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**Research Report**

## Empirics of Intraday and Real-time Markets in Europe: Spain

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# Empirics of Intraday and Real-time Markets in Europe: Spain

Pablo Rodilla & Carlos Batlle<sup>1</sup>

*Abstract*

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## Índice

1. Brief overview of the timing of the markets run by the MO and the TSO in Spain .....	3
2. Technical Constraint Resolution Markets (TCRM): the mechanism to carry out TSO-driven redispatches .....	7
2.1. TSO requested information and system state forecast.....	7
2.2. Description of the TCRM two-phase mechanism .....	8
3. Balancing services markets .....	9
3.1. Balancing responsible parties in Spain.....	9
3.2. Balancing reserves products .....	10
3.3. Balancing reserve requirements.....	12
3.4. Market mechanism for procuring regulation reserves .....	13
3.5. Mechanisms for pricing and allocating balancing energy costs .....	14
3.5.1. Secondary energy usage .....	14
3.5.2. Tertiary energy usage .....	15
3.5.3. Imbalance pricing.....	16
4. Another type of reserve: the interruptibility service .....	17
5. Critical assessment and conclusions .....	18
6. References .....	20
7. ANNEX A- Coordination of forecasts with neighboring countries .....	21

## Acronyms

BRP – Balancing Responsible Parties

DA – Day Ahead

DAFFD – Day Ahead Final Feasible Dispatch

DAM – Day Ahead Market

ID – Intra Day

IDM – Intra Day Markets

MO – Market Operator

OMIE - Operador del Mercado Ibérico polo Español

OMIP - Operador del Mercado Ibérico polo Portugués

RT – Real Time

TCRM- Technical constraints resolution market

TSO – Transmission System Operator

## 1. Brief overview of the timing of the markets run by the MO and the TSO in Spain

In the long term horizon, there is an organized market of long-term (financial and physical) energy contracts that is managed by the Iberian Energy Market Operator OMIP<sup>2</sup>. Market agents can also enter into bilateral contracts with a delivery timeframe established by the market parties involved in these contracts (OTC, over the counter), in parallel with those organized production markets. These contracts can be signed prior to the day before delivery.

The short-term power production market in Spain, the focus of this paper, is integrated by a set of commercial transactions of energy (purchases and sales) and also by the so-called system adjustment services, both type of transactions involving a range of different time frames.

In order to ease the description of the elements making up the short-term electricity market in Spain, it is worth sketching beforehand the timing of these markets. In Fig. 1 this sequence is represented. The energy markets, all being run by the Market Operator (OMIE<sup>3</sup>), have been represented in green, while the adjustment services markets, which are run by the TSO (REE<sup>4</sup>), have been represented in blue. Dark and light rectangles (either green or blue) represent respectively the time interval for the market processes and the time horizon for the schedules associated to each market process.

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<sup>2</sup> Operador del Mercado Ibérico polo Portugués

<sup>3</sup> Operador del Mercado Ibérico, polo Español

<sup>4</sup> Red Eléctrica de España

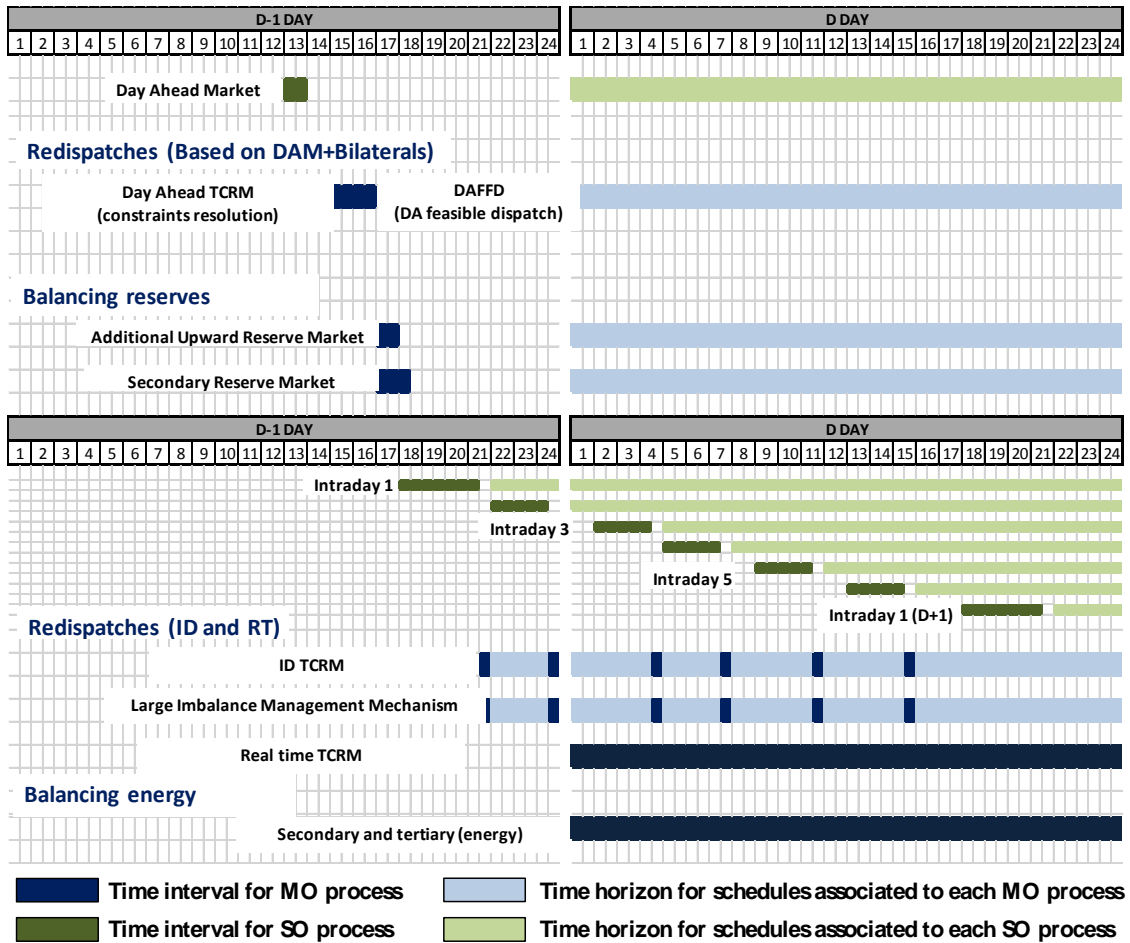


Fig. 1. Timing of the MO and SO markets in Spain (source: own elaboration based on REE)

