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Description of load-frequency control concept and market for control reserves

Study commissioned by the German TSOs

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Consentec GmbH

Grüner Weg 1
52070 Aachen<

Germany

Tel. +49. 241. 93836-0
Fax +49. 241. 93836-15
E-Mail info@consentec.de

www.consentec.de

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1 Legal and regulatory framework

Besides providing network infrastructure for a long-distance electric power transmission, the provision of indispensable ancillary services is one of the most important duties of transmission system operators (TSOs) in order to secure operation of power supply systems. Among these ancillary services the socalled load-frequency control[1] is of importance not only because of technical complexity but also due to essential cost relevance — in relation to the costs of other ancillary services as well as to the total transmission network costs — and the interdependency with the electricity generation and supply sectors. Accordingly, load-frequency control has already been regulated for a long time. This regulation comprises general directives and rules for technical codes as well as dedicated antitrust and regulatory specifications.

Currently, the regulatory framework for load-frequency control comprises regulations and decisions as follows:

- On the European level the binding rules for load-frequency control will mainly result from network codes for the issues of "Load Frequency Control & Reserves" as well as "Electricity Balancing". The assembly of the European network of Transmission System Operators for Electricity (ENTSO-E) accepted both network codes and has sent them to the Agency for the Cooperation of Energy Regulators (ACER). Until these grid codes will come into force the ENTSO-E Operation Handbook (formerly UCTE Operation Handbook) — a collection of principles for system operation of the European TSOs — defines the European framework for carrying out load-frequency control.
- The national legal framework deals with questions concerning reserve and balancing energy relating issues not only in the specified regulation on access to power systems (in German: Stromnetzzugangsverordnung (StromNZV)) but also directly in the Energy Act. Besides general rules e.g. on the TSO's responsibility for system security these regulation and Act define precise requirements for market-based procurement and provision of balancing services, in particular control reserve. The fact that load-frequency control, in contrast to other ancillary services, is ruled explicitly in the Energy Act underlines the importance of load-

[1] In addition to the term "load-frequency control" relating issues are often addressed by further terms such as reserve and balancing energy system.

frequency control. On this basis the StromNZV lays down detailed requirements for deployment of load-frequency control and allocation of its costs. Moreover, the German renewable energy act (in German: Erneuerbare-Energien-Gesetz (EEG)) defines prerequisites under which power generators based on renewable energy sources (RES) may participate in control reserve markets.

- In addition to the legal requirements mentioned so far, further technical regulations are relevant for the complex of load-frequency control. In particular, this concerns the pre-qualification of approved technical units for the provision of control reserve. The corresponding requirements of pre-qualification are originally described in the Transmission Code of the German TSOs (latest edition of 2007). Further requirements for pre-qualification are agreed on contractual basis with the providers. The latest status can be taken out of published model contracts. Likewise, the duties of balance responsible parties (BRPs) are regulated in so-called balancing group contracts, the newest edition of which is also provided as model contract by the TSOs.

- Additionally, German regulator Bundesnetzagentur provides market rules for different control reserve segments in regulatory decrees and will adapt them if necessary. The last amended regulatory decrees result from 2011. Regulations concerning allocation of balancing costs to market participants were adapted in 2012 for the last time. Furthermore, German regulator Bundesnetzagentur influences the procedure of load-frequency control by providing numerous rulings on detailed questions.

This short summary already describes the complexity of the relevant legal and regulatory framework for the field of load-frequency control. One may easily understand that procurement, provision and balancing of these ancillary services are subject to a continuous development. The following elaboration has been developed to provide a compact and as complete as possible overview (status: November 2013) to those interested readers not being familiar with this subject.

2 Network access model

2.1 Organisation of system balance

Stable operation of power supply system requires that the system balance of feed-in, offtake and losses in the total system are balanced at any time or that it will be balanced within a few seconds in case of any deviations. A surplus of feed-in power cannot directly be stored. In contrast to e.g. a gas supply system, the grid is not able to store any energy. Although an indirect storage is possible by principle, it will, however, only be feasible in a limited way with regard to power supply systems of today. One such storage option is to pump water from a lower reservoir into the upper reservoir of a pumped-storage power plant. Other storage techniques are feasible as well. Nevertheless, also feed-in and supply to and from storage systems demand for an active control.

The users of a power supply system are obliged to control system balance within very short time slices with suitable control systems ensuring this balance. The control systems must have access to controllable feed-in (or controllable demand side resources) in order to impact the system balance as needed.

As shown in figure 2. 1 system balance is preserved from the technical point of view if power frequency can be kept within a very small range around the nominal frequency of 50Hz.

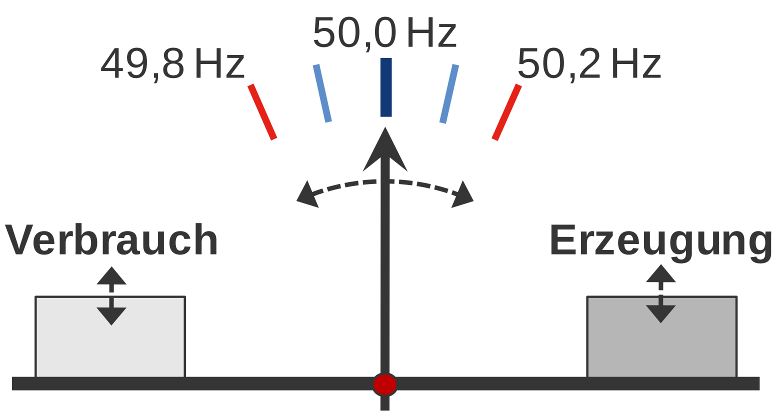

Fig. 2.1: Necessity of keeping the balance between demand and generation in the power system to preserve the frequency set point of 50.0 Hz

Deviations between feed-in and offtake and thus system imbalances cannot be avoided by precise planning in advance. Neither the supply by single or collective users nor the feed-in taken from generators — especially those based on intermittent RES (e.g. wind and sun) – can exactly be forecasted. Thus, the active, continuous regulation of system balance is absolutely necessary.

According to the German Energy Act (EnWG) the four German TSOs are responsible for this regulation task called load-frequency control. Each TSO operates one control area in which it balances the system by continuously operating and coordinating different control mechanisms. Chapter 3 and 4 describe in detail how this concept is technically implemented and in which way required control reserves are procured.

This concept of central control responsibility by the TSO (or by another central stakeholder) has proved as appropriate and efficient in Germany as well as in other countries. It requires far smaller effort of control technology and control reserves than the theoretically possible concept of control responsibility by single utilities. Namely, this would mean that every utility would require real-time metering data on the consumption of all its customers and the feed-in of the generators used to supply the utility's customers. It would also require control systems and suitable control reserves in form of controllable feed-in and/or demand-side units. This would result in an unjustifiably high effort, and the additional burden to power utilities would be particularly high for those utilities serving only a small group of customers. Beside the inefficiencies and risks for the stability of the total system, such an approach would also be problematic as regards the point of view of competition.

2.2 Balancing regime

Within the German legal framework for the energy sector, load-frequency control is a common task undertaken by each TSO for all grid users within its control area as a part of its responsibility for system security as defined by the German Energy Act. Arising costs are passed on to the users.

In order to realize this task and to allow a charging of control costs based on responsibilities for imbalances, suppliers and traders form balancing groups. These are entities within one control area in which feed-in of generators as well as offtake of customers and traded energy quantities of the members of the balancing group are pooled. Each quantity of generation, load and traded energy has to be allocated to exactly one balancing group at a particular time in order to guarantee a full and unambiguous balancing of the system. A BRP is responsible for the control of each balancing group.

At the end of each month the TSO responsible for the control area determines the imbalance of each imbalance group and for each balancing period (1/4 hour) by netting the metering values of generation and load within one balancing group and taking into account energy deliveries between balancing groups. The imbalance of a balancing group is defined to be the balancing energy which the balancing group has made use of.

According to StromNZV and the balancing-group contract the BRPs are responsible of keeping feed-in and offtake within their balance groups balanced within every quarter of an hour. Due to forecast deviations and other reasons, however, imbalances and consequently a demand for balancing energy are unavoidable. A balancing group requiring the delivery of balancing energy from the system has a shortage of energy, a balancing group delivering balancing energy into the system has a surplus, correspondingly. The total of imbalances of all balancing groups of one control area equals the imbalance of the control area as a whole. The TSO will balance this system imbalance by the deployment of control reserves. As with balancing groups, a control area has a shortage if the total offtake of control energy by the balancing groups exceeds the deliveries to the system, in the opposite case the area has a surplus.

The respective TSO settles the balancing energy used with the balance responsible party. This settlement is based on an imbalance price which is calculated for each quarter of an hour and multiplied with the respective imbalance of a balance group, in order to calculate the net payment or revenue from the balancing system. This price, being either positive or negative, is used throughout Germany for all balancing energy quantities (shortage as well as surplus). The costs arising for the TSOs by using control reserve in the respective quarter of an hour are covered by the imbalance energy price (cf. section 5.2).

The concept of a uniform imbalance price (per energy quantity and for a given quarter of an hour) implies that the imbalance system does not differentiate between different reasons for the balancing demand of particular balance groups. Instead, all (parallel) imbalances (of one direction) are treated in an equal manner, irrespective of their causes. In this respect, BRPs are treated by a solidarity principle, with cost of load-frequency control being shared among them without any differentiation as to the causes of imbalances but solely according to the amount of balancing energy taken from or delivered to the system.

Normally, volumes of BRPs' positive and negative balance energy quantities for one quarter of an hour exceed the amount of control reserve deployed in the same period, as in every quarter of an hour positive as well as negative imbalances arise. Thus balance groups unconsciously provide each other imbalance energy.

