H2FUTURE
Green Hydrogen

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Technical Prequalification

Version 1.0

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Notations, Abbreviations and Acronyms

AB	Advisory Board
CA	Consortium Agreement
DoA	Description of Action
DSO	Distribution System Operator
EU	European Union
GA	Grant Agreement
PEM	Polymer Electrolyte Membrane / Proton Exchange Membrane
TSO	Transmission System Operator
WP	Work Package
FCR	Frequnency Containment Reserve
aFRR	Automatic Frequency Restoration Reserve
mFRR	Manual Frequency Restoration Reserve

Table 1: Acronyms list

1 Introduction

1.1 The H2FUTURE Project

As part of the H2FUTURE project a 6 MW polymer electrolyte membrane (PEM) electrolysis system will be installed at a steelworks in Linz, Austria. After the pilot plant has been commissioned, the electrolyser is operated for a 26-month demonstration period, which is split into five pilot tests and quasi-commercial operation. The aim of the demonstration is to show that the PEM electrolyser is able to produce green hydrogen from renewable electricity while using timely power price opportunities and to provide grid services (i.e. ancillary services) in order to attract additional revenue.

Subsequently, replicability of the experimental results on a larger scale in EU28 (EU27 since Feb 2020) for the steel industry and other hydrogen-intensive industries is studied during the project. Finally, policy and regulatory recommendations are made in order to facilitate deployment in the steel and fertilizer industry, with low CO2 hydrogen streams also being provided by electrolyzing units using renewable electricity.

1.2 Scope of Document

The electrolyser system provides Frequency Containment Reserve (FCR), automatic and manual Frequency Retoration Reserve (aFRR, mFRR) to the Austrian Transmission Grid Operator APG. The pre-qualification (PQ) with APG was a requirement for the execution of the demonstrations in WP 8, particularly W.P 8.3 (Grid services) and WP 8.7 (Quasi-commercial operation). The pre-qualification was executed by VERBUND and APG following standard legal processes.

The scope of this document is the description of the procedure of the technical prequalification for ancillary services and the report on the results of the process of obtaining the permission from the Transmission System Operator (TSO) APG for the supply of control energy from the electrolyser system.

2 Information about Technical Prequalification Process

A balance between generation and consumption is essential at all times to guarantee a stable grid frequency. Deviations from this balance, which could for example be caused by power plant failures or unexpected changes of load, must permanently be compensated through the activation of appropriate reserves from generation or load units. In its role as Transmission System Operator (TSO), APG is responsible for the procurement activation and monitoring of the required control reserves in the APG LFC area. (An LFC area is a grid area in which the balance between generation and consumption is coordinated by a single entity – the TSO.)

Since 2012, all components of control reserves required in the APG LFC area have been procured by APG by means of regular tenders. Each market participant, who meets specific technical (prequalification process) and contractual conditions, can participate in these tenders.

For technical and economic reasons, a distinction is made between three types of control reserves: FCR, aFRR and mFRR.

2.1 Frequency Containment Reserve (FCR)

Frequency Containment Reserve is a solidary reserve in Continental Europa. It is needed to automatically compensate an imbalance between generation and consumption within a few seconds through corresponding activation (control). FCR works like a common safety net and stabilises the frequency of Continental Europe within compatible limits. FCR power in the amount of +/-3000 MW is continuously available in the grid of Continental Europe. Each LFC Area contributes to this common reserve based on an agreed yearly distribution key. The volume of FCR that must be provided by the APG LFC area lies at approximately +/-70 MW.

2.2 Automatic Frequency Restoration Reserve (aFRR)

The automatic Frequency Restoration Reserve is an individual automatically activated reserve, which has to be hold ready by each TSO for its LFC area. In case of an imbalance aFRR follows the activation of the common FCR, but is only activated in the LFC area where the imbalance originates. As a result, FCR is relieved and is again available to compensate further imbalances in Continental Europe. Whereas FCR has to be activated within seconds, activation of aFRR must be completed after 5 minutes (full activation time requirement in the LFC area APG).

The dimensioned volume of aFRR within a control area depends on the requirements of “COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation”.

2.3 Manual Frequency Restoration Reserve (mFRR)

Manual Frequency Restoration Reserve is used to avoid longer lasting activation of aFRR (several consecutive quarters of an hour), with the effect of breaking clear aFRR, which would be blocked for other additional imbalances otherwise. Further, it is essential for the LFC area APG to compensate larger imbalances – e.g. outages of large generators, since aFRR is too little to cover such

imbalances. The combined aFRR+mFRR has to be able to compensate expectable imbalances within 15 minutes.

