Small Flexibility-based Frequency Containment Reserves – Opportunities Analysis and Modeling

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Due to an increase of renewables in the electricity mix in Europe in the last years and plans to shut down coal-fired power plants in the future, balancing services being provided by small aggregators is getting increasingly important. The aim of this thesis is to qualitatively analyze and compare different market accesses in Europe for small flexibility based FCR providers. For the analysis, five different countries were chosen: Switzerland, Belgium, Germany, Portugal and Spain. For the market access analysis for FCR services of the different countries, the prequalification process of each of these countries was explained and later compared. Out of the five countries compared, the one that appears to have less entry barriers and shows greater possibilities of working in a case-to-case basis is Switzerland, followed by Belgium and then by Germany. In addition to the qualitative analysis, a case study was developed, presenting the pilot project between the German start-up KOENA tec and it partners. In this project, industrial coffee machines are aggregated to provide FCR services to the grid, thanks to KOENA tec's smart plug that can control the power output of the coffee machine. Their goal is to provide 50kW of marketable power in the Swiss grid by aggregating coffee machines. In this sense a simulation of the prequalification test was performed to determine the number of coffee machines that should be used to pass this test. This was done through data analysis of the power profile of a coffee machine. The results show that a minimum of 278 coffee machines need to be aggregated to be able to provide 50kW of balancing services to the grid by using the specified coffee machines.

1. Introduction

With an increase of renewables in the electricity mix in Europe the last years and a trend for them to gain even more importance [1], comes higher uncertainties in the grid, as renewables sources such as wind and solar are intermittent. In this context, balancing services in the power system are increasingly becoming more challenging. Traditionally, large hydro and fossil-fuel based power plants are the ones responsible for providing ancillary services. However, as many European Union countries have announced their intention to phase out coal-fired power plants by 2030 [2], small balancing providers such as prosumers, demand response and small storage units will become more necessary and important.

Aggregators have a vital role in this context, as the balancing markets have a minimum marketable service that can be provided, and therefore aggregating small units lowers their entry barriers in the markets. Aggregators are still a new concept within the balancing market context, and its function is to combine multiple consumer loads or/and small generators' electricity for sale, purchase or auction in the electricity market.

However, entities responsible for organizing the European balancing markets in their area of operation, the Transmission System Operators (TSOs) [3], do not have harmonized rules for the balancing market throughout the whole European Union yet, as decisions about it are set out to be determined by each TSO in their area. This paper aims to research and analyze the market access for small aggregators in the balancing market in selected countries in the European Union, comparing their policies and prequalification process, as well as researching what are the unified rules for these countries. The objective is to identify opportunities and barriers for small aggregators in providing Frequency Containment Reserve (FCR) services to the grid.

This research is done in collaboration with KOENA tec, a German start-up that provides data analysis and energy efficiency tools for consumers through its smart plug, focused on the gastronomy sector. It is currently developing the pilot project Coffee2Grid to offer FCR services to the grid through industrial espresso machines in Switzerland. The pilot project goal is to successfully provide data-driven energy efficiency advice for operators of espresso machines, as well as to prove it is economically feasible to aggregate these espresso machines as small flexible power assets in order to provide ancillary services to the grid.

2. Balancing Market Overview

In order to maintain the nominal frequency of the system it is established a market to exchange capacity and energy to balance the system, the balancing market. Balancing markets are the institutional, commercial and operational arrangements that establish market-based management of balancing services [4].

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) [3]. In Figure 1 the time of activation and duration of each product can be seen.

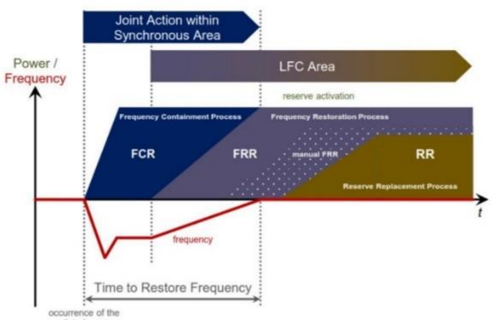

Figure 1: Activation structure of balancing services in relation to time and frequency deviation [5].

