Title:

Cost Reduction Potentials within the German Market of Control Reserves

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Abstract

This article examines potential cost reductions in the markets for control reserve and control power by pooling all four German control areas. In a united control area both the procurement and the activation of control reserve may be more efficient than in four separated control areas. We use historical bids on control reserve and actual control power flows. Our reference scenario simulates the market results for all types of control reserve and control power. We then construct a united control area by pooling all historical bids of each control area and netting the area control errors. We show that the total costs of control reserve and control power can be reduced by 15 % and the costs for secondary control power can be reduced by 42 %.

1. Introduction

Four control areas exist in the German electricity market in which positive and negative control reserve is activated at the same time. This article examines the cost reduction potential by pooling all control areas using historical data.

By pooling the four German control areas three major efficiency gains may be obtained. First, the control reserve could be reduced. Currently, a level of 0.1 % of all power flows has to be procured as control reserve. Haubrich (2008) computes the potential economies of scope of a united control area and concludes that the standby capacity of positive control power can be reduced from 5813 MW to 5404 MW and for negative control power from 4391 MW to 3356 MW. As control reserve is compensated with a demand charge, the reduction of procured control reserve can lead to a significant cost reduction.

Second, a major potential cost reduction can be expected from netting antipodal control power in different control areas. Since each control area is controlled independently, the area control error – the difference between planned and actual power flows – in one control area can be positive and the area control error in another can be negative. A netting of area control errors results in lower control area balances and thus in a cost reduction, because control power is compensated with an energy rate. Furthermore, since the supplier of control reserve with the least energy rate is activated first, a reduction in control power reduces the level of energy rates.

Third, the procurement auctions of control power could be more efficient in a single German control area. Currently, only a small fraction of suppliers of control reserve are bidding in all control areas because they are required to prequalify in all control areas separately. The prequalification is meant to guarantee that a power station is technically feasible to supply control reserve. As the prequalification process is time and cost consuming, most suppliers offer control reserve in only one control area which leads to a market separation. A supplier of control reserve whose bid was not accepted in a given control area with extremely low demand rates might have been accepted in a united control area. In a united control area there are more suppliers of control reserve than in each of the current four control areas which can also reduce energy rates.

The goal of this article is the numerical determination of potential cost reductions by pooling the control areas with historical data. We start by building a reference scenario which represents the actual status quo of the German control power market: the control areas will be balanced independently from each other and the suppliers of control power are required a separate prequalification for each control area. The reference scenario gives us reconstructed demand and energy rates which are used to test our model against the actual market results. Subsequently, we assume a united control area by pooling all bids and netting the area control errors. Therefore, the united control area is fictional in that way that historical bids and area control errors are used. In order to distinguish the influence of the different potential efficiency gains, two more scenarios are applied: in one scenario only the bids are pooled and in another scenario only the area control errors are netted.

The rest of the paper is structured as follows. The second section introduces the German market design of control reserve and power. The third section describes the data. The fourth section contains the model description and the fifth section the scenario results. The sixth section concludes the article.

2. The German market design of control reserve and power

Consumers and producers of electricity compose an electrical circuit in which the energy feed-in must equal the energy feed-out at all times. Whenever this is not the case, a power imbalance occurs. Such a power imbalance can result from unanticipated events such as a power station failure or errors in the load forecast. As a consequence, the power frequency changes which can result in a complete breakdown of the power grid. In the case of a too high (low) energy feed-in, we have a power surplus (shortage) and a rising (falling) power frequency. Following UCTE guidelines, the power frequency in Germany is 50 Hz. The stabilization of the power frequency is assigned to the CAO (control area operator) and is part of the ancillary services he has to provide. Other ancillary services are voltage stabilization, re-establishing the grid after a breakdown and the overall net management.

The German power grid is divided into four control areas which have to be balanced at all times with control power. Each control area consists of 100 to 200 balancing areas which pool energy feed-in and feed-out and are controlled by a balancing authority. The CAOs of these control areas are subsidiaries of the four big energy providers in Germany: EnBW, E.On, RWE and Vattenfall.

There are three different types of control reserve, namely primary, secondary and tertiary control reserves. These are distinguished by activation times and duration of operation. Activated control reserve is called control power. The primary control reserve has to be fully activated within 30 seconds and must remain operational for at least 15 minutes. Secondary control reserve is succeeding the primary control reserve and has to be fully activated in 5 to 15 minutes after a grid imbalance. Both primary and secondary control power are activated automatically. The tertiary control power is managed manually and replaces the secondary control power after 15 minutes to 60 minutes.[1]

In the procurement of control reserve, the CAO has a monopsony. To remedy the potential market power of the CAO, the procurement of control power must take place in an anonymous, open auction to guarantee a non-discriminatory access to the market to all suppliers of control reserve. [2] The auction should minimize the procurement costs of control reserve. The German regulation authority, Bundesnetzagentur, has opted for multi-dimensional, multi-unit auctions to procure secondary and tertiary control reserve since two services are procured simultaneously: control reserve and control power. Therefore, a bid consists of two prices: a demand rate with the dimension €/MW and an energy rate with the dimension €/MWh.[3] As the activated primary control reserve cannot be measured for technical reasons, in this case a bid consists only of a demand rate. All bids are ordered according to their demand rates and all bids are accepted until the determined demand for control reserve is met. This procedure is called scoring rule. Afterwards, the accepted bids of secondary and tertiary control power are ordered according to their energy rates. By the settlement rule, in the case of a power imbalance the control reserve with the lowest energy rates is activated first. Accepted bids are compensated with bid-prices, i.e. each bidder gets exactly the price from his bid.

