D4.1 Flexibility within the electrical systems through demand side response: introduction to balancing products and markets in Germany, France, and the UK

Update report D4.12

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Contents

1 Introduction

In order to ensure the reliability and the quality of supply within electrical systems, the operation of electrical networks requires an exact balancing of electrical flows: the demand has to match the generation at anytime. This ideal situation is managed by scheduling electricity generation for dispatchable units and by forecasting both end users' consumption and the generation of renewable energy systems (RES), usually one day, some hours, or some minutes before the delivery. Nevertheless, external factors such as meteorological events, failures and other events (including forecasting residual errors) can lead to unbalances. Those physical unbalances must be immediately compensated to ensure the stable and reliable operation of the electrical system. Within Europe, this task is given to the Transmission System Operators (TSOs) who are explicitly responsible for the physical balance of the grid. To be able to restore the balance between consumption and generation flows at any time, flexibility means are required and secured in advance through bilateral reserve contracts between operators of assets (either at the generation or at consumption side) and the Transmission System Operator. These contracts are remunerated by the TSOs, often for both availability and utilization of assets and hence enable operators of assets to monetize their flexibility with regards to the systemic needs of the electrical network they are connected to.

In the context of the project H2 Mobility Europe, these contracts are of interest, as buffer storage installed at electrolytic hydrogen refuelling stations can enable flexible operation of electrolysers for hydrogen supply. Smart operation strategies make it possible to decouple the hydrogen generation profile from the hydrogen end user consumption profile and hence monetize flexibility by providing balancing services to the electrical system. The revenues of such contracts is expected to decrease the net production cost of hydrogen.

In the long term, electrolysers, operated as flexible loads, could significantly contribute to the balancing of the grid as the share of conventional dispatchable generation is replaced by more and more non-dispatchable generation (such as renewables). Moreover, operation of electrolysers in frequency responsive modes can counterbalance the introduction of increasing power electronic driven loads (e.g. solar PV systems) which reduce the overall electricity system inertia.

In both cases, HRS-electrolysers, adequately operated as flexibility means, could play a significant role and enable efficient and virtuous synergies between mobility and electricity sectors, contributing to decarbonizing both. The modelling work performed within the WP4 of the H2ME project aims to assess the possible contribution of HRS with onsite electrolysers to the flexibility needs of electrical systems with different configurations (UK, FR, DE) with a prospective and integrated vision of the electricity and mobility sectors.

This report summarizes the inputs related to flexibility markets gathered within the Work Package 4 "Electrolysers in advanced grid operations" of the European funded H2-Mobility Europe project.

Warning notice:

The European electricity sector is changing quickly. Electricity generation mixes and regulation have undergone significant changes over the past years and may continue to do so. The Generation mix is impacted by environmental policies at the national and the European level while market rules and design are continually adapting to the changes to the electrical system, and also under the influence of collaborative pan European organizations (ENTSO-E, ACER) in order to develop competition and non-discriminatory access within and to the concerned markets at European level. This report summarizes information publicly available in August 2019.

2 Balancing products in Germany

The German electrical transmission system consists of four control areas operated by four different TSOs, responsible for the physical balance of the electrical flows within their control areas.

In order to keep the total requirements for control reserves as low as possible, close cooperation between German TSOs has been implemented by the introduction of the Grid Control Cooperation (GCC). Via the GCC, the four German transmission system operators (TSOs) optimize their control energy use and their control reserve provision technically and economically through intelligent communication between each of their load-frequency controllers. This close collaboration allows Germany to be considered as a uniform market (i.e. there is uniform payment, uniform product specification and concerted activation) for flexibility products. The procurement of reserves is carried out via tender auctions for each control reserve product with participation of numerous bidders including those on the demand side (both plant operators and electricity customers). Although a minimum size of load or generation capacity is required to enter the tender, by aggregating smaller units (generation facilities and controllable consumer loads) in order to reach the minimum lot size (see description of the different control reserve types), it is possible for small bidders to take part. The price settlement method is “pay as bid”. Prior to any participation in the balancing markets, the participants have to pass pre-qualification tests, where they have to demonstrate that their technical units (or pool of units) meet the requirements for the relevant balancing products.

The following flexibility product are currently implemented in Germany:

- Primary Control Reserve – Frequency Containment Reserve (FCR)
- Secondary Control Reserve – automated Frequency Restoration Reserve (aFRR)
- Tertiary Control Reserve – manual Frequency Restoration Reserve (mFRR)
- Quickly and Immediately Interruptible Loads (restricted to large consumption sites)

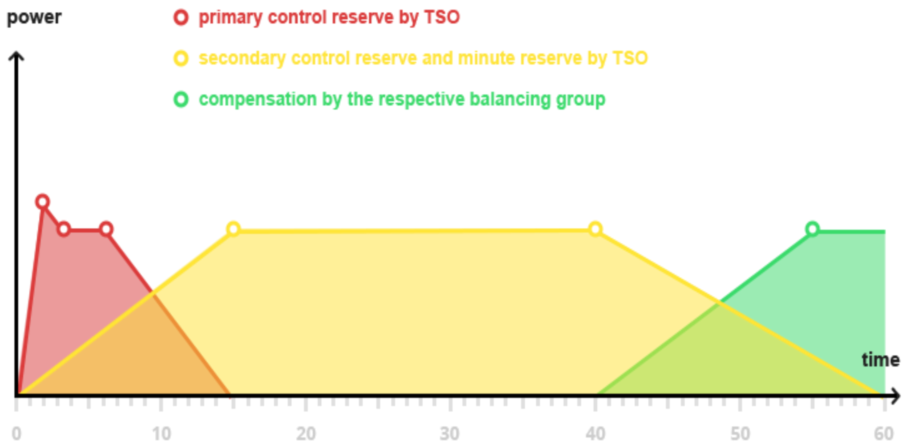

Figure 1 Schematic diagram illustrating the activation time and response required for different balancing services in Germany[1]

2.1 Primary control reserve – Frequency containment reserve FCR

Primary Reserve is regulated collectively by the European countries connected to the transmission networks of the Synchronous Grid of Continental Europe (formerly the UTCE). This reserve is tailored to compensate within 30 seconds to the loss of the two most important generators on the network, which represent 3GW of generation capacity. This overall requirement is then split between the interconnected countries. For Germany, the ENTSO-primary control reserve requirement hasn't varied significantly over the last years. In May 2020, the market size was about 573 MW.[2]

[1] Source : www.regelleistung.net
[2] Source: https://www.next-kraftwerke.de/wissen/primaerreserve-primaerregelleistung

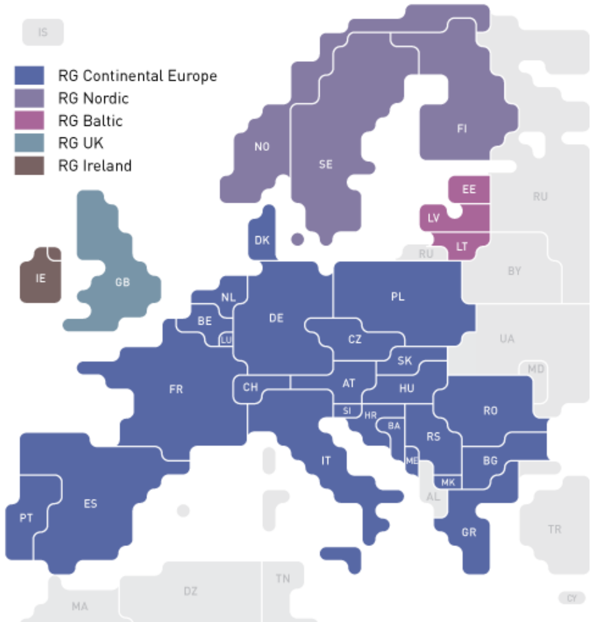

Figure 2 Countries with transmission systems connected to the Synchronous Grid of Continental Europe[3]

The corresponding reserve is activated locally at power plants (via the regulation of the speed of spinning components) or through local power input and output regulation using other assets such as batteries. The response is proportional to the measured frequency deviation up to 200 mHz which is the reference activation signal. Hence, there is no differentiated activation of the participating assets.

> For a given frequency deviation, 50% of the required reserve should be provided within 15 seconds and 100% within 30 seconds. The activation period to be covered for the reference incident is 15 minutes. The reserve must be fully activated for a 200 mHz frequency deviation and is symmetrically specified (i.e. modulation in both directions is required) [See detailed dynamic specifications in 6.1.2]

[3] Source : www.entsoe.eu

For primary control reserve in Germany, the procurement is conducted on a daily basis, with 6 blocks of 4 hours. Primary control reserve is a symmetric service, meaning the market participant must modulate in both positive and negative directions - as required - for a given amount of submitted capacity. Since the 27th June 2011, the minimum lot size has been set at +/- 1 MW (as compared to the previous minimum of 5 MW). This minimum size can be reached by aggregating several assets either to the distribution or transmission networks. The offers are selected according the financial merit order and are remunerated "paid as cleared" with a payment for availability (no energy based remuneration).

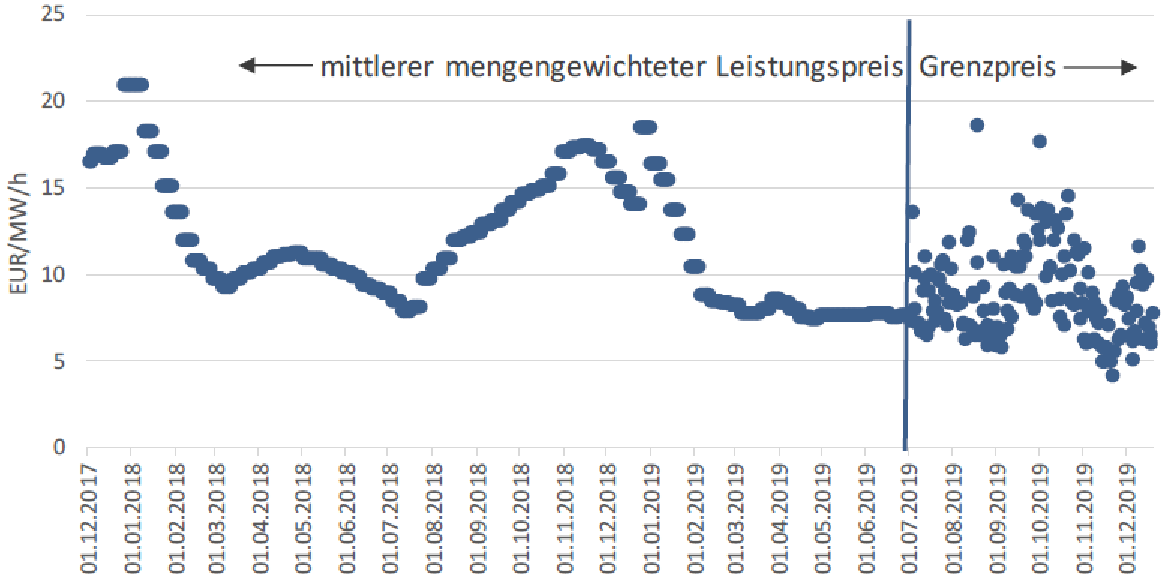

Figure 3 Frequency Containment Reserve prices (daily resolution) [4]

2.2 Secondary control reserve – automatic Frequency Restoration Reserve aFRR

Secondary Reserve acts to restore the system frequency to its nominal set point of 50 Hz in order to re-establish commercial exchanges of electricity between partners at their

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[4] Source : Beschreibung von Konzepten des Systemausgleichs und der Regelreservemärkte in Deutschland (May 2020)

contractual value. Each country/control area of the Synchronous Grid of Continental Europe determines its own reserve size and activation procedure. In Germany, the activation of the secondary control reserve by the TSO is based on a merit order list. Here, the TSO automatically calls available generators sequentially based on their financial merit order.

The full activation of the requested secondary reserves must be attained within 5 minutes, and the duration of activation is not limited in time (unless it reaches the end of the contractual period). The secondary control reserve is not symmetrically specified (distinct products exist for negative and positive modulations) [See detailed dynamic specification in 6.1.2].

The old system with only two HT (peak time) and NT (off-peak time) time slots has also been replaced since 12 July 2018. Now SRL is traded on the control energy market in 4-hour blocks, i.e. six blocks per day, analogous to the minute reserve power. The first calendar-day auction took place on Wednesday, 11 July 2018 for the following Thursday.

The minimum lot size has been decreased from 5 MW to 1 MW. This can be achieved by aggregating several capacities connected to either the distribution or to the transmission network. A tender specifies a certain amount of capacity, a direction, a time slice and the corresponding expected payments:

- An availability (capacity) price, corresponding to the expected remuneration for being available during the periods defined by the contract (low or high loads hours) expressed in €/MW/h
- A utilisation (activation) price, corresponding to the expected remuneration for each energy unit of MWh of secondary control reserve physically activated

The submitted offers are selected based on the merit order for availability price, and are then activated in the merit order for utilisation price. This is referred to as *differentiated activation*.

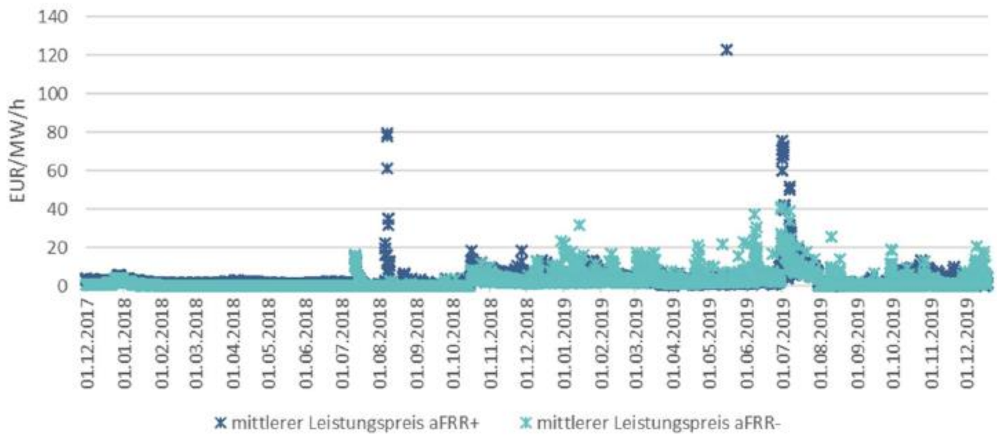

Figure 4: Automated Frequency Restoration Reserve prices (hourly resolution)[5]

The market size is 1820 MW for decremental (negative output modulation) reserves and 1876 MW for incremental (positive output modulation) reserves as of Q2 2018.

