Integration of demand-side response in the Swiss ancillary service markets through the ENTSO-E central settlement model

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Abstract: The major challenge for integrating demand-side response is preparing a suitable market platform with clear rules regarding the interaction of the different stakeholders. Demand-side response has the technical capability to offer diverse grid services and the most challenging hurdle is to adapt the existing market rules which were initially conceived with centralized power generation in mind. The market rules must take the different stake holders into consideration. The ENTSO-E (European network of transmission system operators for electricity) central settlement model allows a central entity to settle the transfer of energy with the BRP (balance responsible party) which has been activated by an independent aggregator. This model allows the participation of demand-side response and distributed generation units in the Swiss ancillary service markets. The implementation is explained with the example of a municipal waste incineration plant that takes part in the Swiss aFRR (automatic frequency restoration reserves) and mFRR (manual frequency restoration reserves) markets through an aggregator.

Keywords: Ancillary services, Demand-side response, Demand-side management, Waste heat, Waste incineration plant, Power generation control, Power generation planning, Power system stability

1 INTRODUCTION

Demand-side response is gaining more focus as a provider of grid services. The ideal market design will be a deciding factor for enabling demand-side response. ENTSO-E has suggested different market design models for enabling the participation of demand-side response in the reserves and energy markets [1]. In Switzerland the Swiss electricity branch had already decided on a solution to enable the reserve providers to aggregate geographically distributed technical units to provide ancillary services to the Swiss transmission system operator (TSO, Swissgrid). This solution was implemented in October 2013. When providing balancing services different entities are involved. The relevant entities are the technical unit, the supplier of energy, the BRP, the reserve provider and the TSO. The balance group is an energy account managed by a BRP [2]. The BRP is responsible for assuring the energy balance of its balance group. The supplier provides the customers with energy as per energy supply contracts and absorbs energy form technical units as per energy acquisition contracts [3]. The reserve provider is a legal entity with a legal or contractual obligation to supply ancillary services [5]. The TSO is responsible for the safe, reliable and efficient operation of the transmission grid and the control area. The TSO utilizes ancillary services for the grid operation [3]. Among the different market models suggested in [1], Switzerland has implemented the central settlement model, which supports the settlement of energy from technical units belonging to balance groups outside the BSP's own balance group. The corresponding aggregator model [3] was developed by the electricity branch of Switzerland as illustrated in Fig. 1.

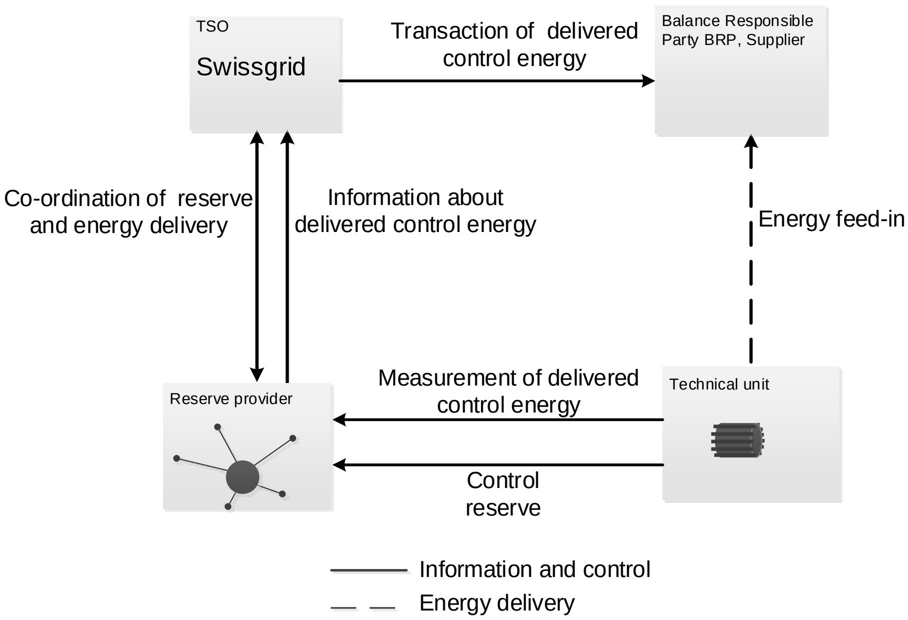

Fig. 1. Energy, information and control flows in the central settlement model implemented in Switzerland. A reserve provider portfolio consists of technical units grouped into reserve providing units or groups. Illustration based on [3].

