Timing of Markets- the Key Variable in Design of Ancillary Service Markets for Power Reserves

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Abstract

Proper design of ancillary service markets for power reserves, which are used as the means to insure system security and to balance generation and consumption in real time (also known as balancing services), is a complex task regarding the variables in design of these markets and high interrelations of these markets with other electricity markets. This paper concentrates on timing of these markets as a decisive and widely overlooked variable in design of balancing services markets. The case of Germany is studied as the main case and the market in the Netherlands is used for comparison. The focus of the study is on the secondary control markets (both reserve capacity and balancing energy) and we study the influence of alternative settings regarding timing of these markets on performance of the market as a whole analyzing the bid prices, excess supply ratios, pivotal supplier tests, and imbalance volumes.

I. Introduction

This paper is part of our currently ongoing research on design of ancillary service markets for power reserves. These markets are aimed at procurement of services that are essential for system security and balancing generation and consumption in a power system and so are called *Balancing Services*. And thus, the marketplaces used for trading of these services are called *balancing services markets*. Any difference between supply and demand in an electricity grid leads to system frequency deviations which consequently might result in equipment damage and serious system stability problems. Therefore, keeping the balance between supply and demand in real-time plays a crucial role in secure and reliable operation of the grid. Based on their technical characteristics, e.g. response speed, and the method of activation, balancing services are categorized[2] and, for procurement of each category of balancing services, separate markets are employed. For each type of balancing services, there are two main types of markets; *reserve capacity market* and *balancing energy market*. Reserve capacity markets are longer-term option markets in which service providers (providers of power reserves) are compensated for availability of their service (availability or capacity payment), regardless of actual delivery in real-time. Balancing energy markets are real-time markets in which service providers are compensated for the actual delivery of energy (utilization or energy payment).

Our research aims to analyze alternative design options for these balancing services markets. As the first research step, we identified the design variables (the variables on which a decision needs to be made in the process of design of balancing services markets) and the performance criteria (the criteria which should be used in order to assess the effect of design variables on market performance) which are presented in [2]. The next step is to use that study as the basis and analyze the effect of alternative decisions made on each design variable on the performance of the market as a whole using the performance criteria. Some of the design variables presented in [2], specifically *Method of Procurement, Pricing Mechanism and Capacity/Energy Markets,* have been extensively analyzed in literature, whether as variables in design of balancing services markets or in design of

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[2] Different categorizations are being used in different countries/regions depending on the categorizing criteria and technical characteristics of the system. Detailed descriptions of differences in various countries are given in [1].

electricity markets in general [3]- [9]. However, some variables in design of balancing services markets have been fully or partially ignored in the studies on design of these markets. The most crucial variable in this category is *Timing of Markets* which as a very fundamental design variable has serious influences on performance of the entire market. This paper specifically focuses on this variable and analyzes the effect of various alternative decisions on this complex variable on market performance. The two main aspects of Timing of Markets are *Timing of Bidding Procedure* and *Timing of Markets Clearance.* "Timing of bidding procedure" includes frequency of bidding (which determines the time horizon of the market) and gate opening/closure times for bidding in balancing services markets which need to be carefully coordinated with those of other electricity markets, e.g. day-ahead (DA) and intra-day (ID) energy markets. "Timing of market clearance" includes frequency of balancing services markets clearance and their coordination with clearance of other markets.

In this paper, we use the case of Germany as the main case study because of two basic reasons:

- Unique transparency in the balancing services markets of Germany: All the "bids" (volumes and prices) are accessible in all the markets (reserve capacity and balancing energy) in Germany. Thus, in addition to the outputs of the markets, all the inputs are accessible and all the bids offered in the markets can be used for the analysis.
- Design characteristics of the German balancing services markets: In Germany, the designs of different balancing services markets are not only different from the designs used in other countries/areas, but also they differ from each other, i.e. different designs are used for different types of balancing services in Germany.

Since design of the day-ahead and intra-day markets are similar in the Netherlands and Germany, but the design of balancing services markets are totally different, using the case of the Netherlands for comparison, can lead to meaningful insight into the effect of different designs of balancing services markets in the two countries.

We use different indicators in order to "measure" the effect of different decisions on the performance criteria; minimum/maximum and weighted average of the selected bid prices in each market, excess supply ratios, number of pivotal suppliers, and imbalance volumes.

In line with the UCTE[1] categorization [10], in continental Europe, three types of balancing services are procured by the Transmission System Operator (TSO) in the three corresponding markets: Primary control, Secondary control and Tertiary control. This paper specifically focuses on the secondary control (SC) markets because both reserve capacity and balancing energy markets are used for this service and also because of its unique design in Germany which results in unique market outcomes.

II. Timing of Balancing Services Markets as a Design Variable

As noted, timing of markets for different types of balancing services has two main aspects: timing of bidding procedure and timing of market clearance.

- *Timing of bidding procedure:* The time horizon for the bidding procedure of all the reserve capacity and balancing energy markets for all types of balancing services need to be carefully arranged. As an example, in Germany, the bidding procedure of the reserve capacity market for secondary control service is monthly, so capacity providers submit their monthly bids that are fixed for the whole coming month, while the reserve capacity market for tertiary control (called Minute Reserves in Germany) is a daily market and capacity providers submit their bids on a day-ahead basis. Time horizon of the bidding procedure for balancing services markets, which is related to the frequency of bidding, highly depends on the characteristics of the service (type of the balancing service) and the type of the market (reserve capacity vs. balancing energy). After making the decision on the time horizon of balancing services markets (possible from annual to quarter-hourly), the gate opening and closure times of these markets need to be determined. Since, basically generators have the possibility to offer their capacity in wholesale electricity markets (such as day-ahead and intra-day markets) or in reserve capacity or/and balancing energy markets for various types of balancing services, the gate opening and closure times for the bidding procedure in balancing

[1] Union for the Coordination of Transmission of Electricity is the association of system operators in continental Europe.

services markets (both reserve capacity and balancing energy) need to be carefully coordinated with gate opening /closure times of other balancing services markets as well as wholesale electricity markets, DA and ID markets. This timing coordination aspect significantly influences the interrelations between different markets and plays a critical role in the effect of balancing services markets design on efficiency and liquidity of these markets.

