A comparison of imbalance settlement designs and results of Germany and the Netherlands

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Abstract—Imbalance settlement is a vital part of the balancing market, i.e. the institutional arrangement that establishes market-based balance management in liberalized electricity markets. We investigate the impact of the imbalance settlement design on the behaviour of Balance Responsible Parties and thereby on balancing market performance by means of a comparison of the German and Dutch imbalance settlement designs and balancing market results for the period May-December 2009. It is found that Germany has much higher activated balancing energy volumes, imbalance prices and actual BRP cost levels than the Netherlands, but these differences are perhaps rather caused by balancing energy market design differences and differences in intermittent generation shares than by imbalance settlement design differences. The real-time publication of balance regulation in the Netherlands enables internal balancing by BRPs, which may reduce the size of system imbalances. Generally, BRPs will over-contract a little, because of the lower risk of having a negative individual imbalance and because of the evening out of imbalance costs over a longer time period.

Index Terms—balancing market, imbalance settlement, Balance Responsible Parties (BRPs)

I. Introduction

In liberalized electricity markets, the power system service of balancing electricity supply and demand (balance management) is not only carried out by the Transmission System Operator (TSO), but also by the market parties. We define a 'balancing market' as the institutional arrangement that establishes market-based balance management in electricity power systems, and that consists of three main pillars: balance responsibility, balancing service provision, and imbalance settlement. In balancing service provision, balancing services are offered by the market to the TSO in the form of bids, who activates the bids in price order to

resolve the real-time system imbalance. Balance responsibility and imbalance settlement are closely related. The first defines the role of the Balance Responsible Party (BRP), which is a market party that has a responsibility for balancing a portfolio of generation and/or consumption connection connections. This responsibility takes form by the obligation to submit production/consumption/trade schedules, or 'energy programs', to the TSO, and to be financially accountable for deviations from those programs. Imbalance settlement is concerned with the determination of the deviations, or 'individual imbalances', and of the imbalance prices that the BRPs must pay for each megawatthour (MWh) of deviation. The paper focuses on imbalance settlement.

Earlier study of different (mainly European) balancing markets has revealed that there are many different ways to determine BRP imbalance volumes and imbalance prices [1, 2, 3]. Although at first sight the imbalance settlement design of different countries (balancing markets) may appear similar, because they all calculate an imbalance price for each PTU and BRPs must pay this price for deviation from energy programs, the detailed imbalance settlement rules in fact are different. This results in a unique imbalance settlement design for each country, giving a unique set of incentives to Balance Responsible Parties to balance their portfolio.

The main research question that is tackled in this paper is: 'To what extent do different imbalance settlement designs lead to different market behaviour and balancing market performance?' This will shed light on the relevance of imbalance settlement design. The larger the impact of imbalance settlement design on balancing market performance, the more relevant careful design of imbalance settlement is, and the more important it will be to harmonize imbalance settlement if governments, energy regulators and TSOs aim to integrate the balancing markets of different countries. Such balancing market integration has received recent interest from the European Commission [2, 4], European TSOs [3, 5, 6, 7], the European regulators' Group for Electricity and Gas (ERGEG) [8], and the electricity sector organization Eurelectric [9]. In the documents concerning possible balancing market integration, the harmonization of balancing market rules, including imbalance settlement rules, is mentioned as an important initial integration step. However, this puts forward the question of which imbalance settlement design should be incorporated in a uniform, regional balancing market design.

The research question is tackled by means of a comparative analysis of the imbalance settlement designs and resulting balancing market performance levels of Germany and the Netherlands. To this extent, system imbalance levels and imbalance prices of Germany and the Netherlands are compared for the period May-December 2009, and offset against the imbalance settlement designs of those two countries.

The structure of the paper is the following. In Section II, the fundamentals of imbalance settlement are explained and elaborated on in detail. Then, in Section III the imbalance settlement designs of Germany and the Netherlands are compared,

and in Section IV the balancing market results. Next, in Section V, the results are discussed, attempting to explain the differences in performance on the basis of the imbalance settlement design differences. Finally, the conclusions are presented in Section VI.

II. FUNDAMENTALS OF IMBALANCE SETTLEMENT

Imbalance settlement is one of the three main pillars of the balancing market (closely interrelated with balance responsible), and concerns the determination of individual imbalance volumes of Balance Responsible Parties (BRPs) for each Program Time Unit (PTU), as well as the imbalance price(s) with which these imbalance volumes are settled between the TSO and the BRPs for each PTU.
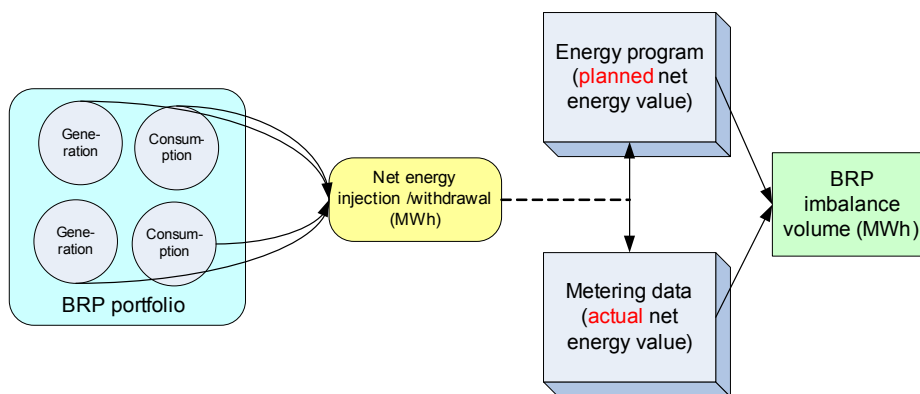

Fig. 1. Determination of BRP imbalance volumes

The general dynamic market mechanism is the following: The imbalance price stimulates the BRPs to submit accurate energy programs to the TSO, and to stick to those programs. Deviations from these programs (see Figure 1) determine their imbalance volume. BRPs are able to influence their imbalance volume by means of more or less accurate forecasting, over- and under-contracting, and internal balancing in real-time. In any case, the net sum of imbalance volumes of all the BRPs (representing all production and consumption in a power system) is equal to the system imbalance. This system imbalance is a net energy imbalance over a Program Time Unit; within the PTU itself the TSO has responsibility for balancing (thus for the power balance). The size of the system imbalance determines the amount of balancing energy (upward and/or downward regulation) that has to be activated by the TSO from the balancing energy market (real-time market) in order to restore the system balance. In turn, this activation determines the imbalance prices that are calculated by means of the specific imbalance pricing mechanism in place in the relevant balancing market. All BRP are then settled for each MWh deviation from scheduled energy with that

imbalance price (in €/MWh), which provides them with new incentives to form/adapt their behaviour regarding portfolio balancing for the next PTU(s).
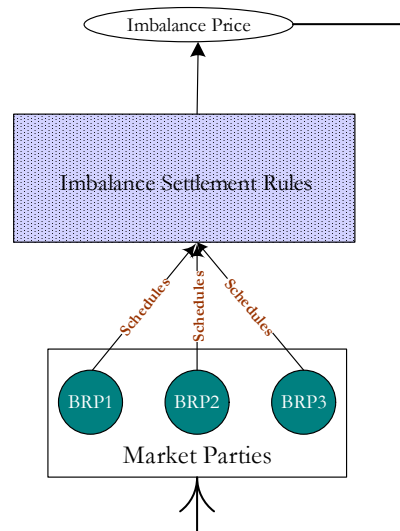

Fig. 2. The feedback loop that makes up the incentive mechanism of imbalance settlement

This *incentive mechanism*, in which the imbalance price is changed on a PTU-to-PTU basis on the basis of the size of the system imbalance, is a core feature of the balancing market. It comes down to the thing that market (BRP) behaviour determines balancing market results, and that those results influence BRPs again (see Figure 2). This incentive mechanism 'steers' the market towards a system balance:

For example, when in PTU A there was a large system shortage, the large amount of activated upward regulation bids will result in a high imbalance price, as a result of which BRPs may generally increase their efforts to provide accurate energy programs and to follow up the level of energy injection/withdrawal indicated in these programs. This would result in a smaller system shortage in PTU B, or to a system surplus, possibly because BRPs try to prevent ending up with a costly individual negative imbalance by all means. In turn, this lower system imbalance in PTU B would lead to a lower imbalance price for that PTU, which reduces the incentive for BRPs to balance their portfolio again.

