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Balancing Market Design

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RESULT (summary)

The present report is one of the two final reports in the project "Balancing Management in Multi-national Power Markets".

A balance market design can be described with the help of a number of design variables that together constitute a design space. The design variables are divided in two groups, the variables that define the market design in one Control Area and those that define the balancing market interaction between Control Areas. The latter group consists of the five variables Market arrangements for Balancing Energy Market, Types of Exchanged Balancing Energy, Market arrangements for Reserve Capacity Markets, Reservation of Cross Border Capacity for Balancing, and Definition of Balancing Regions, referring to the fact that Balancing Regions can correspond to Balancing (or Control) Areas or can comprise several Balancing Areas that are merged.

Using these design variables, a number of basic market designs for Multi-National Power Markets are defined and performance criteria are established. Based on a quasi-quantitative approach, the most promising designs are: Netting of the Area Control Errors (or rather Imbalances), Common Merit Order lists for Balancing Energy and possibly also Reserve Capacity and Full Harmonization, which means that in addition to Common Merit Order lists also other design variables are harmonized. While Imbalance Netting is straight forward and can be implemented with relatively small efforts, the other design proposals are more complicated and will take more time to realize, while also their rewards are greater.

Designs that involve direct cooperating between Balancing Service Providers in one Control Area and the TSO in another Control Area are concluded to have significant disadvantages. However, they may be relevant in a transitional period between the Nordic area and the Central Western European system to give incentives to realize the necessary investments in Automatic Generation Control in the Nordic system.

KEYWORDS

SELECTED BY AUTHOR(S)		
	Power Market	System Balancing
	Market Design	Reserves

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TERMS AND ABBREVIATIONS

AGC	Automatic Generation Control
AVP	Additional Voluntary Pool
BE	Balancing energy
BEE	Balancing energy exchange
BEM	Balancing energy market
BM	Balancing Market
BRP	Balancing Responsible Party
BSM	Balancing Services Market
BSP	Balancing Service Provider
CBC	Cross-border capacity
LFC	Load Frequency Control
MBM	Multinational Balancing Market
MOL	Merit Order List
PTU	Program Time Unit (the settlement period for the Balancing Market)
RC	Reserve capacity
RCE	Reserve capacity exchange
RCM	Reserve capacity market
TSO	Transmission System Operator

1 INTRODUCTION

The present report is one of the two final reports in the project "Balancing Management in Multi-national Power Markets" (2007-2011). This report has a conceptual view, while the other report "Alternative schemes for exchange of balancing resources between the synchronous systems in Northern Europe" [31] is addressing issues related to implementation and operation of potential exchange schemes.

Although the name of the project refers to multinational power markets, we have in the course of the work concluded that multi Control Area balancing markets is a better description. The reason is that although Control Areas often coincide with national borders, this is not necessarily the case. The notable exception is Germany, and this is an important case because of the developments in recent years.

The main underlying idea behind this report is that a balance market design can be described with the help of a number of *design variables* that together constitute a *design space*. This idea was first introduced in [2]. We divide the design variables in two groups. The first group exists of the variables that define the market design in one Control Area. These variables do not take into account the possible cooperation between Control Areas, they assess all (or at least many of the) possible issues that necessarily must be defined in order to describe the balance market design of a Control Area. These variables are presented and discussed in Chapter 4.1. Naturally this list of variable cannot be complete in a report like this – a complete list with a full description would constitute the laws and regulations for the balance market in the actual Control Area. Rather we have tried to focus on a number of important design variables in suitable degree of detail. In theory, a market design would be unambiguously described by its design variables.

Subsequently in Chapter 4.2 we describe what we have called the "design defining" variables, which in the context of the present work are the variables that describe the *international* or rather *multi Control Area* balance market design. These variables are:

- The market arrangements for Balancing Energy Markets, which can be None, ACE netting, Additional Voluntary Pool, Common Merit Order List or Full Integration
- The types of Exchanged Balancing Energy, secondary or tertiary reserves
- The market arrangements for Reserve Capacity Markets, which can be None, Additional Voluntary Pool, Common Merit Order List or Full Integration
- Reservation of Cross Border Capacity for Balancing, which can be None, Daily Auction or Long Term Reservation
- Definition of Balancing Regions, referring to the fact that Balancing Regions can correspond to Balancing (or Control) Areas or can comprise several Balancing Areas that are merged

More explanation on these variables is given in Chapter 4.2. The major idea is that the values of these variables determine the main characteristics of a multi Control Area balancing market. Using these variables we identify eight different market designs, which are described in Chapter 5.

The next step is a comparison of these market designs. To do this, it is necessary to have a set of performance criteria. The criteria introduced in [3] and [4] were used as a basis for the criteria described in Chapter 6. Subsequently these criteria will be used in Chapter 7 to evaluate the various market designs. Chapter 8 sums up and concludes.

The analyses in this report are mainly of a static character, i.e. focus is on describing how exchange of balancing services should be organized, and not on how to come from today's system with mainly separate balancing markets to a possible future with integrated balancing markets. A notable exception is a short discussion in Chapter 7 involving the exchange between the Nordic area and the Central Western European system, based on the fact the Nordic system does not presently have Load Frequency Control.

Like many other reports, this report has unfortunately become rather long. Readers familiar with the subject may well catch the main contents of the report by reading Chapter 8, which to some extent is self-sustaining. It will be possible to leaf back and check some of the assumptions and definitions for clarification. Readers with a little more time are suggested also to read Section 7.3 (quickly jumping over Table 7-3, because this gives a much better insight in the actual evaluation and the assumptions that are made. Sections 7.1 and 7.2 can be skipped unless one wants to check the details behind each evaluation. Further details in each Chapter can be read according to time and interest.

2 THE ROLE OF SYSTEM BALANCING

As an introduction to the subject of this report a short description of the role of system balancing and the central power system actors will be given here. Readers who are not familiar with power system balancing are recommended to read some of the references [1], [5], [6], [17], [19].

As electricity is non-storable and demand and production (outages, renewable) are hard to predict accurately it is not possible to match or balance production and demand ahead of time. The operation of power plants and power markets are complicated processes, that necessarily must be done some time ahead of actual operation, and consequently it is necessary to have mechanisms in place to make certain that the system can be balanced in real time. Insufficient resources for balancing will lead to load shedding or ultimately system collapse and blackout.

Ideally, market participants would trade electricity until real-time and completely balance their portfolios based on bilateral market mechanisms or power exchanges. However, due to the complexities of the power system this is not possible because most market participants do not have a complete real-time overview of their portfolio and are not able to respond fast enough to cope with disturbances and deviations. Therefore it is necessary that shortly before real time a central part, the Transmission System Operator or TSO takes over and ensures the system balance in real time. This is illustrated in Figure 2-1.

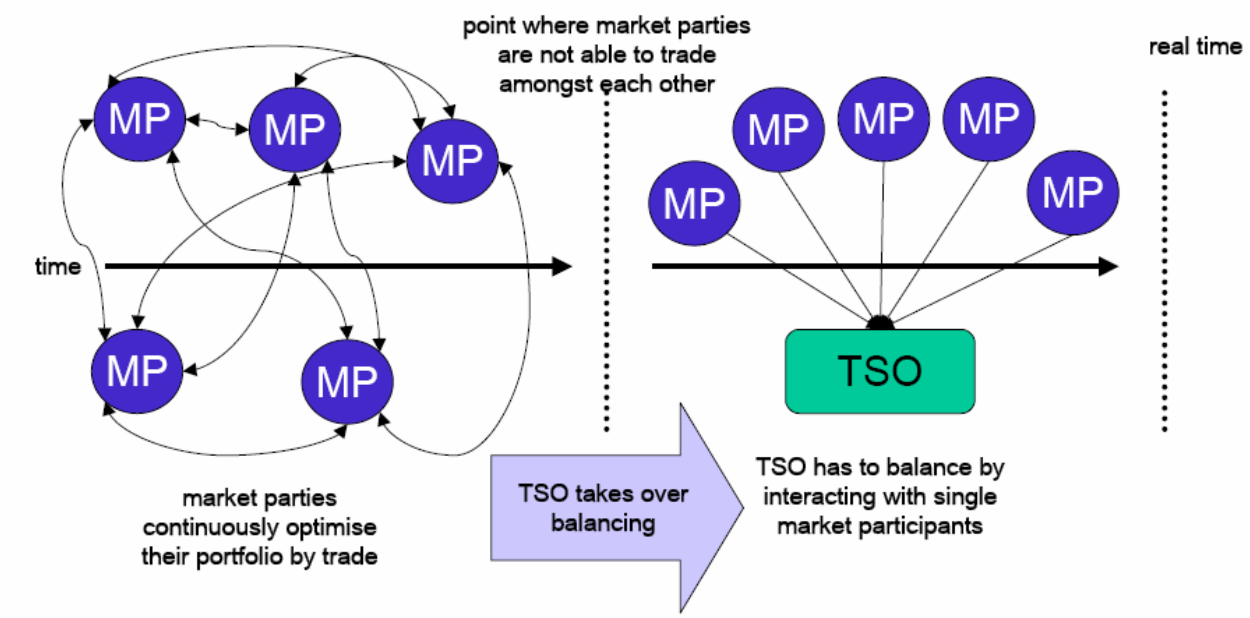

Figure 2-1: Illustration of change in market rules before real time [19]

Article 9 of the second Electricity Directive states – with respect to the procurement of balancing services – that:

[…] the TSO shall be responsible for ensuring a secure, reliable and efficient electricity system and, in that context, for ensuring the availability of all necessary ancillary services insofar as this availability is independent from any other transmission system with which its system is interconnected;

TSOs, appointed as the single buyer of balancing services, are consequently in charge of guaranteeing an adequate provision of all types of services at all times and to all locations requested [9]. To ensure continuous and sufficient availability, TSOs often make reservations beforehand by not only paying for the delivery of balancing services via the real-time market (energy or utilisation payments) but also for holding reserves via the reserve market (capacity or availability payments – on a longer term basis – through bilateral contracts or tenders).The method of procurement and remuneration for similar services and the time period for the capacity reservation differ significantly between countries.

Because procurement of reserve capacity is strongly related to system security, TSOs in most system ensure the availability of reserves some time in advance, e.g. annually, monthly or daily before or integrated with the clearing of the spot market. The longer before actual operation reservations are made, the more certain the TSO can be that the required resources will be available. On the other hand, longer reservation times will often increase costs, because market participants must commit themselves for a long time without having full overview over the consequences.

In a European context the ETSO report [17] defines in its reference model the following reserve types, cf. also [1]:

- Frequency Containment Reserves (FCR) are operating reserves necessary for constant containment of frequency deviations (fluctuations) from nominal value in order to constantly maintain the power balance in the whole synchronously interconnected system. Activation of these reserves results in a restored power balance at a frequency deviating from nominal value. FCR are normally called primary reserves.
- Frequency Restoration Reserves (FRR) are operating reserves necessary to restore frequency to the nominal value after sudden system disturbance occurrence and consequently replace FCR if the frequency deviation lasts longer than 30 seconds. The main share of FRR exists of secondary reserves, but also primary and tertiary reserves can contribute to this category.
- Replacement Reserves (RR) are operating reserves necessary to restore the required level of operating reserves in the categories of frequency containment (FCR) and frequency restoration (FRR) reserves due to their earlier usage. The most common name for RR is tertiary reserves.

This report focuses on secondary and tertiary reserves, assuming primary reserves are in place.

All market participants interact with the market through a Balance Responsible Party (BRP), or are a BRP themselves. Before the hour of operation, each BRP has a market position or balance, existing of the sum of all its obligations in the form of sales and purchases in organized markets like day-ahead and intraday, and through bilateral transactions. The balance is defined for each Program Time Unit or PTU, which typically can be 15, 30 or 60 minutes[1]. The BRP is generally obliged to try to act in such a way that it complies with this balance in real time, although the strength of this requirement varies between different markets. The price for deviations is normally higher (for a deficit) respectively lower (for a surplus) than the corresponding spot price, giving an incentive to be in balance[2].

In an unbundled system, where the main functions in the market are performed by separate entities, the TSO normally has no resources of its own to compensate for the aggregate deviations of the BRPs. Note that from a system point of view the individual imbalances of the BRPs are irrelevant, it is only the net sum of all deviations at the system level that contributes to deviations in the frequency and needs to be compensated. To balance the system, the TSO therefore uses the resources of Balancing Service Providers (BSP). To a large extent BSPs are producers with generation resources that can provide these services, but consumers can also contribute, provided that they satisfy the technical requirements for the relevant service.

If the prices paid by the BRPs exactly match to the prices paid to the BSPs, the balancing market is economically neutral for the TSO. In this case the role of the TSO is purely that of the operator of the balancing market. This is the case for a one price – single price system, where single price indicates that each PTU is settled as if it regulated in only one direction, upward or downward. In other cases, the TSO will end up with a deficit or a surplus from the balancing market, depending on the specific market design. In these cases the regulation of the TSO determines how the deficit respectively the surplus will be treated.

The same resources used for balancing will often also be used for congestion management, because this normally entails increasing production on the downstream side of the congestion and reducing production on the upstream side. It is normally required that the use of these resources for congestion handling does not have an impact on the prices in the balancing market.

[1] The length of the PTU has an impact on the division of responsibilities between the BRPs and the TSO. While the former have the responsibility for their balance over the whole PTU, the TSO has the responsibility within the PTU. Obviously, a longer PTU increases the responsibility of the TSO and decreases that of the BRPs.
[2] In some markets it may be profitable for a BRP to deviate from its balance if this contributes to maintaining the system balance. This is the case for the one-price system discussed in [5].

3 EXCHANGE OF BALANCING SERVICES BETWEEN CONTROL AREAS

The description in the previous chapter implicitly assumes that there is one TSO that is responsible for the operation of “the system”. Large interconnected systems are normally divided in several subsystems with separate TSOs for each subsystem or Control Area. In a European context, the Control Areas largely correspond to the countries, but Germany exists of four control areas (that are increasingly cooperating and developing in the direction of one control area). In a system existing of more than one control area, it is important that the responsibilities of each TSO are clearly defined. In an ENTSO-E context, there are two important principles:

- The principle of joint action [7] which implies that Each TSO must contribute to the correction of a disturbance in accordance with its respective contribution coefficient to primary control.
- The principle of the network characteristic method [7] that relates to the fact that each control area must be equipped with a secondary controller to minimize the Area Control Error (ACE) in real time.

We will not here go further into the details of ACE, but only refer that ACE includes contributions from frequency deviations and deviations between planned and actual exchanges between control areas. In areas where the balance is according to plan, ACE will be zero. Further details can be found in [7], [1] or other references.

While primary control by definition of the principle of joint action is shared between all control areas, secondary and tertiary control have until recently mainly been reserved and activated within each control area. However, among others the integration of the balancing in the Nordic countries has shown that this can be advantageous, and a process of more integration between these markets in general has been going on for some years cf. [5], [17], [19].

Exchange of balancing services between areas obviously requires new rules and regulations – essentially a new market design, which is what this report is about.

4 DESIGN VARIABLES

In this chapter we present and discuss a large number of design variables for Balancing Markets. A design variable can be defined as a characteristic of the market that can be freely chosen (within certain limits) in the market design and described explicitly in the market rules, laws and regulations. E.g. the “accreditation requirements for BRPs” is a market design variable[3], because the relevant parties (TSO, market operator, regulator) can determine them within the context of the relevant market and higher level requirements (e.g. from ENTSO-E). On the other hand, the number of bidders in a specific market is of course a market characteristic but not a design variable, because it cannot be freely chosen and determined by rules.

On a high level, we can distinguish between variables that generally define the design of Balancing Markets within one Control Area, and design variables that pertain to Balancing Markets that cover two or more Control Areas. E.g. the bid requirements typically constitute a variable that is important within the context of one Control Area. On the other hand, the principles for reservation of Cross Border Capacity available for balancing are part of the definition of an international or Multi-Control Area Balancing Market. In Section 4.1 we present the design variables for Balancing Markets operating within one Control Area, while the variables that pertain to the cooperation between Control Areas are described in Section 4.2.

4.1 DESIGN VARIABLES FOR BALANCING MARKETS WITHIN ONE CONTROL AREA

It is neither possible nor desirable to define all possible variations of balance market design through design variables. In the following we have defined the most important variables and the main values they can take. These variables define the major design characteristics of the Balancing Market within one Control Area. The variables are divided in three groups for balance responsibility, balance service provision and imbalance settlement respectively. They are of a generic character, and pertain to both Reserve Capacity and Balancing Energy Market. Figure 4-1 shows the design variables for Balancing Markets operating within one Control Area. An explanation of each variable and the values it can take is given in Table 4-1 to Table 4-3. These descriptions naturally are rather superficial, and many details have necessarily been left out. Still a description of these variables and their values should give a basic overview of a specific market design.

[3] One might argue that these requirements constitute many market design variables. However, we choose to define our design variables at a relatively high level, which means that we group detailed variables together in single, more generic variables.

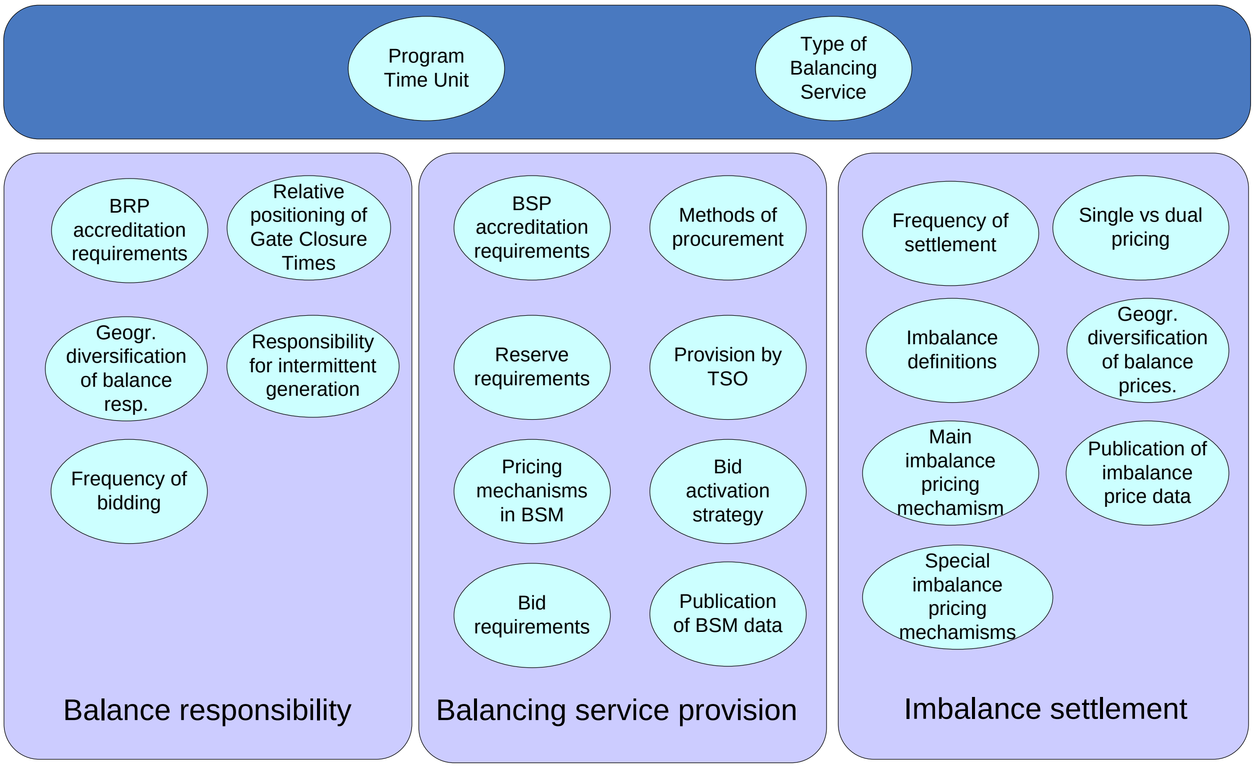

Figure 4-1: Design variables for Balancing Markets

The two most central design variables are the Program Time Unit (PTU) and the type of balancing service, basically secondary or tertiary reserves. The PTU can be 15 minutes (or even shorter), a half hour or one hour. It should be noted that the PTU relates to the Balance Market only, and is not necessarily equal to the time step in the day ahead market. E.g. in the Netherlands the day ahead market has an hourly time solution, while the length of the PTU is 15 minutes.

The following tables describe for each design variable in Figure 4-1 its definition and the values it can take. The values are not complete and for some it is not possible to give specific values, while for others the number of values may be very large. In those cases it is only indicated what kind of values the variable can take.

The last column describes the “Need for harmonization between Control Areas”. Here we have given some comments on the need for harmonization of the variable in the case of harmonization respectively integration of Balancing Markets. Balancing Markets can be fairly well integrated without the need to harmonize all market rules, as illustrated by the Nordic experience between 2001 and 2009. The last column gives a first indication of what variables it is important to focus on with respect to market integration.

No in-depth analysis of the various design variables is included in this report. Some more details are given e.g. in [11] and in other papers in the references.

Table 4-1: Design variables regarding balance responsibility

Design variable	Definition	Values	Need for harmonization between Control Areas
BRP accreditation requirements	The regulations that define the legal, technical and economic requirements to BRPs, i.e. the prerequisites to become accepted as a BRP.	n.a.	Medium/high Considerable market integration will be possible without strong harmonization of these requirements, and differences will almost always remain due to different legal environments in participating countries. However, these differences can be used to exclude foreign market parties, and therefore harmonization is important.
Geographical diversification of balance responsibility	The extent to which balance responsibility refers to the whole Control Area or parts of it (*must be seen in relation to day ahead market, i.e. the number of price areas in the Control Area)*	• Single price for the whole Control Area • Zonal • Nodal	More analysis required. Single price and zonal clearly go together, because a single price system is just seen as one zone. Cooperation between a zonal and a nodal system obviously needs specific rules, if it is feasible at all.
Frequency of bidding[4]	The frequency of bidding in the relevant markets (Reserve Capacity and Balancing Energy)	Many values are possible, but typical values for the frequency of bidding would be daily, weekly or monthly, with the possibility for longer periods.	Medium Some differences should not be problematic, but the bigger the difference, the greater opportunities for gaming, and the more unequal treatment of market participants.
Relative positioning of Gate Closure Times	The positioning of the times when market participants are obliged to submit their bids in the day ahead, intraday and Balancing Markets.	Intraday must necessarily lie between day ahead and real time, but the GCTs of the Balancing Markets can be positioned in may ways.	High Differences in GCTs result in arbitrage opportunities and gaming between markets.
Responsibility for intermittent generation	The laws and regulations that define the responsibility for the imbalances of intermittent generation	A principle distinction between • special treatment of intermittent generation • intermittent generation is treated as all other generation	Medium Same comment as under “Imbalance definitions”, the Nord Pool market has operated with considerable differences (especially Denmark)

[4] Frequency of bidding is an important parameter especially for Reserve Capacity markets. This is extensively discussed in [10], where it is concluded that infrequent (e.g. monthly) auctions for reserve capacity in general will lead to higher prices because of the uncertainty involved.

Table 4-2: Design variables regarding Balancing Service provision

Design variable	Definition	Values	Need for harmonization
BSP accreditation requirements	The regulations that define the legal, technical and economic requirements to BSPs	n.a.	Medium/high Considerable market integration will be possible without strong harmonization of these requirements, and differences will almost always remain due to different legal environments in participating countries. However, these differences can be used to exclude foreign market parties, and therefore harmonization is important.
Reserve requirements	The requirements to amounts and technical performance of reserves in the relevant categories (secondary, tertiary)	• Amounts in MW • Response times • Duration • etc	High Most of the harmonization is already provided for through ENTSO. However, it is important that countries do not use specific technical requirements to exclude foreign market parties.
Payment for the provision of balancing services	The laws, rules and regulations that determine the prices paid to BSPs	• Marginal price • Pay-as-bid	High Different pricing mechanisms lead to considerable inequality in an integrated market, leading to distortions, opportunities for gaming etc.
Bid requirements	The requirements to submitted bids in the Balancing Market(s)	A wide variety of possibilities regarding quantities, prices, grid area, activation time, duration, divisibility, possibilities to recall etc.	Medium/High Similar comments as under “BSP accreditation requirements”
Methods of procurement	The way balancing energy resources are procured for daily operation	• Through capacity markets • Bilateral • Daily bids • Other / combinations	Medium/High Significant harmonization necessary to avoid distortions. E.g. if one country procures capacity on a capacity market where balancing energy bids are given, while other countries base procurement on daily bids there may occur huge price distortions and capacity “leakage”.