- *Timing of markets clearance:* Just like "timing of bidding procedure", timing of markets clearance for balancing services has two main elements; frequency of balancing services markets clearance and coordination of balancing services markets clearance with other markets. Generally speaking, the frequency of bidding (related to the time horizon of the bidding procedure), can be different from the frequency of the clearance of the market. For example, the balancing energy market for secondary control in Germany is monthly and generators submit one price and one capacity for all the coming month (frequency of bidding is once per month), while the balancing energy market is cleared once for each Program Time Unit (15 minutes in Germany) based on the real-time imbalance of the system that occurs in each PTU (frequency of clearance is once per quarter an hour). Since balancing energy markets are aimed at resolving system imbalances in real-time using balancing energy bids, the "demand" in these markets is different for different PTUs (based on the system imbalance volume) and therefore these markets need to be cleared for each PTU which leads to the clearance frequency of once per PTU for energy markets. Because the time horizon of reserve capacity markets can theoretically be anything from one year to one PTU, the frequency of reserve capacity markets clearance can have any value higher than once per year and less than once per PTU. The second aspect of "timing of markets clearance" is the coordination of balancing services markets clearances with those of other electricity markets, specifically day-ahead and intra-day markets. Figure 1 shows the elements of timing of balancing services markets and its interrelation with day-ahead and intra-day markets. As the figure shows, since balancing energy markets are real-time markets and are cleared at the time when all other markets are closed and cleared, there is no coordination needed between clearance of balancing energy markets and other markets. On the contrary, clearance of the reserve capacity markets may need to be coordinated with clearance of day-ahead or intra-day markets, based on the frequency of market clearance of the reserve capacity markets. In case of a day-ahead reserve capacity market (e.g. tertiary control service in Germany, and day-ahead scheduling reserves in PJM [11]- [12]), there are two main possibilities in terms of coordination of the reserve capacity market clearance with the day-ahead market; sequential and simultaneous clearance. Another example is coordination of reserve capacity markets clearance with each other (and not day-ahead or intra-day markets). The Californian ISO (CAISO) uses four reserve capacity markets for four different services (regulation service, spinning reserve, non-spinning reserve, and replacement reserves) [13]- [14]. CAISO used to clear these markets sequentially (from higher quality services to lower quality ones) and has recently changed it to simultaneous clearance of all four reserve capacity markets because of efficiency and liquidity considerations.

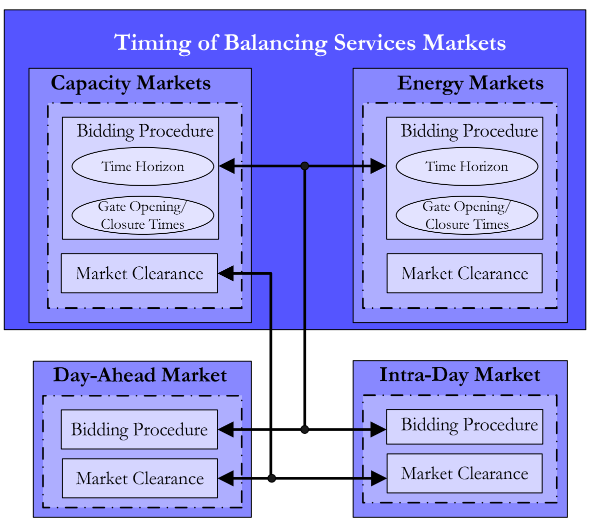

Figure 1- Timing of balancing services markets and its interrelation with other markets

As described above, this design variable (timing of markets) significantly influences the interrelations of balancing services markets (both reserve capacity and balancing energy) with each other and with other electricity markets. Therefore, the decisions that need to be made on this design variable demand meticulous studies of the effect of this variable on the performance of balancing services markets as well as day-ahead and intra-day markets.

Although this paper does not explicitly study the issue of *coordination* of timing of balancing services markets with DA and ID markets, high interrelations of all these markets are noticeable in the results presented in the following sections. This paper focuses on frequency of bidding and frequency of market clearance for balancing services markets and studies the influence of these two decisions on market performance.

III. Timing of the Secondary Control Market in Germany

Since 2001, the German TSOs have been separately procuring their required secondary control reserve on an open market. Until 30 November 2007, each TSO individually procured secondary control reserve via half-yearly auctions. Following a consultation involving the various market participants, the National Regulatory Authority BNetzA (Federal Network Agency) fixed 01 December 2007 as the start date for the common tendering [15], and the market was changed to a monthly market. Although, since December 2007, the four German TSOs have been using a common platform for trading, they had not pooling the bids in a single integrated market for secondary control. The last component in bids for secondary control service shows which areas the bid is “available” to. In May 2009, three German TSOs, 50Hertz (previously known as Vattenfall), EnBW and Transpower (previously known as EON) announced their market integration for secondary control service. And effectively since July 2009, (according to the “availability” bid component) every bid available to one of these three areas is available to the other two as well.