The energy markets run by the MO are fully integrated between Spain and Portugal, leading to an implicit allocation of the cross-border capacity connecting both systems. As well-known, the integration of the Iberian energy markets in the DA horizon is at the EU level (by means of the Price Coupling of Regions). The markets for system adjustment services are not integrated, however, and Spain and Portugal TSOs (REE and REN respectively) manage them independently.

Therefore, as it is common practice in most European systems, energy and system adjustment services are procured in a not fully co-optimized way, although these markets are closely linked as we shall see.

### Day Ahead and Intraday markets (MO):

Short-term energy markets run by the Market Operator consists of a Day Ahead Market (DAM) and Intraday Markets (IDM). In the shorter term, intraday markets allow market agents to first adjust the schedules resulting from the DAM and then to also adjust their subsequent schedules

as real time approaches. These markets are designed as a sequence of six discrete auctions, held every four hours<sup>5</sup>.

It is noteworthy that in Spain, intraday markets are the only means for generators to change the schedule committed after DAM, since no bilateral transactions are allowed after this market. Intraday markets are also used, as we shall see, to adjust the schedule of generating plants having committed upward regulation reserve and not being able to ensure its provision - although the intraday volumes associated to this latter driver are low-. For these two reasons, among others<sup>6</sup>, the Spanish intraday markets present greater liquidity than many other European intraday markets. For a detailed discussion about the reasons behind this high liquidity as well as empirical evidence, see (Chaves & Fernandes, 2015).

Electricity sale bids presented by sellers to the market operator in the intraday market may be simple or incorporate complex conditions. Simple bids are electricity sale bids consisting of 1 to 5 price-quantity blocks that the physical units present for each hourly period and each production or purchase unit that they own.

Allowed complex conditions in intra-day markets are: (i) load gradient constraints, (ii) minimum income condition, (iii) complete acceptance of the first block of the sale bid, (iv) minimum number of consecutive hours of complete acceptance of the first block of the sale bid, and (v) maximum matched energy. For further details on these complex conditions, please refer to the website of the MO<sup>7</sup>.

#### **System adjustment services markets (TSO):**

System adjustment services are run by Spanish TSO and involve: (i) the Technical Constraints Resolution Market, (ii) the procurement of balancing reserves (balancing capacity), (iii) the large imbalances management mechanism and (iv) the use of balancing energy. We briefly introduce them next and further analyze its design and performance in subsequent sections:

(i) The Technical Constraints Resolution Market (TCRM<sup>8</sup>). This market focuses on carrying out redispatches to solve system constraints, including network constraints, security considerations, coal production quotas (a transitory mechanism), etc. These markets are systematically run after each energy market session (DAM and IDM), but can also be called at any time based on the TSO criterion. As illustrated in Fig. 1, the first TCRM is called right after the DAM. The TSO takes the declared programs derived from bilateral contracts and the DAM results, checks their technical feasibility and makes any necessary adjustments (redispatches). As a result of the redispatches the so-called Day Ahead Final Feasible

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<sup>5</sup> Since the scheduling horizon corresponding to the first intraday market of Day D begins at 22 h of Day D-1, in practice there are seven intraday markets where the energy in the last hours of the day can be traded. This can be easily observed in Fig. 1.

<sup>6</sup> There are two additional reasons that have increased liquidity in intraday markets: first and foremost, there have been price arbitrage opportunities between de DAM and IDM in the last years. Second, the details about the national coal support mechanism has given incentives to some units to avoid being committed in the DAM and bidding in the IDM instead.

<sup>7</sup> <http://www.omie.es/> (<http://www.omie.es/en/home/markets-and-products/electricity-market/our-electricity-markets/intraday-market>)

<sup>8</sup> Mercados de Resolución de Restricciones Técnicas in Spanish.

Dispatch (DAFFD<sup>9</sup>) is obtained. After the DAFFD, it follows the procurement of balancing reserves (secondary reserve and the additional upward reserve).

(ii) The procurement of balancing reserves (or balancing capacity) for ensuring the provision of frequency regulation services. Primary regulation capacity provision is obligatory and not remunerated, while secondary regulation capacity and additional upward regulation capacity are procured through market mechanisms.

During the operation day, there is a mechanism whose objective is to deal with large expected imbalances.

(iii) The large imbalances management mechanism. This mechanism is (at least in theory) thought as an exceptional tool for the SO to resolve large expected imbalances between generation and demand (>300MW) which could appear between the end of one intraday market session and the beginning of the next one. In other words, it is a kind of one-sided intraday market run by the TSO which is called only when the expected imbalance is large.

All the previous processes take place ahead of real time. The last system adjustment service corresponds to the real time energy usage for balancing.

(iv) The shortest term “system adjustment service” is the use of frequency regulation (energy) in the real time. This includes the actual use of energy associated to the secondary regulation capacity (fast response regulation) and upward regulation capacity (slower response regulation) and also the tertiary regulation procurement in real time.

As shown in the figure below, in 2014, the system adjustment services that involved a larger volume of energy were the day-ahead technical constraint resolution market and the tertiary regulation market.

