

Just, Sebastian; Weber, Christoph

Working Paper

Strategic Behavior in the German Balancing Energy Mechanism: Incentives, Evidence, Costs and Solutions

EWL Working Paper, No. 04/12

Provided in Cooperation with:

University of Duisburg-Essen, Chair for Management Science and Energy Economics

Suggested Citation: Just, Sebastian; Weber, Christoph (2012) : Strategic Behavior in the German Balancing Energy Mechanism: Incentives, Evidence, Costs and Solutions, EWL Working Paper, No. 04/12, University of Duisburg-Essen, Chair for Management Science and Energy Economics, Essen

This Version is available at:

<https://hdl.handle.net/10419/103285>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



Strategic Behavior in the German Balancing Energy Mechanism: Incentives, Evidence, Costs and Solutions

Sebastian Just* and Christoph Weber

*Chair of Management Sciences and Energy Economics, University of Duisburg-Essen,
Universitätsstr. 11, 45117 Essen, Germany*

Working Paper - Version October 28, 2012

ABSTRACT

This paper investigates the incentives market participants have in the German electricity balancing mechanism. Strategic over- and undersupply positions are the result of existing stochastic arbitrage opportunities between the spot market and the balancing mechanism. This strategic behavior can be clearly identified in aggregate market data. These structural imbalances increase the need for reserve capacity, raise system security concerns, and thus burden significant cost on the customers. More effective market designs include changes in the balancing mechanism, the reserve capacity and the intraday spot markets.

JEL classification: L94, Q41, Q47

Keywords: Electricity market design, balancing mechanism, reserve capacity, strategic behavior

* Corresponding author. Email: Sebastian.Just@stud.uni-due.de.

1. INTRODUCTION

The liberalization and the resulting deconstruction of the integrated electricity value chain brought new necessities for adequate coordination to reflect the technical requirements of the electricity system. The technical characteristics are still remaining the same, especially the crucial requirement of keeping the system continuously balanced. To avoid frequency changes and in the most severe case blackouts, the amount of consumed and produced electricity has to be balanced second by second.

Before liberalization, the integrated utility, which was typically a regional monopoly, took care of the balancing necessity in its network area – the balancing task was fully internalized. In many liberalized electricity markets around the world, the crucial balancing task has been essentially separated into two stages: decentrally coordinated planning via balancing groups before gate closure and centralized coordination or balancing by the transmission system operators (TSOs) via the use of flexible reserve capacity afterwards.

The concept of balancing groups was introduced to administrate and coordinate the system with potentially thousands of active market participants. It is an accounting procedure, which keeps entries of all injected and withdrawn electricity within a specified timeframe for each balancing group – in Germany for every 15 minutes. Each market participant (i.e. supply companies, large consumers, generators, and traders) is required to be part of a balancing group. At the planning stage before gate closure, all balancing groups are – or better have to be – balanced. E.g. a supply company forecasts its supply commitments towards its customers and obtains the equivalent electricity. The according energy schedules have to be submitted daily to the TSOs before gate closure. At this stage, the system is balanced at least from a planning perspective.

After gate closure, all the responsibility shifts to the TSOs. They are responsible to balance all deviations between the actual and the planned schedules in real-time. The balancing is done by the use of system reserve capacity, which is procured by the TSOs beforehand. The required balancing or reserve energy is called from this reserve capacity as needed.

The measured deviations for every balancing group are balanced and settled at the balancing or reserve energy price. If a balancing group is undersupplied, it pays for the additionally required electricity and vice versa. This procedure is called the balancing mechanism. It is a very critical element of a well-functioning electricity system. It shall coordinate the system and provide the right incentives to minimize the imbalances that can otherwise only be resolved by limited reserve capacity or forced load shedding.

The German balancing mechanism and suspected gaming behavior of market participants have very recently sparked the public attention (see among others FAZ, 2012). During a cold spell and times of critical system conditions in February 2012, the German electricity system was structurally undersupplied, which almost led to a severe blackout. Market participants were suspected to have intentionally misused balancing energy to avoid buying more expensive electricity in the spot markets. Some market participants claimed on the other hand that the unexpected cold weather led to an underestimation of the actual electricity demand. For any specific moment, it is however hard to determine whether undersupply behavior was intended or merely the result of unavoidable forecasting uncertainty.

This paper investigates the German balancing mechanism and the empirical evidence of potential strategic behavior of market participants more closely using longer time series. In Germany, the prices for reserve/balancing energy and spot (day-ahead and intraday) electricity are largely disconnected due to the specific market design. This provides structural opportunities for strategic behavior at one of the most crucial links in the electricity system. As we will show, market participants have a clear incentive to over- and undersupply their expected load commitments depending on the expected spot price.

The German market for reserve capacity has attracted an increasing attention in the economic literature, in which the market design and results have been heavily debated.¹ However, the balancing mechanism and the link to the spot markets have only been studied very selectively. Wawer (2007) shows that balancing groups have an incentive to oversupply in off-peak periods and undersupply in peak periods. When the balancing price is lower than the spot price, market participants use the arbitrage opportunity and tend to undersupply, and vice versa. Moeller et al. (2011) apply time series analysis to detect strategic positions taken in the German balancing mechanism. They conclude that those strategies and the market design that fosters them contribute to the overall effectiveness of the electricity market.

Outside the specific German context, Boogert and Dupont (2005) study gaming-behavior in the Dutch balancing mechanism, which differs from the market design in Germany. They find that strategic behavior is rarely profitable in the Netherlands and comes with large risks. Vandezande et al. (2010) discuss different balancing designs by the use of simplified examples and conclude that a mechanism designed as a one-price system like in Germany without penalties or link to spot prices should be preferred.

The aim of this paper is to extend the previous work and to increase the awareness about the insufficient German market design by studying explicitly the incentive for strategic behavior. We show that a broader spectrum of incentives for over-/undersupply exists than described by Wawer (2007). These theoretical patterns of gaming behavior can be observed to a high degree in aggregated market data. This indicates that the currently used abuse-clauses by the TSOs are not sufficient and that large external costs are finally burdened on to the customers. Solutions to prevent the strategic behavior exist and their implications are investigated. Our analysis leads to different conclusions than Moeller et al. (2011) and Vandezande et al. (2010). The reasons for the apparent divergence are discussed at the end of this paper, showing that our findings add an important perspective to an effective market design at the core of the electricity system.

The paper is organized as follows: Section 2 describes the specific electricity market design in Germany. The data basis and analysis horizon is described in Section 3. The price formation in the balancing mechanism and its predictability is studied in Section 4. In Section 5, the incentives in such a market are explored and formalized. Empirical evidence of strategic behavior is investigated in Section 6. The implied costs of this behavior are estimated in Section 7 and possible solutions to prevent it are discussed in Section 8. Finally, the conclusions are drawn.

2. MARKET DESIGN AND SEQUENCE OF ELECTRICITY MARKETS IN GERMANY

The German electricity market – like many other European electricity markets – consists of a sequence of separate bilateral markets. This philosophy is in contrast to centrally coordinated pool market designs used in most liberalized markets in the US.

Broadly, three types of markets or mechanisms can be distinguished in Germany (see Figure 1). First are energy markets, in which the actual output of power plants is traded. Some time ahead of delivery, energy is continuously traded in forward markets either on the EEX power exchange or over-the-counter (OTC). Most of these trades are purely financial and only part of the OTC deals are physical. The financial forward contracts are generally settled at the day-ahead spot price. The exchange-based day-ahead spot market is held at 12am as an auction to accumulate volume and increase the liquidity of the market. The EEX day-ahead spot trading volume has been increasing and reached about 40% of consumption in 2011 and can therefore

¹ Among them are Swider and Weber (2003), Swider and Ellersdorfer (2005), Nailis (2006), Swider (2007a), Just and Weber (2008), Growitsch and Weber (2008), Rammerstorfer and Müller (2008), Haucap et al. (2009), Rammerstorfer and Wagner (2009) and Just (2011).

be considered as highly liquid. Physical energy can be traded for individual hours of the following day across all locations in Germany. After the day-ahead spot market is held, all market participants (technically all balancing groups) have to submit their ¼-hourly energy schedules to the TSOs, basically to check the feasibility of the expected power flows. Those schedules can be adjusted until gate closure 45 minutes ahead of delivery. There is a continuous intraday spot market to facilitate physical energy transactions necessary for those re-schedulings. At the EEX hourly products (with traded volumes of ~3% of consumption) and OTC ¼-hourly increments are traded. These are the last market-based transactions before the energy schedules are fixed and binding. After gate closure the TSOs take over the responsibility for any further action.

Second, parallel to the energy markets, the TSOs procure system reserve capacity. Reserve capacity is necessary for continuously balancing all deviations between consumed and produced electricity after gate closure or – in other words – for balancing the deviations between planned and actual load schedules in real-time.

The four German TSOs procure reserve capacity via one-sided auctions – the reserve capacity market – some time ahead of its contingent use. Thereby three different reserve qualities are distinguished: primary, secondary and tertiary reserve capacity. The main difference is the response time. Primary reserve activates immediately and has to reach full response within 30 seconds. The activation of secondary reserves starts also immediately and reserves need to be fully available within 5 minutes. The objective of tertiary reserves is to release and supplement secondary reserves starting 15 minutes after the manual activation.