3 Realisation of power-frequency control

3.1 Requirements for power-frequency control

As described before, feed-in and offtake of energy in a power supply system have to be balanced at any time. In principle, this system balance is maintained by continuous and fast adjustment of controllable generation or load units. These are in particular – but not exclusively – power plants having fast controllable power output.

This balancing works on different levels:

- In system operation the system balance is continuously and unavoidably disturbed due to, for example, stochastic behavior of network users regarding power feed-in and offtake that cannot be coordinated. As generation of power plants as well as the load of controllable demand side resources can only be adapted by delay, only the inertia of all rotating masses in the interconnected power system, in particular of synchronous generators, guarantees the instantaneous system balance. This unselective and automatic process equally decelerates (withdrawal of inertia in case of power deficit) or accelerates (storing-in of inertia in case of power surplus) all rotating masses. Due to the synchronous coupling between the rotation speed of the synchronous generators and the network frequency, this process also means a decrease or increase of network frequency. Observing network frequency hence provides direct information on the present system balance on interconnected network level and triggers further regulating interventions.
- As a stable network frequency without larger deviations from the set point of 50 Hz is a significant feature of quality of supply and substantial deviations from this set point cannot be tolerated from the technical point of view, a restoration of system balance using only inertia – anyhow limited – is not acceptable. On the contrary, this instantaneous reserve has to be replaced by additional reserves as soon as possible in order to restore system balance and to reset network frequency to its set point. Only very small deviations of network frequency of up to 10 mHz – i.e. deviations of network frequency within the range of 49.99 Hz to 50.01 Hz – are tolerable without further regulating interventions.

In addition to guaranteeing constant network frequency – and thus to maintaining the balance of power in the total synchronously interconnected area – TSOs' load-frequency control mechanisms serve an additional purpose. They also ensure on control area level that the power balance of a control area closely complies with the set points[2] which have been agreed in advance between the TSOs on the basis of accepted schedules submitted by network users. For this purpose every TSO runs its own load-frequency controller for its control area that constantly meters the power balance of the control area (by means of load flows via interconnectors) as well as the network frequency and compares these values with the appropriate set points. In case of deviations reserves can be activated in the control area responsible for a deviation in order to realign set point and actual value.

3.2 Types of control reserve

In order to realise load-frequency control, TSOs procure different qualities of control reserves which can be activated at different ramp rates and are used in successive steps over time (deployment of control reserve). The following describes the characteristics and purposes of the different reserve qualities as well as the interactions between them. Figure 3.1 gives a first overview. In addition, figure 3.2 shows the interdependencies between different qualities of reserve over time.

After a failure event *primary control reserve* (PCR) has to stabilize network frequency as fast as possible. In order to guarantee this fast reaction and to keep the share that has to be contributed by each unit as small as possible, primary control reserve is activated in a non-selective manner from the total interconnected system. Possibly arising load flows are taken into account by safety margins when cross-border network capacities are calculated.

PCR is designed as proportional regulation. Its deployment proportionally follows the deviation of network frequency from its set point. As PCR deployment is fully controlled by the network frequency, identically within the synchronously coupled area, no central control instance is necessary. In fact, deployment occurs by decentralized controllers of the participating technical units. These are basically the turbine speed controllers of power plants.

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[2] As announcing a supply of energy from control area A to control area B increases the set point of power balance in A and correspondingly decreases it in control area B. Within the total synchronous interconnection balance of power has to be compensated.

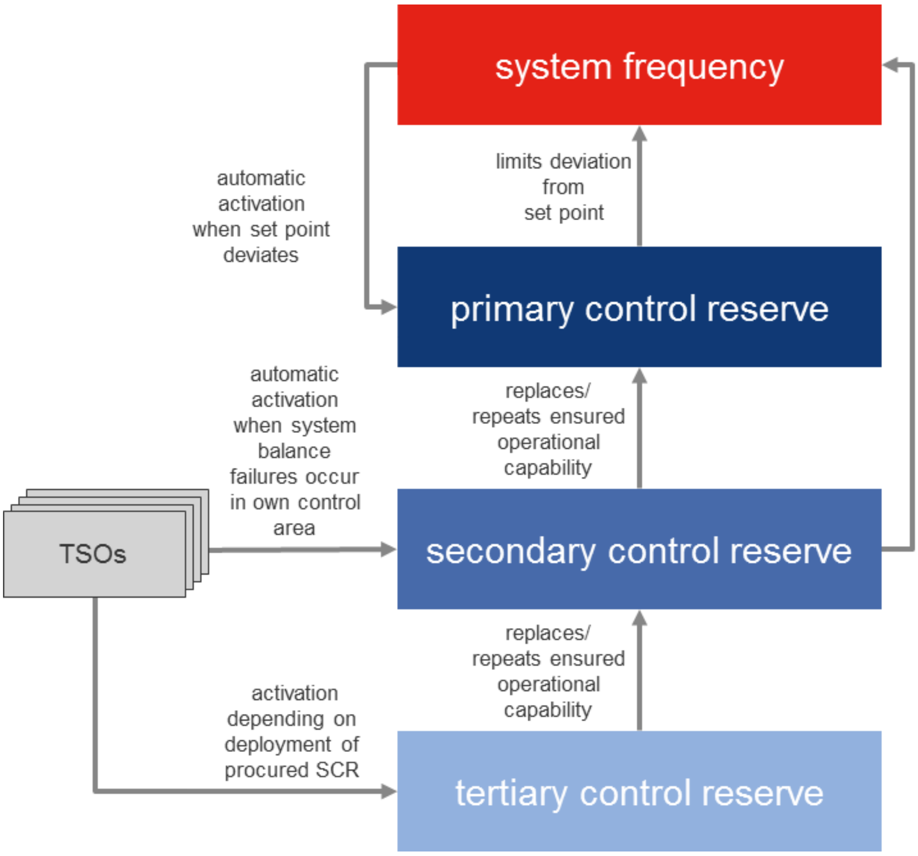

Fig. 3.1: Overview: Application and responsibilities of different qualities of reserve

The prequalification requirements in Germany provide that a complete deployment of activated primary control reserve has to be realised within 30 seconds (cf. section 4.1). Accordingly, large-scale thermal and hydro power plants providing the option of fast change of power output are possible suppliers of PCR. In thermal power plants, especially the steam storage capacity of the vessels realises this fast change of power and thus an increase of power which is limited in volume. Due to the restrained steam storage capacity this increase is only feasible within a closely restricted time period so that PCR should be substituted by other reserve qualities as fast as possible.

As PCR is a proportional regulation it is only able to balance an occurred power imbalance (e.g. caused by a power plant failure) and to stabilise system and network frequency at a new operating point. However, a steady state deviation of frequency from the set point remains. It is up to secondary control reserve to bring network frequency back to this set point (and thus to deactivate PCR, which occurs automatically due to its frequency-proportional activation characteristic).

Secondary control reserve (SCR) is – as primary control reserve (PCR) – an automatically activated control reserve. In contrast to PCR, SCR is not deployed in a nonselective manner but takes into account responsibilities for imbalances. Hence, SCR is always only activated in those control areas where system imbalances occur.[3] Accordingly, no cross-border transmission capacity has to be reserved for any potential activation of SCR. The load-frequency controller which each TSO operates in its control areas locates the system imbalance occurring in a control area and automatically activates the required reserves. This controller operating with a clock frequency of only a few seconds continuously calculates the required secondary control reserve by comparing power flows between the control area and the neighboring control areas or network frequency with the corresponding set points. Following, the controller passes a control signal to the control power plants or power plant pools which are electronically connected to the controller. TSOs may pursue different deployment strategies (e.g. proportional participation of all control power plants or minimization of deployment costs). In Germany deployment follows a socalled merit order based on costs for procured SCR.

Unlike the PCR being exclusively frequency-controlled, SCR minimizes deviations of network frequency from its set point as well as deviations of cross-control area power flows from previously agreed schedules. Implemented as socalled proportional integral (PI) controller, no steady state deviation remains as a result of secondary control. Thus, control parameters are exactly reset to their set points. For example, after a power plant failure the control area where the failure occurs will be supplied with a surplus of power until the frequency reaches its set point of 50 Hz again and PCR is completely deactivated. Only after replacing PCR which is anyhow only temporarily applicable, it will be available for further occurring failures. Consequently, deployment of SCR is a time-sensitive process with an allowed maximum lead time of five minutes in Germany.

At the same time SCR aims at reserve capacities which can be deployed not only for a short term but also for a longer time period. Typically, thermal power plants in dispatchable operation are capable of providing SCR as they can adjust their operating point within short time. If filling levels of storage basins are adequate, (pump) -storage power plants are an additional source for

[3] Deviations from this basic concept result from the cooperation in the grid control cooperation NRV, explained in section 3.3

SCR which can reach any operating point even from standstill within very short time. Optimized deployment is often provided by power plant pools so that regulation requirements can be fulfilled under the most economical conditions for the pool operators.

Owing to the high technical requirements for the units providing SCR, SCR is neither useful nor necessary to manage even longer lasting system balance failures, e.g. due to forecast errors or power plant failures.[4] Instead, this reserve demand is partly provided by socalled tertiary control reserve. Requirements to this tertiary control reserve (TCR) are accordingly lower (deployment time within 15 minutes, no continuous control signal but delivering control energy on the basis of schedules defined in 15-minute intervals). Thus, technical units having less flexibility than those used for SCR may be used for TCR, such as e.g. open-cycle gas turbines which can be fired up within a very short time. Additional sources are demand-side management resources, virtual power plants or directly marketed RES generators (particularly biomass). In contrast to SCR and PCR, TCR is not activated automatically. In fact, system-responsible TSOs activate tertiary control reserve case-by-case and depending on effective utilisation of SCR and its foreseeable development. Generally, SCR already deployed for a longer time period shall be replaced, so that the SCR band is again completely made available for a renewed deployment required within a short time. In particular cases, tertiary control reserve may be deployed in a preventive manner in order to compensate expected larger balance deviations. In Germany tertiary control reserve is electronically activated using the socalled merit-order-list Server (MOL-Server) which manages the merit-order list" (MOL) related to the offers received on the reserve market.