2.3 Tertiary control reserve – manual Frequency Restoration Reserve mFRR

The Tertiary Reserve is used by TSOs to recover the secondary reserves or to balance the physical flows when there is a quick increase of consumption or generation (morning or evening ramps), but also to preempt such an offset. Each country of the Synchronous Grid of Continental Europe plate administers its own reserve sizing and activation procedure.

Full activation of the requested tertiary reserves must be achieved within 15 minutes, and is not limited in time (unless the contractual period closes). The tertiary control reserve is not symmetrically specified (i.e. distinct products exist for negative and positive modulation). [See detailed dynamic specifications in 6.1.2].

For tertiary control reserve, procurement is conducted through daily tenders taking place one working day prior the contract's start. Tenders must be submitted by 15:00, and are allocated

[5] Source : Beschreibung von Konzepten des Systemausgleichs und der Regelreservemärkte in Deutschland (May 2020)

by 16:00 on the same day. A bid is related to as single direction, either positive or negative, and to one of six pre-defined, four hours long, time slices of the day. Since the 12th July 2018, the minimum lot size has been set at 1 MW (the previous minimum was 5 MW). This can be reached by aggregating several assets connected to either the distribution or transmission network. Similarly to secondary control reserve, an offer is related to a certain amount of capacity, a modulation direction and a time slice and sets out the corresponding expected payments:

- An availability (capacity) price, corresponding to the expected remuneration for being available during the periods defined by the contract (low or high loads hours) expressed in €/MW/h
- A utilization (activation) price, corresponding to the expected remuneration for each energy unit of MWh of secondary control reserve physically activated.

The submitted offers are selected in the merit order for availability price, and are then activated sequentially, based the merit order for utilization price.

The market size is 874 MW for decremental reserves and 1067 MW for incremental reserves as of Q1 2019.

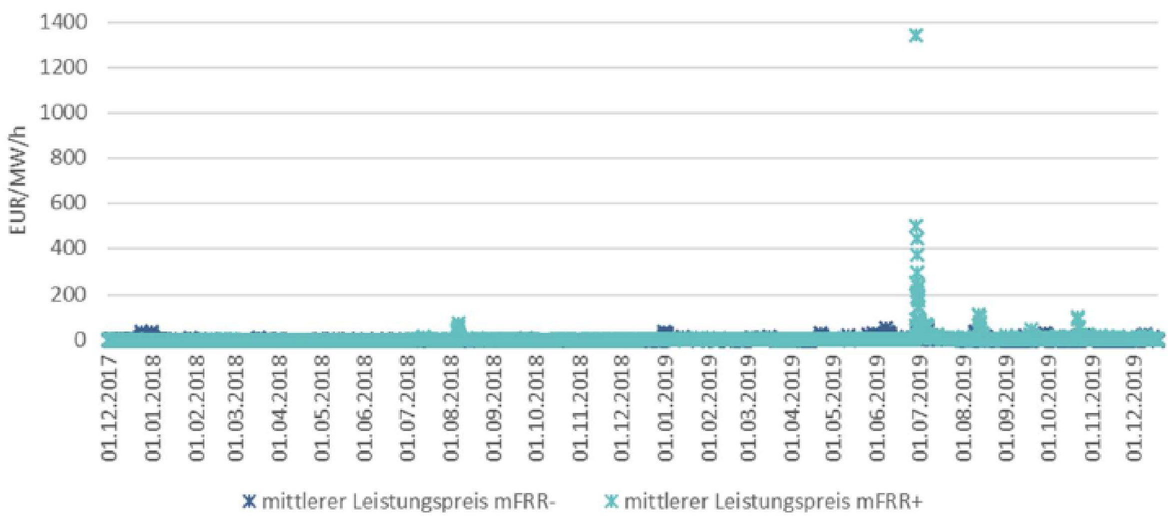

Figure 5: Manual Frequency Restoration Reserve prices (hourly resolution)[6]

2.4 Rapidly and immediately interruptible loads

Interruptible loads are defined as large consumption units which are connected to the high and extra high voltage grid, and nearly continuously consume a large volume of electricity and which can, when called upon, reduce or interrupt their demand on short notice and for a fixed minimum duration.

The immediately interruptible loads must be activated within 200 ms to 1 second (typically 350 ms) in response to any frequency deviation greater than a fixed threshold determined by the TSO. Rapidly interruptible loads can be activated by TSO within 15 minutes.

The German TSOs issue a weekly call for tenders for 802 MW of immediately interruptible loads (SOL) and 1582 MW for rapidly interruptible loads (SNL)[7]. The minimum lot size is 5 MW and the maximum is 200 MW.

[6] Source : Beschreibung von Konzepten des Systemausgleichs und der Regelreservemärkte in Deutschland (May 2020)

[7] https://www.regelleistung.net/ext/static/abla

For each of these products, the submitted tender sets out the contract period, the amount of capacity (MW) provided, and the expected availability payment.

Generally, these services are provided by large loads ($\geq$50 MW) connected to the very high voltage grid and so are unsuitable for on-site fuel production at electrolytic hydrogen refueling stations. Therefore, these will not be set out further, as they are likely unsuitable to near to mid-term road fuel production.

2.5 Synthesis of flexibility products for Germany

The following graph summarizes the price evolution between 2013 and 2019.

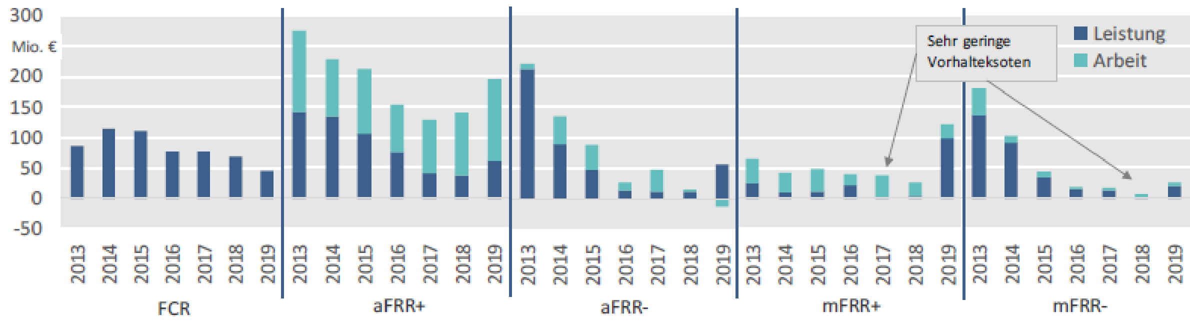

Figure 6: Development of costs for standard services and work in Germany[8]

The table below summarizes the main characteristics of previously described flexibility products.

<u>Notice:</u> An asset (or pool of units) has the possibility to allocate different portions of its capacity to different types of reserve, as long as these portions do not overlap.

[8] Source : Beschreibung von Konzepten des Systemausgleichs und der Regelreservemärkte in Deutschland (May 2020)

Table 1 Synthesis of balancing products open to demand response in Germany

Type of reserve	Activation			Access to market			Product specifications		Auctions		
	Dynamic	Type	Duration	Minimum lot size	Voltage level	Pooling allowed	Direction	Time slices	Payment	Selection rule	Activation rule
PRIMARY CONTROL RESERVE FCR	50% of required reserve released within 15s & 100% of required reserve released within 30s	Undifferentiated activation. All participating units react proportionally to their contracted capacities and to the observed frequency deviation	For the reference incident, the reserve must be kept activated for 15 minutes minimum	1 MW	Any	YES	Positive **AND** Negative	4 hours long time slices (6 time slices each day)	Payment for capacity (pay as cleared)	Offers are selected in the capacity price merit order until the reserve requirement is fulfilled	All selected offers are activated
SECONDARY CONTROL RESERVE aFRR	100% of the required reserve activated within 5 minutes	Differentiated activation: the TSO sends a (de-)activation order specifically to each participating unit	The possible activation duration is unlimited during the whole duration of the contract	1 MW	Any	YES	Positive **OR** Negative	4 hours long time slices (6 time slices each day)	Payment for capacity & Payment for energy activated (pay as bid)	Offers are selected in the capacity price merit order until the reserve requirement is fulfilled	Selected offers are activated by the TSO following the energy price merit order
TERTIARY CONTROL RESERVE mFRR	100% of the required reserve activated within 15 minutes	Differentiated activation: the TSO sends a (de)activation order specifically to each participating unit	The possible activation duration is unlimited during the whole duration of the contract	1 MW	Any	YES	Positive **OR** Negative	4 hours long time slices (6 time slices each day)	Payment for capacity & Price for energy activated (pay as bid)	Offers are selected in the capacity price merit order until the reserve requirement is fulfilled	Selected offers are activated by the TSO following the energy price merit order

3 Balancing products in France

RTE is the national Transmission System Operator of France and procures a range of ancillary services to ensure the balance of consumption and generation. EDF ("Electricité de France") used to have a monopoly over electricity generation in France, and thus used to be the only provider of supply side services. Because of this, there wasn't a nuanced market design, EDF would be called upon to provide control reserve, this is known as the *compulsory principle.* The provision of control reserve has long remained based on a compulsory principle: major players of the electricity market had the obligation of providing a certain share of the required reserves with regard to their respective generating capacities. A flat rate payment for these is applied. Since a few years however, the French flexibility market has been opening and is becoming progressively transparent. Processes that are more competitive are replacing the compulsory procurement methods. Therefore, grid rules (defining technical conditions to provide ancillary services) and provision methods are evolving continuously.

Similarly, to Germany, the French TSO RTE offers the following types of service:

- primary control reserve
- secondary control reserve
- tertiary control reserve which can be divided into four sub-types:
    - Fast reserve
    - Complementary reserve
    - Demand turn off
    - Adjusting mechanism (non-contractual reserves)

Additionally, a capacity mechanism has become operational since 2017.

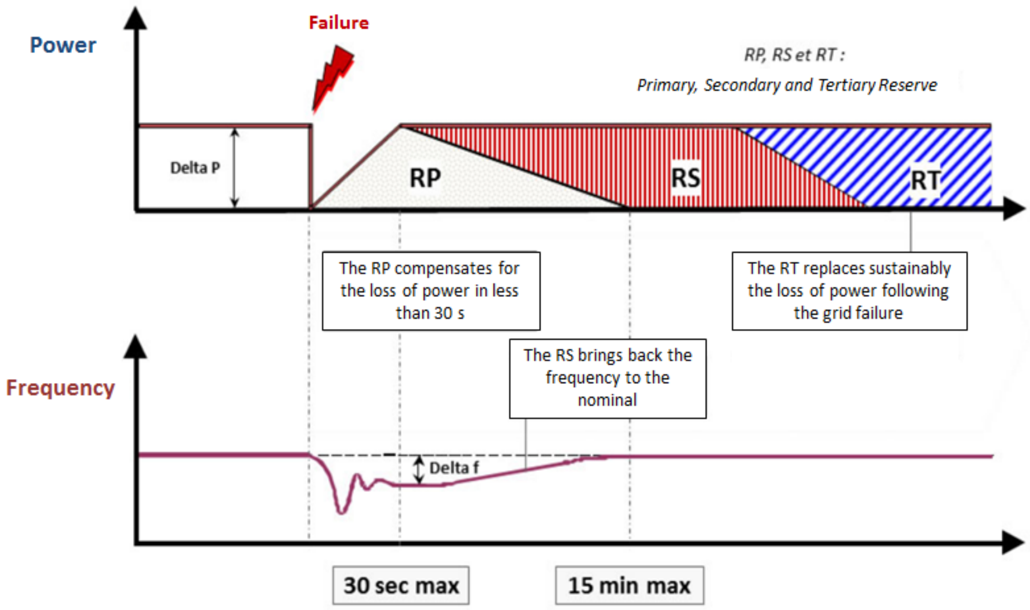

Figure 7 Schematic illustrating the activation of balancing services in France[9]

3.1 Primary control reserve

The same principles described for Germany apply to France, where the required amount of primary control reserve to be procured is 569 MW. This reserve is automatically activated by the local speed controller loops of the participating plants or through electric power regulation using other assets such as batteries.

Primary control reserve response is proportional to the measured frequency deviation and must be fully activated for a 200 mHz frequency deviation.

For a given frequency deviation, 50% of the required reserve must be provided within 15 seconds and 100% within 30 seconds. The activation period to be covered for the reference

[9] Source : www.cre.fr

incident is 15 minutes. The reserve must be fully activated for a 200 mHz frequency deviation and is symmetrically specified (modulations in both directions are required) [See example of testing protocol issued by TSO in 6.2.1].

The procurement of primary control reserve was based on a compulsory principle until 2016 (compulsory reserve allocation for major electricity companies). Since the beginning of 2017, procurement has taken place via tenders each Tuesday of the week prior to the contract's start. This is conducted through the common tender platform www.regelleistung.net (the same as for Germany). The minimum lot size is set at +/- 1 MW and can be reached by aggregating several assets connected to either the distribution or the transmission system. Gate closure is at 15:00, and tenders are allocated at 16:00 the same day. A bid is related to a week long period starting on Monday at 00:00:00 and ending Sunday at 23:59:59. The offers are selected according to the financial merit order and are remunerated "paid as bid" with a payment for availability (no energy based remuneration).

From July 2019, procurement will take place each working-days in D-2. The call for tenders will be on Thursday for a Saturday and Sunday delivery, and on Friday, for a Monday and Tuesday delivery. The offers will be selected according the financial merit order and will be remunerated "paid as cleared". It will change the price structure but we don't know what the impact on the actual price will be.

