Utilities Policy 80 (2023) 101477

Contents lists available at ScienceDirect

Utilities Policy

journal homepage: www.elsevier.com/locate/jup

Full-length article

Opportunities and challenges for small-scale flexibility in European electricity markets

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ARTICLE INFO

Handling Editor: Janice A. Beecher

Keywords:
Ancillary services
Balancing markets
Balancing service providers
Frequency containment reserves
Small-scale balancing providers

ABSTRACT

The increase of renewables in the electricity mix in Europe in the last years and the plans to shut down coal-fired power plants will change the power system operation rules. Expectations are that small unit aggregators can soon provide flexibility and balancing services in several European countries. This paper aims to perform a qualitative comparison of European market rules for small-scale-scale flexibility. The work focused more specifically on the prequalification process that the Balancing Service Providers should develop to participate in Frequency Containment Reserve Services and the specific needs of the small-scale flexibility and balancing providers. Five countries were chosen for the analysis: Switzerland, Belgium, Germany, Portugal, and Spain. Of the five countries compared, the one that appears to have fewer entry barriers and shows greater possibilities of working on a case-to-case basis is Switzerland, followed by Belgium and Germany. Portugal and Spain are developing their ancillary service markets and should soon allow the participation of small-scale balancing providers in ancillary services.

1. Introduction

1.1. Context and motivation

With the increase of renewables in the electricity mix in Europe in the last years and a trend for them to gain even more importance (D. E. S. and regional statistics. U. E. 5. E. EUROSTAT, 2020) comes higher uncertainties in the power system, as renewable energy resources such as wind and solar are intermittent (Sirin and Yilmaz, 2021). In this context, ancillary services are increasingly becoming more challenging (Scherer et al., 2013). Traditionally, large hydro and fossil-fuel-based power plants are the ones responsible for providing ancillary services. However, many European Union countries have announced their intention to phase out coal-fired power plants by 2030 (Climate Analytics, 2017), which in countries like Germany accounts for more than 20% (16.2% Lignite and 7.5% Hard Coal (Statista, 2021)) of the total installed power capacity, small-scale balancing providers (such as small-scale producers, prosumers, active consumers, and small-scale-scale storage energy systems) will be essential.

The concept of small-scale distributed energy resources (DERs) or small-scale flexibilities can have different interpretations. First, small-scale DERs are typically associated with the installed capacity. In that case, 100 kW is the maximum acceptable limit (IRENA, 2019). Afterwards, it is related to the voltage level of the installation. Following this assumption, the DERs connected to a low-voltage grid can be considered small-scale DERs (Majumdar and Alizadeh-Mousavi, 2021). Finally, from the point of view of the market, offers from small-scale flexibility are below the minimum power threshold.

Since balancing markets have a minimum marketable service that can be provided, aggregators have a vital role in this context aggregating small units and reducing the barriers to participating in the markets. Aggregators are still a new concept within the balancing market context, and their function is to combine multiple consumer loads, generation and storage of multiple actors for jointly sale, purchase or auction in the electricity market. Aggregators can participate in the balancing market in different configurations, and it is up to each Member State of the EU to choose the most appropriate model and procedure to administer independent aggregators (European Parliament, 2019). Given the increasing importance of aggregators, it was stated in the Clean Energy for All Europeans Package that the Member States should allow and encourage the participation of demand response through aggregation.

Nevertheless, entities responsible for organizing the European

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https://doi.org/10.1016/j.jup.2022.101477
Received 20 February 2022; Received in revised form 17 December 2022; Accepted 17 December 2022
Available online 3 January 2023

balancing markets in their area of operation, the Transmission System Operators (TSOs) (European Commission, 2017), are yet to have harmonized rules for the balancing market throughout the whole European Union, as decisions about it are set out to be determined by each TSO in their area. This article aims to research and analyse the market access for small-scale actors (consumers, producers, prosumers, and aggregators) in the balancing market in selected countries in the European Union.

In (Falabretti et al., 2021), an overview of the European regulation concerning the participation of DERs in the energy markets is presented. Afterwards, a detailed analysis of the Italian framework is explained. However, the paper's primary focus is on the aggregation strategies and not the prequalification process. New opportunities in Italian ancillary services markets are also addressed in (Zeffin, 2020). However, the level of detail is insufficient, and the main barriers beyond the installed capacity/bidding size are not identified. Another perspective is provided in (Rancilio et al., 2022), where different ancillary services, beyond frequency regulation, are discussed. Harmonization between European markets and System Operators and BSPs perspectives are also compared considering a high-level vision of the market rules. A similar discussion is presented in (van der Welle et al., 2021), but with more emphasis on the new market design recommendations. Some results of the EASY-RES European project are presented in (Oureilidis et al., 2020), also addressing market design at the distribution networks level. Local flexibility markets are also proposed in (Valente et al., 2021) but more from the perspective of coordination between transmission and distribution system operators.

1.2. Contribution and objectives

As small-scale flexibility participation in FCR services is still a novelty, there are few up-to-date studies related to market access in the European balancing markets, including FCR, for this type of provider. This analysis will incentivize small-scale flexibility providers to enter these markets and know which option would be a better option for them, based on the opportunities and barriers imposed in each country, as well as contribute to the development of more studies on this topic. FCR services were selected due to the expectation of profits for small-scale flexibilities, as demonstrated in (Figgener et al., 2022). Additionally, these services are limited in time, as explained in the following sections. In summary, the main contributions of the present paper are.

- Propose a methodology allowing the identification of rules and policies for the participation of small-scale flexibilities in frequency regulation services;
- Identify and compare the main rules and policies for the prequalification process in FCR markets in five European countries;
- Evaluate and discuss the implications of the existing rules and policies in the participation of small-scale flexibilities in the analysed markets;
- Identify the opportunities and barriers for small-scale actors in providing Frequency Containment Reserve (FCR) services to the grid.

1.3. Document structure

This article consists of six sections. This first section provides an introduction to the subject and the motivation for the article's development. In section 2, the methodology used is presented. After that, in section 3, an overview of the balancing market's structure is given, explaining its products and leading actors. Section 4 lays out the common market access regulations for providing FCR services in the European Union and their efforts to implement a common balancing market for FCR services. In section 5, the prequalification processes for small units of FCR providers in selected European countries are described in order to compare the market access in these countries. Finally, in section 6, an overview of the main results and an analysis of the differences between the market accesses in selected countries conclusions are performed.

2. Methodology

The adopted methodology is composed of three main parts, each one following a different approach, as depicted in Fig. 1.