Design variable	Definition	Values	Need for harmonization
Provision by TSO	The extent the TSO owns generation resources for secondary and tertiary control, and the conditions for their use.	• The TSO does not own any generation resources • The TSO owns generation resources • Conditions for use, e.g. o Regular o Extreme conditions	High In general TSO ownership of generation is potentially market distorting, especially if these resources are used on a regular basis. If they are used only to avoid system collapse this is less relevant, but it is important that the effect of their usage on Balancing Market prices is highly harmonized between countries.
Bid activation strategy	The criteria, timing and order of bid activation	The values depend on the type of service. For secondary control they will depend on the technical implementation of the controller, the need for response speed etc. For tertiary control they depend on the actual operator strategies.	With a low level of integration the need for harmonization is probably low. The more integrated markets become, the stronger the need for harmonization.
Publication of BSM data	Time of publication and level of detail with respect bids and activation data.	A wide variety of possibilities	Low/Medium This could be viewed as part of Transparency and therefore a performance criterion. However, it may have a direct impact on participant behaviour, depending on the pricing rules. The need for harmonization does not appear to be very strong, apart from the fact that more (harmonization) is better.

Table 4-3: Design variables regarding balance settlement

Design variable	Definition	Values	Need for harmonization
Frequency of settlement	The frequency at which the payments for BRPs and BSPs are settled	Many possibilities, e.g. weekly, monthly, quarterly etc.	Low/Medium Apparently this is not an important issue. However, the deadline for settlement requires all parties to settle their own data and conversely this will probably not be done before the deadline. A low frequency of settlement may then result in much uncertainty about final positions and payments, and therefore less ability to act rationally. The need for harmonization does not appear to be very strong, apart from the fact that more (harmonization) is better.
Imbalance definitions	The number of imbalances for each BRP, their definition and their pricing	• One – total balance (“one-price system”) • Two balances, production and trade/consumption (“two-price system”)	Medium In general it is an advantage if all mechanisms related to pricing are harmonized as much as possible for reasons referred above. However, the Nord Pool market functioned well for many years with different numbers of imbalances, so apparently some inequality is acceptable here.
Main imbalance pricing mechanism	The main principles and rules for imbalance pricing	• Marginal price • Average price • Add-ons / penalties • Other (e.g. “tagging” in the UK)	High The main principles for imbalance pricing should be equal, otherwise market integration will be strongly obstructed with resulting inequalities and distortions, cf. [9], 3.1.
Special imbalance pricing mechanisms	The use of special (administratively determined) prices under special circumstances	There are many possibilities, but this primarily refers to situations where the market does not clear.	High Without harmonization significant market distortions will occur in those cases where these prices are actually utilized.

Design variable	Definition	Values	Need for harmonization
Single vs dual pricing	The number prices (one of two) within one PTU that are used for pricing	• Single pricing – only one price is used during one PTU, based on the major direction of regulation • Dual pricing - two prices are used during one PTU if there is both upward and downward regulation	Medium/High Dual pricing is relevant when there is both upward and downward regulation within the same PTU. With single pricing, the "dominating regulation direction" will determine the system state and imbalance price, while with dual pricing there will be two separate prices. This is one of the kernel points of the pricing of imbalances, and differences in rules may create opportunities for gaming as well as inequality.
Geographical diversification of imbalance prices	The extent to which different balance prices are used within the transmission grid	• Single price • Zonal • Nodal	See "Geographical diversification of balance responsibility"
Publication of imbalance price data	The time, frequency and level of detail of the publication of imbalance price data	There are many possibilities, from momentary publication of all prices to delayed publication of average prices and everything in between	High As long as this is treated differently between markets there will be a different treatment of market participants, speculation about the situation in the least open system etc. In the case of strong integration with a common merit order list, this will be harmonized by default because the markets will normally have the same prices.

4.2 DESIGN VARIABLES FOR MULTIPLE CONTROL AREA BALANCE MANAGEMENT

The design variables in the previous section define the main characteristics of a Balancing Market operating within one Control Area. However, they do not address specific issues relating to the exchange of balancing services between Control Areas. In Figure 4-2 five "Design defining variables" for Multi Control Area Balancing Markets are added to the variables discussed in the previous section. The total market design of the cooperating markets will be determined by the top level design defining variables, as well as the more detailed variables pertaining to each separate market. These latter variables can be harmonized to a lesser or greater degree, depending on the level of cooperation between the markets.

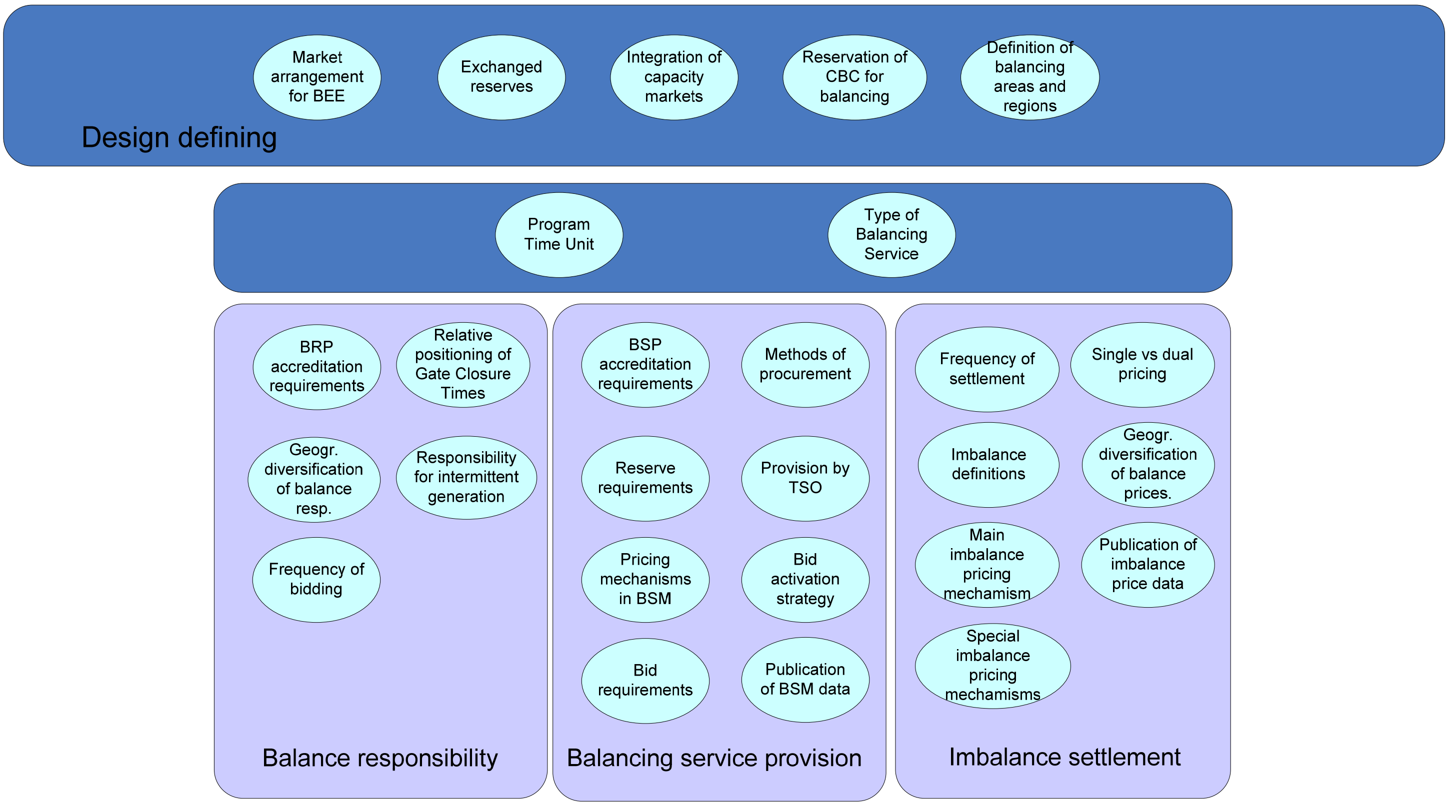

Figure 4-2: Design variables for Multi Control Area Balancing Markets

Note that while the lower part of the figure (i.e. the part corresponding to Figure 4-1) is generic with respect to Reserve Capacity and Balancing Energy, these are differentiated explicitly under the design defining variables. The reason is that with respect to cooperation between Balancing Markets there is a great difference between cooperation with respect to Balancing Energy on the one hand and Reserve Capacity on the other hand. While the former can have a more short term character based on surplus resources, cooperation with respect to Reserve Capacity requires a strong long term commitment. Also, exchange of Balancing Energy is not dependent on the reservation of cross border interconnection capacity (although this may be possible), while the exchange of Reserve Capacity probably will be combined with the reservation of cross border interconnection capacity (because the buyer otherwise may pay for something that may not be available).

There are other relevant design variables as well, regarding control issues, interconnection, information, coordination and cost allocation. These will be analyzed further in other parts of the project. In the present context it suffices to include the design defining variables.

Table 4-4 gives an overview over the variables, their definitions and the values they can take in the context of this report. The variables and their values are discussed in Sections 4.2.1 to 4.2.5.

Table 4-4: Design defining variables for Multi Control Area Balancing Markets

Design variable	Definition	Values
Market arrangements for Balancing Energy Exchange	The major market arrangements for Balancing Energy	• None • ACE Netting • BSP-TSO Trading • Additional Voluntary Pool • Common Merit Order List • Full Integration
Type of Exchanged Balancing Energy	The type of reserves that is exchanged between the Control Areas	• Secondary reserves • Tertiary reserves • Secondary and Tertiary Reserves
Market arrangements for Reserve Capacity Markets	The major market arrangements for Reserve Capacity	• None • BSP-TSO • Additional Voluntary Pool • Common Pool • Full Integration

Reservation of Cross Border Interconnection Capacity for Balancing	The arrangements for Cross Border Interconnection Capacity for Reserve Capacity and Balancing Energy Exchange	• None
		• Reservation on daily auctions
		• Long term reservation
		  o On a permanent basis
		  o Coordinated with Reserve Capacity Markets

Definition of Balancing Regions	The relation between Balancing Areas (Control Areas) and Balancing Regions	• Balancing Areas correspond to Balancing Regions (separate balancing areas) • Two or more Balancing Areas are merged into Balancing Regions

4.2.1 Market arrangement for Balancing Energy Exchange

This variable describes the basic market arrangement for BEE. Although other variants naturally are possible, in this report we focus on the values given in the last column.

None
There is no exchange of balancing services, each Control Area completely handles its own balancing.

ACE netting[5]
ACE netting occurs on a seconds-basis, not a PTU basis. It does not involve pricing of netted power, but the "combination and redistribution of ACEs" just leads to different inadvertent exchange. ACE netting is obtained by modifications in the secondary control algorithms. Note that this will result in changes in the exchange between the areas, and this is what the secondary control algorithms must account for.
The main effect is a reduction of the activated balancing energy bids. Because of this, prices will also be lower for upward regulation or higher for downward regulation, so market parties that have an imbalance will lower their costs. There is no clear effect on security of supply (or it should be increased interdependency of power system security).

BSP-TSO trading
In [5] this from of arrangement is defined as a "direct participation system" where two or more TSOs work towards establishing compatible Balancing Markets which allows the participants to decide into which Balancing Market they want to bid (local or neighbouring market). A certain harmonization between the markets is necessary. In [6] B-D7 the adaptation of the secondary controller for the purpose of border-crossing secondary control is explicitly addressed. In the case of direct control of the generation unit the load frequency control of the "reserve receiving TSO" sends its request for power directly to the generation unit. The measurement value (either an absolute or a relative value corresponding to the request) is used for adaptation of the secondary controllers of both the "reserve connecting" and the "reserve receiving TSO", cf. Figure 4-3 for the case of secondary control. This introduces the concept of virtual tie-line which connects the generation unit in the Control Area of the reserve connecting TSO directly to the Control Area of the reserve receiving TSO.

[5] In the case of exchange between synchronous systems, ACE is not relevant. However, the same principle can be applied – in this case we should rather use the term Imbalance Netting, cf. [15].

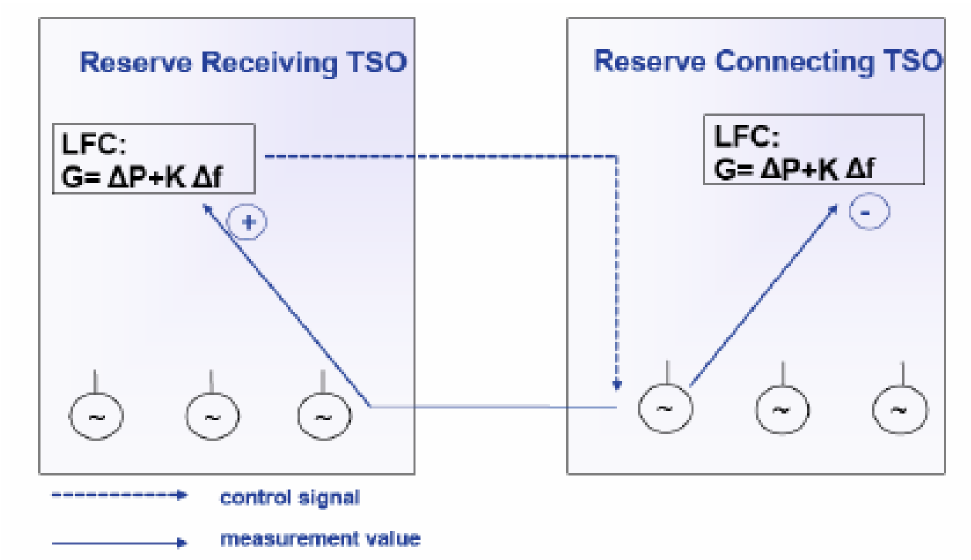

Figure 4-3: Secondary control of generation unit by reserve receiving TSO and delivery of the activated reserve by measurement value from generation unit [6]

As an alternative, Figure 4-4 shows the case of control by reserve receiving TSO through the reserve connecting TSO. The Reserve receiving TSO sends its request for power directly to the reserve Connecting TSO. The reserve connecting TSO adjusts either the power of the plants which the reserve receiving TSO has contracted with or the power plants the Reserve connecting TSO has contracted with itself.

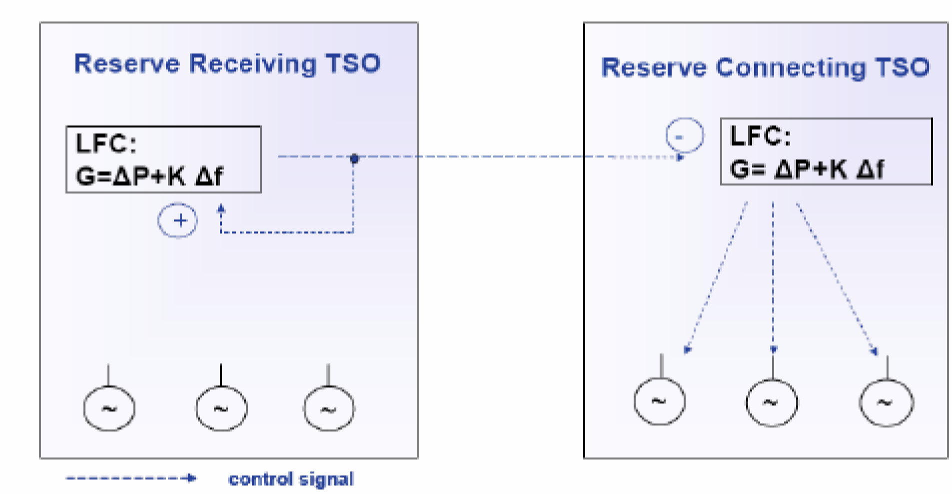

Figure 4-4: Control by the reserve receiving TSO through the reserve connecting TSO [6]

Similar arrangements are described in [6] for the case of tertiary control.

<u>Additional Voluntary pool</u>

An additional Voluntary pool implies the creation of an additional market place where the TSO(s) can choose to share parts or whole of their national balancing energy bids with the other TSO(s). This is clearly a form for “TSO-TSO” trading in the terms of [9] or [14] and [17]. Figure 4-5 from [14] illustrates the concept.

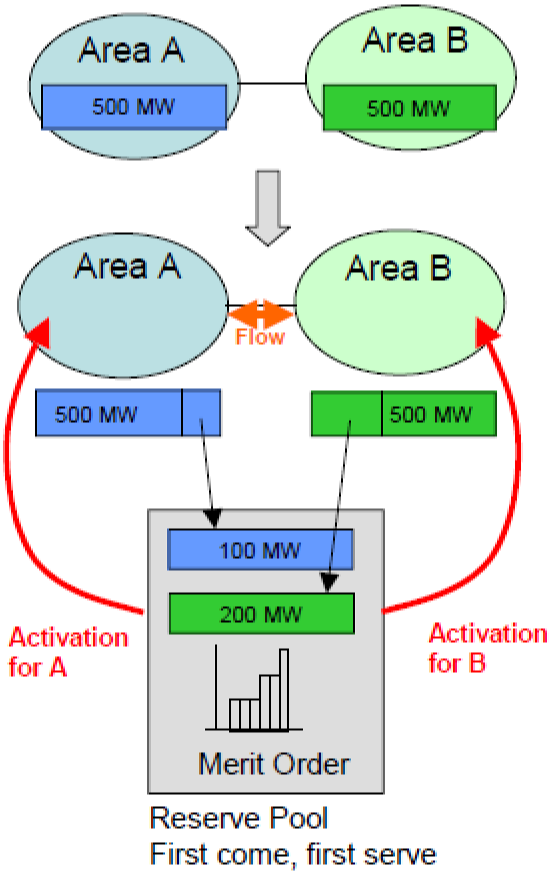

Figure 4-5: Additional Voluntary Pool (Cross Border Reserve Pooling [14])

It should be noted that while [14] discusses this model in the context of tertiary reserve trading, our corresponding design variable can be valid both for tertiary and for secondary reserves, depending on the Type of Exchanged Balancing Energy.

It is of course arguable to what extent TSOs would be willing to offer “their” resources to TSOs of other Control Areas. But if they have similar resources, there can be a mutual effect – today you use my resources, tomorrow I use yours. If their resources have quite different cost characteristics, the TSO with the cheapest resources may be less willing to offer those to others, although it should be noted that the dispatch of balancing energy is not a cost to the TSO but to the market parties with imbalance. Still the TSO will probably under pressure to save the cheapest resources for its own Control Area. But even in such cases there may be surplus low cost resources that can be offered on a voluntary common pool.

It should be noted that the BSP-TSO model and the Additional Voluntary Pool not necessarily are mutually exclusive. On the one hand one of the TSOs could buy Balancing Energy from a specific supplier in the other Control Area, while at the same time TSOs could agree to share some resources on an additional voluntary pool. Naturally the resources a TSO buys from specific suppliers would normally not be offered on this list (although they could in special cases if resources are contracted long term and appear to be not needed by the buying TSO in some short periods). At a certain stage of market development both the BSP-TSO model and the Additional Voluntary Pool can thus in principle exist beside each other. We will however not include this kind of combinations in our analysis. Typically this would happen in an early phase of integration, as indeed the Additional Voluntary Pool would. This does not appear to be a desirable market design in the long run.

Common Merit Order List
In this case we move to a model where it is mandatory for the participating TSOs to share their resources in a common pool. A common bid ladder is established by means of a combination of the bid ladders. This results in a common balancing energy market, containing the energy bids of the entire region.

Given that interconnections between Control Areas normally have less capacity than internal links within Control Areas, there will probably be a higher occurrence of congestion related to balancing energy procured in another Control Area, creating the necessity to deal with this effectively in the dispatch of balancing energy. In the case of secondary control, this may require sophisticated updates of the control algorithms to handle congestion which will become much more prominent than in today's national markets. It is probably possible to treat the case of tertiary control in a less formal way, relying on operator experience, which is the present situation in the Nordic area. Ideally, however, such dispatch should be based on clearly defined, transparent and verifiable rules.

Full Integration
Full integration of Balancing Energy Markets implies, apart from a common merit order list for energy, harmonizing of balance responsibility and imbalance settlement rules, introduction of equal incentive mechanisms for Balancing Responsible Parties, and therewith a level-playing field for all Balancing Market parties. The full merging of the Control Areas and the System Operators is a possible next step. A major difference with existing Control Areas will then be a higher occurrence of congestion within the new merged Control Area, with similar comments as above. However, note that merging of Control Areas into a Balancing Region is handled by the separate design variable "Definition of Balancing Regions", cf. Table 4-4 and Footnote 6.

4.2.2 Type of exchanged Balancing Energy

Control Areas can exchange either secondary control reserve or tertiary control reserve or both. Secondary control makes use of a centralised and continuous Automatic Generation Control (AGC), modifying the active power set points of generation sets or controllable load [6]. Exchange of secondary control therefore by definition requires border crossing control signals, cf. Section 4.2.1. This raises a large number of questions related to technical implementation, requirements, compatibility, interactions etc. An important issue is the handling of transmission constraints in real time, because bottlenecks are much more prevalent between Control Areas then within.

Exchange of secondary control reserves is now realized between all four German Control Areas. Intially according to [16]: "The three TSOs - EnBW Transportnetze AG, transpower stromübertragungs gmbh (former E.ON Netz GmbH) and Vattenfall Europe Transmission GmbH (now 50 Hz Transmission GmbH) have decided within the optimised interconnection between grid balancing operators (*optimierter Netzregelverbund - ONRV*) to introduce a balancing zone-transcending compensation energy price (*regelzonenübergreifender einheitlicher Bilanzausgleichsenergiepreis - reBAP*). As a result, the same compensation energy price has been applied in the three balancing zones currently included in the ONRV for the duration of ¼ h each as from May 2009. The reBAP is generally calculated as a division of all balancing energy costs that incur in the three balancing zones and the corresponding balancing energy volumes for each ¼ h. In addition to the reBAP, the corresponding volume of balancing energy used by the 3 involved balancing zones for each ¼ h is listed. A plus sign corresponds to the procurement of positive balancing energy due to a shortage in the balancing zones. A minus sign stands for the procurement of negative balancing energy (sale of excess power) in the event of surplus electricity in the involved balancing zones." As of 1 May 2010 also the fourth German TSO, Amprion has joined this cooperation. More details on the integration of the German Control Areas are given in [15].

Earlier, Germany created a common tertiary control reserve (Minutenreserve) market in December 2006 (for the four Control Areas together). Bids by BSPs for secondary and tertiary control contain both a capacity price and an energy price, so it appears to be a *combined bid*.

Tertiary control on the other hand is normally manually activated, and exchange of tertiary control can therefore more easily be accommodated by adapting procedures of the cooperating TSOs. Existing schemes for the exchange of BE like in the Nordic market and FR-UK-IE involve the exchange of tertiary reserves only.

4.2.3 Market arrangements for Reserve Capacity Markets

Integration of BEMs has an obvious potential of reducing costs by increasing access to cheaper resources in the market with the highest costs, and by making such markets more competitive, although the effect is limited because present ENTSO-E rules limits the import of balancing energy to 34 % and of secondary plus tertiary reserves to 50 %, cf. [6] Standard B-S4.5. However, the effect on the total costs may be limited if the cost of balancing energy constitutes only a minor share of the total costs. E.g. this seems to be the case for Germany in 2007, where the energy payment constitute only 25 % of the total balancing costs, the remaining share being capacity payments [18]. Although we have not verified such number for other Control Areas, it is clear that a harmonization of the Reserve Capacity Markets can have a potential for cost savings in addition to those in the BEMs. However, these savings could be counteracted by the cost of reservation of interconnection capacity, cf. the next section.

In principle, the design variable describing the arrangements for RCMs can take the same values as the one for the BEMs. However, integration of RCMs will come after or go together with the integration of BEMs, but not come ahead of it. E.g. it makes sense to have a common merit order list for balancing energy without having the same for capacity, but the opposite is not true: the whole point of reserving capacity is to use it in the BEM, so obtaining capacity in another Control Area without using it in the BEM appears rather meaningless.