The energy rates are also used in the settlement of imbalances in balance areas. The balance authority of a balance area has to pay the average weighted energy rate (AWER) if his balance area had a power shortage and he receives the AWER if his balance area had a powersurplus.

3. Data

We use data of 12 consecutive months between December 1, 2007 and November 30, 2008. Tertiary control reserve is auctioned daily in 4-hours-time-slices since December 1, 2006. Until November 30, 2008 primary and secondary control reserves were procured for six months each. Since December 1, 2007 the auctions are held monthly and in the case of secondary control power the auction is split between peak and off-peak phases. The peak phase covers all workdays between 8 am and 8 pm, the off-peak phase all other times including weekends and public holidays. The differentiation between peak and off-peak times expresses the significant changes in the electricity market throughout the

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[1] Cf. Wawer (2007) and Swider (2007).

[2] Cf. StromNZV, BNetzA (2007).

[3] Cf. Chao/Wilson (2002)

day. Therefore, we have 17 different auctions for control reserves: one monthly auction for primary control reserve, four monthly auctions for positive and negative, peak and off-peak secondary control reserve and 12 daily auctions for each 4-hours-time-slice and for positive and negative tertiary control reserve.

All data after November 30, 2008 were not used, because in December 2008 a co-operation between the control areas of E.On, EnBW and Vattenfall started to reduce antipodal area control errors. As this may have caused a structural break in the data, we limited the time horizon to 12 months. All data was obtained from the websites of the CAOs who on behalf of the Bundesnetzagentur are obliged to publish a wide range of grid statistics.

3.1 Auctions

Primary control reserve: As described in the last section, primary control power is not divided in positive and negative control reserve and the supplier is only compensated with a demand rate. Consequently, primary control power does not depend on area control errors.

We observed 578 bids for primary control power which were all accepted. Altogether 7,985 TW primary control reserve were procured costing 114.81 million euro. The average bid size was 13.81 MW and the average demand rate was 198 €/MW for one month. Figure 1 depicts the development of the procurement costs of primary control power in time and in million euros.

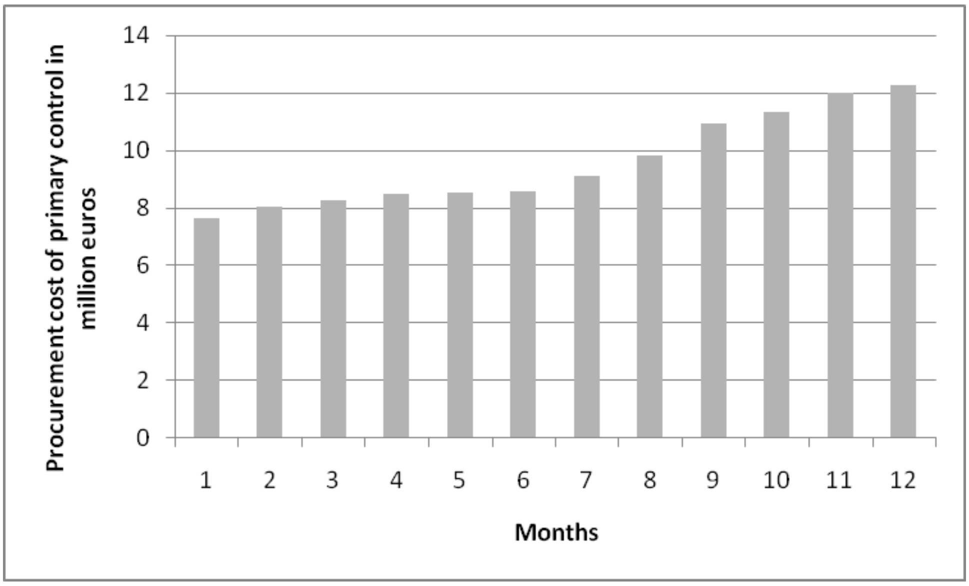

Figure 1: Procurement costs of primary control power

Secondary control reserve: The data contains 423 bids for positive and 338 bids for negative secondary control reserve. These bids are further divided into equal parts of peak and off-peak bids, i.e. we have an average of 13 bids per auction for secondary control reserve. In the case of positive secondary control reserve 84 % of the bids and in the case of negative control reserve 94 % were accepted.