Imbalance settlement can be viewed like this: the rules for imbalance settlement, the *imbalance settlement design*, form the 'rules of the game' for Balance Responsible Parties. These determine how BRP imbalance volumes and imbalance prices are calculated for each PTU, and when and how frequent the financial settlement takes place. But within the boundaries that the rules provide, the BRPs are free to behave as they wish. This includes that BRPs are free to create or leave an imbalance on purpose,

although they are obliged to pay for that imbalance with the relevant imbalance price. Of course, the nature of the rules will influence the BRPs, as these rules determine the height of the individual imbalance volumes and imbalance prices. In short, we can say that *the imbalance settlement design shapes the behaviour of Balance Responsible Parties*.
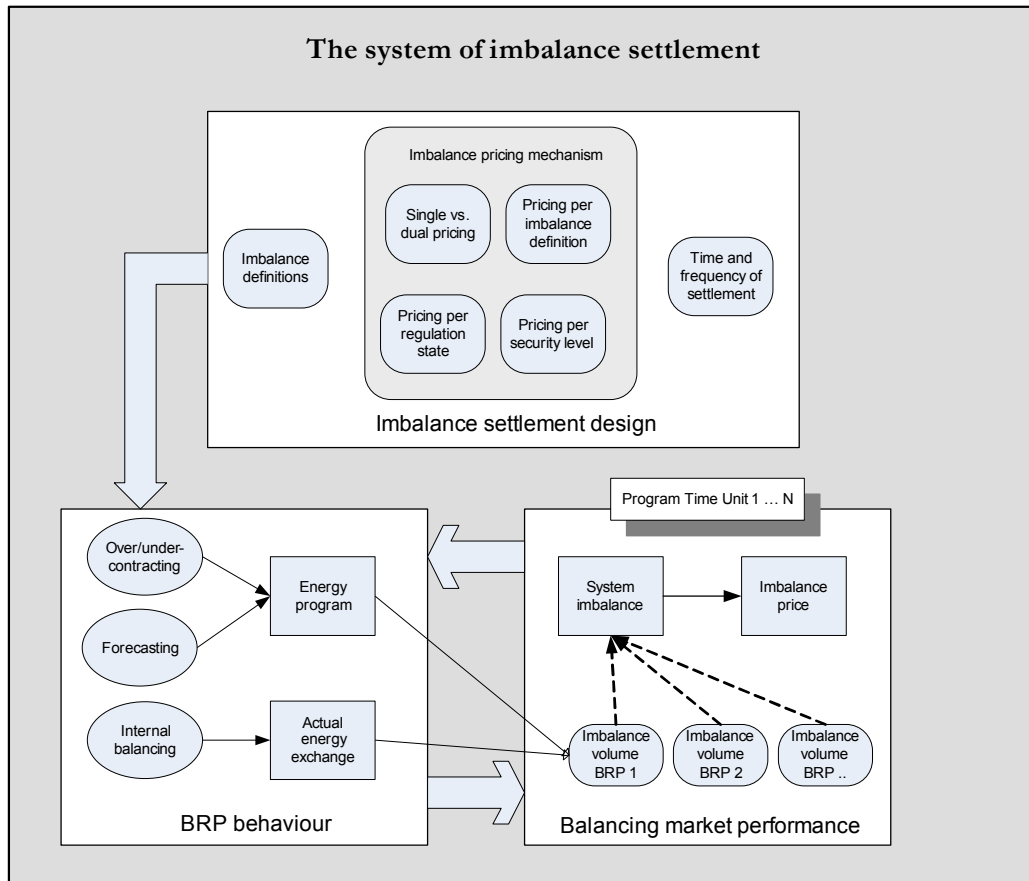

Fig. 3. The system of imbalance settlement: The imbalance settlement design shapes the behaviour of Balance Responsible Parties, which together determine balancing market performance, which in turn gives incentives to the BRPs with regard to their role of energy portfolio balancing.

Before we compare imbalance settlement designs, BRP behaviour and balancing market performance of Germany and the Netherlands, we need to elaborate on these three elements in the 'system' of imbalance settlement. This system is visually represented by Figure 3.

A. The imbalance settlement design

Let's delve somewhat deeper in the design variables that form together the imbalance settlement design space. First of all, the determination of individual imbalances of Balance Responsible Parties is represented by the design variable of 'imbalance definitions'. There are two main possibilities (variable values): BRPs have to balance production and consumption separately or

combined. If separate production and consumption balances are applied, overestimations of production cannot be cancelled out by underestimations of consumption. Also, it prevents the real-time balancing of consumption by a BRP by means of real-time adjustment generation units. This design variable can also be considered to be part of balance responsibility. Secondly, the variable 'time and frequency of settlement' concerns the financial settlement of individual imbalances between BRPs and the TSO. Often, the frequency of settlement is weekly or monthly, which means that the imbalance costs (BRP imbalance volume times imbalance price) for each PTU in the week or month are added up, and settled in one transaction. The time of settlement can be e.g. a week or a month after the final day of the used time period for financial settlement. Finally, there is the high-level design variable 'imbalance pricing mechanism, which is the most important variable, and also the variable with the most possible variable values. In Figure 3, this is represented by four low-lever variables, and all of them concern the possible differentiation of imbalance pricing for specific cases. 'Single vs. dual pricing' deals with the application of either the same or different imbalance prices for positive and negative BRP imbalances. A positive BRP imbalance means a surplus (too much actual production or too little actual consumption); a negative BRP imbalance means a shortage (too little actual production or too much consumption). This is the most important low-level variable. 'Pricing per imbalance definition' deals with the possible differentiation of imbalance pricing for production and consumption balances, if separate balances are applied (see above). 'Pricing per regulation state' deals with different imbalance pricing rules for different 'regulation states'. Regulation states can be defined by the TSO or regulator on the basis of actual upward/downward regulation within a PTU, and each PTU will after real-time be labelled with a regulation states based on those definitions. 'Pricing per security level' concerns the dependency of imbalance pricing on the level of security of supply of the power system, as affected by balance management. Again, different security levels could be defined, e.g. related to the amount of balancing resources being used.

B. Behaviour of Balance Responsible Parties

As said above, BRPs are able to influence their imbalance volume by means of more or less accurate forecasting, over- and under-contracting, and internal balancing in real-time. Forecasting is the forecasting of production and consumption, which is needed to submit accurate energy programs. Over-contracting is the deliberate purchase/sale of more/less energy than is forecast to be needed to balance the BRP portfolio (which will be reflected in the energy program) in order to limit the financial risks of imbalance costs, or to speculate in the imbalance direction[1]. Internal balancing is the real-time adjustment of generation or load that is part of the portfolio of a BRP, by this BRP, in order to minimize the individual imbalance, or to speculate in the

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[1] This is possible when the imbalance pricing mechanism is such that BRP that have an individual imbalance that is opposite to the system imbalance, and are thus 'passively balancing' the system, receive the upward regulation price for having a surplus, or only pay the downward regulation price for having a shortage. See Section III.

imbalance direction. As shown in Figure 3, forecasting and over/under-contracting influence the scheduled energy exchange (energy program), whereas internal balancing influences the actual energy exchange.

A useful distinction can be made between intentional imbalance and unintentional imbalance. As consumption and production (especially intermittent generation) cannot be precisely forecast, some intentional imbalance will usually occur. However, the BRP can also create an intentional imbalance by means of overcontracting or internal balancing, which may reduce the risk, or even prevent, ending up with a negative imbalance (which is generally more costly for the BRP), or which may even generate income instead of costs[1]. Thus, the *imbalance costs* of a BRP, which is the individual imbalance volume in a PTU, multiplied by imbalance price for that PTU, are not necessarily actual costs.