2.4 Legal framework for balancing

- The Electricity Industry and Organisation Act [Elektrizitätswirtschafts- und -organisationsgesetz (ElWOG)]
- Technical and Organisational Rules for System Operators and Users (TOR)
- ENTSO-E Synchronous Area Framework Agreement, Policy on LFCR
- COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation

2.5 Technical prequalification

Technical prequalification is the first step in gaining accreditation as a supplier of control energy. Suppliers undergo a technical prequalification to examine whether they meet the technical criteria required to guarantee the necessary quality of the FCR, aFRR and mFRR. The prequalification procedure must be carried out separately for each type of control energy. The suppliers are, however, not obliged to prequalify for all three control energy types. They may opt to supply just one or two control energy types (e.g. only mFRR or FCR and aFRR, ...).

The framework conditions are laid down in the Operation Handbook of ENTSO-E, Policy 1. The application for the technical prequalification is carried out based on standardized documents provided by the TSO, which must be fully completed by the applicant. This guarantees that the required applicant and power plant data is provided.

The prequalification is valid for three years and must be renewed in due time. If fulfilment of the individual requirements is confirmed, the validity of the prequalification for the corresponding plants will be extended for a further three years. The supplier will be informed with regard to the extension. In the event of significant changes to the corresponding plants of a supplier, e.g. change in congestion capacity or conversion of the controller, a new prequalification will be required for the plants concerned. If an application for the technical prequalification of further plants is submitted and accepted at a later point in time, these will have the same expiry date as the originally prequalified plants.

On submission of the prequalification documentation, the applicant will be registered as a user on the auction platform. The applicant will subsequently be provided with a user name and access code.

The second step in gaining accreditation as a supplier involves the conclusion of a framework agreement. This agreement, which contains details relating to the legal relationship between the supplier and the control area manager, is identical for all suppliers. The framework agreement itself does not oblige the supplier to supply FCR, aFRR or mFRR within the framework of a tender. When the agreement has been signed by both partners, the supplier will, however, be listed as an accredited supplier and, as of this point in time, has the possibility to participate in all tenders for control energy for the APG control area via the electronic tendering platform. A separate framework agreement must be signed for each type of control energy.

3 Technical Prequalification Process for H2Future plant

Within VERBUND Group two control reserve providers are active. At the time of commissioning of the H2Future plant, only one of the providers had the technical prequalification for all the three control reserve products, these are Frequency Containment Reserve (FCR), automatic Frequency Restoration Reserve (aFRR) and manual Frequency Restoration Reserve (mFRR). A technical prequalification that has yet to be applied for poses a certain risk of falling into a project delay. For this reason, VERBUND decided to integrate the control reserve pool of the provider VERBUND Energy4Flex GmbH (VEF).

3.1 Reserve pool VERBUND

In accordance with the current prequalification conditions of APG, all technical units of a provider that have been prequalified for the provision and supply of control reserve are integrated in a reserve pool. The provider VEF uses the possibility of dividing the reserve pool into reserve groups.

These are:

- Reserve group „Donaukraftwerke“ (power stations of the river Danube)
- Reserve group „Draukraftwerke“ (power stations of the river Drava)
- Reserve group „Thermische Kraftwerke“ (Thermal power plants)
- Reserve group „Speicherkraftwerke“ (Storage power stations)

In the reserve groups “Donaukraftwerke” and “Thermische Kraftwerke” there are only plants that are prequalified for the provision and supply of primary control reserve.

The power plants and technical units, which are summarized in the reserve group " Draukraftwerke ", can be used for the provision and supply of primary and secondary control reserve.

The technical units that are assigned to the reserve group “Speicherkraftwerke” can be used for the provision and supply of primary, secondary and tertiary control reserve as well as for load sequence operation (balance group control). The controllable load of the H2Future electrolyzer is assigned to this reserve group in addition to the controllable units of the storage power plants and other controllable loads.

In the balance group VERBUND (13XVERBUND1234-P), the deviation from the total target generation, which mainly results from forecast errors, power plant malfunctions or failures and schedule deviations, is compensated as best as possible by the so-called balance group controller (load controller). For this purpose, the same technical units of the reserve group “Speicherkraftwerke” are used that are also applied for the supply of Frequency Containment Resserve, automatic and manual Frequency Restoration Reserve.

In order to ensure transparency in the monitoring, the suitable technical units of the reserve group "Speicherkraftwerke " are divided into two subgroups (clusters).

These are:

- the automatic Frequency Restoration Reserve cluster – due to the former definition is called secondary control reserve cluster (SRR cluster) and
- the balance group cluster (BG cluster)

Each of the two clusters takes on special tasks. The requested secondary control reserve $P_{SReg,soll}$ is only provided by the technical units that are assigned to the secondary control reserve cluster (SRR cluster). This also means that only technical units which are prequalified for the provision of automatic Frequency Restoration Reserve can be assigned to the SRR cluster. The balance group cluster (BG cluster) regulates the target generation of the balance group (load sequence control).