TSOs procure PCR, SCR and TCR as positive reserves (in order to balance deficits of system balance) as well as negative reserves (in order to balance surplus of system balance).

[4] In Germany the TSOs replace failed generation by control reserve up to one hour after a power plant failure. After that time the power plant operator is responsible for the activation of own reserves.

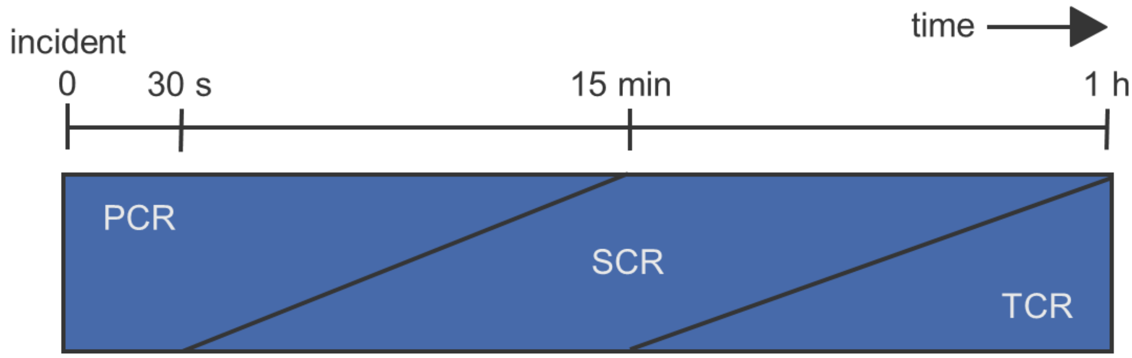

Fig. 3.2: Three-step control concept in the Continental European interconnected system

Beyond these usual reserve qualities[5] – at least in Continental Europe – which have compulsorily to be used according to the regulation on access to electricity supply (StromNZV) German TSOs may apply further measures in case of exceptional situations, e.g. if very high imbalances occur. These measures particularly include the exchange of emergency reserve with other control areas, deployment of non-operating power plants (cold reserve), and provision of specially contracted interruptible load or stock exchange transactions. Depending on their momentary availability, these additional measures are selected and deployed when required.

3.3 Grid control cooperation – national and international

According to the basic concept that SCR and TCR are deployed in the control area responsible for an imbalance, counteracting deployments of reserve may occur in neighboring control areas. For example, in one control area positive reserve could be activated in order to balance a power plant failure while at the same time negative reserve is activated in a neighboring control area in order to correct a load forecast overestimating the effective load. Alternatively, both control areas could do without any reserve deployment and could arrange instead an additional power

[5] Note that the terms of comparable products vary. Tertiary control reserve is called Minutenreserve in Germany. The draft of Network-Codes recently published by ENTSO-E concerning Load Frequency Control defines PCR as FCR (Frequency Containment Reserve), while SCR and TCR are classified as FRR (Frequency Restoration Reserve). These types of reserve differ from their deployment process (automatically activated vs. manually activated).

exchange from the control area having a surplus to that control area having a shortage of power.[6] As far as this power flow is uncritical with regard to network loading this process — depending on the costs of reserve deployment — may reduce the costs of network regulation within the total system.

In general, a cooperation with regard to control reserves is feasible in different fields and varying intensities:

- Netting of power imbalances: This kind of optimisation aims exclusively to avoid or reduce counteracting deployments of SCR. In order to net power imbalances, the demands of secondary control reserve for single control areas are detected and consecutive power exchanges are determined. This procedure allows to avoid counteracting deployments of SCR and reduces the demand for secondary control energy.
- Reciprocal support in case of SCR shortage: In this level of optimisation involved control areas shall support each other by a deliberate power exchange between the control areas in case the available control reserve in the own control area is insufficient. If the detected demand of secondary control reserve in a control area – after deducting the exchanged power by netting power imbalances - exceeds the control band of this control area in one direction, the necessary power exchange is determined so that the total of participating control areas achieve a power balance again. This optimisation level can also be applied for TCR.
- Cost-optimized deployment of SCR: This optimisation level aims at a cost-efficient deployment by using a common merit order list for SCR, filed in the optimisation system for SCR and comprising all selected bids for SCR of the involved control areas. For that purpose the demands for SCR of the involved control areas are considered in total, i.e. a counteracting deployment is also avoided. Moreover, for all involved control areas the total SCR of all participating control areas is available (allowing a reciprocal support in case of SCR shortage). This optimisation level can also be applied for TCR.
- Joint dimensioning (procedure): The deliberate and controlled power exchange in terms of temporary support with SCR or cost-optimised deployment of SCR allows for a joint

6 Such an explicit agreement of power exchange and accordingly a coherent adaptation of set points of exchange programs between load-frequency controllers are necessary because without such agreement the controllers would effectively prevent any power exchange using SCR.

dimensioning procedure of control reserve of the involved control areas. While beforehand each control area had completely to cover its own demand of control reserve, and to dimension any control reserve independently from other control areas, nowadays the total SCR and TCR can be determined, which has to be provided as a sum over all co-operating control areas. In particular, this procedure enables to take into account portfolio effects reducing the demand of control reserve in case of forecast failures, e.g. of load and intermittent RES-infeed. Consequently, a reduction of the procured control reserves and thus a cost reduction are feasible.

- Joint tendering procedure: A type of cooperation in which control reserve is partly or entirely tendered in common. As far as potential technical restrictions are observed, a bidder can procure its control reserve for any control area. Control reserve can be deployed directly by the reserve receiving TSO (TSO-BSP-model) or indirectly by the reserve connecting TSO (TSO-TSO-model).

Since there are no structural bottlenecks within the German transmission network, the German TSOs established the socalled German grid control cooperation (in German Netzregelverbund, typically abbreviated by the acronym NRV) from 2008 to 2010.

While in the initial phase only power imbalances were netted, at present the TSOs cooperatin includes cost-optimized deployment of SCR and TCR, a joint dimensioning and a joint tendering procedure for control reserve. Furthermore, a common market for control reserve has been established, where all bidders of control reserves can equally offer their products to all TSOs. The involved TSOs process the power exchanges needed therefore. Arising from this cooperation, the joint dimensioning procedure has significantly reduced the demand of control reserve and the cost-optimised deployment of SCR and TCR has significantly reduced the costs for deployed control energy in Germany.

Within the cooperation of the NRV for SCR optimization load-frequency controllers of the control areas are not replaced. Instead, the balance of cooperating control areas is coordinately controlled by correction signals so that the necessary control reserve is deployed. A central optimization module installed in the control system of TransnetBW determines the correction signals.

In the four control areas connected by the NRV hence load-frequency control acts as it would do in one single German-wide control area.

In addition to the cooperation in the NRV German TSOs cooperate with different TSOs from neighboring countries (currently: Czech Republic, Switzerland, Belgium, the Netherlands, Denmark) in the International Grid Control Cooperation (IGCC). However, at present only power imbalances are netted. From the technical point of view the IGCC is integrated in the optimization system for SCR of the NRV. The German optimization procedure, however, precedes the international one. The IGCC aims to avoid counteracting deployments of SCR — comparable with the analogous effect of the NRV within Germany — as far as transport capacities for the balance of surplus and shortage quantities across control areas are available. Resulting cost savings are distributed among the TSOs involved. As availability of transmission capacities is not guaranteed and national markets for control reserves differ in many aspects, the cooperation within the IGCC, however, cannot easily be extended in analogy to the NRV.

4 Provision and use of control reserve and control energy

StromNZV demands that control reserve and control energy have to be procured via an internet platform within a common (cross-control area) and anonymized tendering process. They have to be deployed according to the results of the tendering process based on merit-order lists. Originally, this market-based procurement has been introduced in consequence of merger conditions given by the German Federal Cartel Office.

This section gives a detailed overview relating to the precisely regulated procurement and deployment process, starting with technical pre-qualifications of the providers up to obligations of transparency about the resulting practice of publication.

4.1 Pre-qualification of suppliers

StromNZV explicitly points out that suppliers of control reserve products have to provide evidence that they are able to fulfil the technical requirements concerning the provision of different control-reserve qualities. As access conditions for the corresponding markets potential providers of control reserve have therefore to undergo a technical pre-qualification (separately for each control reserve quality).

Beside technical qualifications proper provision of control reserve under operational conditions and economic efficiency of the potential supplier have to be guaranteed. All control reserve qualities are exclusively pre-qualified by the TSO in which control area the Technical Units[7] concerned are connected, independently of the voltage level (reserve connecting TSO).

The pre-qualification process normally requires a period of two months. If on the provider side essential framework conditions related to the pre-qualification change, the supplier has to inform the reserve connecting TSO immediately. A revised pre-qualification may be required on demand.

The pre-qualification follows the minimum requirements differentiated according to control reserve quality and documented in the German Transmission Code (appendix D). A deployment of control reserve for testing purposes is absolutely required for the pre-qualification (normally two times in a row). The corresponding activation patterns for each control reserve qualification

[7] “Technical units” is the generic term for units which provide and generate control reserve. It includes both generation as well as controllable user units.

are published on the tender platform www.regelleistung.net. Fig. 4.1 shows an example of activation for positive tertiary control reserve (set point in red, actual provision in blue, 15 minutes time frame for full activation).