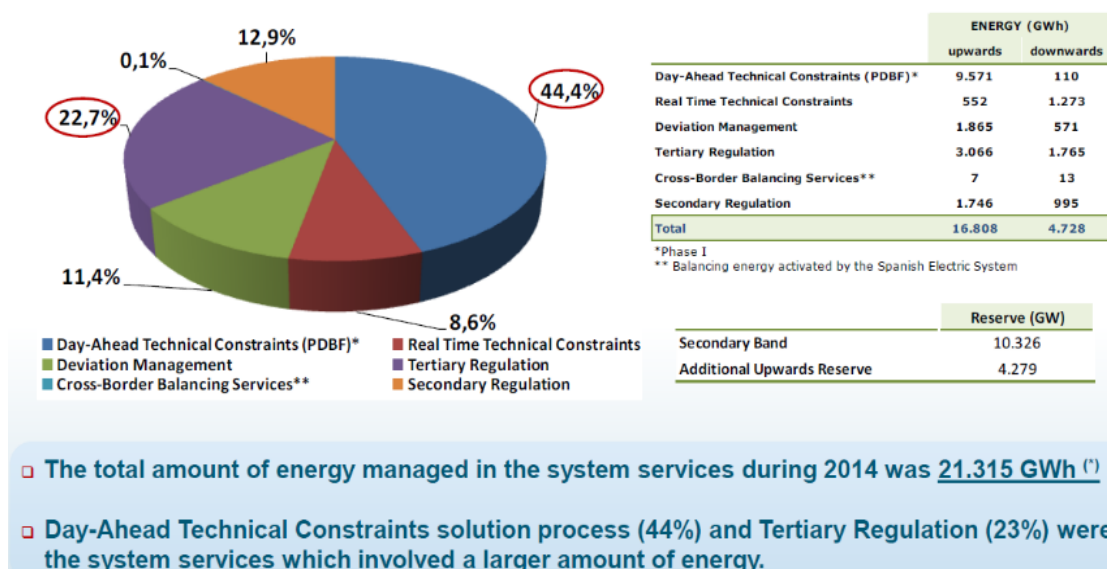


Fig. 2. Energy used in system adjustment services Markets. Source: REE

<sup>9</sup> PDVD in Spanish (Programa Diario Viable Definitivo)

In the remainder of the document we focus on the system adjustment services. First, in Section 2 we review the TSO-security-driven redispatches, which are carried out by means of the so-called Technical Constraint Resolution Markets. Then in Section 3 the procurement of balancing services (reserve and energy) is analyzed.

## **2. Technical Constraint Resolution Markets (TCRM): TSO-driven redispatches**

This section characterizes the essential elements of the TSO-driven redispatch mechanisms in Spain. It discusses how the processes work in practice and their performance.

The information needed by the TSO to estimate the system state and determine the redispatches is first described. Then, we review the two-phase mechanism implemented in Spain to carry out these redispatches.

### **2.1. TSO requested information and system state forecast**

In order to ensure the feasibility of the dispatches, it is essential that the TSO verifies at all times that commercial transactions can be physically delivered. To do so, the TSO needs to make forecasts (e.g. demand and/or RES-E production), check the network state and also request and manage a large amount of information from market agents (e.g. expected schedules, availability, etc). The timing for making forecasts and requesting information to agents varies from one system to another in the EU.

In Spain, the TSO makes a continuous forecast of demand and RES-E production in the short-term<sup>10</sup>. The first relevant TSO forecast is made public just before the DAM session<sup>11</sup>.

The TSO obtains information about all physical schedules from the DAM results and the declared programs (also in the DA horizon) derived from bilateral contracts. While in the DAM the bidding is made on a unit-by-unit basis for thermal plants, this is not the case for other types of units. Right after the Day Ahead Market is closed, after nominating bilateral contracts, all generation companies have to disaggregate their production programs on a physical unit-by-unit basis for the TSO (RES-E production can however be aggregated at this stage, although we will review that there are constraints as regards the level of aggregation applying to imbalance settlement).

The TSO bases on the DAM dispatch (unit by unit basis) and on system forecasts many relevant actions aimed at ensuring the short to very short-term security of supply. As a way of example, redispatches and procurement of balancing reserves (capacity) after the DAM (that is, secondary reserve and the additional upward reserve) are based on this “guiding” day-ahead “physical” dispatch.

Despite the relevance of this dispatch, there are no specific incentives for units to provide reliable data other than those provided by pure market price signals. Indeed, there is empirical evidence that some generators and also some retailers have not provided bids representing their

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<sup>10</sup> The TSO also carries out many medium- and long-term planning assessments, but they are mainly focused on ensuring that enough generating resources are in place to meet future demand requirements.

<sup>11</sup> Relevant TSO’s forecasts are published at <http://www.esios.ree.es/web-publica/>.



actual willingness to buy or sell physical energy in the DAM, see for instance the discussions in (CNE, 2011), (CNE, 2012).

Generators are obliged to update their programs, unavailabilities, and their capability to provide the different services called by the TSO (reviewed below) as soon as possible. Programs can be updated up to the (last) gate closure. The gate closure in Spain is one hour ahead of real time.

Built upon the result of integrating bilateral contracts with the results obtained from the day-ahead energy market, the SO starts the network analysis and solves technical constraints, analyzing the programs of the production plants and the forecasted international exchanges.

Based on this analysis, the TSO detects zonal constraints and minimum and maximum production limits on a locational basis. These limits are made public and taken into account in all subsequent markets, i.e. intraday markets include some additional constraints that are included in the clearing algorithm so as to avoid schedules that violate security criteria.

Additionally, the TSO has to coordinate forecasts with neighboring countries (Portugal and France). The details on this coordination can be found in ANNEX A.

## **2.2. Description of the TCRM two-phase mechanism**

As sketched in the introduction, the Technical Constraints Resolution Markets are called systematically right after the day-ahead and intraday markets sessions are closed and cleared. Redispatches can also be called upon when deemed necessary by the TSO during the real-time operation of the system. Usually the largest volumes of redispatches are decided after the DAM.

After every intraday market session a short-term security analysis is carried out, analyzing the changes in programs derived from these markets and also the updated forecasts of demand, wind and solar power production, and/or the updated expected status of the transmission network and/or the generation. The TSO tends to solve technical constraints by reducing some accepted bids in the intraday market (while also taking into account the economic merit order).