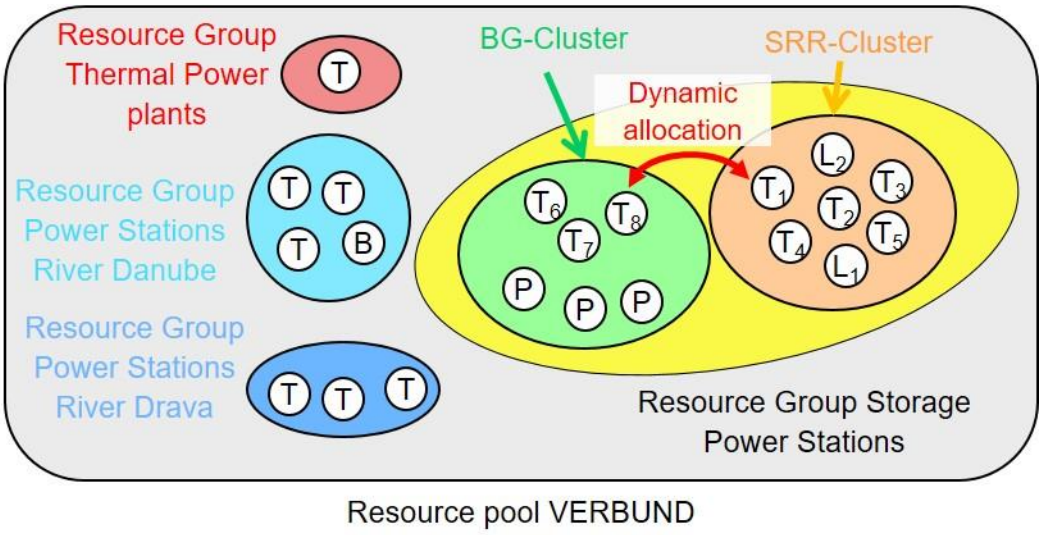

Figure 1: Classification of the reserve pool into reserve groups

3.2 Provision and supply of primary control reserve

The operation concept of the provider VEF for the provision of Frequency Containment Reserve (primary control reserve) in the APG control area provides that the contractually allocated primary control range is made available from the technically prequalified systems of the VERBUND Group and from the controllable load of the H2Future plant without interruption. Within the control area of APG the agreed services are fed into the grid in accordance with the specified rules.

The provision and supply of primary control reserve is divided into the following process steps, which are mentioned below:

- Quantity determination for the tenders
- Operation scheduling of the power plants
- Provision and supply
- Operation point and monitoring
- Monitoring of the provision

Quantity determination for the tenders – Frequency Containment Reserve

At the beginning of the marketing of the Frequency Containment Reserve, it is necessary to determine which service can be securely provided and supplied. Here, considerations about the availability of work and power as well as operational boundary conditions such as feed-in restrictions or operational boundary conditions play an important role. The basis for the marketing decision for the H2Future system is the planned system availability. If the system is available, the marketing decision is an optimization task. The price expectations on the spot market and the expected revenues on the control reserve market are included in this optimization calculation, which is carried out daily. The marketing decision is made on the basis of the result of the optimization calculation.

Operation scheduling of the power plants

The result of the optimization and the result of the control reserve auctions and the spot market are the basis for the operation planning of the H2Future plant.

Provision and supply – Frequency Containment Reserve **of H2Future plant (controllable load)**

In the course of providing and supplying Frequency Containment Reserve, the process for the controllable H2Future load is the same as in the case of using a machine set in a power plant. Under a measuring and control unit the primary control is activated continuously depending on the frequency.

The primary control function can be activated or deactivated via remote control from the VEF control room in the measuring and control unit of the H2Future plant. The measuring and control unit measures the network frequency on site and, by means of an implemented algorithm a corresponding setpoint component is determined taking into account variable indicators for the primary control. This component is also influenced by the setpoint for the operating point. The variable indicators can be adjusted via the remote control from the VEF control room. With the controllable load of the H2Future plant, a central frequency measurement is made available to the measuring and control unit as an additional backup in addition to the local frequency measurement. This central frequency measured value is transmitted from the VEF control system to the measurement and control unit via the communication link.

The operation point of the H2Future plant is scheduled in a 15-minute resolution.

The Frequency Containment Reserve generated by the H2Future plant is determined by the difference between the current output and the operating point.

Availability of power, work and time - primary control reserve

The controllable loads of the H2Future plant are based on a conversion process. The availability of the input materials is a measure of the work availability. In the course of marketing, possible unavailability, the material resources as well as the possible utilization of the produced substances (storage or transport) are taken into account, so that the question of work availability is already clarified before marketing.

In the marketing process possible unavailabilities are also a major limitation to be considered. Planned unavailabilities are taken into account in marketing and operation scheduling. Failures or unplanned unavailabilities lead to the consequence that the capacity is shifted from the H2Future plant to other prequalified systems.