Notice:

Historically, the grid rules used to allow only generation sites of significant size to provide ancillary services operating from the transmission grid level. Since 2014, grid rules started to change and little by little enabled consumption sites to participate. In 2016, RTE also allowed consumption sites to provide ancillary services from the distribution grid: almost any consumption site with significant flexibility and short response time can now participate if

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qualified, either directly or through an aggregator. The corresponding grid rules changed accordingly.

3.2 Secondary control reserve

Similarly to Germany, the Secondary Reserves act to restore system frequency to the nominal set point of 50 Hz in order to re-establish commercial exchanges of electricity between partners at their contractual value. Each country of the Synchronous Grid of continental Europe administers its own reserve sizing and activation procedure. In France, the secondary control reserve requirement varies between 500 and 1180 MW according to the time window and the period of year. The activation of the secondary control reserve is based on a unique national signal elaborated by RTE, and sent to all participating units: the N-signal which takes values between -1 and 1 (between 0 and -1: activation of decremental reserve, between 0 and 1: activation of incremental reserve). The activation of the secondary control reserve is undifferentiated and is expected to be proportional to the signal. There are no limitations regarding the possible activation duration of secondary control reserve.

The dynamic of the requested response is exposed by RTE as it follows:

For $-\frac{2}{133}\ s^{-1} < \frac{dN}{dt} < \frac{2}{133}\ s^{-1}$:

The theoretical instantaneous response is defined as $P_{theo} = RS \cdot N$ (where RS is the secondary reserve to be provided by the asset) and the real observed response should fulfill the following condition: $\Delta(P_{real} - P_{theo}) \leq \frac{dN}{dt} \cdot RS \cdot T_{eq}\ with\ T_{eq} = 20\ seconds$

If $\frac{dN}{dt} > \frac{2}{133}\ s^{-1}$ (respectively$< -\frac{2}{133}\ s^{-1}$), the activation of the reserve is fixed at its last known level. Additionally, if the N signal is lost, the reserve is maintained at its last known level.

Thus, the emergency ramp ($\frac{2}{133}\ s^{-1}$) applied to the activation signal N and the present undifferentiated activation method used leads to more dynamic exigencies for the French secondary control reserve as for the German one [See example of testing protocol issued by TSO in 6.2.1].

The vote on the European Electricity Balancing guideline (EGBL) regulation in March 2017 generated an evolution of the rules concerning the secondary reserve.

As such, a European PICASSO project is being developed. Currently, it is in the process of defining the specifications. The platform will be developing during the second half of 2019 until the end of 2020. The real production will start in the 2nd half of 2021.

The activation of the frequency restoration reserves with automatic activation (aFRR) will be carried out according to the Merit Order. The reserve providers applying to the aFRR must submit offers consisting of a volume (MW), a price in €/MWh, a direction (increase or decrease), a validity period, a ramp, a reserve entity. The offer validity period will be 15 minutes (96 desks per day) and the closing of the offer submission window for reserve managers with RTE (TSO) will be at H-25 minutes before the real time. Then, RTE will have to send the aFRR offers to the PICASSO platform between H-20min and H-10min before the real time to constitute the CMOL (common merit order list of replacement reserve). This platform will have the list of offers from each country, the capacity at the borders and, thanks to a clearing algorithm, will transmit the necessary data to RTE (TSO) to calculate the necessary MW, select the offers to be activated and calculate the activation signal of each reserve entities. Activation will be carried out according to economic priority over the cheapest groups, with the emission of an individualized level N signal. It won't be a generalized N level for all participants. Payment for the energy will be made at the Marginal Cross Border Price.

Currently, the time required to mobilize the secondary reserve in France is 400 s (6min40s). By 2025, the target in terms of mobilization time is 5 minutes. But the PICASSO platform will encourage stakeholders to react faster than 5 minutes.

3.3 Tertiary control reserve

The Tertiary Reserve is used by RTE to recover the secondary reserves or to balance the physical flows when there is a quick increase of consumption or generation (e.g. morning or evening ramps), but also to anticipate such an offset. Each country connected to the Synchronous Grid of Continental Europe administers of its own reserve sizing and activation procedure.

French tertiary reserve is composed of four different categories of products:

- **The fast reserve**, which is activated within 13 minutes (R13) for a maximum duration of 120 minutes. It can be activated twice a day, with a minimum single activation duration period of 30 minutes.

- **The complementary reserve**, which is activated within 30 minutes (R30) for a maximum duration of 90 minutes each time. It can be activated twice a day, with a minimum single activation duration of 30 minutes.

- **Contractual interruptible load (cut off) capacities** meant to contribute to the adjustment mechanism for which activation delay time can reach up to 2 hours. These are tendered on an annual basis to make a given amount of interruptible load available over an entire year. The capacity and the energy are remunerated.

- **The non-contractual reserve for which activation delays may reach up to 2 hours**. These are procured in a more flexible way than Contractual interruptible load (e.g. they can be procured a day before). Only the energy is remunerated, and the remuneration is generally much lower than for Contractual interruptible load.

Note: the contractual reserves (fast and complementary reserves, contractual interruptible loads) only involve positive modulation while the non-contracted reserves consist of both negative and positive modulation.

The procurement of contractual tertiary reserves (fast and complementary reserves, contractual interruptible loads) is based on an annual call of tenders for contracted reserves (fast and complementary reserve, interruptible loads) and on a market platform with daily submissions for the non-contractual reserves. Contractual reserves receive payments both for availability and activation while non-contractual reserves only receive remuneration for activation. [See examples of payments observed for tertiary reserve in 6.2.2]

3.3.1 Contractual reserves (fast and complementary reserves, interruptible loads)

RTE contracts each year (only 1 call of tenders) with voluntary participants, capacities which will be available over predefined periods in order to secure the reserve over a whole year. RTE procures services via tenders on an annual basis. These specify predefined periods for each participant's capacity which together secure reserve requirements for an entire year, including:

- the fast reserve with 1000 MW up
- the complementary reserve with 500 MW up
- Contracted interruptible loads with 2100 MW up

For availability secured over longer periods, the reserve providers receive an availability payment. The awarded capacities are paid for their full availability over the duration of the concerned period (except for a restricted number of days to take malfunction or maintenance work into account). The remuneration is based on the marginal price. The marginal price refers to the highest price of all selected offers within the call. This determines the remuneration for all selected offers applying to that period. The availability remunerations hence vary each week, with different prices either for working days or non-working days. The resulting prices for each week are published by RTE on their website.

The reserve participants also receive an utilisation (energy) based payment. The utilisation-based remuneration of the offer is paid as bid (and proportional to the energy activated). Selected offers, paid as cleared for their availability are then activated according to the activation-price merit order.

Currently, contracts allow interruptible loads to provide both fast and complementary reserve. Aggregators use two strategies to operate such interruptible loads:

1. Vertical pooling: where several loads are aggregated together at the same time
2. Horizontal pooling: where capacities which are available over different periods are aggregated

The minimum bid size is usually 10 MW. However, in some cases, 1MW capacity are permitted for demand side response providers.

In 2016, 450 MW of the 1500 MW fast and complementary reserve requirement was met by demand side response.

Offers associated with the proposed energy must be placed on the balancing energy market.

For contracted interruptible loads, the availability load must be made available within a period (a *time slice*) between 06:00 to 20:00, including at least the 08:00-14:00 period (morning peak). 200 MW of residential and tertiary capacities and 1900 MW of industrial capacities were contracted in 2016.

Contracts last between 3 and 12 months. Within these periods, RTE can activate assets up to a set number of times (usually 15 times for 3 months and 30 times for a one-year contract). These are forecast by RTE, and providers are notified the day before. The provider then enters themselves onto a merit order list for activation. This process is known as solicitation.

Two erasure calls for tenders are organised each year (in July and September). They are intended for electricity consumption sites. The erasure capacity to which the candidate commits in his offer is greater than or equal to 1 MW and is expressed as an integer of MW. The application specifications are published each year by RTE.

By contracting via the erasure call for tenders, the candidate undertakes to make his erasure capacity available during a minimum availability period on :

- quick and complementary reservations or/and,
- the adjustment mechanism and/or NEBEF.

Each call for tenders consists of two lots:

- Lot 1, reserved for sites with a subscribed power less than or equal to 1 MVA (low voltage) and 1 MW (HTA). The volume requested in 2018 is 300 MW, 500 MW over 2019, 800MW in 2020 and 1000 MW in 2021 (forecast).
- Lot 2, for sites with a subscribed power greater than 1 MVA (low voltage) and 1 MW (HTA). The volume requested in 2018 is 1900 MW, 2000 MW in 2019, 2100 MW in 2020 and 1000 MW in 2021 (forecast).

3.3.2 Non contracted reserves (adjusting mechanism)

In addition to the midterm secured capacities described above, it is also possible to formulate at any time an offer on the adjusting mechanism corresponding to pre-qualified capacities for different time slices (6 time slices each day). There is then no capacity payment, but only an utilisation payment (which is only paid as bid if the corresponding offer has been activated by RTE). Dispatchable loads can then be valorized as incremental or decremental reserves. The minimum bid size is 1MW. Major generating companies have the obligation to declare residual (non-used) flexibility margins for their operating assets on the adjusting mechanism.

3.4 Capacity mechanism

The capacity mechanism is intended to safeguard the security of electricity supply in France during peak winter periods. It is based on the obligation for obligated parties to cover consumption during peak periods and on the certification of generation and demand response capacities.

- Capacity operators (generation and demand response capacity) undertake to ensure availability during peak winter periods. In exchange, RTE gives them certificates that they can then sell to obligated parties
- Obligated parties demonstrate on an annual basis that they are able to cover customer consumption during peak winter periods. To meet this obligation, they must hold certificates. Obligated parties are suppliers, as well as end consumers and system operators for their losses, which, for all or part of their consumption, are not supplied by a provider.

The capacity mechanism begins four years upstream. During the year of delivery, RTE notifies each day in day-ahead the peak days PP1 (for the obligated parties) and PP2 (for operators) during which obligated parties and capacity operators will have to fulfil their respective obligations. 10 to 15 days PP1 and 10 to 25 days PP2 may be notified each year, from 1 January to 31 March and from 1 November to 31 December (except during the Christmas holidays and during week-ends), and from 7:00 to 15:00 and from 18:00 to 20:00.

Price

Obligated party: 4€/MW of reference power per year (RTE fee for calculating obligation for the total perimeter of the obligated party).

Certification Entity:

- 500€/account/year (fixed costs for REGA account management)
- 0.38€/capacity guarantee/year (variable costs for managing the capacity guarantees registry invoiced during any sale of capacity guarantees, capped at 1€/guarantee/year).

- 10€/MW (PTS certification fee)

3.5 Interruptability

There is also an “interuptability” service allowing very reactive consumption sites connected to the transmission system, with a large load (25 MW and above), to be remunerated for their capability to immediately turn off demand. It only concerns extraction sites with more than 25 MW of power capacity, able to cut their electricity consumption in a few seconds. As a consequence, it will not be treated in this synthesis as this description does not fit to hydrogen refueling stations using on-site hydrogen generation, which use a range of power far lower than that.

The European Electricity Guideline (EGBL) plans to develop two European platforms where all European stakeholders can indicate their needs. The first one for complementary reserve (TERRE) and the second one for the fast reserve (MARI). The operation will be identical for both platforms:

- European reserve providers will be able to submit their offers on a European platform via their TSO. The offer will indicate the MW, the price, and must correspond to a standard product (10-minute ramp).
- European TSO will be able to submit their needs on the European Platform.
- Then, the European platform will inform each national TSO of the offers to be activated.

3.6 Synthesis of flexibility products for France

The following table summarizes main characteristics of previously descripted flexibility products.

Notice:

A technical unit (or pool) has the possibility to allocate different "portions" of its capacity to different types of reserve, as long as the concerned "portions" are not overlapping.

Table 2 Synthesis of balancing products open to demand response in France

Type of reserve	Activation			Access to market			Product specifications		Auctions			
	Dynamic	Type	Duration	Minimum lot size	Voltage level	Pooling allowed	Direction	Time slices	Schedule	Payment	Selection rule	Activation rule
PRIMARY CONTROL RESERVE	50% within 15s 100% within 30s	Undifferentiated activation. All participating units react proportionally to the observed frequency deviation	For the reference incident, the reserve must be kept activated for 15 minutes minimum	1 MW	Any	YES	Positive **AND** Negative	1 week from Monday to Sunday	Tuesday a week before the contract begins	Payment for capacity (1week)	Financial merit order	All selected offers are activated

Evolution Primary control (from July 2019)								Day + 2.	Every working days			
SECONDARY CONTROL RESERVE	Emergency activation ramp of 133 seconds	Undifferentiated (de-) activation National activation via the N signal	No limitation unless the end of the availability contract	1 MW	Any	YES	Positive **AND** Negative	1 hour	No auction: compulsory reserve mechanism. A secondary market exists	Flat rate of ~18 €/MW/h, activated energy = SPOT price	Compulsory reserve	All participating units reacts to a national undifferentiated activation signal (N)
Evolution secondary control reserve		Differentiated signal activation								RTE will activate the best offer (merit order device)		Only participants selected by RTE with a differentiated signal.
TERTIARY CONTROL RESERVE	100% of the required reserve activated within 13 minutes (FR), 30 minutes (CR) or up to 2 hours (AM, IL)	Differentiated activation: the TSO sends an (de-)activation order specifically to each participating unit	The possible activation duration can reach up to 120 min. for FR, 90 min. for CR, variable time slice duration for AM and IL	10 MW (relaxed to 1 MW for demand response)	Any	YES	Only Positive for FR and CR, IL, Positive **OR** Negative for AM	Annual contracts for FR,CR, and IL, 6 time slices a day for AM	Annual tender for FR, CR and IL Working day prior to the contract start for AM.	Payment for availability only for FR,CR and IL. Payment for energy activated for all types of products	Financial merit order (availability payment for FR, CR and IL)	Financial merit order (energy payment)

4 Balancing products in UK

The UK is a self-dispatch system, meaning suppliers will trade directly with generators to buy the volume of energy they require for a particular settlement period. However, as in the previous cases, the Transmission System Operator, National Grid (NG), is responsible for the physical imbalance of electrical flows between consumption and exports on one hand, and generation and imports on the other hand. Therefore, balancing services are required by NG to manage the range of issues which the market wholesale market is not able to solve itself.