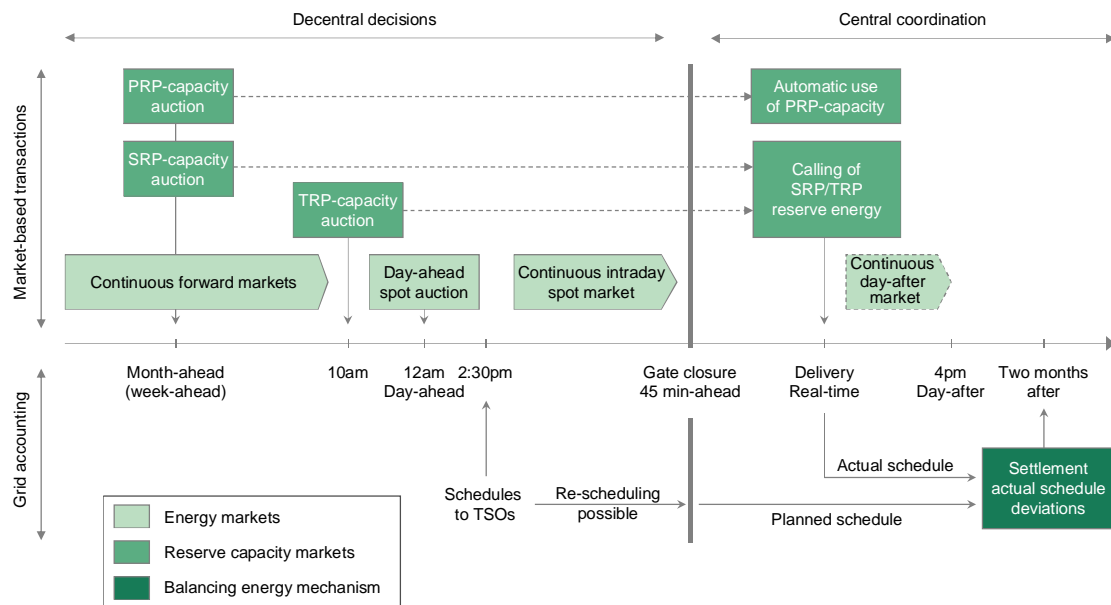


FIGURE 1: SEQUENCE OF ELECTRICITY MARKETS IN GERMANY

The option-like character of reserves is mirrored by the two-part pricing. A reservation price (€/MW) is paid for keeping the capacity in reserve and a reserve energy price (€/MWh) is paid for exercising the reserve option in order to generate the required energy in real-time.²

² For primary reserve only a reservation price is applied. The actual use is not rewarded separately as it is assumed that the incremental and decremental primary reserve energy offset each other. Furthermore, it cannot be attributed to individual parties. Primary reserve is not further considered in this paper.

The reservation prices are of little relevance for the following discussion and the focus is on the reserve energy prices.

The auctions for secondary reserve capacity have been held monthly³, separately for peak and off-peak periods. Tertiary reserve is procured daily ahead of the day-ahead spot market in six separate four-hour time segments. For both secondary and tertiary reserve, separate incremental and decremental reserve products are defined. Incremental reserve is required when the consumed electricity is larger than the produced electricity (the control zone has a deficit) and vice versa. In case decremental energy is called, the provider pays the reserve energy price, whereas for incremental reserve energy the provider is paid.

Finally, the balancing energy mechanism (it is not really a market, but rather an accounting procedure) distributes the costs of that reserve energy among the originators of the imbalance. Therefore, the necessary reserve energy is also called balancing energy – they are actually two sides of the same coin.

The mechanism determines ex post the individual payments for countering the individual imbalances (difference between planned and actual load schedules) of every balancing group.⁴ Partly, the imbalances of the balancing groups offset each other within a control zone. The remaining imbalance is offset by the TSOs via employed reserve energy as described above. This sets the price for all individual imbalances within the control zone for this ¼-hour – either the decremental balancing price when the control zone is long (i.e. oversupplied) or the incremental balancing price when the control zone is short (undersupplied). All balancing groups with a positive balance (an oversupply of energy) receive this balancing energy price and all undersupplied balancing groups have to pay for the missing energy. Hence, it is a cost-based one-price system and a zero-sum activity for the TSOs as all reserve energy related costs are passed through the balancing groups.⁵

Given its physical and commercial characteristics, balancing energy is a substitute for any electricity traded in the energy markets.

For completeness and as it becomes relevant later in the paper, the balancing groups have the possibility to adjust their planned and submitted schedules retroactively until 4pm the day-after. This does not change anything physically, but the grid accounting. Theoretically, energy can be traded retroactively on paper between two balancing groups to change their respective planned schedules. In other words, individual imbalances can be traded in the day-after market, which is basically an OTC market. However, given the design of the balancing mechanism as a one-price system, there are no win-win situations between balancing groups with opposite imbalances that could be facilitated by trading, if the balancing prices are known. Only reducing the uncertainty, until the balancing prices are known two months later, provides an incentive why market participants should exchange their imbalances. We will see in the next section that there is a rather high predictability of the balancing prices. This is in line with reality. The day-after market exists, but is largely irrelevant in practice. For that reason, we will not consider it further in our discussion for the time being.

³ During the main part of the period considered in this paper the auctions for primary and secondary reserve capacity were held monthly. Before December 2007, it was held half-yearly. Since June 2011, weekly auctions have been held.

⁴ BRPs are responsible for keeping the balance between all power supplies and withdrawals in every ¼-hour within their balancing groups. Every electricity market participant needs to be part of a balancing group, one for every of the four control zones it has transactions in. Balancing groups can consist of one or multiple market participants; i.e. supply companies and generation companies.

⁵ The costs for keeping capacity in reserve are passed on via the grid charges to the consumers of electricity.

3. DATA BASIS AND TIME HORIZON FOR FOLLOWING ANALYSES

The behavior of market participants within the German balancing mechanism should ideally be investigated at an individual balancing group level. Unfortunately, the corresponding planned and actual energy schedules are not publicly available. Therefore, the aggregate imbalance data for each control zone are utilized instead.

The four German TSOs publish ¼-hourly balancing price and imbalance data for their respective control zones (Amprion, 2012; TennetTSO, 2012; 50Hertz, 2012 and TransnetBW, 2012)⁶. Furthermore, the published ¼-hourly load data has been used to determine the relative imbalances in the respective control zones. This allows normalizing the imbalance data during daily, weekly and seasonal load cycles as well as for the different relative size of the control zones. The spot day-ahead and intraday price data for the German market has been used as principal reference. It can be obtained from the European Energy Exchange (EEX, 2012).

The analyzed data spans an overall time period of over 5 years starting in January 2006 until April 2011. The market data has been investigated in 5 individual periods: 2006, 2007, 2008-Apr 2009, May 2009-Apr 2010 and May 2010-Apr 2011. This specific selection has been chosen for two reasons. First, the periods should have sufficient sample size to obtain statistically significant results. Second, it reflects two relevant changes in the market design and thus in market data. Due to an order of the German regulator, the German TSOs had to manage their separate control zones as a unified one in order to realize size and portfolio effects. Essentially that meant that they balance any imbalance among the control zones in order to reduce the need for reserve or balancing energy. This led to the fact that only one balancing price exists anymore for the unified control zone and that only the imbalance of the unified control zone is published. Due to technical circumstances, TennetTSO, 50Hertz and TransnetBW had to start with this new procedure in May 2009. This joint management is called Grid Control Coordination (GCC) or Netzregelverbund in German. Amprion joined one year later in May 2010.

The following analysis focuses on the two recent one-year periods May 2009-April 2010 and May 2010-April 2011. The analysis of the previous periods is included in the Appendix.

4. PRICE FORMATION AND PREDICTABILITY IN THE BALANCING ENERGY MECHANISM

Even if the actual balancing energy prices are only published with a delay of two months, the market participants can obtain a good indication before. The merit orders for balancing or reserve energy are basically known as both auctions for secondary and tertiary reserve are held before the spot markets. Adding to the foresight, balancing energy prices are mainly determined by the secondary energy prices as tertiary reserve is only called occasionally (see Figure 2).

⁶ In the following, TSOs are only referred to by their current company names. Due to changes in ownership and/or unbundling requirements, the names of all four TSOs have changed in recent years: Amprion is the former RWE Transportnetz Strom, TennetTSO is the former E.ON Netz, which was named Transpower in between, and 50Hertz is the former Vattenfall Europe Transmission. TransnetBW is the legally unbundled TSO of EnBW.

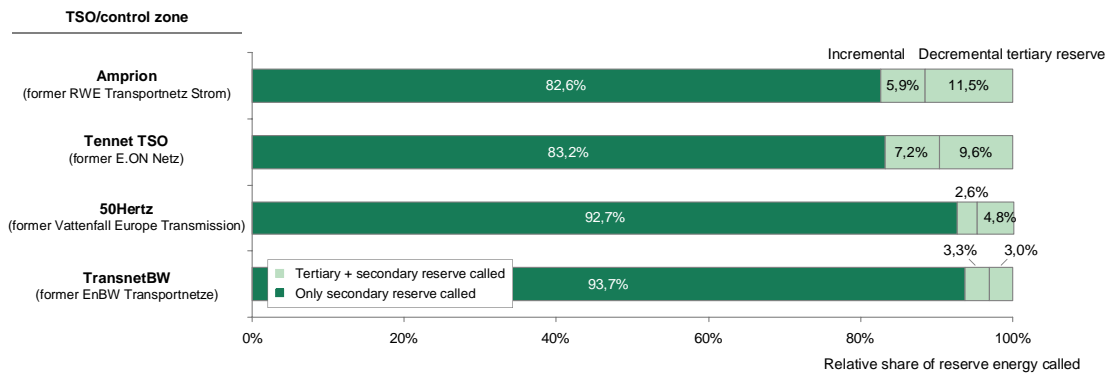


FIGURE 2: RELATIVE USE OF TERTIARY RESERVE CAPACITY IN 2010

Monthly (or even half-yearly before) auctions for secondary reserve imply that the reserve energy price bids apply throughout this whole period and the resulting merit order of those reserve energy price bids is theoretically static. This can be observed in Figure 3, in which the actual balancing energy prices and the secondary reserve energy bid curves are exemplary depicted for the peak period in January 2010.⁷ Balancing energy prices can be distinguished for ¼-hours in which only secondary reserve and in which additionally tertiary reserve energy is called. Prices for tertiary energy tend to be in a similar range like secondary energy prices. The known secondary energy bid curves allow a good estimation of the expected balancing prices.