Activation of reserves in the event of frequency deviations exceeding ± 200mHz

As to the controllable load of the H2Future plant, in the event of a frequency deviation exceeding ± 200mHz, the activated reserve is limited to the value of the maximum primary control reserve, which is activated in the event of a frequency error of ± 200mHz.

3.3 Concept for the provision and supply of automatic Frequency Restoration Reserve

The contractually allocated automatic Frequency Restoration Reserve (secondary control reserve), which the provider has to supply and maintain, is made available from the prequalified hydropower plants of the VERBUND Group and the controllable loads such as the H2Future system without interruption and fed into the network.

The procedure for marketing, maintaining and providing automatic Frequency Restoration Reserve is analogous to the process for maintaining and providing the Frequency Containment Reserve. The individual process steps are comparable to the process steps described in the primary control reserve area. These are:

- Quantity determination for the tenders
- Operation scheduling of the power plants
- Provision and supply
- Monitoring

The provider VEF tends to use the systems that are used for the provision and supply of automatic Frequency Restoration Reserve as much as possible. This means that the systems are generally used for the combined provision of several control reserve products from one and the same technical unit as well as the simultaneous use of the technical units for the provision and supply of control reserve and load sequence operation.

Quantity determination for the tenders

This process step is carried out together with the quantity determination of the Frequency Containment Reserve and manual Frequency Restoration Reserve. In the offer phase for the upcoming tender, all operating information and forecasts known for the delivery period are used in order to estimate the maximum maintainable and achievable automatic Frequency Restoration Reserve that can be reliably provided under the given framework conditions. For the quantity determination the following aspects are considered:

- Planned and known unavailability,
- Forecasts and energy availability (influx to the storage facilities, development of storage content)
- Operational parameters (machine-specific parameters, priorities, etc.)
- Special performance limiting conditions (feed-in restrictions by transmission system operators, congestion management that has already been announced, etc.) and
- Planned sales volumes or already known obligations for the provision of other types of control reserve (Frequency Containment Reserve or manual Frequency Restoration Reserve)

By checking the remaining storage contents, the provider VEF also assesses the work availability of the storage power plants for the delivery period. The results of the work availability check can also lead to a limitation of the secondary control reserve that can be offered. With these considerations, the expected availability of work and performance is taken into account as much as possible already in the tendering phase before the offer is submitted.

For the H2Future system, the performance and work availability are considered in the same way as for the quantity determination for the Frequency Containment Reserve.

Operation scheduling of the power plants

In the section on the concept for the provision and supply of Frequency Containment Reserve, power plant operation scheduling has already been discussed. The storage power plants and the controllable loads are used flexibly for the provision and supply of control reserves and on the spot market. Due to the limited number of possible operating hours, the disposable use of the storage power plants is planned depending on the spot market prices. For the commercial use of the H2Future loads and other controllable loads, the procedure is analogous to that and a possible use is planned up to a certain limit price. Therefore, there is also a stake for the H2Future load that depends on the spot market price.

At the beginning of the daily operational planning price-dependent offers are set up for the marketing of available services on the spot markets of the power exchanges, taking into account all contractual obligations for the provision and supply of control reserves and other contractual obligations (e.g. electricity purchase rights of partners). After the results of the day-ahead spot market auctions are available, an operation schedule of the storage power plants and controllable loads as well as a plan for providing the control reserves for the upcoming day will be created. The following updated data is included in the operation schedule:

- Contractual operating reserve to be provided (primary, secondary and tertiary),
- Planned and known unavailability,
- Forecasts and energy availability (influx, development of the storage content)
- Operational parameters (machine-specific parameters, priorities, etc.) as well as
- Particular performance-restricting conditions (feed-in restrictions from network operators, congestion management that has already been pronounced, etc.)

Provision and supply of automatic Frequency Restoration Reserve

The technical units of the reserve group “Speicherkraftwerke” will continue to be used as flexibly as possible and a combined provision of control reserve and load control (balance group control) is pursued. For the transparent management of the automatic Frequency Restoration Reserveon the one hand and the efficient handling of the demand for the balance group on the other hand, the implemented cluster model is therefore used in the reserve group “Speicherkraftwerke”. Two clusters are managed in this reserve group:

1) SRR-Cluster
2) BG-Cluster

The technical units assigned to the SRR cluster are responsible for maintaining and providing the automatic Frequency Restoration Reserve. The technical units assigned to the BG cluster are intended to cover the variable balance group load. The technical units of both clusters can also be used for the combined provision of Frequency Containment Reserve, automatic and manual Frequency Restoration Reserve (SRR cluster) or load control operation, Frequency Containment Reserve and manual Frequency Restoration Reserve (BG cluster).

In accordance with the contractual power range of automatic Frequency Restoration Reserve, a sufficient and appropriate number of prequalified technical units is allocated to the reserve group “Speicherkraftwerke”. In this procedure it is considered that the operationally available power range of the technical units assigned to the SRR cluster are greater than the contractual power range automatic Frequency Restoration Reserve at all times.