The TSO permanently analyzes the actual and expected system state along the entire programming horizon and detects possible technical constraints that appear in the next programming periods. The possible imbalances between generation and demand caused by the technical constraints resolution identified in real time are solved jointly, with the rest of the deviations that could appear in real time, through the usage of real-time balancing services.

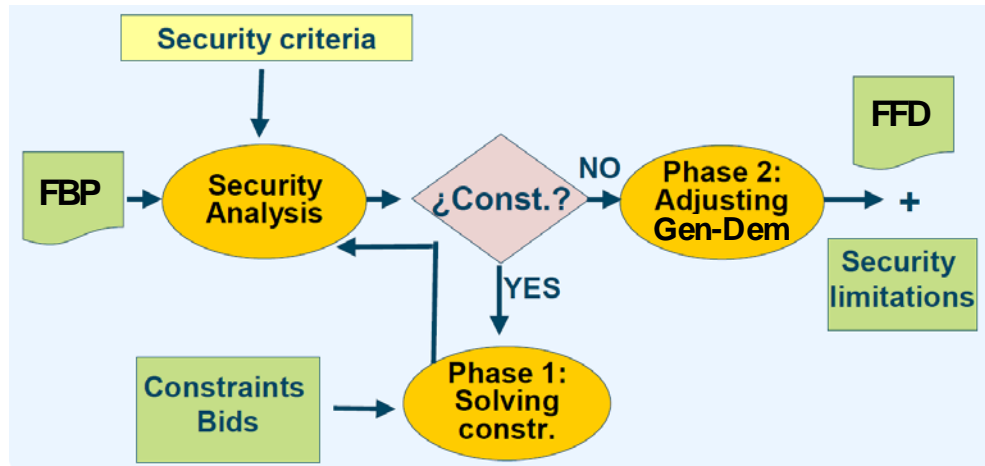
The mechanism for carrying out TSOs driven redispatches is market based. TSO measures are based on the acceptance of offer bids of market participants that are able to deal (alleviate) the constraints. These bids are based on an upward/downward energy bid system. The TSO may apply, in the case of having some equivalent technical solutions, different discrimination criteria based on the bids that guarantee a minimum cost.

The technical constraints market is divided into two sequential stages:

- 1st Phase: Resolution of the technical constraints identified in the system through the application of the program limitations and redispatching both upwards and downwards. In this phase the national balance between generation and demand is usually lost.

- 2nd Phase: Re-programming of the generating units, of the energy imports and/or of the pump storage units, subject to program limitations established in the 1st stage, with the purpose of reestablishing the generation-demand schedules balance.

In the following figure this two-phase mechanism is represented.



FBP – Final Basic Program (Program resulting from the DAM results plus bilateral contracts)  
FFD – First Feasible Dispatch

Fig. 3 Technical constraints resolution market process. Source: REE

In the regulation it is established that bids should be chosen based on a cost minimization criterion. This has been interpreted by the TSO as a requirement to minimize the acquisition cost in Phase 1 without accounting for the cost consequences in Phase 2. As a consequence of this decision, some gaming strategies have arisen.

Regarding the associated cost allocation, all costs are paid by the demand side according to metered consumption (except for pumping and exports).

Units affected by the redispatch can still participate in subsequent intraday markets or provide balancing services as long as they do not generate constraints (which is usually the case if they were called to increase or reduce production to solve a zonal constraint). As mentioned above, once the zonal constraints are identified based on the DAM, maximum and minimum zonal productions are imposed in the IDMs.

### 3. Balancing services markets

This section characterizes the essential elements of balancing services markets and discusses their performance. The section is divided in five parts: (i) the definition of balancing responsible parties, (ii) a review of the balancing reserves products, (iii) the methodology to determine the balancing reserves requirements, (iv) the elements of the markets for procuring balancing reserves (capacity) and (v) the mechanisms (market-based or not) for the use of balancing energy in the real-time.

#### 3.1. Balancing responsible parties in Spain

One key design element in the very short-term is the aggregation level at which imbalances will be settled. This aggregation level is usually known as the Balancing Responsible Party (BRP).

As has been pointed out, market participants have to submit schedules on a unit-by-unit basis (from the DAM onwards) to allow the SO to ensure system security. However, final deviations from schedules are not settled on such a level of disaggregation.

The imbalances from the program declared at the gate closure are measured and charged hourly and over groups of units (BRP). Generally speaking there are two types of BRP, those including all units of a given company providing secondary reserve through a common AGC<sup>12</sup> system (this type of BRP is known as “regulation zone”, *zona de regulación*), and those created for units that are not part of the AGC system.

### **BRP incentives to avoid imbalances in real time**

Today, balanced schedules are incentivized through a dual imbalance pricing scheme (the dual imbalance pricing mechanism in force is reviewed below). However, there is a proposal of the TSO to add additional penalties for imbalances.

Market prices give incentives to the BRP to solve schedule deviations as soon as possible, since the sooner the deviation is balanced, the lower the uncertainty of the imbalance cost involved. To restore the balance before the real time the generator needs to buy/sell energy for the upcoming deviation in the centralized intraday markets, as no bilateral trading is allowed after the DAM.

A generation company can avoid imbalance charges by compensating the (positive or negative) imbalance with another plant within its BRP. However, depending on the mix available in the BRP, paying the imbalance charges may be more economical than self-compensating the imbalance.

## **3.2. Balancing reserves products**

There are three types of reserve products: the primary reserve regulation, the secondary reserve regulation and the tertiary reserve regulation (with respect to the latter service, in Spain it is only a concern to ensure that there will be enough upward tertiary reserve in real time).

### ***Primary reserve regulation:***

Primary regulation is an automatic service provided by the speed regulators of the production units. Its time dynamic performance is characterized by a time constant of 30 seconds (steady state reaching time), and the maximum duration of the service can be 15 minutes. Primary reserve would be equivalent to the FCR (Frequency Containment Reserve) defined in ENTSO-E's Network Codes.