There are different actors involved in balancing markets in the EU. The Transmission System Operator (TSO) is accountable for the organization of European balancing markets. Within this scope, they develop the qualification process for those interested in providing balancing services to the grid, 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 to the balancing service providers (BSP) and the balance responsible parties (BRP).

Balance Responsible Parties (BRP) in the electricity market 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 they balanced in real time [4]. An imbalance charge can be placed to the BRP depending on its imbalance and the state of the system, where the BRP can either have to pay or receive a payment. This imbalance charge is a crucial element of the balancing market and it is called imbalance settlement.

A Balancing Service Provider (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 electricity production and the development of demand response, there was an increase of potential balancing service providers. However, since their balancing capacity is limited, these small producers faced several market barriers. In this context, the role of the third-party aggregator was formed, and its function is to combine multiple consumer loads or/and small generators' electricity for sale, purchase or auction in the electricity market [6].

3. Unified Market Access Regulation for FCR service provider in the EU

The main 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 in order to ensure system security, enhance efficient use of the network and increase competition in the system [3]. 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 the development of cross-border balancing markets.

Regarding the harmonized rules for the FCR prequalification process, this process is set and defined by each TSO in its connecting area. In it, the FCR provider should prove it satisfies the technical and additional requirements set out in the system operation guideline. Despite this process being developed by the TSOs, the guideline determines the deadline periods for this process.

The Guideline on Electricity Balancing (EB GL) established that, if two or more TSOs in the European Union would like to (or already do) exchange balancing capacity, development of a proposal with harmonized rules and processes for the exchange and procurement of balancing capacity need to be made by them [4]. The TSOs from Austria, Belgium, Netherlands, France, Germany and Switzerland had created the FCR Cooperation for the development of a common FCR market in 2016 and, in that sense, released the draft of Proposal for the establishment of common and harmonized rules and processes for the exchange and procurement of FCR [7]. The FCR Cooperation is a common market which plans to integrate the FCR balancing market in the European Union in order to increase competitiveness, efficiency and security of supply, while creating incentives for new BSPs and different technologies to provide FCR services.

In this proposal, key aspects are defined for the common market. First, regarding the bid size, the minimum bid size is set for 1 MW, divisible with the bid resolution of 1MW, and indivisible bids' maximum size is 25MW. 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 to the grid and storing energy). Third, it is targeted to have daily auctions one day before delivery of the service, having this started on June 2020 [8]. Fourth, it is proposed that the product duration is 4 hours and symmetrical, instead of the initial one week (from Monday 0h until Sunday 24h) symmetrical.

4. Market Access for FCR Services in Selected Countries

The countries selected for the study were chosen for different reasons. Germany was chosen for being the country where KOENA tec is located, while Switzerland was chosen since KOENA tec's pilot project is located in this country. Moreover, these two countries and Belgium were selected as they are one of the countries that participate in the FCR Cooperation project. Portugal and Spain were selected due to their high beverages servings establishments ratio in relation to their population.

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

4.1 Prequalification Process in Switzerland

The prequalification process in Switzerland is developed and organized by the only TSO present in the country, Swissgrid. In the process, the potential BSP needs to fill out a form for the specific service it wishes to provide and send it together with a list of all the providing units and Technical Units 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 substations that compose a virtual providing unit must also be provided, along with the system type, nominal rated power, metering point ID and other information.

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 to the potential BSP.

4.1.1 Operational & Control

The most important test developed for the prequalification process for FCR services in Switzerland is the capability test [9]. 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 speed or grid frequency is reduced or increased from 50 Hz to either 49.8 or 50.2 Hz within 10 seconds, and the power deviations of the providing unit/group are recorded after 30 seconds. The FCR service must be fully activated within 30 seconds of the frequency deviation, and it must be provided for at least 15 minutes. These requirements are in accordance with what is established by the SO GL for Continental Europe.

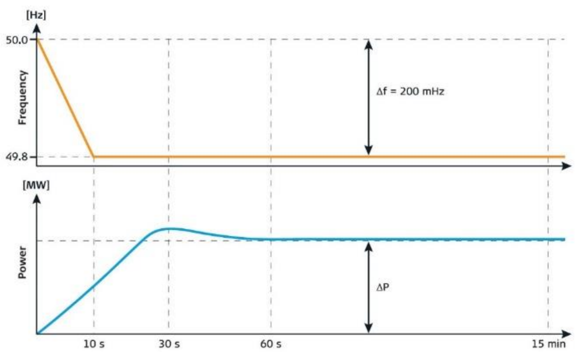

Figure 2: Ideal test signal for FCR capability [9].