1) When providing an overview of **ancillary services market structures** and their different model organizations, the use-case methodology (Gottschalk et al., 2017) was chosen. The methodology is comprised of describing a system's objectives, its actors, how they relate to each other and the system's boundaries, giving a comprehensive knowledge about a structure.
2) For the **unified rules for market access** in the European balancing market, since the development of unified market access in the European Union is still a novelty, not many research papers could be used for this research. Instead, a focus on regulations published by the European Union was given, and extensive reading and analysis of these publications were performed, and this chapter was divided according to the main aspects related to balancing market access.
3) A similar methodology was preferred when researching the **market access for selected countries**: since prequalification of small-scale flexibility FCR providers is still under development in many countries and constantly being updated, there were sparse applicable research papers on this subject. Thus, for the market access analysis of selected countries, research on the balancing service provision of each country was made. This analysis allows us to determine if the balancing market exists in that country or if it is a mandatory service that should be provided by a large power plant connected to the transmission system. In case a balancing market exists in the country, the prequalification process was studied by visiting the official website of the TSO (or TSOs) operating in the country and looking for the most updated documentation published by them that could be relevant. These publications from the TSOs regarding their requirements on market access regulations were then researched and thoroughly analysed, dividing their requirements into different categories and subcategories to facilitate the comparison between the different market access for each country. For the division of the categories, the prequalification process of Germany was used as the reference (50 HertzAmprionTenne and BW, 2020).

3. Ancillary services description

Ancillary Services are defined in Directive (2009)/72/EC as "*a service necessary for the operation of a transmission or distribution system*" (European Parliament and of the Council, 2009). Several services can be necessary and procured in different ways. In power systems, essential services are related to the balance between generation and consumption, assuring the frequency of the system (Rebours et al., 2007). Balancing markets have been proposed allowing the share of balancing services and reserve capacities between TSOs/regions, the participation of more players in the services and, consequently, increasing the opportunities to have economic benefits (MacDonald, 2013). Balancing markets can be considered the institutional, commercial and operational arrangements that establish market-based management of balancing services (EuropeanCommission, 2017).

Different products can be acquired in the balancing markets. Their main differences are in the time of activation and the duration of activation. The four reserve products defined by the Guideline on Electricity Transmission System Operation (SO GL) are Frequency Containment Reserves (FCR), Automatic Frequency Restoration Reserves (aFRR), Manual Frequency Restoration Reserves (mFRR) and Replacement Reserves (RR) (European Commission, 2017). In Fig. 2 the time of activation and duration of each product can be seen.

In the EU, there are different actors involved in balancing markets.

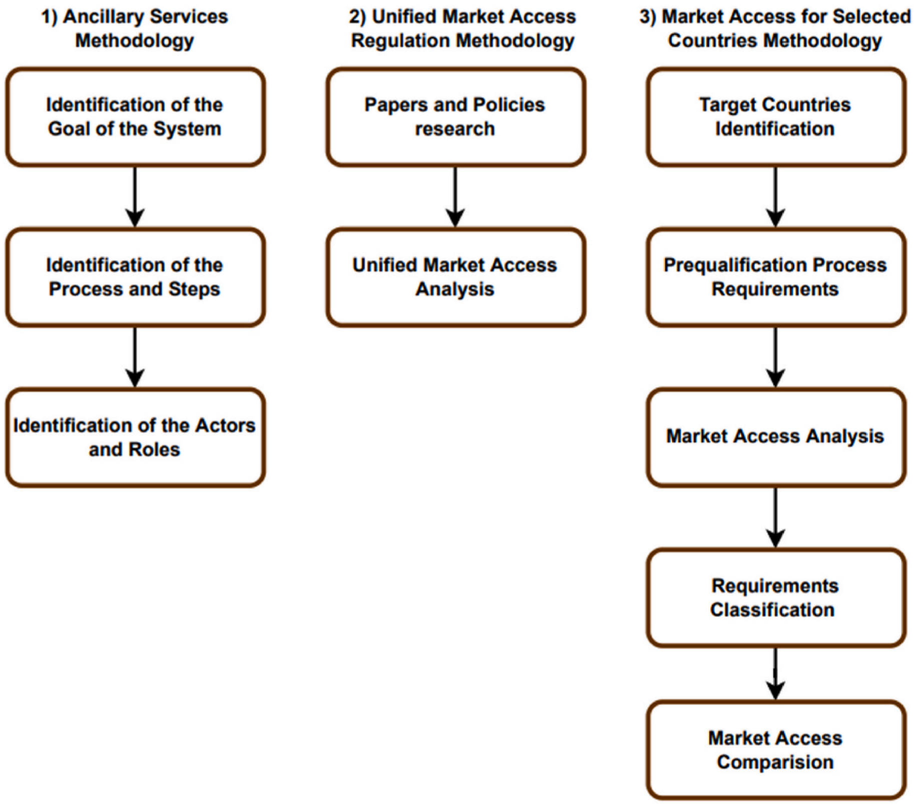

Fig. 1. Diagrams of methodologies adopted for each section of the article.

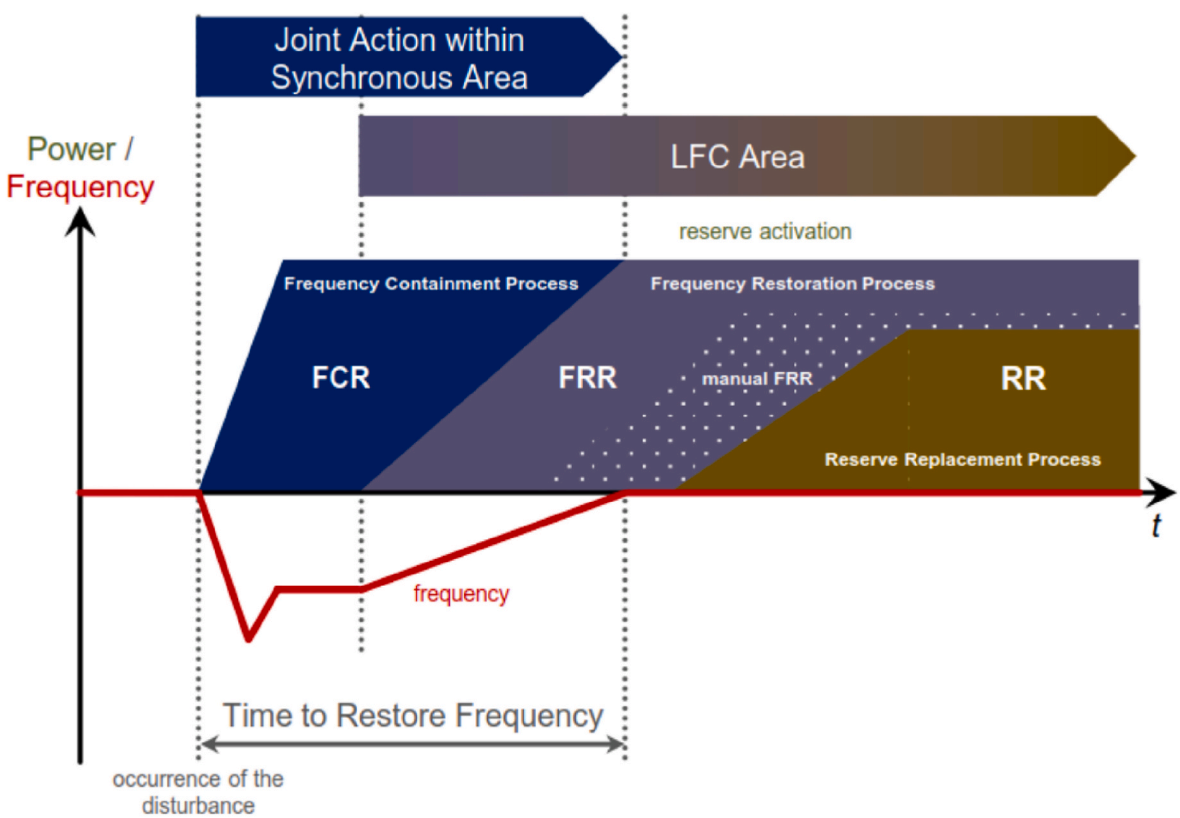

Fig. 2. Activation structure of balancing services concerning time and frequency deviation (ENTSO-E, 2018a).