The remaining controllable technical units of the reserve group “Speicherkraftwerke” are assigned to the BG cluster (default assignment). These technical units are used to cover the flexible power demand of the balance group.

The individual machines are manually assigned to the appropriate cluster in the load balancer according to the respective demand of the controlling power range and the demand of storage management (SRR cluster for providing automatic Frequency Restoration Reserve, BG cluster for power control of the balance group). A technical unit of the reserve group “Speicherkraftwerke” is therefore assigned to either the BG cluster or the SRR cluster.

H2Future and automatic Frequency Restoration Reserve

The controllable loads are integrated in the reserve group “Speicherkraftwerke“, because the controllable loads have comparable control properties. The H2Future system was integrated into the reserve group as the first controllable load. The electrolyzer produces hydrogen (and oxygen) from water. The hydrogen produced is fed into the voestalpine coke oven gas network (COG). Significantly more hydrogen is required at the voestalpine site in Linz than can be generated by the H2Future plant. It is therefore not necessary to pay attention to the storability of the end product in this configuration as the amount of hydrogen from the electrolyzer can be also covered by the existing system. The availability of water is also not a limiting factor.

The amount of hydrogen produced is directly proportional to the electricity used. By regulating the electricity, it is possible to provide control reserve for the control area manager.

The technical connection of the electrolyzer to the control technology of the provider VERBUND takes place via a data connection and a local measuring and control device at the electrolyzer. The required messages, measured values, commands and setpoints are exchanged between the local control device and the control technology at the VERBUND control room via this data connection. The transmitted setpoints are output from the local control device to the controllable load.

The power distribution of the requested secondary controlling power range to the individual technical units is realized by a distribution algorithm. For the implementation of the power distribution, the reference power, the operating point, is specified by means of a schedule that can change every quarter of an hour.

Due to the rather small control range of the electrolyzer, VEF does not perform a combined provision of Frequency Containment Reserve and automatic Frequency Restoration Reserve from the H2Future system.

3.4 Concept for the provision and supply of manual Frequency Restoration Reserve

The concept for the provision of the manual Frequency Restoration Reserveis based on the approach for the provision and supply of the automatic Frequency Restoration Reserve and the existing organizational procedure for the provision and activation of the manual Frequency Restoration Reserve. Only machines and controllable loads from the reserve group “Speicherkraftwerke” are used to provide the manual Frequency Restoration Reserve.

Quantity determination for the tenders

This process step is carried out together with the quantity determination of the Frequency Containment Reserve and automatic Frequency Restoration Reserve. In the offer phase for the

upcoming tender, all operating information and forecasts known for the delivery period are used in order to estimate the maximum maintainable and achievable manual Frequency Restoration Reserve that can be reliably provided under the given conditions. For the quantity determination the following parameters are considered:

- Planned and known unavailability,
- Forecasts and energy availability (influx to the storage, development of storage content)
- Operational parameters (machine-specific parameters, priorities, etc.)
- Particular performance-restricting conditions (feed-in restrictions by network operators, congestion management that has already been announced, etc.) and
- Planned sales volumes or already known obligations for the provision of other types of control reserve (primary or secondary control reserve)

By checking the remaining storage content, the provider VEF also assesses the work availability of the storage power plants for the delivery period. The results of the check of the availability of work can also lead to a limitation of the manual Frequency Restoration Reserve that can be offered. With these considerations, the expected availability of work and performance in the tendering phase before the offer is submitted is taken into account as much as possible.

Provision and supply of manual Frequency Restoration Reserve

After the auction for manual Frequency Restoration Reserve has ended, the APG tendering platform will transfer the list of the bid of VERBUND to the database for operating and planning data and save it in this software tool. In the daily operational planning of the storage power plants and controllable loads for the following day, the manual Frequency Restoration Reserveto be kept is taken into account as a standby reserve and is marked as a capacity that has already been contracted and is to be kept available. This means that these services are no longer available for marketing on the day-ahead market or intraday market.

The activation or deactivation of the manual Frequency Restoration Reserve is generally carried out electronically by APG. At VERBUND, the software tool, in which the current list of accepted bids is also saved, processes the activation document and, once the activation requests have been successfully transfered, automatically transmits the requested manual Frequency Restoration Reserve $P_{TReg,soll}$ to the control system.

In principle, all technical units of the reserve group “Speicherkraftwerke” (SRR clusters and BG clusters) are available for the physical supply of the manual Frequency Restoration Reserve. Contrary to the technical units of the storage power plants, there is no combined provision of Frequency Containment and manual Frequency Restoration Reserve with the controllable H2Future load.

The activation or deactivation of the manual Frequency Restoration Reserve takes place at VEF by a software tool in the control system. The requested manual Frequency Restoration Reserve can be distributed to the technical units by using two methods.