In the markets for procurement of secondary control in Germany, there is a clear distinction between upward (positive) and downward (negative) services and they are traded in two different sets of markets. In addition, separate auctions are used for off-peak[1] and peak[2] hours in Germany. Thus, in each month, there are four separate auctions in which service providers offer their capacities as secondary control reserve; negative capacity for off-peak hours, negative capacity for peak hours, positive capacity for off-peak hours and positive capacity for peak hours. Each bid in each of these four auctions has three main components: volume (in MW), capacity price (in €/MW) and energy price (in €/MWh). Bids are selected on the basis of the capacity price only. Thus, during the preceding month, four reserve capacity auctions are cleared and the selected bidders will be compensated for their availability of capacity. Selected bidders are obliged to keep their selected capacity available (free) for the entire coming month. Then, for each PTU, 15 minutes in Germany, based on the real-time imbalance of the system, bids will be selected based on their energy price to be actually activated in order to resolve the real-time imbalance. Thus, while the reserve capacity markets for secondary control are cleared on a monthly basis, the balancing energy markets have to be cleared on a quarter-hourly basis using the same set of bids for all the PTUs (the energy bids are fixed all through the month). Therefore, as mentioned above, in case of the reserve capacity markets for secondary control, the frequency of bidding is once per month (time horizon of one month) and the frequency of market clearance is once per month as well. Nevertheless, in case of the balancing energy markets for secondary control, while the frequency of bidding is once per month (time horizon of one month), the frequency of market clearance is once per 15 minutes.

In the following sections, we study how this design of the secondary control market can influence the bid prices, excess supply ratios, pivotal suppliers and imbalance volumes.

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[1] Off-Peak hours are defined as the hours between 00:00h and 08:00h as well as between 20:00h and 24:00h from Monday through to Friday (excluding public holidays applicable to Germany) as well as all day on Saturday, Sunday and public holidays applicable to all Germany [15].

[2] Peak hours are defined as the hours between 08:00h and 20:00h from Monday through to Friday (excluding public holidays applicable to all of Germany) [15].

IV. Bid Prices

Figure 2 shows the average selected upward energy bid prices (in €/MWh) for secondary control (SC) in Germany for 2009, for peak as well as off-peak hours [15]. The figure compares these prices with the monthly average Intra-Day (ID) prices in Germany for 2009 [16]. As noted, a monthly market is currently employed for procurement of secondary control in Germany. So the frequency of bidding is once per month. Though, the frequency of market clearance (for the balancing energy market) is once per 15 minutes. Thus, the frequency of market clearance is a lot higher than the frequency of bidding. While the average ID price in Germany (for 2009) is 39 €/MWh, the average selected positive SC energy bid price is 128 €/MWh and 178 €/MWh for off-peak and peak hours, respectively.

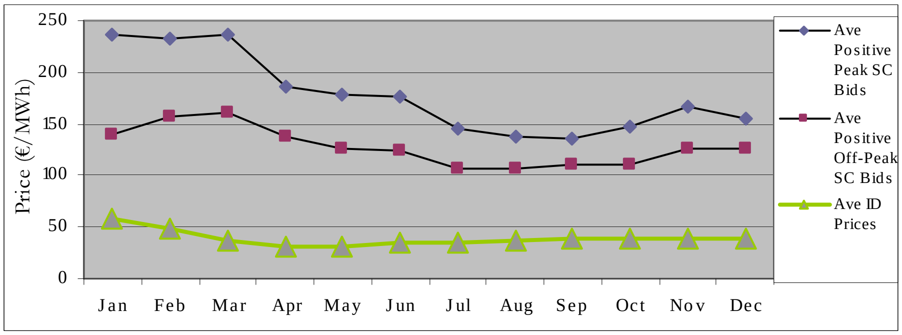

Figure 2- Average selected positive secondary control energy bid prices (peak and off-peak hours) compared to the monthly average intraday prices for Germany in 2009

Figure 3 illustrates the average selected positive SC energy bid prices divided by the average ID price for different months of 2009 in Germany. As can be seen, the average SC energy bid prices (which are actually the real-time energy bids determining real-time price of electricity) are considerably higher than the intraday energy prices; from two to seven times higher.

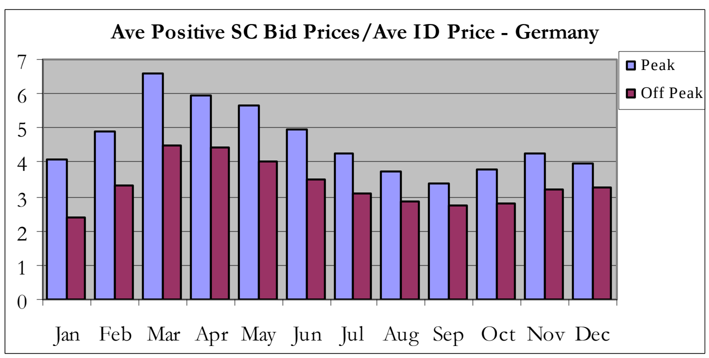

Figure 3- Average selected positive secondary control energy bid prices (peak and off-peak hours) divided by the monthly average intraday price for Germany in 2009

In order to see how serious this situation is, we compare the last selected positive SC energy bid prices of Germany with those of the Netherlands in Figure 4 (2009). It shows the maximum selected positive SC energy bid price (corresponding to the last selected bid in the reserve capacity market) divided by the average intra-day price. In case of the Netherlands, the entire bid ladder is not published publicly but the TenneT website publishes four prices corresponding to four different points on the bid ladder, including the bid price for 300 MW [17]. Since TenneT reserves 300MW for regulating power (equivalent of secondary control) in the Netherlands (by annual contracts), we used the price corresponding to this volume in Figure 4. As the figure illustrates, although the maximum SC bid in the Netherlands does not go higher than three times the average ID price, the maximum SC bid of off-peak hours in Germany varies from four to nine times the average ID price, and for peak hours it changes from five to even twenty times the average ID price.