Above, we have stated that the incentive mechanism in imbalance settlement works such that BRPs are influenced to adapt their behaviour, which will thereby alter balancing market performance. However, it is uncertain to what extent BRPs will really respond to the 'steering signals' that the imbalance prices provide.

For an important part, it depends on the imbalance pricing mechanism. The imbalance pricing mechanism may work such that BRP that have an individual imbalance in the same direction as the system imbalance are really punished with an imbalance price that create costs for them, while an imbalance in the opposite direction actually creates income. With such a pricing mechanism, the BRPs may for some PTUs gain, and for some PTUs lose, and end up on a net basis with zero imbalance costs. If this is the case, the BRPs are not really stimulated to adapt behaviour on the basis of the imbalance price. Furthermore, when the strategy of a BRP is to minimize individual imbalance, higher imbalance prices will not lead to more accurate energy programs, because the forecasts can probably not be improved, and because BRPs have a standard forecasting procedure. Also, BRPs that overcontract to reduce the risk of the more costly BRP shortage (negative individual imbalance) will not quickly adapt their behaviour when the risks of being short are still higher than the risks of being long. Finally, changing imbalance prices not necessarily drive BRPs that speculate in the imbalance direction to adapt their operating strategies either, if they are satisfied with their profit or accept a possible reduction in profit.

The uncertainty of the response of BRPs to imbalance price signals also relates to the different nature of BRPs, both physically and mentally. Physically, BRPs can be small or large in size, can have all different kinds of consumption and generation portfolios (different types of customers and generation technologies). Also, the market party that plays the role of Balance Responsible Party may also play the role of Balancing Service Provider, or not. These differences lead to different decisions and operational strategies with regard to portfolio balancing. Furthermore, BRPs have different viewpoints and philosophies with regard to their role, as already reflected upon above. BRPs may have different goals. e.g. imbalance costs

minimization of profit maximization, they may be risk-averse or risk-prone, and they may favour complex optimisation strategies or simple 'satisficing' strategies.

C. Balancing market performance

As can be seen in Figure 3, the individual imbalances of BRPs (in MWh), the system imbalance (in MWh or MWh/h) and the imbalance price (in €/MWh) are main performance indicators for the impact of the imbalance settlement design on balancing market performance. These indicators all differ per Program Time Unit (PTU); as imbalance settlement takes place on a PTU-basis. As all production and consumption is represented by a Balance Responsible Party, the sum of the individual imbalances of all BRPs in a power system (control area) for a specific PTU is the system imbalance, the energy imbalance over that PTU. The imbalance price then follows from the amount of activated balancing energy from the balancing energy market that has been activated to maintain the system balance during that PTU. This way, the imbalance price is indirectly determined by the BRP imbalances.

A general remark that we like to make here is that it is not obvious how balancing market performance should be defined. It is debatable what are relevant balancing market performance criteria and performance indicators, and what is their relative importance. With regard to imbalance settlement, BRP imbalances and the system imbalance indicate the effectiveness of balance management. Because the imbalance price follows from the system imbalance, it is a more indirect indicator of effectiveness, but is also gives an indication of the societal costs of balance management, and indicates balancing energy market efficiency. However, some reservations should be made here. First of all, the above indicators alone do not give much information yet. The system imbalance should be related to the average system load and the availability of balancing resources to indicate the scope and effectiveness of balance management in a power system. Furthermore, the imbalance price should be related to the day-ahead price in order to indicate the actual costs of imbalance settlement, as we can regard the difference between those two prices as the opportunity costs for BRPs for not balancing their portfolio on the day before delivery. This price difference appears a useful indicator of societal costs of balancing. However, it is not a clear indicator of actual costs for the market, because BRPs may on a weekly/monthly basis have negligible imbalance costs, because the imbalance costs per PTU have evened out.

For the comparison of balancing market results of Germany and the Netherlands, the imbalance prices could be obtained, but not the individual imbalances. And although TenneT, the Dutch TSO, publishes the total net imbalance of BRPs, this is not given by the German TSOs. Therefore, we compare the net activated balancing energy per PTU, which all TSOs have published for the selected period of May-December 2009. This value should resemble the system imbalance, although it does not take into account

the inadvertent exchange of electrical energy with other control areas, which also contributes to the resolution of the system imbalance[2]. This is another point to keep in mind.

III. COMPARISON OF IMBALANCE SETTLEMENT DESIGNS

In this Section, we compare the imbalance settlement designs of Germany and the Netherlands. Germany and the Netherlands are of interest, because their imbalance settlement design are quite different, while they are neighbouring countries that are part of the same synchronous zone, and while they both use a Program Time Unit of fifteen minutes. The comparison is summarized in Table I, and based on earlier work [10].

TABLE I
IMBALANCE SETTLEMENT DESIGN OF GERMANY AND THE NETHERLANDS

Design variables	Germany	The Netherlands
Imbalance definitions	Total balance (production and consumption combined)	(production and consumption combined)
Time and frequency of settlement	Monthly settlement; several weeks after ending of the month	Weekly settlement, ten days after the ending of the week
Imbalance pricing mechanism	Based on total net costs of balance regulation	Based on marginal prices of upward and downward regulation
Single vs. dual pricing	Single pricing	Dual pricing
Pricing per imbalance definition	Not applicable	Not applicable
Pricing per regulation state	No	Yes: four different regulation states
Pricing per security level	No	Yes: additive components depending on inadvertent exchanges and on activation of emergency power

With regard to the design variable 'imbalance definitions', Germany and the Netherlands both make use of the total balance, one balance that contains both production and consumption. This means that BRPs can have responsibility over both energy production and consumption, and that consumption imbalances could be offset by production imbalances, possibly intentional ones (internal balancing; see above).

With regard to the time and frequency of settlement, Germany applies a monthly settlement, which takes place several weeks after the end of the month. The Netherlands applies a weekly settlement, which takes place ten days after the end of the week. This means that Dutch BRPs are faced much quicker with the imbalance costs, and 'feels' the incentives that the imbalance prices provide thus much quicker (although this does necessarily mean different BRP behaviour, see above).

With regard to the imbalance pricing mechanism, a fundamental difference is that the imbalance prices in Germany are based on the total net costs of balance regulation, whereas the Netherlands bases the imbalance prices on the marginal prices of upward and downward regulation bids selected in the balancing energy market. In Germany, the net costs of all activated balancing

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[2] Unfortunately, the inadvertent exchange values cannot be found for Germany.

energy bids (both upward and downward) are calculated, and these are divided by the net activated balancing energy volume. It is important to note here that selected providers in Germany receive their own bid prices, instead of the price of the last (marginally) selected bid as is done in the Netherlands. Because the German imbalance pricing mechanism could lead to very high prices in PTUs with almost equal upward and downward regulation, there is an imbalance limit that is equal to the most expensive selected balancing energy bid. In the Netherlands, there are two imbalance prices per PTU, which can be based on the price of the last selected upward regulation bid and/or the price of the last activated downward regulation bids (see below). This design difference makes the level of imbalance prices apparently more uncertain for Germany than for the Netherlands.

With regard to single vs. dual pricing, the first low-level imbalance pricing variable, Germany applies single pricing whereas the Netherlands applies dual pricing. Single pricing means that BRPs with a shortage are faced with the same imbalance price as the BRPs with a surplus[3]. Thus, only one imbalance price is determined per PTU. With dual pricing, separate imbalance prices are determined for positive imbalances (BRP surpluses) and negative imbalances (BRP shortages). As said above, these imbalance prices are based on the marginal prices of upward and downward regulation, depending on the regulation state (see below). This design difference appears to give more strict incentives to Dutch BRPs to balance their portfolio, but in reality this is limited by the low occurrence of regulation state '2' in the Netherlands (see below).

The imbalance pricing per imbalance definition is not applicable here, because neither Germany nor the Netherlands apply different imbalance definitions (see above).