3.5 Control dynamics

The provider VEF pursues the approach that every technical unit submitted for technical prequalification fulfills the required dynamic range. Many of the technical units have a significantly faster and better control dynamic than required in the prequalification conditions. This also includes

the controllable H2Future load. Using a suitable machine ensures that the required total performance gradient for automatic Frequency Restoration Reserve is maintained even when the operating point is shifted and the Frequency Containment Reserve, automatic and manual Frequency Restoration Reserveand tertiary control reserve are activated at the same time.

3.6 Operative structure

The operational maintenance and provision of the control reserve is carried out by the operational team of the provider VEF in Vienna. This also includes the implementation of the control reserve concept in the control system of the main control center in Vienna. The VEF control system is state-of-the-art. The implemented IT security management system was certified according to ISO 27000 for the first time. The certification process continuously takes measures to ensure that the control system continues to operate safely.

The following tasks are processed in the load balancer:

- Responsibility for the composition of the reserve groups including machine allocation and allocation of the controllable loads to the corresponding control reserve types
- Planning and optimization of the operating point (day-ahead and ongoing)
- Planning and ongoing monitoring of the power ranges / control areas (including contract limits) and the operating points for the SRR cluster and the BG cluster as well as the reserve groups
- Responsibility for the optimal use of the machine, taking into account the effects of the automatic Frequency Restoration Reserve
- Start or stop of machines and technical units
- Operational management of the Frequency Containment Reserve including the exclusive power range for the supply of Frequency Containment Reserve in storage power plants
- Call management of the manual Frequency Restoration Reserveand the distribution between the two clusters
- Optimal power distribution to the individual machines (implementation of the higher-level operating point on the individual machines) or definition of the operating points of the controllable loads
- Energy management monitoring of the machines and technical units
- Coordination of availabilities
- Malfunction management related to energy market

In operational management, the VEF control room works together with the control rooms responsible for the corresponding prequalified technical units. The responsible control rooms are in charge of the operational management and monitoring of the technical units and issue the release for the provision of control reserves. The control room of the provider VEF is responsible for the use of the energy, for the compliance with the contractual obligations for the control reserve as well as for the performance specifications. The existing control systems are used for practical operational management, on the one hand to meet the prequalification requirements and on the other hand to offer the operators the best possible support in coping with the tasks.