The Transmission System Operator is accountable for the organization of European balancing markets. Within this scope, they organize the qualification process for those interested in providing balancing services to the system, as well as determining the reserve capacity required and the dimensioning rules. In the balancing markets, they are responsible for activating or procuring balancing services for the Balancing Service Providers (BSP) and the Balance Responsible Parties (BRP).

In the electricity markets, BRPs are the actors financially responsible for the imbalances to be settled with the connecting TSOs. They have their individual supply and demand, and they are obliged to keep them balanced in real time (EuropeanCommission, 2017). An imbalance charge can be placed on the BRP depending on its imbalance and the state of the system, where the BRP can either pay or receive a payment. This imbalance charge is a crucial element of the balancing market and it is called *imbalance settlement*.

A BSP is a market participant providing balancing services to the grid. They can provide either or both balancing capacity and balancing energy by lowering or increasing their energy injection to the grid. Possible actors that can become BSPs are owners of power generating facilities (either from conventional or renewable energy sources), third parties, demand facility owners and energy storage units' owners.

The aggregator is still a new concept. With the development of legislation in Europe allowing decentralized, small-scale electricity production and the development of demand response, there was an increase in the potential for balancing service providers. However, these small-scale producers face several market barriers since their balancing capacity is limited. In this context, the role of the third-party aggregator was formed, and its function is to combine multiple consumer loads or/and small-scale generators' electricity for sale, purchase, or auction in the electricity market (European Parliament, 2019). The aggregator enables resource owners that would be too small to participate independently in the electricity market. A diagram to better understand the role of the aggregator and other actors, not only for flexibility markets but also for grid operation, is presented in Fig. 3.

4. Unified market access for FCR services in europe

When analysing and comparing the different market-access processes for small units in FCR services across different European countries, it is necessary to investigate the possible common rules for the European Union. The purpose of this section is to understand and layout what are the unified rules regarding market access for FCR service providers in the European Union, as well as to understand what is left for each TSO of a Load-Frequency Control (LFC) area to decide when it comes to the minimum requirements for market access.

The primary regulation that established common guidelines for market access procedures in the European Union is the System Operation Guideline (SO GL), released in 2017. It sets harmonized rules on system operation to ensure system security, enhance the efficient use of the network and increase competition in the system (Climate Analytics, 2017). It sets out harmonized requirements for the provision of load-frequency control (LFC) and reserves for the efficient operation of the internal electricity market, providing the technical structure for developing cross-border balancing markets.

Regarding the harmonized rules for the FCR prequalification process, this process is set and defined by each TSO in its control area. The FCR provider should demonstrate that all the technical requirements are satisfied according to the operation rules. Despite this process being developed by the TSOs, the guideline determines the deadline periods for this process.

The Guideline on Electricity Balancing (EB GL) (European-Commission, 2017) established that, if two or more TSOs in the European Union would like to (or already do) exchange balancing capacity, the development of a proposal with harmonized rules and processes for the exchange and procurement of balancing capacity need to be made by them. The TSOs from Austria, Belgium, Netherlands, France, Germany and Switzerland created the FCR Cooperation for the development of a common FCR market in 2016 and, in that sense, released the draft of a Proposal for the establishment of common and harmonized rules and processes for the exchange and procurement of FCR (50 Hertz et al., 2018). The FCR Cooperation is a common market which plans to integrate the FCR balancing market in the European Union to increase competitiveness, efficiency and security of supply while creating incentives for new BSPs and different technologies to provide FCR services. Nevertheless, as is discussed in the present paper, the prequalification process is very different in each studied country.

In (50 Hertz et al., 2018), key aspects are defined for the common market. First, the minimum bid size is set to 1 MW, the bids can be divisible with the bid resolution of 1 MW, and the indivisible bids' maximum size is 25 MW. Second, it is established that the product needs to be symmetric, meaning that the procurement of upward and downward FCR is done together (both injecting and consuming energy from the grid). Third, it is targeted to have daily auctions one day before service delivery, starting on June 2020 (Tennet, 2020). Fourth, it is proposed that the product duration is 4 h and symmetrical, instead of the initial one week (from Monday 0 h until Sunday 24 h) symmetrical. The

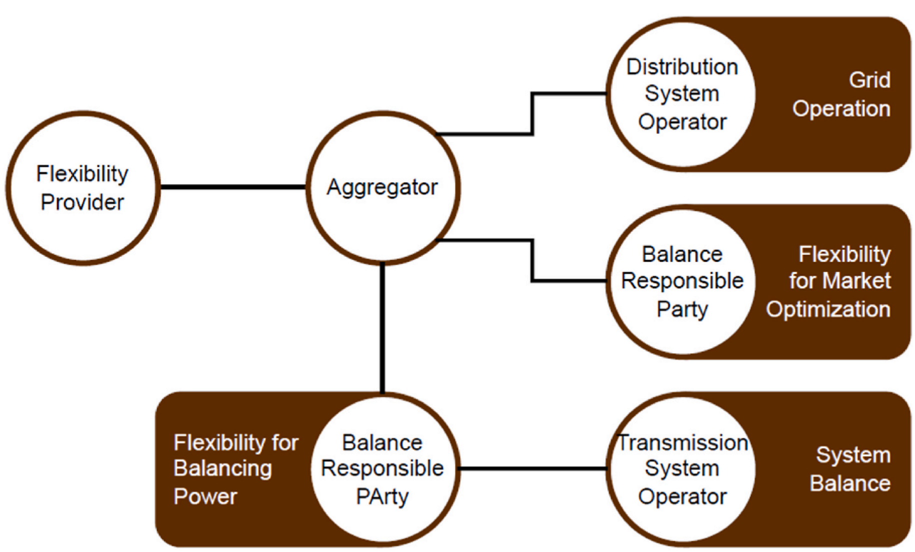

Fig. 3. The role of the aggregator between the balancing resource owner and the market. Based on (Hodemaekers, 2017).

Table 1
FCR properties in the different synchronous areas (European Commission, 2017), where CE stands for Continental Europe, GB is Great Britain, IE is Ireland and NI stands for Northern Ireland.

FCR properties in the different synchronous areas		
Minimum accuracy of frequency measurement	CE, GB, IE/NI and Nordic	10 mHz or the industrial standard if better
Maximum combined effect of inherent frequency response insensitivity and possible intentional frequency response dead band of the governor of the FCR providing units or FCR providing groups.	CE	10 mHz
	GB	15 mHz
	IE/NI	15 mHz
	Nordic	10 mHz
FCR full activation time	CE	30s
	GB	10s
	IE/NI	15s
	Nordic	30s if system frequency is outside standard frequency range
FCR full activation frequency deviation	CE	±200 mHz
	GB	±500 mHz
	IE/NI	Dynamic FCR ±500 mHz Static FCR ±1000 mHz
	Nordic	±500 mHz

key FCR properties in the different synchronous areas are summarized in Table 1.