BSP-TSO trading
The case of BSP-TSO trading in an RCM means that BRPs in one area are allowed to offer their capacity on the RCM of the TSO of another Control Area. To be effective, there would have to be a corresponding reservation of interconnection capacity, cf. Section 4.2.4. Still this is not a necessity. A TSO might assess the probability of the availability of the interconnection capacity, and be willing to reserve capacity if it is available sufficiently often and if the cost advantage is considerable. This depends on the frequency of the clearing of the markets for Reserve Capacity and cross border interconnection capacity, and the degree of predictability of cross border congestion. In the relatively short run (e.g. month) and in some markets (e.g. a hydro based market during the winter), this may be predictable.

Additional Voluntary Pool
As for the BEM, also reserve capacity could be shared on a voluntary basis in a pool.

Common Pool
Corresponding to a common merit order list in the BEM is a binding common pool for the RCM, meaning that the TSOs in cooperation would determine which resources to contract in which Control Area. This task is similar to the division between price areas that Statnett uses today in the Reserve Options Market, although it will probably be more complicated in more meshed networks and the use of secondary control.

Full Integration
In the case of the RCMs there it is probably only a small step from the common pool to full integration, which implies strong of full harmonization of the rules governing these markets.

Reservation of cross border interconnectioncapacity for balancing is an important issue for all values of this design variable.

4.2.4 Reservation of Cross Border Capacity for balancing

To be able to ensure certain access to reserve capacity across Control Area interconnections, it is necessary to reserve a corresponding transmission capacity on the interconnection. It should be noted that such reservation is controversial. E.g. Eurelectric states that “Cross-border capacity should be allocated to balancing purposes only if available after intra-day market closure” ([19], Section 3.6). Also in the case of the FR-UK-IE cross border balancing procurement, the proposal states that the “TSO will not be able to preferentially reserve interconnector capacity for the purpose of securing cross border balancing services” [20]. Reference [9] is more ambiguous, on the one hand stating that “cross-border capacity does not need to be reserved for real-time energy delivering services (like secondary or tertiary control)” but on the other hand also stating “If no cross-border capacity is reserved for real-time energy delivering services…”, implicating that this possibility is not ruled out. ERGEG [5] writes for the case of the TSO to TSO model that “The TSOs are responsible for the acquisition of cross-border capacity”. Statnett and Energinet.dk have actually determined to reserve 100 MW of capacity on the planned 600 MW Skagerrak 4 cable for system and balancing services for the first 5 years, with the intention to extend this period [21].

4.2.5 Definition of Balancing Regions

The ETSO reference model [14] uses Balancing Areas, “that in the context of UCTE could be conceived as the Control Areas[6]”. However, it is added that “the borders of the balancing areas should be defined according to principles to be agreed by the TSOs who operate the networks of the regional Balancing Market”. Subsequently ETSO defines the principles for a regional balancing function, cf. Figure 4-6:

1. A balancing region consists of one or more balancing areas within a synchronously interconnected system.
2. Within a synchronously interconnected system there can be more than one balancing region.
3. Each balancing area in the region is responsible for balancing supply and demand in the area.
4. Under normal circumstances the balancing areas may hand over certain (execution) tasks to the regional balancing function for efficiency reasons.
5. What is “normal” as well as the detailed responsibilities should be defined as a regional standard within an agreement between individual TSOs in the region

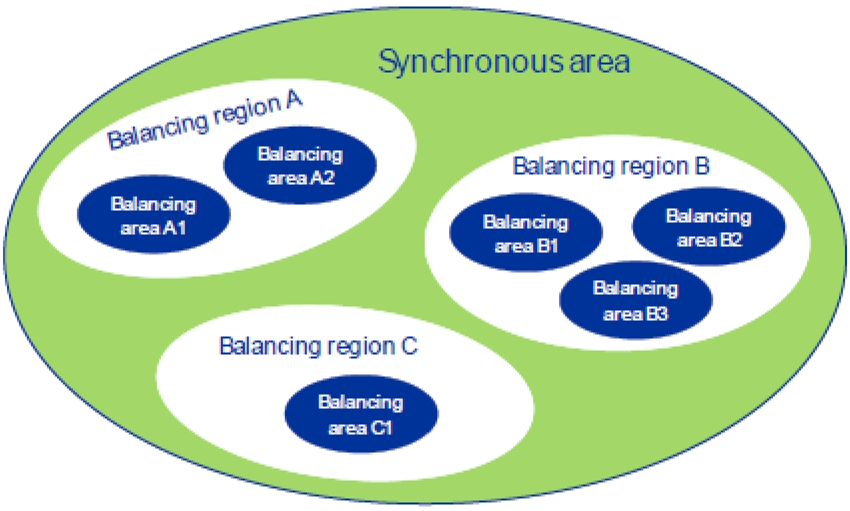

Figure 4-6: Synchronous area, Balancing Regions and Balancing Areas [14]

In this case it would be the responsibility of the Control Region (i.e. the agent acting on its behalf) to keep the Balancing Region ACE equal to zero, while the ACEs of the participating Balancing Areas would be ignored. In this case the Balancing Areas can be said to some extent to have vanished, while the relevant entity now is the Balancing Region.

[6] A Control Area is a coherent part of the UCTE interconnected system (usually coincident with the territory of a company, a country or a geographical area, physically demarcated by the position of points for measurement of the interchanged power and energy to the remaining interconnected network), operated by a single TSO, with physical loads and controllable generation units connected within the Control Area. A Control Area may be a coherent part of a Control Block that has its own subordinate control in the hierarchy of secondary control [8].

It should be noted that grouping of Balancing Areas into a Balancing Region not automatically implies a full merging of the Control Areas, cf. the ENTSO-E (UCTE) definition of Control Areas.

Such merging has some significant impacts. One impact is on the way Load Frequency Control is performed in practice. Because congestion is much more prevalent between the present Control Areas than inside each area, the algorithms controlling the dispatch of balancing energy should be redesigned to take into account congestion in order to ensure a smooth cooperation between the Balancing Areas, i.e. inside the Balancing Region. Another effect is on the recommendation of the quantity of secondary reserves. The equation defining the curve in Figure 6-2 is empirical, based on the present definition of Control Areas within the former UCTE synchronous area. Merging of Balancing Areas into a Balancing Reion reduces the total quantity of secondary reserves because of the concave form of the curve. It must be carefully considered if this would require a redefinition of the recommended amount of secondary reserves.

5 MULTI CONTROL AREA BALANCING MARKET DESIGN PROPOSALS

Section 4.1 in the previous chapter describes the major design variables that define the design space of a Balancing Market within the context of one Control Area. Each combination of values chosen for the specific variables defines one unique Balancing Market Design. Subsequently, Section 4.2 describes the “design defining variables” for Balancing Markets that include two or more Control Areas. Also here each combination of values for these variables defines one unique market realization in the relevant design space. If the variables from Sections 4.1 and 4.2 are combined, the number of possible design alternative is extremely high. However, the focus of this report is on multinational (or multi Control Area) balancing markets, and therefore we choose to focus on the “design defining variables” from Section 4.2. This means that a unique market design based on the design defining variables from Section 4.2 is not unique if the variables in Section 4.1 are taken into account. However, in the context of defining the design space of balancing markets covering two or more Control Areas, the variables from Section 4.1 are of less importance. Still, their actual values must be taken into account in specific cases, and moreover, the need for harmonization as identified in Table 4-1 to Table 4-3 is important.

5.1 AN OVERVIEW OF RELEVANT MARKET DESIGNS

Although there are only five design defining variables, they can take from 2 to 6 values each (disregarding a lot of detail), resulting in 540 possible combinations. However, in practice many combinations are either impossible (e.g. a Balancing Region existing of two merged Control Areas combined with no arrangements for the exchange of Balancing Energy) or irrelevant (e.g. full integration of the Reserve Capacity Market but no arrangements for the exchange of Balancing Energy), reducing the number of relevant market designs significantly.

Table 5-1 on the next pages defines the most relevant market designs along two main dimensions, the market arrangements for Balancing Energy Exchange (BEE) and the market arrangements for Reserve Capacity Markets (RCM). Within each relevant combination of values for these two variables, actual values for Cross Border Capacity reservation (none/daily/long term) and Balance Region definition (separate/merged Control Areas) are specified. Values in parentheses are less relevant, while **bold** values are highly relevant. Most designs are relevant for secondary and tertiary reserve exchange, so no distinction between these has been made in the table. The situation with no cooperation (i.e. arrangements for Balancing Energy Exchange = None) is not included in the table due to space considerations.

A short discussion as well as a rationale for the selected choices is given after the table, where for each Reserve Capacity Exchange option the actual combinations with Balancing Energy Exchange options are discussed. Subsequently Section 5.2 discusses the relevant market designs.

Table 5-1: Design defining variables and market designs

	Market arrangements for Balancing Energy Exchange *CBC: Cross Border Capacity reservation (none/daily/long term), BR: Balance Regions (separate/merged)*									
Market Arrangements for Reserve Capacity Exchange	ACE netting		BSP-TSO		Additional Voluntary Pool		Common Merit Order List		Full Integration	
	CBC	BR	CBC	BR	CBC	BR	CBC	BR	CBC	BR
None	**n**	s	**n** d **l**	**s** s **s**	**n** (d) (l)	s s s	**n*** (d) (l)	s/m s/m s/m	**n*** (d) (l)	**m** m m
BSP-TSO			(n) (d) l	s s s	(n) (d) l	s s s				
Additional Voluntary Pool			(n) (d) l	s s s	(n) (d) l	s s s				
Common Merit Order List							(n) d **l**	s/m s/m s/m	n* (d) (l)	m m m
Full Integration									**n*** (d) (l)	**m** m m

* System dependent

In general, the level of cooperation in BEE is higher than in the RCM, because it does not make sense to reserve capacity if you cannot be assured of being able to use it in real time. As an example, it is of no value for a TSO to reserve capacity from a BSP in another Control Area, if he cannot utilize this capacity in the daily balancing. This is the reason why only the upper right triangle of the matrix in Table 5-1 is filled in (the exception is BSP-TSO and Additional Voluntary Pool, which are not necessarily mutually exclusive as discussed in Section 4.2.1). In the following we discuss the various relevant combinations of RCM and BEE, as well as the reasons why some others are not relevant (even when they lie in the "upper triangle").

Note that ACE-netting will be a natural ingredient in many of the other arrangements for cooperation. The fact that the ACE-netting column is not filled in for the RCE arrangements apart from "None" does not imply that it cannot be combined with these arrangements, but that it will be included as part of a higher level form of cooperation. E.g. it does not make sense to have a Common Merit Order list for Reserve Capacity and then only engage in ACE-netting in the BEM.

5.1.1 Reserve Capacity Markets: no capacity reservation

In this case all cooperation is purely related to the exchange of Balancing Energy. Reserve Capacity Markets are either not existing or they operate separately within each Control Area.

BEE: ACE-netting
Reservation of cross-border capacity is not relevant, because the objective of the model is to reduce common regulation resources by utilizing mutual "free resources". As this is a "low-level" form of cooperation, integration of Balancing Areas is not relevant. As a first step towards further cooperation, various forms of harmonization may be under development. In the case of secondary reserves, some coordination between the secondary controllers will be necessary to realize ACE-netting. Tertiary reserves can be handled directly by communication between the operators in the respective control centres.

BEE: BSP-TSO
The BSP-TSO model can be used for both secondary and tertiary reserves. In the case of secondary reserves, the reserve receiving TSO and/or the BSP would probably want to reserve interconnection capacity to ensure the actual possibility to utilize the reserves, because investments need to be made to realize this scheme. However, we have not assessed these costs. In the case of tertiary reserves this is to a lesser degree required, because no or low investments are necessary to enable the exchange of these reserves. Integration of Balancing Areas is not relevant at this level of cooperation.

BEE: Additional Voluntary Pool
An Additional Voluntary Pool is most relevant for tertiary reserves, because the low degree of commitment probably does not warrant the investments necessary to realize the exchange of secondary reserves. Reservation of CBC will normally not be desirable to avoid interaction with the energy markets, although it may be relevant in special cases. Integration of Balancing Areas is not relevant at this level of cooperation. The exchange of balancing services across the cable

between the UK and France [20] does not have Reserve Capacity reservation, and can be seen to be of the Additional Voluntary Pool type.

BEE: Common Merit Order List
This is a much more binding form for integration, and the exchange of both secondary and tertiary reserves can be relevant. Reservation of CBC will be system dependent. In most cases this will probably not be economical, but in special situations the TSOs may agree on such reservation, especially in the case of very different system characteristics, e.g. between Denmark and Norway. In this case the Balancing Energy resources for tertiary reserves in Norway are abundant and have a low cost, and will to a large extent be available even without obtaining Reserve Capacity. Secondary reserves require more commitment and higher costs, and reservation of CBC is more likely to be a relevant option. Integration of Balancing Areas can be relevant for this model.

BEE: Full Integration
The more market rules are harmonized, the closer the model is to Full Integration, even if detailed regulations still may differ. Full integration may be relevant for either secondary or tertiary Balancing Energy markets or both. By its nature the model would probably involve both forms of reserves. Reservation of CBC is in principle possible, but may be less relevant, like it is uncommon to have this kind of reservation within one Control Area. At this stage, a full merging of Balancing Areas and disregarding of internal ACE seems the most relevant model.

With respect to existing markets, the present Nordic market represents the situation with no integration of the Reserve Capacity Markets, but Full Integration of the Balancing Energy Markets for tertiary reserves.

5.1.2 Reserve Capacity Markets: BSP-TSO

In this case TSOs can buy Reserve Capacity from specific suppliers in another Control Area. The arrangement can be used for secondary and/or tertiary reserves. Once this possibility is realized, the reserve receiving TSO would obviously want to use this capacity in the Balancing Energy Market, which means that there will be a dedicated exchange of Balancing Energy between the Control Areas. ACE netting, as a first cooperation step is less relevant in this case.

The frequency of bidding in the Reserve Capacity Market (cf. Table 4-1) becomes an important design variable for this case, and it should preferably be harmonized between the participating Control Areas. E.g. the German market today uses monthly auctions for secondary reserves. Should Norwegian resources participate in this market, then the auctions in Norway ideally should also be on a monthly basis. On the other hand this may be a disadvantage for hydro power, which then must be in operation during the whole month. This illustrates some of the harmonization issues that come up when markets are connected.

BEE: BSP-TSO
If a TSO reserves cross border capacity he would certainly be interested to use this in the BEM, so this is a relevant option.

BEE: Additional Voluntary Pool
TSOs would normally not reserve capacity in another Control Area and afterwards make it available in an additional Voluntary Pool. However, note the remark at the end of Section 4.2.1 on the possible coexistence of BSP-TSO and Additional Voluntary Pool.

BEE: Common Merit Order List
In the case of a Common Merit Order List all bids on the list are treated as equal and activated based on their price level if that is feasible with respect to transmission constraints. This means that all cooperating TSOs have equal access to this list, and it makes little sense for one TSO to contract capacity from a BSP in another Control Area. Therefore this does not appear to be a relevant market design[7].

BEE: Full Integration
The same comment can be made as under the previous point: it does not make sense for one TSO to reserve capacity from one BSP when all others can utilize this capacity.

5.1.3 Reserve Capacity Markets: Additional Voluntary Pool

The role of an additional Voluntary Pool for capacity is to make capacity available for TSOs in other Control Areas. A TSO that reserves capacity this way would naturally want to use it in its own BEM. Here this could be either through a BSP-TSO arrangement or and Additional Voluntary Pool in the BEM. The same remark as before can be made about the possible coexistence of BSP-TSO and Additional Voluntary Pool. The Additional Voluntary Pool for capacity can be seen as an organized way for the TSOs to procure reserve capacity from BSPs in other Control Areas.

5.1.4 Reserve Capacity Markets: Common Merit Order List

A Common Merit Order List in the RCM implies that all available capacity in the common area is made available for all TSOs. This obviously requires a high degree of cooperation between the TSOs. Probably they would have to establish a common organization for the procurement of reserve capacity, taking into account an optimal division of resources between Control Areas, given the existing transmission constraints. This can be compared to the way Statnett in Norway presently buys capacity in its Reserves Option Market ([24], [25]; the first reference is in English, but somewhat outdated, the second is in Norwegian and more up-to-date). Once the capacity is bought on behalf of the cooperating TSOs, it could in principle be divided between the TSOs and used on a BSP-TSO basis in the BEM. However, given the advanced state of cooperation required in the common procurement of capacity, it seems odd that this should be combined with low level cooperation in the BEM. Consequently we assume that a Common Merit Order List in the RCM is combined with the corresponding model for the BEE or with full integration of the BEE.

Common Merit Order Lists can either be obtained for secondary or tertiary reserves.

[7] Of course the TSOs could still obtain reserve capacity within their own area, but that does not mean there is exchange of reserve capacity.

If this should go together with the reservation of CBC or not will depend on the physical characteristics of the cooperating Control Areas (plant characteristics, major direction of power flows, level of congestion etc.) and how close to full integration the cooperation has come. Ultimately it will be the economics of the specific case that determine the need for CBC reservation. Less equal plant characteristics and more congestion in the desired direction for the delivery of upward regulation will lead to a stronger desire of reservation of CBC. A full merge of Control Areas will remove the reservation of CBC because all congestion becomes internal to the resulting Balancing Region.

5.1.5 Reserve Capacity Markets: Full Integration

With full integration of the RCM the only natural option for the BEE is also full integration. In this case the TSOs would commonly procure capacity and use it in a way as if there was one single Balancing Market with transmission constraints.

Table 5-2 sums up the relevant market designs as combinations of RC and BE markets more clearly and with less detail.

Table 5-2: Relevant market designs for combinations of RC and BE markets

BE arrangements / *RC arrangements*	**ACE netting**	**BSP-TSO**	**Additional Voluntary pool**	**Common MOL**	**Full integration**
None					
BSP-TSO					
Additional Voluntary pool					
Common MOL					
Full integration					

Red: impossible or highly irrelevant; grey: possible but not very relevant; green: possible and relevant

5.2 DISCUSSION OF RELEVANT MARKET DESIGNS

In the following we identify a number of relevant market designs on the basis of the analysis in the previous section. In the following these market designs are identified by a name that primarily indicates their main focus and purpose.

5.2.1 ACE netting

ACE netting is described in Section 4.2.1 and involves by definition only Balancing Energy Exchange. As stated before, it does not involve pricing of netted power, but the "combination and redistribution of ACEs" reduces inadvertent control actions. There are some issues about the division of the remaining imbalance. One approach is that this remains the responsibility of the

TSO that has the resulting imbalance, or there may be some pro rata division. Often both TSOs will have some remaining imbalance, depending on the available CBC for netting.

Example

The Area Control Errors of Area 1 and 2 are +100 MW and -200 MW respectively. After ACE netting, the remaining ACEs of the two areas are 0 and -100 MW respectively. This -100 MW could be the full responsibility of the TSO of Area 2, or alternatively the TSOs could share this responsibility equally or pro rata e.g. according to system size.

A form of ACE netting between Belgium and the Netherlands is described in [22]. ACE netting is a low-level form of integration that does not increase available resources for the TSOs directly, but it reduces regulation that is unnecessary from a system point of view when this is possible with available generation and cross border interconnection resources. Therefore neither Reserve Capacity nor CBC is reserved for this purpose. ACE netting affects secondary reserves, and Balancing Areas are kept separate.

Important issues for this market design:

- The level and direction of congestion between the Control Areas. More congestion leads to less effect of ACE netting[8].
- The impact on level and volatility of the Balancing Energy prices. On the one hand, ACE netting leads to less regulation actions and therefore on average lower prices in both areas. On the other hand, greater volatility might result from the fact that it is possible to net the ACEs in some periods but not in others.
- Compatibility of market designs; e.g. if one of the Control Areas pays significant amounts for Reserve Capacity, it may be reluctant to share its resources with a Control Area that pays nothing or little for Reserve Capacity [22]. In such cases more harmonization of the market designs is probably necessary before exchange of balancing energy can be acceptable.
- Issues related to technical realization.
- Distribution of benefits. Depending on the characteristics of the systems, most of the benefits may accrue to only one of the cooperating areas. This is specifically relevant if one area (e.g. hydro dominated) has large resources with very low regulation costs, while the corresponding costs in the other area are high.

  Example

  Assume that the cost of upward regulation in area 1 on average is 5 €/MWh higher than the spot price, while the cost for downward regulation is 5 €/MWh below the spot price. For simplicity we assume that this cost is inelastic, but this does not change the principal argument. This means that a BRP that is underbalanced in the case of upward regulation faces an additional cost of 5 €/MWh, while a BRP that is overbalanced in the case of downward regulation also has a cost (loss) of 5 €/MWh (it has bought power at the spot price and sells it back at a price that is 5 €/MWh lower). In

[8] It could be assumed that congestion has no impact because the flows are already there and as such are “feasible”. But although the flows are there, they may still violate security limits and therefore be unsustainable.

area 2 the corresponding costs are 50 €/MWh over respectively below the spot price. The following table shows the economic effects of ACE netting on the BRPs with imbalances for two different cases:

	Area 1	Area 2
Case 1 ACE	+100 MW	-100 MW
Cost to BRPs	500 €	5000 €
ACE after netting	0	0
Profit of netting	500 €	5000 €
Case 2 ACE	-100 MW	+100 MW
Cost to BRPs	500 €	5000 €
ACE after netting	0	0
Profit of netting	500 €	5000 €

Obviously, as shown in the table, the economic advantage of netting is much greater for the BRPs in the system with the highest costs. In cases with large structural cost differences a kind of compensation payment from area 2 to 1 may therefore be relevant, paid e.g. through an increase in the grid tariff in area 2. This payment could then go to a reduction in grid tariff in area 1.

5.2.2 BSP-TSO trading

The basic model for the BEE is described in Section 4.2.1 that also shows high-level proposals for realization as given in [6] for secondary and tertiary reserves respectively. In the case of secondary reserves, investments must be made to realize the reserve receiving TSO's control of the generator in the reserve connecting Control Area as described in Section 4.2.1. Because of this, the reserve receiving TSO and the generator would probably want some form of CBC reservation, although this may depend on the level of congestion: if there is normally little congestion in the relevant direction this may not be needed. Because of preferences for TSO-TSO models (e.g. [5], [14]) and barriers in the form of technical solutions and investments, this is not a very probable model. On the other hand, in the case of tertiary reserves no or small investments are needed, and because of this the parties would probably be able to accept this model without CBC reservations. This is relatively easy to realize and may be viable for a certain period.

The benefits depend on the characteristics of the systems. If there are large differences in the costs of tertiary reserves, if there are ample resources and if there is not too much congestion between the Control Areas in the relevant direction there may be significant benefits because the reserve receiving TSO can utilize reserves that would not have been used anyway. In other cases the benefits may be quite limited.

In general the fact that BSPs can bid in two separate markets results in an efficiency loss. Because the BSPs do not know beforehand where they will be activated, there may be excess resources in one market and a deficit in the other market. There will be a tendency that everybody wants to bid in the market with the expected highest prices, resulting in possibly insufficient bids in the other market or at least a reduction of resources resulting in higher prices. However, the total quantity needed by the reserve receiving TSO is limited by the available transmission capacity and by the maximum share this TSO is willing or allowed to import from another Control Area. The most expensive bids in excess of this amount could be returned to their original area. BSPs could be obliged to submit an alternative bid for this purpose. Because of arbitrage opportunities, there would probably be a tendency towards price convergence between the markets, as far as sufficient CBC is available.

Example

An illustration is given in Figure 5-2. The leftmost bar represents the available reserves in Area 1. The next bar symbolizes the reserves that are bid into Area 2. However, the transmission capacity between the systems (or the quantity Area 2 wants to procure from another area) is less than the total quantity of reserves bid into Area 2 as shown in the middle of the figure. The limited quantity is added to available reserves in Area 2, while the remainder (the upper part of the second bar from the left) can still be utilized in Area 1.