Primary regulation is a mandatory and non-paid service in Spain for dispatchable generation. The TSO performs random inspections to ensure that generators can provide the required band (1.5% of nominal capacity).

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<sup>12</sup> Automatic Generation Control: is a system for adjusting the power output of multiple generators at different power plants, in response to system imbalances. The secondary reserve service is characterized by a hierarchical automatic control scheme: a master regulator (owned by the SO) commands orders to the AGC of the different regulation zones.

The amount of primary regulation available is thus based on dispatchable plants producing at any given time. Thus, the available primary regulation is not dependent on the situation in the grid.

Additionally, it is noteworthy that large production levels of RES-E can reduce the amount of available primary regulation under the current requirement.

***Secondary regulation reserve:***

Secondary regulation is an automatic service provided through the activation of a Master Regulator (owned by the TSO) and AGC on units' regulators. This activation seeks to restore frequency and/or imbalances respect scheduled cross border trade programs.

The reference dynamic performance is characterized by a time constant of 100 seconds (i.e., steady state settling time of the service = 300 seconds = 5 minutes). The maximum duration of the service is 15 minutes. Secondary regulation reserve would be equivalent to the FRR (Frequency Restoration Reserve) defined in ENTSO-E's Network Codes.

The secondary regulation reserve product links the amount of upward and downward reserve that has to be provided in the so-called "regulation band" (*banda de regulación*). There is a single hourly (marginal) price for remunerating the reservation of this regulation band.

This service is remunerated by means of a market mechanism via two concepts: (i) availability (secondary reserve) and (ii) usage (secondary energy usage).

The procurement of secondary regulation reserve is carried out day ahead for the 24 hours of the next day (see Fig. 1). Exceptionally, secondary regulation may also be procured during the day of operation when additional unexpected requirements are detected.

The providers of secondary regulation services are the so-called regulating zones ("zonas de regulación" in Spanish, which are the BRP with the capability of providing these services). Within each regulating zone, as stated in the network codes, only the conventional generation (thermal and hydro) and the manageable renewable generation authorized by the System Operator can be included in a regulation zone and participate in the secondary regulation. For further details on prequalification requirements see P.O. 7.2.<sup>13</sup>.

***Tertiary regulation reserve (optional procurement through the technical constraints resolution sessions):***

Tertiary regulation is a manual service that seeks to adapt the operation of units to match generation to load and recover secondary reserves availability. It is defined as the maximum variation of power generation that a generation unit (or pump storage unit) can command (upwards and downwards) within a maximum of 15 minutes dynamic time, and which can be maintained for at least 2 consecutive hours. The time horizon to apply the service is up to 1 hour. Tertiary regulation reserve is the equivalent to the RR (Restoration Reserve) as defined by ENTSO-E in the Network Codes.

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<sup>13</sup> In this network code it is described the required physical tests that the plant needs to pass so as to get the license to provide secondary regulation services.

Energy use of tertiary regulation is determined in the real-time tertiary regulation energy market where offering all available energy is mandatory for generators. This real-time market for tertiary reserve is usually considered the balancing market in Spain. As we shall see, there is no real-time market mechanism for the use secondary regulation energy and it is based on a pro-rata criterion.

According to the national network codes, the abovementioned “technical constraints resolution session” can be used to reschedule units (or start up new units) so as to ensure that enough tertiary regulation reserve will be available in real-time operation. This technical constraint session can be called at any time by the System Operator.

Through this mechanism, only units subject to reschedules are remunerated (as previously reviewed, based on upward and downward bids).

With the increasing penetration of RES-E there was in Spain an increasing need of rescheduling units with this purpose just after the DAM. Reschedules were often carried out to bring online more generation units so as to ensure enough upwards tertiary regulation in real time. This led in 2012 to the implementation of an ad-hoc mechanism for this purpose that is described next.

Tertiary regulation can be provided by conventional generating units, pumping consumption and other types of manageable generation authorized by the System Operator (for further details see P.O. 7.3.<sup>14</sup>).

***Additional upwards reserve (optional procurement of reserves):***

After closing the first day ahead feasible program (right after introducing the redispatches by means of the technical constraints resolution market), the SO verifies if there is enough upward reserve.

If the SO estimates that there is not enough upward reserve capability, a market to ensure this upward reserve gap is called. The bidders in this market are thermal units that have not been committed so far in the DAM (their production has to be zero in the production day). This mechanism only remunerates the upward capacity of this additional units (other units already providing tertiary reserve after the DAM are not remunerated).

Units that have been assigned to participate in the provision of additional upward power reserve must participate in the intraday market sessions, scheduling at least the minimum production level to bring the unit online and guarantee the provision of the committed upwards reserve to the system. To facilitate their commitment in the intraday markets, these units offer their energy as price takers. If the unit fails to commit in the intraday market, they have to immediately communicate this situation to the System Operator, who can introduce redispatches. The units that failed to schedule their minimum production level have to pay for the costs associated with these redispatches.

### **3.3. Balancing reserve requirements**

Generally speaking, there is not a precise definition of reserve requirements in the regulation and national network codes (*Procedimientos de Operación* in Spanish) published by the TSO.

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<sup>14</sup> In this network code it is described the required physical tests that the plant needs to pass so as to get the license to provide tertiary regulation services.

There are only guidelines describing some criteria taken into account when defining the quantities to be procured:

- Secondary regulation reserve: every day, the SO publishes the requirements of secondary regulation reserve both upward and downward, for every hourly period corresponding to the programming schedule of the next day. According to the national network codes for the determination of the requirements it is taken into account, among others: (i) UCTE formula for upward reserves, (ii) the hourly slope of the demand, (iii) the downward reserve has to be between 40% and 100% of upward reserve (iv) other considerations such as: variations of demand due to changes in tariffs (TOU periods) and abnormal circumstances (sport events, strikes, etc.).
- The minimum recommended values of secondary regulation reserve are respectively 500 MW for upwards reserve and 400 MW for downwards reserve.
- Tertiary regulation reserve: the minimum reserve will be determined by the potential failure of one large element (e.g. a forced outage of the largest generation, a nuclear plant) and the 2% of the demand value.
- Although in theory the reserve requirement set by the SO is a fixed quantity, the markets run for the procurement of both secondary and tertiary reserves take this quantity as flexible. The market clears once the algorithm has committed the predefined quantity with an absolute tolerance of plus-minus 10%.