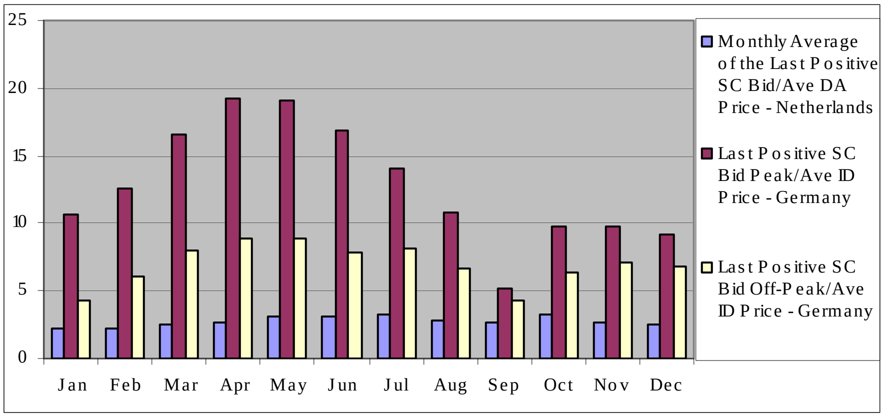

Figure 4- Comparison of the monthly average of the last energy bid price for positive secondary control in the Netherlands and Germany (peak and off-peak)- 2009

The first reason is the difference in time horizon of these two markets; monthly market in Germany and quarter-hourly market in the Netherlands. Thus, the uncertainties in bidding in the German market are a lot higher than in the Dutch market (because of all the uncertainties in forecasting the wholesale electricity market demand and prices one month in advance) which will push the bid prices higher. The second reason is the difference between the frequency of bidding (once per month) and frequency of market clearance (once per quarter an hour) in the German market. The consequence of this design is that since each bidder has to submit one single bid price for the entire coming month (all the 15-minutes of the coming month), their SC bid price can not follow the electricity price changes in day-ahead (DA) and intraday (ID) markets. Therefore, if for example, the bidder offers its SC energy at the expected monthly *average* ID or DA price, it means that it will lose some profit in half of the PTUs of the month (on average) because its SC bid price will be lower than the ID or DA price (it could offer its energy in the DA/ID market other than the SC energy market). This phenomenon leads to an indirect introduction of a noticeably large Lost Opportunity Cost (LOC) in the bids for SC energy market, even though this service, in its nature, creates no LOC for the provider (in contrast to the capacity reservation service which creates LOCs for the provider by nature). This large LOC will push the bid prices even higher; the effect that can be seen in Figure 4.

Figure 5 shows the last energy bid price for positive secondary control in Germany (for peak hours) and the Netherlands, in December 2009. As expected, the last selected energy bid price in Germany is a fixed value for all the PTUs of the month. The figures also illustrate the volatility of the energy bid price in the Netherlands which originates from the fact that the frequency of bidding in the Netherlands for the energy market for secondary control is once per PTU. Thus, the service providers, in the Netherlands, can submit different bids for different PTUs so they have the opportunity to take into account the changes of electricity prices in other electricity markets (day-ahead and intra-day) in their energy bids for secondary control (which represent the real-time bid prices for electricity). The secondary control service providers can follow the electricity price changes in different hours of different days by their energy bids for secondary control.

Figure 5 shows the monthly maximum and average of the last bid in the Netherlands too. It clearly illustrates what was described as introduction of lost opportunity costs by having different frequencies for bidding and clearance. As one can see in the figure, the monthly average of the last bid in the Netherlands is 99 €/MWh, while the monthly maximum of the last bid is 246 €/MWh. In case of a monthly bidding in the Netherlands (one single bid for the entire coming month), the bidders would go for the expected monthly *maximum* price in order to make sure that in all PTUs, their bid price is high enough so that they would not lose any profit in other electricity markets. Therefore, in Figure 5, for each PTU, the difference between the last bid and the monthly maximum of the last bid corresponds to the opportunity cost that would be added in case of having a monthly bidding in the Netherlands. As can be seen, the last bid (for peak hours) in Germany is even higher than the monthly maximum of the last bid in the Netherlands which can be attributed to the uncertainties in forecasting the electricity prices one month in advance, which as noted, will increase the bid price levels even more.

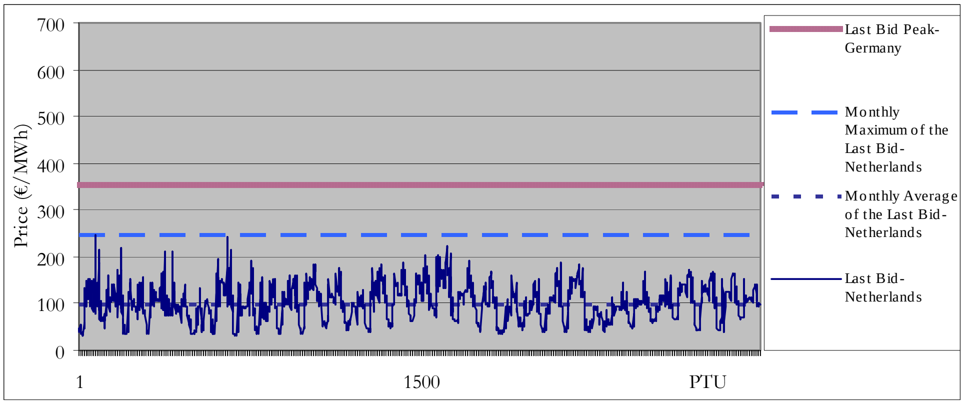

Figure 5- The last energy bid price for positive secondary control in Germany (Peak hours) and the last bid price in the Netherlands- December 2009

Figure 6 shows the probability distribution function of the intraday prices and the average selected positive secondary control energy bid price (peak and off-peak hours) for Germany in January 2009 (as an example).