As mentioned, one of the particularities of the FCR Cooperation is the auction of symmetric products, meaning that upward and downward FCR services are procured together. When storage systems provide the service, an energy buffer for charge and discharge should be reserved (Schweer et al., 2016). However, providing symmetric services can be complicated for some technologies, including active consumers and small-scale generators (Belhomme et al., 2021), and thus a barrier to participating in small-scale flexibilities in FCR markets.

5. Market access for FCR services in selected countries

To compare the market access for small-scale flexibility FCR providers between the different countries, a comprehensive analysis of the prequalification process of each one of them is crucial. Understanding the tests to be performed, the requirements that need to be fulfilled in case of limited energy storage and how to become a BSP in each country is needed to evaluate the balancing market requirements. With that in mind, in this section, the prequalification processes for Switzerland, Belgium, Germany, Portugal and Spain are laid out, and an overview of them and their comparison will be made. These countries are chosen because Germany, Belgium and Switzerland already participate in FCR Cooperation and Portugal and Spain are already preparing to join this platform.

When applying for a prequalification process, a BSP can apply for at least one providing unit or providing for a group of units. A providing unit is a single or aggregation of power generating modules or demand units connected to a common connection point, while a providing group is an aggregation of power generating modules, demand units or reserve providing units connected to more than one connection point in the transmission system. One power-generating module or demand unit is defined as a Technical Unit (TU).

5.1. Prequalification process in Switzerland

The prequalification process in Switzerland is developed and organized by the only TSO present in the country, the Swissgrid. In the process, the potential BSP needs to fill out a form indicating the specific service that wishes to provide and send it to the TSO. Attached to this form, the BSP should provide a list of all the virtual providing units and TU intended to provide the service. When submitting a virtual providing unit to the prequalification process (the case for aggregated small units), a list of all primary substations in which the aggregated units are connected must also be provided. Additionally, the BSP should identify, along with the system type, the nominal rated power, the metering point ID and other information if required.

After sending the form and the list of the providing units, Swissgrid needs to confirm them and only after that should the prequalification documents be sent to Swissgrid. Besides that, the TSO might also request some additional tests and requirements for the potential BSP. The main documents containing the requirements and explanation of the prequalification process in Switzerland are “Prequalification documents – ancillary service provider” (Swissgrid, 2013a), “Prequalification documents – primary control” (Swissgrid, 2013b), “Test for primary control capability” (Swissgrid, 2011), “Requirements for the list of generating units” (Swissgrid, 2013c), “Requirements for schedule data and electronic data Exchange” (Swissgrid, 2020a), “Monitoring data requirements” (Swissgrid, 2020b) and “Framework Agreement for the Supply of Primary Control Power” (Swissgrid, 2016).

5.1.1. Operational & control in Switzerland

The capability test is a key element of the prequalification process for FCR services in Switzerland (Swissgrid, 2011). This test aims to verify if a providing unit meets the necessary technical conditions. Since the offers for FCR in the Swiss balancing market must be symmetrical, tests in both directions (upward and downward) need to be performed.

In the activation of test signals, the nominal grid frequency is reduced or increased from 50 Hz to either 49.8 or 50.2 Hz within 10 s, and the power deviations of the providing unit/group are recorded after 30 s. The FCR service must be fully activated within 30 s of the frequency deviation, and it must be provided for at least 15 min. These requirements are in accordance with what is established by the SO GL for Continental Europe (EuropeanCommission, 2017). The signal used in the FCR services prequalification test in Switzerland is presented in Fig. 4.

Another test performed during the prequalification process is the monitoring test (Swissgrid, 2020b). After submitting the signed Terms & Conditions, and Swissgrid accepts them, the BSP needs to install the RTU (Remote Terminal Unit) for data monitoring, and the providing units/groups are then connected to both the network controller and the monitoring center. After that, and before starting the prequalification test for capability, a monitoring test is performed in close cooperation with the TSO, in which the communication system between the providing groups or providing units and the TSO is tested according to (Swissgrid, 2020a).

5.1.2. Security & software in Switzerland

The control system of the BSP is connected to the TSO Swissgrid through a dedicated Swisscom LAN interconnected network available for real-time monitoring. The data availability rate required by the TSO is, at minimum, 99.5%. The online monitoring data needs to be updated at a maximum resolution of 10 s. The connection between the TSO’s control center and the reserve provider’s control system must be based on point-to-point control technology.

Moreover, the communication between the BSP and the TSO must be protected from other networks by using closed user groups. The potential BSP is responsible for the costs and for applying to a connection with the closed user group with the telecommunications provider.

5.2. Prequalification process in Belgium

For providing FCR services in Belgium, different requirements are set by Elia, the Belgian TSO, that need to be met by the BSP and its providing group(s). When applying a new providing group for supplying FCR services, the BSP needs to hand in the Energy Management Strategy, a detailed document which it proves the compliance of this providing group with the requirements for the provision of FCR. Among other

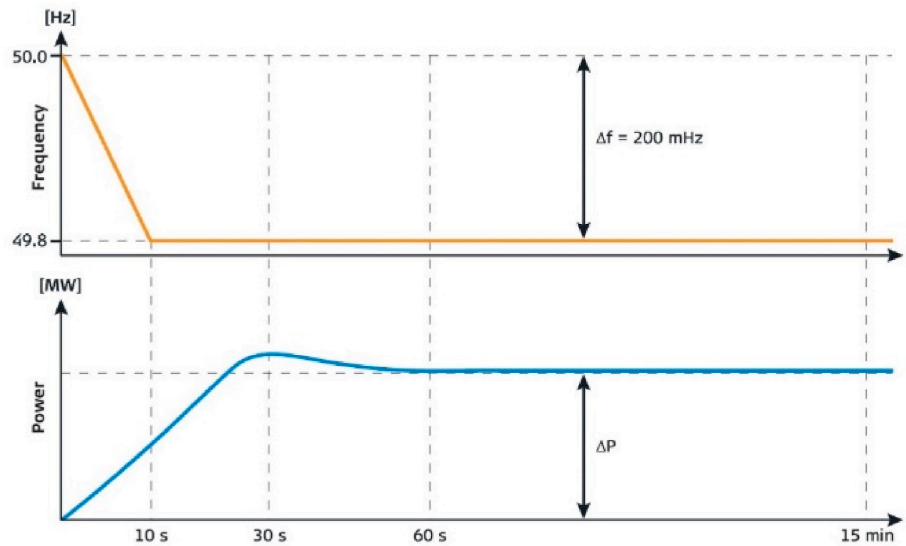

Fig. 4. Ideal test signal for FCR capability in Switzerland (Swissgrid, 2011).

things, in this document, the BSP informs if the providing group has limited energy storage or not and needs to prove its Energy Management Strategy does not impact third-party entities.

The primary documents regarding the FCR prequalification process in Belgium for Non-CIPU (Coordination of the Injection of Power Units) TUs are the "General Framework for Frequency Containment Reserve Service by Non-CIPU Technical Units" (Elia, 2019a), the "Terms and Conditions for the Frequency Containment Reserve Service by Non-CIPU Technical Units" (Elia, 2019b) and the "FCR – Communication Requirements" (Elia, 2020).