With respect to imbalance pricing per regulation state, Germany does not define separate regulation states that influences imbalance pricing. The Netherlands does: It has defined four regulation states, '0' (no regulation), '1' (up-regulation), '-1' (down-regulation) and '2' (two-sided regulation). Depending on the development of the 'balance-delta', i.e. the real-time activated balancing energy throughout the PTU, each PTU will be labelled with a regulation state. In case of regulation state '1', both imbalance prices (for BRP shortages and for BRP surpluses) are the same as the marginal price of upward regulation. In case of regulation state '-1', both imbalance prices are the marginal price of downward regulation. In case of regulation state '0' both imbalance prices are the average of the first bid in price order in both regulation directions. In case of regulation state '2' , the positive imbalance price is the marginal price for downward regulation and the negative imbalance price is the marginal price for upward regulation. The existence of regulation state '2' actual creates the difference between single pricing in Germany and the dual pricing in the Netherlands. However, this regulation state did not occur a lot in the considered period, only about 10%. Thus, Dutch BRPs are apparently not driven more strongly to a balanced portfolio.

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[3] In general, BRPs with a shortage pay the imbalance price that is applicable to them to the TSO, whereas BRPs with a surplus receive the imbalance price that is applicable to them from the TSO. This can be regarded as the purchase or selling of 'balancing power'. It should be noted that having a surplus can still create actual costs for the BRP, namely when the received imbalance price is lower than the day-ahead spot price.

With regard to imbalance pricing per security level, Germany does not make use of this. In the Netherlands, there are two additive components to the imbalance price that can be activated based on specific criteria. The so-called incentive component is activated when the number and average of the involuntary exchange with the UCTE over time intervals of five minutes are too large. Weekly, the incentive component can be enlarged or decreased based on meeting these criteria, with 0.1 or 0.2 €/MWh. Furthermore, when there was not enough regulating power (secondary control power) and emergency power had to be activated, the imbalance price can be enlarged by 10%. Both additive components will increase the incentives to BRPs to balance their portfolio in the next PTUs/day/week, which will improve the security level (amount of involuntary exchange; use of emergency power) again.

IV. COMPARISON OF BALANCING MARKET RESULTS

The compared period is from 1 May 2009 up to and including 31 December 2009. This is because from May 1st 2009 onward, three out of four German control areas, those of the TSOs 50Hertz, EnBW and transpower, applied a common balance regulation and imbalance settlement [11]. This means that balancing energy is activated for the three areas combined, and that a uniform imbalance price is determined. Before that, each control areas had separate balancing markets, and separate balancing service prices and imbalance prices developed. To keep matter simple, we compare Germany and the Netherlands for the eight-months-period after this integration step. The three cooperating control areas of 50Hertz, EnBW and transpower are called the 'optimierter Netzregelverbund' (optimised grid control cooperation). The fourth control area, operated by Amprion, applies the same balancing market rules, but still carried out the balance regulation and imbalance settlement separate from ONRV in the period May-December 2009. We will compare the results of both ONRV and Amprion, next to those from the Netherlands.

A. Balancing market results for the period May-December 2009

In order to place the overall results in perspective, we first give the relative sizes of the considered (group of) control areas. See Table II [12]. As we can see, ONRV is about three times larger than the Netherlands in terms of electricity consumption. We would therefore expect three times as much activated balancing energy (system imbalances), assuming that unintentional production and consumption imbalances have a similar likelihood of occurrence in both areas. The difference in system size is not expected to affect the level of imbalance prices, assuming equal generation mixes in both countries. That this is not the case, should be taken into account when differences in performance are explained in Section V.

TABLE II
SIZE OF THE CONSIDERED CONTROL AREAS

Control area	Rough yearly consumption (GWh)	Proportion compared to Netherlands (-)
ONRV	350,000	2.9
Amprion	200,000	1.7
Netherlands	120,000	1

The overall balancing market results with regard to imbalance settlement for Germany and the Netherlands are summarized in Table III. These results are based on data retrieved from the TenneT website [13], and the general German website about the balancing market auctions and results [14], which provides links to data on the websites of transpower, EnBW, 50Hertz and Amprion. The results relate to three indicators, as referred to in Section II: the net activated balancing energy (as and indicator for system imbalance), the imbalance price, and the 'actual BRP costs'. The latter are calculated as the difference between the

imbalance price and the day-ahead spot price, so that these indicate the opportunity costs of not having balanced the portfolio by means of trading in the day-ahead market for electricity. The results will be interpreted in Section V.

TABLE III
BALANCING MARKET RESULTS RELATED TO IMBALANCE SETTLEMENT FOR GERMANY AND THE NETHERLANDS

Balancing market results for the period 1 May 2009 – 31 December 2009	ONRV	Amprion	the Netherlands	
Activated balancing energy				
Occurrence negative BE volume	52.1%	58.4%	52.5%	
Occurrence positive BE volume	47.9%	41.6%	47.5%	
Average BE volume (MW)	-11	-70	-6	
Average negative BE volume (MW)	-481	-327	-82	
Average positive BE volume (MW)	500	291	78	
Total BE volume (GWh)	-66	-412	-34	
Total of negative BE volumes (GWh)	-1474	-1124	-253	
Total of positive BE volumes (GWh)	1407	711	218	
Imbalance prices			Negative	Positive
Average imbalance price (€/MWh)	41.7	35.9	41.5	37.9
Average imbalance price for negative BE volumes (€/MWh)	-19.3	-21.1	18.2	15.6
Average imbalance price for positive BE volumes (€/MWh)	107.9	115.7	67.4	62.7
Average day-ahead spot price (€/MWh)	36.4		36.6	
Actual BRP costs				
Average BRP costs for a shortage (€/MWh)	5.2	-0.6	5.0	
Average BRP costs for a surplus (€/MWh)	-5.2	0.6	-1.3	
Average BRP costs for shortage for negative BE volumes (€/MWh)	-52.2	-55.6	-16.1	
Average BRP costs for surplus for negative BE volumes (€/MWh)	52.2	55.6	18.8	
Average BRP costs for shortage for positive BE volumes (€/MWh)	67.7	76.6	28.3	
Average BRP costs for surplus for positive BE volumes (€/MWh)	-67.7	-76.6	-23.6	

1) Activated balancing energy

As we can see in Table III, in all three considered areas (ONRV, Amprion, and the Netherlands), there has been a larger occurrence of negative balancing energy (BE) volumes than positive balancing energy volumes. The *balancing energy volume* is defined here as the net activated balancing energy volume for a specific Program Time Unit. If it is positive, more upward regulation (positive balancing energy) has been activated than downward regulation (negative balancing energy) during the PTU, and vice versa. The larger occurrence of negative BE volumes indicates that, on a net basis, the system was more often 'long/ (positive system imbalance) than 'short' (negative system imbalance). This means that also Balance Responsible Parties have been 'long' rather than 'short'. This suggests that BRPs are generally overcontracting because of the higher imbalance costs associated with a BRP shortage. The proportion of positive and negative imbalances is about equal for ONRV and the Netherlands, but Amprion has a significantly higher occurrence of negative BE volumes (system surpluses), 58.4% compared to 52.1% for ONRV and 52.5% for the Netherlands (see Figure 4), suggesting that the imbalance risks for BRPs of 'being short' are much larger than those of 'being long'.
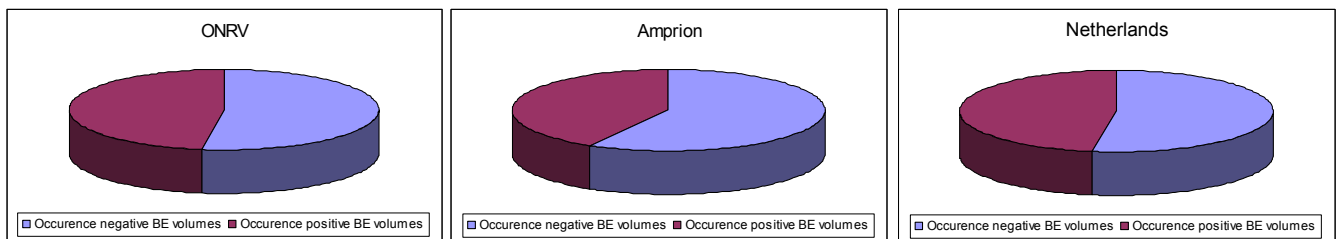

Fig. 4. Occurrence of positive and negative balancing energy (BE) volumes in Germany and the Netherlands in the period May-December 2009

When we take a look at the average overall, negative and positive BE volumes (see Figure 5), it becomes clear that the average BE volume (system imbalance) is quite small for ONRV (-11 MW) and the Netherlands (-6 MW), but relatively large for Amprion (-70 MW). This is due to the large occurrence of negative BE volumes in the Amprion area. From the average negative BE volumes (-481 MW for ONRV, -327 MW for Amprion, and –82 MW for the Netherlands) and the average positive BE volumes (500 MW for ONRV, 291 MW for Amprion, and 78 MW for the Netherlands) can be spotted that the average sizes of positive vs. negative BE volumes is of similar size, but also that the proportion of average BE volumes of Germany vs. the Netherlands is much larger than the proportion in system size given in Table II. This suggests that system imbalances in Germany are generally larger, and that BRPs leave larger individual imbalances to be resolved in real-time.