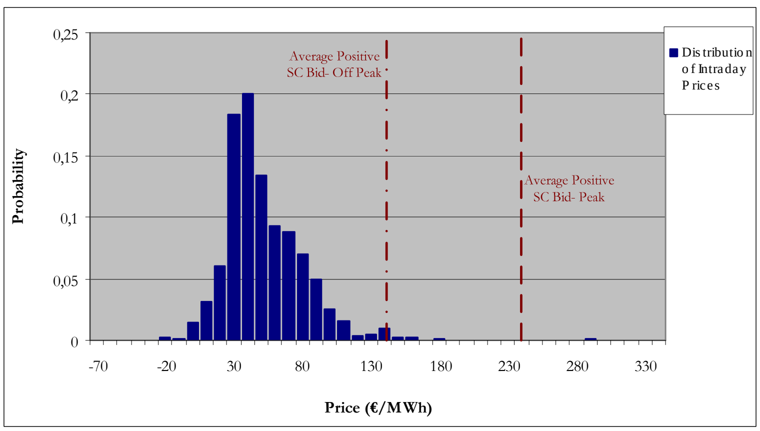

Figure 6- Distribution of intraday prices and the average positive secondary control energy bid prices (peak, off-peak) for Germany in January 2009

This figure aims at illustrating the fact that in case of a monthly balancing energy market for secondary control, while the market is cleared on a quarter-hourly basis (once per PTU), the service providers tend to get close to the monthly maximum price for electricity (intraday prices used here) in order to make sure that in all the PTUs of the month, their energy bid for secondary control is high enough compared to the intraday prices, which in fact shows the effect of the lost opportunity costs indirectly added to the bids. In January, while the average intraday price in Germany is 58 €/MWh and the maximum intraday price is 300 €/MWh, the average of selected positive secondary control energy bid prices for peak hours is 237 €/MWh. It should be noted that since bidding in the monthly secondary control market occurs in the preceding month, service providers have to forecast the electricity prices in the coming month and use them in their bidding procedure. Obviously, forecasting the maximum electricity price in the coming month can not be accurate because, firstly, the forecast period is very long (one month) so very limited information is available compared to daily forecasts, and secondly, forecasting the "maximum" price leads to even more errors because of the very high volatility of this price in different months. Therefore, our goal in Figure 6 is to compare the level of (maximum) intraday prices and the average positive secondary control bids and not proving that the secondary control bids definitely converge to the monthly maximum intraday price.

Figure 7 shows the average selected capacity bid prices for each of the four auctions of secondary control in 2009. It should be noted that the bids are originally in €/MW and the time horizon of the market is a month, so the unit has been converted to €/MW/hour in Figure 7. As expected, the capacity price for negative power in off-peak hours is the highest due to the fact that, during off-peak hours, the resources that are synchronous and can deliver negative power compatible with secondary control standards is very limited compared to peak hours. The same reason makes the capacity price for negative power in peak hours cheapest, as shown in Figure 7. Regarding the positive power, the capacity price in peak hours is higher because of the limited availability of free capacities to regulate upward during peak hours.

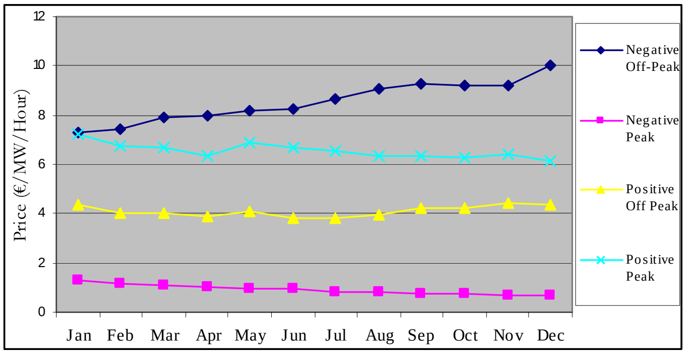

Figure 7- Average selected capacity bid prices (in €/MW/Hour) of the four auctions for secondary control in Germany 2009

One other important issue worth being mentioned here is the effect of high time horizon for balancing services markets on reserve capacity and balancing energy bids. As illustrated in different figures so far, the balancing energy bids for secondary control in Germany are very high compared to the intraday prices, Figure 4 specifically compares the situation in Germany with the Netherlands. However, as can be seen from Figure 7, the reserve capacity prices are not as high. The main component in the bids for reserve capacity is the lost opportunity cost related to the possibility of offering the capacity in other electricity markets, e.g. day-ahead and intraday markets. Obviously, in case of a monthly market where one single capacity bid price is submitted for the entire coming month, this lost opportunity cost will be the sum of the LOCs in all the PTUs of the coming month, which is the difference between the electricity price (in other electricity markets for example intraday) and the unit's operating costs (determining the potential profit that will be lost by offering the capacity in another market). This capacity bid price will be in €/MW (per month) and by dividing it to the number of hours in a month it will be converted to €/MW/hour. Therefore, the capacity bid price of a balancing capacity supplier would be the *average* of all the expected LOCs in the PTUs of the coming month. In contrary, as already discussed extensively, for the balancing energy bid price, in case of a monthly market where one single bid price is submitted for the entire month, the supplier would focus on the "maximum" monthly electricity price in order to make sure that its bid price is high enough for all the PTUs of the month and that no potential profit will be lost. This difference between reserve capacity and balancing energy markets originates from the fact that the reserve capacity market is cleared once a month while the balancing energy market has to be cleared for every PTU in the month; difference in frequency of market clearance.

V. Excess Supply Ratios

Another crucial issue regarding increasing the time horizon of markets is the influence on incentives of service providers to offer their capacities in the corresponding market. As the time horizon of the market increases, uncertainties regarding forecasting the capacities that will be sold in other electricity markets and the corresponding prices will limit the offered capacities in the market and the number of service providers interested in offering their capacity. It simply originates from interrelations of different electricity markets; generators have the opportunity to offer their capacities in different electricity markets as different services, therefore these markets compete with each other to attract capacities from suppliers. Thus changing the design of one market (e.g. changing the time horizon of one market) can lead to serious changes in the offered capacities and bid prices in the corresponding market, simply because of interrelations of different electricity markets. Table 1 shows the excess supply ratio, defined as the excess of supply (not selected bid volumes) divided by demand (selected bid volumes), for the four auctions of secondary control in Germany for different months of 2009.