5.2.1. Operational & control in Belgium

The operational test to be performed in the Belgian prequalification process is the Synthetic Frequency Profile test. For this test, the TSO receives the measurements via the real-time connection of each delivery point of a providing group, except for virtual delivery points, where the aggregated data is considered. The test consists of steps with a frequency deviation of 50 mHz in each step, in which the number of steps varies depending on the service type.

The providing group must have a particular power profile depending on the service type (either symmetric 200 mHz, symmetric 100 mHz, asymmetric up or asymmetric down). For the 200 mHz test, the profile

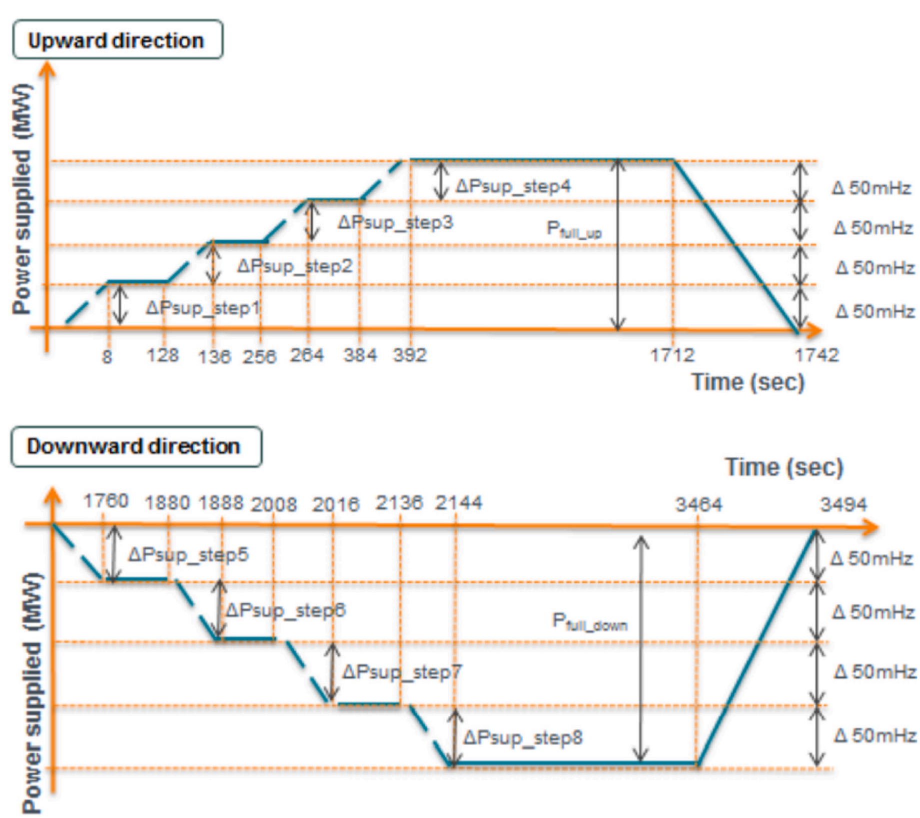

Fig. 5. Power supplied profile during synthetic frequency profile test for service type 200 mHz (Elia, 2019a).

presented in Fig. 5 must be obtained by the providing group.

In the test, the providing group must, in a maximum of 13 s, reach the volume of each step of 50 mHz, and must keep the power supply for 2 min before going to the next 50 mHz step. After achieving the maximum power, it can supply, the providing group must provide this power for 22 min. For symmetrical FCR, the providing group is prequalified for each direction, and the maximum time difference between each test is of 24 h.

For providing the 100 mHz service type, asymmetric up and downward directions, the power supplied profiles during the tests for upward and downward directions are in Fig. 6.

In these tests, the providing group must deliver the volume of each 50 mHz step in a maximum of 20 s and maintain this volume for 2 min before going to the next 50 mHz step. Once the maximum supplied power is achieved, it must be maintained for 27 min. Like the 200 mHz service type test, the test for the opposite direction must be performed within 24 h of the first test.

Another test required is a test under operational conditions for a continuous period of 4 h. If during this test, there are one or more frequency deviations greater than 40 mHz, the TSO will verify if the BSP has responded accordingly to the highest frequency deviation that occurred.

Before starting the prequalification tests, the BSP needs to show that its connection to the TSO's control system works correctly and that it has the ability to exchange data with the TSO. This is done through the Communication Test, in which both the nomination communication and real-time communication are tested.

5.2.2. *Security & software in Belgium*

The Belgian TSO requires a redundant communication channel with the BSP, with the communication protocol determined by the TSO. If the TSO decides to improve specific procedures or real-time exchanges, the BSP commits to applying these changes in a reasonable time. The BSP's communication system must be available at least 95% of the time monthly for real-time data transfer. Moreover, the BSP must have its entire real-time communication system and its processes redundant. The BSP control system must have two physical communication links and two different Uninterruptible Power Supplies (UPS) with a minimum of 8 h of autonomy per physical link.

5.3. *Prequalification process in Germany*

There are different minimum requirements to provide FCR services in Germany, and they should be proven to be met in the prequalification process developed by the four TSOs operating in Germany: TransnetBW, TenneT, Amprion and 50 Hz Transmission. In this prequalification process, a potential BSP must submit certain documents concerning providing units or groups to meet the minimum requirements to provide balancing services to the grid. They must be part of a pool consisting of a single or multiple aggregated providing units or groups. In order to pass the prequalification process, at least one performance measurement must be carried out for each TU.

The main documents regarding the prequalification process in Germany are the "Prequalification procedure for reserve providers (FCR, aFRR, mFRR) in Germany" (50 HertzAmprionTenne and BW, 2020) (in