This observation is confirmed by total BE volumes for the period May-December 2009, as illustrated in Figure 6. On average, they are -66 GWh for ONRV, -412 GWh for Amprion, and -34 GWh for the Netherlands, but for negative BE volumes they are -1474 GWh, -1124 GWh and -253 GWh and for positive BE volumes they are 1407 GWh, 711 GWh and 218 GWh, respectively

for ONRV, Amprion and the Netherlands. Again, the proportion of positive and negative BE volumes for Germany compared to the Netherlands are much higher than is to be expected from the proportion of the system size. The total net activated balancing energy values for the entire period show that in the ONRV area and in the Netherlands that there was slightly more downward regulation than upward regulation, but that in the Amprion area, much more downward regulation occurred, as already found above.
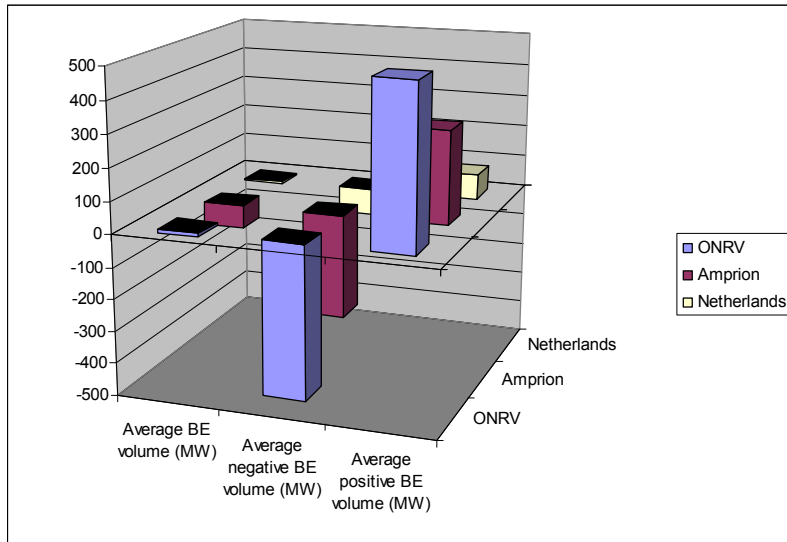

Fig. 5   Average balance energy (BE) volumes, BE volumes for PTUs with a negative BE volume, and BE volumes for PTUs with a positive volume
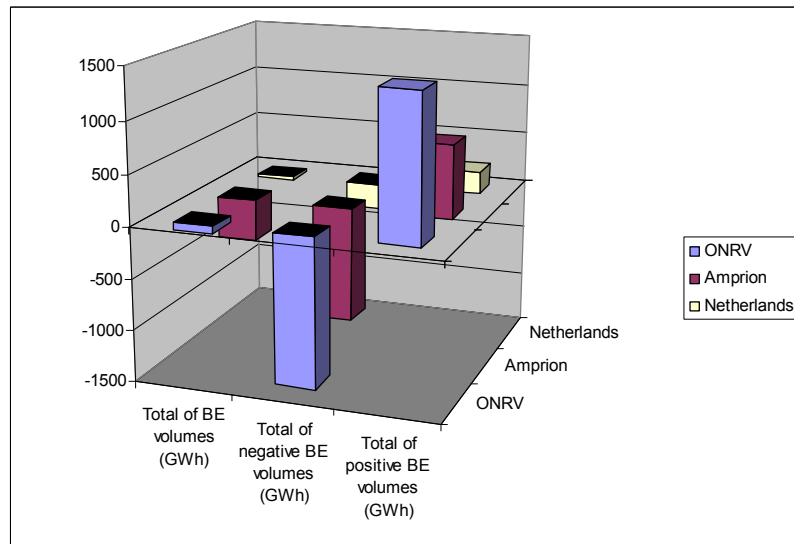

Fig. 6   Total of balancing energy (BE) volumes, negative BE volumes and positive BE volumes

Finally, the above observations are confirmed by the distribution graphs of BE volumes for the period May-December, which are plotted in Figure 7. The size of net activated balancing energy volumes is much higher in Germany than in the Netherlands.
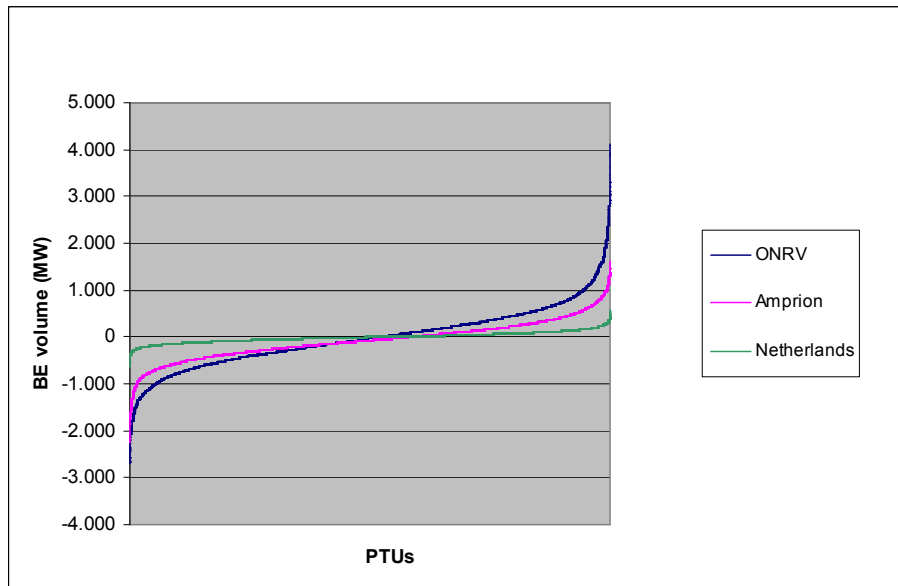
Fig. 7 Distribution of balancing energy volumes over the period May-December 2009

2)   Imbalance prices

The average imbalance prices in €/MWh, as given in Table III, are visually represented in Figure 8. For the Netherlands, the average negative and positive imbalance prices are given, but as in only 9.8% of the PTUs the two imbalance prices actually had a different value, these prices are similar. The average imbalance prices for the period May-December 2009 are 41.7 €/MWh for ONRV, 35.9 €/MWh for Amprion, 41.5 €/MWh for BRP shortage in the Netherlands, and 37.9 for BRP surplus in the Netherlands. Actually, these imbalance prices lie within the same range, although ONRV and the Netherlands (for shortage) have higher prices than Amprion. This is probably caused by the larger level of downward regulation in Amprion, which is cheaper to provide than upward regulation[4]. Compared to the day-ahead price, which was on average 36.4 €/MWh in Germany and 36.6 €/MWh in the Netherlands, the average imbalance prices are limited for all areas, namely in the order of 1-5 €/MWh (see below).