Another test performed during the prequalification process is the monitoring test. After submitting the Terms & Conditions signed and Swissgrid accepts the document, 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 and/or providing units and the TSO is tested.

4.1.2 Security & Software

The control system of the BSP is connected to the TSO Swissgrid through a Swisscom LAN interconnected network available for real-time monitoring. The data availability to the TSO is requested to be, at minimum, 99.5%. The online monitoring data needs to be updated at a maximum resolution of 10 seconds. The connection between the TSO's control center and the reserve provider's control system must be based on a 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 the responsible for the costs and for applying to a connection with the closed user group with the telecommunications provider Swisscom.

4.2 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 in which it proves the compliance of this providing group with the requirements for the provision of FCR. Among other 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.

4.2.1 Operational & Control

The operational test to be performed in the Belgian prequalification procedure is the Synthetic Frequency Profile test. For this test, Elia 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 of frequency deviation of 50mHz in each step, in which the number of steps varies depending on the service type.

The providing group must have a certain power profile depending on the service type (either symmetric 200mHz, symmetric 100mHz, asymmetric up or asymmetric down). For 200mHz, the following profile must be obtained by the providing group in the test:

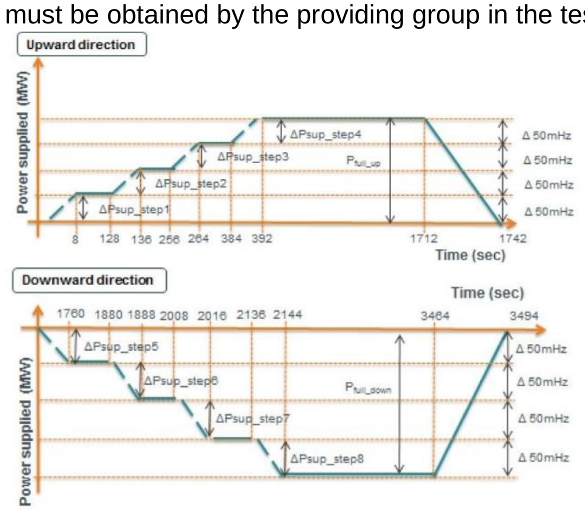

Figure 3: Power supplied profile during synthetic frequency profile test for service type 200mHz [10].

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

For providing the 100mHz service type, asymmetric up and downward directions the power supplied profiles during the tests for upward and downward direction are in Figure 4.

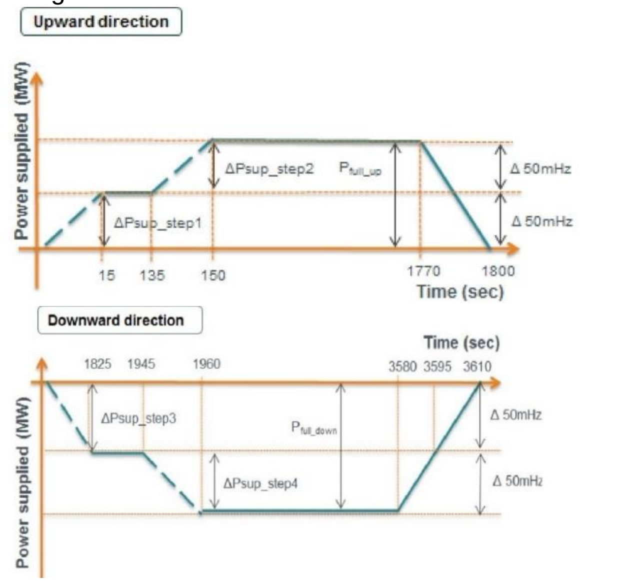

Figure 4: Power supplied profile during synthetic frequency profile test for service type 100mHz [10].

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

Another test required is a test under operational conditions for a continuous period of four hours. If during this test there is one or more frequency deviation larger than 40mHz, Elia 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 its connection to the TSO's control system works correctly and that it has the ability to exchange data with Elia. This is done through the Communication Test, in which both the nomination communication and real-time communication are tested.