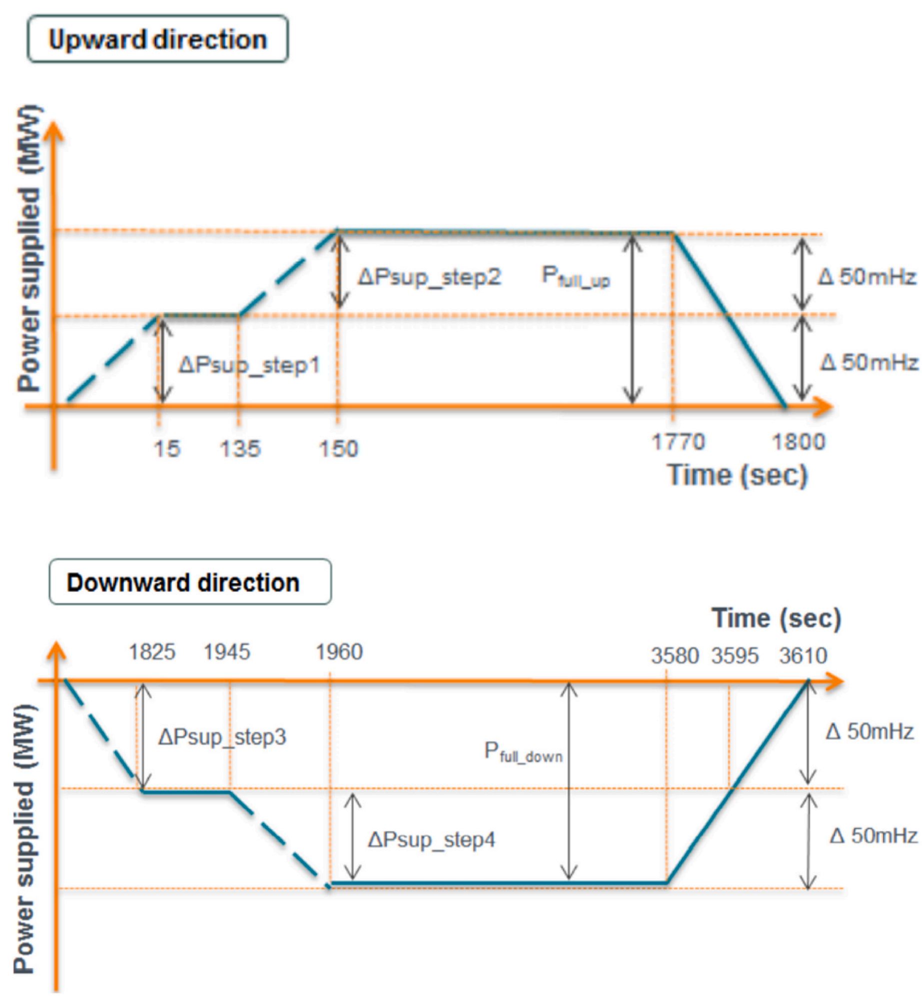

Fig. 6. Power supplied profile during synthetic frequency profile test for service type 100 mHz (Elia, 2019a).

German) and the “Minimum requirements for the reserve provider’s information technology” (50 HertzAmprionTenne and BW, 2019).

5.3.1. Operational & control in Germany

An element of the prequalification process in Germany is the Operational Test. During the operational test, the BSP must record the following data for transmission to the prequalification portal: measured power, operating point and setpoint of the relevant TU and providing unit/group. The setpoint is the control reserve provided by the BSP. The control power measured value consists of the difference between the measured power and the operating point. This data, when put in a graph (see Fig. 7), needs to result in a “double hump curve” consisting of three retention phases and two delivery phases. The duration of each phase for the provision of FCR is a 15-min schedule interval, and the providing unit/group reaches the specified setpoint within 30 s.

An Operational Test for FCR provision has three different time ranges: Service Change Range (SCR), Transient Area (TA) and Stationary Area (SA). The SCR begins with the setpoint jump, usually a frequency deviation of $\pm$ 200 mHz and lasts a maximum of 30 s, ending when the setpoint is reached for the first time. The transient area begins at the end of the SCR, at the latest 30 s after the setpoint step. It ends 90 s after the setpoint jump. The Stationary Area begins 90 s after the setpoint jump and lasts at least 13.5 min.

Additionally, the German TSOs also have other requirements in case of limited energy storage, such as that the working capacity of the energy storage device must reach or exceed two differently defined lower limits and that the useable work capacity must be demonstrated in the operational test. The sizing of storage systems should consider these limits. Afterwards, storage system owners can adjust their strategy to participate in multiple services (Wang et al., 2019). Finally, the operating conditions and the degradation of storage systems in the sizing process must be considered (Calearo and Marinelli, 2020).

Besides the operational test, an 8-h trial run under operational conditions is conducted. As part of the FCR trial, the data points measured feed-in, measured frequency, setpoint, and operating point must be recorded and transmitted. Besides these points, in case of limited energy storage, the BSP must also measure the work capacity in both directions. As part of the FCR trial, a failure of the connection of the providing unit/group to the central control unit is simulated, and the correct reconnection is checked.

5.3.2. Security & software in Germany

The availability of an individual connection between the TSOs and BSPs control system must be set at 98.5%. The connection between the TSO’s control center and the BSP’s control system must be based on dedicated point-to-point control technology.

An IT requirement regarding the control system is the obligation to duplicate the reserve provider’s central control system. The delay on the transmission route E2E (End-to-End) must be a maximum of about 5 s. The communication between the TU and control systems must be protected from other networks by using closed user groups, and the TUs should only communicate with each other via the central gateway to the reserve provider’s control system. Each TU must be connected to the BSP’s control system with an availability of at least 95%.

5.4. Prequalification process in Portugal

The primary frequency control service in Portugal is considered a mandatory system service, which means that all generators connected to the transmission network regulated by the TSO *Redes Energéticas Nacionais* (REN) must provide this service in a non-remunerated scheme (Entidade Reguladora dos Serviços Energéticos, 2014). Therefore, market access for FCR providers through demand response and small units is impossible.

One indication that there might be a possibility of opening the balancing market for demand response providers is the public consultation done by REN in May 2018, in which it proposes terms and conditions for BSPs and BRPs, including demand response and distributed generation as potential providers of balancing services (REN, 2018). This document proposes that the terms and conditions will allow the aggregation of consumption installations, energy storage systems and generation systems to offer ancillary services to the grid. It will also establish the rules and conditions for the provision of ancillary services by these agents, as well as the prequalification process and all the requirements to become a balancing service provider.

5.5. Prequalification process in Spain

Similar to Portugal, in Spain, primary frequency control is a mandatory service that needs to be provided by every generator connected to the Spanish transmission system, including distributed generators. If a generator cannot provide FCR services, it needs to contract

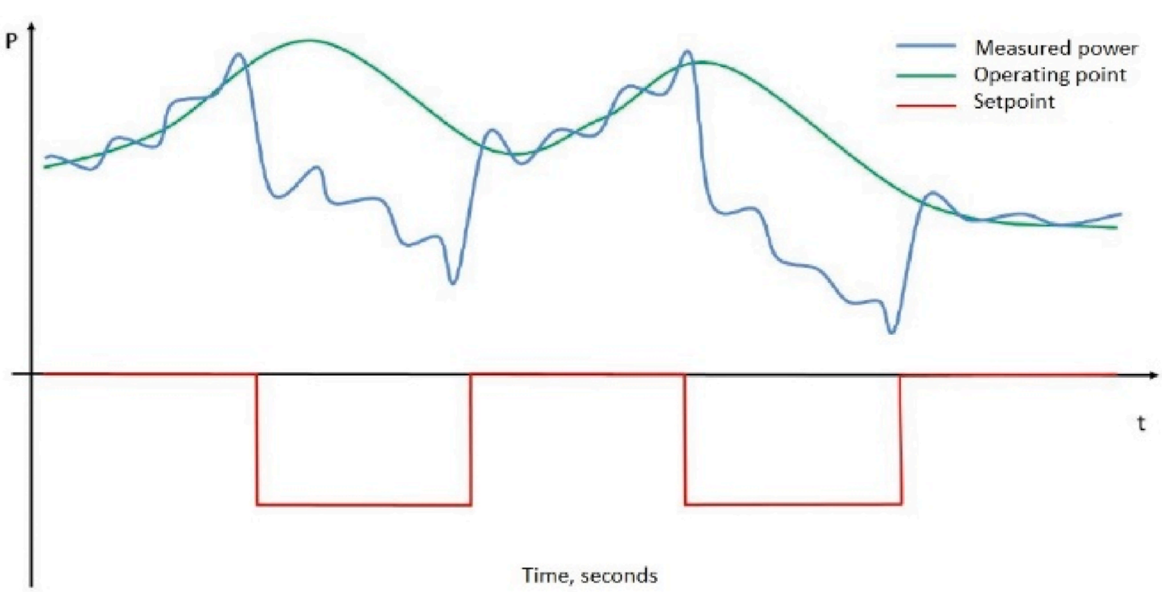

Fig. 7. Data recorded during the operational test (based on an image from (50 HertzAmprionTenne and BW, 2020)).

the service from another generator to fulfil its obligations (Smart Energy Europe, 2018).