However, the average imbalance prices for specific directions show a different picture: For negative BE volumes these are -19.3 €/MWh, -21.1 €/MWh and 18.2/15.6 (shortage/surplus), and for positive BE volumes these are 107.9 €/MWh, 115.7 €/MWh and 67.4/62.7 (shortage/surplus) €/MWh, respectively for ONRV, Amprion and the Netherlands. The average imbalance prices for negative BE volumes are negative for Germany, meaning that that the TSO on a net basis has to pay money while more downward regulation than upward regulation was activated. This happens when providers of downward regulation are only willing to provide when they are paid, instead of paying themselves (which could be profitable if fuel costs are saved). The result is that, on average for PTUs with a negative BE volume, BRPs with a shortage receive money whereas BRPs with a surplus pay

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[4] For the provision of upward regulation, generation resources must set some generation capacity aside, which could alternatively have been utilized for trade in the conventional power markets. The provision of downward regulation merely requires that the generation unit is able to ramp down.

money. Needless to say that BRPs with a shortage make a large profit in this case, whereas the BRPs with a shortage lose a lot of money. We come back on this under 'actual BRP costs' below. The imbalance prices in Germany for positive BE volumes are very high, indicating that the costs of upward regulation are very high as well. For the Netherlands, the difference between average imbalance price and imbalance price for positive/negative BE volumes is smaller: more in the order of 20-30 €/MWh than the 60 €/MWh or more for Germany. The somewhat lower imbalance prices for BRP surpluses are caused by the occurrence of regulation state '2', where the positive imbalance price is based on the marginal downward regulation price.

Figure 9, which shows the distribution of imbalance prices for the considered period, confirms the above. It shows that the imbalance prices never lie close to the day-ahead price level of 36 €/MWh, but always lower than 15 €/MWh and higher than 60 €/MWh. This may indicate that a lot of balancing energy is activated, as we already saw is true, but may also indicate that balancing energy prices are high.
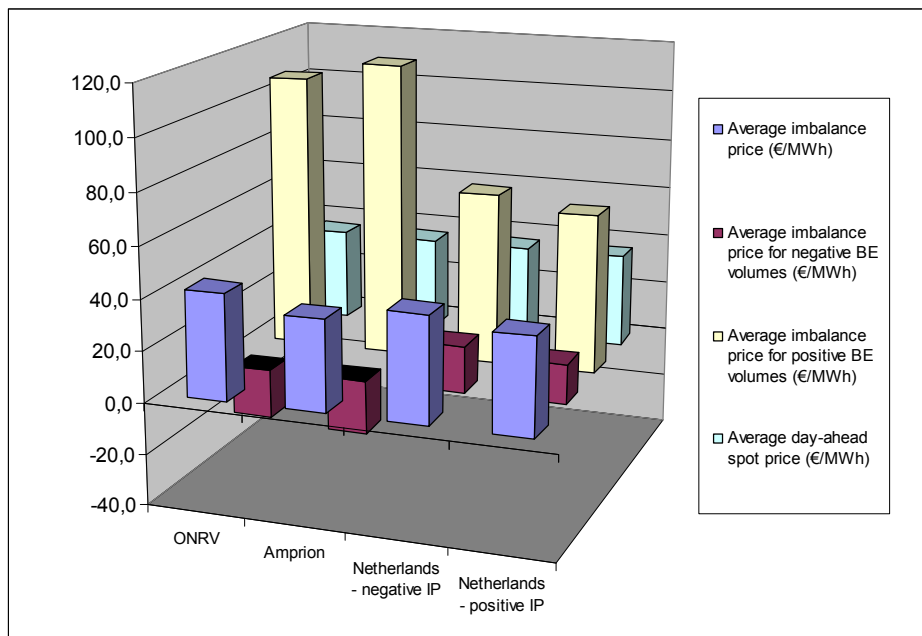

Fig. 8   Average imbalance prices over the entire period, for negative BE volumes, and positive BE volumes
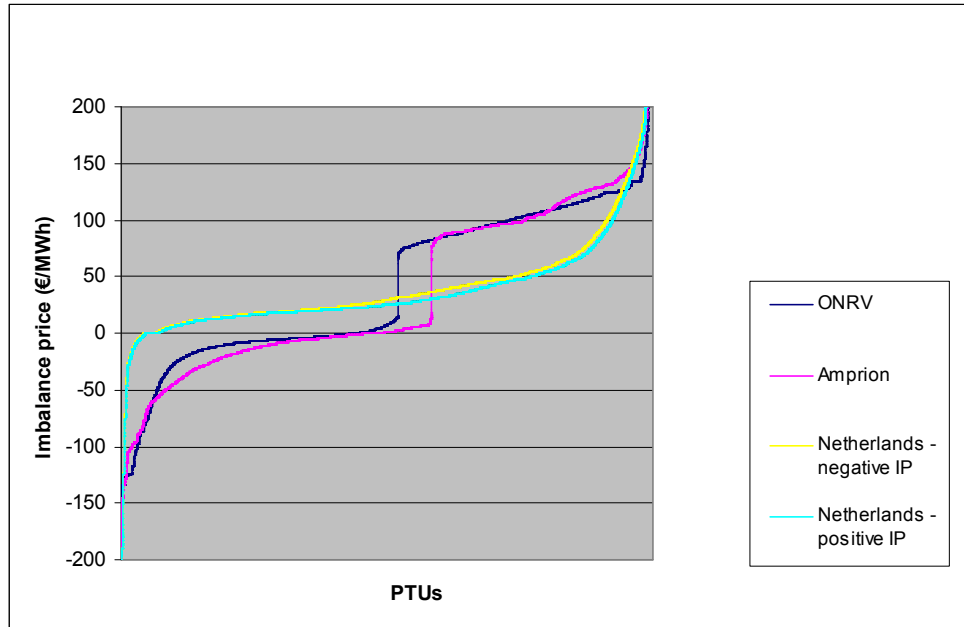
Fig. 9 Distribution of imbalance prices over the period May-December 2009

3)   Actual BRP costs

The actual BRP costs are the actual costs that Balance Responsible Parties incur. These are different from the imbalance costs, because imbalances could have been prevented by means of trading away the imbalance on the day-ahead or intraday time frame (although this is not possible for unintentional imbalances). We regard the difference between the day-ahead spot price and the imbalance price to represent the opportunity costs of having an imbalance. A negative value means that there actually is a profit for the BRP. The BRP costs of having a shortage (negative individual imbalance) are the imbalance price minus the day-ahead price for Germany, and the negative imbalance price minus the day-ahead price for the Netherlands. The BRP costs of having a surplus (positive individual imbalance) are the day-ahead spot price minus the imbalance price for Germany, and the day-ahead price minus the positive imbalance prices for the Netherlands.

The average actual BRP costs are relatively low: for BRP shortages they are 5.2 €/MWh, -0.6 €/MWh and 5.0 €/MWh, and for BRP surpluses they are -5.2 €/MWh, 0.6 €/MWh, and -1.3 €/MWh. This is striking, because much more balancing energy is activated in Germany than in the Netherlands, and much more downward regulation is activated in Amprion. We believe this is the case, because in general, BRPs will behave in such a way that that their BRP costs are minimized, and that due to the slow level of change in BRP strategies a 'market equilibrium' will emerge that is acceptable for all BRPs. This equilibrium is generally the same, but the combination of BRP strategies that result in this equilibrium depends on the balancing market design. We come back to this below.

The reason why the average BRP costs for shortage and surplus for Germany are opposite to each other, is because of the single imbalance price applied. Because of the dual pricing, different actual BRP costs have developed for BRP shortages and

surpluses in the Netherlands. Again, it can be seen that it is more costly to be short in the Netherlands. Moreover, being long on average generated money for Dutch BRPs. This is even more so the case for being long in the ONRV area.

The average actual BRP costs for being long and short for the PTUs with negative or positive balancing energy volumes shows, as expected, that it costs you to be short when there is a positive BE volume (the system was short), and vice versa. This is logical, because as a BRP you contribute to the system imbalance when your individual imbalance is in the same direction as the system imbalance. Looking at the specific numbers for the different areas, as given in Table III and depicted in Figure 10, shows that is much more costly/profitable to be in the wrong/right direction in Germany, than it is in the Netherlands. The actual costs lies in the range of (-) 50-70 €/MWh for Germany, against 15-30 €/MWh for the Netherlands. This shows that the imbalance risks (and opportunities) are much higher in Germany. Apparently, BRPs are not able to reduce these risks, or benefit from these opportunities, otherwise lower BE volumes would have emerged. Again, we come back on this in the next Section.