Tables 1 a/b shows the mean, standard deviation, minimums and maximums of bid sizes, demand rate, energy rate of the bids for positive and negative secondary control reserve. Both the demand rates and the energy rates are on average decidedly higher in peak times than in off-peak times. This results from higher opportunity costs of power stations in the peak time. Although the same power stations with identical costs are used in peak and off-peak times, such bids are not inefficient, because a power station always has the opportunity to offer its production at the day-ahead market. A supplier has to be compensated not to be active at the day-ahead market.

	bid size (MW)		energy rate (€/MWh)		demand rate (€/MW)	
	peak	off-peak	Peak	off-peak	peak	off-peak
Mean	206.1667	208.0899	157.3394	111.3185	5641.844	3448.692
Std. dev.	258.0763	253.9685	91.36015	41.10115	1130.713	347.8984
Maximum	1250.000	1250.000	770.0000	275.0000	12607.75	5660.000
Minimum	30.00000	30.00000	71.00000	55.00000	2130.000	2222.000
Obs.	180	178	180	178	180	178

Table 1a: Descriptive statistics of bid size, energy rates and demand rates of accepted bids for positive secondary control power

As bidders on negative control power receive energy, the bidding logic differs from that of positive control power. Many suppliers of negative control power are content with a zero payment and both the average energy rates and the average demand rates are much lower than for positive control power. Furthermore, the absolute differences between peak and off-peak times are lower compared to positive control power. However, the relative differences of the energy rates of peak and off-peak times are quite high since in off-peak times mostly inflexible base load power stations are online.

	bid size (MW)		energy rate (€/MWh)		demand rate (€/MW)	
	peak	off-peak	peak	off-peak	peak	off-peak
Mean	184.7500	184.1139	7.215625	1.503797	2418.139	2525.643
Std. dev.	169.7999	159.0162	7.339235	2.241165	1397.105	2173.330
Maximum	1000.000	1000.000	26.00000	10.00000	6500.000	13619.00
Minimum	30.00000	30.00000	0.000000	0.000000	900.0000	958.7500
Obs.	160	158	160	158	160	158

Table 1b: Descriptive statistics of bid size, energy rates and demand rates of accepted bids for negative secondary control reserve

Tertiary control reserve: As tertiary control reserve is auctioned daily in 4-hour-time-slices, we observe immensely more bids compared to primary or secondary control reserve. Our data contains of 343,786 bids for positive and 406,178 bids for negative tertiary control reserve of which 58 % and 66 % were accepted. But since 12 auctions occurred per day, each auction had on average of only 26 bids for positive and 30 bids for negative tertiary control reserve.

The rationale for bidding on positive and negative tertiary control reserve corresponds to secondary control reserve. In order to allow an easy comparison between secondary and tertiary control reserve, we have pooled all 4-hours-time-slices according to the peak and off-peak times of secondary control power.

Tables 2 a/b show the mean, standard deviation, minimums and maximums of bid sizes, demand rates and energy rates of accepted bids for positive and negative tertiary control power. As in the case of secondary control reserve, the energy rates and the demand rates are higher in peak times than in off-peak times. Although, the relative differences between peak and off-peak times are not as sharp as in the case of secondary control reserve.

	bid size (MW)		energy rate (€/MWh)		demand rate (€/MW)	
	peak	off-peak	peak	off-peak	peak	off-peak
Mean	25.27452	24.60728	169.3708	140.7930	29.58284	13.24848
Std. dev.	21.02770	19.34135	252.7839	225.8539	79.81084	17.95378
Maximum	180.0000	160.0000	2001.000	1400.000	762.5000	200.0000
Minimum	15.00000	15.00000	0.000000	0.000000	0.000000	0.000000
Obs.	70965	128867	70965	128867	70965	128867

Table 2a: Descriptive statistics of bid size, energy rates and demand rates of accepted bids for positive tertiary control reserve

Contrary to the secondary control reserve, the average energy and demand rates for negative tertiary control reserve are more expensive than the average energy and demand rates for positive tertiary control reserve. This peculiar constellation is due to several factors. Tertiary control reserve is rather scarcely and infrequently activated and therefore cannot be integrated in the optimal schedule of a power station. Furthermore, a power station which supplies tertiary control power has to be online, i.e. it must be running or must have very low ramp up costs. While positive tertiary control power can be provided by power station with very low ramp up costs like combined-cycle plants, negative tertiary control power can only be provided by running power stations. As the activation of tertiary reserve happens only seldom, power stations should run at their maximum energy efficiency. In this situation a forced reduction in production results in lower efficiency and higher costs.

	bid size (MW)		energy rate (€/MWh)		demand rate (€/MW)	
	peak	off-peak	peak	off-peak	peak	off-peak
Mean	23.63807	23.59069	392.8512	313.1369	38.85511	13.03259
Std. dev.	17.49043	17.09946	319.4370	270.1430	51.23309	21.44109
Maximum	150.0000	150.0000	2000	1600	470.5000	3000.000
Minimum	15.00000	15.0000	0. 0000	0.0000	0.0000	0.0000
Obs.	96913	171604	96913	171604	96913	171604

Table 2b: Descriptive statistics of bid size, energy rates and demand rates of accepted bids for negative tertiary control reserve

3.2 Control power

The control power quantities are published by the CAOs for every quarter of an hour, i.e. we have 35,136 observation points for secondary and tertiary control power. In many quarters of an hour both positive and negative control reserve is activated. Altogether 28,857 GW secondary control reserve was activated which consisted of 10,484 GW positive and 18,373 GW negative secondary control power. The probability of an activation of positive and negative secondary control reserve differs strongly between the control areas. In general, the chance of an activation of negative secondary control reserve is higher than an activation of positive secondary control reserve. Table 3a overviews the magnitude of secondary control power for each control area.