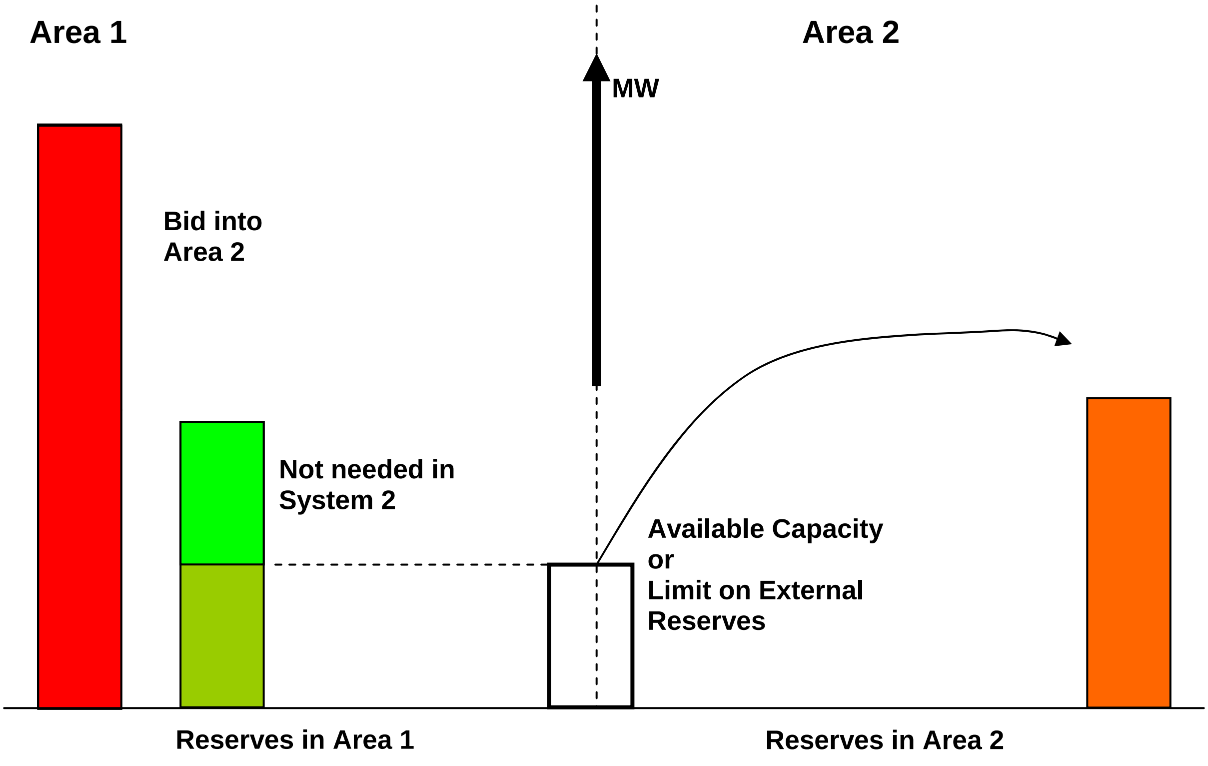

Figure 5-1: Exchange of reserves between areas, BSP-TSO cooperation

Important issues for this market design:

- Necessary level of harmonization of the Control Area specific design variables (e.g. gate closure times, BSP requirements etc)
- For the reserve receiving TSO: how much Balancing Energy to buy in the other Control Area
- For BSPs: how much Balancing Energy to offer in the other Control Area
- Which resources would be eligible for TSOs in other Control Areas

- Impact on congestion and losses in the Control Area of the reserve connecting TSO
- Impact on Balancing Energy market prices in the area of the reserve connecting TSO
- The inefficiency caused by dividing BSP resources between two markets
- The utilization of surplus capacity bids in another market that are not used
- Technological issues related to controllers in the case of secondary reserves

5.2.3 BSP-TSO Balancing Energy trading with Reserve Capacity Exchange

BSP-TSO trading in the BEM can be combined with a corresponding trade in the RCM. In this case one TSO allows a TSO in another Control Area to buy reserve capacity in its own area. This can be arranged in many ways. In a low level implementation, the TSO in one area can allow other TSOs to buy reserve capacity that is not needed in its own area. This can be advantageous if there is surplus capacity in one area at a lower cost than the capacity in the other area.

Probably trading of tertiary reserves is most relevant for this model, but it may also be used for secondary reserves. Reserve Capacity reservation in another Control Area would normally be combined with the reservation of CBC, to make sure that the acquired Reserve Capacity actually would be available. Without such reservation, congestion may lead to situations where the reserve receiving TSO would have paid for a resource that is not available.

In addition to the issues in the previous section, specific issues for this market design are:

- For the reserve receiving TSO: how much Reserve Capacity to buy in the other Control Area
- For BSPs: how much Reserve Capacity to offer in the other Control Area
- Ensuring that no capacity remains unavailable for any of the Control Areas, i.e. making sure that there is a fall-back mechanism to transfer any capacity from pools (“lists”) where they never will be used
- Reservation of Cross Border Capacity; how much should be reserved, by whom, for what time horizon
- The use of Reserve Capacity that becomes unavailable for the reserve receiving TSO due to congestion

5.2.4 Additional Voluntary Pool for Balancing Energy

In this market design one or several TSOs make some of the resources from their BSPs available for TSOs in other Control Areas. As a result, the TSOs each have two merit order lists, one specific for their own Control Area with resources only from that area, and another common merit order list with resources (potentially) from all cooperating Control Areas. Whenever there is a need for upward or downward regulation, the TSO would pick the cheapest resource from either list. The common list could be used on a first come first served basis – whichever TSO needs a certain resource will use it if it is cheaper than the marginal resource in its own area specific list. In the common list it would have to be indicated continuously which resources are already in use and which are available. Of course availability would at any time be dependent on the availability of Cross Border Capacity in the desired direction.

Example

The interaction between the two merit order lists is illustrated in Figure 5-2 below.

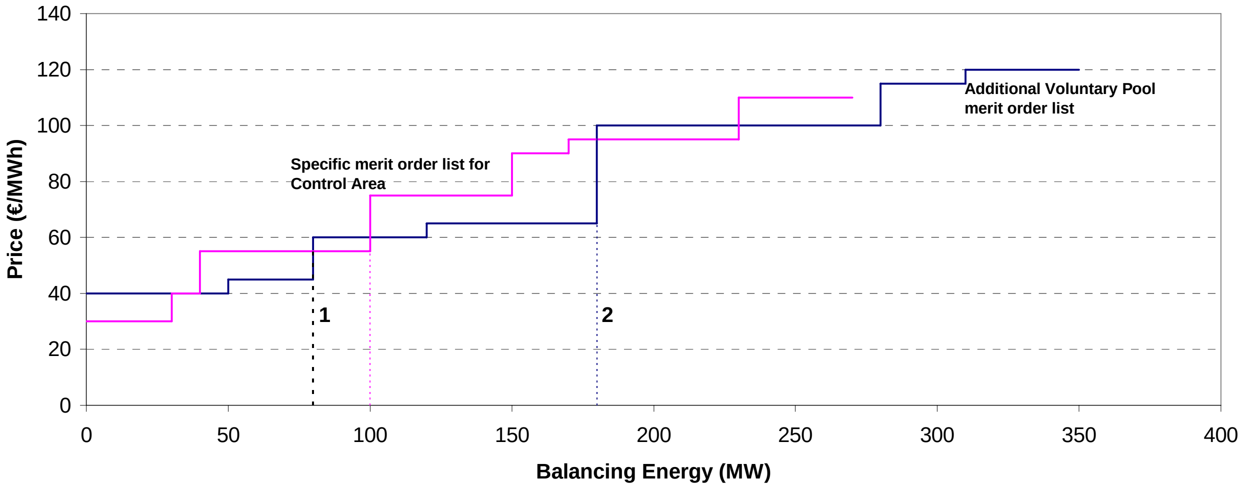

Figure 5-2: Interaction between specific and common bid ladder

Assume that in a Control Area 100 MW of the area specific balancing resources are activated, i.e. the marginal price in the area is 55 €/MWh, and the cost of activating the next MW is 75 €/MWh. If 80 MW of resources on the common merit order list are used (1), the cost of activating the next MW from this list is 65 €/MWh, i.e. the TSO would select a unit from the common merit order list. However, if other TSOs already have used 180 MW of the common merit order list (2), it would be cheaper to activate the next unit from the area specific merit order list.

In the case of tertiary reserves the system operators would need dedicated software to help them select the optimal resource at any time, but congestion issues might be solved using operator experience only. This is basically the case in today's Nordic market. However, in more mashed networks this is probably hard to realize effectively, and online computations would be necessary to identify the optimal resources at any time.

In the case of secondary reserves there is obviously a need for adaptation of the secondary controllers. This may be a significant complication in densely mashed networks with much congestion. An algorithm that solves this problem is presented in [30].

The Additional Voluntary Pool is a form for "TSO to TSO" model in the terms of [5]. An alternative would be that the TSOs bid resources from their own market directly in the market of a neighbouring Control Area. However, we believe the Additional Voluntary Pool as described here is a more flexible model with less complications with respect to the selection and pricing of the resources, as well as a better integration between all available resources. Also if the TSO engages in bidding in other Control Areas, the question occurs of which resources to put in which market, and suboptimal solutions will occur.

Important issues for this market design:

- Which resources to put in the Additional Voluntary Pool

- Criteria for use of the common resources
- The impact of the use common resources on the pricing of the Balancing Energy in the separate markets
- Handling of congestion

5.2.5 Common Merit Order List for Balancing Energy

The important difference between this design and the previous is that in this case there is one common merit order list where all resources in the participating Control Areas are placed. Based on the relevant control criterion, the TSOs together use these resources for their common balancing purposes. In principle it might be possible that the individual Control Areas keep observing their Area Control Error. In this case the ACE must be modified whenever resources outside the area are used. However, if one a common merit order list is used, it would be advantageous to neglect the ACE between the participating Control Areas, and focus only on the ACE for the combined areas. In this case there should be one entity that has the responsibility for the ACE of the combined areas. This could be one of the participating TSOs, or a separate entity. Alternatively one common TSO could substitute the separate TSOs, in which case the areas in practice would be merged.

A special case is the Nordic area, where the common merit order list comprises the total synchronous area. In this case there is no longer an Area Control Error, and the frequency becomes the sole control signal. Special for the Nordic case is also that the Swedish TSO Svenska Kraftnät and the Norwegian TSO Statnett together have the responsibility for the balancing of the total area.

Important issue for this market design:

- Experience from the Nordic system has shown that it can be challenging to maintain an acceptable quality of the system frequency, cf. Figure 5-3, although it is not obvious if the observed deterioration results from integration of balancing markets or other effects.

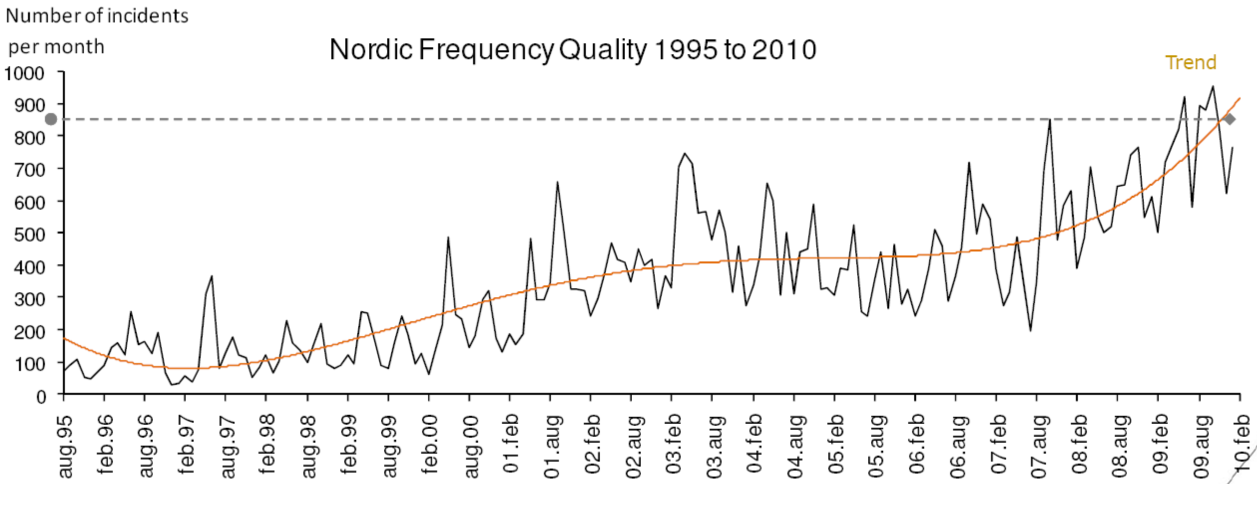

Figure 5-3: Nordic frequency quality 1995 to 2010

5.2.6 Full Integration of Balancing Energy Markets

To step from a Common Merit Order List to full integration implies a far-going (though not necessarily complete) harmonization of the design variables for each Control Area. This will create a level playing field for all BRPs and BSPs, and result in the most efficient common balancing market because it opens up for a system-wide utilization of the cheapest available resources. An important question is what kind of Balancing Services are included – tertiary, secondary or both. In areas that use both secondary and tertiary control, "Full Integration" of tertiary control in reality is a rather limited form of integration, because tertiary control plays a much smaller role that secondary control. In principle there could be a situation with full integration between tertiary control markets and no cooperation between secondary control markets. In those cases cooperation on secondary control would have to be initiated before more integration between the areas in practice would be relevant.

The Nordic system there is close to full integration, but in this system there is as yet no secondary control, which means that full integration of the tertiary control markets in practice means full integration of system balancing.

A full merge of the Control Areas is a logical next and final step after full integration.

Important issues for this market design:

- To determine the necessary level of harmonization. For various reasons it may be difficult to harmonize everything, and it may be challenging to determine what is necessary and what is not necessary, or even to define what is "full" harmonization.
- Who has the responsibility for the area balance – a common TSO, one of the participating TSOs or a separate entity that exists beside the TSOs for each area
- The inclusion of tertiary and/or secondary control
- Handling of congestion
- Pricing in the case of congestion (this is also an issue for the design in 5.2.6)
- Imbalance settlement design. There may be a uniform imbalance price for the entire balancing region, or different imbalance prices in different control areas, based on area system imbalance (even though there is a common MOL). The balancing region may also split into different regulation price areas in case of congestion. It is difficult to say what the impact is of different options on balancing market efficiency. In general price differences should reflect real constraints, and if there are no such constraints, prices should be equal.

5.2.7 Common Merit Order List for Balancing Energy and Reserve Capacity

In addition to a common merit order list for Balancing Energy, a next step towards full integration would be also to have a common merit order list for Reserve Capacity. A prerequisite is that both cooperating Control Areas do acquire Reserve Capacity. Of course there is an issue about the TSOs being willing to share resources for the common good. The TSOs of areas with low cost resources might be reluctant to share these resources with areas with higher cost resources, because that may increase their procurement costs. This is also an issue in the case of Balancing Energy, but to a large extent (or completely, depending on the pricing mechanisms) these costs are born by the BRPs that cause the imbalances. In the case of Reserve Capacity, these costs are often included in the grid tariffs[9], and the TSO may be reluctant to increase these, or even have problems in having the regulator approve such increases. Obviously, the role of the regulator is important in all forms of cooperation between Control Areas, and especially when Reserve Capacity is included.

There is a significant need for harmonization of the procurement procedures for Reserve Capacity with respect to timing, requirements and principles for payment. Reservation of CBC is also an important issue. When a TSO buys Reserve Capacity in another Control Area, it would want to make sure that this capacity would be available in the Balancing Energy market, which may require the reservation of CBC, cf. the discussion in Section 5.2.4.

The integration between the German Control Areas is probably on its way to this model [26].

Important issues for this market design:

- Reserve requirements and location
- Who is/are the buyer(s); because there are still multiple areas, the area-specific reserve requirements stay intact, but there could be one entity buying all this. Then the distribution of reserve capacity also becomes an issue. It is not clear if this design is compatible with multiple TSOs.
- Frequency of capacity auctions
- Payment principles
- Cross-border Capacity reservation
- Distribution of costs and benefits

5.2.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The final step in cooperation on balancing between Control Areas is Full Integration of their Balancing Energy and Reserve Capacity Markets. This can only be reality if both secondary and tertiary reserves are included (unless one of these reserve types is not used like in the Nordic area). It is not possible to define unambiguously how much should be harmonized before we can speak of Full Integration, but a guideline can be those design variables where the need for harmonization in Section 4.1 is identified as high or high/medium, i.e.

- BRP accreditation requirements
- Frequency of bidding
- Gate closure times
- BSP accreditation requirements
- Reserve requirements
- Payment for the provision of balancing services

[9] In [9] it is proposed to include the cost of Reserve Capacity in the imbalance price. The argument for this is that the cost of imbalanced should be paid by those that cause them. On the one hand this is a sound argument, but the disadvantage is that this creates a wedge between the marginal costs of balancing and the imbalance price, leading go inefficiency.

- Bid requirements
- Methods of procurement
- Provision by TSO
- Main imbalance pricing mechanism
- Special imbalance pricing mechanisms
- Single vs dual pricing
- Publication of imbalance price data

6 PERFORMANCE CRITERIA

In order to develop and subsequently evaluate various MBM designs, it is necessary to describe the requirements to such markets. In this report we divide requirements in objectives or performance criteria and constraints.

Performance criteria are properties of the market design that are recommended or desirable, while it is hard to define an absolute minimum (or maximum) value. E.g. a BM should be efficient. But apart from the difficulties of defining this precisely (see below), it is also hard to quantify the required efficiency. On the other hand, it may be possible to classify different BMs with respect to their efficiency, and a more efficient market is better than a less efficient market with respect to this criterion. The performance criteria are measured or valued by performance indicators. Obviously this can be a challenging task, especially for prospective market designs. In many cases it will only be possible to do a qualitative evaluation.

The objectives may be potentially conflicting. Firstly, from a societal point of view, there may be several objectives that are desirable, but cannot all be satisfied at the same time. An example is the accuracy of the balancing planning. On the one hand, maximum accuracy is desirable to make sure that the system always is in balance, and to reduce the efforts of the TSO. On the other hand, accurate balancing by every BRP is not cost-effective, because there will be a lot of unnecessary balancing, and the cheapest resources will not always be used. Secondly, there are conflicts of interest between stakeholders. An obvious conflict is between producers and consumers in the “Balancing Services exporting country”, where producers will profit, while consumers lose.

The performance indicators are quantitative (preferably) or qualitative measures of the corresponding performance criteria.

Constraints are absolute requirements that must be satisfied by any BM design. On the other hand, once the constraint is satisfied, there should be no benefit of “doing even better”. If that is the case, that part should again be formulated as objective. Constraints will mainly be of a technical character.

Example: the quantity of secondary reserves must satisfy the ENTSO-E requirement. This is a constraint. E.g. if the requirement is 300 MW, than 290 is not an acceptable solution, but there is no reason to try to obtain 310 MW. However, more reserves will improve system security, so an objective could be to have “as much secondary reserves as possible”. This would relate to the quantity in excess of 300 MW, but this would be weighed against the costs, while the constraints must be satisfied “at any cost”.

Figure 6-1 shows the relation between requirements, objectives and constraints.

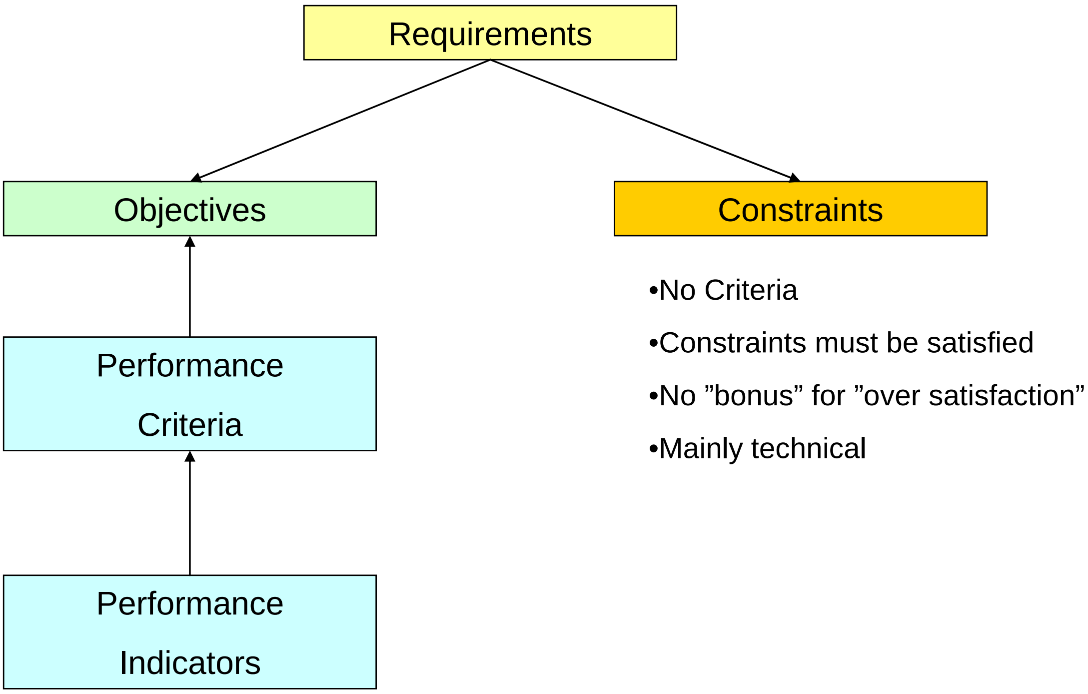

Figure 6-1: Classification of requirements

The constraints are mainly of a technical character, and will in a European context for the case of load frequency control normally imply that the standards in ENTSO-E Policy 1 [6] must be satisfied. Specific issues in the present context are:

- The amount of secondary control reserve[10]
  Reference [6] refers four methodologies for sizing of secondary and tertiary control reserves (B-D5).
  - Empiric Noise Management
    In this case the amount of secondary control reserves is calculated as
    $$R = \sqrt{a \cdot L_{max} + b^2} - b$$
    where L_{max} is the area's maximum load, a=10 MW and b=150 MW. Figure 6-2 shows the resulting recommended reserve as a function of L_{max}. Guideline B-G4 in [6] states that the minimum amount of secondary control according to this formula should be guaranteed within each Control Area, i.e. this is the de facto ENTSO-E standard.

[10] In this context we view the ENTSO-E requirements as absolute constraints and do not discuss their values in relation to their theoretical optimum. Although this is an important issue. it is outside the context of this report.

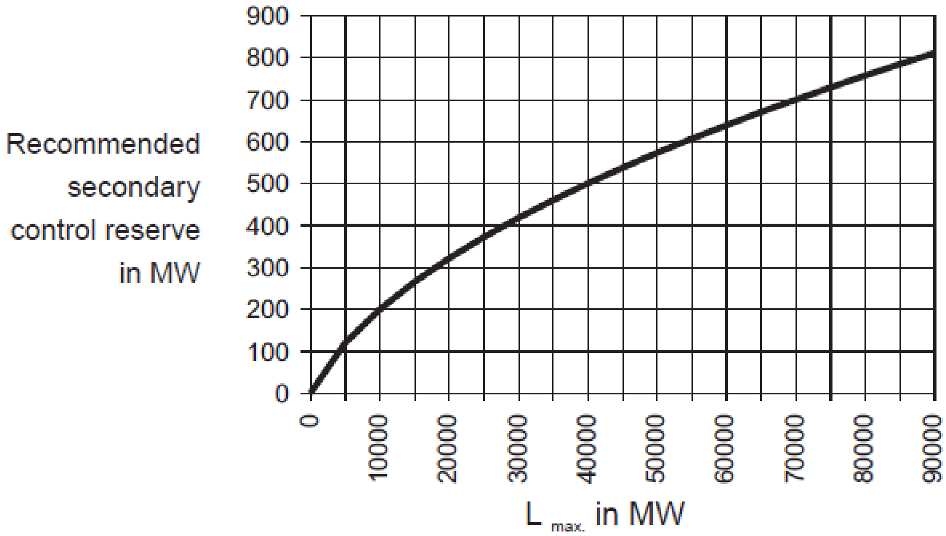

Figure 6-2: Recommended secondary control reserve [7].