A last interesting observation is that in all three areas, the actual BRP costs of having a shortage during PTUs with a positive BE volume are higher than the actual BRP costs of having a surplus during PTUs with a negative BE volume, which proves that it is better to be long than short, and again explains the larger occurrence of negative BE volumes. For ONRV the difference between the two mentioned situations is 15.5 €/MWh, for Amprion it is 21.0 €/MWh, and for the Netherlands 9.5 €/MWh. The difference is highest for Amprion, where the occurrence of downward regulation was highest as well.
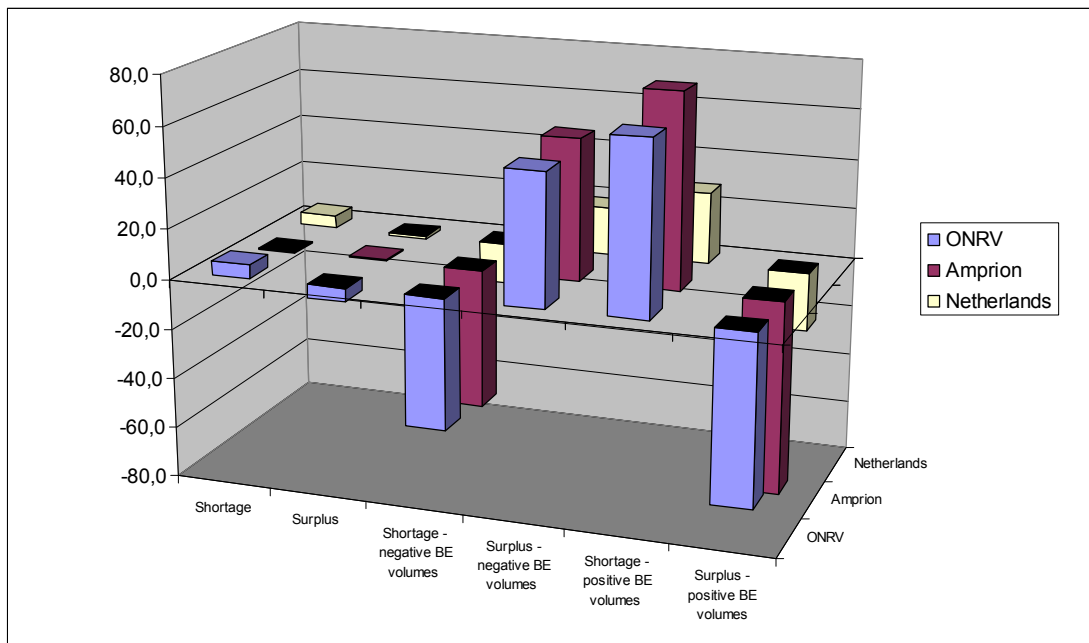

Fig. 10 Average actual BRP costs in €/MWh for having a shortage or a surplus, and for negative or positive BE volumes

In Figure 11, the distribution of actual BRP costs for shortage and surplus are shown, which is in line with the above results. The low occurrence of actual BRP costs that are close to zero in Germany again points towards a consistently large difference between balancing energy bid prices and the day-ahead spot price, which does not hold for the Netherlands. Also, it can be seen that actual BRP costs are generally much higher in Germany than in the Netherlands.
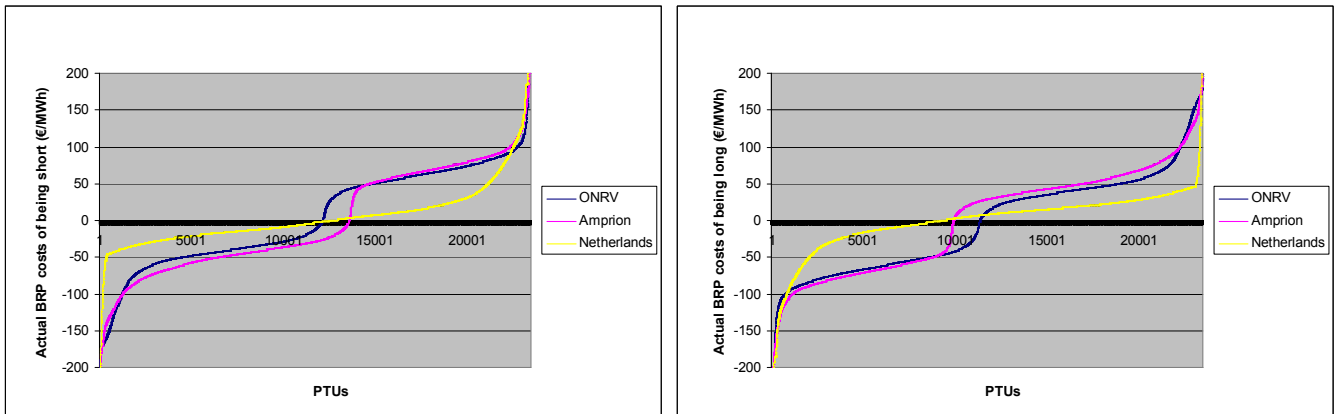

Fig. 11   Distribution of actual BRP costs of a shortage (left) and of a surplus (right)

B. Wrapping up on the relative balancing market performance of Germany and the Netherlands

Wrapping up on the three identified performance indicators for imbalance settlement, the following observations have been made on the relative balancing market performance of Germany and the Netherlands:

The *activated balancing energy*, is on average quite small, but is in absolute GWh's much larger for the German areas than for the Netherlands than to be expected from the difference in yearly consumption. The occurrence of PTUs with a negative balancing energy volume (more downward regulation than upward regulation) is higher than that of PTUs with a positive balancing energy volume in all three areas, although in Amprion the occurrence of negative BE volumes is much higher.

The *imbalance prices* are on average again on a similar level, and relatively close to the average day-ahead spot price, but the average imbalance prices for negative BE volumes are negative in Germany, and above the 100 €/MWh for positive BE volumes. This means a deviation from the average imbalance price of more than 60 €/MWh. In contrast, the imbalance prices for negative and positive BE volumes within the Netherlands lie about 20-30 €/MWh away from the average imbalance price.

The *actual BRP costs* are again on average on a similar level, and rather close to zero: within the range of [-5,5] €/MWh. This is also the case for Germany, despite the large differences between average day-ahead price and typical imbalance prices for specific BE volumes. Average BRP costs are more than three times higher for Germany than for the Netherlands. Depending on the direction of the BE volume (system imbalance), BRPs in Germany either lose at least 50 €/MWh or win at least 50 €/MWh, whereas in the Netherlands the loss or profit is on average less than 30 €/MW, given a balance regulation direction and an

individual imbalance direction. Although the average values indicate a slight profit for being short in Amprion, the comparison of average BRP costs of being short while the system is also short (positive BE volume) with the average BRP costs of being long while the system is also long (negative BE volume) shows that generally being long is the most beneficial BRP strategy, assuming that the BRP is not able or willing to speculate on the system imbalance direction.

V. DISCUSSION: RELATING PERFORMANCE TO DESIGN

A. Explanation of performance

Now we know the differences in imbalance settlement design and the different in balancing market performance between Germany and the Netherlands, we can try to explain the differences in performance on the basis of the differences in imbalance settlement design.

Generally, we have observed larger activated balancing energy volumes (more than expected based on system size), larger imbalance price levels and larger actual BRP costs for Germany than for the Netherlands. Looking at the imbalance settlement design differences, the time and frequency of settlement may have to do with this, because financial settlement takes place much sooner in the Netherlands than in Germany. However, this does not give incentives on the PTU level. The imbalance pricing mechanism is a much more obvious explanatory variable. In Germany, the general pricing mechanism consisting of the dividing of net balance regulation costs by net activated balancing energy creates a lot of uncertainty on the value of imbalance prices. However the dual pricing and imbalance pricing based on regulation states and security in the Netherlands also creates uncertainty. Thus, we have to look further than the imbalance settlement design in order to explain the differences in balancing market results.