National Grid uses a number of ancillary services to perform its role as TSO, achieving real time balancing of supply demand on the electricity network. National Grid uses reserves and response services to increase system frequency (positive services) or decrease system frequency (negative services). A positive service provider will either increase its power export, provide power from a standstill or reduce its grid demand, while a negative service provider will do the opposite. These services are generally contracted ahead of time with large flexible generators or from energy consumers able to alter their demand upon request. Historically, nearly all balancing services have been provided from large centralised coal and gas power plants. However, as government policy is driving the generation mix away from such technologies towards inflexible low carbon generators (like wind, solar PV & nuclear), new sources/ means of flexibility to balance the system are becoming necessary. Hence NG launched the Power Responsive campaign in 2015 which introduced several measures to encourage new technologies and market entrants from demand side providers.

In the following, the described flexibility products refer to balancing services open to demand side response (additionally to balancing services, the demand side response can also participate in the capacity market). Balancing services open to demand side response consist of reserve products and frequency response products.

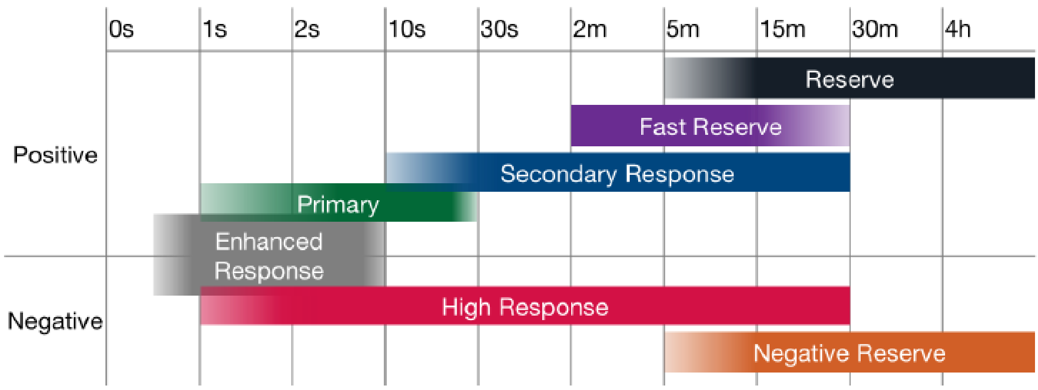

Figure 8 Schematic activation of balancing services in UK[10]

Response services provide power within seconds and are automatically triggered by a local frequency reading, whereas reserve services provide power within minutes triggered by receipt of an instruction. The volume requirements both for frequency response and reserve are expected to remain relatively stable until 2020, excluding particular situations when the system has very low inertia [See 6.3.1].

4.1 Frequency response

To maintain system stability frequency response services are procured from generators and demand side providers who are able to automatically vary their active power level within seconds to frequency deviations (undifferentiated activation). High frequency response is a decrease in generation (or increase in demand) when frequency rises above 50Hz, and low frequency response is an increase in generation (or decrease in demand) when frequency drops below 50Hz.

Low frequency response can be split out into two categories in terms of the response speed and duration requirements.

[10] Source : www2.nationalgrid.com

- Primary response is a change in active power within 2 seconds of a frequency deviation, reaching full power within 10 seconds and sustaining this level for 30 seconds from a frequency deviation.

- For secondary response, full power must be reached within 30 seconds and sustained for 30 minutes of a frequency deviation.

High response is a change in active power within 2 seconds of a frequency deviation, reaching full power within 10 seconds and sustaining this level for 30 minutes from a frequency deviation.

Hence, it is possible for a single asset to provide primary, secondary and high response at the same time.

On average around 600MW of high frequency response and 1400MW of low frequency response is needed. More low response is required than high response as sufficient capacity must be maintained to cover the loss of the largest generator online at the time (this is usually the interconnector to France). The requirement both high and low frequency response is greater overnight because when fewer thermal generators are online the frequency becomes less stable. However, frequency response is required constantly and hence all the services described below are needed 24/7 to ensure system stability.

This low- and high- frequency response reserves requirements are fulfilled either by the provision of static or dynamic reserves products which are set out in the following sections:

4.1.1 Dynamic Frequency response

Dynamic frequency response manages the grid frequency by responding to any deviation from 50Hz (in either direction) with a change in active power. Usually providers deliver 100% of their available low capacity (increasing generation output) when frequency is at 49.5Hz and 100% of their high capacity (reducing generation output) at 50.5Hz.

This service has traditionally been sourced from generators who are able to reduce their output to a part-load point and then 'track' the frequency by altering their output around this part-load point.

Of the low frequency response requirement (around 1400MW on average) there is a minimum dynamic requirement of at least 600MW. The entire high frequency response requirement is dynamic.

Dynamic Firm Frequency Response (Dynamic FFR)

Every month there is a tender opportunity called Firm Frequency Response (FFR), whereby dynamic providers are able to tender their capacity to provide Primary, Secondary and High response.

Providers can tender for any period within two years (however generally NG do not accept tenders for starting provision more than six months out). The payments available are:

- Availability payment – paid for the duration of the tendered period
- Nomination payment – paid for whenever NG instruct a winning provider to become frequency responsive. Winning providers are nominated well over 90% of the time so this payment can effectively be combined with the availability payment.
- Window initiation fee – paid whenever NG instructs a nomination period to begin. Providers seem to always bid £0/window here.
- Response Energy Fee – paid for the resultant energy imbalance caused by tracking the frequency (effectively an utilisation payment). Providers seem to always bid £0/MWh here.

Notice:

There is currently a 10MW minimum requirement to submit a tender into the FFR market and hence to encourage new providers NG has developed an FFR Bridging arrangement whereby smaller providers can participate until they have sufficient volume to enter the FFR market.

FFR Bridging takes the form of a bilateral contract between the provider and NG with fixed rates for availability for high and low response; providers then nominate the volumes (between 1MW and 9MW) of frequency response they can provide at a week ahead stage which NG will guarantee to accept and pay for. Note, as of 2017, the threshold for entry into the FFR market has been reduced to 1MW.

Enhanced Frequency Response

In addition to the previously described dynamic frequency response products, *Enhanced Frequency Response* is a new service for which NG received tenders in July 2016. The motivation behind setting up a new service was to procure faster acting frequency response which would specifically help to ensure frequency stability at times of low demand.

The dynamic requirements for *Enhanced Frequency Response* are:

- Response time of <1 second to a frequency deviation
- Ability to sustain response at full power for 15 minutes
- A symmetric capability to provide high and low response
- An accurate proportional response (other frequency services do not penalise for over delivery)

NG is procuring about 200MW (of high and low response) from the first procurement round of EFR. Providers could submit only an availability price into the tender.

4.1.2 Static Frequency response

Static frequency response is a post-fault service which means it is only activated once the frequency has passed below a certain trigger point (indicating the loss of a large generator). This trigger point is usually set to 49.7Hz and hence static providers are called upon around 10 times per year.

Since early 2015, NG has been increasing the proportion of the frequency response requirement it gets from static providers. As this simpler service is easier to provide than dynamic frequency response, it is more economical for NG to purchase as much frequency response from static as possible.

Of the low response requirement (around 1400MW on average) there is a minimum dynamic requirement of at least 600MW. The rest of the requirement can in theory be made up of a simpler static frequency response service. There is no use for a high static service as the entire high frequency response requirement must be dynamic.

Static Firm Frequency Response (Static FFR)

Every month there is a tender opportunity called Firm Frequency Response (FFR), whereby static providers are able to tender their capacity for either primary secondary static provision; in practice however all volume tendered is secondary response.

Static providers are also able to submit bids into the monthly FFR tender round for either primary secondary static provision (low frequency response); however in practice all volume tendered is secondary response.

The most common form of static FFR (Type 4) is simply to provide at full output for 30 minutes.

Like Dynamic FFR, there is currently a 10MW volume requirement but smaller providers are able to enter a static FFR Bridging contract until they have sufficient volume to tender in the FFR market.

Frequency Control by Demand Management (FCDM)

FCDM is static frequency response service available to energy consumers capable of interrupting their processes at very short notice. It is one of the oldest demand response services procured by NG, traditionally it was largely provided by aluminium smelters. Like static FFR it is activated by a trigger frequency of 49.7Hz however providers must react within 2 seconds to this and hold for at least 30 minutes (primary plus secondary). For this service providers use equipment provided by NG which has a direct connection to the control room.

This enables much greater flexibility than static FFR as providers can effectively nominate their availability just hours before delivery.

There is no tendered market for FCDM and all volume is procured through bilateral contracts.

4.2 Balancing Mechanism (BM)

The BM is the largest flexibility market in the UK in terms of traded volumes and cash flows and is used constantly to balance both system level and locational issues. All power stations over a certain size must be registered as a BM Unit which effectively means NG is able to send real time instructions to alter the generators output. BM Units each declare a price for Bids (reducing output) and Offers (increasing output) and NG issues instructions by accepting a bid or offer price from an individual plant. Bid/Offer Acceptance (BOA) is the term given to these trades.

There are BM units which represent demand as well as generation. Each supplier will have a BM unit to represent the demand of their consumers within each part of the transmission network. Therefore, it is theoretically possible for demand side participants to enter this market. Hence Bids/Offers could be posted by the supplier (representing the ability to increase/decrease the consumption of the supplier’s consumer portfolio). However, in practice the requirement to contract with a supplier represents a significant commercial barrier (one that isn’t present in other balancing markets) and has prohibited demand side providers from the BM.

4.3 Reserve

National Grid must maintain a certain level of Operating Reserve at all times. This is done through a combination of instructing power stations to maintain headroom in real time (through the Balancing Mechanism more dedicated to large generation plants) and contracting reserve services ahead of time. These reserve contracts are generally only required over the morning and evening peaks (when generation outages are most likely to occur and demand forecast errors are likely).

Reserve products can be split in three classes of products

- Short Term Operating Reserve (STOR)
- Fast Reserve
- Balancing Reserve

4.3.1 Short Term Operating Reserve (STOR)

STOR is the largest reserve service in terms of volume with NG maintaining around 3GW throughout the year. The market is open to demand side participants, transmission connected and embedded generators. The tender calendar is divided into 6 STOR seasons (of varying length) for which there are multiple opportunities (tender rounds) to submit a tender for service provision over this period. Revenue is earned through a combination of an availability payment for providing capacity over the service windows and an utilisation payment for the energy delivered upon instruction from NG.

Providers must be capable of sustaining delivery for 2 hours, while the response time is a tendered parameter; generally, a response time of under 20 minutes is required to win a tender. 3MW is the minimum tender size however this can be aggregated across different assets/sites.

With around 5GW of providers tendering regularly for this requirement, it has been a highly competitive market for many years which has kept the market value down [See 6.3.1]. STOR Runway is a separate tender process which runs alongside the main STOR market where only demand side participants can enter. The minimum volume requirement is relaxed to 1 MW for STOR Runway and providers can continue to tender here up to a volume of 10MW when they must participate in the main STOR tender rounds.

Committed STOR

Committed STOR providers guarantee their capacity will be available for the periods in which they tender. This certainty means the service is valued much higher than other types of STOR. BM Units are only able to provide this service type of STOR.

Flexible STOR

This was introduced to allow demand side participants the ability to declare availability to provide STOR after a tender has been awarded, NG then has the choice whether to accept this availability (and pay for it via an availability fee). This enables providers the flexibility to respond to price signals (such as Triads) by withdrawing from STOR provision.

Premium Flexible STOR

Certain service windows in the year are of higher priority than others so NG offers to guarantee it will accept any availability offered by flexible providers over these periods if they tender for a Premium Flexible service. This shifts a risk onto NG that they may over procure their requirement and so the Premium Flexible service experiences lower payments than the Flexible Service. The service was introduced as Flexible providers were experiencing that their availability payments were being undercut by other providers at later tender rounds meaning NG wouldn't accept their availability even after a tender had been won.

Enhanced Optional STOR

This service was introduced in January 2016 largely in response to the issue that behind-the-meter and small-scale distributed generation does not participate in the BM; and hence NG has no mechanism to utilise the large amount of these providers who do not win STOR contracts.

Such providers who do not win tenders in the main STOR market are able to offer an utilisation price only to NG who might choose to instruct them if that price represent a more economical choice than an offers available in the BM.

There has been little interest in Enhanced Optional STOR and National Grid have not yet announced any successful tenders for this service.

4.3.2 Fast Reserve

Fast Reserve is another service used to meet the Operating Reserve requirement. This is a more specialist reserve service with stricter requirements such as a defined ramp rate and much larger minimum volume requirement.

Active power delivery must start within 2 minutes of the dispatch instruction at a delivery rate of over 25MW/minute, and the reserve energy should be sustainable for a minimum of 15 minutes.

Until this year the market had been entirely dominated by the pumped storage plants in the network and seen very consistent pricing. Though recently new tenders from aggregated gas reciprocating engines have entered the market and been accepted. Like STOR, this service is only required over the morning and evening peaks. It is often used to provide capacity after a generator has failed until another one can be brought up to replace it. Both an availability payment and utilisation payment are available in this market. It is open to both large generators and demand side participants alike although the minimum volume requirement of 50MW has been a significant barrier to aggregated providers.

4.3.3 Balancing reserve

Contingency balancing reserve and **supplemental balancing** reserve represent two temporary measures introduced in response to short term concerns over capacity. However, both services has disappeared in Winter 2016/17 as the main the Capacity Market begins delivery the year after. Hence, they will not be further described here.

Demand Side Balancing Reserve (DSBR) is only available to demand side participants able to decrease consumption (or activate back-up generation) upon request from NG. The simple technical requirements of the service (for example no additional metering or communications infrastructure is necessary) allowed NG to source large volumes in the first year of tendering. The service only features an utilisation payment and no availability payment (although a set-up fee is available). Very high utilisation rates (up to £12,500/MWh) are observed in this market however given how little it is used, the achievable revenue in this market is low. In the two years of operation so far, only 43MW have been dispatched for one hour. National Grid has procured around 500MW of DSBR each winter since 2014/15 to help ensure a level of system margin during the winter peak. In August 2016, National Grid announced that none of the tenders the assessed for provision over winter 16/17 were successful and therefore the service would be withdrawn.