The TSO publishes the secondary regulation reserves requirements for the following day before 16:00 of the day ahead (D-1). After publishing these requirements, REE opens a process to receive bids to provide the secondary regulation service (see P.O. 3.1. for further details).

### **3.4. Market mechanism for procuring regulation reserves**

In general, reserves are procured on a national basis, without zonal specific requirements considerations.

#### *Secondary reserve*

Eligible agents are able to submit offers for secondary regulation consisting of a band of power (MW) and a price (€/MW) for each settlement period (24 hours) of the following day. The secondary regulation band links upward and downward reserve. The relationship between these bands should be equal to the ratio between the total upward and the downward reserve required by REE for the whole system. The offer can be composed of different price-quantity blocks, with the possibility of defining one of these blocks as indivisible (see P.O. 7.2.).

Secondary reserve offers are selected based exclusively on the capacity price<sup>15</sup> (no energy price is taken into account<sup>16</sup>). Units cleared in the auction receive the marginal price for capacity reserve, which is the same for upward and downward reserves.

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<sup>15</sup> The acceptance of an offer cannot result in new technical constraints.

<sup>16</sup> There are no offers for secondary energy usage and the price of secondary energy usage is determined based on the bids for tertiary balancing energy.

Not providing the committed secondary reserve is penalized with a factor of 1.2 applied over the secondary reserve marginal price. Units covering that gap receive the same price for the reserve provided (1.2 times the secondary marginal reserve price).

If a unit fails repeatedly to provide the reserve service, the SO can revoke the license to provide secondary reserve.

#### ***Tertiary reserve (through the additional upwards reserve requirement)***

As it has been pointed out previously, tertiary reserve can be procured by means of the TCRM or by means of the additional upwards reserve market (today, it is mainly procured through the latter mechanism).

If produced by means of the TCRM, redispatch associated costs are cleared with the mechanism previously reviewed, and no explicit remuneration for tertiary reserve is provided. If procured through the Additional Upwards Reserves, the reserve capacity is procured and remunerated based on the marginal price of upwards reserve capacity. Bids in this market are simple (price-quantity).

#### ***Participation of demand side and renewables***

Generally speaking, neither demand side nor RES-E can participate in reserve markets yet. New proposals for changing the SO's operational procedures are underway. Among different changes proposed, a relevant one is to allow any type of resource (generation or demand) to provide reserve and balancing services as long as they pass the test and requirements established in the regulation.

In any case, there is a significant barrier associated to the provision of secondary reserve: linking the upward and downward secondary reserve requirements in the so-called "regulation band" product does not allow RES-E generation and demand response (best suited to provide a larger share downwards reserve) to efficiently participate.

### **3.5. Mechanisms for pricing and allocating balancing energy costs**

#### **3.5.1. Secondary energy usage**

The dispatch of secondary energy usage in the real time is performed following a pro-rata criterion. That is, the energy usage is proportional to the capacity committed in the secondary regulation reserve market.

The BRP net energy usage (positive or negative) is valued at the marginal price of the tertiary regulation energy that would have been necessary to use in the settlement period to replace the secondary regulation energy delivered. There is an upward and a downward price for the secondary energy usage. The determination of these prices is as follows: on the basis of the step-wise aggregated offer curve for tertiary energy regulation, the secondary energy usage is added to the tertiary energy usage to determine the secondary reserve energy marginal price with the sum of both quantities. There is an upwards secondary regulation (uniform) price and a downwards secondary regulation (uniform) price. The following figure illustrates how the upward and downward reserve price are calculated.

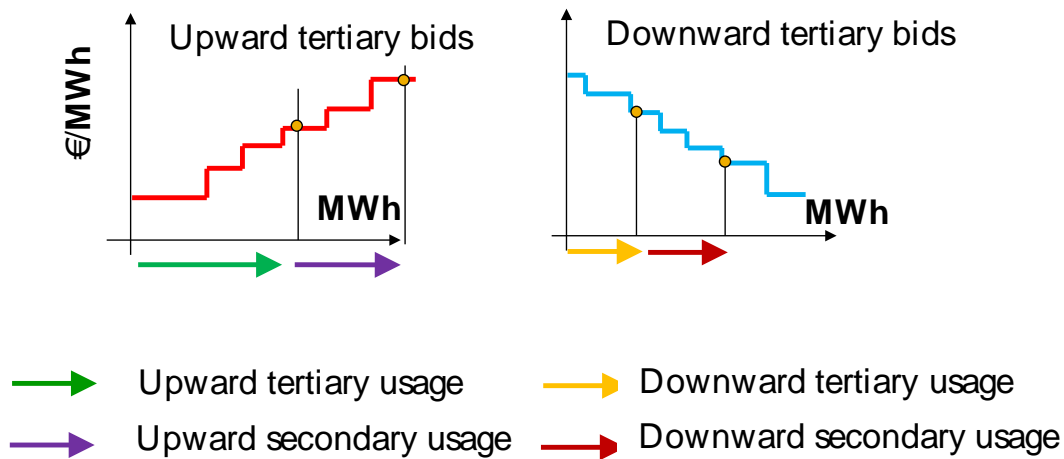


Fig. 4 Determination of the secondary energy usage prices (Source: Prepared by the authors)

Secondary regulation energy costs are allocated to market agents proportionally to imbalances.

### 3.5.2. Tertiary energy usage

Tertiary regulation energy is dispatched in real time based on submitted energy price bids (upward and downward).

The tertiary regulation bid consists of a price-quantity bid, where two additional constraints can be included: a ramp-up/ramp-down limit and an indivisibility condition.