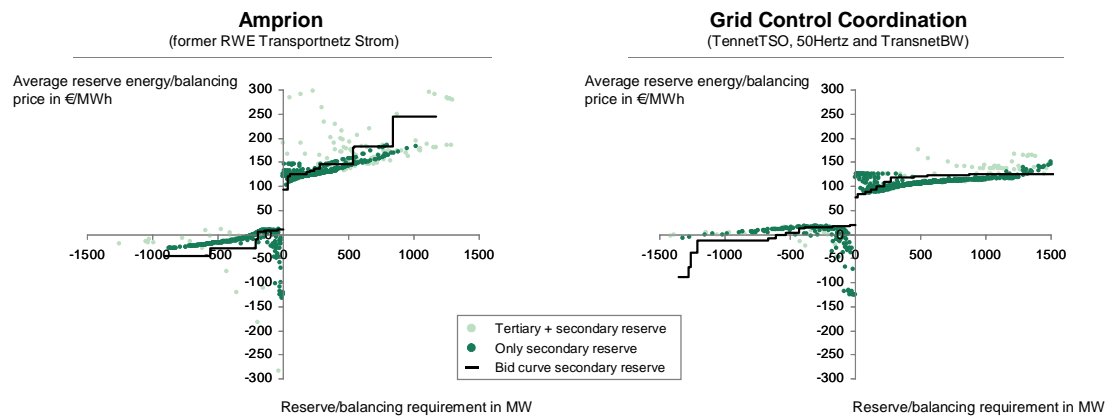


FIGURE 3: RESERVE ENERGY/BALANCING PRICES FOR PEAK PERIODS IN JANUARY 2010

The general price formation is very distinctive with a large gap between incremental and decremental balancing prices. Incremental balancing prices tend to be close to or above 100 €/MWh and the decremental balancing prices below 20 €/MWh. This distinct pattern is

⁷ The actual balancing energy prices in periods when only secondary reserve is called deviate from the secondary reserve bid curves for two reasons. First, pay-as-bid remuneration is applied in the German reserve capacity market, resulting in lower average costs of all called bids. Second, the balancing price is determined by the sum of all cost for reserve energy called divided by the average imbalance during the ¼-hour. This results in large deviations from the bid curve in all ¼-hours when incremental as well as decremental energy is called. These are typically ¼-hours with low average imbalances.

recurrent over time and during peak as well as off-peak periods as indicated in Figure 4, which shows the exemplary balancing prices for January 2011.

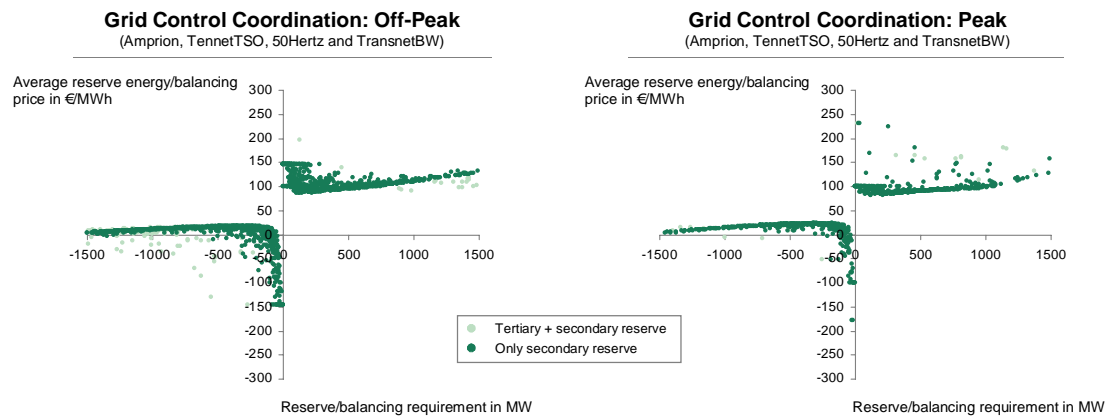


FIGURE 4: RESERVE ENERGY/BALANCING PRICES FOR PEAK AND OFF-PEAK PERIODS IN JANUARY 2011

As the balancing prices result from deployment of reserve energy according to the merit order of bid prices, the prices are generally increasing with a higher balancing requirement and vice versa. However, this tendency is not very pronounced and the price patterns tend to be relatively flat. Furthermore, the balancing prices for relatively low balancing requirements do not follow the merit order logic as explained in footnote 8. As a result the balancing prices are highly dependent on the direction of the imbalance of the control zone, but largely independent from the actual size of the imbalance.

The distinct pattern of the balancing prices can be identified also over longer time periods (see Figure 5). Prices for decremental energy were largely stable around 0 €/MWh. Shortly after the regulator allowed negative prices in 2009, bidders started to request a payment when they reduce the output of their plant.⁸ However, decremental prices returned to a level around zero after one year.

Prices for incremental energy were largely stable in a range of 70-110 €/MWh until beginning of 2008. The year 2008 was generally highly impacted by steeply rising oil and overall energy prices. As a result, also the incremental balancing prices soared, but came back to a more normal level in 2009. After that they have been again relatively stable, lately in a range of 90-120 €/MWh.

Whereas in the long-run (incremental) balancing prices are and should be expected to be correlated with electricity prices, they are largely independent from spot electricity prices in the short-run. Correlation coefficients have been in a range of 0.1-0.2. Balancing energy prices in Germany are highly predictable. A property that can be exploited by market participants as discussed in the following chapter.

⁸ This offering behavior is likely rather a result of the absence of competition than caused by technical constraints. Negative prices appeared in the German day-ahead spot market in the last years in periods with relatively low demand and high wind generation. In such periods coal power plants are usually already in part-load, which makes further reduction very costly, especially when the full load is needed again in a few hours. The situation in the secondary reserve market is different, especially in peak periods. While providing decremental reserve energy, plants lower their output level and save on fuel costs, but do not hand off the contracted income from the unreduced output. Hence, under competitive conditions a positive payment towards the TSO should be expected – as seen in the EnBW control zone before 2009.

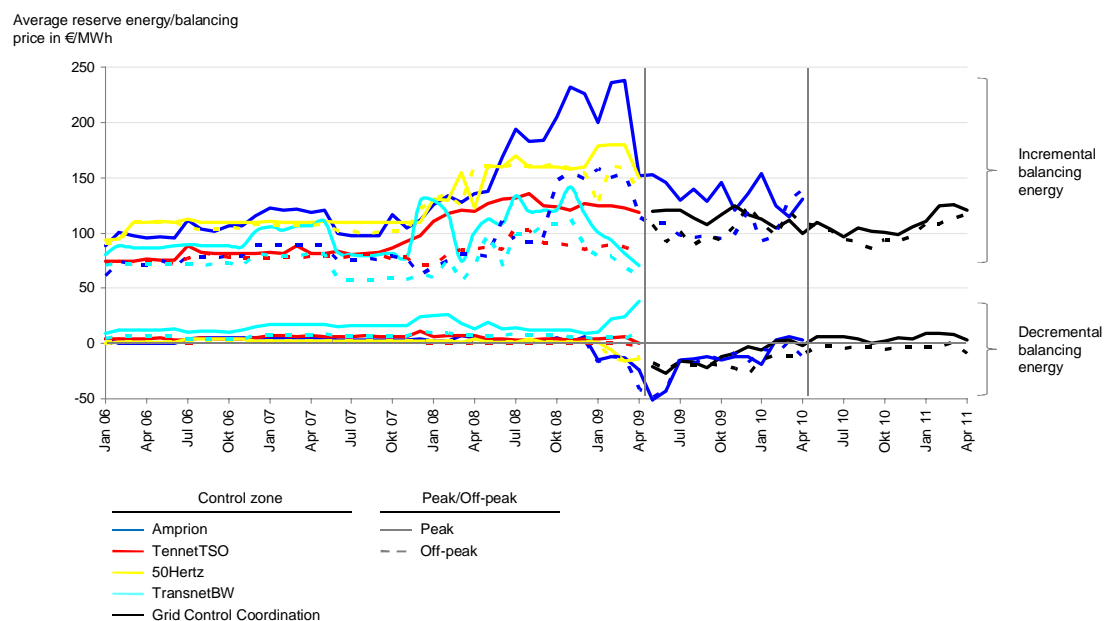


FIGURE 5: AVERAGE RESERVE ENERGY/BALANCING PRICES 2006-2011

5. INCENTIVES IN THE BALANCING MECHANISM

Balancing groups are expected to provide unbiased energy schedules that reflect their best estimate of the actual energy flow. Supply companies should forecast their supply commitments and procure the necessary energy to match their best forecast.

However, given the relatively high predictability of balancing prices and their very low correlation with spot prices, they could be taken into account when deciding on how much electricity a supply company should procure. The resulting decision space is summarized in Figure 6.

An undersupply strategy is straightforward when spot prices are expected to be extremely high. This is a fairly simple market arbitrage situation. Independent of the imbalance of the control zone, balancing energy is very likely less expensive than spot electricity. As it is a dominant strategy for all market participants, the risk of large imbalances and thus instable system conditions is high. This puts a further burden in situations when the electricity system is already under stress – reflected by high spot prices – and might even cause blackouts. Imbalances exceeding the reserve capacity can only be resolved by load-shedding, which is generally considered very expensive.

On the other side, when the expected spot price is below the decremental balancing price, the dominant strategy is to oversupply one's expected supply commitments. These are basically off-peak situations with high wind feed-in when must-run generation capacity serves the marginal load and spot prices are negative. Imbalances that exceed the reserve capacity can only be resolved by out-of-market shut downs of must-run capacity. Note that in such situations the electricity system is also under extreme stress, even before any further oversupply imbalances added to the system.