An important issue in the case of MBM is the validity of this recommendation in the case of merging of Control Areas. Because of the concave character of the function that describes the size of the recommended reserve, the total reserve for two merged Control Areas will be less than the sum of the sizes for each area individually. For example two areas with a peak demand of 20000 MW will have a recommended reserve of 322 MW each, but only 500 MW together (instead of 644 MW). This can be seen as a way to reduce costs, but it will also reduce the total amount of available secondary reserves in the system, which may result in reduced security of supply. The validity of the equation above in the case of the merging of Control Areas must therefore be carefully considered.

- Probabilistic Risk Management
  From [6] "A probabilistic sizing approach for the total required reserve (secondary and tertiary) is based on a requirement to enable the control of the area control error to zero in for example 99,9 % of all hours during the year (that in this case corresponds to up to 9 hours of deficits in the reserve expected for a full year). The calculation of the size of the reserve is based on the individual distribution curve of the power imbalance (local recovery of imbalances by GenCo, BRP and others, depending on the market system) of the Control Area (statistical data)." This is the theoretically correct criterion that would adapt to cross-border exchange of secondary reserves and the actual way this exchange is implemented. However, it is hard to apply in practice.
- Largest Generation Unit or Power Infeed
  From [6] "The sizing of the required reserve is done based on the assumption and expectation of the largest possible generation incident (e.g. generation units or sets, HVDC-links, power infeed on single bus-bars) that is considered to happen for the Control Area). The size of the total reserve must match the size of the incident." This is a simple criterion that is straightforward to apply. However, it is deterministic and inflexible, and may either overstate or understate the actual need for reserves.

- Extra-ordinary Sizing
  From [6] "Other criteria might influence the size of the reserve e.g. capability to control large changes in total exchange programs, topology of the Control Area / block, expected load variations and behaviour or other special situations like events of public interest, adverse climatic conditions, strikes etc."

- The quality of secondary control reserve
  The quality of secondary control reserve is discussed under the Guidelines in [6], B-G3 Monitoring and Observation, and more specifically in [7], Section 8 and 9.
  - Quality during normal operation
    The frequency deviation during normal operation is evaluated statistically each month by determining the standard deviation σ:

$$\sigma = \sqrt{\frac{1}{n} \cdot \sum_{1}^{n} \left(f_i - f_0 \right)^2}$$

    where n is the number of average values of 15 minutes.
  - Quality during large deviations
    During large deviations, ENTSO-E Guidelines recommend the use of the trumpet curve method, which describes an "envelope curve" for the maximum frequency deviations in the course of a 15 minute period after the occurrence of a major incident, depending on the size of the incident, varying from ± 400 to 3200 MW, cf. [7] Section 9.

Maintaining the standards prescribed in [6] can be seen as the most important constraints in the design of MBM. It should be noted that compared with earlier UCTE versions of the document, [6] already has a number of definitions, standards and guidelines that explicitly refer to border crossing secondary and tertiary control[11].

In [5], ERGEG proposes Guidelines for Good Practice. They are related to balancing mechanisms, transparency and information management and dealing with market power. With respect to balancing mechanisms, ERGEG discusses security of grid operation, acquisition of transmission capacity for balancing purposes, efficiency and competition, operation of balancing mechanism and market and regulation and governance. Several of these issues are closely related to our requirements, but there is no one-to-one relation. The ERGEG guidelines are normative, while our performance criteria are more descriptive.

Figure 6-3 demonstrates the performance criteria related to design of Balancing Markets. The diagram starts with the most generic abstract criteria and divides each criterion into several other lower-level and more specific criteria that can be measured and studied more easily. It should be

[11] B-D7 Adaptation of secondary controller for border-crossing secondary control, B-S2.5 Responsibility of TSOs in case of border-crossing reserves, B-S4.4 Contribution of reserve to one Control Area, B-S4.5 Border-crossing secondary control reserve, C-D2 Adaptation of secondary control for border-crossing tertiary control, C-S3 Border-crossing tertiary control reserve.

noted that the diagram the hierarchy suggested in the diagram is a way to organize and classify the criteria, and does not show the relative importance of different criteria. In addition, the higher number of market-related performance criteria does not imply that the economic and institutional aspects/criteria are more important than technical ones; the objective of Balancing Markets is to guarantee operational security of supply.

The criteria are defined and discussed in the subsequent sections.

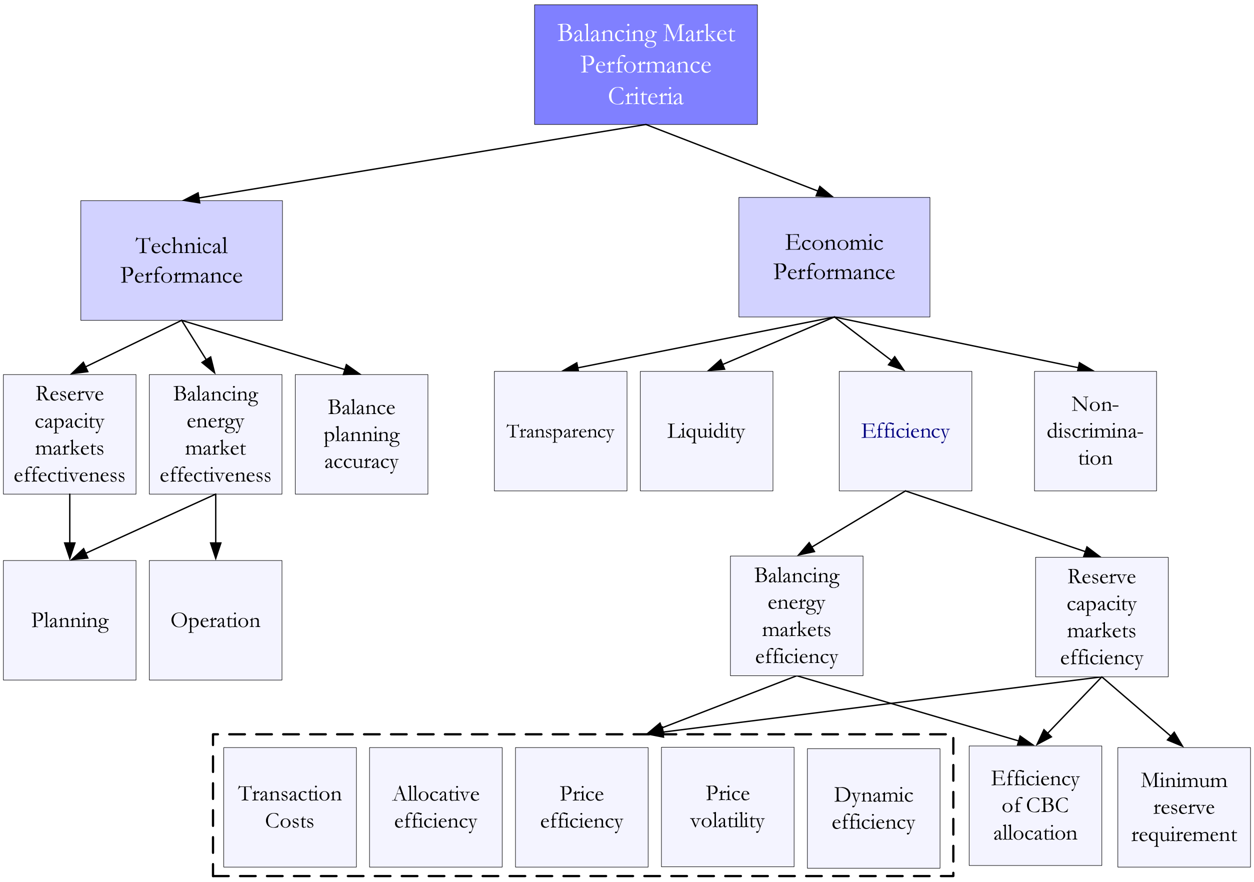

Figure 6-3: Performance criteria for Balancing Markets

It should be noted that the criteria are general criteria for Balancing Markets. In the evaluation of multinational Balancing Market designs in Chapter 7, these criteria will be used to compare the various design proposals.

6.1 TECHNICAL PERFORMANCE

These performance criteria refer to the technical performance of Balancing Markets and relate to effective operation of this mechanism in reaching its main goal which is balancing the system. There can be two different types of markets for procurement of balancing services within Balancing Markets:

- Reserve capacity markets: These markets aim to procure the required amount of reserve capacity for each type of balancing services to insure the secure operation of the system. Selected reserve capacity providers in the market will receive an “option fee” for “availability” of their capacity and are obliged to offer the capacity in real-time markets. Therefore, these markets are mechanisms with which the system operator ensures that enough balancing services will be offered in the balancing energy markets.
- Balancing energy markets: These markets are (near) real-time markets in which balancing energy is purchased respectively sold by the system operator to resolve imbalances. Therefore, they are markets for actual delivery of balancing energy and the selected balancing energy providers receive a payment for “utilization” of their offered energy.

The technical performance criteria of Balancing Markets are directly related to effectiveness of both reserve capacity markets, in meeting the reserve requirements of the system for each type of balancing services, and balancing energy markets in resolving actual real-time imbalances of the system.

6.1.1 Reserve capacity markets effectiveness

This criterion relates to the ability of the reserve capacity markets to attract sufficient capacity with the desired technical characteristics. All participants in this market will have to satisfy the minimum requirements of the Control Area and the Synchronous System. But the TSO may want to have access to units with superior properties. This criterion is very much about giving the right incentives to market participants to provide the required resources or alternatively to have an obligation to provide such resources.

This criterion is difficult to measure, especially *ex ante* (i.e. before an actual implementation). A possible criterion is the number of events where the TSO is not able to attract sufficient reserve capacity. However, this is related to the price: in most systems the TSO will be able to attract sufficient reserves if the price is high enough. Extremely high or unreasonable prices can be an indication of an ineffective reserve capacity market, where the extreme prices are a form of “economic withholding” of capacity. On the other hand high capacity prices can also be the result of a shortage in generation, and can be an incentive to invest in new balancing resources. This would be a long-term aspect of reserve capacity market effectiveness.

6.1.2 Balancing energy markets effectiveness

Balancing energy markets effectiveness determines how effective the Balancing Markets arrangements are in satisfying the system balance criteria. In the ENTSO-E synchronous zone, this would relate to the TSO's ability to keep the area control error close to zero, as well the system frequency. In the previous Nordel zone, the system frequency is the only criterion.

The criterion is difficult to quantify *ex ante*, although it may be possible to get some indications from advanced simulation models. One of the objectives in the present project is to develop such models. The criterion can however be assessed qualitatively. For existing systems, measures can be based on observed performance.

6.1.3 Balance planning accuracy

This relates to the accuracy between submitted energy plans (or in general the physical obligations) of the BRPs and their final real time balances. A high degree of accuracy simplifies the task of system balancing by the TSO, and is therefore desirable from a system security point of view. On the other hand, if BRPs have very strong incentives to keep their balance (e.g. by penalty factors in excess of the marginal cost of system balancing), they will keep reserve capacity on their own hand instead of bidding it in the Balancing Markets. This reduces the TSO's capability to handle remaining imbalances, and may not be cost effective.

With respect to measurement, the same comments as in the previous section apply.

6.2 ECONOMIC PERFORMANCE

An economically efficient market design incentivizes market parties to behave in such a way that best serves the general goal of maximizing economic surplus[12], and leads to the globally optimal solution. Based on their self-interest, agents will use the means available to them to maximize their profit in an open environment. This could lead to undesirable situations and sub-optimal solutions that are more preferable to some agents and not acceptable to others. Therefore, incentivizing agents to behave in such a way that assures the fairness/optimality of the final solution plays a critical role in the design process. Incentive compatibility is the key to defining proper rules.
Economic performance criteria include all the highly interrelated institutional and economic aspects of Balancing Markets. In order to be able to understand and study this high-level abstract criterion, it needs to be divided into more concrete lower-level criteria.

6.2.1 Market transparency

Information availability, information symmetry (equal access to information) and clarity of Balancing Markets rules will lead to transparency which is a prerequisite of a competitive Balancing Market. High level of transparency regarding Balancing Market rules (balance

[12] We use the term ”economic surplus” for the sum of consumer and producer surplus in the partial market for balancing services. Often the terms “social welfare” or “social surplus” are used in similar contexts, but the term “economic surplus” better reflects the fact that we are dealing with a partial market, and not the total economy. In the case of balancing markets the demand is the demand for compensation of imbalances. An alternative is to use a cost minimizing approach.

responsibility, balancing services markets and imbalance settlement), regulation and imbalance prices, volumes of used bids, and imbalance volumes will improve the functioning of the market by enabling market parties to make informed decisions and eventually to encourage new entry and increase competition in the Balancing Market.

ERGEG [5] has published a list of data that TSO's (or other parties responsible for clearing and settlement) are requested to publish, cf. Table 6-1.

Table 6-1: ERGEG transparency and information requirements [5]

Information	Publication	Timeframe	Key benefits of information	Provider
• **Volumes of bids and offers used**	Just after real time, to be kept at least for one month	Per balancing mechanism time unit	• To help market players to formulate their balancing offers • To increase the level of transparency in the management of TSOs	TSO or responsible for clearing & settlement
• **Average and marginal prices of bids/offers with prices corresponding to global imbalance**	Just after real time, to be kept at least for one month	Per balancing mechanism time unit	idem	TSO or responsible for clearing & settlement
• **Imbalance prices**	Just after real time	Per balancing mechanism time unit	• To help balance responsibles to optimise their imbalance's level	TSO or responsible for clearing & settlement
• **Control Area imbalance volumes and volume of manually activated reserve (balancing power) used**	Just after real time	Per balancing mechanism time unit	• To help balance responsibles to optimise their imbalance's level • To enable monitoring	TSO
• **Information on the financial balance of the whole market (expenses on the Balancing Market / payment of imbalances)**	Month M+1 for month M, to be updated until final reconciliation	Per month	• To increase the level of transparency in the management of TSOs	TSO
• **Market information on the type of balancing bids/offers used**	Month M+1 for month M	Per day	• To help market players to formulate their balancing offers • To increase the level of transparency in the management of TSOs	TSO

According to ERGEG, information required for monitoring by the regulators at least should include:

- Detailed bids and offers made by participants (at least offered power, price, notice to deliver, minimum and maximum time of use)
- Those bids that were selected by TSOs.

Also according to ERGEG and especially relevant in the present context, "the data published in each Member State (Control Area) which forms part of the integrated Balancing Market should be identical in terms of type and availability of information. This way any asymmetry in the level of transparency will be avoided, preventing thus the better informed market players from benefiting unduly from their unjust preferred position."

It is not fully clear to what extent these requirements by ERGEG are satisfied presently or how they are enforced (by the national regulators?). Also, this criterion is difficult to assess *ex ante*. For existing markets, it can be verified to what extent the information requirements in Table 6-1 are satisfied, and how easy it is to obtain the information.

In general, one might expect that multinational Balancing Markets require a higher degree of formal rules and agreements on an international level, leading to more transparency. However, in a transitional phase there can occur a patchwork of national rules, which in such a phase might make the market less transparent.

6.2.2 Market liquidity

A market is liquid if there are many buyers and sellers who can access each other easily and have access to information about the market prices. A defining feature of a liquid market is that it can generally absorb the addition or loss of a buyer or seller without a noticeable change in the market price. Liquidity of balancing services markets criterion is related to both reserve capacity and balancing energy markets for each type of balancing services. Since balancing services markets are single buyer markets with system operator as the only buyer, liquidity of these markets relates to the number of balancing services providers and their willingness and ability to offer services in these markets.

6.2.3 Balancing services markets efficiency

This Balancing Market performance criterion refers to the economic efficiency of both reserve capacity and balancing energy markets for each type of balancing services. Market efficiency is one of the primary objectives in design of electricity markets in general, and is one of the major driving factors behind the drive towards multinational Balancing Markets.

6.2.3.1 Transaction costs

The operation of the Balancing Markets will involve costs, and these costs should be as low as possible. From a national perspective, there are various variables in the design of Balancing Markets that influence this aspect of market efficiency, e.g. method of procurement of reserve capacities (bilateral contracts and auctions), the time horizon of reserve capacity and balancing energy markets (frequency of market clearance), etc. In a multinational level, because of different arrangements needed to be made between system operators and balance providers (TSO-BRP arrangements, foreign bidding, etc), operational efficiency even plays a larger role.

The transaction costs for a specific market design are the obvious performance indicator. These are hard to quantify *ex ante*, and may also often be difficult to quantify for existing systems because this would require detailed insight in the accounts of the TSOs. It should be possible to do a qualitative assessment however, looking at the complexity of the solution, required tools, administrative requirements, need for explicit coordination etc.

6.2.3.2 Allocative efficiency

Allocative efficiency is the aspect of market efficiency relating to optimal use of limited available resources. In the case of Balancing Markets, this performance criterion aims at meeting the system's reserve requirements (through reserve capacity markets) and resolving the system's real-time imbalances (through balancing energy markets), with use of the optimal set of available balancing resources. This criterion is influenced by two main factors; the system operator's use of the cheapest balancing resources offered in the markets, and incentives of resource owners to offer their capacity as balancing services in balancing services markets. In case of reserve capacity markets, capacity providers may alternatively offer their capacity in other wholesale electricity markets (such as day-ahead markets) and in case of balancing energy markets, balancing service providers may keep their resources in order to regulate internally (self-regulation).

Performance indicators can be the relation between actual balancing costs and possible (simulated) minimum balancing costs for capacity and energy. *Ex ante* an evaluation must be based on the assumed properties of the market design or possibly on experience from similar markets.

6.2.3.3 Price efficiency

This Balancing Market performance criterion relates to cost-reflectivity of prices in both reserve capacity and balancing energy markets. Therefore, price efficiency criterion deals with the issue of market power and competitiveness in balancing services markets. It is also interrelated with balancing services markets liquidity since it is influenced by the number of balancing services providers and trading volumes, while it is not the same as market liquidity.

The relation between prices and (assumed) costs is a good indicator. Costs can be evaluated *ex ante* for specific markets, although they require significant analysis efforts but prices can only be assessed for existing markets.

6.2.3.4 Price volatility

In general most market participants prefer stable instead of volatile prices. High volatility increases risk and therefore costs. In Balancing Markets it is probably not a problem if prices vary significantly from PTU to PTU, it is more important that average values from month to month are stable. The main problem is if there are occasional extreme spikes, e.g. 2000 €/MWh 2-3 times per year. This is too seldom to increase supply, but still constitute a high risk for market players that cannot control their deviations (e.g. retailers, wind power producers) [9].

The performance criterion is the occurrence of extreme price spikes, which has to be defined in a meaningful manner. This can be readily assessed for existing markets. *Ex ante* it can in principle be simulated.

6.2.3.5 Efficiency of Cross Border Capacity allocation

The limited available capacity of interconnection lines should be used in the most efficient way in a multinational context, taking into account wholesale electricity markets (e.g. day-ahead market), reserve capacity markets, intraday and balancing energy markets. The decisions that are made in the design of a multinational Balancing Market (in terms of time horizons of balancing services markets, gate opening/closure times and their coordination with day-ahead markets opening/closure times, etc) will strongly affect the efficiency in using interconnection capacities between different countries/areas.

Performance indicators relate to the efficient use of interconnection capacities, i.e. a day-ahead power flow consistent with price differences and an efficient use of remaining capacity for intraday and Balancing Markets.

6.2.3.6 Dynamic efficiency

The efficiency criteria in the previous sections all relate to static conditions under a given market structure. In general, static efficiency is obtained by optimally employing existing technologies and inventing new process technologies. Companies can also push their current production possibility frontiers continuously outward or invent new frontiers by introducing new products. While static efficiency is about optimality under given conditions, dynamic efficiency is about innovation with the objective to perform better in the future. According to [13], "… economic history and econometrics both suggest that the welfare gains from being dynamically efficient are much greater that those from being statically efficient." In relation to Balancing Markets, static efficiency will provide sufficient capacity and utilize it in an efficient way. Dynamic efficient market designs on the other hand will give incentives to develop innovative solutions that are cheaper and/or result in higher system security in the long run, e.g. by attracting new types of providers of balancing services or by motivating existing provides to develop other balancing resources. In the present context incentives for attracting demand side suppliers of balancing services are especially important. An example of the second kind is the development and utilization of appropriate storing technologies. E.g. very strict technical criteria with respect to reaction, speed and minimum volumes do not motivate to such innovation.

Quantitative performance indicators for this criterion are difficult to define, and evaluations must be based on qualitative assessment of the actual market designs.

6.2.3.7 Minimum reserve requirement

This criterion is related to the "need" for reserve capacities for different types of balancing services. It deals with the "demand" for reserve capacities in reserve capacity markets. In these markets, the demand is fixed and determined based on the minimum reserve requirement of the system that is required for secure operation of the system, for example it can be a specific percentage of the peak load or of the annual consumption, etc. This factor impacts the costs of capacity reservation of the system to a very large extent and plays a crucial role in the efficiency of the Balancing Market as a whole.

In the context of MBMs it is especially important to assess if the integration of Balancing Markets and Control Areas reduces the total need for balancing capacity without degrading system security below the required level.

The performance indicator is obviously the required amount of reserve capacity for different categories. It is much harder to determine these amounts, because present requirements largely are based on experience and engineering judgement, cf. the ENTSO-E recommendation for the required minimum amount of secondary control reserve $R = \sqrt{a \cdot L_{max} + b^2} - b$.

6.2.4 Non-discrimination

This criterion concerns the allocation of costs/benefits of balance management to TSOs and market parties proportional to the negative/positive contribution of these TSOs and market parties to balance management. Fair distribution of capacity reservation costs, balancing energy costs, and benefits from balancing trade, plays an important role in achieving an incentive-compatible Balancing Market design. This criterion mainly relates to rules and regulations in balance responsibility and imbalance settlement that determine the procedure of allocation of different components of balancing costs to market parties. In an integrated multinational Balancing Market, the problem becomes especially complex. A special issue is the effect of trade on consumers and producers in the participating countries, where consumers in the exporting country and producers in the importing country may perceive the trade as “unfair”, because it increases respectively decreases prices. However, this is a general effect of trade, and outside the scope of this report. But there are other issues related to a fair distribution of costs. An example is the allocation of the reserve capacity costs. Fairness would suggest that the costs are paid by market participants according to their contribution to deviations. One issue is what is meant by “their contribution” – peak deviation (that determines the need for capacity) or average deviation? Another issue is how this distribution should be obtained. In [9] it is suggested to add these costs to the balancing energy costs. However, this would drive a wedge between the price and marginal cost of balancing energy, and reduce price efficiency in this market. In general, fairness is a very difficult criterion.

6.2.5 Performance criteria overview

Table 6-2 gives an overview over the performance criteria. For each criterion an attempt is made to give a performance indicator. Most of these criteria can be used for existing markets if there is sufficient transparency such that the necessary data are available. However, for prospective market designs, it will be difficult or impossible to quantify the indicators, and evaluation must be based on a qualitative assessment.

Some of the criteria also depend less on the market design itself as the actual implementation and the objectives of key actors like regulators and TSOs. A certain market design may be very transparent in a country with a strong regulator and a strict unbundling between system operation and production, while the same design may lack transparency in a country with a weak regulator and strong ties between system operation and production. On the other hand, one form of design can inherently be more transparent than another. In general more complexity probably leads to less transparency, everything else being equal.

In Chapter 7 the criteria will be used for a simplified qualitative analysis of the market designs presented in Chapter 5.