Bids are submitted right after the DAM is closed. Submitting tertiary reserves bids for all available tertiary energy is mandatory for generators. Bids can be updated up to 1 hour ahead of real time.

Generally speaking, demand side cannot participate in balancing markets. That said, and as later reviewed, the new interruptibility demand service can be used by the TSO to provide tertiary (upwards) reserves when some conditions are met in real-time operation (both technical and economical).

The settlement period is one hour, which is clearly a quite long time step for the dynamics of electricity systems in this time scope. During such a long settlement period, changes can take place as regards the sign and value of the system imbalance energy needs. This is represented in the left part of the figure below.

The hourly marginal prices (upwards and downward) correspond to the maximum usage of energy both upwards and downward during the settlement period. Bids are selected by merit order and receive the marginal price (upward or downward). The right part of the figure illustrates the determination of the marginal price in each settlement period.



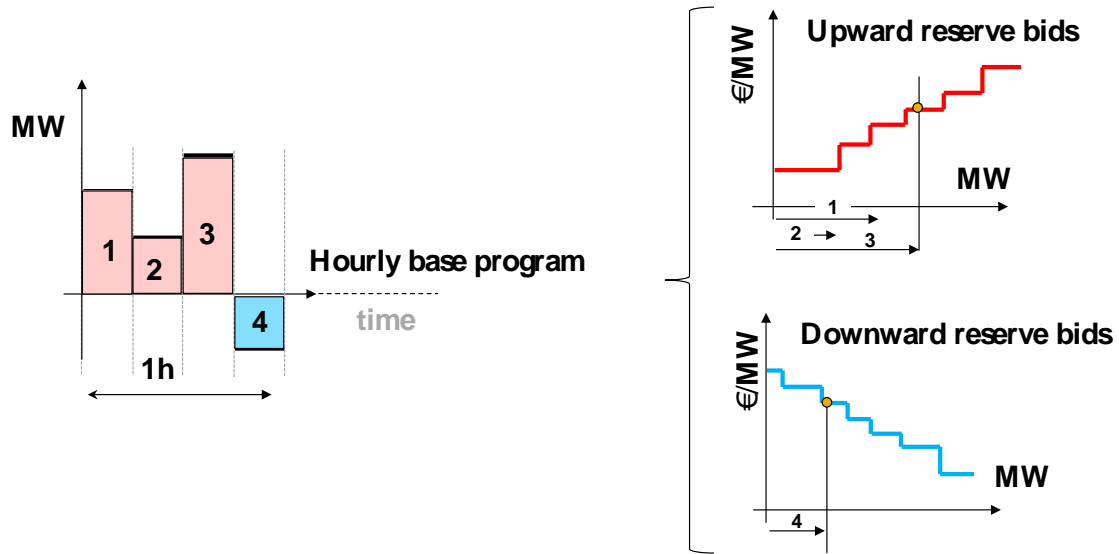


Fig. 5 Determination of the tertiary regulation energy price (Source: Prepared by the authors)

### 3.5.3. Imbalance pricing

In Spain, different imbalance prices are applied to balance responsible parties (BRPs) with long and short imbalance positions. BRPs are short when their real time generation is lower than the scheduled program at the gate closure and they are long when generation is higher than the scheduled program at the gate closure.

A dual imbalance pricing scheme is used to charge and remunerate imbalances in the settlement period (hourly) as shown on the next table:

		System imbalance	
		Negative	Positive
Balance Responsible Party Imbalance	Positive	MPDA	$MPR_{dw}$
	Negative	$-MPR_{up}$	-MPDA

Fig. 6 Prices charged for imbalances

Where  $MPR_{up}$  and  $MPR_{dw}$  are respectively the marginal price of upward tertiary regulation and the marginal price of downward tertiary regulation and MPDA is the DAM clearing price.

This way, when the BRP imbalance goes in the same direction as the system imbalance (or in other words, the BRP contributes to the system imbalance), the marginal price of the balancing regulation services applies. More precisely, the imbalance is settled at the average procurement price of the activated balancing energy (including energy from the deviation management market when called, the secondary regulation energy, the tertiary regulation energy and the cross-border balancing energy). For further details see P.O. 14.4.

When the BRP imbalance goes in the direction opposite of the system imbalance (or in other words, the BRP is “helping” the system), the price that applies is the DAM price, which is generally less advantageous than the price of the balancing services. This less advantageous

price when “helping” the system has the objective of giving additional incentives to BRP not to deviate. The downside is that it affects the “marginal” system signal and does not encourage BRPs to efficiently help the system in real time either.

#### *Timing of the information available to agents*

The information on the balancing charges and prices is available to market participants the day after. The detailed information including individual offers and bids is published 90 days after.

## **4. The demand interruptibility service**

In Spain there is an additional and separated type of reserve that is exclusively provided by large industrial consumers (a demand-side type of reserve). This reserve has been traditionally contracted by the TSO to be used as a last-resort strategic adequacy reserve (i.e. only to meet the peak demand). However, since late 2014, this service has a two-folded objective: to be used as last-resort capacity and also as last-resort tertiary reserve.

The TSO defines the interruptibility service as follows:

“The interruptibility service is a demand-side management tool aimed at providing flexible and rapid response to the needs of the electricity system operator in situations of imbalance between generation and demand. This service is activated in response to a power reduction order issued by Red Eléctrica to large consumers that are providers of this service, and that are mainly large-scale industry.”

According to the regulation that governs the interruptibility service allocation mechanism, Red Eléctrica is the company responsible for organizing and managing an auction system to assign the interruptibility service, in a competitive and efficient manner.

Large electricity consumers (large-scale industry), in response to an order issued by the system operator, reduce their consumption to maintain the balance between generation and demand, so that the rest of consumers do not lack electricity. These large energy consumers receive financial reward in return for providing this service.

The power reduction can be performed not only for technical reasons, i.e. in an emergency, but also for economic reasons that may result if the cost of interrupting the supply is less than that for applying system adjustment services.”