3.7 System architecture

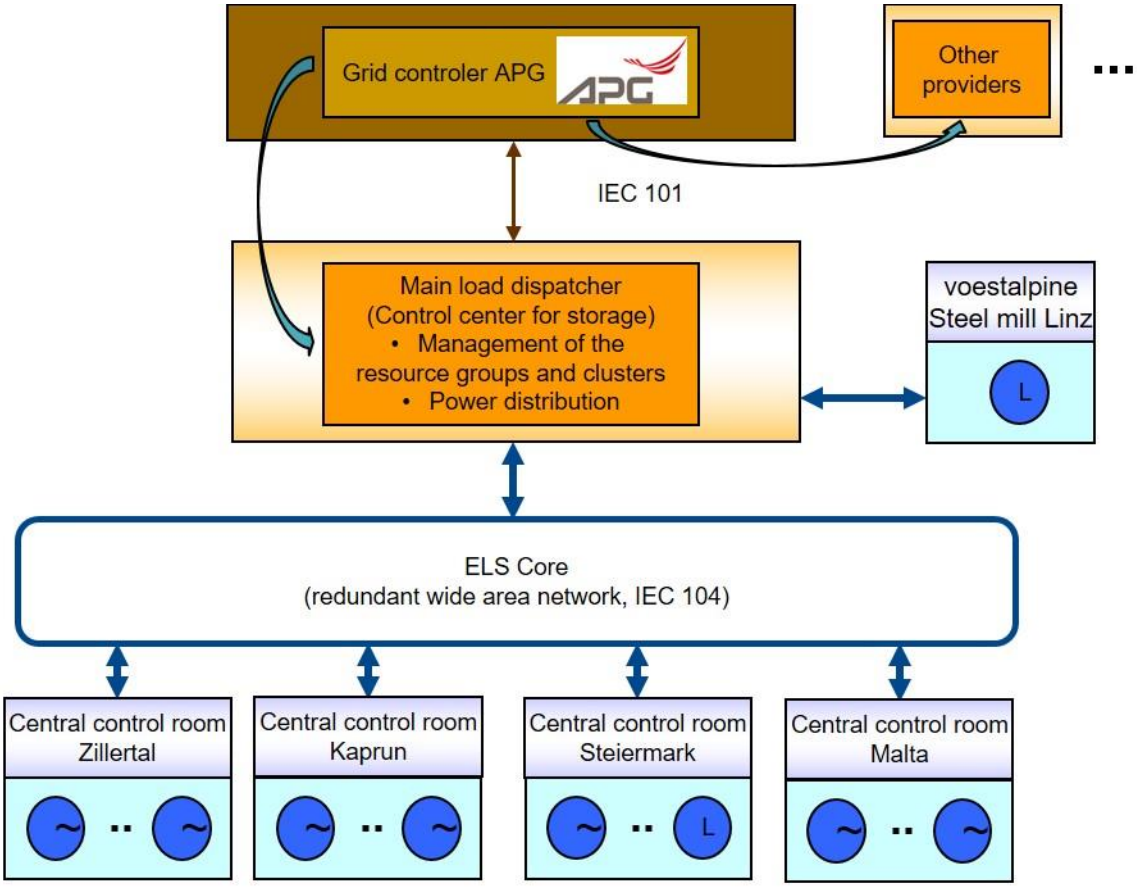

Figure 2: Structure of the control and communication system

Basically, the system architecture for providing control reserves is based on the control system structure shown in figure 2. According to this structure, APG distributes the target value to the providers in line with the market. At the VEF provider, the control request is sent to the allocation management and processed there accordingly. The distribution management is implemented in the redundant control system (redundant system at 2 locations) and includes the processing of setpoints, the calculation of corresponding variables and the power distribution to the respective units.

3.8 Measurement and variables for the transmission of documents

Prior to the submission of the prequalification documents, reference measurements had to be made and operating parameters had to be provided.

Measurement of the Frequency Containment Reserve

To prove the function of the Frequency Containment Reserve, a frequency deviation of ± 200mHz is simulated in a model test. This frequency deviation leads to a change in output of ± 1 MW in the documents submitted.

Figure 3: Measurement report for primary control reserve

Figure 3 shows that the minimum requirement of 30 seconds for activating the maximum Frequency Containment Reserve is reached. In addition, it can be seen that the power currently consumed is superimposed with a slight amount of random noise.