Table 1- Excess supply ratios (in percentage) of the four auctions for secondary control- Germany 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Negative Off-Peak	16.7	17.4	19.5	0	0	0.4	0	0	0	1.8	9.1	2.7	5.6
Negative Peak	11	8.3	1.1	0	10.1	4.6	0	17.5	14	11.6	12.9	3.2	7.8
Positive Off-Peak	6.7	7.8	1.9	2.2	2.2	9	5.1	0	3.1	8.9	7.9	9.9	5.4
Positive Peak	15.2	9	0	0	0	8.1	16.3	16.7	24.2	17.2	15.6	19.6	11.8

One can see in the table that in 18 auctions (out of 48) the excess supply ratio is less than 3% and in 11 auctions, the ratio is zero which indicates that absolutely all the bids are needed to meet the demand (in order to meet the reserve requirement for secondary control). This simply shows that because of the limited number of service providers and consequently the limited amount of capacity offered in these markets, considerable market power exists in the markets for secondary control in Germany. As noted, one important reason of this phenomenon is the long time horizon of these markets (monthly markets) which leads to high uncertainties regarding the capacities that will be sold (throughout the coming month) in other electricity markets with shorter time horizons, especially day-ahead and intra-day markets, and also regarding the corresponding prices. Another factor is the interrelations of different balancing services markets with each other, e.g. the secondary control market with tertiary control market. Since the resources that are eligible for secondary control will definitely be eligible for tertiary control as well (because of looser restrictions on tertiary control), the secondary control service providers basically have the opportunity to offer their capacity in tertiary control market (rather than secondary control) which depending on the time horizon of these two markets and also the market prices (compared to each other) could possibly transfer some capacities from secondary control market to tertiary control market.

VI. Pivotal Suppliers

Table 2 shows the number of pivotal suppliers (for each of the four German control areas) in the auction for positive secondary control in "off-peak" hours for all the months of 2009. The table confirms the existence of market power in the markets for secondary control in Germany. As can be seen, in March, April, May and August 2009, absolutely all the bidders are pivotal which illustrates serious market power, not even for the suppliers with large market shares but also for all the small suppliers of secondary control reserve (for off-peak hours) in these 4 months. In addition, in more than 60% of the time, more than one supplier is pivotal in the auction for positive secondary control during off-peak hours.

Table 2- Number of pivotal suppliers in the auction for positive secondary control in off-peak hours- Germany 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ENbW	0	3	10 (All)	6 (All)	8 (All)	0	3	18 (All)	5	0	1	1
Transpower	0	0	11 (All)	8 (All)	10 (All)	0	3	18 (All)	5	0	1	1
Amprion	3	4	11 (All)	9 (All)	10 (All)	3	9 (All)	8 (All)	4	4	4	4
50 Hertz	1	3	9 (All)	6 (All)	7 (All)	0	3	18 (All)	5	0	1	1

Table 3 shows the result of the One-Pivotal Supplier Test for the auction for positive secondary control in off-peak hours for each of the four German areas in 2009. As can bee seen, the market passes the test only in 8 auctions out of the 48 auctions in 2009. The market fails the Two-Pivotal Supplier Test in all the twelve months of 2009 in all the four German areas. So even in those periods where the market passes the one-pivotal supplier test, it fails the two-supplier test. Obviously, the market fails the three-pivotal supplier test in all months as well.

Table 3- Result of the One-Pivotal Supplier Test applied to the auction for positive secondary control in of-peak hours- Germany 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ENbW	**Passed**	Failed	Failed	Failed	Failed	**Passed**	Failed	Failed	Failed	**Passed**	Failed	Failed
Transpower	**Passed**	**Passed**	Failed	Failed	Failed	**Passed**	Failed	Failed	Failed	**Passed**	Failed	Failed
Amprion	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed	Failed
50 Hertz	Failed	Failed	Failed	Failed	Failed	**Passed**	Failed	Failed	Failed	**Passed**	Failed	Failed

Table 4 shows the number of pivotal suppliers (for each German area) in the auction for positive secondary control in "peak" hours for all the months of 2009. Compared to Table 2, the number of pivotal suppliers is more promising for peak hours, which is expectable simply because, in off-peak hours, the units that are synchronous to the grid and can deliver power compatible with secondary control characteristics (fully activated within 15 minutes) are very limited. However, according to Table 4, still during 3 months of 2009, all the units in all the four German areas are pivotal; so all suppliers are needed to meet the demand which creates serious market power concerns.

Table 4- Number of pivotal suppliers in the auction for positive secondary control in peak hours- Germany 2009

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ENbW	0	0	10 (All)	6 (All)	8 (All)	0	0	0	0	0	0	0
Transpower	0	0	11 (All)	8 (All)	12 (All)	0	0	0	0	0	0	0
Amprion	0	3	11 (All)	10 (All)	12 (All)	3	10 (All)	1	0	6	0	2
50 Hertz	1	1	9 (All)	7 (All)	9 (All)	0	0	0	0	0	0	0

The pivotal supplier tests are applied to the positive secondary control auctions for peak hours and Table 5 shows the percentage of the time in which the auction passes each test in each German area separately. As one can see, in Amprion, in only 25% of the time, the auction passes the one-pivotal supplier test and always fails the two- and three-pivotal supplier tests. The other three areas can pass the two-supplier test in less than 50% of the time and they pass the three-supplier test in only 25% of the time. These tables show that serious attention is needed to solve the noticeably high market power concerns in the markets for secondary control in Germany.