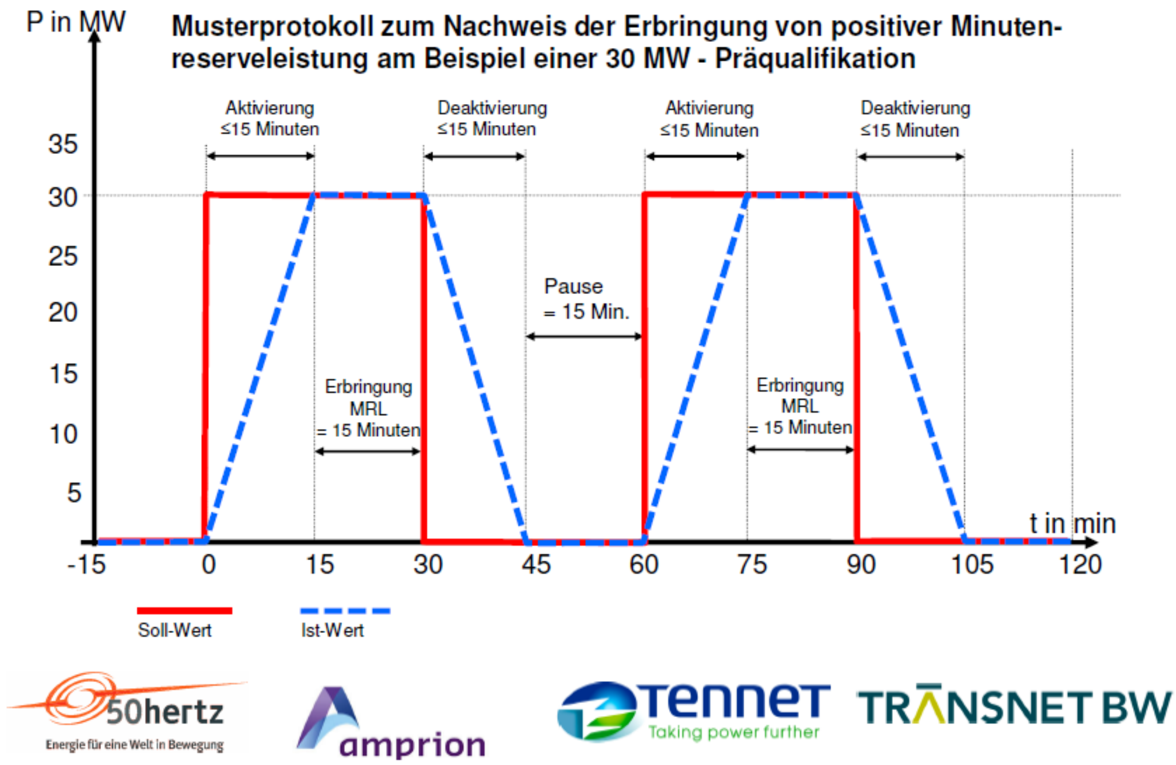

Fig. 4.1: Deployment of positive TCR for testing purposes during prequalification (source: www.regelleistung.net)

One result of the prequalification process is the power prequalified for offers. It equals the deployable power change within the activation time (PCR: 30 seconds; SCR: 5 minutes; TCR: 15 minutes). Furthermore, prequalification checks connections of control and communication facilities (e.g. with the load-frequency controller of the reserve connecting TSO) for SCR resp. with the MOL-Server for TCR) as well as organizational requisites (consent of the owner of the Technical Unit resp. of the balance responsible party).

By now, a pooling of reserves is feasible for all qualities in order to optimise provision and deployment of control reserves offered. For the different qualities of control reserve the provider has to guarantee that the total pool will be directly accessible for the reserve connecting TSO.

As soon as pre-qualified power exceeds the minimum offered quantity the reserve connecting TSO concludes a framework contract with the supplier for each quality of control reserve (model contracts published on www.regelleistung.net). The conclusion of a framework contract is a prerequisite to participate in the tendering process.

According to the list of providers published by the German TSOs currently 14 entities are pre-qualified to provide PCR, 20 entities to provide SCR and 36 entities to provide TCR. While prequalified providers for PCR and SCR mainly (but not exclusively) comprise operators of large-scale power plants, numerous large-scale consumers and local municipal utilities operating smaller generation units are pre-qualified to provide TCR.

4.2 Dimensioning control reserve

For market-based provision of required control reserve the identification of demand should be transparent. One has to distinguish between PCR on the one hand or SCR and TCR on the other hand.

According to the rules of the ENTSO-E Operation Handbook, a total PCR of 3,000 MW has to be provided in the continental European synchronously interconnected system. This rule aims at securely controlling two simultaneously occurring socalled reference incidents by applying PCR provided. A reference incident is described as the largest expected power imbalance due to only one single cause. In the present system this reference incident refers to the spontaneous failure of one of the largest operated power units in the synchronously interconnected system. Presently, large nuclear power plants with a nominal power of approx. 1,500 MW belong to these units which explains the volume of the totally demanded PCR. Furthermore, each control area has to provide a share on this totally demanded PCR which corresponds to the share of the total generation in the synchronously interconnected system. According to this calculation rule the PCR which has to be procured by each TSO is updated once a year. For 2014, the PCR demand for Germany is 568 MW.[8]

In order to dimension SCR and TCR, the specifications of ENTSO-E are less relevant. Consequently, practical dimensioning of the European TSOs significantly differs. For many years the

[8] Note: A total of 628 MW is tendered on the German internet platform (compare with section 4.3). This includes a share of 25 MW from the demand of Switzerland and 35 MW of the demand of the Netherlands.

German TSOs have been applying a probabilistic dimensioning method which enables to dimension demand of control reserve such that (at least on statistical average) procured control reserves are not sufficient to completely balance the system only in a very short time of the year (presently approx.4 h). The dimensioning process refers to the mathematical approach of convolution of probability density functions. It allows for different possible causes of failures, inter alia power plant and forecast failures, e.g. of load and intermittent RES-infeed, short-term fluctuations of load and schedule shifts. In 2008 and again in 2010 method and input data were agreed with the German regulation authority Bundesnetzagentur supported by external experts. Since then German TSOs determine the necessary provision of SCR and TCR every three months for the next quarter (in March, June, September and December). This process considers empirical data referring to a.m. relevant factors – taken from the four previous quarters.

Presently[9], the provision tendered for positive SCR is 2,042 MW and for negative SCR 1,969 MW. For TCR 2,472 MW (positive) and 2,838 MW (negative), respectively, are tendered.

As shown in fig. 4.2, the tendered volume of SCR and TCR changed significantly in recent years. Changed behavior of network users as well as structural changes of load-frequency control in Germany due to the introduction of NRV are the reason for this change of volume.

[9] This data refer to the 1st quarter of 2014.

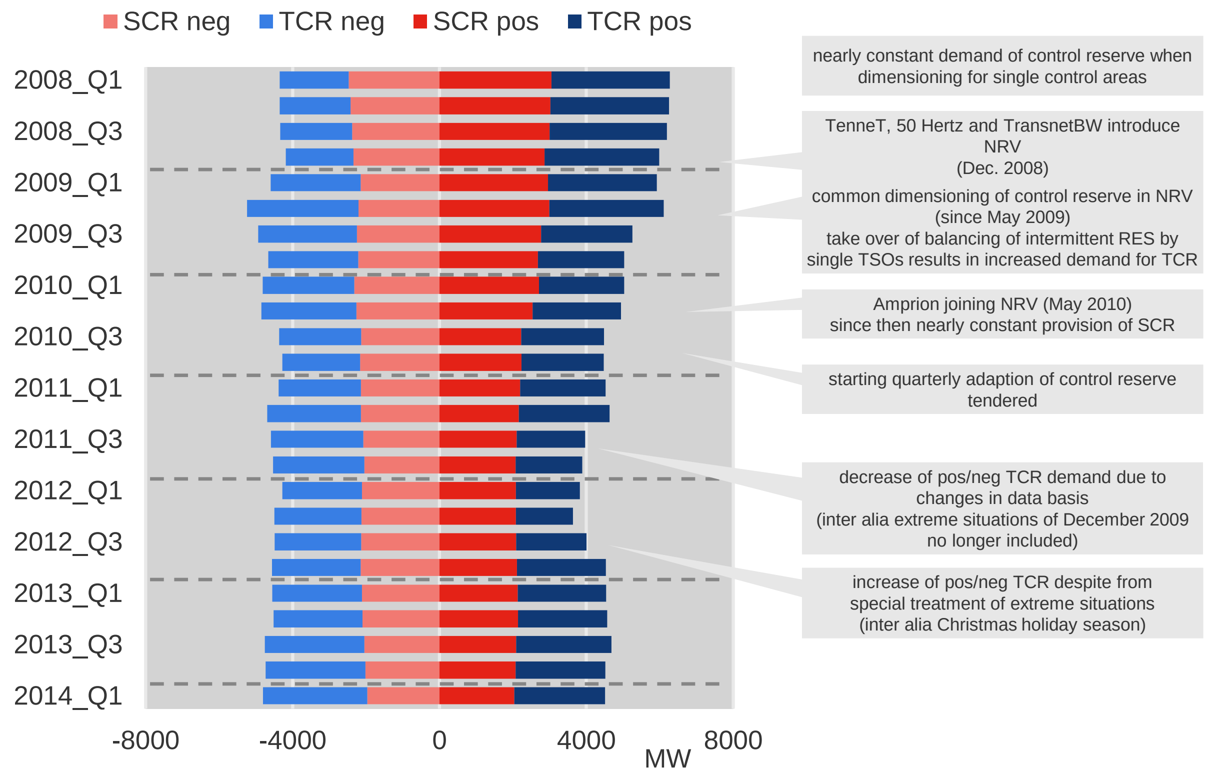

Fig. 4.2: Quarterly average values of the control reserve tendered (own research acc. to www.regelleistung.net)

4.3 Control reserve markets

Control reserve is tendered on the internet platform www.regelleistung.net which is commonly operated by the TSOs. Each bidder has its individually secured bidder’s domain at the disposal on the internet platform for the submission of offers and access to the allocation results.