4.2.1 Security & Software

The TSO Elia requires a redundant communication channel between the BSP and Elia, with the communication protocol being determined by the TSO. If Elia decides to improve certain procedures or real-time exchanges, the BSP commits to apply 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, then, have two physical communication links and two different Uninterruptible Power Supplies (UPS) with a minimum of 8 hours of autonomy per physical link.

4.3 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 50Hertz Transmission. In this prequalification process, a potential BSP needs to submit certain documents concerning its providing units or providing groups to meet the minimum requirements to provide balancing services to the grid. They have to be part of a pool, which consists of a single or multiple aggregated providing units and/or providing groups. In order to pass the prequalification process at least one performance measurement must be carried out for each TU.

4.3.1 Operational & Control

An important test within the prequalification procedure 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. 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, needs to result in a "double hump curve", consisting of three retention phases and two delivery phases. The duration of each phase for provision of FCR is a fifteen-minute schedule interval, and the providing unit/group reaches the specified setpoint within 30 seconds.

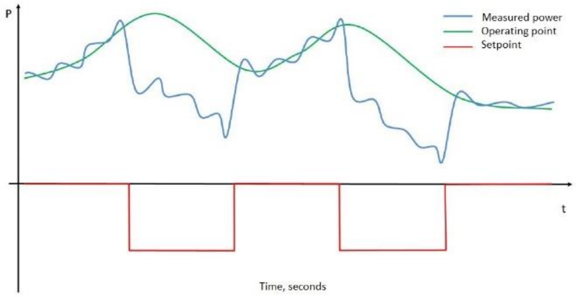

Figure 5: Data recorded during operational test (based on image from [11]).

An Operational Test for FCR provision has 3 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 +/- 200 mHz and lasts a maximum of 30 seconds, ending when the setpoint is reached for the first time. The transient area begins at the end of the SCR, at the latest 30 seconds after the setpoint step. It ends 90 seconds after the setpoint jump. The Stationary Area begins 90 seconds after the setpoint jump and lasts at least 13.5 minutes.

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 usable work capacity must be demonstrated in the operational test.

Besides the operational test, a trial run under operational conditions is done for a continuous period of eight hours. 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 re-connection is checked.

4.3.2 Security & Software

The availability of an individual connection between the TSO's and BSP's control system must be set and should be of a value similar to 98.5%. The connection between the TSO's control center and the BSP's control system must be based on a dedicated point-to-point control technology.

An IT requirement regarding the control system is the obligation of duplicating the reserve provider's central control system. The delay on the transmission route E2E must be of a maximum of about 5 seconds. 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%.

4.4 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) needs to provide this service in a non-remunerated scheme [12]. Therefore, market access for FCR providers through demand response and small units is not possible.

One important point that indicates 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 [13].

4.5 Prequalification Process in Spain

Like Portugal, in Spain primary frequency control is a mandatory service that needs to be provided by every generator connected to the Spanish electricity network, including distributed generators. Although small-scale storage is not able to provide FCR services to the Spanish grid yet, due to the need of implementing the EB GL, a public consultation has been published in order to define a work plan for the participation of storage and demand in balancing markets [14].

4.6 Market access comparison between studied countries

Despite all the countries studied being part of the FCR Cooperation (except Portugal and Spain, who do not have an open market for FCR services), the requirements and the prequalification process for each of them can differ greatly. This can be observed in the operational test, in which in Switzerland the service must be continuously provided in full power for 15 minutes, the German TSOs require it to be provided for 13.5 minutes and the Belgian TSO requires 27 minutes of continuous provision during the test.

Another considerable difference between the prequalification processes between these countries is when it comes to security & software requirements. The German TSOs provide an excel file with a checklist of all the requirements related to Information & Technology, totaling 36 requirements, and divided these requirements into different categories, such as Network, Encryption and Closed User Group. The Belgian and Swiss TSOs, however, 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 information related to Security & Software 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 section suggesting it has the least requirements and tests in the prequalification process for FCR services, this may not be true. As it has been mentioned before, after the BSP submits the documents and the list of the providing units, the swiss TSO needs to confirm the documents and, after that, analyses and coordinates 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 a more openness to small flexibility units.