4.4 Demand Turn Up

Demand Turn Up is a negative reserve service procured for the first time for Summer 2016. As the name suggests, this service is only available to demand side participants (i.e. participants outside the Balancing Mechanism).

Increases in the amount of embedded generation (such as solar PV and CHP) have driven down electricity demand at the transmission level and now there are significant issues in maintaining system stability at the times of lowest demand in the year. These occur for instance in summer during the night and during the very middle of the day (when PV generation is at its highest). Demand Turn Up rewards providers who can increase the demand on transmission network during these times (for example by increasing consumption or turning down on-site generation).

The service is effectively in trial as NG have been very flexible with requirements like response time and response duration in their first round of procurement (through which 309 MW was contracted). The availability price was set at £1.50/MW/hr and providers could choose a utilisation price of £60/MWh or £75/MWh (providers are able to tender a utilisation price of over £75/MWh, however no availability payment is then available). The footroom required by National Grid for 2017 will be of 3-5GW. However, the exact requirement for

Demand Turn Up is difficult to define as this footroom can be met through a number of solutions and the grid operator will consider all options and take the most economic course of action. In general, the negative reserve requirement is not forecasted to rise significantly over the next five years. Volatility in the maximum requirement can be explained largely by solar PV.

4.5 Synthesis of flexibility products for UK

The following table summarizes main characteristics of the previously described flexibility products.

Table 3 Synthesis of balancing products open to demand response in UK

Service	Volume Requirements	Upward or downward regulation?	Activation Principle	Response Time	Response Duration	Allowed Providers	Aggregation Allowed?	Min. Unit Size	Availability Window?	Availability Payments (£/MW/hr)	Utilisation Payments (£/MWhr)	Market Value (£/MW/yr)	Over delivery acceptable?
BM		Both	Dispatch	5m	1-1.5h	BM Units	In theory	1MW	Live Market	-	0-12,500		
STOR - C	3000MW	Down	Dispatch	~15m **TP**	2h	All	Yes	3MW	Defined	0-10	60-250		Yes
STOR - F		Down	Dispatch	~15m **TP**	2h	Non-BM	Yes	3MW	**TP**	0-5	60-200		Yes
STOR - PF		Down	Dispatch	~15m **TP**	2h	Non-BM	Yes	3MW	**TP**	0-2	60-200		Yes
EO STOR	<300MW	Down	Dispatch	<20m	2h	Non-BM	Yes		Defined	-			Yes
Fast Reserve		Down	Dispatch	2m	15m	All	Yes	50MW		6-8*	100-150	~35,000	Yes
DSBR	500MW	Down	Dispatch		2-4h **TP**	Demand	Yes		**TP**	Service withdrawn			Yes
Dynamic FFR	1200MW	Both	Automatic	<10s	30m	All	Yes	10MW	**TP**	10-20*	-	90-190,000	Yes
MFR		Both	Automatic	<10s	30m	BM Units	No	1MW	Live Market				Yes
EFR		Both (sym)	Automatic	<1s	15m	All	Yes	1MW	**TP**		-	30-52,000	No
Static FFR	800MW	Down	Automatic	30s	30m	All	Yes	10MW	**TP**	~3.2	-	~28,000	Yes
FCDM		Down	Automatic	2s	>30m	Demand	Yes	3MW	**TP**	~2.5	-	~22,000	Yes
DTU	309MW	Up	Dispatch	Flexible	Flexible	Demand	Yes	1MW	Defined	1.50	60/75	10-15,000	Yes

5 Conclusion

This document introduced the structure of balancing products for three different reference markets: Germany, France and the UK. It also described the procurement method and the current payment rates for these products.

This information will facilitate the following:

- Assessment of the flexibility of different electrolysers type with regard to the requirements of each product
- Quantification of the added value of flexibility for electrolysers with respect to these markets
- Development of optimised capacity allocation strategies in order to maximize the added value of flexibility on balancing markets

6 Apppendix

6.1 Germany: additional information

6.1.1 Historical values for reserve requirements

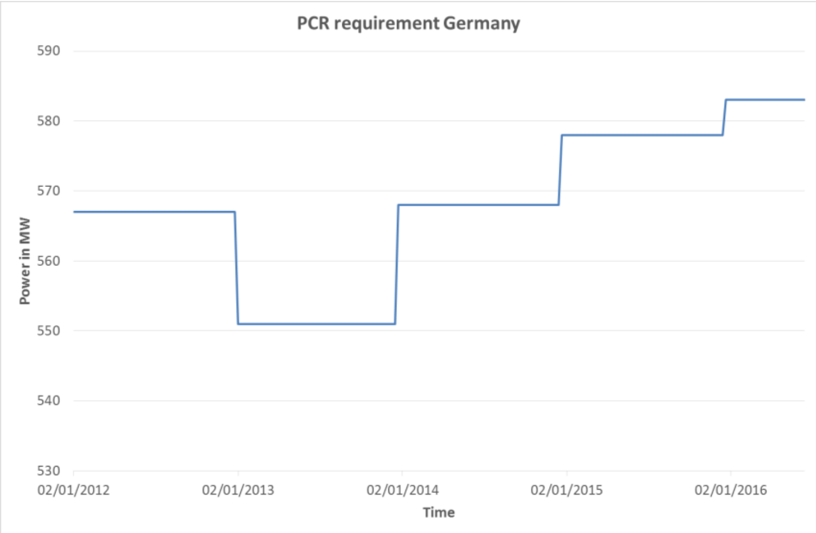

Figure 9 Primary control reserve requirements period 2012/2016

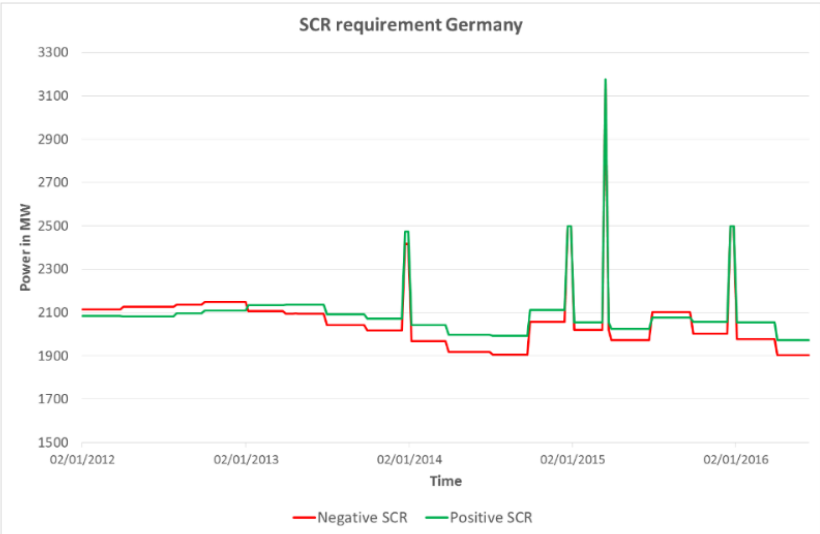

Figure 10 Secondary control reserve requirements period 2012/2016

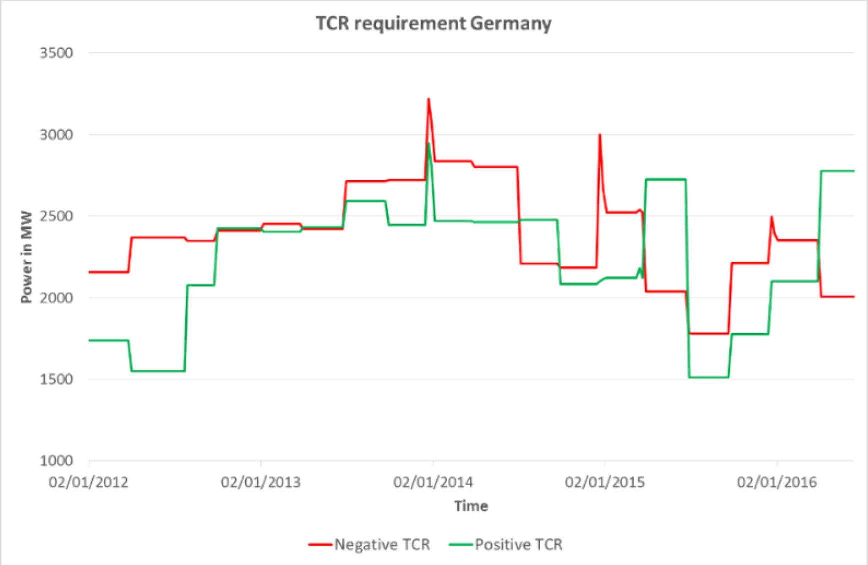

Figure 11 Tertiary control reserve requirements period 2012/2016

6.1.2 Qualifying tests for balancing products in Germany

Primary control reserve

Generalities

The activation signal for the primary control reserve is the grid frequency (local measurement). The idealized activation of the PCR must be:

- proportional to the frequency deviation $f - f_0$ with f_0=50 Hz
- fully activated for $f = 50{,}200\ Hz$ or respectively $f = 49{,}800\ Hz$
- Maintained up to 15 minutes if needed for a ±200 mHz step.

Considering a technical unit providing a certain amount of PCR noted “PCR” [MW/0,2Hz], the idealised response should be equal to (in MW):

$$-5\ PR \cdot (f(t) - f_0) \quad for\ 49{,}8\ Hz < f < 50{,}2\ Hz$$

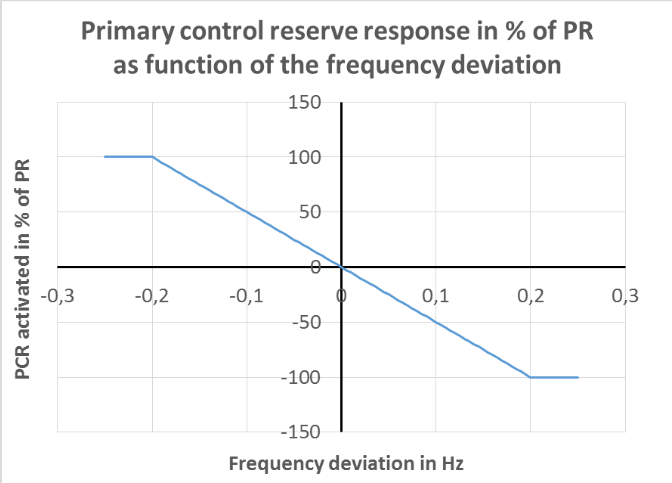

Figure 12 Theoretical primary control reserve response

The amount of PCR provided by a technical unit should correspond at least to 2% of its nominal power.

Precision of the frequency measurement must be better than 10 mHz.

Dynamic requirements

The PCR is expected to be fully activated within 30 seconds, for both positive and negative modulations. The prequalification protocol published by the responsible TSOs is based on a square signal were the system response must be proportional to this activation signal with a lag that does not exceed 30 seconds. Prequalification test protocols are applied the same way for both directions of modulation.

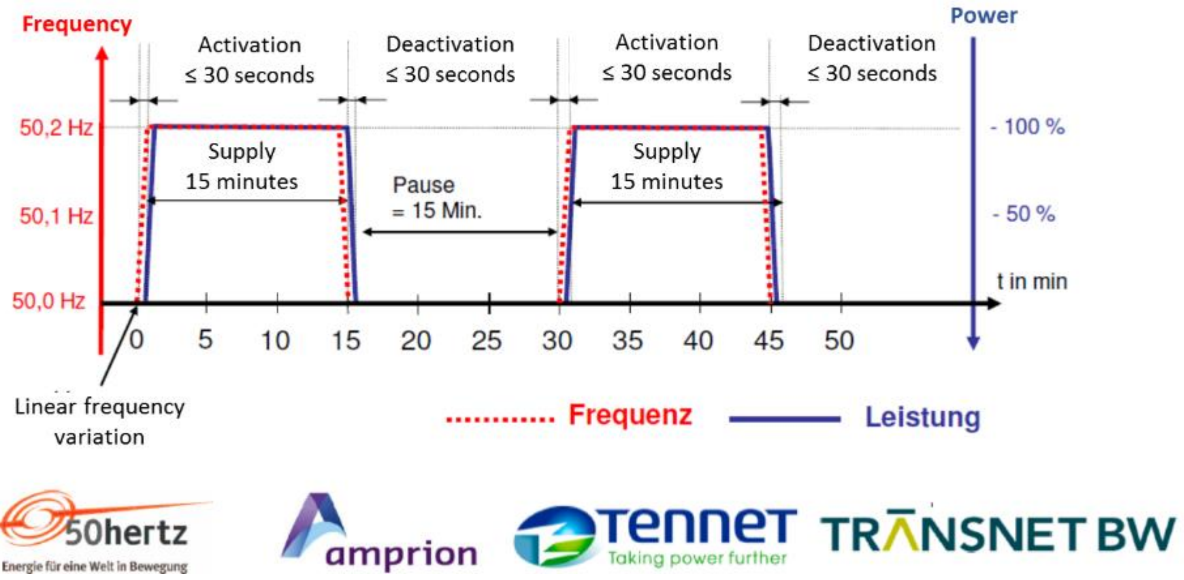

Figure 13 Pre qualifying test protocol for primary control reserve[11]

Additionally, the delivery of PCR must be ensured also during any load following operation.

Degrees of freedom

The dynamic system response is dictated by the idealised response and the limit response corresponding to the minimal dynamic requirements.