	ENBW		E.ON		RWE		VET	
	positive	negative	positive	negative	positive	negative	positive	negative
Mean	53.87834	99.22876	231.6896	221.0247	234.0752	258.9458	138.4256	207.2065
Median	30.88000	56.56000	226.0000	216.0000	167.0000	199.0000	112.8000	188.0700
Maximum	409.0000	753.2000	1322.000	570.0000	2265.000	1581.000	580.0000	649.7600
Minimum	0.010000	0.010000	1.000000	1.000000	1.000000	1.000000	0.010000	0.010000
Std. dev.	61.32056	119.0037	127.6240	113.0484	230.3859	236.8735	108.3722	138.3514
Activ. prob.	0.7145	0.7818	0.3242	0.6334	0.5762	0.6703	0.3604	0.6360
Quant.	1352616	2725913	2639408	4918683	4739086	6098951	1753022	4630236
Quant. %	0.0469	0.0945	0.0915	0.1704	0.1642	0.2113	0.0607	0.1604
Obs.	25105	27471	11392	22254	20246	23553	12664	22346

Table 3a: Positive and negative secondary control power

Tertiary control reserve was activated with a total of 9,708 GW whereof 91 % was negative tertiary control power. Furthermore, tertiary control reserve was activated not nearly as frequently as secondary control power: only in 5 % of all quarter of an hour, tertiary control reserve was activated. Table 3b gives the descriptive statistics for tertiary control power.

	ENBW		EON		RWE		VET	
	positiv	negativ	positiv	negativ	positiv	negativ	positiv	negativ
Mean	173.188	117.028	184.8225	276.0737	325.0235	04.6160	220.5215	240.70
Median	150.0000	90.0000	187.0000	200.0000	295.0000	250.0000	200.0000	200.00
Maximum	449.0000	231.000	550.0000	800.0000	948.0000	1054.000	555.0000	397.00
Minimum	45.00000	45.0000	45.00000	50.00000	30.00000	15.00000	45.00000	130.00
Std. dev.	0.0056	0.0020	0.0079	0.0228	0.0509	0.0324	0.0186	0.0025
Activ. prob.	90.36150	50.6926	88.16576	144.4168	165.0784	190.3716	105.4473	95.284
Quant.	33945.00	8309	51011.00	221135.0	581142.0	346653.0	143780.0	21423
Quant. %	0.0035	0.8559	0.0053	0.0228	0.0599	0.0357	0.0148	0.0022
Obs.	196	71	276	801	1788	1138	652	89

Table 3b: Positive and negative tertiary control power

4. The model

The total cost of control reserves (*C*) consists of the procurement costs of control reserves (*PC*) and the activation costs of control reserves (*AC*). We use a two-stage, linear programming model to emulate the market of control reserve. Figure 2 gives an account of the model sequence.

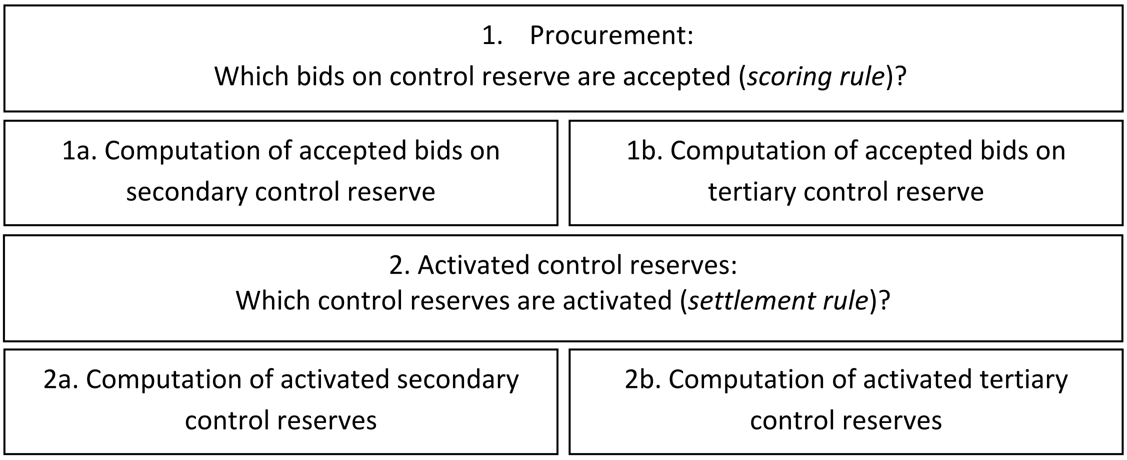

Figure 2: Model sequence

The procurement determines which bids on control reserve are accepted (scoring rule). Each bid *b* is valid for one or several quarter of an hour *t* for one or more control areas *c*and consists of a demand rate *dr*, an energy rate *er* and a maximum amount of control power $\overline{x}$. The control reserve is differentiated in secondary control reserve m_{sc} and tertiary control reserve m_{tc}. As the procurement costs of control reserve are minimized, we have the following objective function:

$$PC \overset{\min!}{=} \sum_b \sum_t \sum_c dr_{b,t,c} \cdot m_{b,t,c} \ . \qquad (1)$$