The German regulator Bundesnetzagentur determines market rules and access conditions for each control-reserve quality after consulting the TSOs and bidders. The most recent determination was in 2011. Figure 4.3 gives an overview of the most significant product characteristics. The main distinguishing characteristics will be explained hereafter.

- While provision of positive and negative SCR and TCR are tendered separately, PCR is procured as a symmetrical product. Suppliers have to provide an upward resp. downward regulation related to the power offered. However, for both regulation directions, different technical units can be deployed.

	PCR	SCR	TCR
tender period	weekly	weekly	daily
tender time	as a rule on Tuesdays (W-1)	as a rule on Wednesdays (W-1)	as a rule Mo-Fri, 10 a.m.
product time-slice	none (total week)	peak: Mo-Fri, 8 a.m. to 8 p.m., without public holiday off-peak: residual period	6 x 4 blocks of hour
product differentiation	none (symmetric product)	positive / negative SCRL	positive / negative TCR
minimum bid amount	1 MW	5 MW	5 MW (submission of bid for a block of max. 25 MW possible)
increment of bid	1 MW	1 MW	1 MW
call for tender	capacity price merit-order	energy price merit-order	energy price merit-order
remuneration	pay-as-bid (capacity price)	pay-as-bid (capacity price and energy price)	pay-as-bid (capacity price and energy price)

Fig.4.3: Main product characteristics of control-reserve qualities tendered in Germany

- PCR and SCR are procured in weekly tenders, TCR in daily tenders. Furthermore, the products differ in the delivery periods. While successful offers of PCR have to be able to guarantee a provision over a weekly period, SCR is separated in two and TCR even in six time slices procured as separate products. With SCR time slices are called peak (Monday to Friday between 8 a.m. and 8 p.m.) and off-peak (remaining time periods, especially weekends and public holidays). TCR separates each day into six time-slices consisting of 4 hours. Due to a larger scale of products and shorter tendering periods, TCR is as attractive as controllable for smaller operators and controllable consumers, evident in the structure of the pre-qualified providers of the products (cf. above).

- With SCR and TCR, provision of control reserve capacity and deployed control energy are separately paid. Therefore, the bid of each supplier has to specify a capacity price bid for provided reserves (paying the provision) as well as an energy price bid for deployed reserves (paying a possible activation). However, with PCR only provision is paid, the deployed energy will not be paid separately.[10]

[10] Note that positive and negative deployments balance in a long-term average.

In general, selected bidders are selected for provided control reserve only in accordance with the merit order of capacity prices.[11] Bids for the deployment (energy price bids) are only considered in case where marginal bids have identical capacity prices.[12] All selected bidders are paid according to their individual capacity-price bid (pay-as-bid).

Referring to the tender of control reserve some special characteristics have to be considered:

- In general and in accordance with the German regulator Bundesnetzagentur, TSOs may define a minimum share of reserves (in German: Kernanteil) which have to be kept inside each control area, i.e. a minimum of provision within this control area. Such minimum share may be responsible for bids for the provision of control reserves within a control area being considered as a matter of priority up to the amount of the minimum share regardless of the bidding price. Currently, however, such minimum shares are not required.
- Since March 2012 the Swiss TSO Swissgrid participates as fifth TSO in the common PCR-tender of the German TSOs on the platform www.regelleistung.net. This common tender is in accordance with the German market rules, thus presently procuring 25 MW of the Swiss PCR demand. Swissgrid is the Reserve Connecting TSO for the Swiss bidders. Similarly, since January 2014 the Dutch TSO Tennet BV participates as sixth TSO in the common PCR-tender procuring 35 MW of the Dutch demand with Tennet BV as Reserve Connecting TSO for Dutch bidders. The common tender is open for German bidders as well as for the pre-qualified Swiss and Dutch bidders of PCR.[13]

The following figures give an overview of how the capacity prices developed for the control reserve qualities PCR, SCR and TCR from 2008 to 2013.[14]

[11] Only in case of equal capacity prices for marginal offers the energy price will be considered.

[12] Suppliers may and will consider expected revenues in the capacity price bid.

[13] Due to this regulation 5 Swiss and 3 Dutch power plant operators are presently pre-qualified to provide PCR in Germany.

[14] For each auction the bid price is averaged for all accepted bids, then averaging this average value over a period of one year (average capacity price)

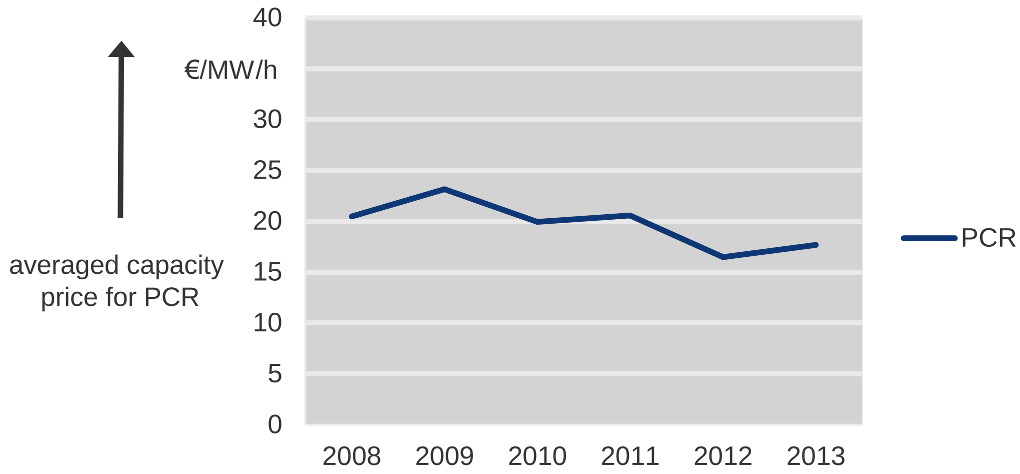

Fig. 4.4 Development of averaged capacity price of accepted bids for PCR (data base: www.regelleistung.net)

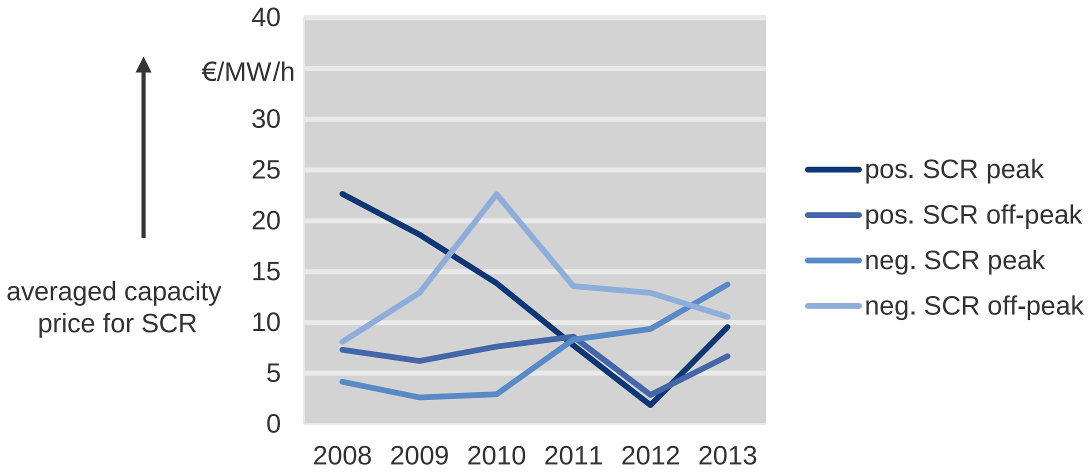

Fig. 4.5 Development of averaged capacity price of accepted bids for SCR (data base: www.regelleistung.net)

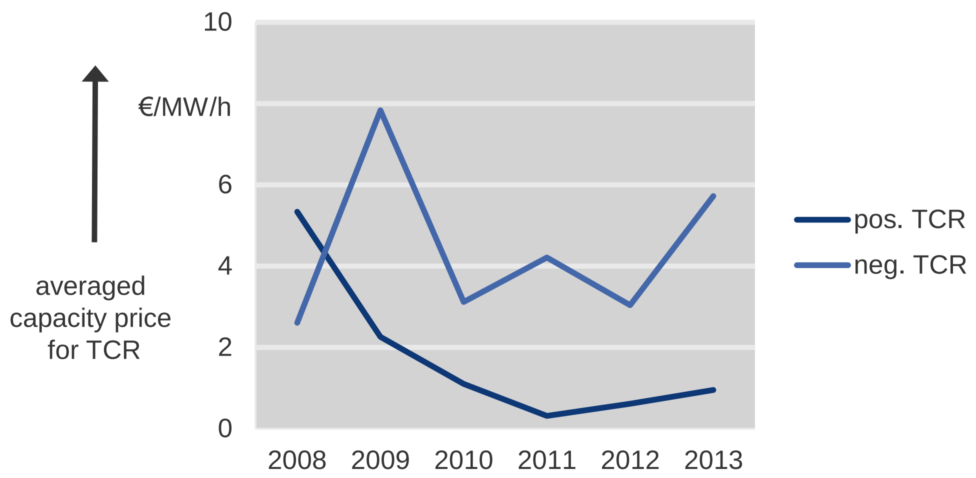

Fig. 4.6 Development of averaged capacity price of accepted bids for TCR (averaging over all product time-slices, data base: www.regelleistung.net)

Considerable price fluctuations over time can be recognised. On the other hand, there is a tendency of decreasing prices being of different degrees for the various products. Latter development can be explained due to the significant increase of intensive competition on the markets of control reserves, and on the other hand due to the general development of electricity price within this time period.[15]

However, the partly considerable fluctuations prove that price development on the markets for control reserves run in a more volatile and less fundamental manner than on energy spot markets.