When analyzing and comparing all the prequalification processes across the different countries, despite all of them being open to small FCR providers and allowing their aggregation, the German prequalification process imposes some restrictions to small FCR units. It is the only country between the ones analyzed with additional requirements to 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" a new requirement was set, adding the concept of bundling of small units and allowing the connection of micro-installations through a pool.

5. Case Study

5.1 Coffee2Grid

KOENA tec is a German start-up that provides data analysis and energy efficiency tools for consumers through its smart plug, focused on the gastronomy sector. It is currently developing a pilot project, Coffee2Grid, with Gruppo Cimbali, a traditional espresso machines manufacturer, BKW AG, a power generation and distribution utility company, and Vassalli AG, the only distributor of Cimbali machines in Switzerland, to offer balancing services to the grid through industrial espresso machines in Switzerland.

KOENA tec's Smart Plug is a plug-and-play device that, once connected between the appliance and the power socket, enables the measurement of electricity consumption and sends this data to KOENA tec's cloud server. In addition to that, with the software updates and extension of IoT protocol of the coffee machines, the smart metering device will also be able to control the temperature of the coffee machines, thus providing FCR services to the grid.

Regarding the coffee machine used for the pilot project, it is of heat exchanger boiler type, in which the water in the coffee boiler is heated through a hot water & steam boiler when wrapped inside this main boiler. The coffee machine used in the pilot project is the M100 GTA manufactured by LaCimbali. It has 3 groups of coffee boilers, and an installed power of around 6.7-8kW.

5.2 Prequalification test

In this quantitative assessment, a simulation of the Capability Test will be made in order to determine the minimum number of espresso machines that need to be aggregated to successfully pass the test and provide FCR services to the Swiss grid. The goal is to be able to provide 50 kW of power to be pooled together with the virtual power plant portfolio of BKW.

5.2.1 Methodology

In order to do the prequalification test simulation to determine the minimum number of coffee machines that need to be aggregated to pass this test in Switzerland, data analysis of an industrial espresso machine was performed. KOENA tec, in collaboration with one of the partners, connected one espresso machine to its KOENA Energiebox for data measurement. Data was collected from March 2019 until March 2020, however, due to technical reasons related to the data acquisition, for the scope of this thesis only the data for the period of 61 days, from October 1st until November 30th of 2019, was analyzed. The calculation is done by analyzing the heating cycle of an espresso machine with similar specifications as the Cimbali one and applying the appropriate margin increase given the difference in the installed power between the two coffee machines.

5.2.2 Available Data

KOENA's Energiebox data collection is done by collecting power data from the three phases of the coffee machine separately in seconds resolution and continuously transfers them to the main server. The three phases are connected to the electrical equipment in the following manner: phase 1: hot water/steam boiler and coffee boiler, phase 2: coffee boiler, phase 3: hot water/steam boiler and a pump. To simplify the data analysis and calculation, when collecting and plotting the heating cycle of the espresso machine the three phases were summed and they cannot be differentiated in the graphs.

In Figure 6 the recurring high peaks represent the heating of the hot water and steam boiler to maintain the temperature at the optimum setting. Periodical and more flattened power usage signify the Proportional Integral Derivative (PID) controller is working to maintain the water temperature of the coffee boiler at the ideal temperature.

The coffee machine selected is a La Marzocco Linea Classic model EE. Although the data analysis was not performed for the same coffee machine model as the one that will be effectively used to provide FCR services to the grid, they have similar operating modes and specifications, having the La Marzocco coffee machine a lower installed power of around 4.93-7.79kW.

5.2.3 Results

Looking more closely at the heating cycle of the espresso machine, the hot water/steam boiler consumes 5kW power for about 12 seconds, and that the distance between two peaks is, on average, of 120 seconds.

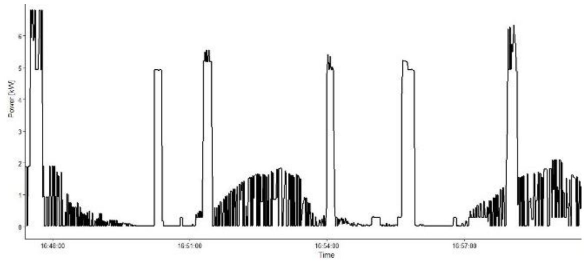

Figure 6: Heating cycle of coffee machine La Marzocco on October 10th, 2019.