Furthermore, it has to be guaranteed at all times and for all control areas that the sum of all procured control reserve *m* is equal to the required quantity of control reserve $\overline{m}$ in a control area, i.e. the required quantity of control reserve $\overline{m}$ must be identical to the total auctioned control reserve

$$\sum_b m_{b,t,c} = \overline{m}_{t,c} \qquad \text{for every quarter of an hour } t \text{ and all control areas } c. \qquad (2)$$

Although trivial, it has also to be assured that the procured control reserve *m* is equal or lower than the maximum control power $\overline{x}$ declared in the bid

$$\sum_c m_{b,t,c} \leq \sum_c \overline{x}_{b,t,c} \qquad \text{for all bids } b \text{ and every quarter of an hour } t. \qquad (3)$$

In the second phase of the model, all bids *b* are ordered accordingly to the settlement rule to balance area control errors (*ACE*) with minimum costs:

$$AC \overset{\text{min!}}{=} \sum_b \sum_t \sum_c er_{b,t,c} \cdot x_{b,t,c} \, , \tag{4}$$

i.e. it is determined on the basis of the energy rates which control reserve is activated. For every quarter of an hour *t* the area control error (ACE) has to be compensated with activated control reserve *x*.

$$\sum_b x_{b,t,c} = ACE_{t,c} \qquad \text{for every quarter of an hour } t \text{ and all control areas } c. \tag{5}$$

Like the procured control reserve, the control power *x* consists of secondary control power x_{sc} and tertiary control power x_{tc}. Also, the control power x must be equal or lower than the maximum control power $\bar{x}$ declared in the bid at all times and for all bids.

$$\sum_c x_{b,t,c} \leq \sum_c \bar{x}_{b,t,c} \qquad \text{for all bids } b \text{ and every quarter of an hour } t \tag{6}$$

Legend
C: total costs of control reserve and control power [euro]
PC: procurement costs of control reserve [euro]
AC: activation costs of control reserve/cost of control power [euro]
t: time [index; quarter of an hour]
p: primary control reserve/power [index]
sc: secondary control reserve/power [index]
sc: tertiary control reserve/power [index]
c: control area [index]
b: bid (consists of demand rate, energy rate and maximum control power for one or more t) [index]
dr: demand rate (bid-based) [€/MW]
er: energy rate (bid-based) [€/MWh]
$\bar{x}$: maximum control power (bid-based) [MW]
m: procured control reserve (bid-based) [MW]
ACE: area control errors: the difference between the actual and the reference value for the power interchange of a control area. [MWh]
$\bar{m}$: required quantity of control reserve (based on auction design) [MW]
x: activated control reserve/control power (based on area control errors) [MWh]

5. Scenario results

We are examining four scenarios with scenario 1 as reference scenario in which the market results of the current system are reconstructed. In Scenario 2 all bids on control reserve are pooled and all area control errors are netted thus simulating one single German control area. Scenarios 2a and 2b explicitly capture single effects which are somewhat meddled in scenario 2, thereby allowing a more detailed analysis. Consequently, in scenario2a the bids on control reserve are not pooled, but the area control errors are netted whereas in scenario 2b the bids on control reserve are pooled, but the area control errors are balanced independently for each control area. Figure 3 depicts the total costs of control reserve and control power of all four scenarios.

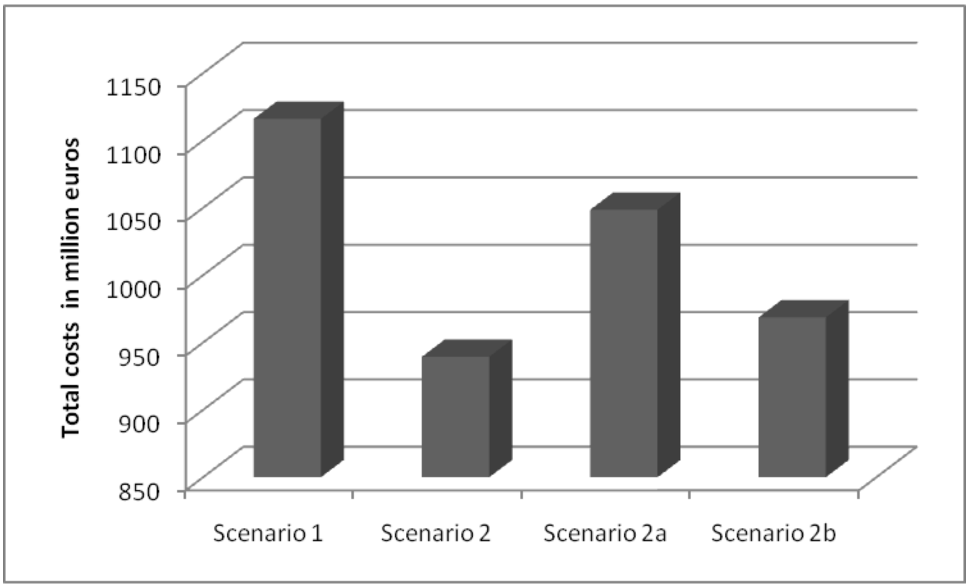

Figure 3: Total costs of control reserve and control power in million euros

As scenario 2 captures all effects obtaining efficiency increases and scenarios 2a and 2b capture only one effect each, the cost reductions in scenario 2 are highest. The effect of netting the control area impalances (2a) does not seem to have such a strong impact than the effect of pooling the suppliers' bids on energy procurement, captured in scenario 2b. In the next sections these effects are further analyzed.