4.4 Use of control reserve

At any time during operation control reserve is exclusively activated for bidders which capacity bid for providing control reserve was accepted according to the process described in the previous section.

[15] In principle it must be assumed that with decreasing electricity prices at least prices for providing positive control reserve will decrease, as opportunity costs for not offering these reserves on spot markets will decrease, too.

There is no central activation for PCR, rather the existing technical units provide PCR according to the network frequency locally metered. TSOs are allowed to require – as proof of provision – the actual values which the participating technical units fed in over time.

SCR is automatically activated by the power-frequency controller which considers deviations of power exchange as well as frequency from the corresponding set points. According to the merit order for activated control energy[16] bids are activated, with the German NRV guaranteeing an all-German merit order independently from power plants connected to the controller.[17] This selection helps to minimize the costs of deployment related to the required control energy of each type of control reserve. In order to verify the effective provision, TSOs are entitled to request various information, such as actual values of feed-in and of the provided SCR by the participating technical units over time. The bidders have to provide them online.

As far as it is useful and necessary for operational reasons, TSOs will activate TCR. In particular, TCR is activated in case of foreseeable longer lasting failures of system balance to replace the more valuable SCR which can be activated at short notice. Thus, the complete secondary control range will be available again which can then control further shortly occurring failures of system balance. The decision between SCR and TCR activation is not based on economic criteria. TCR bids to be deployed, however, are activated by means of all-German merit order of the energy price bid in order to minimize the costs of TCR deployment.

With TCR deviations from merit order may be necessary, e.g. if bidders have cancelled TCR or if provision of deployed TCR would cause network congestion at a certain point in the network (cf. § 7 StromNZV). Since in the middle of 2012 TCR has no longer been deployed by telephone as before but electronically using the socalled merit-order-list-server (MOL-Server or MOLS). TCR is activated via schedules. This means that in case TCR is demanded the balance group of the bidder and the TCR balance-group of the reserve connecting TSO arrange an adequate schedule. In this process activations have to occur 7.5 minutes before the start of the

[16] Note that especially for the deployment of negative SCR and TCR bids indicating negative prices (delivery direction of power and cash flow having same direction) are permitted and usual.

[17] Only in exceptional cases deviations from the German-wide merit-order can occur. In case of network congestions within Germany individual TSOs may limit their participation in the NRV such that – regardless the German-wide merit-order – SCR is preferably deployed within the own control area. Failures in control technology in the NRV or occurrences such as deployments for testing purposes can also cause deviations from the merit order. The deviations are documented by the TSOs (cf. section. 4.7).

schedule at the latest. Deviations of demanded and provided TCR result in balancing energy demand of the provider. In addition, bidders are obliged to prove the TSOs on request that demanded TCR was effectively deployed. Furthermore, TSO may check the provision by means of testing.

A further important element in understanding the way how control reserve is used is that contributions of control reserve deployed within a balancing period of 15 minutes do not necessarily have the same sign for various reasons:

- The demand of SCR shows high volatility often changing the sign also within a quarter of an hour or even within single minutes so that within the same quarter of an hour positive and negative secondary control energy is deployed. Moreover, command signal and real provision of SCR may differ due to inevitable inertia of the technical units providing SCR. In particular, when sign of reserved demand changes, e.g. positive SCR e.g. may be requested as command signal but at the same time negative SCR may still be delivered or positive and negative SCR may be delivered even at the same time.
- In relation to the demand of SCR TCR is deployed naturally time-delayed and with slower ramp up and down rates. Therefore, it is not able to respond to all fluctuations (and signs) arising in SCR. Thus deployments of both qualities of control energy may even have opposite signs within a quarter of an hour.

4.5 Accounting and payment flow between bidders and TSOs

As described in section 4.3, remuneration based on capacity prices is paid for control qualities of PCR, SCR and TCR, moreover for control qualities of SCR and TCR a remuneration based on energy price is paid for the actual used control energy. The TSO always pays a remuneration for provided control reserve to the bidder. Remuneration for deployed control energy may be a payment from the TSO to the bidder or even vice versa for a taken bid depending on the sign of control energy demand or of the energy price.

Remuneration of provided control reserves and of deployed control energy is accounted considering the following principles:

- The volumes to be accounted determine the level of remuneration (i.e. capacity provided resp. energy delivered) as well as the prices the bidders indicate for each bid (pay-as-bid).

- Remunerations are accounted for each delivery month, namely in the first weeks of the following month. For the provision of control reserve remuneration for bids which refer to a delivery period going beyond the end of the month, is divided accordingly and matched to the relevant months.
- Accounting is performed by the TSOs, irrespective of whether the TSO pays the bidder (i.e. a credit note from the TSOs-side perspective) or whether the bidder pays the TSOs (i.e. an invoice from the TSOs-side perspective. The TSOs send the accounting as a draft to the bidders who will verify and settle it if needed before the respective payment is executed.
- Each TSO accounts for the procured control reserve and the deployed control energy with the bidders whose technical units providing control energy are connected at the TSO's control area, independently where a certain volume of control energy is requested. The TSOs call this assignment "reserve connecting TSO principle". Each technical unit refers to exactly one TSO responsible for the accounting. Hereby, compensation payments are needed for procured reserves as well as for deployed control energy within the group of TSOs (cf. section 4.6).

Remunerating the provision of control reserves for qualities of PCR, SCR and TCR the quantities to be settled (i.e. provided control reserves) result directly from the accepted bids in the tenders for control reserve. These quantities may only be corrected in exceptional cases if bidders sign out after the time of assignment, due to e.g. technical unavailability.

The energy volumes relevant to the remuneration of deployed control energy of the qualities of SCR and TCR are calculated separately for each bid of each bidder and for each quarter of an hour related to the delivery month. Then they are summed up to monthly accounting amounts after being multiplied with the corresponding bid prices. The single amounts and thus the monthly sums may be positive or negative depending on the sign of control energy and of the bid prices and thus payments between TSOs and bidders in different directions. (cf. above).

Volumes of control energy being relevant to settlement are already determined during a delivery month at the working days after a closed delivery day and coordinated between TSO and bidders. SCR and TCR have different approaches:

- SCR works with a clock rate of one or a few seconds. During each clock interval the control signals are updated and transferred to the connected control devices. The set points of the

SCR are filed in the control systems of the TSOs. Furthermore, the bidders inform the control systems about the real values of the secondary control energy provided. This value results from the actual measurement of power provided by units connected to the regulation and the scheduled values for the deployed units. The actual data are also filed in the control system.

For each delivery day set points and actual values are subsequently calculated every 15 minutes taken from the filed data provided and transferred to the bidders for checking purposes. In this process exactly one set point and one actual value are determined for each bidder and every 15 minutes interval each for positive and negative control energy, even if several bids of the same bidder were selected within that quarter of an hour. When settling, energy values are distributed to variously deployed bids of the bidder according to the merit order of the energy prices.

After potential corrections are clarified and realized the volumes to be settled are determined based on set points and actual values. The general principle is that TSOs select those values from set points and actual values in each quarter of an hour which lead to lowest costs and highest revenues for the TSOs. For example, when applying positive SCR bidding positive prices the lower of both values is taken (set points and actual). If the bidder feeds-in more control energy than required (i.e. actual value is higher than set point) the excessive volume is not remunerated. If the bidder feeds in less energy than required (i.e. the actual value is lower than the set point) only the actual value is remunerated. Negative control energy and (especially for this case relevant) differentiation regarding the sign of bidding prices are respectively considered.

- Unlike SCR, TCR provision is not metered separately so that the actual deployment cannot separately be recorded. On the contrary, TCR is taken into consideration in the balancing system by generating a 15-minute exchange schedule for each deployment between the balance responsible party of the TCR bidder and the TCR balance group of the TSO. If the bidder provides TCR exactly as required and thus according to the generated schedule, the schedule will balance any changes – related to provision – of generation and consumed metering values of the bidder. If – however – deviations occur, these will automatically be determined within the scope of the accounting of the balancing party and treated as balance energy which the bidder has made use of.

For accounting TCR volumes, the quarter-hourly values of the operating schedule which the MOL-server of the TSOs transfers to the bidder are decisive.

4.6 Accounting and payment flow among TSOs

The cooperation of the TSOs in the German NRV and the IGCC effects that the distribution of provision and the application of control reserve resp. control energy in the control areas generally differ from the distribution of activations. In order to enable still a cost-accounting with reference to responsibilities or origins for imbalances, there is a need for compensation payments between the TSOs.

For this purpose German TSOs coordinate a mutual accounting – considering the different remuneration components – for each delivery month during the month following. In this connection a desired distribution is determined which – according to a previously agreed key – allocates costs incurred by one of these components to the control areas. The desired costs of each TSO are compared with the actual costs which arise – due to the ”Reserve Connecting TSO-principle” – from the accountings between the TSO and the bidders of control reserve in its control area. This comparison results in compensation payments each TSO has to settle or to receive.

For calculating desired cost levels for reserve capacity (PCR, SCR and TCR), from 2014 on total reserve capacity costs are distributed among TSOs according to the cost allocation formula that is also used for cost balancing of the surcharge for combined heat and power units (in German: KWK Umlage) and which is reflecting the control areas' shares in total electricity consumption. The actual costs result from bidder-accounting of the TSOs for the provision of control reserve.