The use of the interruptibility service as an adequacy last-resort mechanism is carried out by simply reducing the demand when necessary. When this situation takes place, the demand does not set the market price. Therefore, the day-ahead market price is usually reduced after applying the interruptibility service.

On the other hand, the use of the interruptibility service as tertiary reserve is based on economic criteria (to all intents and purposes the interruptibility is triggered by a certain threshold administratively determined price).

## 5. Critical assessment and conclusions

The short-term power production market in Spain is integrated by energy markets and also by the so-called system adjustment services. The energy markets are run by the Market Operator (OMIE), while the adjustment services markets are run by the TSO (REE) in separate markets.

Energy markets (DAM and IDM) are liquid, although there are many reasons behind this liquidity: no bilateral trading allowed after the DA, arbitrage opportunities between markets, strategies derived from the national coal support scheme, etc.

### *Interactions among markets*

Energy and system adjustment services markets are sequential, rather than co-optimized, although they all are closely linked and several interactions exist. As previously reviewed, some of the sequential markets run by the Market Operator and the System Operator are highly interconnected and are mutually dependent:

- Day-ahead and intraday markets are used by the SO as the physical reference dispatch. Based on the results of these markets, the SO commands reschedules and takes preventive measures to ensure security of supply in real time. The position taken in the day ahead reserve markets can condition the trading possibilities in the intraday energy markets (although these reserve commitments can be transferred to another unit, under the approval of the SO).
- Some markets run by the SO for adjustment services rely on the existence of subsequent energy markets. As pointed out, the additional upward reserve market is acquired from thermal units non-committed in the DAM<sup>17</sup>. These units have to participate in intraday markets to commit their minimum technical output so as to ensure the fulfillment of their upward reserve commitment.

Additionally, some relevant negative interactions among markets have been detected by the National Regulatory Authority in reports published along the last 3-4 years:

- There have been excessively recurrent arbitrage opportunities between the DAM and the intraday energy markets. This has led to some of the generation to have bid in these two markets to all intend and purposes as a virtual bid, i.e. overcommitting in the DAM and then rescheduling (buying) energy in the intraday market.
- In order to take a competitive advantage in the redispatching mechanisms run by the SO, some thermal units have been intentionally committing energy below their minimum technical output in the DAM. The root of this behavior is in the clearing algorithm previously presented (consisting of two independent phases). The SO has recently sent a proposal to change such procedure.
- The adjustment services markets have had traditionally little influence over the final consumer electricity price. However, the costs have experienced a significant increase in the last year, a fact that has triggered some monitoring from the National Regulatory Authority.

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<sup>17</sup> As previously reviewed units committed at DAM that have upward spare capacity cannot participate in this market.

### *Need to rethink the balancing markets*

One of the major flaws of the design of the SO services markets (and particularly reserve markets) is that, neither demand side nor RES-E can participate. A new proposal for changing national network codes is underway. A relevant change is to allow all generating plants and demand resources to provide reserve and balancing services as long as they pass the test and requirements established in the regulation.

In any case, the need for faster markets and products will probably call for a redesign of reserve markets. Some design elements such as the settlement period for imbalances, or the product definition (e.g. the unnecessary link between upward and downward secondary reserve requirements in the so-called “regulation band”) will probably need to be rethought to send more efficient signals to all resources.

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P.O. 3.1 Programación de la generación

Operation procedures related to the provision of frequency regulation products:

P.O. 1.5 Establecimiento de la reserva para la regulación frecuencia-potencia

P.O. 7.2 Regulación secundaria

P.O. 7.3 Regulación terciaria

P.O. 14.4 Derechos de cobro y obligaciones de pago por los servicios de ajuste del sistema

Operation procedure of Cross-Border trading:

P.O. 14.6 Liquidación de intercambios internacionales no realizados por sujetos del mercado

Regulation of the demand-side interruptibility service:

P.O. 14.9 Liquidación y facturación del servicio de interrumpibilidad prestado por consumidores que adquieren su energía en el mercado de producción

P.O. 14.11 Liquidación y facturación del servicio de gestión de la demanda de interrumpibilidad

P.O. 15.1 Servicio de gestión de la demanda de interrumpibilidad

P.O. 15.2 Servicio de gestión de la demanda de interrumpibilidad

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## 7. ANNEX A- Coordination of forecasts with neighboring countries

Forecasts are coordinated with neighboring TSOs (RTE in France and REN in Portugal) when the commercial interconnection capacity has to be determined in order to implicitly or explicitly allocate it. In particular:

### Spain-Portugal interconnection:

A week ahead both TSOs have to determine the maximum and minimum cross-border capacity and inform the Market Operator (OMIE).

The definitive values will be established by the TSOs in the day-ahead horizon. Particularly, before the DAM session, the TSOs have to provide the Market Operator with the maximum exporting and importing capacity so as to be included in the DAM clearing process.

In case any reduction of the available capacity takes place after the “limit hour” defined for allowing changes in the available commercial cross-border interconnection capacity, TSOs will have to coordinate actions to ensure the committed cross-border capacity is firm.

### Spain-France interconnection:

There are long-term explicit auctions (yearly and monthly), where the capacity to be auctioned is determined and decided by both TSOs. RTE and REE transferred in March 2014 these long-term auctions on the French-Spanish border to the supra-regional platform (CASC).

Before the DAM session, the TSOs (RTE and REE) have to provide the Market Operator with the maximum exporting and importing capacity.

The capacity that is not used after the DAM session is offered in explicit auctions in the intraday time horizon. Again, the updated capacity to be auctioned is coordinated between RTE and REE.

Since June 2014 the three TSOs (RTE, REE and REN) have implemented a cross-border balancing exchanges scheme. There are two bilateral mechanisms: IFE (since June 11th, 2014) and IPE (since June 17th, 2014). They both use the BALIT platform owned by RTE to coordinate the use of cross-border Replacement Reserve (with manual control of the ATC by the TSOs). TSOs offer their upward/downward surpluses of balancing reserves to the other TSOs and the ATC is that of resulting from the last ID market (without any coordination between short term and real time cross-border needs/opportunities).