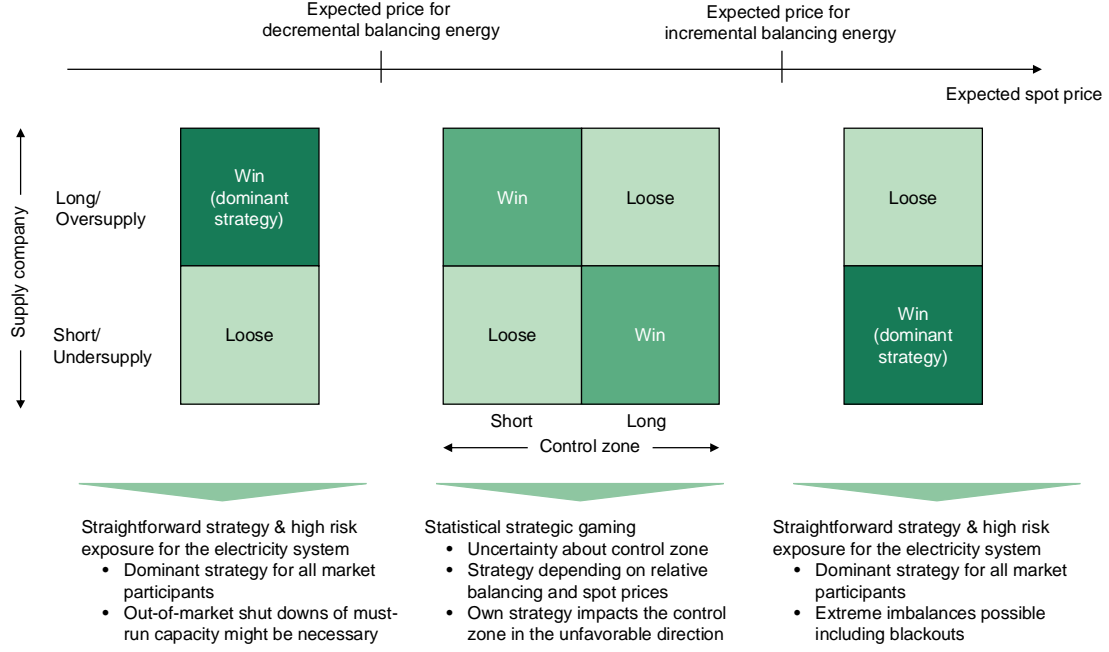


FIGURE 6: STRATEGIES TO GAME THE BALANCING MECHANISM

For all situations in between, the strategy depends on the expectation of the imbalance of the overall control zone and the relative amount one can gain. Under the current balancing mechanism in Germany, it pays off to be contrary to the control zone and thereby reducing the overall imbalance.⁹ Then you either receive a relatively high price for an excess or pay a relatively low price (or even receive a payment in case of negative decremental balancing prices) for a shortage of energy. As the direction of the imbalance of the control zone is largely random, it is a statistical arbitrage game with expected pay-offs depending on the relative differences between balancing and spot prices, which can pay off even if the probability of being contrary to the control zone is significantly below 50%. The success of such a strategy is, however, curbed and limited as the own action influences the imbalance of the control zone in the unfavorable direction. Nevertheless, the incentive to behave strategically exists.

To explore this incentive issue further, a simplified model of the strategic over-/undersupply decision is developed. Suppose all supply companies active in a control zone are able to forecast the demand of their customers on average correctly and the forecast error is normally distributed. Thus, the actual demand D^{Total} in the control zone is normally distributed around the expected demand $E(D^{Total})$ with a standard deviation $\sigma = e * E(D^{Total})$ and follows the cumulative distribution function $F(D^{Total})$.

Without loss of generality, there are n supply companies that behave strategically in their procurement decision. They serve each a share k_i of the demand within the control zone. Thus, the expected demand of company i is $E(D_i) = k_i * E(D^{Total})$. It procures an amount d_i in the spot market.

$$d_i = (1 + a_i) E(D_i) \quad (1)$$

⁹ However, a strategic position taken in one or the other direction moves the imbalance of the control zone in that direction.

The factor a_i denotes the relative over-/undersupply of its expected supply commitments. The total amount procured is

$$d^{Total} = \sum_{i=1}^n d_i = \sum_{i=1}^n (1 + a_i) k_i E(D^{Total}) \quad \text{with} \quad \sum_{i=1}^n k_i = 1. \quad (1)$$

The probability that the control zone is long/oversupplied is $F(d^{Total})$, and $1 - F(d^{Total})$ that it is undersupplied.

The supply company i is assumed to maximize its expected profit $E(\Pi_i)$ while choosing the parameter a_i :

$$\max_{a_i} E(\Pi_i) = P^{Retail} E(D_i) - E(P^{Spot}) d_i - E(P^{Balancing}) [E(D_i) - d_i] \quad (2)$$

with P^{Retail} the retail price, $E(P^{Spot})$ the expected spot price and $E(P^{Balancing})$ the expected balancing price. Using the definition (1), it can be reformulated as a maximization problem with the expected profit margin:

$$\max_{a_i} E(\pi_i) = P^{Retail} - E(P^{Spot}) + a_i [E(P^{Balancing}) - E(P^{Spot})] \quad (3)$$

The expected balancing price is determined by

$$E(P^{Balancing}) = F(d^{Total}) E(P^{Dec}) + (1 - F(d^{Total})) E(P^{Inc}) \quad (4)$$

with $E(P^{Dec})$ and $E(P^{Inc})$ the expected decremental and incremental balancing prices. For simplicity reasons, both are assumed to be independent of the size of the imbalance of the control zone. This assumption is in quite good accordance with the reality as indicated by Figure 3 and Figure 4.

The optimal strategy a_i can be derived from the first-order condition of the profit maximization problem

$$\begin{aligned} \frac{E(P^{Inc}) - E(P^{Spot})}{E(P^{Inc}) - E(P^{Dec})} &= F(d^{Total}) + a_i k_i E(D^{Total}) f(d^{Total}) \quad \forall i \\ &= \Phi\left(\frac{\sum_{j=1}^n a_j k_j}{e}\right) + \frac{a_i k_i}{e} \varphi\left(\frac{\sum_{j=1}^n a_j k_j}{e}\right) \quad \forall i \end{aligned} \quad (5)$$

with $\varphi(\cdot)$ and $\Phi(\cdot)$ the probability density and cumulative distribution function of the standardized normal distribution.

Since the optimality condition is analogous for all i and only depends on the product $a_i k_i$, the strategic Nash equilibrium must be symmetric and the relationship between the optimal strategies may be derived as:

$$a_j = a_i \frac{k_i}{k_j} \quad \forall i, j \quad (6)$$

Thus, the optimal strategy a_i in a Nash equilibrium can be restated as

$$\frac{E(P^{Inc}) - E(P^{Spot})}{E(P^{Inc}) - E(P^{Dec})} = \Phi\left(\frac{n a_i k_i}{e}\right) + a_i k_i \phi\left(\frac{n a_i k_i}{e}\right) \quad (7)$$

The optimal relative over-/undersupply a_i is hence inversely proportional to the market share k_i in expected demand of company i . Or stated in other words: the absolute over-/undersupply quantity $a_i \cdot k_i$, is in equilibrium independent of the size of the market participant.

Given the non-linear characteristics of the equilibrium condition (7), analytical solutions and approximations are difficult. Therefore the optimal strategies are determined by numerical simulation¹⁰. Choosing the following reasonable parameters: average forecast error $e = 2\%$, expected incremental and decremental balancing price $E(P^{Inc}) = 120 \text{ €/MWh}$ and $E(P^{Dec}) = 0 \text{ €/MWh}$, the optimal strategy a_i is determined depending on the relative share k_i and the expected spot price $E(P^{Spot})$. The results are shown in Figure 7 for the case of $n=10$. For a better visualization, the strategic over-/undersupply factor a_i is depicted on a log scale.

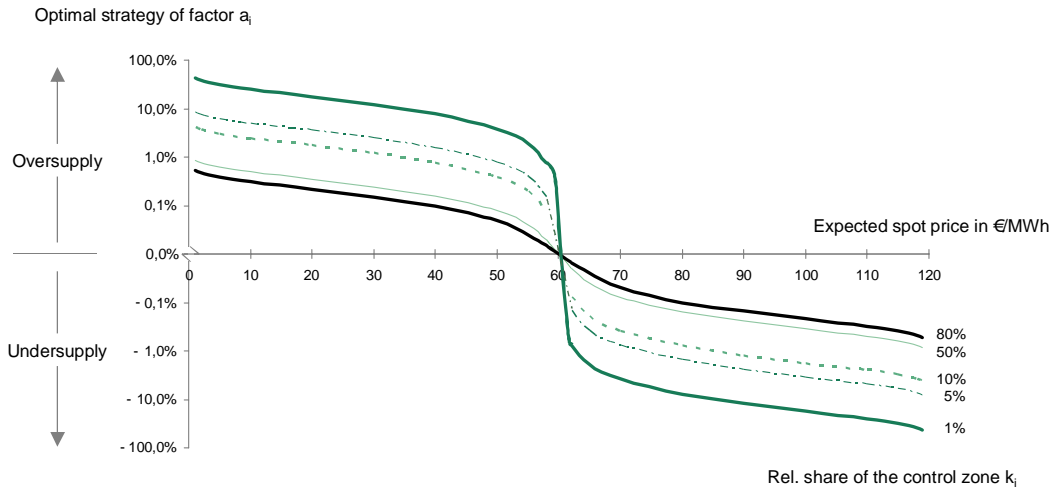


FIGURE 7: OVER-/UNDERSUPPLY INCENTIVE DEPENDING ON SPOT PRICE AND RELATIVE SIZE OF A SUPPLY COMPANY

In all situations with spot prices between the decremental and incremental balancing energy price, deviations from the best forecast are advantageous. The closer the spot price is to the incremental balancing price, the stronger is the incentive to undersupply. The higher the spot price, the higher is the relative benefit from the low or negative decremental balancing price in case of an oversupplied control zone and the lower is the relative penalty from getting charged the incremental balancing price in case of undersupplied control zone. The opposite holds for low spot prices. Only for expected spot prices equal to the average of the decremental and incremental balancing energy prices, there is no incentive to deviate from the forecast.

The illustration also shows that smaller supply companies have a larger relative incentive to behave strategically. Their own impact to move the overall control zone in the unfavorable direction is smaller. This implies also that the more companies play the over-/undersupply game, the less profitable it is and the lower is the strategic incentive for the individual

¹⁰ Given the properties of the probability density and cumulative distribution function, the RHS of equation (7) is strictly monotonically increasing within the co-domain $]0;1[$, which is exactly the co-domain of the LHS for $E(P^{Dec}) < E(P^{Spot}) < E(P^{Inc})$. Hence, the obtained numerical solution is unique.

company. This self-regulating effect should prevent a too extensive abuse in the situations when the expected spot price is between the expected decremental and incremental balancing prices.

The individual strategic behavior results in an expected over-/undersupply pattern of the overall control zone (see Figure 8). Thereby the magnitude of the expected deviation is increasing with the number companies acting strategically. From equation (6) follows that the relative size among the companies does not impact the expected over-/undersupply pattern of the control zone, as the relative strategic incentive is inversely proportional to its market share.