Although small-scale storage is not able to provide FCR services to the Spanish grid yet, due to the need to implement the EB GL (EuropeanCommission, 2017) (which foresees the provision of balancing services through generation, demand and storage sources), a public consultation has been published in order to define a work plan for the participation of storage and demand in balancing markets (Red Eléctrica de España (REE), 2019). In the public consultation, modifications in the current electricity sector law are expected, as well as their minimum bid requirements, which would go from 1 MW to 10 MW and allow the aggregation of technical units to provide the services (Red Eléctrica de España (REE), 2019). The resolution that approves the new Terms & Conditions related to BSPs and BRPs was released by the end of 2019, and small units cannot yet participate in the Spanish balancing market (Comisión Nacional de los Mercados, 2019).

In the Terms & Conditions for BSPs and BRPs, it is established that to provide balancing services to the grid, they need to go through a prequalification process, and the prequalification tests will be specified in the operational procedures' documents. Meanwhile, while these documents are not updated and approved, the prequalification tests to be used are the ones for the participation of system adjustment services in the Resolution of December 18th, 2015, by the Secretary of State for Energy (E. y T, 2015).

5.6. *Overview of the prequalification process for selected countries and identification of main barriers*

Besides the requirements explained in the previous subsections, the TSOs of the studied countries impose other requirements on the potential balancing services providers, such as any additional requirements in case of limited energy storage and data availability. These requirements are key aspects when comparing the market access in these countries; therefore, they are listed in Table 2 for a better understanding of the differences in the prequalification process of selected countries. This prequalification process is valid for several types of DERs, including active consumers (power demand control), distributed generators and storage systems. The storage systems can be batteries, electric vehicles or thermal storage units. This methodology has been tested in a pilot project called Coffee2Grid,[1] considering the participation of industrial coffee machines in FCR services in Germany and Switzerland. We note that Belgium, Germany and Switzerland are part of FCR Coordination (ENTSO-E, 2018b), proposing similar services in a joint market. Nevertheless, as presented in Table 2, the technical requirements are different in each country.

In summary, several barriers can be mentioned, such as the lack of observability of DERs, which limits their ability to participate in FCR services. Limited observability also implies problems in the control of these units as well as the execution of some algorithms, such as forecasts. Additionally, other barriers can be mentioned, such as the limits imposed by the TSOs in the offering capacity limits. Aggregators have been proposed in various markets to overcome this barrier. However, differences in the definition and roles of aggregators can limit the participation of these aggregators in different markets. Finally, communications availability and latency requirements can imply the use of expensive equipment and dedicated communication channels, which can limit the interest in the participation of small-scale DERs in the FCR markets.

6. Conclusion and policy implications

This work was developed to qualitatively analyse and compare different market accesses in the European Union for small-scale flexibility-based FCR providers. As allowing aggregation of small-scale electricity producers or consumer loads for providing balancing services is still a relatively recent development, regulations are constantly changing, and studies do not address a detailed prequalification process. Five countries were chosen for the analysis: Switzerland, Belgium, Germany, Portugal and Spain.

Out of these five countries, Switzerland appears to have fewer entry barriers and shows greater possibilities of working on a case-to-case basis. The TSO, Swissgrid, has no additional entry requirements for providers with limited energy storage (the case of small-scale flexibility-based providers). Upon receiving the initial documentation from the potential FCR provider, Swissgrid evaluates this documentation in order to determine if they should request any additional tests or requirements. Additionally, in the prequalification tests set by the TSO of each country (in the case of Germany, set by its four TSOs), the time at which the service must be continuously provided at full power also varies greatly, being Germany the country with less restrictive time (13.5 min), followed by Switzerland (15 min), and Belgium by far the most restrictive one, requiring the provision of full power for 27 min, which might hinder the provision of FCR services from small-scale providers with limited energy storage. These differences are due to the maximum activation time of FCR services of each country during the provision of the service: while Germany and Switzerland have a maximum activation time of 15 min, Belgium has a 30-min maximum activation time. Therefore, it is understandable that the test to provide FCR services in Belgium has a longer continuous period.

Another considerable difference in the prequalification processes between these countries is related to security & software requirements. The German TSOs provide an *Excel file* with a checklist of all the requirements (36 requirements) related to Information & Technology divided into different categories, such as Network, Encryption and Closed User Group. However, the Belgian and Swiss TSOs only publish requirements related to the BSP's control system and its connection to the TSO control system. One plausible assumption is that in-depth security & software information is only available to the potential BSPs in these countries once they have started the prequalification process.

One important detail that needs to be pointed out is that despite the Switzerland prequalification process having the fewest requirements and tests in the prequalification process for FCR services, this may be different for each case. As mentioned, after the BSP submits the documents and the list of the providing units, the swiss TSO needs to confirm the documents and, after that, analyse and coordinate the next steps for the prequalification process and the additional requirements for that case. The impression given by the documents provided by the TSO is that it works more closely with the BSP and analyses each case individually, which might indicate more openness to small-scale flexibility units.

When analysing and comparing all the prequalification processes across the different countries, despite all of them being open to small-scale FCR providers and allowing their aggregation, the German prequalification process imposes some restrictions on small-scale FCR units. It is the only country analysed with additional requirements for providing units or groups with limited energy storage. However, it is interesting to notice some recent changes made by the German TSOs, showing their intention to allow more balancing services provision through small units. In a recent change in their document, "*Minimum requirements for the reserve provider's information technology for the provision of control reserve*" (50 HertzAmprionTenne and BW, 2019), a new requirement was set, adding the concept of bundling of small units and allowing the connection of micro-installations through a pool.

Another aspect to be considered when analysing a potential market to enter to provide FCR services is the possibility of providing these services to other countries without having to do another prequalification process. It is, then, interesting to consider the collaboration of a TSO in the FCR Cooperation project, of which three out of the five countries analysed are already participating. Moreover, as they have import and

[1] Coffee2Grid – Smart Grid und Energieeffizienz mit Kaffeemaschinen und Restaurants - Categories (admin.ch).

Table 2
Overview of the Prequalification Process and Technical Requirements for selected countries.