Table 6-2: Overview over Balancing Market performance criteria

Performance criterion	**Description**	**Performance Indicator**
Technical performance	The technical performance of Balancing Markets related to effective operation with respect to balancing the system	–
Reserve capacity market effectiveness	The ability of the reserve capacity markets to attract sufficient capacity with the desired technical characteristics and technology mix	Number of events where insufficient reserve capacity is available, or where it is only available in excess of a predefined price limit
Balancing energy market effectiveness	The effectiveness the Balancing Markets arrangements in satisfying the system balance criteria (exchange programs, frequency)	Average deviation in MW and Hz Number of PTUs with deviation in excess of predefined limits
Balance planning accuracy	The conformity between submitted energy plans (or in general the physical obligations) of the BRPs and their final real time balances	Average deviation in MW or percent Number of PTUs with deviation in excess of predefined limit
Economic Performance	The degree the market design incentivizes market parties to behave in a way that best serves the general goal of maximizing economic surplus, and leads to the globally optimal solution for the Balancing Markets	–
Market transparency	Information availability, information symmetry (equal access to information) and clarity of markets rules	Degree of compliance with ERGEG transparency and information requirements
Market liquidity	The number of balancing services providers and their willingness and ability to offer relevant services	The number of active balancing services providers
Balancing energy and reserve capacity market efficiency	The economic efficiency of both reserve capacity and balancing energy markets for each type of balancing services	–
Transaction costs	The cost of market operation	The administrative and other fixed costs of operating the balancing markets in €/MWh of final consumption
Allocative efficiency	The degree of optimality in the use of balancing resources, i.e. the degree to which the most suitable / cheapest resources are used	Correspondence between the estimated real cost of balancing and a theoretical benchmark
Price efficiency	The cost-reflectivity of prices in both reserve capacity and balancing energy markets	Markup between prices and marginal costs

Table 6-2: Overview over Balancing Market performance criteria

Performance criterion	Description	Performance Indicator
Price volatility	Volatility or variation over time of BE and RC prices	Volatility measures like the number or price spikes according to some definition
Efficiency of CBC allocation	The relation between the flows of balancing services on the interconnections and the price differences between the markets	Number of occurrences and size of flows from high price to low price
Dynamic efficiency	The existence of incentives to develop innovative solutions that are cheaper and/or result in higher system security in the long run	Hard to evaluate, but flexibility and openness to new participants can be potential indicators
Minimum reserve requirement	The need for reserve capacities for different types of balancing services (RCM only)	Required reserve as a share of system load
Non-discrimination	Degree of equality and fair treatment of all market participants like TSOs and large and small BRPs and BSPs.	Hard to evaluate. Relates to fair distribution of costs and benefits between the various groups and the degree to which there is equal treatment between small and large market participants.

7 EVALUATION OF MULTINATIONAL BALANCING MARKET DESIGNS

In this Chapter, the eight relevant multi control area balancing market designs identified in Chapter 5 are evaluated qualitatively on the basis of the performance criteria listed in Chapter 6. This is done by assessing the impact of each of these designs on the performance criteria compared to the reference design of separate balancing markets with separate reserve capacity reservation in each market and without any cross-border balancing. We have chosen to structure the evaluation on the basis of the different performance criteria. Thus, for each performance criterion, we will describe the effect of each of the eight designs on this criterion (Section 7.2). This enables a better comparison of the designs. However, it requires that we start with a first high-level, general evaluation of the designs (Section 7.1). These effects are summarized in Table 7-1, after which the results are wrapped up and general conclusions on the relative value of the different designs are drawn in Section 7.3.

The analyses in this report are qualitative, based on our analysis of the impact of the various market designs on the criteria. It is our intention that the ongoing research in the project will make it possible to quantify some of the effects in a later phase, specifically those effects that are related to prices.

7.1 GENERAL EVALUATION

7.1.1 ACE netting

The only difference between ACE netting and the reference design of no cross-border balancing is that counteracting regulation in the involved control areas is prevented by the adaptation of the Area Control Errors. This ACE netting reduces the amount of regulation volumes activated by the Secondary Controller whenever area imbalances oppose each other. This will create lower imbalances, and thereby reduce balancing energy prices. As a result, balancing costs for the BRPs in the involved control areas will decrease. However if the market is not competitive, BSPs could respond to the lower frequency of activation by increasing their balancing energy bid prices, which could cancel out the price reductions. Also, lower prices give lower incentives to BRPs to keep their balances and therefore increase area imbalances. Furthermore, because ACE netting is only possible when the ACEs have opposite signs, it may lead to larger price fluctuations, which would increase the financial risks for BSPs and BRPs.

7.1.2 BSP-TSO trading

In the multinational balancing market design of BSP-TSO trading the balancing service providers are able to bid into the balancing energy markets of other control areas. The impact of this design really depends on the detailed bidding and settlement procedures, and on the availability and allocation of CBC. If bids can be placed into only one BEM at a time (each PTU), and the BSPs have total freedom to choose a market, BSPs of cheap areas will tend to go to the most expensive market, possibly creating shifts in balancing energy prices and imbalance prices in all areas. However, this would again change the profitability of the markets and therefore shift the bids. Over time, arbitrage between the markets should level out price differences if sufficient CBC is available. To avoid that capacity remains on idle lists in one market, provisions are necessary to return unnecessary capacity to its original market. This can be done for the capacity bid into another market that exceeds the available CBC by requiring BSPs to give subsidiary bids in their home market, cf. Section 5.2.2.

There is also an issue with respect to the arbitrage possibility for BSPs to not provide the balancing energy but still receive the external BE price, while paying the internal, much lower imbalance price.

If the connecting TSO has to approve of the bids that BSPs want to submit somewhere else, the TSOs will be able to prevent adverse effects of balancing energy exchange on balancing market performance. This latter case resembles the Additional Voluntary Pool.

The effect of this model will also depend on the reservation of CBC, however such reservation is probably less relevant without also reserving reserve capacity, which is the design discussed in the next section.

7.1.3 BSP-TSO trading with Reserve Capacity reservation

In this design, BSPs can submit reserve capacity bids into RCMs of neighbouring control areas. If these bids are selected, corresponding balancing energy bids must be submitted in the BEM. The RCM will normally be combined with reservation of cross-border capacity, which bears costs to BSP and/or reserve receiving TSO, and reduces utilization of the CBC. The advantage of this model compared with the model in 7.1.2 is that balancing resources can be secured before operation, or even before the clearing of the spot market. If combined with reservation of CBC, this will give access to a certain resource, pending outages. In many systems the reservation costs are quite high, so this model has a scope for significant cost reductions if cheap resources are available in other Control Areas.

7.1.4 Additional Voluntary Pool for Balancing Energy

In an additional voluntary pool for balancing energy, the BSPs are not involved in the BEE, but only the TSOs; it is the TSO that will decide to share balancing energy bids in a regional pool with other TSOs. The big difference with BSP-TSO trading is that the TSO has full control over the BEE in this design (compared to no or limited control for BSP-TSO trading). It is likely that the TSO will share only those bids that will not be needed nationally. Another difference with BSP-TSO trading is that alternative regulation pricing can more readily be applied to the exchanged bids. Balancing energy prices and imbalance prices in the importing, expensive areas will reduce. Despite the TSO control, the additional voluntary pool may still lead to balancing energy price increases in the cheap areas, e.g. when BSPs aim to get selected for BEE and receive the higher BE price of the importing area.

However, this depends strongly on the actual design and the objectives of the cooperation, e.g. general improvement of social welfare or increasing mutual security.

7.1.5 Common Merit Order List for Balancing Energy

The integration of balancing energy markets in this design of the common merit order list will potentially establish an economically optimal system imbalance resolution for the balancing region as a whole. We assume this includes ACE netting. Therefore, the balancing costs reductions may very well be larger than that of ACE netting and the AVP together. An important lower-level design choice is the settlement procedure in case of cross-border congestions. When there is no congestion, a uniform regional BE price will develop. However, when there is congestion, it is possible to either split the region into multiple price areas, or to continue with the application of uniform prices. The first appears more logical, but has the disadvantage that prices may fluctuate a lot. The general effect of the BE price merging will be that cheap areas will generally be faced with increasing prices and expensive areas with decreasing prices. Furthermore, there is another design choice between regional and control area imbalance pricing. It is possible to maintain the national imbalance pricing mechanisms, but this may damage the incentives for market parties to offer resources to the common MOL.

7.1.6 Full Integration of Balancing Energy Markets

Compared to the common merit order list, rules for balance responsibility and imbalance settlement, and possibly remaining rules for balance regulation, are harmonized in this design. The relative difference in impact compared to the common merit order list for BE depends on the initial differences in balance responsibility and imbalance settlement design variables between the control areas. Furthermore, if a uniform imbalance price is already applied in the merit order list design, this design is almost the same. However, the impact of the harmonization of balance responsibility and imbalance settlement will be large when national differences continue to exist. BRPs will get equal incentives to balance their portfolio, which creates equal market conditions, and makes balance management generally more efficient. The size of this impact really depends on initial design differences, and the adopted imbalance settlement design in the balancing region (see common merit order list for balancing energy).

7.1.7 Common Merit Order List for Balancing Energy and Reserve Capacity

In a common merit order list for balancing energy and reserve capacity, also the reserve capacity is procured regionally, and the cheapest reserve capacity bids available are procured. However, the required availability of cross-border capacity needs to be taken into account here. CBC needs to be reserved, but compared to the design of BSP-TSO trading with RC reservation, this CBC reservation may be utilized in an economically optimal way instead of merely by one BSP or bid. Therefore, CBC reservation may very well pay off in this case and result in significantly larger balancing costs reductions than for the common merit order list for BE only. If no CBC is reserved for balancing purposes, the potential for RCE will be smaller. In this case the balancing costs reductions expected from this may be small compared to BEE. In any case there is an important and unsolved issue with respect to how much Reserve Capacity to procure in each area, given the level of congestion in the actual system[13].

7.1.8 Full Integration of Balancing Energy and Reserve Capacity Markets

Compared to the common merit order list for balancing energy and reserve capacity, rules for balance responsibility and imbalance settlement are also harmonized. This will create a level playing field in the balancing region and create equal market conditions for market participants in different control areas. The difference in impact of this design compared to the common merit order list for BE and RC is similar to the difference in impact between the common merit order list for BE only and full integration for BEMs.

7.1.9 The Nordic system and the CWE system – a special case

The analyses in this report are mainly of a general character and intended to be valid both *within* and *between* synchronous systems. Exchange of balancing services between the Nordic system and the CWE system is special mainly because of two reasons:

1. It involves two separate synchronous systems
2. The Nordic market presently has no automatic Load Frequency Control (LFC)

The first point is extensively treated in reference [15]. We will here shortly discuss the impact of the second point.

The analyses in this report assume implicitly that the markets that potentially can integrate their balancing services already have established arrangements for the services to be integrated. Until now, the Nordic market has not had automatic LFC, and therefore no secondary control according to Policy 1 of ENTSO-E [6], [7], which by definition is automatic. The use of Fast Active Disturbance Reserves (FADR), more or less corresponding to tertiary reserves in ENTSO-E terms, has until recently been sufficient to maintain the system frequency, due to the favourable regulation properties of hydro plants. However, as shown in Figure 5-3, this situation has now probably come to an end, and work is going on to introduce LFC in the Nordic system.

In the context of this report and on the background of the whole project, an important question is if the fact that LFC does not presently exist in the Nordic system changes the evaluation of the respective models for exchange of balancing services, and if so, in what way. A major issue is that as

[13] Statnett has a similar challenge in its procurement of capacity in the RKOM market, which is divided in zones. By our knowledge this division is is solved rather informally today.

long as there is no LFC in the Nordic system, it is not possible to exchange secondary reserves. Still, in principle it would be possible to deliver secondary reserves to the CWE system by way of the HVDC interconnection [15], and continue to use the FADR to control the frequency in the Nordic system. However, this is not a relevant option, given the difficulties in keeping the frequency today (cf. Figure 5-3) and the increased control requirements resulting from the CWE balancing requirements.

To exchange secondary reserves and thereby exploiting the favourable characteristics of the hydro plants, it is therefore necessary to make investments to establish LFC and AGC on particular generators. Naturally, incentives are needed to realize such investments, and the question is if the exchange models recommended in this report (moving from imbalance netting to common merit order lists) are suited to motivate to such investments.

It is hard to answer this question in a general way. It will in all cases depend on the details of the actual regulations and agreements and not at least on the benefit sharing, cf. the discussion in Section 5.3.2 in [15]. Obviously, arrangements that leave most of the benefits to the TSO will not give incentives to generators to invest in AGC. Also, imbalance netting, as discussed in the report, will reduce balancing actions and therefor reduce BSP (i.e. mainly generator) revenues and therefore not give incentives to invest in AGC.

In this context it may be that particular BSP-TSO models can be relevant in a transitional period to trigger the necessary investments. A straight forward implementation is to couple certain generators directly to balancing control actions of the HVDC cable, and let these generators participate directly in the foreign balancing market. Probably this would only be relevant if interconnection capacity were reserved for this purpose. This model has however several inefficiencies, and a better option is probably to look at one of the TSO-TSO models discussed in Section 5.3.2 in [15], allocating a significant share of the profits to the BSPs/generators in a transitional period (e.g. 5 years) to compensate for the investment cost of AGC. An argument in favour of such a transitional arrangement is that as long as only a few generators have AGC, there are no problems of dividing resources between markets (all LFC is allocated to the HVDC cables in this period) or of efficiency losses caused by bidding in two separate markets (cf. Section 5.2.2 in this report).

In the longer run, once LFC is established in the Nordic market and many generators have invested in AGC, the more general analyses in this report should also be valid for the exchange of balancing services between the Nordic market and the CWE region.

7.2 IN-DEPTH EVALUATION PER PERFORMANCE CRITERION

Importantly, the evaluation takes both a regional / systems perspective and an individual control area perspective. The systems perspective is obviously important to obtain a single assessment of different multinational balancing market designs. The control area perspective is relevant, because different control areas are not likely to participate in balancing market integration when this has a negative impact for their control area (without being compensated for this in some way).

7.2.1 Reserve capacity markets effectiveness

7.2.1.1 ACE netting

This design has no effect on reserve capacity markets effectiveness, because the reduced activation of balancing energy will not enable a reduction of reserve capacity procurement. After all, ACE netting is only possible when area imbalances oppose each other, and it cannot be predicted in which PTUs imbalances oppose or not.

7.2.1.2 BSP-TSO trading

RCM effectiveness may reduce in this design, if BSPs whose reserve capacity was contracted in one control area are still able to bid the corresponding balancing energy in another control area. However the TSO or rather the balancing market rules themselves, should prohibit this, in which case RCM effectiveness is not affected. However, the fact that capacity must be divided between two markets has a potential to reduce this markets effectiveness,

7.2.1.3 BSP-TSO trading with Reserve Capacity reservation

Reserve capacity exchange takes place in this design. This will normally be combined with CBC reservation, and the extent to which the reserved CBC is really available in real-time for BEE determines the degree of RCM effectiveness reduction. As this can only be the result of large system imbalances or interconnector failure, it is not expected that a significant reduction will take place. An exception is formed by an interconnector that has a relatively large chance of failure, like the NorNed cable, which has been out of operation for months at a time Additional Voluntary Pool for Balancing Energy.

7.2.1.4 Additional Voluntary Pool for Balancing Energy

In this design no RCE takes place, and reserve capacity procurement cannot be reduced, so RCM effectiveness will not be influenced.

7.2.1.5 Common Merit Order List for Balancing Energy

In this design no RCE takes place, and reserve capacity procurement cannot be reduced, so RCM effectiveness will not be influenced.

7.2.1.6 Full Integration of Balancing Energy Markets

The same can be said for this design as for the common merit order list for balancing energy, because the harmonization of balance responsibility and imbalance settlement has no impact on reserve capacity procurement. So, this design has no effect on RCM effectiveness.

7.2.1.7 Common Merit Order List for Balancing Energy and Reserve Capacity

The common merit order list for RC and BE requires the reservation of CBC. This enables not only RCE, but possibly also the reduction of RC volumes. To both, some risks are attached with regard to RCM effectiveness, but especially to the latter. If the possible RC volume reduction given a certain CBC reservation is carefully calculated, it should be possible to increase the RCM effectiveness through a better coordinated procurement.

7.2.1.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The same can be said for this design as for the common merit order list for balancing energy and reserve capacity, because the harmonization of balance responsibility and imbalance settlement has no impact on reserve capacity procurement.

7.2.2 Balancing energy markets effectiveness

7.2.2.1 ACE netting

If ACE netting is applied, the task of ACE control has been made easier and more immediate – ACE adaptation is much quicker than upward/downward regulation. Also, the reserve margin between offered balancing energy and activated balancing energy will increase due to ACE netting, which decreases the likelihood of having insufficient BE bids for restoring the system balance. Thus, balancing energy markets effectiveness increases.

7.2.2.2 BSP-TSO trading

If BSPs have a lot of freedom in choosing in which control area to bid, the reserve margin for balancing energy in the expensive BEM may increase, but at the expense of an equal decrease in the cheap BEM. Which effect dominates depends on the respective system characteristics. If the TSO monitors the BEE, overall BEM effectiveness could increase. It is not expected that this increase is large, considering that each control area will have enough balancing resources to balance their system in the first place. On the other hand, there is a negative effect of the BSPs dividing their resources over two areas.

7.2.2.3 BSP-TSO trading with Reserve Capacity reservation

If we assume that only the balancing energy bids that correspond with the exchanged reserve capacity bids are exchanged, in case they are activated, the impact of this design on BEM effectiveness is small. Compared with an uncontrolled exchange without RC reservation this means a small decrease, and in case of controlled exchange by TSOs it means a very small increase. However, on the negative side there is like above the negative effect of the BSPs dividing their resources over two areas, so the overall expected result is neutral.

7.2.2.4 Additional Voluntary Pool for Balancing Energy

If TSOs share all BE bids that are not used in the own area, BEM effectiveness will increase. This increase will be larger than for the most favourable case under BSP-TSO trading, because the bids are pooled rather than bilaterally exchanged, but will still be limited considering that there will be sufficient reserve capacity procurement in each control area.

7.2.2.5 Common Merit Order List for Balancing Energy

Due to both the inherent ACE netting and the regional dispatch of balancing energy, the availability of balancing energy bids will increase significantly. The BEM effectiveness will increase as a result, but to a lower extent, as BEM effectiveness is assumed to be reasonably good in the reference design.

7.2.2.6 Full Integration of Balancing Energy Markets

The impact on BEM effectiveness from the harmonization of balance responsibility and imbalance settlement comes from the expected decrease in imbalance prices caused by full integration, which will invluence incentives to BRPs. This may change the system imbalance volumes and thereby the sufficiency of balancing energy bids. The net direction of this impact depends on the different initial imbalance settlement designs and the final regional design. The analysis in [27] shows however that the impact of changes in imbalance settlement design on system imbalance volumes will be limited, due to the feed-back loop between balancing market behaviour and performance that stabilizes balancing market performance. Therefore, the same evaluation as for the common merit order list for BE is given: BEM effectiveness will increase.

7.2.2.7 Common Merit Order List for Balancing Energy and Reserve Capacity

In this design, the reservation of CBC that is needed for the RCE will increase the availability of balancing energy from other control areas. However, if the reserved RC volumes are reduced, this availability becomes more necessary as well. Because this RC volume reduction should not endanger operational security of supply, we conclude that BEM effectiveness will increase. Here too, the increase is limited relative to the reference design (see above).

7.2.2.8 Full Integration of Balancing Energy and Reserve Capacity Markets

As described under 7.2.2.6, the impact of imbalance settlement design changes is expected to be limited, which will also limit the relative difference in impact of this design compared to the common merit order list for balancing energy and reserve capacity. Thus, the BEM effectiveness is expected to increase only moderately compared with these designs.

7.2.3 Balance planning accuracy

7.2.3.1 ACE netting

ACE netting will lead to lower balancing energy prices, and thereby imbalance prices. This may in principle give lower incentives to BRPs to balance their portfolio, which may result in increasing BRP imbalances and thus decreased balance planning accuracy. However, it is not clear to what extent balance planning accuracy will really decrease. BRPs will be content with the lower imbalance prices and the resulting lower imbalance costs. The only reason why imbalance volumes would become larger, would be because BRPs are in the reference design making costs to prevent imbalances, by large forecasting efforts, intraday trade and/or internal balancing, and increasing imbalances in the new design of ACE netting is the lowest cost option for the BRPs. Also, the threat of high prices is still there, because netting is not possible in all hours and conditions leading to incidental extreme cases will continue to exist.

7.2.3.2 BSP-TSO trading

As follows from the evaluation under 7.2.3.1 , the change in balance planning accuracy depends on the change in imbalance price levels, but it is unclear to what extent accuracy will really decrease due to imbalance price reduction. BSP-TSO trading can lead to large imbalance price reductions in the expensive areas, so balance planning accuracy might reduce there. More clear is that the higher imbalance prices that will develop in the cheap areas when there is a large uncontrolled BEE will increase accuracy, because BRPs will put more effort to prevent the higher imbalance costs that they incur. On overall, BE prices are expected to increase in case of uncontrolled BEE, which means an overall increase in balance planning accuracy.

7.2.3.3 BSP-TSO trading with Reserve Capacity reservation

If we assume like in 7.2.2.3 that the balancing energy exchange in this design is small, the impact on balance planning accuracy will be very small. In case of uncontrolled BEE accuracy will slightly increase, and vice versa.

7.2.3.4 Additional Voluntary Pool for Balancing Energy

If the unused balancing energy bids are shared among TSOs, the balancing energy prices in the expensive areas will probably decrease significantly, which can create a similar reduction of imbalance prices in those areas. As stated above, balance planning accuracy will not necessarily decrease to a similar degree; it could roughly remain the same.

7.2.3.5 Common Merit Order List for Balancing Energy

In general, balancing energy prices will be reduced in this option, possible significantly, and thus imbalance prices as well, which points to a decrease of balance planning accuracy. From an individual control area perspective, however, the imbalance price level will decrease for the expensive areas and increase for the cheap areas. If it is so that the BRPs faced with a higher imbalance price are more effectively stimulated to reduce imbalances than the BRPs faced with a lower imbalance prices will increase imbalances, overall imbalance volumes from a system perspective might reduce, and thus result in a balance planning accuracy increase. The impact of this design on accuracy thus again depends on the current efforts and corresponding costs the BRPs are putting into their portfolio balancing (see 7.2.3.1).

7.2.3.6 Full Integration of Balancing Energy Markets

The harmonization of imbalance settlement designs, compared to the common merit order list for balancing energy, is only relevant in case different national imbalance settlement designs were still being applied in the common merit order list. In this case, full integration will equalize imbalance pricing, but it depends on the initial design what the effect of that is on imbalance prices. Thus, nothing can be said about the impact of this design on balance planning accuracy.

7.2.3.7 Common Merit Order List for Balancing Energy and Reserve Capacity

Compared to the common merit order list for balancing energy only, this design is expected to establish an even larger reduction in balancing energy prices, and thus in imbalance prices. Consequently, balance planning accuracy will probably decrease, although it may be to a smaller extent than the imbalance price decrease, depending on the costs BRPs are making in the reference design to balance their portfolio (see 7.2.3.1).

7.2.3.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The same things can be said here as under 7.2.3.6 , namely that compared to the last design, full integration will have an impact only compared to a common merit order list that make use of different national imbalance pricing mechanism, and that the impact on balance planning accuracy depends on the nature of these mechanisms. In general, however, the common merit order list present in this design is expected to decrease balance planning accuracy to some unknown degree, just like for the common merit order list for balancing energy and reserve capacity.

7.2.4 Market transparency

7.2.4.1 ACE netting

Three aspects of market transparency are information availability, information symmetry (equal access to information) and clarity of market rules. In case of ACE netting, balancing market designs do not change, and therefore market transparency remains the same.

7.2.4.2 BSP-TSO trading

In this design, BSPs should be notified of the possibilities to bid into the BEM of other control areas, and with the possible detailed bidding and settlement procedure of exchanged balancing energy bids. In the case were the TSO selects the bids that are allowed to bid into external BEMs, clarity of rules could reduce. Information availability could also be low, e.g. when BSPs cannot easily find or understand the market rules of the external BEM. Finally, it is also possible that information availability on external BEMs and/or bid exchange rules is different in different control areas, in which case there is information asymmetry. We conclude that there is a risk of transparency reduction. At minimum, the increasing complexity of market opportunities for BSPs will cause a small transparency reduction due to increased complexity.

7.2.4.3 BSP-TSO trading with Reserve Capacity reservation

The impact of this design on market transparency is the same as for the BSP-TSO trading design. The addition of the market opportunity to exchange RC and corresponding BE bids will lead to additional complexity, information about this opportunity may be hard to find, and the involved control areas could be informed in different degrees of this opportunity. Thus, there will probably be a transparency decrease.