Depending on the relative prices in the spot market and the balancing mechanism, structural over-/undersupply situations over longer periods are to be expected. As a result the mean of the distribution of imbalances for a full year might significantly deviate from zero.¹¹

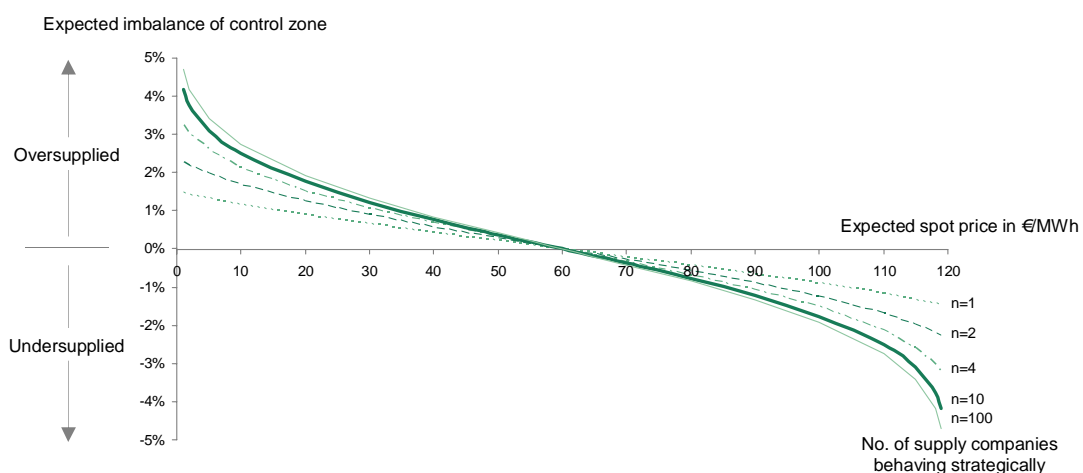


FIGURE 8: EXPECTED OVER-/UNDERSUPPLY PATTERN OF THE CONTROL ZONE DUE TO STRATEGIC BEHAVIOR

This discussion shows that there exist ample opportunities for strategic behavior at one of the most crucial links in the electricity system. The TSOs are afraid of such critical situations that could arise from the abuse of these opportunities. For that reason, they included anti-abuse clauses in the contracts with the balancing groups:

"Control energy is exclusively reserved for maintaining security and reliability of the transmission system and is therefore not available for any energy disposition. A remuneration of a surplus of energy takes only place if there are no clues about abusive additional feed-in."

"The balancing group contract can be terminated when a short supply was intended or tacitly approved." (Amprion, 2012b)

Abusive behavior is assumed when systematic deviations exist, *"so that the arithmetic average value of all negative and positive differences is positive [or negative] to a greater extent"* (Amprion, 2012b)

In reality, it might be difficult to draw a clear line between forecast errors and intended behavior – especially if the balancing groups (and supply companies) do not act naively. In

¹¹ As power plant failures are partly responsible for imbalances there is generally a slightly higher probability of an undersupplied control zone.

the next section, we will explore whether the anti-abuse clauses are sufficient to prevent strategic behavior in practice.

It should be mentioned that not only supply companies have an incentive for strategic behavior. Also generators, large industrial customers and the TSOs themselves have their own or are part of balancing groups. The same incentives apply for them as well. However, it is generally easier to investigate the reasons why generating companies deviate from their production schedule. If the TSOs would game their own mechanism, it would happen without independent control.

6. EMPIRICAL EVIDENCE OF STRATEGIC BEHAVIOR

The previous section revealed that balancing groups have at least theoretically the incentive to strategically over-/undersupply their expected supply commitments. Now, the empirical evidence is investigated.

Unfortunately, data about the historical "best" forecasts of the supply companies does not exist or is private. Also actual data on imbalances for individual balancing groups is not publicly available. However, the TSOs are bound to publish the imbalance data for every ¼-hour. Figure 9 shows the actual imbalances relative to the intraday spot price for the period May 2009 to April 2010 in the Amprion and GCC control zones. The intraday spot price is chosen since the intraday market is the last opportunity for adjustments. Furthermore, the market participants have a very good indication about the intraday spot price as the day-ahead spot price is known and intraday products are continuously traded.¹²

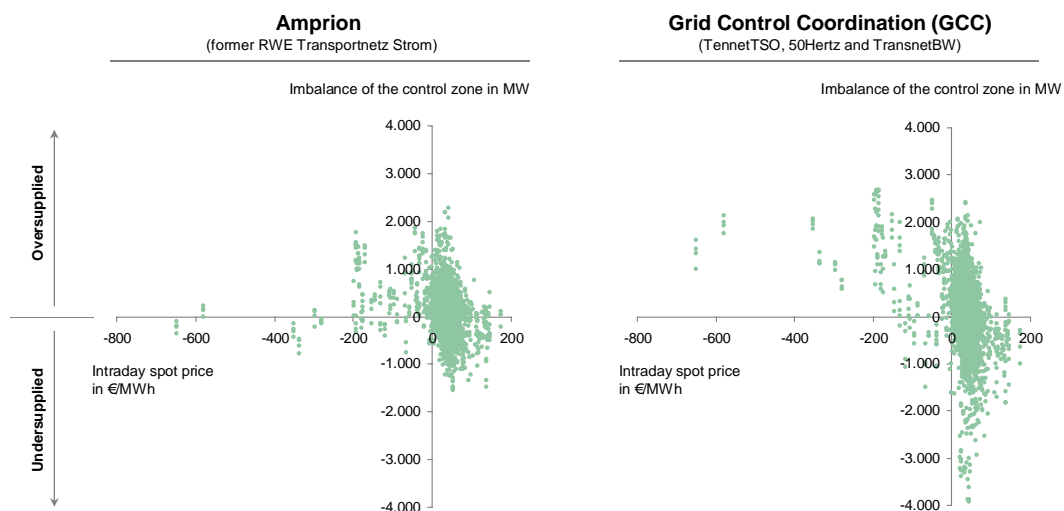


FIGURE 9: ACTUAL IMBALANCES IN CONTROL ZONES MAY 2009-APRIL 2010

Both control zones show clear tendency that market participants use the arbitrage opportunity to fulfill their supply commitment with relatively cheap balancing energy when spot prices are relatively high, and vice versa. In periods with intraday spot prices above 120 €/MWh, the control zones are predominantly undersupplied. The Amprion control zone is undersupplied

¹² The day-ahead spot prices are a more robust price signal as the day-ahead market is significantly more liquid. Therefore, the following analysis has been conducted both with day-ahead and intraday spot prices (see Appendix). The results are structurally identical with only minor deviations.

in 75% and the GCC control zone in 80% of those 64 ¼-hours, with an average imbalance of -267 MW and -488 MW, respectively. The opposite is true for prices roughly below -20 €/MWh – with Amprion being oversupplied in 77% with an average of 501 MW and GCC in 74% of those 196 ¼-hours with 819 MW on average.

It should be noted that imbalances did not exceed the contracted reserve capacity and that periods with extreme spot prices were not overly exploited as the incentives might suggest. The risk of being caught with abusive behavior increases significantly if the TSOs find themselves in situations with insufficient reserve capacity. Situations with required out-of-market actions such as load shedding cause public interest and the attention of the regulator. As a result, the TSOs might be inclined to investigate the causes more carefully.

Figure 10 takes a closer look at the same data for the periods with non-extreme spot prices. The imbalances are depicted in relative terms using the actual ¼-hourly load in the control zones as a denominator. In this way, they are comparable with the results from the theoretical model above. The empirical average imbalance is calculated for individual spot price clusters. The strategic behavior of structural oversupply at periods with low intraday spot prices and structural undersupply while spot prices are high is clearly visible. The empirical average imbalance matches very closely the average expected theoretical imbalance for the case $n=10$. It lags the theoretical expectations only somewhat for high intraday spot prices. This might be partly due to the reasons explained in the paragraph above.

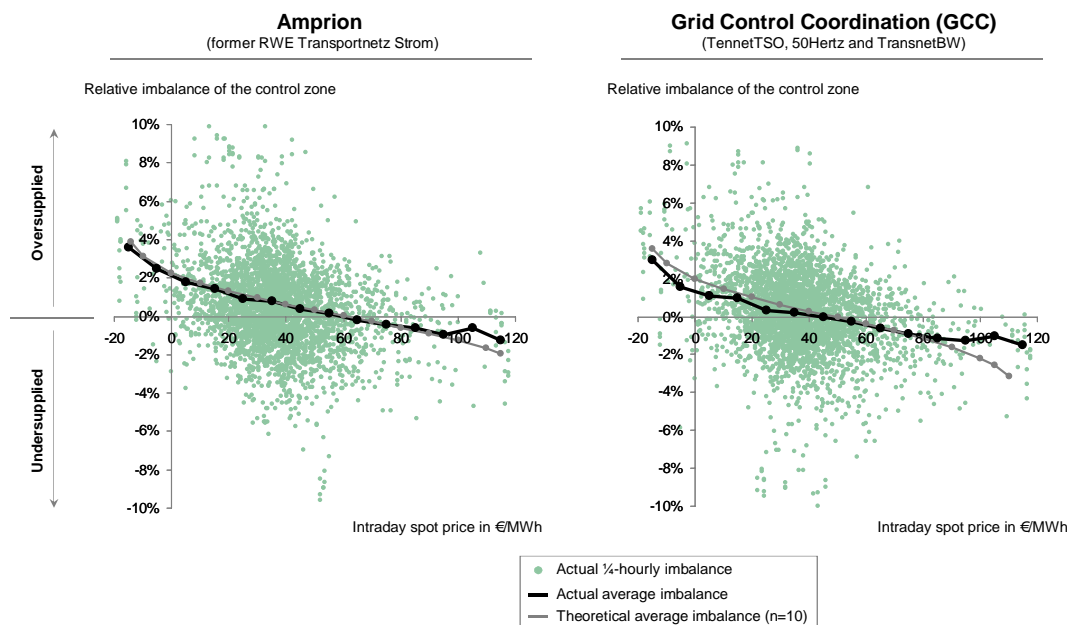


FIGURE 10: ACTUAL IMBALANCES VS. EXPECTED IMBALANCE IN CONTROL ZONES MAY 2009-APRIL 2010

The identified pattern is not specific to the considered time horizon, but can be generally traced in the years before¹³ (see Appendix) as well as in the most recent analyzed period of May 2010-April 2011 (see Figure 11). The strategic over-/undersupply behavior is less pronounced compared with the prediction by the theoretical model than in the twelve months before. This might be partially explained by the ownership change in two of the German

¹³ Moeller et al (2011) also show that market participants took strategic positions in the German balancing system during the years 2003-2008.