[11] Source : www.regelleistung.net

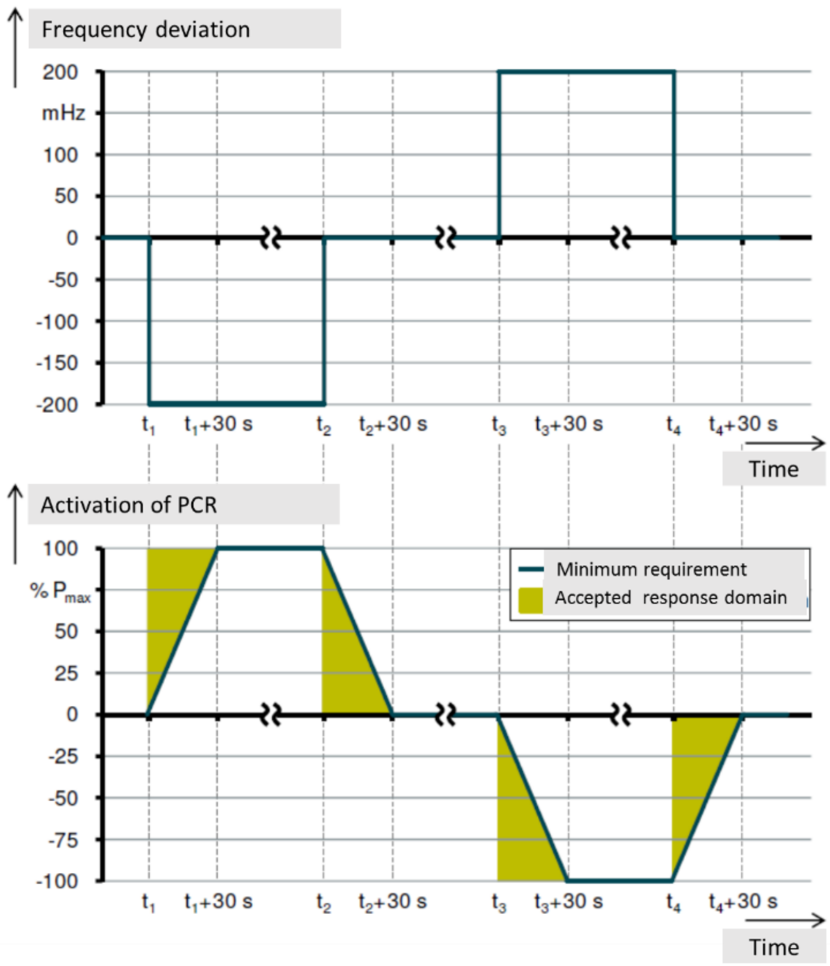

Figure 14 Response dynamic: degree of freedom for primary control reserve[12]

A dead band up to 10 mHz can be tolerated for activation: for frequency deviations lower than 10 mHz (positive or negative direction), PCR does not necessarily need to be activated. The possible use (and the size) of this dead band is conditioned by the accuracy of the frequency measurement (a precision of 10 mHz enables no use of any dead band!)

[12] Source : www.regelleistung.net

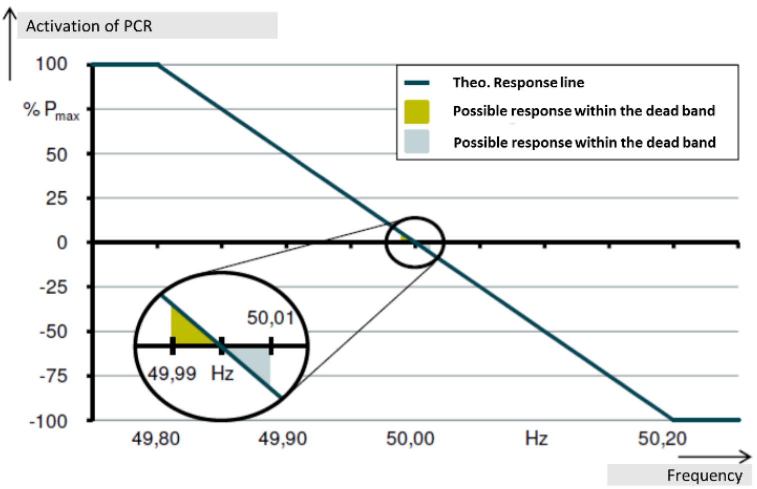

Figure 15 Dead band for primary control reserve response[13]

The response of the system can vary between the theoretical response and up to 120% of the theoretical expected response. This optional over-fulfilment can be defined in the contract signed between the balancing provider and the TSO. The real system response should never fall below the theoretical response line.

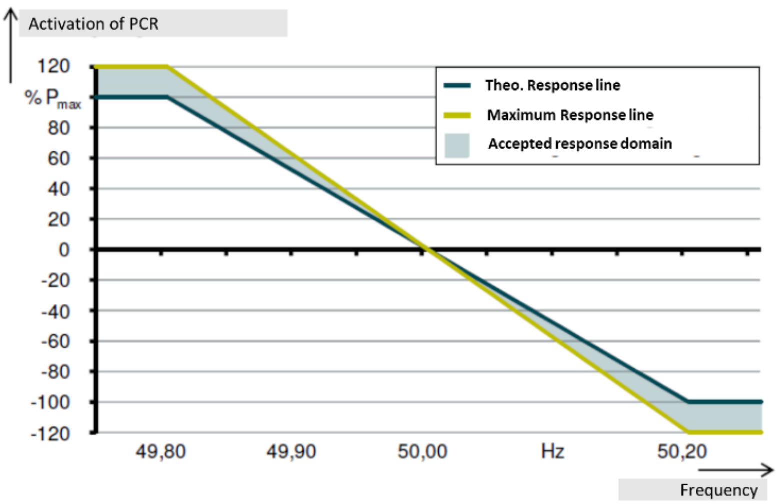

Figure 16 Over-fulfillment tolerance band for primary control reserve

[13] Source : www.regelleistung.net

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under the Grant Agreement n. 700350

Secondary control reserve

Generalities

For the secondary control reserve, the activation signal is decided by the TSO-grouping and dispatched to the relevant units (as the activation is order is based on a financial merit order system). The activation signal is therefore based on price and is adjusted every 5 seconds.

Dynamic requirements

The proposed amount of SCR is expected to be fully activated within 5 minutes. This requirement applies for both positive and negative directions. The prequalification protocol published by the responsible TSOs is based on a square signal were the system response has to fit to this activation signal (sent by the TSO) with a lag that does

not exceed 5 minutes, the first MW of the proposed capacity has to be activated within the first 30 seconds (minimum lot size: 5MW). Prequalification test protocol is applied the same way for both directions of modulation. (The following is an example of test protocol for 25 MW of SCR for positive modulations).

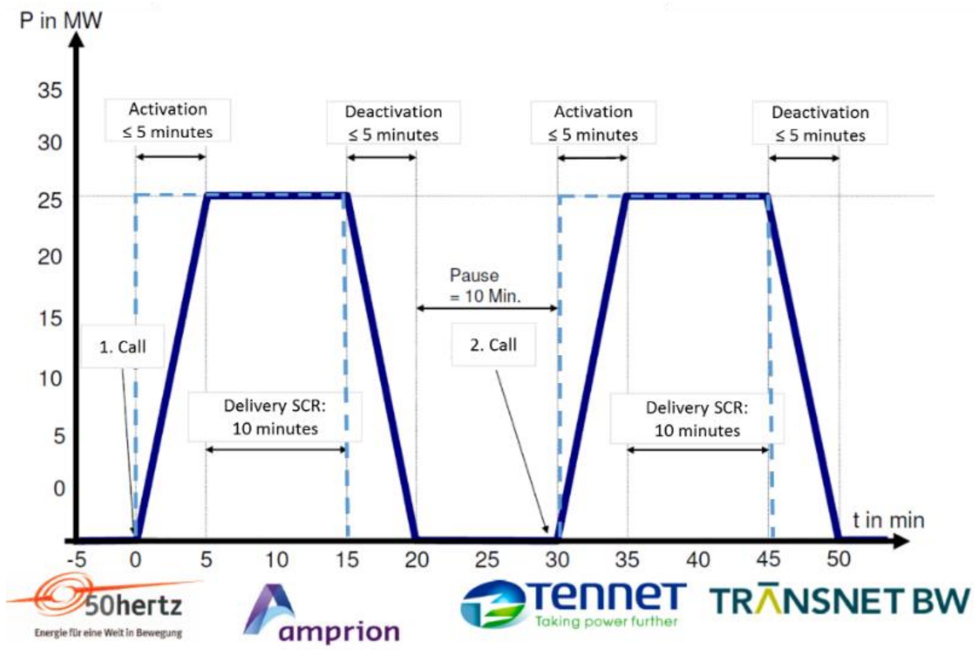


Figure 17 Pre-qualifying test protocol for secondary control reserve[14]

Additionally, the delivery of SCR must be ensured also during any load following operation.

Degrees of freedom

[14] Source : www.regelleistung.net

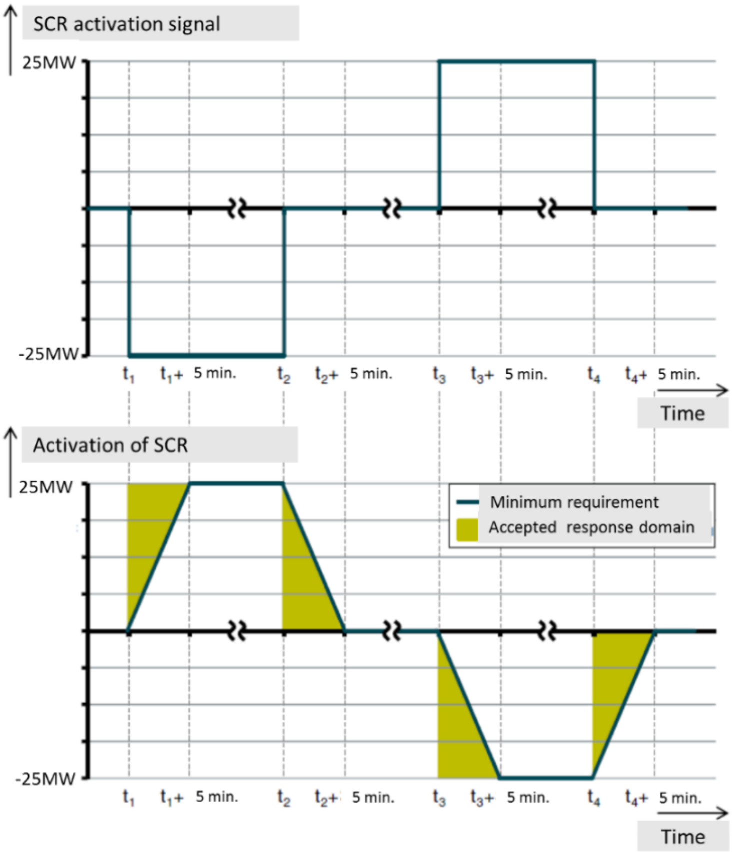


Figure 18 Response dynamic: degree of freedom for secondary control reserve[15]

The dynamic system response can vary between the idealised response and the limit response corresponding to the minimal dynamic requirements. Additionally, a short over activation is tolerated up to 10% of the activation set point.

Tertiary control reserve

Generalities

For the tertiary control reserve, the activation signal is decided by the TSO-grouping and dispatched to the relevant units (as the activation order is based on a financial merit order principle). The activation steps are multiples of 1 MW, apart from when the tender has been

[15] Source : www.regelleistung.net

declared as block tender (the TSO then has the possibility to skip it). Activations orders are based on 15 minute activation schedules.

Dynamic requirements

The TCR is expected to be fully activated within 15 minutes after the release of the last activation order received. This requirement applies for modulations in both positive and negative directions. The prequalification protocol published by the responsible TSOs is based on a square signal (sent by the TSO) where the system response must fit to this activation signal with a lag that do not exceed 15 minutes. Prequalification test protocol is applied the same way for both directions. (The following is an example of test protocol for 30 MW of TCR).

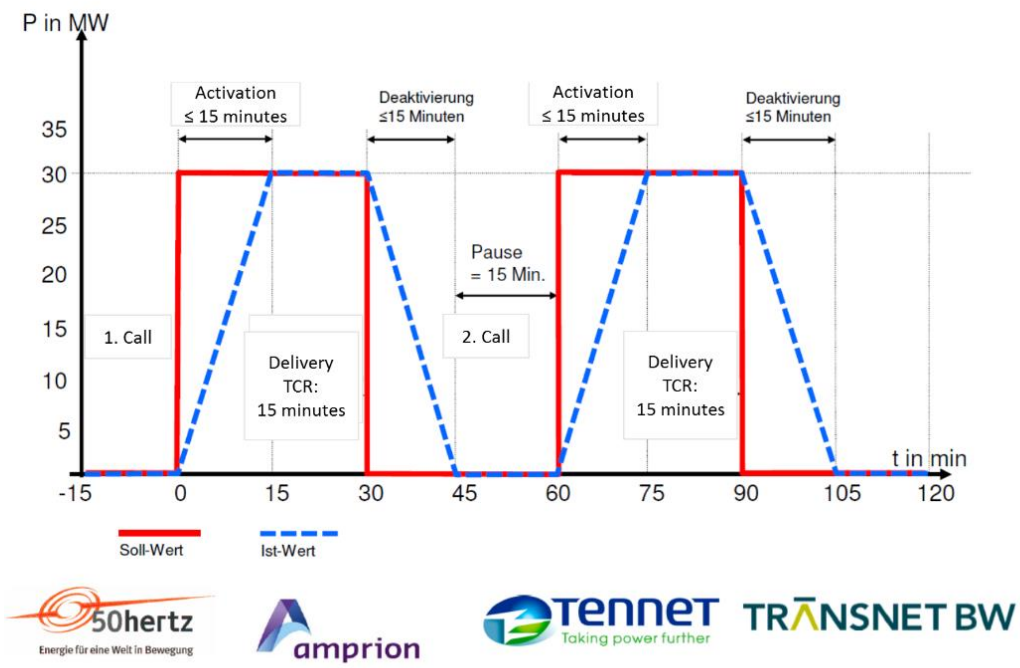


Figure 19 Response dynamic: degree of freedom for tertiary control reserve[16]

[16] Source : www.regelleistung.net

6.1.3 Examples of payment s for balancing products in Germany

Notice: Past performance is not a guide to future performance

Primary control reserve

The following table shows the availability payments observed for primary control reserve (in €/MW/h)

	Average Values in €/MW/h					
	Min	**25%**	**Median**	**75%**	**Max**	**Interval**
2012	15,04	15,81	16,16	17,15	20,58	5,54
2013	16,69	17,32	17,60	17,97	19,06	2,37
2014	19,19	20,15	20,73	21,48	23,82	4,62
2015	20,10	21,25	21,76	22,35	23,68	3,58