As regards costs of the deployment of control energy (SCR and TCR), the desired costs of a TSO for each quarter of an hour result from the balance of its control area (in German: Regelzonensaldo) – representing the total demand of balancing energy in the control area – and the balancing price calculated for the respective quarter of an hour. On the one hand, the actual costs include costs and revenues resulting from bidder accounting for the use of control reserve. On the other hand they comprise costs/revenues resulting from compensation payments within the scope of IGCC.

The cooperation in the IGCC reduces the costs for the use of control energy in the total cooperation area because

- as a general rule costs for the deployment of positive SCR are significantly higher than the revenues for the deployment of negative SCR[18] and
- it is more cost-efficient from the perspective of the total system to avoid the activation of counteracting reserves.

Due to significantly different price systems for control energy this cost-efficiency does not automatically divide into the cooperating partners in a way that is considered as fair and provides sufficient incentives to participate in the cooperation. When introducing the IGCC a price system was established determining how the participating TSOs would account deliveries to and from the IGCC. The settlement price being the same for all IGCC deliveries during a quarter of an hour and is calculated as a volume weighted price based on saved costs (less deployment of positive SCR) and on saved revenues (less deployment of negative SCR) of the cooperating partners. It is determined in a way that as many partners as possible benefit from the IGCC-cooperation. The settlement price of the IGCC and the settlement of the IGCC deliveries are monthly determined ex post based on this price and the correction signals calculated by the IGCC-module.

Besides the costs and revenues components mentioned before, the accounting of compensation payments between the German TSOs has recently also concerned an additional position. As a consequence of the price mechanisms introduced in December 2012 additional revenues could arise to the TSOs when accounting balancing energy to the balance responsible parties (cf. section 5.2). These revenues determined by minimum and maximum prices as well as price supplements and reductions are distributed to the TSOs according their shares of the total provision costs of the qualities of control reserve SCR and TCR. Differences between set and actual distribution of these revenues are balanced by compensation payments. According to the specifications of the German regulator Bundesnetzagentur the TSO first settles the resulting amounts of these revenues with its share to the costs of provided control reserve. Then the costs are taken into consideration when calculating network tariffs.

[18] In case of negative prices even costs may occur.

4.7 Transparency requirements

Due to different reasons (inter alia: reducing barriers for market entries and competition intensity in the control energy markets, possibility to assess comprehensively the situation on the wholesale energy-markets, tracing of balancing energy prices) tenders, provision and utilisation of control energy shall be as transparent as possible.

Appropriate guidelines affect the StromNZV (§9) as well as the decrees of the German regulator Bundesnetzagentur of 2011 on market rules for the different qualities of control energy.[19] Various information are required to be published on www.regelleistung.net. Such as

- for PCR
  - exact demand for Germany and participating TSOs from abroad,
  - anonymized list of selected bids for PCR (incl. offered power and price),
  - averaged-weighted capacity price and marginal price,
- for SRL
  - exact demand for each product and control area, incl. minimum control-area internal shares (Kernanteile), if applicable,
  - anonymized list of selected bids for SCR (incl. offered power, bid of capacity price and bid of energy price) and indicating bids which were accepted only due to control-area internal shares,
  - averaged-weighted capacity price and marginal price for each product,
  - time series of 15 minutes of deployed secondary control energy (separated for positive and negative SCR) for the total German NRV and differentiating between the providing control areas
  - indicating and justifying any period of deviation from merit order,
- for TCR
  - exact demand for each product, incl. minimum control-area internal shares, if applicable,

[19] procedure BK6-10-097, BK6-10-098, BK6-10-099

- anonymized list of all TCR bids (incl. offered service, bid of capacity price and bid of energy price and acceptance status of the bid) indicating bids which were accepted only due to control-area internal shares,
- averaged-weighted capacity price and marginal price for each product and all time slices
- time series of 15 minutes of deployed TCR (separated for positive and negative TCR) and differentiating between the providing control areas
- indicating and justifying any period of deviation from merit order.

In addition, on time series of 15 minutes also the balance for all four control areas and for the complete German NRV[20] as well as the names of pre-qualified bidders shall be published for all reserve qualities on www.regelleistung.net.

The data needed to fulfill the requirements of transparency are completely available on regelleistung.net. Among them are available:

- lists of pre-qualified bidders to be found under the menu item "Control reserve",
- information concerning the demand on single reserve qualities and the tender results to be found under the menu item „Tender details" and
- information concerning deployed control energy, control areas resp. NRV balances and deviations from merit order to be found under the menu item "Datacenter". Here additional information are published relating to the exchange within the scope of IGCC as well as on balancing periods with a deployment of more than 80% of contracted reserves (a threshold which is relevant for the balancing price system, cf. section 5.2). Note that due to short periods of publication some data only show operational characteristics and are thus not quality assured. They could be corrected within further accounting and data processing.

Beyond the data published on www.regelleistung.net, deployed control reserve energy has to be available for bidders and potential bidders as a high resolution (i.e. few seconds) time-series over a period of at least 12 months. Adequate provision can be found on the website of the German TSOs.

[20] Due to the definition of BK6-12-024 that relates to the further developed price system of balance energy since 1 December 2012, TSOs have had to publish the balance of the NRV at the latest 15 minutes after the accounting interval is closed.

5 Determination and settlement of balancing energy

5.1 Determination and settlement of the amounts of balancing energy

As described in section 2.2, the TSOs are responsible for determining and settling the amounts of balancing energy taken by the BRPs operating in their respective control areas. The required information exchange, the obligation to cooperate and the deadlines to be observed for this settlement process – in German called “Bilanzkreisabrechnung” – are regulated by the markets rules established by a decree called “MaBiS” of the German regulator Bundesnetzagentur. The process includes the following essential steps before and after the date of delivery:

- The BRPs operating in a control area inform the TSO — who in this context serves as the socalled “balancing coordinator” (in German “BIKO”) — before the delivery about schedules of all planned exchange transactions between balance groups within the control area as well as across the control area boundaries. These schedules are provided electronically in automated processes. After the time of delivery, the balance responsible parties of an individual control area may still inform the TSO about agreed changes of the schedules on the following day until 4 p.m.
- All network operators (transmission and distribution network operators) within one control area determine the 15-minute time series of the metering values of generation and load units connected to their networks, as well as the standardised load profiles needed to account for the consumption of small customers in the settlement process. The network operators sum up these values for each BRP, distinguishing between different kinds of generation and consumption. The resulting data are submitted to the BIKO who in turn forward them to the BRPs and calculate the total balancing energy time series for each individual BRP. This data provision and settlement process is carried out for each delivery month. Reconciliation of the energy balances per ¼ hour for each individual balance group between each network operator and the BRP has to be closed no later than the 29th working day after the delivery month. The data available to the TSOs at that time are, according to market rules, the relevant basis used for settlement of balancing energy. The settlement has to be prepared by the BIKOs no later than the 42th working day after the delivery month.
- Subsequent to this milestone, network operators and/or BRPs may still submit corrected data to the BIKO if corrections turn out to be necessary. To take account of such corrections,

a second run of the settlement process based on corrected data is carried out eight months after the delivery month. Deadlines for data exchange and clearing for this second run are also fixed with the MaBiS.

- The TSOs have to determine the imbalance prices which are needed for the settlement of balancing energy at the latest on the 20^{th} working day after the delivery month – i.e. already before the reconciliation of the balancing energy data for the settlement has been completed. The balancing energy prices have to be published and electronically transferred to each BRP.

Similarly to the process for settling control reserve power and energy with the providers of control reserves, it is always the TSO to issue the invoices for balancing energy to the BRPs, irrespective of whether an invoice results in a payment from the TSO to a BRP, or vice-versa.

5.2 Determination of the imbalance price reBAP

Balancing energy is settled in line with the guidelines of StromNZV using symmetric imbalance prices for each 15-minute time period. The imbalance price deployed for an accounting period of 15 minutes is therefore used likewise for offtake of balancing energy out of the system by a balance group having a shortage of energy (i.e. positive balancing energy) and for feed-in of balancing energy into the system by a balance group having a surplus of energy (i.e. negative balancing energy). Moreover, this symmetric imbalance price indicated in EURO per MWh has been determined as a single uniform price for the whole of Germany since the NRV had been introduced. It is called “reBAP” as an acronym for the German expression “regelzonenüber-greifender einheitlicher Bilanzausgleichsenergiepreis”.

The reBAP is determined in principle by dividing the control energy costs arising in a specific quarter of an hour by the balance of the deployed amount of control energy in that same time interval. Since control energy costs can be either positive or negative, the reBAP can also be positive or negative. A positive reBAP means that the BRPs pay the TSO for the balancing energy offtaken from the system (i.e. in case of shortage of their balance group), and that they are paid by the TSO for the balancing energy fed into the system (i.e. surplus of their balance group). If the reBAP is negative, the payment flows are in the opposite directions. Table Table 5.1 summarises these effects for the four possible combinations of signs of the BRP imbalance and of the reBAP.

balance of the balance group	*offtake/feed-in of balancing energy*	*sign of reBAP*	*financial effect for BRP*
shortage	offtake	positive	invoice
shortage	offtake	negative	credit
surplus	feed-in	positive	credit
surplus	feed-in	negative	invoice

Table 5.1: Financial effects of utilising balancing energy, depending on the signs of the balance of the balance group and the reBAP

Deviating from the basic calculation method of the reBAP explained so far, different mechanism were introduced by decisions of Bundesnetzagentur in recent years that have to be applied by TSOs to adapt the reBAP under specific circumstances:

- The reBAP is generally limited to the highest price of the activated control energy bids within the respective ¼ hour interval in order to avoid price peaks which would occur especially when the required amount of control energy is very small (due to dividing the costs by a very small quantity of control energy).
- Since December 2012, a price reference taken from the intra-day market of the power exchange EEX has been taken into consideration as a lower or upper bound for reBAP (depending on the sign of the balancing quantity) in order to eliminate potential incentives to BRPs to utilise balancing energy intentionally for optimising their energy procurement.
- Also in December 2012, a further regulation was introduced: In case that 80% or more of the total positive (or negative) SCR and TCR capacity is utilized for balancing the system, a surcharge (or a deduction) is applied to the reBAP in order to provide an incentive to BRPs to better balance their balance groups and thus to avoid such situations in the future.