TSOs during the first half of 2010. The former E.ON Netz was sold to the Dutch TSO Tennet in January 2010 and the former Vattenfall Europe Transmission, now 50Hertz, was sold to a consortium of the Belgium TSO Elia and the Australian infrastructure fund IFM in May 2010. The higher degree of independence and the uncertainty about the behavior of the new owners is might have led market participants to reduce their over- and undersupply strategies. Furthermore, the electricity industry was high on the public and political agenda during 2010 with the debate on the extension of the life time of the nuclear plants. This might have also curbed the behavior of some of the market participants in order not to spark undesired attention.

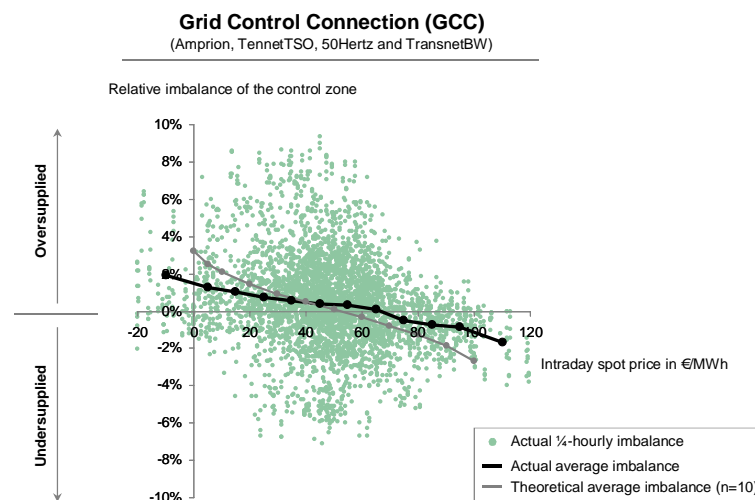


FIGURE 11: ACTUAL IMBALANCES VS. EXPECTED IMBALANCE IN CONTROL ZONES MAY 2010-APRIL 2011

The imbalance pattern has been analyzed in large data samples. Each of the analyzed periods comprises at least 35,000 of 1/4-hourly data points. Furthermore, the obtained results have been tested for statistical significance. The average empirical imbalances for nearly all price clusters are statistically different from the overall average imbalance of the data sample at a 1% confidence level (see Figure 13 in the Appendix). Only in a very few cases with moderate spot prices, the imbalance is not significantly skewed in either direction.

The analysis clearly shows that strategic behavior exists and that the statistical arbitrage opportunities between spot markets and balancing mechanism are utilized. The anti-abuse clauses applied by the TSOs are not sufficiently effective. The biased schedules increase the need for reserve energy and capacity which has to be contracted before and/or increase the risk of severe system instabilities in case the contracted reserve capacity is insufficient.

7. ESTIMATION OF THE FINANCIAL IMPACT OF THE STRATEGIC BEHAVIOR

This section intends to shed more light on the associated costs caused by the strategic behavior. Instead of using comprehensive modeling of all effects and detailed probabilistic analysis to determine the resulting impact on reserve capacity requirements, rough estimations are used to gain a basic understanding of the financial impact of the abuse of balancing energy and reserve capacity. The financial impact is estimated for the May 2009-April 2010 period.

There are three factors that drive the associated costs of the strategic behavior: increased need for reserve capacity, arbitrage gains between spot and balancing energy, and costs for increased risk of system instabilities.

First, the increased need for reserve capacity is considered. The strategic behavior effectively moves the conditional mean of the probability distribution of the imbalance depending on the price expectations. During periods of low spot prices, the imbalance probability distribution is moved towards more positive imbalances, and vice versa. Hence, strategic behavior increases overall the variance of the imbalances and the confidence intervals of the imbalance distribution, which is the major driver of the required amount of reserve capacity.

Figure 12 shows that the standard deviation of the imbalances is largely constant and independent of the intraday spot price and thus of the strategic behavior. Assuming that the imbalances are normally distributed – they are mainly the result of forecast errors – means that the confidence intervals are shifted in parallel with the conditional mean of the imbalance distribution. With this observation in mind, the increased need for reserve capacity can be estimated directly from the impact the strategic behavior has on the average imbalance.

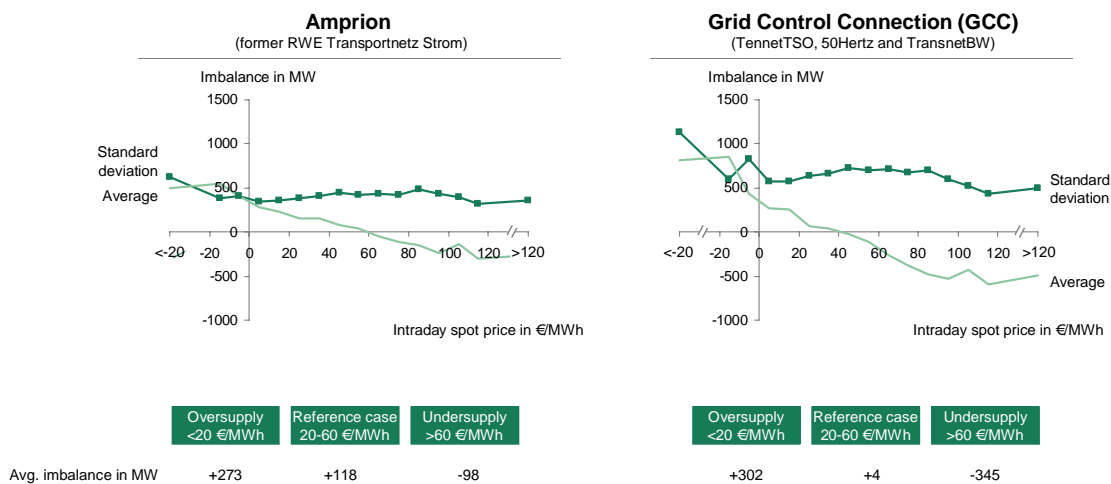


FIGURE 12: IMPACT OF STRATEGIC BEHAVIOR ON IMBALANCE DISTRIBUTION

Therefore a reference case with unbiased imbalances (intraday spot prices 20-60 €/MWh) is chosen and compared to periods with over-/ undersupply behavior (spot prices <20 €/MWh and >60 €/MWh). This yields the estimation that the strategic behavior drives an increased need of about 450MW incremental and about 575MW decremental reserve capacity (cf. Figure 12). Based on the current ratio between demanded secondary and tertiary reserve capacity and the prices for reserve capacity from May 2009-April 2010, this would have resulted in about €65m lower capacity payments.

Less required incremental secondary reserve capacity has an impact on spot market prices as less generation capacity is effectively withdrawn from the spot markets. This issue is discussed in more detail in Just and Weber (2008) and Just (2011). Applying the secondary reserve market equilibrium model with parameters for the German market used in Just (2011), the resulting dampening effect on the average spot price is estimated at about 0.20 €/MWh. Even if only about 40% of the electricity demand is currently traded through the EEX spot market, the price effect would eventually trickle through the whole market of about 550 TWh

in Germany. The spot market saving effect would be about €110m, making the total effect about €175m for less required reserve capacity in the absence of strategic behavior.

Second, gains from arbitrage between the balancing and the spot energy are considered, which are the incentive for the strategic behavior. The direct effect can be estimated by comparing the costs for the actual imbalances with the imbalances corrected by the average imbalance, valued with the respective balancing and spot prices. For every negative imbalance, the spot price was avoided before and the incremental balancing price is paid, and vice versa. The effective arbitrage gains for the full year are about €18m, assuming no influence on the prices themselves.

Undersupply behavior implies lower demand in the spot markets and thus keeps spot prices relatively lower, whereas the opposite is true for oversupply. Given the generally convex form of the supply curve, the overall effect is dominated by the price dampening. This secondary effect on the spot prices is estimated as the impact the average imbalance has on the supply-demand balance. The spot supply curve is estimated via a regression of hourly prices against hourly load as in Just (2011). The average dampening spot price effect is about 0.02 €/MWh or €11m for the overall market. The secondary effect on balancing prices is expected to be negligible as the balancing supply curves are relatively flat.

Overall the benefits from the market arbitrage between the balancing and spot energy market are about €30m. These benefits offset partly the costs from increased reserve capacity need discussed before.

Third, the probability of unavoidable load shedding and blackouts increases, particularly in periods with extreme spot prices in which strategic behavior is a dominant strategy. The macroeconomic costs can be immense. The economic impact of the August 2003 blackout in the Northeastern US/Canada blackout was estimated with \$ 7 to 10 billion (see ICF, 2003). The value of lost load is often estimated in a range of 5,000-10,000 €/MWh. One hour blackout in Germany with 70,000 MW lost load would have macroeconomic costs of €350-700 million. Even if such extreme scenarios are not likely, their probability is increased due to strategic behavior – although a quantification of this effect is hardly possible.

The implied net costs of the insufficient market design and the strategic behavior are significant and likely to be at least in the lower hundred million Euro range per year. This is too much to be ignored. Possible options for fixing this expensive flaw are discussed in the next section.

8. DISCUSSION OF SOLUTIONS OF THE INCENTIVE PROBLEM

The root of the incentive problem or strategic behavior is the disconnection of the spot markets and the balancing mechanism. Under the current market design in Germany, the balancing mechanism is directly linked with the reserve capacity market. However, the reserve capacity market is largely disconnected from the spot markets. As a result, balancing energy prices do not move in line with spot market prices. In fact the correlation between them is very low. This creates largely predictable opportunities that can be exploited.

Basically, there are two ways to fix this problem: Either establishing a direct link between the balancing and spot prices while cutting the link to the reserve capacity market or improving the link between the reserve and the spot markets.

First, any deviations of the balancing groups could be remunerated at the spot price for this period. This eliminates the incentive to deviate from the best forecast as nothing can be gained. But at the same time there is no incentive to increase the forecast accuracy. Rather the

balancing groups are indifferent about the expected imbalance they cause, which could likely result in outcomes that are worse than under the current mechanism.

Adding/deducting a penalty to/from the spot price would solve this problem.¹⁴ The required positive balancing energy while undersupplying would cost more than the spot price, and vice versa. The payment is independent of the overall balance of the control zone and just applies to the imbalance of the balancing group. From the analysis in Section 4 follows that the penalty needs to be symmetrical to induce the correct incentive. Otherwise, a steady bias is to be expected in the direction in which the penalty is lower.¹⁵ Actually, the higher the penalty, the higher is the incentive to invest in better forecasting of the supply commitments – with the positive effect of further reduced reserve capacity.