5.1 Scenario 1

The reference scenario simulates the market of control reserve and power before December 2008, i.e. the control reserve is auctioned separately for each control area and the area control errors are also balanced independently. The suppliers of control reserve are required to be prequalified for each control area. Table 4 reviews the monthly costs of control reserve and control power for each month and type of control reserve and control power.

	PC_p	PC_{sc}	AC_{sc}	PC_{tc}	AC_{tc}
December-07	7.61	37.86	13.29	42.18	2.24
January-08	8.03	30.81	13.57	15.40	1.91
February-08	8.23	31.44	12.74	13.09	1.00
March-08	8.45	31.21	13.53	10.16	61.18
April-08	8.51	31.61	16.88	20.59	4.99
May-08	8.57	28.99	13.44	12.09	39.95
June-08	9.10	23.26	12.74	30.46	15.84
July-08	9.83	28.48	7.44	15.29	2.73
August-08	10.93	34.19	10.64	14.64	19.12
September-08	11.34	28.48	14.67	18.33	5.97
October-08	11.99	29.01	13.25	22.67	30.29
November-08	12.24	23.40	10.13	12.64	77.37

Table 4: Results of scenario 1 in million euros.

The total costs add up to 1116.02 million euro. The procurement costs for primary control make up for 10 % of the total costs. Although primary control does not show high volatility, its procurement costs show a noticeable increasing trend. This may be on account of increasing costs of combustibles in 2008 but requires further investigation. Procurement costs as well as activation costs for secondary control are rather constant. This is owing to relatively constant quantities of control reserve and control power. Tertiary control shows much more volatility in both procurement and activation costs. The latter is due to the very unstable activation of tertiary control reserve. In some periods there is no tertiary control reserve has to be activated at all whereas in others there are major imbalances leading to a massive increase in tertiary control power. The reason for the volatile procurement costs of tertiary reserve is less obvious but might be due to the auction design. Auctioning on a daily basis as is the case for tertiary control may introduce more volatility than auctioning on a monthly basis in the case of secondary control because short term events such as power station breakdowns can be taken into account. On a monthly basis this is not possible, hence the participants bid expected rather than actual demand rates.

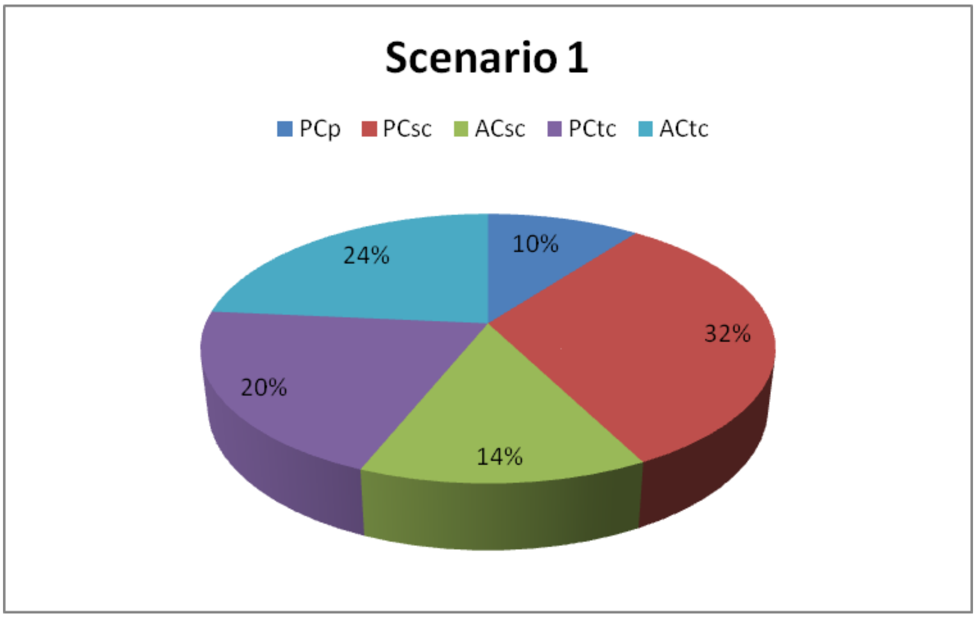

Figure 4: Shares of different types of control reserve and control power of total costs in scenario 1

As can be seen in Figure 4, secondary control has with 46 % the greatest share of total costs. This is not surprising as it has a higher quality than tertiary control and therefore higher procurement costs (32 %). On the other hand, tertiary control has a greater share in activation costs than secondary control. As the level of demand for tertiary control is much lower than the demand for secondary control, the high energy rates therefore make up for the low activation rates.

Primary control is not affected by pooling the control areas so that the absolute level of primary control is the same throughout all scenarios and hence will not be further considered. The share of primary control may vary nonetheless, owing to a different size of the pie.