Since these mechanisms of price adaptation only impact the price in a small part of the 15 minute accounting periods, control-energy costs and quantities primarily determine the reBAP.

However, there is no simple correlation between these entities, such that for instance the specific (quantity related) control-energy costs monotonously increase with the control-energy quantity (or decrease if negative). Rather, prices are influenced strongly by the fact that the control reserve qualities SCR and TCR are procured on the basis of independent bidding markets and thus having strongly differing price structures. These two control reserve qualities, as described in section 4.4, may simultaneously be deployed with opposite signs. Therefore, control reserve costs may be high even if control energy demand is low, or they may be subject to fluctuations even in periods during which control energy demand is relatively constant, because the allocation to SCR and TCR may change. Thus, the level of the reBAP and its timely development can only be explained if costs as well as amounts of both SCR and TCR control energy are considered and possible additional measures taken for balance compensation are taken into account.

As an example, Fig. 5.1 visualises the correlation between reBAP and the demand for balancing energy in the German NRV for the ¼ hour intervals in the period from January to March 2012. The diagram shows that the spread of this correlation is quite significant. (Note: In this time period, the second and the third of the aforementioned price adapation mechanisms had not yet been introduced.)

The price adaptation mechanisms described above have the effect that the balance of payments between TSOs and BRPs for balancing energy do not exactly coincide with the control-energy costs in each ¼ hour. Since December 2012, these deviations between payments and cost have been taken into account in the determination of TSOs‘ network costs in the context of calculating the tariffs for use of the transmission system. Previously, those deviations were only caused by the first of the three mechanisms described (price cap). They were called non-transferable costs, and were taken into account by a uniform surcharge or deduction to the reBAP values for all ¼ hour intervals within the respective settlement month.

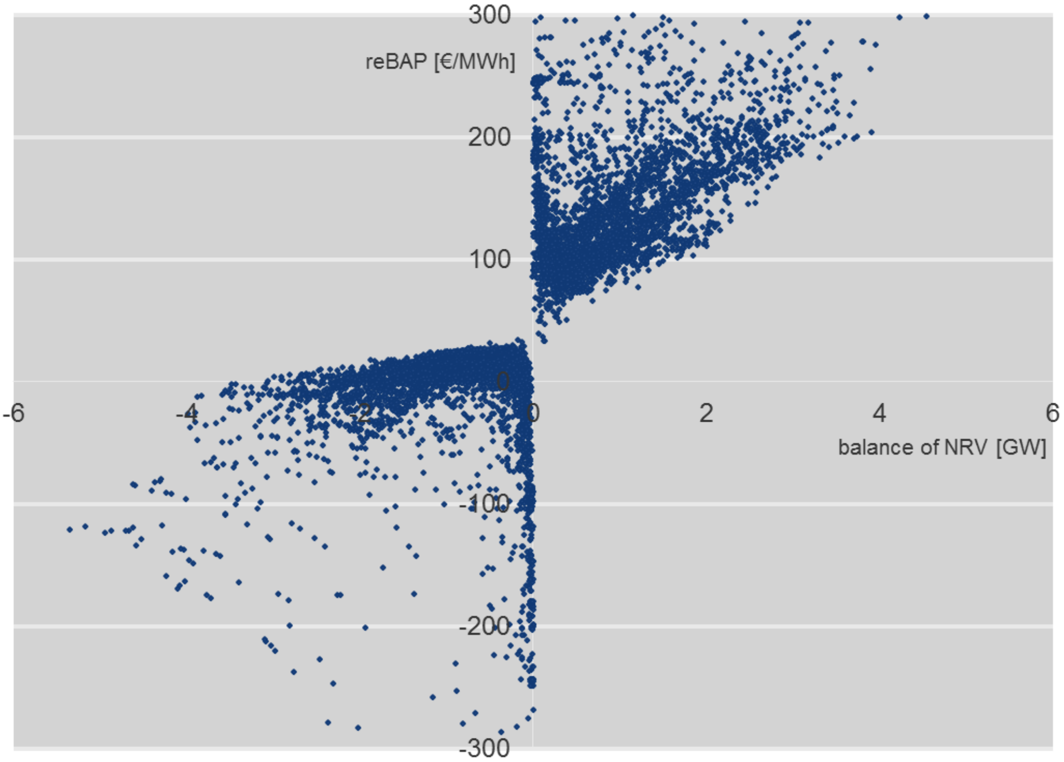

Fig. 5.1: Correlation of the balancing energy price reBAP with the balance of the German NRV in the first quarter of 2012; each dot represents the data for 15 minutes

The reBAP calculation process works such that the four TSOs provide each other with full information concerning the resulting costs/revenues and the deployed quantities of control energy that result from the settlement process between TSOs and the providers of control energy (and the contracting parties for any additional measures). Together with data on the IGCC settlement (which is also exchanged among TSOs) plus data from further sources (e.g. peak prices of control energy bids deployed in 15-minute time series), each TSO is able to calculate the reBAP for the respective month. The TSOs have agreed that one of them is in charge officially for the calculation, and the other three ones compare the calculation results with those results they have obtained themselves. After having agreed, as far as necessary, on required corrections, each TSO publishes the reBAP data for the delivery month via the internet. Demand for such correction occurs very seldom in practice. It can for example be caused by changes in the calculation methods or data exchange practice.

The principles of quality assurance inherent to this process help to ensure that the reBAP values are determined and checked by all 4 TSOs based on identical sets of data. Experience has shown, however, that the input data for this calculation occasionally have to be modified ex post, e.g. due to mistakes in the IGCC settlement process that are detected after the reBAP values have already been published. The German TSOs have agreed with the regulator Bundesnetzagentur that even in such cases, the reBAP values are not adapted any more after having been published. Rather, the cost differences caused by such mistakes shall be taken into account in the reBAP calculation for the subsequent month after the mistakes have been detected. This is done by calculating a uniform surcharge or discount on reBAP throughout the respective month (analogously to the way in which “non-transferable cost” have been treated prior to December 2012; see above). If the cost differences exceed a limit of 3% of the control energy cost in the subsequent month, or if the surcharge or discount would be higher than 3 EURO/MWh, the surcharge or discount is capped to respect these limits, and the remaining cost difference is taken into account in the reBAP calculation of further subsequent months.

This additional mechanism for price correction that has been introduced by 1st October 2013, as well as further details of the reBAP calculation method explained above, are laid down in a document agreed by the TSOs and Bundesnetzagentur that has been published by the TSOs on the internet platform www.regelleistung.net.

5.3 Effects on cost allocation and principle of solidarity

As described in section 2.1, the concept of load-frequency control performed by the TSOs in contrast to a theoretically possible decentralized control approach is suited to provide considerable savings for all network users because it does not require feed-in and consumption of all network users to be measured in real time, and it minimises demand of control reserve by making optimal use of portfolio effects. Each individual BRP has to pay only for a small portion of the control-energy costs that would arise if it had to balance its balance group based on own control mechanisms and resources.

Although balancing energy price is often considerably higher than the prices on electricity markets (e.g. the power exchange markets), costs and revenues of the individual BRP compensate over time as the demand for balancing energy frequently changes direction. Over the long term, each BRP bears a share of TSOs’ control energy costs. The level of this share strongly depends on how the balancing energy demand by the individual balance party statistically correlates with the total balancing energy demand of all balance parties. Fluctuations – by pure chance – which do not systematically correlate to the demand fluctuations in the total system do not – on average – cause considerable balancing energy costs.

This concept of sharing control energy costs in a manner of solidarity among BRPs requires all parties to accept that the share of costs allocated to one balance party does not only depend on its own balancing energy demand, but also on the balancing energy demand of other balance groups. For example, the balancing energy price for a balance group having an energy shortage in a given ¼ hour may be below or above the price on the electricity market, depending on whether the collective of all balance groups has a shortage or a surplus of energy in that period. Moreover, the balancing energy price tends to be linked to the total demand of balancing energy of all balance groups owing to the merit order of bids for control energy.

This concept is essentially characterized by the fact that in principle, the reasons of balancing energy demand arising in each balance group do not affect the settlement of balancing energy. Notwithstanding the requirement that each BRP obliged to manage, as far as possible, the balance of its balance group in each quarter of an hour, it is accepted that a demand of balancing energy arises to a certain extent and that the quantity of balancing energy demand is decisive as a basis for settlement. The reasons for the individual deviations, as well as the factors impacting the level of the deviations, such as quality of forecasts, intensity of information exchange between BRPs and consumers as well as the quality of measures taken for short-term balance, are not taken into consideration.

Only if the BRPs use balancing energy in an unacceptably extensive manner, they may be sanctioned according to the balance group contract. However, a BRP is not generally obliged to justify the demanded quantity of balancing energy. Only if the TSOs identify significant imbalances, they will attempt to clarify with the respective BRP what could have been done by them to avoid the high level of imbalances.

5.4 Transparency requirements

In addition to the transparency requirements to TSOs' described in section 4.7, requirements for publication of information in the context of balancing energy settlement basically concern the publication of reBAP values. Information concerning balancing energy demand of individual balance groups is treated as confidential and is therefore not published.