When the link to the reserve market is cut, the reserve energy cost/receipts do not necessarily equal the balancing energy receipts/costs anymore. Thus, the TSOs would generate a financial deficit or surplus due to the change in balancing mechanism. The regulation of the grid tariff would have to pass on the surplus or to allow for full recovery of the deficit. This does not have an efficiency but a distribution effect. Whether a possible re-distribution of those costs among different market participant or customer groups is more or less "fair" than the current distribution can not be answered without a thorough review of the overall cost allocation of all grid and system related costs.

The change from a one-price to a two-price system implies that portfolio effects arise. Larger balancing groups have then an advantage as netting of imbalances pays off under a two-price system. However, the possibility of re-adjusting the schedules until 4pm the following day through trading in the day-after market might allow even small players to reap the portfolio effects. Under a two-price system, the possibility of trading imbalances allows win-win situations for balancing groups with opposite imbalances. The agreed prices would be equivalent to a "fair" sharing of the portfolio effect, if the two were just one combined balancing group.

The switch to a two-price system comes with another implication, which needs a more detailed examination. As Moeller et al. (2011) argue, the current one-price balancing mechanism induces the incentive to use highly predictable arbitrage opportunities resulting from the mismatch of the hourly traded products in the spot markets and the ¼-hourly scheduling requirements during times of large load changes. During hours when load is increasing (e.g. the typical morning ramps) there is usually a predictable positive imbalance/oversupply situation in the first ¼-hour and a negative imbalance/undersupply situation in the fourth ¼-hour, and vice versa during hours of decreasing load. This effect results from the limited availability of ¼-hourly products. The required ¼-hourly schedules can only be obtained OTC or from own generation capacity. Many market participants with load commitments are more or less forced to rely on hourly products and have to incur the above described imbalances within their balancing groups. These largely predictable imbalances can be profitably exploited by "unwanted behavior" – taking an opposite position (e.g. generating less than the generation schedule sold during the first ¼-hour of an hour with increasing load) – resulting in lower overall average imbalances. In this way, gaming the balancing mechanism is essentially – like Moeller et al. (2011) correctly describe it – deployment of uncontracted reserve capacity. However, this beneficial gaming can be only employed by market participants that have the necessary flexibility to depart from the contracted schedule – which are mainly non-intermittent generators. Hence, the market design

¹⁴ Technically, the balancing mechanism would be a two-price system as different prices are applied for positive and negative balancing groups. Currently, it is a one-price system as the same balancing price applies for positive and negative imbalances. (see Vandezande et al., 2010)

¹⁵ A slightly unsymmetrical penalty can be used to reduce the overall system costs, if the reservation prices for in-/decremental reserve capacity deviate largely. With penalty the relative demand of in-/decremental reserve energy and thus of in-/decremental reserve capacity can be influenced.

of the hourly traded products and the ¼-hourly scheduling combined with the one-price balancing mechanism transfers money from the inflexible (the ones that are largely stuck with the hourly products) to the flexible market participants.

In a two-price balancing mechanism, this type of beneficial gaming opportunity disappears. However, from a regulatory perspective, this ramping problem can be more effectively solved directly through a (liquid) intraday spot market with a ¼-hourly granularity than indirectly through a gaming opportunity in the balancing mechanism that is advantageous for flexible generators.

Second, the link between the reserve and the spot market could be improved, while keeping the current identity of the reserve energy and balancing energy prices. This implies that balancing prices are still depending on the overall imbalance of the control zone and the mechanism remains a one-price system. As discussed in Section 4, the incentive for strategic behavior breaks down only when the expected incremental and decremental balancing prices are always symmetrical relative to the expected spot price. The incentive is significantly reduced if the spread between incremental and decremental reserve price is smaller or if the correlation between spot and balancing prices would be higher.

Part of the problem is the design of the reserve capacity markets. The secondary reserve is currently procured for a period of one week. Reducing the contract duration would certainly lead to a stronger alignment between the reserve capacity market and the spot market.¹⁶ Furthermore, the current scoring rule in both the secondary as well as the tertiary reserve market distorts the energy price bids. In both markets the successful offers are selected by the reservation price only, this likely results in relatively higher incremental and relatively lower decremental energy prices (see Swider, 2007b).

The latest changes in the reserve capacity market have certainly reduced the incentives of strategic behavior in the balancing mechanism, albeit it should be expected that they still exist to a certain extent. The changes would yield additionally more efficient results in the reserve capacity market. The existing properties of the one-price balancing mechanism as a zero-sum activity for the TSOs, an equal playing field due to the absence of portfolio effects, and the beneficial opportunity to exploit the balancing mechanism during ramping periods would still remain.

Alternatively, the market design of the reserve capacity market could be changed by remunerating the called reserve energy at the spot price. The remuneration could include a symmetrical premium/discount for incremental/decremental reserve energy to improve the forecasting accuracy of the balancing groups.

This design change would definitely solve the strategic over-/undersupply problem. Yet, it also comes with some new obstacles. On the one hand, the auction procedure simplifies to a one-price auction with the reservation price only. All the difficulties of choosing an appropriate scoring rule disappear.¹⁷ On the other hand, productive efficiency of calling the reserve energy by their increasing marginal costs can not be achieved.¹⁸ Additionally, the reservation price bids might be distorted by the new remuneration rule. Non-recovered costs or surplus profits from the use of the reserve energy would augment or reduce the minimum required reservation price under competitive conditions, respectively.

¹⁶ Reducing the contract durations for secondary reserve can additionally lead to significantly more efficient market results as shown by Just (2011). The resulting improved generation dispatch yields lower prices in the reserve capacity market as well as in the spot markets. Furthermore, a shorter contract duration would lower the barriers of entry in the secondary reserve market for smaller companies and thus lead to more competitive market results.

¹⁷ The effectiveness of scoring rules for two-price reserve capacity auctions are discussed by Bushnell and Oren (1994), Chao and Wilson (2002), Schummer and Vohra (2003), and Swider (2007b).

¹⁸ Productive efficiency is only achieved if reserve capacity is employed in merit order of its marginal generation costs. This is not possible as no information about generation costs is revealed.

The productive efficiency and distortion problem can be corrected by bidding mark-ups/mark-downs on the spot price as a second part of the bid. However, this does not guarantee that the resulting balancing prices are symmetrical.

The discussion of the various options shows that none is perfect. The reason for the imperfection is mainly that spot energy and reserve energy are not homogeneous. Technical requirements differ and the economic decision on which plants are more economical to provide reserve capacity influences the reserve energy bids.

All options reduce the incentive for strategic behavior relatively to the current market design and should therefore be preferred. The choice of the most appropriate option is a matter of compromises. Accurately evaluating those compromises requires more in-dept research.

When the balancing or reserve energy prices are to be linked to the spot price, the question is to which one? The day-ahead spot price is the main reference point in the electricity system, at which all the majority of financial products are settled. It is also very reliable as the EEX day-ahead spot volume reached more than 0.6 TWh per day lately, which is about 40% of the German electricity consumption. However, balancing groups can adjust their schedules using the spot intraday market until gate closure. Even if the traded volume is still relatively low with about 3% of the consumption¹⁹, it should be the logical choice. If the day-ahead spot price were to be taken as the basis for the balancing price, the continuous intraday-trading would allow for risk-free optimization between the spot intraday price and the known balancing prices. Additionally, the recently introduced switch to ¼-hourly intraday spot market would make it the consistent choice.

9. CONCLUSION

This paper studies the incentives for balancing groups to deliberately under- and oversupply their expected load commitments. The market design of the balancing mechanism in Germany suggests ample opportunities for strategic behavior depending on the spot price. Empirical market data mirrors the suspected pattern extremely well. Market participants use stochastic arbitrage opportunities between the spot markets and the real-time one-price balancing mechanism. Thereby, the balancing groups' consideration is somewhat complex and depends on the expected difference between spot and balancing prices as well as on the expected direction of the imbalance of the overall control zone. The outcomes are relatively simple. The higher the spot price, the higher is the expected pay-off from an undersupply strategy and the stronger is the expected undersupply, and vice versa. This results in structurally biased imbalances of the electricity system, which might be dangerous and lead to blackouts in extreme cases.

The anti-abuse clauses currently used by the TSOs prove to be insufficient. The strategic misuse of the balancing energy artificially inflates the need for reserve capacity and increases the probability of required load shedding. The implied costs are significant and likely to be at least in the lower hundred million euro range per year. These costs, which are finally burdened on the customers, are too high and the security concerns are too severe to be ignored.

¹⁹ The relatively low intraday trading volume has to be seen in reference to the overall market setup. The day-ahead market is predominantly used to obtain the still needed physical volumes for the expected load commitments as well as sell the output from the intermittent renewables. Hence, the overall electricity system is largely dispatched as needed in real-time. Afterwards in the intraday spot market mostly adjustments to those positions are traded. By nature, smaller volumes will be traded in the intraday spot market.

Various options for altering the market design and reducing the incentives for the strategic behavior have been discussed. They include changes in the balancing mechanism, in the reserve capacity and the intraday spot market design. None of them is perfect and comes without other side issues. The reason for this imperfection is that spot and reserve energy are not homogeneous due to different technical requirements. Nevertheless, all options remove or reduce the incentive for strategic behavior relatively to the current market design and should therefore be preferred. The choice of the most appropriate option is a matter of compromises and should be subject to a detailed discussion with the regulator. Accurately evaluating those compromises is a field for further research.

At first sight, our conclusions significantly differ from those drawn by Moeller et al. (2011) and Vandezande et al. (2010). Yet obviously both recognize that balancing mechanisms induce incentives for arbitrage between markets in a very similar way as this paper does. And the remaining differences may be explained by looking in detail at the setup of the different analyses.

Studying the German balancing mechanism with time-series analysis, Moeller et al. (2011) indirectly find strategic arbitrage positions market participants take in the balancing mechanism. These are basically the same ones we identified when looking directly at the incentives. Their conclusions that the current balancing mechanism allows market arbitrage, reduces price peaks in the spot market, diminishes the ability to exploit market power, and thus effectively contributes to a functioning electricity market is undisputable in a general context and without restrictions. However, explicitly considering that the balancing mechanism cannot supply unlimited electricity, that the potential supply of balancing/reserve energy comes with reservation costs for having the capacity in place for immediate use, and that reserve capacity is partly withdrawn from the spot markets, adds “external” costs to the arbitrage mechanism. This pushes the conclusion in the other direction as those external costs likely outweigh the arbitrage gains (cf. section 7). In other words, the increased need for incremental reserve capacity to keep the same security level means essentially that valuable inframarginal generation capacity is not fully utilized. This underutilization is the main source of market inefficiencies caused by the strategic arbitrage behavior.