5.2 Scenario 2

Scenario 2 assumes a united German control area. Therefore, the control reserve is procured in a single auction and area control errors are netted. For example, if one control area has a large positive ACE and another control area has a negative ACE with equal magnitude, the resulting ACE would be zero. Therefore, special restrictions of control areas such as the prequalification process for each control area or rules directing that a specific share of control reserve has to be procured in a given control area are not relevant anymore. Consequently, the costs of control power are reduced significantly compared to scenario 1.

The required quantity of control reserve $\overline{m}$ remains unchanged, i.e. the same quantity of control reserve is procured in scenario 1 and 2. But as the bids of all control areas are pooled and only such bids are accepted that are efficient in a united control area, the procurement auction results differ in the two scenarios.

	PC_p	PC_{sc}	AC_{sc}	PC_{tc}	AC_{tc}
December-07	7.61	20.38	8.75	42.18	2.67
January-08	8.03	18.67	6.35	15.40	1.88
February-08	8.23	18.04	5.68	13.09	0.99
March-08	8.45	18.97	7.64	13.84	56.39
April-08	8.51	17.92	12.86	15.30	4.34
May-08	8.57	18.69	9.75	14.44	37.04
June-08	9.10	18.56	7.40	25.68	14.63
July-08	9.83	20.72	3.40	21.57	3.35
August-08	10.93	20.35	5.30	33.25	20.80
September-08	11.34	19.86	9.08	14.63	7.12
October-08	11.99	20.25	7.53	20.50	30.06
November-08	12.24	18.74	3.54	19.68	77.33

Table 5: Results of scenario 2 in million euros.

Table 5 shows the scenario results. As stated above, primary control is fixed for all scenarios. Looking at the costs of secondary control, it is easily determined that there is a major reduction in total costs. Procurement costs are down to 231.15 million euro from 358.74 million euro in scenario 1. This implies a cost reduction of 127.59 million euro. The reason does not lie in a reduction of quantity (as the quantity of procured energy is fixed) but in the more efficient auction design. This effect will be more closely analyzed in szenario 2b. Because of the netting of the area control errors the costs of secondary control power decrease by 65.04 million euro from 152.32 million euro to 87.28 million euro.

The reasons for potential cost reductions in tertiary control are twofold. First, the greater part of the procured reserve is already auctioned across all control areas so that the procurement costs cannot be amply reduced. Accordingly, the procurement costs are not reduced at all but actually increase by 22.02 million euro from 227.54 M€ to 249.56 million euro.[4] Secondly, there are hardly periods with activated tertiary control power in more than one control area at the same time so the netting effect is quite small. Consequently, costs of control power decrease only by 5.99 million euro from 262.59 million euro in scenario 1 to 256.6 million euro in scenario 2.

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[4] This result is only preliminary and is attributed to a higher number of accepted bids compared to scenario 1. We had to accept more bids in order to control every single control area imbalance. The historical data indicates that this was not always possible, leading to co-operations across all control areas.

Having almost constant total costs of primary and tertiary control and a major cost reduction of secondary control it is easily ascertained that the share of total costs of secondary control decreases sharply – that is to say the share of secondary control decreases from 46 % in scenario 1 to 35 % in scenario 2. This is illustrated in figure 5.

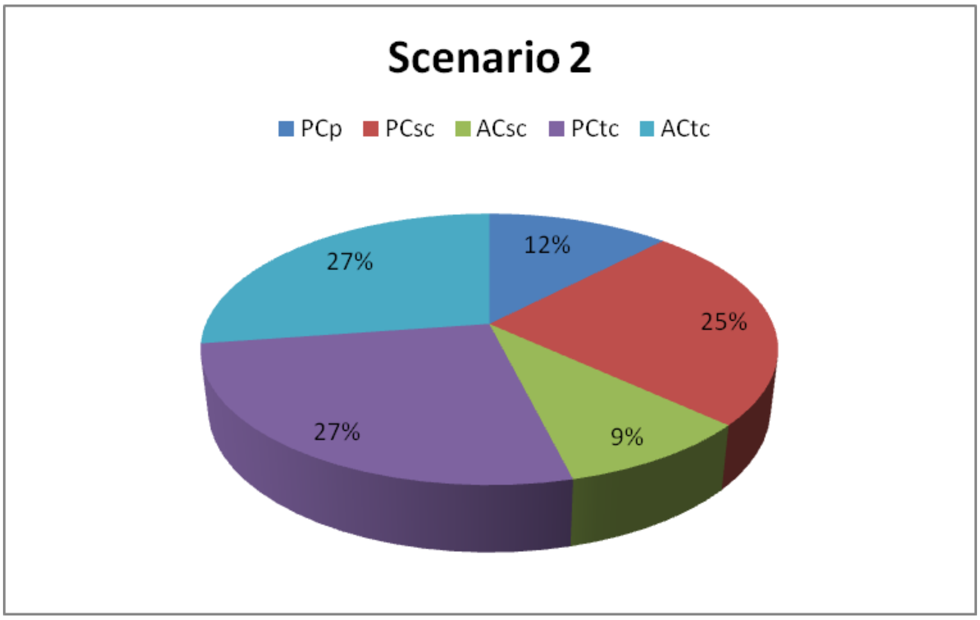

Figure 5: Shares of different types of control reserve and control power of total costs in scenario 2

By pooling all four control areas, the importance of secondary control diminishes in favor of tertiary control. The systems total cost thereby decrease by 176.6 million euro from 1116.02 million euro in scenario 1 to 939.42 million euro in scenario 2. That is to say there is a potential of cost reduction of 15.8 %.