It is very obvious that causes of performance differences may also be found in the balancing energy market design, as imbalance prices are dependent on activated balancing energy. There is one clear balancing energy market design variable that has an important impact on BRP behaviour: The publishing of real-time information on system balancing. In the Netherlands, the minute-to-minute activated balancing energy and the bid price of the last activated bid in both directions is published on the TenneT website in real-time, whereas in Germany no real-time information on the system balance state is spread to the market. This has very important implications: In the Netherlands it is possible to internally balance the BRP portfolio based on the real-time information, speculating on the regulating state and the resulting imbalance prices, whereas in Germany BRPs have no idea of the sign of the BE volume, which has such an important impact on imbalance prices and actual BRP costs.

Furthermore, as the balancing market results indicate, the balancing energy price level appears to be a lot higher for Germany compared to the Netherlands. This may have to do with the fact that for Germany the balancing energy bid ladder for secondary

control is fixed for the entire month, while balancing energy bids in the Netherlands can be adapted up to an hour before the PTU of delivery.

Furthermore, than can be other explanations other than balancing market design that may (partly) explain the found differences in performance. Importantly, the inadvertent energy exchanges of the areas with neighbouring areas has not be taken into account, whereas this also contributes the balance management of a control area. TenneT, the Dutch TSO, applies a reactive balancing energy activation strategy, whereas Germany applies a proactive strategy, which can partly explain the larger balancing energy volumes in Germany. This proactive strategy relates to another differences that may explain the different balancing energy volumes: the differences in wind and solar power output and operation. Germany has more than 20 GW installed wind power capacity in its power system, whereas the Netherlands has about 2 GW. This will cause much larger system imbalances, as these energy sources are unpredictable and uncontrollable. In addition, in Germany the responsibility for wind and solar power lies predominantly with the German TSOs, and these TSOs are proactively balancing their wind and solar power portfolio. This will create larger amounts of activated balancing energy, and thus higher imbalance prices.

B. Explanation of BRP behaviour

To what extent can the BRP behaviour be explained, apart from what has already been stated above? In general, the large imbalance prices for BRPs in Germany should lead to large incentives to balance the portfolio. However, the activated balancing energy volumes show that much larger imbalances arise than in the Netherlands! How can this be explained?

First of all, the actual BRP costs are on average close to zero, which does not give an incentive to the BRPs to deviate from a simple and fixed strategy of imbalance minimization. Second, internal balancing is not a viable strategy in Germany, because BRPS apparently have no clue on the system imbalances and resulting imbalance prices that are to be expected, due to a lack of real-time balance regulation information. Third, compared to Germany, there is an extra incentive to BRPs to balance their portfolio after PTUs with large amounts of both upward and downward regulation, because of the occurrence of regulation state '2'. Finally, there is more unintentional imbalance in Germany than in the Netherlands, due to the high share of wind and power.

Another finding is that, in general, the higher imbalance risks of being short drive BRPs to overcontract a bit, which explains the higher occurrence of negative balancing energy volume (positive system imbalances).

Finally, the average actual BRP costs for the period May-December 2009 are very small for all areas, which appears to suggest that a balancing market equilibrium develops. The sign of this small average costs may shift from plus to minus, as balancing keeps being a stochastic phenomenon, and the results remain dependant on exact BRP behaviour. But most

importantly, it shows that on average, BRPs will not be faced with large costs, which takes away the incentive to improve balancing the BRP portfolio due to higher imbalance prices, and means that BRPs will not adapt their behaviour frequently. BRPs can suffice with simple imbalance minimization, assuming that positive and negative BRP imbalance will occur equally during both PTUs with positive and negative BE volumes, or with overcontracting, in case of simple imbalance risk minimization. Only when the system imbalance will be shifted to such an extent (possibly by changing BRP behaviour) that average BRP costs are higher, BRPs will adapt behaviour, finally ending up in a new equilibrium.

To illustrate this, in ONRV, BRPs received on average a 5.2 €/MWh profit for being long, but the occurrence of negative BE volumes remains limited. This can be explained by the higher costs of a shortage during negative BE volumes. BRPs have no certainty about what others are going to do, and will not take the risk of ending up with much higher imbalance costs, but stick to their proven simple strategies with acceptable results.

VI. CONCLUSION

Based on the comparison of balancing market results in Germany and the Netherlands for the period May-December 2009, we can answer the research question, 'To what extent do different imbalance settlement designs lead to different market behaviour and balancing market performance?', as follows:

Imbalance settlement designs have an impact on the behaviour of Balance Responsible Parties, but not so much as expected. The main imbalance pricing mechanism and single vs. dual pricing are found to be the most important imbalance settlement design variables. Balancing market performance is also dependent on balancing energy market design, on generation portfolio differences and on actual BRP behaviour, which may differ per BRP. In general, BRPs will stick to a simple strategy of slight overcontracting, because it is less risky to be long, and because imbalance costs even out over a larger time span. Internal balancing of the BRP portfolio is hardly possible in Germany, but very well possible in the Netherlands, which probably is an important explanatory factor of the lower activated balancing energy volumes, imbalance prices and actual BRP costs in the Netherlands, next to the lower intermittent generation share and the reactive activation strategy of the TSO.

Due to the differences outside the realm of imbalance settlement, we cannot conclude on the relative favourability of the German and Dutch imbalance settlement designs. Although the balancing market results suggest that Dutch imbalance settlement design is more favourable, we cannot extract the influence of the lower wind power share and the lower balancing energy price level. This remains a task within further research on balancing market design and performance.

VII. REFERENCES

[1] Grande, O.S.; Doorman, G.; Bakken, B.H., 2008. "Exchange of balancing resources between the Nordic synchronous system and the Netherlands / Germany / Poland", SINTEF Energy Research, Project Number 12X535.02

[2] KU Leuven en Tractebel Engineering, 2009. "Study of the interactions and dependencies of balancing markets, intraday trade and automatically activated reserves," Final report, TREN/C2/84/2007, Feb. 2009

[3] ETSO, 2003. "Current State of Balance Management in Europe"

[4] European Commission, 2007. "Inquiry pursuant to Article 17 of Regulation (EC) No 1/2003 into the European gas and electricity sectors (Final Report)," COM(2006) 851 final, Jan. 2007. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0851:FIN:EN:PDF

[5] ETSO, 2005. "Current State of Trading Tertiary Reserves Across Borders in Europe"

[6] ETSO, 2006. "Key Issues in Facilitating Cross-Border Trading of Tertiary Reserves and Energy Balancing"

[7] ETSO, 2007. "Balance Management Harmonisation and Integration – 4th Report"

[8] ERGEG, 2009. "Revised ERGEG Guidelines of Good Practice for Electricity Balancing Markets Integration (GGP-EBMI)," Ref: E09-ENM-14-04, Sep. 2009

[9] EURELECTRIC, 2008. "EURELECTRIC Position Paper Towards Market Integration of Reserves & Balancing Markets" SG Balancing & Intra-day Markets

[10] Van der Veen, R.A.C., and Hakvoort, R.A., 2009. "Balance Responsibility and Imbalance Settlement in Northern Europe – An Evaluation" conference paper, 6th European Energy Market conference, 27-29 May 2009, Leuven (Belgium)

[11] Technische Universität Dortmund and E-Bridge, 2009. "Optimierung der Ausregelung von Leistungsungleichgewichten" report for the Bundesnetzagentur, August 2009. Available at: http://www.bundesnetzagentur.de/media/archive/17278.pdf

[12] ENTSO-E, 2009. "Statistical Yearbook 2008" Available at: http://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/Statistical_Yearbook_2008.pdf

[13] TenneT website, http://www.tennet.org/english/operational_management/index.aspx, data retrieved in February 2009.

[14] Combined website of German TSOs, https://www.regelleistung.net/regelleistungWeb/, data retrieved in February 2009.