Table 5- Percentage of the time in which the market passes the pivotal supplier tests- Positive secondary control for peak hours, Germany 2009

	One-Pivotal Supplier Test	TWO-Pivotal Supplier Test	THREE-Pivotal Supplier Test
ENbW	75%	50%	25%
Transpower	75%	50%	25%
Amprion	25%	0	0
50 Hertz	58%	42%	25%

It should be noted that since the published bid data in Germany is anonymous, these results are based on the implicit assumption that each bid is from a different supplier. However, obviously a supplier might offer different parts of its capacity with different prices, leading to different bids from the same supplier. Thus, the results of this analysis, showing serious market power issues, could be much worse if the identity of every bidder was known. In other words, the results presented above are *optimistic*, in terms of existence of market power in the markets for secondary control in Germany.

VII. Imbalance Volumes

In analyzing the effect of timing of balancing services markets on real-time imbalances of the system, which concerns the incentives of Balance Responsible Parties regarding scheduling before real-time, the bid prices for balancing services (in both positive and negative directions) play a decisive role. Figure 8 shows the probability distribution function of intraday prices and also the distribution of selected positive secondary control energy bid prices (peak hours) for Germany in 2009. The intraday prices are the market clearing prices that come out of the intraday market for each hour so they are the outputs of the market.

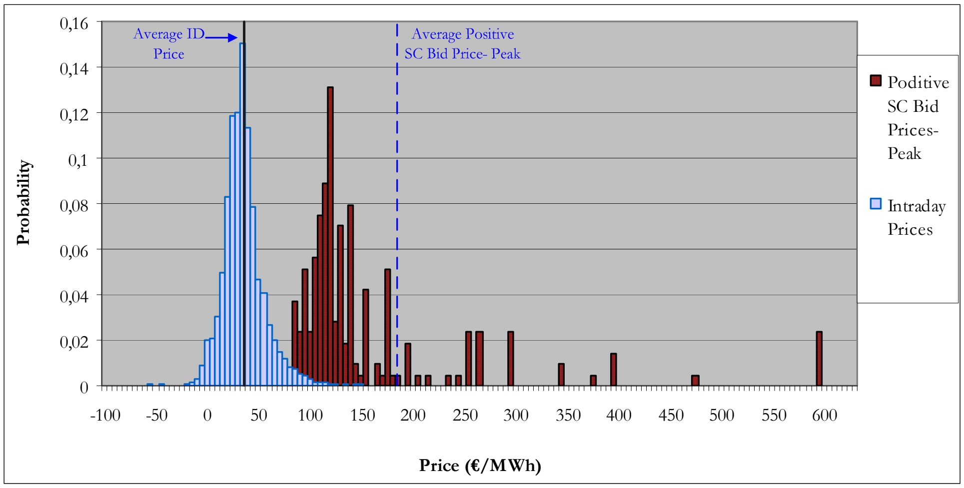

Figure 8- Distribution of intraday prices and selected positive secondary control energy bid prices (peak hours) in Germany for year 2009

As shown in Figure 8, while the average intraday price in Germany for 2009 is 39 €/MWh, the average of the selected energy bid prices for *positive* secondary control is 178 €/MWh. In addition, although one of the arguments behind having markets with longer time horizons (e.g. monthly rather than daily or hourly markets), is lower volatility of prices, according to the figure the energy bid prices for positive secondary control are more volatile (compared to the intraday prices) and, in some months, the bid prices go up to more than three times the yearly average bid price for positive secondary control. Although these extremely high prices, only happened in a few auctions in 2009, because the auctions are monthly and the bids will be fixed all through the month, these high prices will influence all the PTUs of the corresponding months and will increase the imbalance prices. However, in case of a shorter term market, e.g. daily markets, the effect of these high prices will be much more limited.

Figure 9 shows the distribution of intraday prices compared to the distribution of *negative* secondary control energy bid prices (peak hours) for Germany in 2009. While the average intraday price in Germany is 39 €/MWh, the average of the selected energy bid prices for negative secondary control is -16 €/MWh. The high volatility of the negative secondary control bids (compared to intraday prices) can be seen in the figure, just like the positive secondary control bids. The bids go down to more than 15 times lower than the yearly average bid price for negative secondary control.

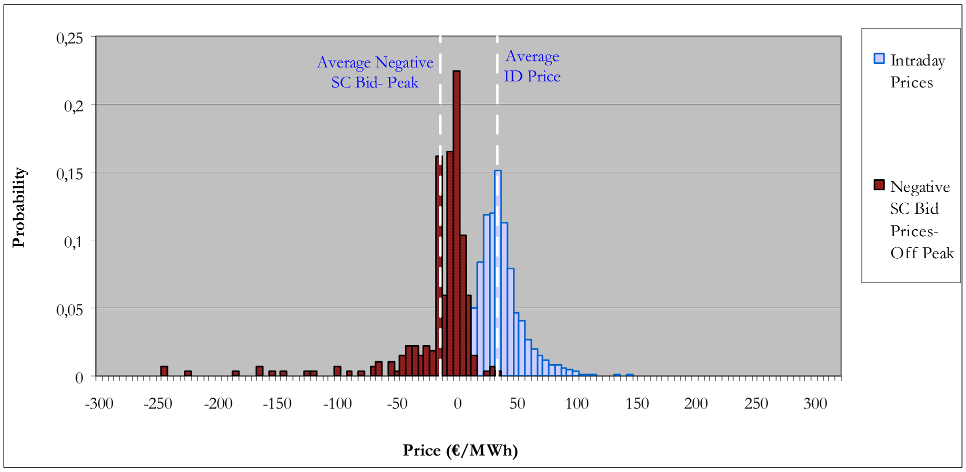

Figure 9- Distribution of intraday prices and negative secondary control energy bid prices (peak hours) in Germany for year 2009