By applying a margin increase of 15%, one coffee machine can store energy when needed by the grid with a power of 5.75kW for 12 seconds. In order to avoid overheating the boiler, the coffee machines were divided into groups, and each group would operate for 12 seconds by providing FCR services in the negative direction. These would then have a "resting period" of 120 seconds, while other groups of coffee machines provide the balancing service needed to the grid. Considering the total length between the start of the first group and the end of last group of coffee machines (132 seconds), a total of 11 groups are needed to pass the prequalification test for the swiss market.

For the calculation of the number of coffee machines each group is composed of, dividing 50kW by the total power of each machine, gives a total of 8.7. Rounding it up gives a total of 9 coffee machines per group. Multiplying it by the number of groups needed gives the total number of coffee machines that need to be aggregated to pass the prequalification test in the negative direction: 99 coffee machines.

To provide balancing services in the positive control direction, only the coffee boiler is going to be used. The coffee boiler consumes energy for a longer, more stable period when being heated to reach the optimum temperature for coffee beverages and that it spends, on average, two minutes on and two minutes off.

As for the power usage of a coffee boiler, it is on average of 2kW. As the coffee boiler is turned on when the temperature reaches the minimum allowed to ensure the product quality (90°C) and it is turned off when it reaches the maximum allowed (96°C), that means that every minute the temperature of the coffee boiler will vary 3°C. This means that if instead of 2kW of power is consumed, the coffee boiler consumes half of it (1kW), the temperature of the boiler will be maintained. Thus, if optimal temperature is reached, less power can be consumed during the participation in the FCR services to the grid.

For the simulation of the prequalification test in the positive control direction, the change in the normal operation of the coffee boiler was applied and a decrease in the power consumption was made, considering that in the 15 minutes of the test the coffee machines will vary their temperature from the highest possible to the lowest. In order to rationalize the quantity of coffee machines to be used in the prequalification test, the optimal temperature range of the coffee boiler was extended to 89.5-97°C instead of 90-96°C.

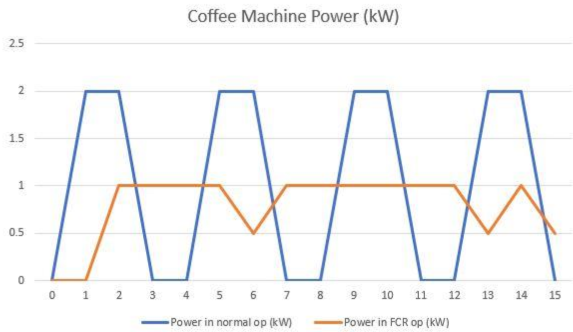

Figure 7: Simulation of coffee machine power output during normal operation and during FCR provision in positive direction.

Considering a group of 16 coffee machines and by reducing the power consumption while maintaining an acceptable temperature, each minute the group of coffee machines can provide 2.5kW of FCR services to the grid in the positive control direction. Applying the margin increase, a group of 16 Cimbali coffee machines can provide 2.875kW of FCR services in the positive direction per minute. Thus, in order to be able to market 50kW of power in the swiss electricity grid, a total of 278 coffee machines need to be aggregated.

6 Conclusions

This work was developed with the aim of qualitative analyzing and comparing different market accesses in the European Union for small flexibility-based FCR providers. As allowing aggregation of small electricity producers and/or consumer loads for providing balancing services is still a fairly recent development, regulations are constantly changing and there are not up-to-date studies related to this subject. For the analysis, five different countries were chosen: Switzerland, Belgium, Germany, Portugal and Spain.

Out of the five countries compared, the one that appears to have less entry barriers and shows greater possibilities of working in a case-to-case basis, is Switzerland. Its TSO, Swissgrid, besides not having extra entry requirements for providers with limited energy storage (the case of small flexibility-based providers), after receiving the initial documentation from the potential FCR provider, evaluates this documentation in order to determine if any additional tests or requirements should be requested by them. 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 minutes), followed by Switzerland (15 minutes), and Belgium by far the most restrictive one, requiring the provision of full power for 27 minutes, which might hinder the provision of FCR services from small providers with limited energy storage.

However, even though there are 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 development of an open market. This is the case of 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.