7.2.4.4 Additional Voluntary Pool for Balancing Energy

On the one hand, the additional voluntary pool can be considered as a larger institutional change from the reference design than BSP-TSO trading, because an additional BEM on the regional level is created. On the other hand, it is not the BSPs who exchange the balancing energy bids, which reduces the risk of transparency reduction. However, it is still important for the BSPs to know about the BEE, because it will change the market opportunities, e.g. bids that are exchange could receive a different balancing energy price. We conclude that there is some risk of transparency reduction.

7.2.4.5 Common Merit Order List for Balancing Energy

In first sight, the common merit order list does not appear to make the balancing market functioning more complicated for the market parties. There is still one relevant BEM for them, only it is now a regional instead of a national one. However, the regional BEM will probably be split into multiple BEMs when there is congestion on the borders between the control areas. It is theoretically possible not to do this, but that would create wrong incentives regarding the geographical needs. This BEM splitting feature adds to the complexity of the balancing market design compared to the reference design, but not a lot. Furthermore, the regional BE prices need to be distributed to the different control areas, but this is really essential in this design, and will therefore be addressed. Therefore, the market transparency will probably only slightly reduce, and clearly be better than in the BSP-TSO models.

7.2.4.6 Full Integration of Balancing Energy Markets

Harmonization of balance responsibility and imbalance settlement has, compared to the common merit order list, a transparency increase effect that is relevant for Balance Responsible Parties who are active in multiple control areas. On overall, market transparency will stay the same or increase a little in this design compared with the design in the previous Section.

7.2.4.7 Common Merit Order List for Balancing Energy and Reserve Capacity

Compared to the common merit order list for balancing energy only, this design has no additional effect on transparency compared with the design in 7.2.4.5 .

7.2.4.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The harmonization of balance responsibility imbalance settlement has, compared to the common merit order list for BE and RC, a transparency increase effect that is relevant for BRPs who are active in multiple control areas. Transparency will stay the same or increase a little.

7.2.5 Market liquidity

7.2.5.1 ACE netting

ACE netting will lead to large reductions in the use of balancing energy bids. This will intensify competition in the BEM, if we assume that the presence of balance energy bids that correspond with reserve capacity procurement is so large that the demand reduction is not offset by supply reduction. This increase in competition means an increase in market liquidity.

7.2.5.2 BSP-TSO trading

In this design, BSPs can bid in BEMs of other control areas, but the market liquidity increase for the BEM that receives more bids this way (the BEM of the expensive area) is accompanied by a liquidity decrease in the BEM that now has fewer bids (the BEM of the cheap area). Unless BE bids can be bid into multiple markets at the same time (which is technically hard to realize and creates large uncertainties regarding availability of bids for the TSOs), liquidity appears to remain the same. Perhaps when this design leads to increased BE prices in the cheap area new bidders will be attracted, but in the other area bidders are discouraged as they are outcompeted by the BSPs of the cheap area.

7.2.5.3 BSP-TSO trading with Reserve Capacity reservation

With the same reasoning as in the previous section it is expected that liquidity will stay the same for this design, because each bid will be available for only one of the RCMs / BEMs.

7.2.5.4 Additional Voluntary Pool for Balancing Energy

In the additional voluntary pool, non-used bids are likely to be shared among TSOs, which results in an increased availability of BE bids for all of the control areas. It can be argued that this means an increase of liquidity, even though the number of BSPs has not increased.

7.2.5.5 Common Merit Order List for Balancing Energy

From the perspective of all control areas, availability of BE bids is much larger. In combination with ACE netting, this means a large increase in competition. When we assume that lower prices do not lead a large-scale withdrawal of BE bids, this means that a large increase of market liquidity will occur.

7.2.5.6 Full Integration of Balancing Energy Markets

Compared to the common merit order list for balancing energy, balance responsibility and imbalance settlement rules are harmonized. This does not have an impact on liquidity of balancing service markets. Thus, here too a large increase in market liquidity will occur.

7.2.5.7 Common Merit Order List for Balancing Energy and Reserve Capacity

In this design, there is not only a common merit order list for balancing energy, but also for reserve capacity. Thus, availability of bids will increase for both types of balancing service markets. Therefore, we can say that market liquidity will increase with more certainty than for the common merit order list for BE only.

7.2.5.8 Full Integration of Balancing Energy and Reserve Capacity Markets

Compared to the common merit order list for BE and RC, balance responsibility and imbalance settlement rules are harmonized. This does not have an impact on liquidity of balancing service markets. Thus, here too a large increase in market liquidity will occur (larger than for full integration of balancing energy markets only).

7.2.6 Transaction costs

7.2.6.1 ACE netting

Compared to the reference design, TSOs will combine and redistribute the ACEs. Also, this will require some settlement of the 'surplus' energy exchanged this way. After all, BRPs in the 'short area' on a net basis pay imbalance costs to their TSO, whereas BRPs in the long area receive imbalance costs from their TSO on a net basis. This will create some additional transactions, but not a large number of them. So, transaction costs will increase only slightly and probably only through an initial investment in software upgrading.

7.2.6.2 BSP-TSO trading

If external BE bids are activated, the TSO needs to check whether there is cross-border capacity available for the exchange. If this is the case, the ACEs need to be adapted. If the BEE involves the (temporary) shift of a generation unit to the other control area through a virtual tie-line, this change must be taken into account in the imbalance settlement process. If TSOs are going to install a separate selection and settlement procedure for BEE, the number of transactions will increase further. In the case where bids can be submitted to all BEMs, and must be removed whenever one TSO selects the bid (when possible), the increase in transactions is huge. Most of the costs will lie in developing of procedures and adaptation of software. Once this is tested and working properly, the daily transaction costs for the TSO should not be much higher than in the reference model. However, there are also transaction costs for the participating BSPs, where there needs to be operator interactions to determine the final bids. Overall there is an increase in transaction costs compared with the reference model.

7.2.6.3 BSP-TSO trading with Reserve Capacity reservation

In this design, we assume that the BEE is limited to corresponding exchanged RC bids, which will be much fewer in number. Therefore, the increase in transaction costs in the BEM will be less, compared to BSP-TSO trading. However, there will be additional costs in the RCM, so overall the increase in transaction costs is comparable with 7.2.6.3 .

7.2.6.4 Additional Voluntary Pool for Balancing Energy

In this design, the unused BE bids are put in the additional voluntary pool. Whenever a bid in this pool is selected by a TSO other than the connecting TSO, the ACEs must be adapted, and the bid should be added to the BEM of the reserve receiving TSO. The increase in transaction costs for the TSO is similar to those in BSP-TSO trading. Two differences are that the virtual tie-line concept is not possible in this design, and that the cumbersome option of parallel addition and removal of BE bids in different BEMs does not exist here. Also, there is no increase in transaction costs for the BSPs. We conclude that transaction costs undergo a moderate increase.

7.2.6.5 Common Merit Order List for Balancing Energy

The number of transactions will increase compared to the reference design, because the availability of CBC must be checked for activation of balancing energy bids, and because the splitting of the regional BEM in case of congestions create additional information flows, due to the required coordination between the TSOs. Furthermore, in this design the balancing costs and imbalance costs may need to be redistributed between control areas. Most of the transaction costs are one-time investment costs, All in all, the increase in transaction costs will be higher than in the previous designs.

7.2.6.6 Full Integration of Balancing Energy Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE will not have an impact on transaction costs, so this design has similar transaction costs as in the previous section.

7.2.6.7 Common Merit Order List for Balancing Energy and Reserve Capacity

This design will, in comparison to the common merit order list for BE only, require additional transaction costs for the operation of the common Reserve Capacity Market. Thus, there will be an additional increase in transaction costs for this design.

7.2.6.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC will not have an impact on transaction costs, so this design causes a similar increase in transaction costs.

7.2.7 Allocative efficiency

7.2.7.1 ACE netting

In terms of efficiency of balancing resource utilization, it is much better to utilize the potential of ACE netting, because it reduces both upward regulation in one area and downward regulation in another area. ACE netting therefore results in a large allocative efficiency increase.

7.2.7.2 BSP-TSO trading

Allocative efficiency is about using the cheapest resources available for the system as a whole. From a system perspective, this means looking at the bid prices of all submitted bids in the region. BSP-TSO trading enables the TSOs in expensive areas to activate cheaper resources from neighbouring areas, resulting in an increase in allocative efficiency. On the other hand, BSP-TSO trading may lead to a separation of resources between two markets, resulting in that some resource may stand unused in the “wrong” list as discussed before. It will depend on actual implementation which effect will dominate, so we may conclude that the expected result for allocative efficiency is neutral.

7.2.7.3 BSP-TSO trading with Reserve Capacity reservation
Because the exchange of balancing services in this design is limited due to the need of reservation of cross-border capacity for the exchange of RC bids, this gives more control with which resources are used and how they are used. This will probably lead to a small increase in allocative efficiency.

7.2.7.4 Additional Voluntary Pool for Balancing Energy
Unlike with BSP-TSO trading, the additional voluntary pool results in a large-scale use of cheaper balancing energy bids present in the region, causing a large increase in allocative efficiency.

7.2.7.5 Common Merit Order List for Balancing Energy
The common merit order list both utilizes the potential for ACE netting, as we assumed, and also use the cheapest balancing energy available in the region. Therefore, this design results in a very large increase in allocative efficiency.

7.2.7.6 Full Integration of Balancing Energy Markets
The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE will have no impact on the use of the cheapest available BE bids, and therefore this design also results in a very large increase of allocative efficiency.

7.2.7.7 Common Merit Order List for Balancing Energy and Reserve Capacity
This design leads, compared to the common merit order list for BE only, to the utilization of cheaper RC bids present in other control areas on a larger scale. In addition, the reservation of CBC also enables an even larger exchange of balancing energy bids, and thereby a higher utilization of the cheapest BE bids offered within the region. Thus, allocative efficiency increases utterly.

7.2.7.8 Full Integration of Balancing Energy and Reserve Capacity Markets
The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC will have no impact on the use of the cheapest available BE bids, and therefore the impact of this design on allocative efficiency is similar as for the previous design.

7.2.8 Price efficiency

7.2.8.1 ACE netting
As described in 7.2.5.1 , competition in the BEM is expected to increase to a large extent, due to the large reduction in demand for balancing energy. However, price efficiency will not necessarily increase. If competition in the reference design was already so large that BSP bid at marginal costs, the introduction of ACE netting cannot further increase price efficiency. Since a lack of liquidity and competition is a general problem in balancing service markets, we conclude that price efficiency will increase moderately.

7.2.8.2 BSP-TSO trading

If the BEE is uncontrolled, price efficiency could increase, but also decrease. When the BSPs from the cheap area outcompete the BSPs in the expensive area and the first BSPs increase their bid prices to just below the price level in the expensive BEM, the price efficiency increase in the expensive area will be smaller than the price efficiency decrease in the cheap area. If the BEE is controlled by the TSOs, price efficiency could still decrease for the same reasons, but the TSO control will make sure that this decrease will be limited. However, if bid prices in the involved control areas are of similar level, controlled exchange in both directions can definitely increase price efficiency due to increased competition. Thus, it is concluded that price efficinecy will probably decrease when there is a large difference in BE prices in the different areas, and will increase when there is not.

7.2.8.3 BSP-TSO trading with Reserve Capacity reservation

Because the exchange of RC and BE bids will be limited in this design, the effect on price efficiency will be limited. The direction of the impact could both be positive or negative, to an important part depending on the relative level of BE prices in the different areas (see 7.2.8.2).

7.2.8.4 Additional Voluntary Pool for Balancing Energy

Compared to BSP-TSO trading, the TSO aims to really exchange the bids that are not needed in the own area, which should lead to an overall increase in price efficiency. However, with the same reasoning as in 7.2.8.2 about the change in bidding behaviour of BSPs, overall BEM price efficiency could also decrease, due to profit maximizing bid price increases by BSPs with cheap balancing resources enabled by their larger market opportunities. Therefore, it is not clear whether price efficiency increases or decreases, and not even whether the effect will be large or small, it depends on the competitiveness of the respective markets.

7.2.8.5 Common Merit Order List for Balancing Energy

Similar arguments as for the additional voluntary pool can be given here: The common merit order list will increase competition due to the integration of BEMs, but the BSPs with cheap resources might be getting more arbitrage possibilities. On the other hand, the result of the latter could be that all the more expensive resources will switch to marginal costs bidding, which as a more probable result an overall price efficiency increase. As stated before, a lot also depends on the price efficiency in the initial separate balancing market designs. Due to the execution of ACE netting, the demand for balancing energy will be reduced, and therefore competition is expected to increase with the effect that BSPs will bid closer to their marginal costs. As a result, price efficiency is likely to increase.

7.2.8.6 Full Integration of Balancing Energy Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE will create a level playing field for all BSPs, which indeed is the intention of integration. It can therefore be assumed that price efficiency will increase more than in the previous design.

7.2.8.7 Common Merit Order List for Balancing Energy and Reserve Capacity

Compared to the common merit order list of BE only, in this design the price efficiency of RC bids are also affected as a result of the common merit order list for reserve capacity. Also for the RCM, the same considerations as above apply regarding the effects on BSP bidding behaviour, with an uncertain effect on RCM price efficiency. Apart from the ACE netting, the reservation of CBC also leads to more competition in the BEM. If all BSPs respond by bidding in at marginal costs, and when market concentration was a large problem in the reference design, there will be a very large increase in price efficiency.

7.2.8.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC will have the additional effect of removing remaining obstacles to competition, so price efficiency will increase at least as much as in the previous design.

7.2.9 Price volatility

7.2.9.1 ACE netting

This design really increases the PTU-to-PTU fluctuations of balancing energy prices, because ACE netting is possible only when the control area imbalances are in opposite direction. The effect is price reductions when netting is effective, and not otherwise. Intuitively one might conclude that this leads to increased volatility, but calculations of standard deviation in simple model do not confirm this. It can therefore be concluded that price volatility will not change very much.

7.2.9.2 BSP-TSO trading

BSP-TSO trading could increase or decrease BEM price efficiency, depending on the relative BE price level in the reference design. If price efficiency increases, more bidders will bid in at marginal costs. This will reduce price volatility, because the bid ladder becomes flatter and because the bid ladder curve will fluctuate less due to the stabler bid strategies. We conclude that price volatility may either increase or reduce depending on relative BE price levels in the involved areas, just like price efficiency.

7.2.9.3 BSP-TSO trading with Reserve Capacity reservation

Because this design has a small but uncertain effect on BE and RC price efficiency (depending on original price levels and competition and potential for balancing service exchange), the effect on price volatility is also small and uncertain.

7.2.9.4 Additional Voluntary Pool for Balancing Energy

It is not clear whether BE price efficiency will increase or decrease due to the implementation of this design (see 7.2.8.4), and therefore it is not clear whether BE price volatility will increase or decrease.

7.2.9.5 Common Merit Order List for Balancing Energy
As stated in 7.2.8.5 , BE price efficiency is expected to increase due to the large increase in competitiveness. The effect on volatility is ambiguous, because it depends on the competitiveness of the respective markets and the previous bidding behaviour of the BSPs. Also the increasaed competition may lead to withdrawal of bids, leading to a more frequent activation of high-priced bids. But unless the BSPs kept more or less the same (high) price before the change of market design, there should be a decrease in volatility.

7.2.9.6 Full Integration of Balancing Energy Markets
The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE has no clear impact on BE price efficiency. Therefore BE price volatility is expected to be reduced, just like for the common merit order list for BE.

7.2.9.7 Common Merit Order List for Balancing Energy and Reserve Capacity
This is design was concluded to have a significant increase in BE and RC price efficiency. Like in 7.2.9.5 there will probably also be a reduction in price volatility.

7.2.9.8 Full Integration of Balancing Energy and Reserve Capacity Markets
The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC will have no clear additional impact on price volatility, so this design will cause a similar decrease in volatility as the common merit order list for BE & RC.

7.2.10 Efficiency of cross-border capacity allocation

7.2.10.1 ACE netting
The performance criterion “efficiency of cross-border capacity allocation” is about the economic value of the chosen distribution of cross-border capacity between cross-border balancing and conventional cross-border trade, compared to the economic value of the situation without cross-border balancing in the reference design. ACE netting does not effectuate a change in this distribution compared to the reference design, because no reservation of CBC takes place. ACE netting does prevent the surplus energy flowing from the ”long” area to the ”short” area, which might reduce the possibilities for cross-border intraday trade in the next PTU(s), but such surplus energy flows will mostly be covered by the Transmission Reliability Margin. Therefore, this design has no effect on this performance criterion.

7.2.10.2 BSP-TSO trading
For this design, the BSP-TSO trading of balancing energy requires cross-border capacity. It is not likely that BSPs will be required to purchase CBC, for that is almost certainly unprofitable for them. If they are nevertheless required to do so, the physical utilization of the CBC may reduce, but the economic efficiency of the allocation will not, as the BSPs will only do this when it is worthwhile. If the TSO reserves CBC to enable BEE on a large scale, they will miss the capacity auction revenues for that capacity. Also, that capacity will only generate economic value if can really be traded, which

depends on the need for upward/downward regulation in the two control areas. Thus, in this case it is likely that the efficiency of allocation will reduce, although a very large difference between BE prices in both areas might make the CBC reservation pay off. Finally, and most probable, only remaining CBC will be made available for BEE, in which case the efficiency of allocation will definitely increase. The size of the increase depends on the volumes of remaining CBC and the BE price differences. It is concluded that the efficiency of CBC allocation will significantly increase, given that remaining CBC is used.

7.2.10.3 BSP-TSO trading with Reserve Capacity reservation

The RCE in this design requires CBC reservation. It is still unlikely that BSPs will buy CBC with the intention to bid into the other RCM, because there is no guarantee that he will be selected (in the RCM, and later on in the BEM). However, it may be the case that BSPs who have bought the CBC already will, in case of a daily RCM with a closure time right after the day-ahead market closure time (which came out as the optimal sequence of markets, see [28]), bid into the RCM whenever their cross-border day-ahead bid was not selected. BSPs are likely to do this when the only two alternatives are the cross-border intraday market (which clears several times on the day of delivery) and losing the CBC to the TSO (application of the ”use-it-or-lose-it-principle”). In this case, the balancing service exchange competes with cross-border intraday trade, but it can be expected that the profit-maximization goal of the BSPs will lead here to an economically optimal distribution. Because it remains doubtful that a lot of balancing service exchange will materialize in this case, the efficiency of CBC allocation is expected to improve slightly in this case. However, CBC reservation by the TSO for balancing service exchange will probably bring about a decrease of efficiency of CBC allocation, even if the reserved volume is carefully dimensioned.

7.2.10.4 Additional Voluntary Pool for Balancing Energy

If remaining CBC is used for balancing energy exchange of unused BE bids, efficiency of CBC allocation will increase compared to the reference design of separate balancing markets without balancing service exchange. If TSOs reserve CBC for the purpose of BEE and this goes at the expense of conventional cross-border trade, this will probably lead to a reduction of the efficiency of CBC allocation.

7.2.10.5 Common Merit Order List for Balancing Energy

If remaining CBC is treated as a constraint in the regional economic optimization of real-time system balancing, an increase in efficiency of CBC allocation will occur. The exact size of this increase depends on the remaining CBC available and the actual utilization of cross-border resources. If the TSO would reserve CBC to facilitate the BEE, the efficiency of CBC allocation will probably reduce.

7.2.10.6 Full Integration of Balancing Energy Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE has no clear additional impact on the efficiency of CBC allocation, so for this design it is also concluded that this performance criterion will increase when remaining CBC is used for the BEE.

7.2.10.7 Common Merit Order List for BE and RC

The reservation of CBC in this design for enabling the common merit order list of RCE reduces the CBC available for conventional cross-border trade. However, efficiency of CBC allocation could increase, because the reserve capacity prices can reduce significantly due to RCE and possible reserve volume reduction, and because the availability of CBC will enable a significant reduction of BE prices due to BEE (if price differences are large, or if there was a serious lack of competition in BEMs). Here too it is very well possible that the gained value for the balancing service markets is not offset by the lost value for cross-border day-ahead and intraday markets; the higher ambition and impact of this design does not change that. Thus, we expect the efficiency of CBC allocation will reduce – however, there will be exceptions on this conclusion.

7.2.10.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC has no additional effect on the efficiency of CBC allocation, and therefore it is concluded here as well that this performance criterion will reduce.

7.2.11 Dynamic efficiency

Dynamic efficiency is about the existence of incentives to develop innovative solutions that are cheaper and/or result in higher system security in the long run. This criterion is one of the hardest to evaluate, but flexibility and openness to new participants can be potential indicators. In general, designs that give the correct price signals and that are open to the demand side are more dynamically efficient than those that only focus on improving the operation of existing markets. Other factors than those related to market integration probably have a much larger impact on this criterion.

7.2.11.1 ACE netting

ACE netting does not change anything fundamentally with the design of the markets, at least not those aspects that are related to BRPs and BSPs. One might argue that lower prices result in reduced incentives for innovative solutions, but this effect will hardly be large. The effect on dynamic efficiency is therefore neutral.

7.2.11.2 BSP-TSO trading

With BSP-TSO trading, TSOs aim to reduce the cost of balancing by cooperation with existing BSPs in other Control Areas, mainly using existing mechanisms, although these must be adapted. This can be seen as “more of the same” instead of opening up for other solutions like e.g. increased demand participation. We assume that this can have a moderately negative impact on dynamic efficiency.

7.2.11.3 BSP-TSO trading with Reserve Capacity reservation

The arguments for this model are very similar to those of the previous one, with a moderately negative impact on dynamic efficiency.

7.2.11.4 Additional Voluntary Pool for Balancing Energy

This model is about a better cooperation on the use of resources between the TSOs. The effect on prices may result in some changes in the incentives to develop other solutions, but overall the effects are probably too small to make an observable difference on this criterion. Like ACE netting, the effect on dynamic efficiency is therefore neutral.

7.2.11.5 Common Merit Order List for Balancing Energy

A common merit order list for BE changes the market more fundamentally then the previous options. The effect on prices differs between the importing and exporting markets, and depends on how homogeneous the markets are with respect to generation mix and other characteristics. However, the dynamics of increased competition and possible price effects in beforehand low priced markets may indicate some increase in dynamic efficiency.

7.2.11.6 Full Integration of Balancing Energy Markets

Full integration of BEMs creates a level playing field with more transparency, making it easier for new entrants to enter the market. The effect on dynamic efficiency may therefore be somewhat higher than for the design in the previous Section.

7.2.11.7 Common Merit Order List for BE and RC

The effect of also sharing the RC market creates additional opportunities for new entrants and new solutions, that may be assumed to increase dynamic efficiency compared with the design in Section 7.2.11.5 .

7.2.11.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The same can be said as in Section 7.2.11.6 , which means that this design probably gives the highest increase to dynamic efficiency.

7.2.12 Minimum reserve requirement

7.2.12.1 ACE netting

This design does not enable the reduction of minimum reserve requirements for secondary and tertiary control, because ACE netting is only possible in about half of the PTUs, and it is not predictable when and to what extent surplus energy exchanges occur. As control areas cannot rely on ACE netting for real-time system balancing, the original reserve requirements need to be maintained.

7.2.12.2 BSP-TSO trading

TSOs cannot rely on the availability of balancing energy bids from other areas, even when they reserve CBC themselves, because it is still uncertain whether BSPs bid into their markets and/or whether enough BE bids are submitted to enable any BEE in the first place. Thus, the original minimum reserve requirements should be maintained.

7.2.12.3 BSP-TSO trading with Reserve Capacity reservation

In this design too, the TSO cannot rely on the availability of balancing services from other control areas, even if ample cross-border capacity is reserved for this purpose, because it is still the BSPs who decide in which balancing service market to bid. Thus, the original minimum reserve requirements should be maintained.

7.2.12.4 Additional Voluntary Pool for Balancing Energy

If there is no CBC reservation by the TSOs, the TSOs cannot rely on external balancing services to enable a reserve requirement reduction. If sufficient CBC is reserved, and the reliability of its actual availability in real-time is close enough to hundred percent, it is possible to reduce the reserve requirements, but TSOs need to be sure then of the availability of unused bids of other areas in the additional voluntary pool.

7.2.12.5 Common Merit Order List for Balancing Energy

If there is no CBC reservation by the TSOs, the TSOs cannot rely on external balancing services to enable a reserve requirement reduction. If sufficient CBC is reserved, and the reliability of its actual availability in real-time is close enough to hundred percent, it is possible to reduce the reserve requirements. The single, regional buyer of balancing energy in the common merit order has access to all BE bids and can resolve all area imbalances, as long as the reserve requirement – CBC reservation volume combination is such that balancing energy market effectiveness does not reduce for either of the involved control areas.