Obviously, the secondary control energy bid prices in these markets determine the final imbalance price with which the Balance Responsible Parties (BRPs) will be charged with, for their real-time imbalance (deviations from their planned schedules). The crucial factor on the incentives of BRPs, regarding their imbalances, is not (only) the level of positive and negative energy bid prices but the level of these prices compared to the electricity prices (in wholesale electricity markets) especially in day-ahead and intraday markets. We consider the intraday prices for comparison because the intraday market is the closest market to real time (before the balancing energy markets) and it is the last opportunity for BRPs to sell/buy power and change their schedules. Regarding peak hours, as shown in Figure 8 and Figure 9, the average positive secondary control bid price is 178 €/MWh, while the average negative secondary control bid price is -16 €/MWh and the average intraday price is 39 €/MWh. It means a price difference of 139 €/MWh between the positive SC bid and the ID price, and also a 55 €/MWh price difference between the ID price and the negative SC bid, on average. If a BRP (which consists of load for example) buys some amount of power more than its actual consumption in the intraday market (at the ID price), it will have a positive imbalance in real-time and will be compensated for being "long" with the imbalance price which is based on the SC energy bids. In other words, it will sell its surplus at the real-time imbalance price. As noted, on average, depending on the sign of the total system imbalance, the BRP might receive the negative price (55 €/MWh lower than the ID price) which means a loss of 55 €/MWh or it might receive the positive price (139 €/MWh higher than the ID price) which means a profit of 139 €/MWh. Therefore, because of the level of positive and negative SC bids compared to the ID price, the decision of the BRP to design a long position for itself (intentionally buying more power than its planned consumption in the ID market) in real-time is simply a profitable action, in general. To put the concept in other words: since the difference between the positive SC bid price and the ID price is a lot higher than the difference between the ID price and negative SC bid price, being in a short position in real time should be avoided as much as possible (in order to avoid high losses due to the high positive SC bids). This simply shows that the current level of positive and negative SC bid prices compared to the ID price, creates a clear incentive, from a BRP perspective, to be in a long position (design a power surplus in real-time).

The same situation holds true for the off-peak hours in Germany, although not as dramatic as in peak hours. For off-peak hours, the average positive SC bid price is 127 €/MWh and the negative SC bid price is -29 €/MWh. Comparing these prices to the average ID price, 39 €/MWh, results in a price difference of 88 €/MWh in the positive direction and 68 €/MWh in the negative direction. Thus, the same argument regarding incentives of BRPs is true during off-peak hours as well.

Figure 10 illustrates the average system imbalances in the Amprion area for 2009 [18]. The average has been calculated over the same PTUs in all the 365 days of the year. Thus, the figure actually shows the average imbalances of Amprion for a day (96 PTUs).

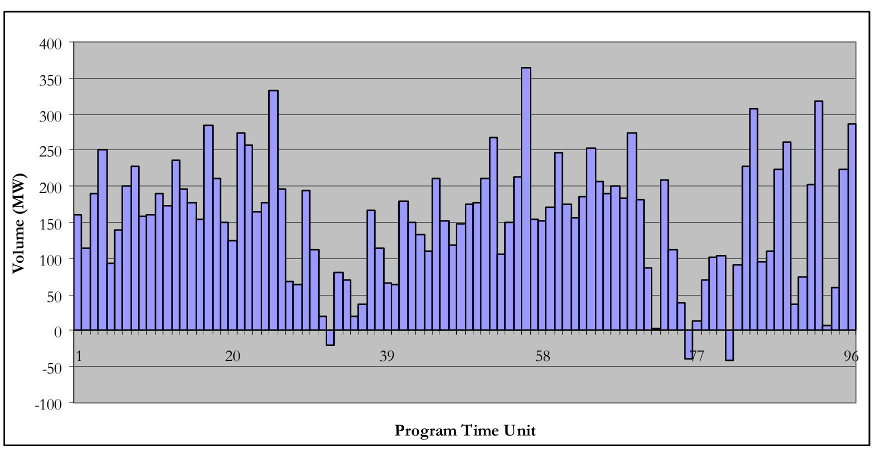

Figure 10- Average system imbalances in the Amprion area in 2009

The figure clearly shows the phenomenon described above about the effect on the incentives of BRPs. As can be seen, the imbalance volume is mostly positive illustrating the incentives of BRPs to avoid short positions (negative imbalances) in real-time in order to avoid possible high profit losses.

VIII. Conclusions

Based on the presented results, and in terms of the performance criteria, it can be concluded that increasing the time horizon of the balancing service market reduces market liquidity and efficiency, in general. However, using different frequencies for the bidding procedure and the market clearance creates even more serious problems in terms of efficiency and liquidity. These two main factors restrict the number of service providers who can offer their capacities in the market, reducing the number of active service providers (and the offered capacity), and consequently decreasing market liquidity, increasing market power (and the possibilities to abuse it), and decreasing market efficiency.

To be more specific, by losing the capacity that could be offered in the market and is indirectly shifted to another market, *allocative efficiency* decreases. In addition, as described in details, using different frequencies for bidding and market clearance leads to much higher prices because of the indirect lost opportunity costs that will be added to bid prices, which consequently decreases *price efficiency* (cost-reflectivity of prices) of the market to a great extent. Nonetheless, price efficiency represents a nuanced concept; only an increase in the level of prices can not be interpreted as reduction of cost-reflectivity of bids. The overall cost of providing a service includes both physical costs (operating, maintenance and fixed costs) and opportunity costs. This second component can be fundamentally influenced by the *design* of the market. Thus, a specific design can lead to introduction of high opportunity cost which consequently increases the bid prices, while no market power is abused by any supplier.

Based on our results, we conclude that the frequency of bidding should be as close as possible to the frequency of market clearance. Therefore, in case of balancing energy markets we recommend using a market time horizon equal to the length of the program time unit. In addition, because of the noticeable interrelations of balancing services markets and other electricity markets, we recommend using daily markets for reserve capacity markets, firstly to limit the unnecessary uncertainties in the bidding procedure, and secondly to be able to coordinate the gate opening/closure times of the reserve capacity market with those of the DA and ID markets.

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