for each Border Trading Zone separately gives,

<table>
<thead>
<tr>
<th>Zone</th>
<th>Contractual Exchange (MWh)</th>
<th>ATC- limits (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTZ1</td>
<td>100-0=100</td>
<td>50</td>
</tr>
<tr>
<td>BTZ2</td>
<td>75-0=100</td>
<td>50</td>
</tr>
</tbody>
</table>

Step 5:

As per section 1.4.6, the two border trading zones, shall be named as congested zones and market splitting shall be used to solve this.

Step 8-10:

The merit order list for both congested zones will only contain one sell offer and the fictive bid created by Market Operator. These two bids, can be summarized, for BTZ1, in the figure below.

Here the Market Clearing Price is the price of the only real bid that exists (i.e. 10 €) and if proceeding in the same manner, we will find the Market Clearing Price, for BTZ2 being equal to 15 €.

Creating the merit order list for the uncongested zone, we will find that the market clearing price has change, due to the fact that we now only take in consideration the bids that belongs to the uncongested zones, in this particular case, the national trading zone. With a market clearing price of 20 € for the national trading zone, the selected zone shall become BTZ1 and BTZ2 shall be considered as uncongested.

Step 11:

Since the contractual exchange is positive and greater than the ATC- limits, the Market Operator shall create a virtual buy offer of 50 MWh, the ATC- value, with a price equal to the maximum price of the price scale, here 60 €, that shall be added to the merit order of BTZ1.
At the same time the Market Operator shall create a virtual bid in the national trading zone, with a quantity equal to 50 MWh (ATC-value) and with a price equal to 0 €. This will then give us the following merit order list for the BTZ1,

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>100 MWh / 10 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 60 €</td>
</tr>
</tbody>
</table>

As for the uncongested zone, which now also contains the energy offers from BTZ2, the Merit Order list becomes,

<table>
<thead>
<tr>
<th>Trader Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>50 MWh / 0 €</td>
</tr>
<tr>
<td>A</td>
<td>125 MWh / 5 €</td>
</tr>
<tr>
<td>E</td>
<td>100 MWh / 15 €</td>
</tr>
<tr>
<td>B</td>
<td>200 MWh / 20 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 60 €</td>
</tr>
<tr>
<td>C</td>
<td>300 MWh / 50 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 0 €</td>
</tr>
</tbody>
</table>

Step 12:

The merit order for BTZ1 can be drawn as the figure shows. This gives that the final market clearing price is settled to 10 € / MWh for BTZ1 and the cleared energy is 50 MWh. By this, BTZ1 is no more congested and its associated energy offers, except the virtual offers created in the uncongested zone to release the congestion, shall not be taken into further account.

As for the uncongested zone the merit order can be interpreted as,

which gives an initial market clearing price of 20 € / MWh.
Step 13:

The finally accepted offers in BTZ1 are then,

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Accepted Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>50 MWh</td>
</tr>
</tbody>
</table>

This zone has now been treated and the matching process shall ignore this zone in the future.

For the uncongested zone the preliminary accepted offers are,

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Accepted Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>50 MWh</td>
</tr>
<tr>
<td>A</td>
<td>125 MWh</td>
</tr>
<tr>
<td>E</td>
<td>100 MWh</td>
</tr>
<tr>
<td>B</td>
<td>25 MWh</td>
</tr>
</tbody>
</table>

Step 4-5 and 10:
(step 8 and 9 are not performed since there is only one congested zone)

From the preliminary accepted offers for the uncongested zone above, we can calculate the contractual exchange for BTZ1 to 100 MWh (100-0). Since this values is greater than the maximum allowed (50 MWh), BTZ2 remains a congested zone. Due to the fact that there are no other congested zones, BTZ2 becomes the selected zone immediately.

Step 11:

Since the contractual exchange is positive, the Market Operator shall create a fictive buy offer with a quantity of 50 MWh (ATC- value) and with a price equals to the maximum price of the price scale (60 €) that shall be included in the merit order for BTZ2. At the same time, the Market Operator shall create a fictive bid in the national trading zone, with a quantity of 50 MWh and with a price equal to zero.

For the selected zone BTZ2, the Merit Order list will consist of the following energy offers,

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>100 MWh / 15 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 60 €</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>50 MWh / 60 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 0 €</td>
</tr>
</tbody>
</table>

As for the uncongested zone, in this case the national trading zone only, the merit order shall contain the energy offers that belong to the corresponding zone and the two fictive bids created by the Market Operator in the market splitting procedure.

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>50 MWh / 0 €</td>
</tr>
<tr>
<td>A</td>
<td>125 MWh / 5 €</td>
</tr>
<tr>
<td>B</td>
<td>200 MWh / 20 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 60 €</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Quantity / Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>300 MWh / 50 €</td>
</tr>
<tr>
<td>F</td>
<td>0 MWh / 0 €</td>
</tr>
</tbody>
</table>
Step 12:
A graphical merit order shows that the final market clearing price for BTZ1 is 15 € / MWh.

The Market Clearing Price is 20€ / MWh for the national trading zone and the finally selected offers are shown in the table below.

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Accepted Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>50</td>
</tr>
</tbody>
</table>

This zone is now deemed to have been settled and shall not be taken into account in the future.

For the uncongested zone, the preliminary selected offers are

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Selected Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>50</td>
</tr>
<tr>
<td>F</td>
<td>50</td>
</tr>
<tr>
<td>A</td>
<td>125</td>
</tr>
<tr>
<td>B</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Selected Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>300</td>
</tr>
</tbody>
</table>

Here, the two fictive bids have been preliminary selected. This must be done to release the congestion, but they can never be finally accepted, due to the fact that they don’t exist.
Step 4, 5, 6 and 7:

Since there are no more congested zones left, the initial market clearing price for the uncongested zone shall become the final price. As for the preliminary accepted offers, they shall become the final accepted offers, except for the two fictive bids mentioned earlier. The matching process has now reached to its end, and the final market results are,

**Sell Offers**

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Accepted Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>125 MWh</td>
<td>20 €</td>
</tr>
<tr>
<td>B</td>
<td>75 MWh</td>
<td>20 €</td>
</tr>
<tr>
<td>D</td>
<td>50 MWh</td>
<td>10 €</td>
</tr>
<tr>
<td>E</td>
<td>50 MWh</td>
<td>15 €</td>
</tr>
</tbody>
</table>

**Buy Offers**

<table>
<thead>
<tr>
<th>Trading Participant</th>
<th>Accepted Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>300 MWh</td>
<td>20 €</td>
</tr>
</tbody>
</table>

Graphically the result from the Matching Process can be represented as figure 5. The figure shows the three different zones and the amount of energy purchased or sold in each zone. Thank to the market splitting, the transit of power from both border trading zones, respect the ATC- limits that are imposed by the National Power Grid.

![Diagram](image-url)

**National Trading Zone**

Border Trading Zone 1  National Trading Zone 2

Figure A1. Schema showing the transit of power, after the execution of the matching process.
REFERENCES

[1] Global Deregulation Reports