5.3 Scenario 2a

Scenario 2a assumes a united control area, i.e. the area control errors are netted, but the same bids are accepted as in scenario 1. Although this setting is not a sensible market design, it allows us to examine the importance of the netting effect more closely.

	PC_p	PC_{sc}	AC_{sc}	PC_{tc}	AC_{tc}
December-07	7.61	37.86	8.61	42.18	2.67
January-08	8.03	30.81	6.26	15.40	1.89
February-08	8.23	31.44	5.56	13.09	0.99
March-08	8.45	31.21	7.64	10.16	59.01
April-08	8.51	31.61	12.86	20.59	4.43
May-08	8.57	28.99	9.74	12.09	36.61
June-08	9.10	23.26	7.40	30.46	16.00
July-08	9.83	28.48	3.40	15.29	3.41
August-08	10.93	34.19	5.31	14.64	17.23
September-08	11.34	28.48	9.08	18.33	6.37
October-08	11.99	29.01	7.54	22.67	32.75
November-08	12.24	23.40	3.49	12.64	79.24

Table 6: Results of scenario 2a in million euros.

As the accepted bids are equal to those accepted in scenario 1, the procurement costs remain unchanged. Hence, we can concentrate on the activation costs. These are quite similar to those computed in scenario 2. This is because in both scenarios the area control errors are netted such that the quantities of energy demand in scenarios 2 and 2a are the same. In effect the difference in activation costs is only about 1.04 %. Obviously, the effect of netting the control areas is the dominating effect on costs of control power. The second effect, namely the effect of a more efficient auction design which is accounted for in scenario 2 (and 2b) does not seem to have a significant influence on the costs of control power. Otherwise the activation costs in scenarios 2 and 2a would indicate a greater difference. That the auction design actually has an influence will be shown in scenario 2b.

5.4 Scenario 2b

In scenario 2b area control errors will be compensated in four control areas separately, i.e. no netting of area control errors occurs. The only difference from scenario 1 is that all bids on control reserve are pooled which of course has also implications for the activation of power reserves. For example, if an area control error occurs, the supplier with the lowest energy rate of all bids will be activated. Therefore, the efficiency gains by the auction pooling can be seen explicitly.

	PC_p	PC_{sc}	AC_{sc}	PC_{tc}	AC_{tc}
December-07	7.61	20.38	13.68	42.18	2.32
January-08	8.03	18.67	13.73	15.40	1.92
February-08	8.23	18.04	13.08	13.09	1.01
March-08	8.45	18.97	13.53	10.16	54.12
April-08	8.51	17.92	16.88	20.59	4.99
May-08	8.57	18.69	13.47	12.09	37.80
June-08	9.10	18.56	12.75	30.46	14.63
July-08	9.83	20.72	7.44	15.29	3.35
August-08	10.93	20.35	10.63	14.64	20.80
September-08	11.34	19.86	14.67	18.33	6.40
October-08	11.99	20.25	13.16	22.67	28.34
November-08	12.24	18.74	10.17	12.64	66.26

Table 7: Results of scenario 2b in million euros.

In this scenario, the accepted bids are equal to those of scenario 2 and also are the procurement costs the same. Hence, efficiency increases in procurement costs result only from a more efficient auction design as long as the quantity of procured energy remains fixed. Again, our focus lies on the activation costs. These are now similar to those observed in scenario 1 which is unsurprising as four control areas have to be controlled and energy demand in scenarios 1 and 2b are the same. However, some differences are apparent: In those months with massive activation of tertiary control such as March and November 2008 the activation costs are considerably lower in scenario 2b, suggesting that by means of a more efficient auctioning process the most expensive bidders are not accepted any more. In those periods with lower demand the difference diminishes entirely. This indicates that in each control area there are a number of rather efficient participants, leading to low overall costs of control power. If, however, a large area control error occurs, less efficient control reserves have to be activated. By pooling all participants, the probability of activating the most expensive control reserves decreases or these participants are even not accepted in the auction process, thus leading to a sharp decrease in activation costs in March and November 2008.

6. Conclusion

This article has shown that by pooling the four German control areas into one single control area major efficiency gains can be achieved. By netting the area control errors and by pooling all reserve bids cost reductions of 176.6 million euro were computed. This reduction comes mostly on account of secondary control because of antipodal control power. Besides we detected two more sources of efficiency gains: Less procurement of control reserve and more efficient auctions. The latter originates from the current prequalification process which leads to a strong market segmentation. In one control area this segmentation is nullified.

Our model results are based on the assumption of a sufficiently high grid capacity. But since no permanent network shortages have occurred in Germany as yet this assumption appears to be reasonable. Hence, the status quo in the German market for control reserve and control power is inefficient.

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