Measurement of the automatic and manual Frequency Restoration Reserve

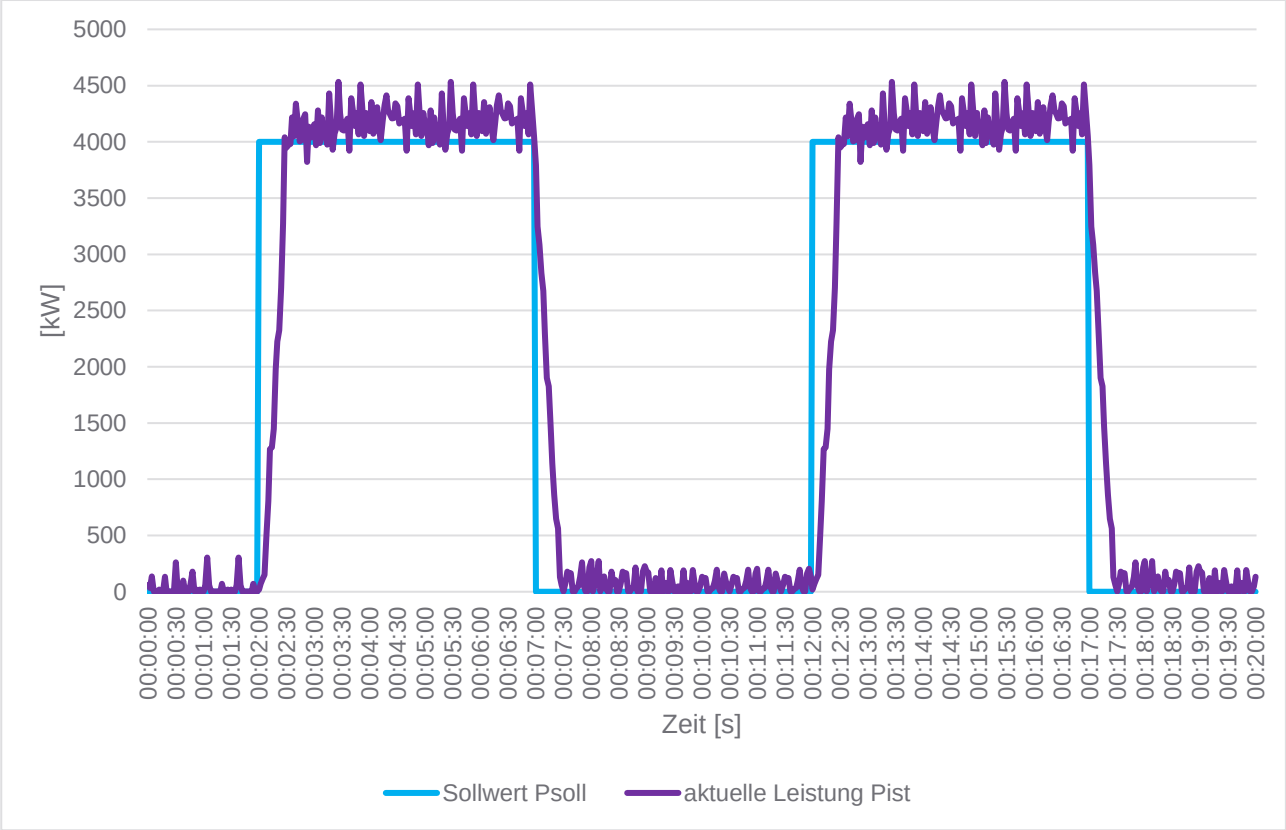

Figure 4: Measurement report for secondary and tertiary control reserve

Figure 4 shows that the minimum requirements for the automatic Frequency Restoration Reserve are met. Since the dynamic requirements of the manual Frequency Restoration Reserve are significantly lower than the requirements for automatic Frequency Restoration Reserve, the measurement for the automatic Frequency Restoration Reserve is also used to prove the tertiary control reserve.

Parameter

In addition to the recorded measurements, a table with the required parameters also has to be sent to APG. The table can be found in the appendix.

Appendix 1: Table of parameters.

4 Implementation and results for H2Future plant

The “double-hump” procedure to verify the ability of the electrolyser system to supply ancillary services was already executed in February 2020. The following figure shows the complete results of this test and also emphasizes the response.

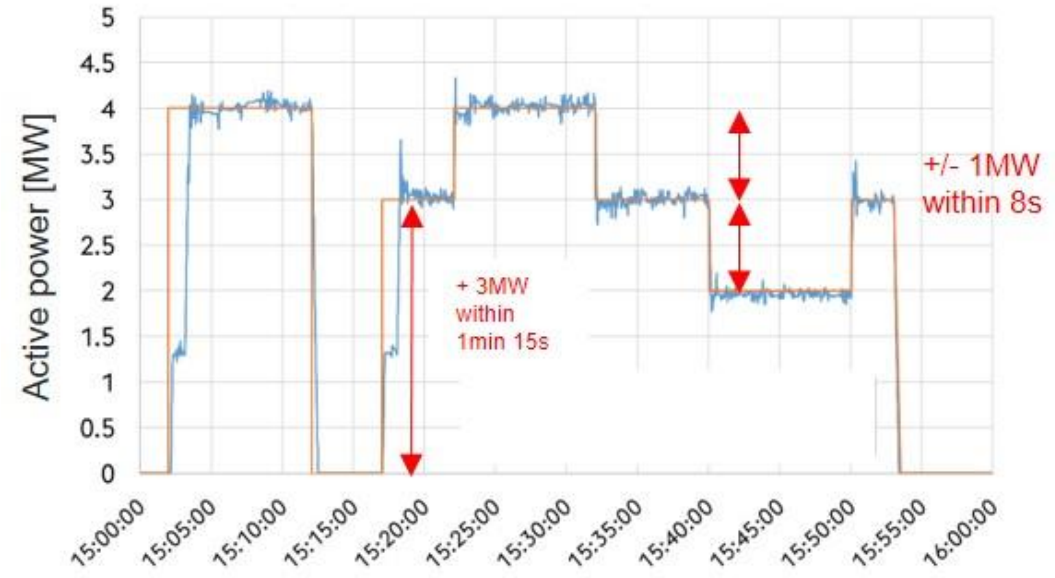

Figure 5: Aggregation of the results of the “double-hump” procedure

It has been proved that the electrolyser system follows the target values very fast and precisely. According to Frequency Containment Reserve the value change of +/- 1MW could be reached within 8 seconds. A value of 3 MW (half load of the system) was reached after 1min 15s from zero. The criteria were thus clearly fulfilled.

5 Conclusions

It can be seen from the measurement records (See Figure 5) that the H2FUTURE electrolyser submitted for technical prequalification fulfills the required control dynamics to participate in the reserve control markets.

As to the provision of Frequency Containment Reserve the H2Future electrolyser plant was able to demonstrate sufficient controllability in the range of +/- 1 MW.

As to the provision of automatic and manual Frequency Restoration Reserve the H2Future plant proved that the system can follow the setpoint changes of +/- 4 MW with sufficient speed, the targets were even exceeded. Additionally, it can be assumed that the dynamics are also sufficient for the complete capacity of 6 MW because was much faster in relation to the allowed time to reach the target value. However, due to technical limitation (min/max load) of the plant during the operation the total capacity range will only be utilized, if the plant starts from zero.

In this way the H2FUTURE plant is qualified to provide both positive and also negative operating reserve to the electrical grid.

Since the confirmation of the verification took a long time, it is advisable to start the prequalification process of such systems for the electricity balancing market at an early stage.

6 References

6.1 Project Documents

D2.3 Specifications of Pilot Test 3 / Use Case 3

D2.8 KPIs to monitor the demonstrations and perform the exploitation tasks

D8.3 Pilot Test 3 - Grid services

D8.7 Quasi-commercial operation

6.2 External Documents

COMMISSION REGULATION (EU) 2017/1485 August 2nd, 2017 guideline on electricity transmission system operation.

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