	Switzerland	Belgium	Germany	PT/ES
Test under operational conditions	The TSO specifies no tests under operational conditions.	Test duration: 4 h. If there is a frequency deviation >40 mHz, the TSO verifies if the BSP has responded accordingly.	Test duration: 8 h. Data points must be recorded and transmitted. Failure of the connection to the central control unit is simulated, and correct reconnection is checked.	–
Additional requirements for limited energy storage	There are no additional requirements in case the providing unit or providing group has limited energy storage.	There are no additional requirements in case the providing unit or providing group has limited energy storage.	The working capacity of the energy storage device must reach or exceed two differently defined lower limits. The energy storage management system must be proven.	–
Delivery behavior	At least linear provision. Activation starts at least 3 s after frequency deviation.	At least linear provision. Activation starts at least 2 s after frequency deviation. Services must be provided for as long as the deviation occurs; in case of limited energy storage, it must provide for at least 25 min and 2 h, maximum, to regenerate its energy reserve.	At least linear provision. Activation starts at least 2 s after frequency deviation. Service must be provided for at least 30 min or an unlimited period, depending on the frequency range. Limited energy storage: maximum period for which it can do it.	–
Communication Test	A monitoring test is performed to check if the connection between the network controller, monitoring system and offering system is correct and data can be exchanged.	Nomination communication and real-time communication are tested. BSP must show the correct recording and transmitting of real-time data required.	May last from one to 2 h. BSP must show that its pool is correctly connected to the TSO's control system. Including the correct recording and transmission of the measured values required as real-time data.	–
BSP connection to TSO	Swisscom LAN interconnected network. Point-to-point control technology. Transmission protocol: IEC 60870-5-104.	A redundant communication channel between BSP and TSO. A bidirectional link in the software TASE2/ICCP is recommended for data transmission.	If the marketable power of a BSP is ≥ 90 MW and the central control system is required, the control system must have a locally redundant design. Point-to-point control technology.	–
Data availability	99.5%	95%	≈98.5%	–
BSP control system	No specific requirements.	Real-time communication systems with redundant processes. BSP's control system must have two different UPSs with a minimum of 8 h of autonomy.	BSP's control system must be redundant. An automatic switch between these two redundant central control systems must appear in a maximum of 15 min. Delay on the E2E transmission route must be of a maximum of around 5s.	–
Closed user group	No specific requirements.	No specific requirements.	BSP is responsible for applying for a connection and a closed user group with the telecommunications provider.	–
TU connection and bundling	No specific requirements.	No specific requirements.	Availability of TU connection to BSP's control system: 95%. Bundling of small-scale TUs is allowed via the public internet with an encrypted VPN; closed user groups are not mandatory. A media break between bundled small-scale TU and the pool provider is mandatory. The maximum size of a small-scale TU is 25 kW, and the maximum size for bundling a small-scale TU is 2 MW. The connection of a micro installation is only allowed to a pool.	–

export limits, it is relevant when deciding which country to do the prequalification process. Fig. 8 below shows the map showing the import and export limits of each country participating in the FCR Cooperation project (Swissgrid, 2020b). Since it is set in the SO GL that the maximum FCR export allowed is 30% of the country's needed FCR and a minimum of 100 MW, accessing the FCR Cooperation through Belgium or Switzerland would be an advantage. This situation allows for higher chances of participation in the internal market and exporting to other market participants of the FCR Cooperation.

However, despite efforts to have a harmonized balancing market in the European Union, there are different levels of commitment throughout the economic block, and countries are in different stages of

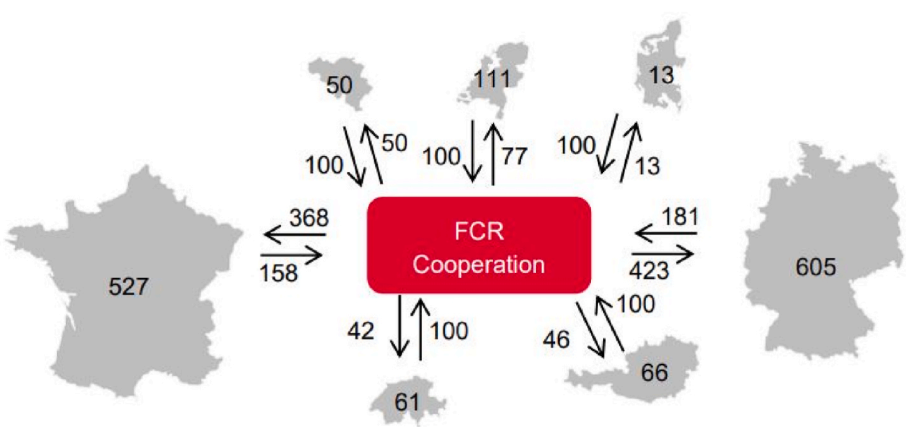

Fig. 8. Demand (2019), import- and export limits in MW per country for FCR in MW (Swissgrid, 2020b).

developing an open market. This situation applies to Portugal and Spain, where the primary frequency control is still considered a mandatory service that should be provided by all generators connected to the transmission network regulated by the TSO in the area.

Based on the analysis presented in this paper, some guidelines can emerge for implementing FCR services in new markets such as Portugal and Spain. First, it is essential to analyse the prequalification process in other countries, mainly France, the only country that can directly exchange energy and services with Spain. The second point is to define clear rules and procedures that can be adopted by large-scale participants but mainly for small-scale flexibilities. These policies are essential in Portugal and Spain due to the high share of renewables connected in medium and low voltage networks. Participation in FCR services should be simplified, and some standard equipment can be adopted. The main goal is that by using the mentioned equipment, the flexibility providers can have the guarantee in the prequalification process, at least in topics related to measurements, sensors and ICT requirements. Another aspect that can facilitate the participation of small-scale flexibilities is the requirements concerning data availability. The requirement of 99% of data availability imposes a redundant connection or a private slice in a 5G network. These solutions are expensive and can limit the interest of small-scale flexibility in FCR services. A possible alternative is to impose this requirement on the aggregator but not for small-scale flexibilities. Finally, the procurement of symmetric products is adapted for some technologies, mainly storage systems, but not for active consumers or small-scale producers. For example, if a small-scale producer wants to provide symmetric FCR, some production curtailment can be required. Aggregators can be used to manage and coordinate small-scale flexibilities trying to provide symmetric products avoiding (or limiting) this rule for small-scale flexibilities.

The evaluation of market access in different countries in the EU was based on extensive research on the current regulations of each country regarding FCR provision and the common market regulation in the EU and its efforts for a harmonized market. As there are no articles with updated information on this matter, the study was limited to official documentation published by the TSOs, and not much information from the point of view of other stakeholders could be found. Further research is needed on additional requirements that TSOs might have for some BSPs after they deliver the documentation during the prequalification process, such as the Swiss TSO Swissgrid.

As the scope of this study was limited, some countries with an established balancing market and a certain level of openness to small-scale aggregators, such as France, Netherlands, Italy and Denmark, were not evaluated. As a future work proposal, an analysis of the balancing market and their prequalification processes in these countries should be considered, as it would enhance the understanding of the different balancing markets and processes to enter them, as well as all the possible processes for it.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgements

Hugo Morais and Andressa Pedro were supported by national funds through FCT, Fundação para a Ciência e a Tecnologia, under project UIDB/50021/2020. Lucas Pereira was supported by FCT, Fundação para a Ciência e a Tecnologia grants CEECIND/01179/2017, UIDB/50009/2020 and EXPL/CCI-COM/1234/2021.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jup.2022.101477.

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