Table 1 – Average capacity payments observed for primary control reserve in Germany

Secondary control reserve

Capacity based remunerations

The following table shows the availability payments observed for primary control reserve (in €/MW/h)

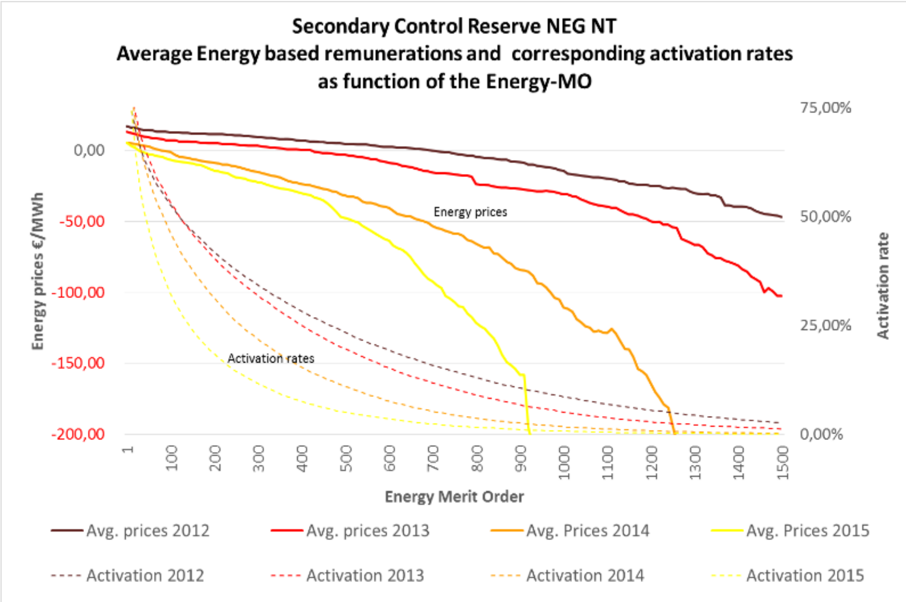
	Average Values in €/MW/h (Product: NEG HT)							Average Values in €/MW/h (Product: NEG NT)					
	Min	**25%**	**Median**	**75%**	**Max**	**Interval**		**Min**	**25%**	**Median**	**75%**	**Max**	**Interval**
2012	4,62	6,38	7,04	7,89	30,20	25,59	2012	9,01	10,89	11,46	12,44	36,16	27,15
2013	7,94	9,71	10,60	11,79	36,40	28,46	2013	8,42	9,65	10,21	11,09	15,40	6,98
2014	2,92	4,29	5,04	6,21	11,09	8,17	2014	2,91	3,95	4,49	5,06	6,40	3,50
2015	0,72	1,60	1,91	2,20	2,83	2,11	2015	1,45	2,38	2,81	3,18	4,00	2,55

	Average Values in €/MW/h (Product: POS HT)							Average Values in €/MW/h (Product: POS NT)					
	Min	**25%**	**Median**	**75%**	**Max**	**Interval**		**Min**	**25%**	**Median**	**75%**	**Max**	**Interval**
2012	1,03	1,43	1,66	1,98	2,73	1,70	2012	2,18	2,61	2,80	3,05	3,62	1,44
2013	6,92	8,24	8,83	9,47	11,38	4,46	2013	5,15	6,13	6,56	7,08	8,24	3,09
2014	5,85	6,97	7,49	8,06	9,87	4,01	2014	5,63	6,66	7,13	7,68	9,33	3,70
2015	4,58	5,43	5,87	6,40	7,44	2,86	2015	4,06	5,04	5,47	5,96	7,22	3,16

Table 2 – Average capacity payments observed for secondary control reserve in Germany

Energy based payment

The following charts show the activation payments observed for secondary control reserve (in €/MWh), sorted in the financial merit order with corresponding activation rates observed (average yearly values).



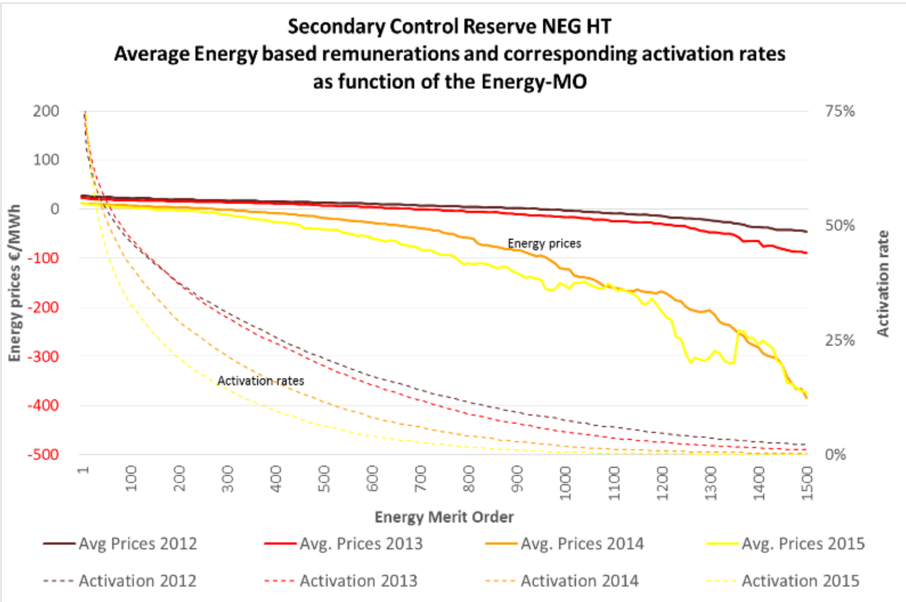
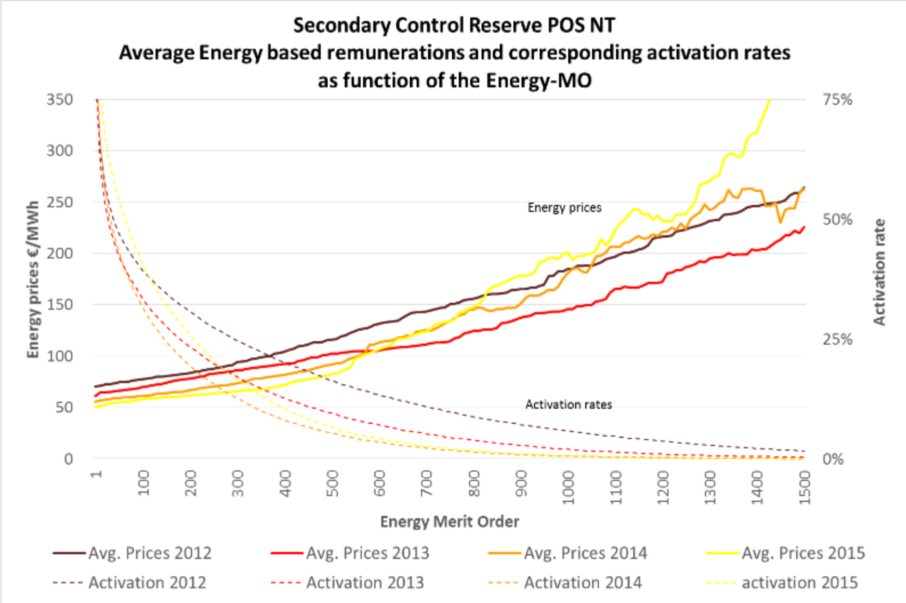


Figure 20 Energy payment and activation rates for secondary control reserve (NEGATIVE)



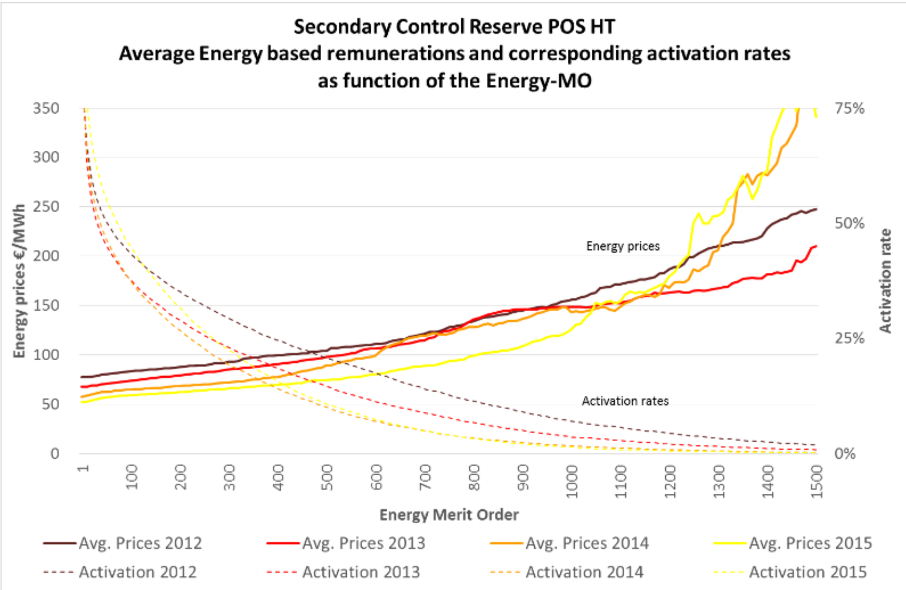


Figure 21 Energy payment and activation rates for secondary control reserve (POSITIVE)

6.2 France: additional information

6.2.1 Performance control for balancing products in France

Primary control reserve: expected system response to a step signal

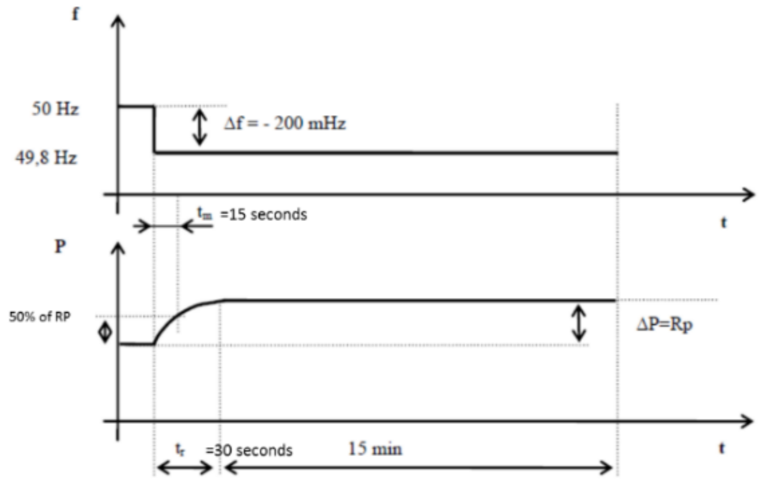


Figure 22 Power response to a frequency step (primary control reserve)[17]

Secondary control reserve: expected system response to an emergency ramp

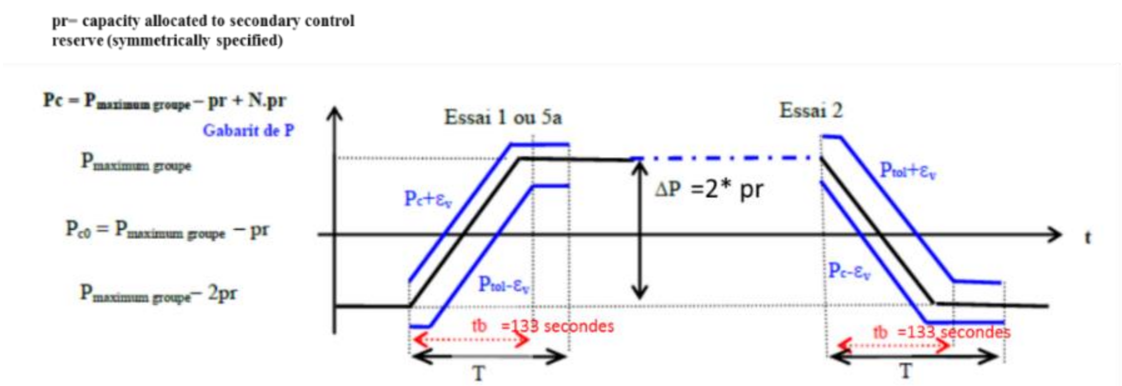


Figure 23 Power response to an emergency ramp (secondary control reserve)[18]

[17] Source : RTE DTR Article 8.14.1 « Trame de Rapport de contrôle de conformité des performances d'une installation de production »

[18] Source : RTE DTR Article 8.14.1 « Trame de Rapport de contrôle de conformité des performances

6.2.2 Example of payments for balancing products in France

Primary and secondary control reserve

Secondary reserve (mandatory reserve) is still paid for by RTE with a flat rate of ~18 €/MW/h. Since the beginning of 2017, primary control reserve is procured via tender through the internet platform www.regelleistung.net (no valuable historical data at that time).

Tertiary reserve

Capacity based remuneration 2017 (for fast and complementary reserves)

Réserves rapide et complémentaire 2017 : résultats

13/10/2016 Source : RTE - DC

RTE retient 11 acteurs d'ajustement, avec une participation accrue de nouvelles capacités et une diminution du coût de contractualisation.

Lancé en septembre 2016, l'appel d'offres visant à la contractualisation des réserves rapide et complémentaire pour la période allant du 1er janvier au 31 décembre 2017 a permis à RTE de retenir 11 sociétés : Actility, Alpiq Energie France, CNR, EDF, Energy Pool Développement, Engie, Novawatt, Smart Grid Energy, Solvay Energy Services, Taranis Commodities et Voltalis. Parmi les 1500 MW de réserve contractualisée, plus de 480 MW seront mis à disposition par des capacités d'effacement. Pour la première fois, des capacités d'effacement diffus contribueront à la réserve rapide. Ces capacités mettront en œuvre des modalités d'observabilité spécifiques dans le cadre de l'expérimentation « observabilité statistique ».