In addition to the qualitative analysis, a case study was developed, presenting the pilot project between KOENA tec, and their partners. Their intention is to provide 50kW of marketable power in the Swiss grid using between 50 and 75 coffee machines. In this sense, a simulation of the prequalification test was performed to determine the actual number of coffee machines that should be used to pass the prequalification process and provide 50kW power to the grid. This was done through data analysis of the power profile of a coffee machine with similar specifications as the one to be used in the pilot project and applying a margin of 15% due to the difference in the installed power of the machines.

As in the swiss balancing market it is determined that a BSP needs to provide services in both directions (upward and downward), calculations were conducted for both. Due to the different power profiles of the coffee boiler and the hot water/steam boiler, for the downward direction, only the hot water/steam boiler was used, and for provision in the upward direction, only the coffee boiler was used. As a result, different values of the minimum number of coffee machines were found for provision in each direction: while for the downward direction, 99 coffee machines shall be used, for the upward direction 278 coffee machines will have to be used.

KOENA tec and its partners have planned to aggregate between 50 and 75 coffee machines for the prequalification test in the swiss FCR market. The results through data analysis of the heating cycle of a coffee machine are higher than the expected value by the start-up. This difference can be related to the fact that, although having a similar technical specification, the coffee machine to be used in the prequalification test and the one with available data provided by KOENA tec might have a slightly different power profile. However, the main cause of this difference is that, when the company performed calculations of the number of machines to be aggregated, they assumed the test would not be performed during operation hours. In this sense, the optimal temperature range of the coffee boiler was not considered, and the temperature range during FCR services was greater than the allowed for maintaining the quality of the beverages served.

7 References

[1] European Commission. The average share of electricity from renewable energy sources in the EU. EUROSTAT, Directorate E: Sectoral and regional statistics. Unit E.5: Energy. Last updated: September 17th, 2020.

[2] Climate Analytics. A stress test for coal in Europe under Paris agreement. (February 2017)

[3] Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (Text with EEA relevance.) C/2017/5310 OJ L 220, 25.8.2017, p. 1–120

[4] Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (Text with EEA relevance.) C/2017/7774 OJ L 312, 28.11.2017, p. 6–53

[5] ENTSO-E. Explanatory document concerning proposal from all TSOs of the Nordic synchronous area for the determination of LFC blocks within the Nordic Synchronous Area in accordance with Article 141(2) of the Commission Regulation (EU) 2017/1485 of 2 August 2017 est, Published on 09/03/2018.

[6] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (Text with EEA relevance.) PE/10/2019/REV/1 *OJ L 158, 14.6.2019, p. 125–199*

[7] 50 Hertz, Amprion, APG, Elia, EnergiNet, Rte, Swissgrid, TenneT, TransnetBW. Proposal for the establishment of common and harmonised rules and processes for the exchange and procurement of Frequency Containment Reserve (FCR). Published on January 15th, 2018.

[8] TenneT official website. The FCR cooperation reaches the next milestone in the development of the largest FCR market in Europe. Published on June 30th, 2020. Available at: https://www.tennet.eu/news/detail/the-fcr-cooperation-reaches-the-next-milestone-in-the-development-of-the-largest-fcr-market-in-europ/ (Accessed on July 15th, 2020)

[9] Swissgrid. Requirements for schedule data and electronic data Exchange. Published on April 6th, 2020.

[10] Elia. General Framework for Frequency Containment Reserve Service by Non-CIPU Technical Units. Published on July 2019.

[11] 50 Hertz, Amprion, TenneT, Transnet BW. Präqualifikationsverfahren für Regelreserveanbieter (FCR, aFRR, mFRR) in Deutschland ("PQ-Bedingungen"). Published on May 29th, 2020.

[12] Entidade Reguladora dos serviços energéticos. Regulamento n.º 557/2014. Diário da República, 2.ª série — N.º 245 — 19 de dezembro de 2014. Published on December 19th, 2014.

[13] REN. Proposta de Termos e Condições Aplicáveis a agentes de mercado habilitados a fornecerem serviços de regulação e os termos e condições aplicáveis agentes de mercado responsáveis pela liquidação do desvio. Published on April 24th, 2018.

[14] Red Eléctrica de España. Propuesta de Hoja de Ruta para la implantación de la Directriz de Balance Eléctrico en el sistema eléctrico peninsular español. Public Consultation. Published on February 8th, 2019.