7.2.12.6 Full Integration of Balancing Energy Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE will not have an additional impact on the minimum reserve requirement, so for this design too it is concluded that the minimum reserve requirements can only reduce to the extent that ample CBC is reserved to guarantee the availability of balancing energy for system balance restoration.

7.2.12.7 Common Merit Order List for BE and RC

In this design, CBC is always reserved, because this is a prerequisite for a common merit order list for reserve capacity. This reservation allows for the reduction of the minimum reserve requirement, as long as this reduction is such that the availability of balancing energy bids for system balance restoration can still be guaranteed for all control areas to a similar degree. A challenge is to determine the division of reserves between Control Areas.

7.2.12.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC has no additional impact on the minimum reserve requirements, thus here too it is concluded that these requirements can be reduced as long as balancing energy market effectiveness is not damaged due to reduced availability of balancing services.

7.2.13 Non-discrimination

7.2.13.1 ACE netting

This design is non-discriminatory in nature, because the occurrence of a system shortage in area A in combination with a system surplus in area B will resemble the occurrence of the opposite. Furthermore, this arrangement creates no new opportunities for BSPs, so discrimination issues do not play a role here. Thus, the level of non-discrimination remains the same after introduction of this design.

7.2.13.2 BSP-TSO trading

With BSP-TSO trading, first of all it is possible that there are still such differences in balancing service market rules, that there are unequal opportunities for BSPs in the different control areas to offer their BE bids in other areas. Furthermore, uncontrolled BEE is likely to create much more benefits for BSPs in the cheap areas and for the BRPs in the expensive areas than for the BSPs in the expensive area and the BRPs in the cheap area, if BE prices and imbalance prices increase in the cheap area disproportionally compared to the price decrease in the expensive areas. TSO-controlled BEE can mitigate such effects, but it is unlikely that it will completely resolve this phenomenon. A final issue is the distinction between the BSPs who and those who are not allowed or able to participate in the export of balancing services. For several reasons it may not be possible to base this fully on market criteria. Thus, this design is expected to have a negative effect on non-discrimination.

7.2.13.3 BSP-TSO trading with Reserve Capacity reservation

As with BSP-TSO trading for balancing energy, it could be that balancing market designs are still so different that unequal balancing service exchange opportunities exist for BSPs of different control areas, and it is also very well possible that balancing service exchange will create more benefits for BSPs in the cheap areas and for the BRPs in the expensive areas than for the BSPs in the expensive area and the BRPs in the cheap area. However, the potential for service exchange is more limited for this design, so the expected infect on non-discrimination is probably smaller.

7.2.13.4 Additional Voluntary Pool for Balancing Energy

Because here the TSOs decide on balancing energy exchange, the described unfair distribution of costs and benefits between BSPs and BRPs of different control areas for the design of BSP-TSO trading will take place to a much smaller degree. It may still take place, however, when there is a large price difference between control areas, e.g. when the non-used bids are put in the AVP, and BSPs try to end up in this pool in order to gain a higher BE price by bidding in at a higher price within their own area. Perhaps a careful detailed design could prevent this. For now, it is concluded that this design will limitedly damage non-discrimination. After all, in the reference design, there are no discrimination issues between the control areas due to the absence of balancing service exchange.

7.2.13.5 Common Merit Order List for Balancing Energy

In the common merit order list, all balancing service market rules should be harmonized, and balancing service exchange should be executed in an objective, economically optimal way. BSPs will have less possibilities to bid strategically, like indicated by the example in 7.2.13.4 for the additional voluntary pool. More probable is that they will bid in at marginal costs, due to increased competition. In general, it is of course still very well possible that some areas / market parties will benefit more from the implementation of this design that others, but this will be a ”natural” welfare shift inherent to market integration, not adverse welfare shifts caused by unequal arbitrage possibilities. For the region as a whole, non-discrimination is not expected to decrease, because the same balancing service market rules and opportunities apply to all control areas and BSPs.

7.2.13.6 Full Integration of Balancing Energy Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE will improve non-discrimination, because BRPs in different areas will also be faced with the same rules, which creates a level-playing field in the entire region. This prevents market parties with both the BSP and BRP role who work in multiple control areas from being subject to the same BE price but to different imbalance prices in different areas, which could create adverse incentives to some areas / market parties. Thus, non-discrimination will improve.

7.2.13.7 Common Merit Order List for BE and RC

The same argumentations apply to this design as to the design of the common merit order list for BE only (see 7.2.13.5). The common merit order list for reserve capacity requires harmonization of RCM rules, but because the reference design did not include the possibility for RCE, non-discrimination does not change. The same holds for the BEM and balancing energy exchange.

7.2.13.8 Full Integration of Balancing Energy and Reserve Capacity Markets

The additional harmonization of balance responsibility and imbalance settlement compared to the common merit order list for BE and RC will improve non-discrimination significantly, because it creates a level-playing field for Balance Responsible Parties. This prevents market parties with both the BSP and BRP role who work in multiple control areas from being subject to the same BE price but to different imbalance prices in different areas, which could create adverse incentives to some areas / market parties.

7.3 WRAP-UP OF EVALUATION

A summing up of the evaluations is given in Table 7-1. The use of the adjectives is to be understood in the following way:

- small < (no adjective) < large < very large
- the word “neutral” may mean that there is no effect or that there are several effects that work in opposite directions.

Table 7-1: Overview of in-depth evaluation of the eight multinational balancing market designs

	1. ACE netting	2. BSP-TSO trading
Reserve capacity markets effectiveness	Neutral	Uncontrolled exchange: reduction Exchange controlled by TSOs: small reduction
Balancing energy markets effectiveness	Large increase	Uncontrolled exchange: large reduction Exchange controlled by TSOs: small reduction
Balance planning accuracy	Possible reduction (depending on original BRP costs of balancing)	Uncontrolled exchange: increase Exchange controlled by TSOs: reduction
Market transparency	Neutral	Small – large reduction
Market liquidity	Increase	Neutral
Transaction costs	Small increase	Increase
Allocative efficiency	Large increase	Neutral
Price efficiency	Moderate increase	Large BE price difference: reduction No large BE price difference: increase
Price volatility	Possibly some increase	Large BE price difference: increase No large BE price difference: reduction
Efficiency of cross-border capacity allocation	Neutral	Use of remaining CBC: increase Reservation CBC by BSPs: small increase Reservation CBC by TSO: reduction
Dynamic efficiency	Neutral	Small reduction
Minimum reserve requirement	Neutral	Neutral
Non-discrimination	Neutral	Reduction

Table 7-1: Overview of in-depth evaluation of the eight multinational balancing market designs

	3. BSP-TSO trading with Reserve Capacity reservation	4. Additional Voluntary Pool for Balancing Energy
Reserve capacity markets effectiveness	Possibly small reduction	Neutral
Balancing energy markets effectiveness	Uncontrolled exchange: small reduction Exchange controlled by TSOs: very small increase	Increase
Balance planning accuracy	Uncontrolled exchange: small increase Exchange controlled by TSOs: small reduction	Possible reduction (depending on original BRP costs of balancing)
Market transparency	Large risk of reduction	Risk of reduction
Market liquidity	Neutral	Increase
Transaction costs	Small increase	Increase
Allocative efficiency	Small increase	Large increase
Price efficiency	Large BE price difference: small reduction No large BE price difference: small increase	Unclear effect
Price volatility	Small and uncertain effect	Unclear effect
Efficiency of cross-border capacity allocation	Reservation CBC by BSPs: small increase Reservation CBC by TSO: reduction	Use of remaining CBC: large increase Reservation CBC by TSO: reduction
Dynamic efficiency	Small reduction	Neutral
Minimum reserve requirement	Neutral	Reduction is possible (if availability of external services can be guaranteed)
Non-discrimination	Small reduction	Limited reduction

Table 7-1: Overview of in-depth evaluation of the eight multinational balancing market designs

	5. Common Merit Order List for Balancing Energy	6. Full Integration of Balancing Energy Markets
Reserve capacity markets effectiveness	Neutral	Neutral
Balancing energy markets effectiveness	Increase	Increase
Balance planning accuracy	Reduction (size depends on original BRP costs of balancing)	Reduction (size depends on original BRP costs and on initial imbalance pricing mechanisms)
Market transparency	Neutral – small reduction	Neutral – small reduction
Market liquidity	Large increase	Large increase
Transaction costs	Large increase	Large increase
Allocative efficiency	Very large increase	Very large increase
Price efficiency	Large increase	Large increase
Price volatility	Reduction	Large reduction
Efficiency of cross-border capacity allocation	Use of remaining CBC: large increase Reservation CBC by TSO: reduction	Use of remaining CBC: large increase Reservation CBC by TSO: reduction
Dynamic efficiency	Small increase	Increase
Minimum reserve requirement	Reduction is possible (if availability of external services can be guaranteed)	Reduction is possible (if availability of external services can be guaranteed)
Non-discrimination	No significant effect	Large increase

Table 7-1: Overview of in-depth evaluation of the eight multinational balancing market designs

	7. Common Merit Order List for Balancing Energy and Reserve Capacity	8. Full Integration of Balancing Energy and Reserve Capacity Markets
Reserve capacity markets effectiveness	Small increase	Small reduction
Balancing energy markets effectiveness	Increase	Increase
Balance planning accuracy	Reduction (size depends on original BRP costs of balancing)	Reduction (size depends on original BRP costs and on initial imbalance pricing mechanisms)
Market transparency	Neutral – small reduction	Neutral – small reduction
Market liquidity	Large – very large increase	Large – very large increase
Transaction costs	Very large increase	Very large increase
Allocative efficiency	Very large increase	Very large increase
Price efficiency	Large – very large increase	Very large increase
Price volatility	Large reduction	Large reduction
Efficiency of cross-border capacity allocation	Reduction	Reduction
Dynamic efficiency	Increase	Increase
Minimum reserve requirement	Reduction is possible (if availability of external services can be guaranteed)	Reduction is possible (if availability of external services can be guaranteed)
Non-discrimination	No significant effect	Large increase

In order to form overall conclusions about the value of the eight different multinational balancing market designs, first the relative importance of and the desired effects on the performance criteria must be considered. Both are listed in Table 7-2.

Table 7-2: Importance and desired effects performance criteria

	Importance	**Desired effect**
Reserve capacity markets effectiveness	High	Maximize
Balancing energy markets effectiveness	High	Maximize
Balance planning accuracy	Moderate	Maximize
Market transparency	Moderate	Maximize
Market liquidity	Moderate	Maximize
Transaction costs	Low	Minimize
Allocative efficiency	High	Maximize
Price efficiency	High	Maximize
Price volatility	Low	Minimize
Efficiency of cross-border capacity allocation	Moderate	Maximize
Dynamic efficiency	Moderate	Maximize
Minimum reserve requirement	Moderate	Minimize (without reducing security of supply)
Non-discrimination	Moderate	Maximize

For coming up with an end evaluation for each of the designs, performance criteria and effects should be weighed. We have done the following:

- Weighing performance criteria with importance ”high” with a weight of 3, ”moderate” with a weight of 2, and ”low” with a weight of 1.
- If the desired effect is ”maximize”: A very large increase of a performance criterion is valued with ”4”, a large increase is valued ”3”, a (moderate) increase is valued ”2”, a small increase is valued ”1”, a small decrease is valued ”-1”, a (moderate) decrease is value ”-2”, a large decrease is valued ”-3”, and a very large decrease is valued ”-4”.
- If the desired effect is ”minimize”: The effects are valued in the exact opposite way as for ”maximize”

Further assumptions for the end valuation:

- For the designs about BSP-TSO trading, the balancing service exchange is assumed to be controlled by the TSOs.
- For the designs without RCE, no CBC is assumed to be reserved for balancing purposes
- It is assumed that a large BE price difference exists between the different control areas in the balancing region
- For BSP-TSO trading with RC reservation, CBC is assumed to be reserved by the BSPs. (For the common merit order list for BE and RC, the reserve capacity is reserved by the TSO)

In Table 7-3, the end evaluations of the eight designs are calculated, given the above valuation rules, weights, and assumptions.

Table 7-3: Importance and desired effects performance criteria

	Wgt	ACE netting		BSP-TSO trading		BSP-TSO trading with RC reservation		Additional Voluntary Pool for BE		Common merit order list for BE		Full integration of BEMs		Common merit order list for BE and RC		Full integration of BEMs and RCMs	
		value	prod.	value	prod.	value	prod.	value	prod.	value	prod.	value	prod.	value	prod.	value	prod.
Reserve capacity markets effectiveness	*3*	0	0	0	0	-1	-3	0	0	0	0	0	0	1	3	1	3
Balancing energy markets effectiveness	*3*	3	9	-1	-3	0	0	2	6	2	6	2	6	2	6	2	6
Balance planning accuracy	*2*	-2	-4	-2	-4	-1	-2	-2	-4	-2	-4	-2	-4	-2	-4	-2	-4
Market transparency	*2*	0	0	-2	-4	-3	-6	-1	-2	-0.5	-1	-0.5	-1	-0.5	-1	-0.5	-1
Market liquidity	*2*	2	4	0	0	0	0	2	4	3	6	3	6	3.5	7	3.5	7
Transaction costs	*1*	-1	-1	-1	-1	-2	-2	-1	-1	-3	-3	-3	-3	-4	-4	-4	-4
Allocative efficiency	*3*	3	9	3	9	1	3	3	9	4	12	4	12	4	12	4	12
Price efficiency	*3*	2	6	-2	-6	-1	-3	0	0	3	9	3	9	3.5	10.5	4	12
Price volatility	*1*	-1	-1	-2	-2	0	0	0	0	1	1	2	2	1	1	2	2
Efficiency of X-border capacity allocation	*2*	0	0	2	4	1	2	3	6	3	6	3	6	-2	-4	-2	-4
Dynamic efficiency	*2*	0	0	-1	-2	-1	-2	0	0	1	2	2	4	2	4	2	4
Minimum reserve requirement	*3*	0	0	0	0	0	0	2	6	2	6	2	6	2	6	2	6
Non-discrimination	*2*	0	0	-2	-4	-1	-2	-2	-4	0	0	3	6	0	0	3	6
Total			**22**		**-13**		**-15**		**20**		**40**		**49**		**36.5**		**45**

Orange = maximize; Blue = minimize

Table 7-3 shows that the designs “BSP-TSO trading” and “BSP-TSO trading with RC reservation” have negative total sums. This means that with the weights we have used and our evaluation of the impact on the criteria, these designs result in a negative overall impact, compared with the reference situation without interaction between reserve markets. Major causes for this result are a reduction of the effectiveness of the BE and RC markets, a reduction in balancing planning accuracy, a reduction in price efficiency because BSPs must divide their resources between two markets and a possible decrease in dynamic efficiency. Although many of these factors will depend on the situation before cooperation starts and it will be possible to mitigate some of the negative effects by various counter measures, BSP-TSO trading does not appear to be an attractive design from the overall perspective of well-functioning international balancing markets. It may however be a short term option as a first step towards further cooperation particularly in the case of the Nordic system to create incentives for investments in AGC.

ACE netting on the other hand has many positive effects, particularly on the effectiveness of the BEM, allocative efficiency and price efficiency. Compared with the other alternatives, the transaction costs are also quite low. Clearly, where possible it should be attempted to realize ACE netting. A possible challenge that has not been discussed so far because it is not directly related to our criteria (maybe with the exception of Non-discrimination) is the distribution of the profits. In the case of two systems with large differences between their balancing costs and an elastic supply in the low cost area, the benefits will mainly occur in the high cost area. BSPs in the exporting area will feel that they contribute to balancing in the other area without getting paid (although this is not really true). There may be an issue of redistribution of the benefits by e.g. a form of counter payments from the high price area.

The Additional Voluntary Pool for Balancing Energy has similar benefits as ACE netting. The major benefits come from an increased effectiveness of the BEM, increased market liquidity and allocative efficiency and a more efficient use of cross-border capacity by actively utilizing unused capacity for balancing purposes.

It should be noted that our weighting and value assignments by no means are linear – they only aim to quantify the qualitative evaluations for each criterion. From this analysis it is correct to conclude that both ACE netting and the Additional Voluntary Pool improve the overall design of the balancing markets, but which one is “best” is hard to say from our analysis, and will anyway strongly depend on the specific situation. Importantly, ACE netting can be realized simultaneously with an Additional Voluntary Pool, realizing the benefits of both designs.

The Common Merit Order List for Balancing Energy appears to have significant advantages particularly with respect to the effectiveness of the BEM, market liquidity, allocative and price efficiency, efficiency of cross border capacity allocation and possibly reduced total reserve requirements. On the negative side balancing planning accuracy may be negatively impacted (because of lower prices) and the transaction costs are high – although most of these costs are one-time investments. In [29] an estimate is made of the cost savings of a design that is comparable with a Common Pool for Balancing Energy for the Nordic, German and Dutch markets, using a cost-minimizing framework. This analysis indicates annual savings between 35 and 40 million Euros, depending on the hydrological situation. It may be assumed that the real savings are larger because of the effect of more competition in the German balancing market. We have not made an attempt to estimate the transaction costs.

Full Integration of BEMs yields additional advantages of reduced price volatility, increased dynamic efficiency and a more level playing field, and is the “best” design according to this analysis.

Common Merit Order Lists for both Reserve Capacity and Balancing Energy do not appear to increase the overall merit of the balancing markets. The reason is that although the effectiveness of the RCM, market liquidity and price efficiency increase, costs also increase and especially the efficiency of the cross-border capacity allocation may be severely reduced because capacity is used for balancing instead of economic exchange. It is important to point out that this is not necessarily a general conclusion, the specific result will heavily depend on the system and market characteristics of the cooperating systems. But there is a considerable danger that this design will impact the utilization of cross border capacity negatively.

Finally, Full Integration of both RCMs and BEMs improves the situation for similar reasons as for the Full Integration of the BEMs only.

8 SUMMING UP AND CONCLUSIONS

The subject of this report is the design of Balancing Markets. In the context of this report Balancing Markets are restricted to mean markets for Secondary and Tertiary Control Reserves as defined by ENTSO-E Policy 1. The main focus is on multi-national Balancing Markets or rather, markets that cover two or more Control Areas.

Chapter 4.1 describes the major design variables that define the Balancing Market in a single Control Area. The rationale behind this is that a multi Control Area Balancing Market is defined by the design in each of the cooperating Control Areas as well as the interaction between them. The variables in Chapter 4.1 are divided in three groups related to balance responsibility, balancing service provision and balance settlement. Together the design variables define a multi-dimensional design space – each specific design will be situated somewhere in this design space. Although there always will be details that are not caught by theses design variables, the intention is that these design variables more or less unambiguously define a specific design of a Balancing Market. This is one of the new contributions of this report.

In Chapter 4.2 we continue with defining the variables that define the interaction for multi Control Areas Balancing Management. The idea behind this is that even though the variables defined in 4.1 define the Balancing Markets in each of the Control Areas, there are still many options for the cooperation between their Balancing Markets. Therefore these variables are also called the "Design defining variables for Multi Control Area Balancing Markets." These variables are:

- Market arrangements for Balancing Energy Exchange
- Type of Exchanged Balancing Energy
- Market arrangements for Reserve Capacity Markets
- Reservation of Cross Border Interconnection Capacity for Balancing
- Definition of Balancing Regions

The definition of the Design defining variables for Multi Control Area Balancing Markets is the second important new contribution of this report.

The central variables are the Market arrangements for Balancing Energy Exchange and the Market Arrangements for Reserve Capacity Markets.

Market arrangements for Balancing Energy Exchange are:

- None
- Area Control Error (ACE) netting
  (imbalance netting in the case of non-synchronous Control Areas)
- BSP-TSO trading
- Additional Voluntary Pool
- Common Merit Order List
- Full Integration

The same arrangements are defined for Reserve Capacity Markets, apart from ACE netting, which by definition is related to Balancing Energy.

In theory, all combinations of these market arrangements are possible, but in practice the arrangements for Balancing Energy Exchange will be of a higher level than those for Reserve Capacity. It makes no sense to have full integration of Reserve Capacity Markets but no integration of the Balancing Energy Markets.

Proposals for the most relevant combinations of these market design variables are given in Chapter 5. The eight identified designs are:

1. ACE netting or in the case of non-synchronous systems imbalance netting. Control Areas agree on netting opposite sign ACE or imbalance deviations. This will affect the planned exchange between the areas, but from a frequency point of view regulating the same volume upward and downward within the same system has no net effect. This is a cheap way of reducing balancing costs in both Control Areas

2. BSP-TSO trading. This means that the TSO in one Control Area (the reserve receiving area) buys balancing energy from a Balancing Service Provider in the other area (the reserve connecting area).

3. BSP-TSO trading with Reserve Capacity Exchange. In addition to BSP-TSO trading this design model also includes the trading of Reserve Capacity between a Balancing Service Provider in one Control Area and a TSO in another Control Area.

4. Additional Voluntary Pool for Balancing Energy. In this case TSOs of different Control Areas agree on sharing some of their resources in a common pool.

5. Common Merit Order List for Balancing Energy. In comparison with the previous design all balancing resources are shared between the cooperating TSOs in a common Merit Order List.

6. Full Integration of Balancing Energy Markets. In this case also all other design variables are harmonized to create a fully level playing field for all market actors.

7. Common Merit Order List for Balancing Energy and Reserve Capacity. In this design the TSOs share the common resources in their systems both in the Reserve Capacity and the Balancing Energy Markets. Obviously, available transmission capacity and reservation of this becomes a major issue.

8. Full Integration of Balancing Energy and Reserve Capacity Markets. In this final and most comprehensive design, the cooperating markets are fully integrated and harmonized.

This classification of Multi Control Area Balancing Markets is another major contribution.

Subsequently Chapter 6 defines performance criteria for the evaluation of the various market designs, while Chapter 7 uses these criteria for an actual evaluation. Unfortunately it is hard to quantify the performance criteria for a specific market design. Ongoing work within the project will probably enable us to quantify some of the criteria related to price behaviour, but at this stage we have used a judgement based scoring system, ranging from -4 for a very inadvertent impact on the criterion to +4 for a very favourable impact. Moreover, the criteria are weighted from 1 for less important to 3 for the most important criteria.

Using this approach, the evaluation of the various designs concludes:

- The designs with BSP-TSO trading end up with a negative value from the evaluation, which means that implementation reduces overall balancing market performance. Major causes for this result are a reduction of the effectiveness of the Balancing Energy and Reserve Capacity markets, a reduction in balancing planning accuracy, a reduction in price efficiency because Balancing Service Providers must divide their resources between two markets and a possible decrease in dynamic efficiency. Although it is possible to mitigate the negative effects in various ways, there is a considerable danger of a negative overall impact. However, in the particular case of exchange between the Nordic and the CWE systems, this model may be relevant in a transitional period to create incentives for investment in AGC, which is presently not used in the Nordic system.
- All other designs have a positive value, which mean their introduction will result in an overall improvement of balancing market performance.
- The four designs that include a common merit order list (the last four designs) come out with the highest values from the evaluation. The difference between them is not large, because harmonization of balance responsibility and imbalance settlement does not lead to a different effect for most performance criteria. Moreover, the reservation of Cross Border Capacity in case of a common merit order list for both Reserve Capacity and Balancing Energy will increase allocative efficiency and price efficiency, but reduces efficiency of Cross Border Capacity allocation.

The recommended balancing market integration process is a first step of introduction of ACE netting, and then a large step to the introduction of the common merit order list for Balancing Energy. However, the installation of an additional voluntary pool as an intermediate pool appears a favourable option, because ACE netting can be continued.

Finally, it must be remarked in general that different initial balancing market designs and different power system and market conditions can significantly change the results of this qualitative assessment of multinational balancing market designs, of which the importance of the choice for reservation of Cross Border Capacity, the relative level of Balancing Energy price and initial competitiveness in balancing service markets for the evaluation of the designs provides proof. Therefore, each specific balancing market integration project requires a dedicated analysis. However, the analyses strongly suggest that a positive value of ACE netting and the common merit order list for Balancing Energy will generally remain, and that the latter will remain to be the most beneficial option in the long run.

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