Malgré un volume d'offres réduit sur certaines semaines de l'hiver, le besoin exprimé par RTE a été couvert en totalité. La forte concurrence sur le marché des réserves rapide et complémentaire a permis de maintenir un coût de contractualisation maîtrisé. Le montant total de la contractualisation s'établit à 36,3 M€, avec un prix de la réserve rapide de 24,3 k€/MW/an (contre 28,6 en 2016) et un prix de la réserve complémentaire à 16,4 k€/MW/an (contre 18,2 en 2016).

La contractualisation découlant de cet appel d'offres assure une rémunération complémentaire des industriels, des installations de stockage, et des groupes de production, en contrepartie d'une mise à disposition permanente de la capacité (24h/24 et 7j/7).

Les réserves rapide et complémentaire contribuent ainsi à la sûreté de fonctionnement et à la gestion de l'équilibre offre-demande du système électrique. Elles peuvent être indifféremment composées de groupes de production ou d'effacements de consommation de sites raccordés sur le réseau public de transport ou sur le réseau public de distribution.

Pour en savoir plus, consultez la dépêche relative au lancement de la consultation 2017

Les prix marginaux hebdomadaires sont disponibles ici : tableau des prix marginaux Janvier-Décembre 2017

Figure 24 Results of the call of tenders for fast and complementary reserves 2017[19]

Energy based remuneration for tertiary reserve (example of monthly report)

d'une installation de production »

[19] Source : site RTE https://clients.rte-france.com

Each month, RTE publishes a report related to the use of tertiary reserves. The following charts have been extracted from the report of Avril 2016 as example. The two following show the utilisation payment observed for the activation of positive and negative tertiary reserve.

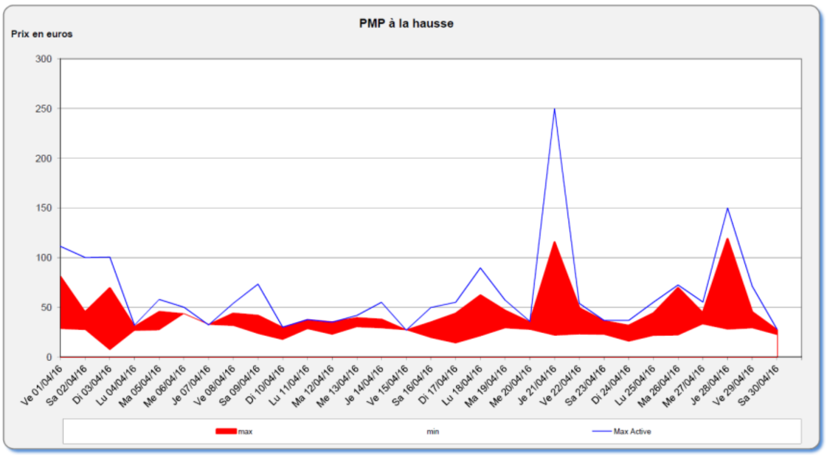


Figure 25 Observed price range of tertiary reserve (Up) activated Avril 2016 €/MWh[20]

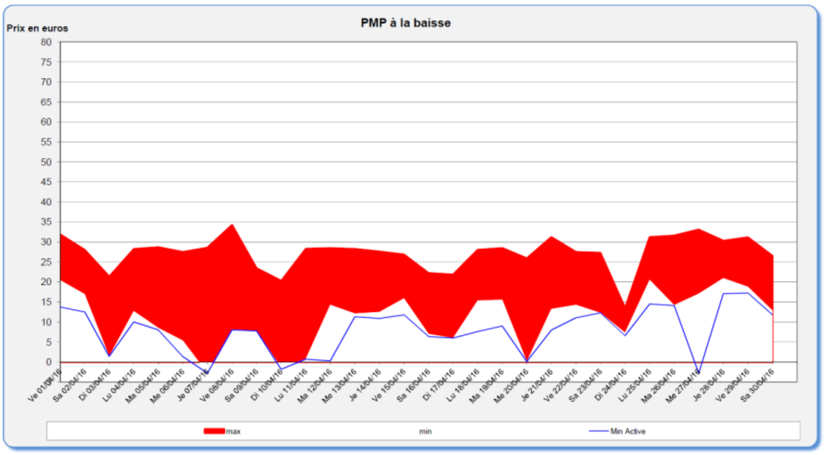


Figure 26 Observed price range of tertiary reserve (Down) activated Avril 2016 €/MWh[21]

[20] Source : site RTE https://clients.rte-france.com

[21] Source : site RTE https://clients.rte-france.com

The following pie-charts show the contribution of each asset type to the provision of tertiary reserve (in terms of energy effectively activated). In April 2016, demand side management accounted for only 0.32% of the activated positive tertiary reserve (0% for negative tertiary reserve).

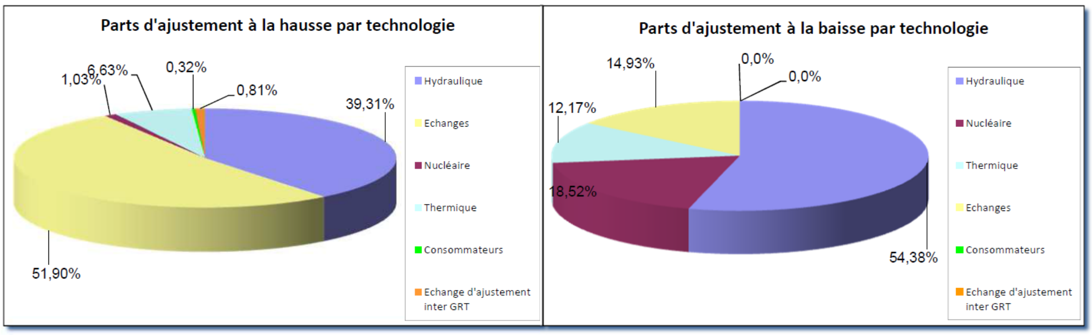


Figure 27 Contribution to activated energy volumes by technologies types (April 2016)[22]

6.2.3 Possible combination of products/mechanisms

The following matrix illustrates the possible combinations of products or mechanisms achievable in order to valorize flexibility with compliance to the grid rules.

[22] Source : site RTE https://clients.rte-france.com

	Consumption Cut-off Capacities	Rapid and Additional Reserves	Adjustment Mechanism	Spot Market	Capacity Market	Ancillary Services	Interruptibility
Consumption Cut-off Capacities							
Rapid and Additional Reserves	✘						
Adjustment Mechanism	✔	✔					
Spot Market	✔	✔	✔				
Capacity Market	✓	✓	✓	✓			
Ancillary Services	✘	✘	✔	✔	×		
Interruptibility	✓	✓	✓	✓	×	✘	

✓	Yes	✔	Yes, but not simultaneously
×	No, because of the rules	✘	Yes, but loss of value because of unavailability

Figure 28 Combination matrix of products/mechanisms[23]

[23] Source : E-Cube Consulting

6.3 UK: additional information

6.3.1 Historical values for reserve requirements

Frequency response

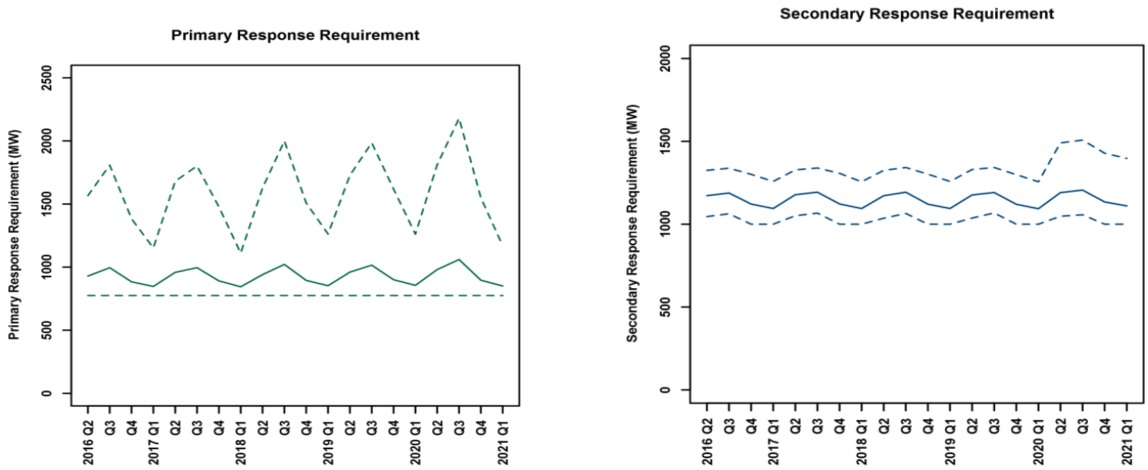


Figure 29 Expected primary and secondary response requirements until 2020[24]

On average, the requirement for primary response remains unchanged most of the time (full line), excluding days when there is low system inertia (requirement corresponding to the top dotted line). A similar trend is observable for the requirement regarding the secondary frequency response.

[24] Source: National Grid "Future requirements for Balancing services"

Reserve

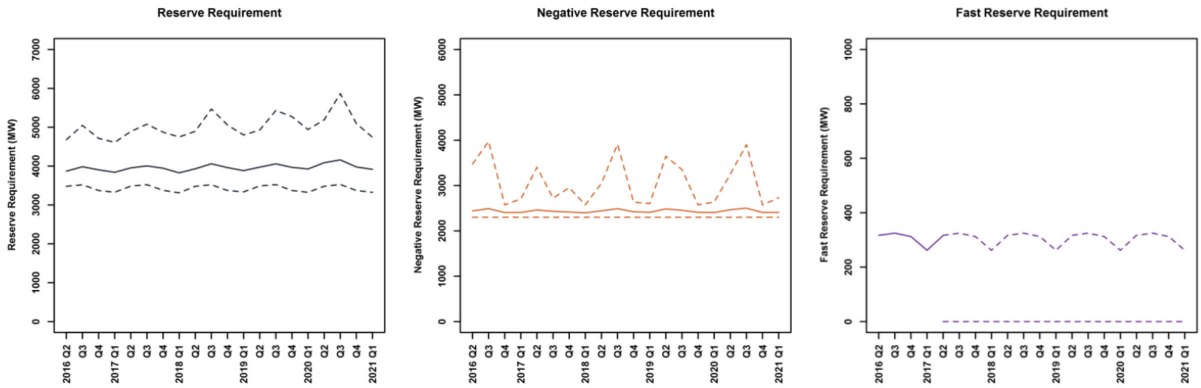


Figure 30 Expected evolution of reserve requirements until 2020[25]

(Positive) reserve requirements slowly increase over the next five years, due mainly to the increase in the need for reserve for response and reserve for wind. The requirement for negative reserve is largely unchanged.

[25] National Grid "Future requirements for Balancing services"

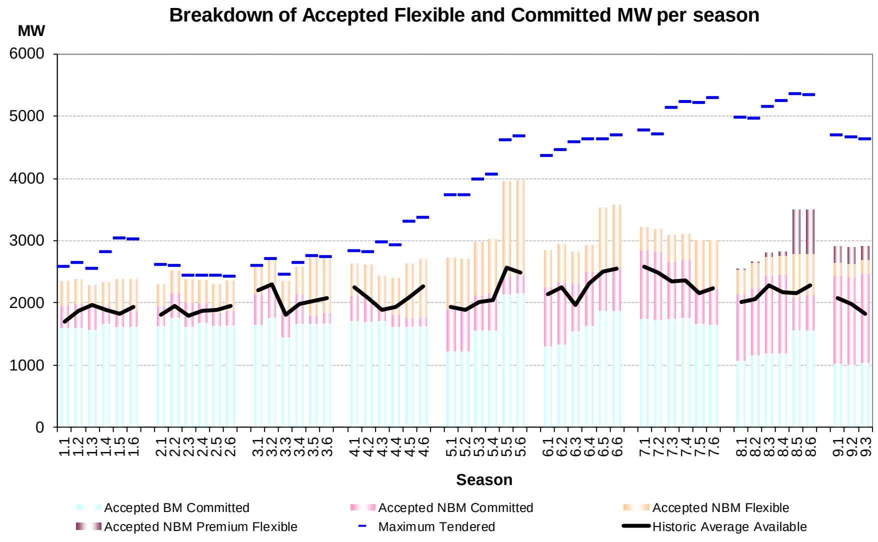


Figure 31 tender and accepted STOR volumes to summer 2016[26]

[26] Source : National Grid

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9 References

Reports

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[2] Verband der Netzbetreiber: “Transmission Code 2007 Network and System Rules of the German Transmission System Operators“ 2007.

[3] RTE : “Règles services système”. 2017.

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[5] National Grid : « Grid Code" – BC3 Frequency Control Process

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[8] http://www2.nationalgrid.com/uk/services/balancing-services/

10 Glossary

ACER	Agency for the Cooperation of Energy Regulators
AM	Adjusting mechanism
DSBR	Demand Side Balancing Reserve
EDF	Electricité de France
EFCC	Enhanced Frequency Control Capability
EFR	Enhanced Frequency Response
ENTSO-E	European Network of Transmission System Operators for Electricity
FCDM	Frequency Control by Demand Management
FFR	Firm Frequency Response
GCC	Grid Control Cooperation (Association of German TSOs)
H2ME	H2 Mobility Europe
HT	High load hours (time slice for secondary control reserve in Germany)
Hz, mHz	Hertz, unit for frequency measurement
IL	Interruptible Load
MO	Merit order (financial)

ms	millisecond (Time unit)
MW	Megawatt (Power unit)
MWh	Megawatt-hour (Energy unit)
N	Setting level for secondary control reserve in France («Niveau de Réglage Secondaire de Fréquence – Puissance »)
NG	National Grid (TSO for UK)
NT	Low load hours (time slice for secondary control reserve in Germany)
PCR	Primary Control Reserve
RC	Complementary reserve (R30)
RP	Primary Control Reserve
RR	Fast reserve (R13)
RS	Secondary Control Reserve
RTE	Réseau et Transport d'Electricité (French TSO)
RTE	Tertiary Control Reserve
SCR	Secondary Control Reserve
SNL	Rapidly interruptible load ("Schnell aschaltbare Lasten")
SOL	Immediately interruptible load ("Sofort abschaltbare Lasten")
STOR	Short Term Operating Reserve
TCR	Tertiary Control Reserve
TSO	Transmission System Operator
UK	United Kingdom

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