Part of their conclusion is that the one-price balancing mechanism provides implicitly an additional marketplace for uncontracted reserve capacity on the 1/4-hourly timescale for the ramping problem (see also the discussion in Section 8). This is an adjuvant property of the current mechanism. The possibility to use this profitable gaming opportunity is limited to the non-intermittent generators. Therefore, a (liquid) intraday spot market with a 1/4-hourly granularity would be a more direct, fair and efficient solution.

Vandezande et al. (2010) discuss different balancing designs by the use of simplified examples. They compare a one-price system with symmetric reserve prices with a two-price system based on spot prices with asymmetric penalties. Given that the ex ante expected imbalance costs correspond to the day-ahead price, there is no incentive for strategic behavior in their setting, whereas the asymmetric two-price system does induce strategic behavior. At first glance, their conclusion that a two-price system should be avoided seems essentially opposite to some of our findings, but essentially the arguments are similar, only the settings investigated differ. The common conclusion is that ex-ante expected balancing prices have to be in line with spot prices in order to avoid systematic over- and undersupply.²⁰

²⁰ The more far-reaching conclusion that real-time markets with similar design than intraday spot markets (i.e. no reservation price) would be the best alternative is only valid if the system is sufficiently flexible in the short run and information on bids and demands is distributed extremely rapidly in the market place. Given the existing trading structures with a separation of trading platforms (power exchanges) and grid operation, the latter condition is difficult to achieve. In a pool market coordinated by an ISO (as in the U.S.) with centralized

By investigating the specific incentive structures in the German balancing market, this paper complements the analyses by Moeller et al. (2011) and Vandezande et al. (2010) and provides important contributions and insights on the subject of balancing mechanisms.

information such a real-time market might considerably reduce (although not fully eliminate) the need for reserve capacity procurement.

APPENDIX

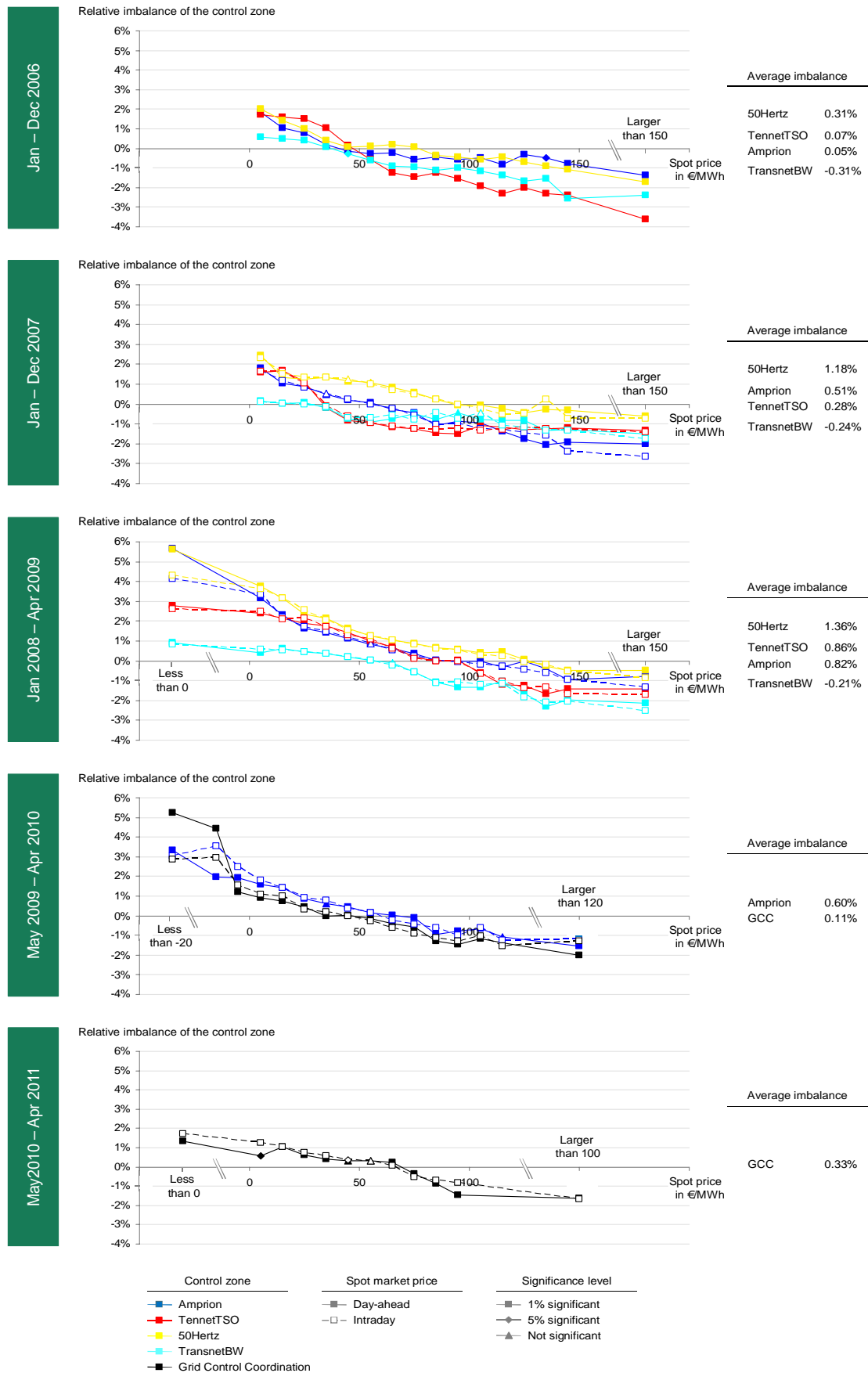


FIGURE 13: ACTUAL IMBALANCES IN THE RESPECTIVE CONTROL ZONES 2006-APRIL 2011

REFERENCES

- 50Hertz, 2012. Balancing price and imbalance data. Online: www.50hertz-transmission.net
- Amprion, 2012a. Balancing price and imbalance data. Online: www.amprion.net
- Amprion, 2012b. Information about Balancing Group Contracts on the Company webpage. Online: <http://amprion.net/en/balancing-group-management>
- Boogert, A., Dupont, D., 2005. On the Effectiveness of the Anti-Gaming Policy between the Day-ahead and the Real-time Electricity Market in The Netherlands. *Energy Economics* 27, 752-770.
- Bushnell, J.B., Oren, S.S., 1994. Bidder Cost Revelation in Electric Power Auctions. *Journal of Regulatory Economics* 6, 5-26.
- Chao, H., Wilson, R., 2002. Multi-Dimensional Procurement Auctions for Power Reserves: Robust Incentive-Compatible Scoring and Settlement Rules. *Journal of Regulatory Economics* 22, 161-183.
- EEX, 2012. Market data on day-ahead spot and intraday prices. Online: www.eex.de
- FAZ, 2012. Dem Kollaps knapp entgangen. *Frankfurter Allgemeine Zeitung* as of February 16, 2012. Available online: www.faz.net/aktuell/wirtschaft/stromversorgung-dem-kollaps-knapp-entgangen-11651935.html.
- Growitsch, C., Weber, C., 2008. On the electricity reserves market redesign in Germany. CNI-Working Paper, Technical University Berlin.
- ICF Consulting, 2003. The Economic Cost of the Blackout – An Issue Paper on the Northeastern Blackout. Online:
- Just, S., 2011. Appropriate Contract Durations in the German Markets for On-line Reserve Capacity. *Journal of Regulatory Economics* 39, 194-220.
- Just, S., Weber, C., 2008. Pricing of Reserves: Valuing System Reserve Capacity against Spot Prices in Electricity Markets. *Energy Economics* 30, 3198-3221.
- Moeller, C., Rachev, S.T., Fabozzi, F.J., 2011. Balancing Energy Strategies in Electricity Portfolio Management. *Energy Economics* 33, 2-11.
- Nailis, D., 2006. Market for System Reserve Capacity at the Turning Point? Repercussions of the EnWG and StromNZV for the Reserve and Balancing Energy (in German). *Energiewirtschaftliche Tagesfragen* 56(1/2), 56-60.
- Rammerstorfer M., Müller G., 2008. A Theoretical Analysis of Procurement Auctions for Minutes Reserve Control in Germany. *Energy Policy* 36(7), 2620-2627
- Rammerstorfer, M., Wagner, C., 2009. Reforming minute reserve policy in Germany: A step towards efficient markets?. *Energy Policy*, 37(9), 3513-3519.
- Schummer, J., Vohra, R.V., 2003. Auctions for Procuring Auctions. *Operations Research* 51, 41-51.
- Swider, D.J., 2007a. Competition in the German Market for Power Systems Reserve? (in German). *Energiewirtschaftliche Tagesfragen* 57(9), 32-37.
- Swider, D. J., 2007b. Efficient Scoring-Rule in Multi-Part Procurement Auctions for Power System Reserve. *IEEE Transactions on Power Systems* 22, 1717-1725.
- Swider, D.J., Ellersdorfer, I., 2005. Cost Efficiency in the German Market for Power Systems Reserve (in German). *Energiewirtschaftliche Tagesfragen* 55, 802-806.
- Swider, D.J., Weber, C., 2003. Design of German Markets for Power Systems Reserve (in German). *Energiewirtschaftliche Tagesfragen* 53, 448-453.
- TennetTSO, 2012. Balancing price and imbalance data. Online: www.tennetso.de
- TransnetBW, 2012. Balancing price and imbalance data. Online: www.transnetbw.de
- Vandezande, L., Meeus, L., Belmans, R., Saguan, M., Glachant, J-M., 2010. Well-functioning Balancing Markets: A Prerequisite for Wind Power Integration. *Energy Policy* 38, 3146-3154.
- Wawer, T., 2007. Incentives for Gaming the German Real Time Electricity Pricing Mechanism. Proceeding of the 30th IAEE International Conference, Wellington, 2007.