The model allows a balance group neutral extension of a reserve provider portfolio in which the Swiss TSO is responsible for the central settlement. The major advantage of the model is that it foresees confidentiality in the pre-contracting phase[1] and in the post-contracting phase[2][1].

Correction of the schedules for energy activated in the balance group and the settlement with the BRP as well as the reserve provider is done by the Swiss TSO. Thus the central settlement model is market friendly but increases the complexity of the process for the central entity which is responsible for the correction of the schedules and the settlement.

[1] The BRP or supplier of the end user does not need to be informed that the end user is entering into a contractual relationship with an independent aggregator. Thus the end user and independent aggregator are not hindered in signing a contract [1].

[2] The BRP or supplier is not aware of a flexibility contract with DSR activations performed by independent aggregators in its portfolio [1].

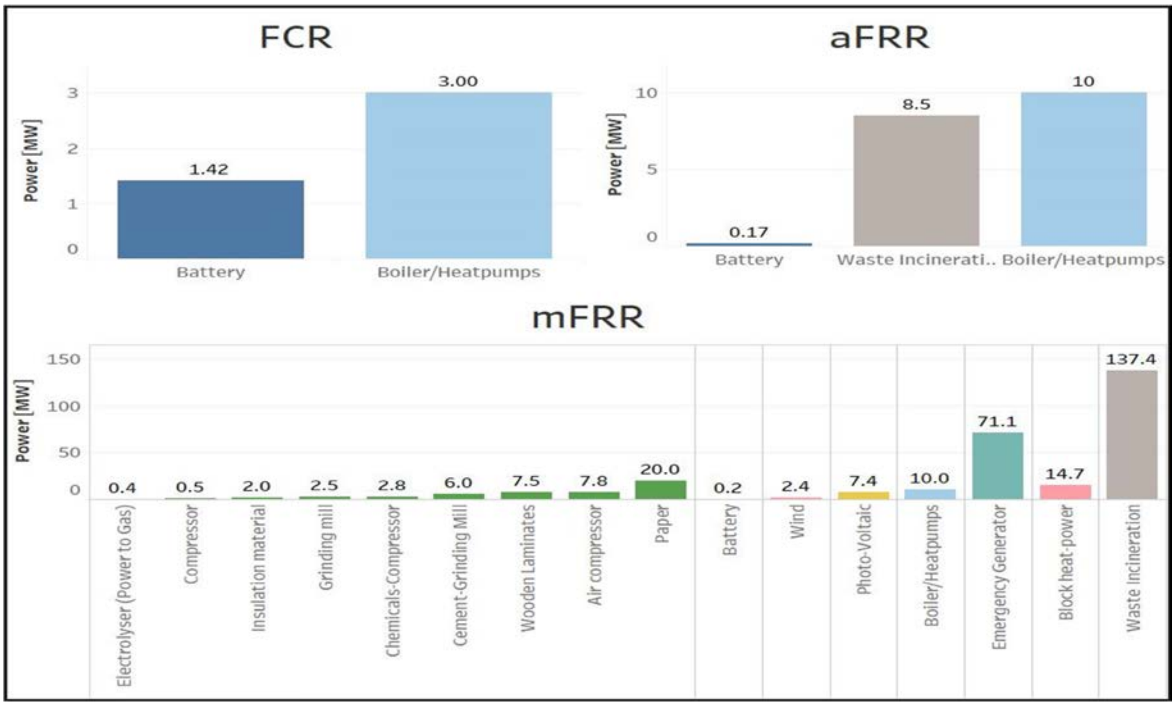

Fig. 2. Alternate technologies prequalified in the Swiss ancillary service markets.

Decentral generation as well as demand-side response units are already active in the Swiss ancillary services market. Fig. 2 shows the decentral technologies and the amounts prequalified for the different ancillary service products.

In this article, the Swiss ancillary service markets and products are briefly explained, then the central settlement model and the processes for its implementation are described. Subsequently the process is illustrated with the example of a municipal waste incineration plant, which offers aFRR, mFRR to the ancillary service markets. Finally the challenges and possible future developments for DSM in the ancillary service markets in Switzerland are described.

2 ANCILLARY SERVICE MARKETS IN SWITZERLAND

The Swiss TSO procures ancillary services from BSPs, based on non-discriminatory, transparent and market-oriented criteria. Within the synchronous integrated electrical grid in Europe the process of balancing generation and consumption at any given point in time is realised by a three-step process, making use of FCR (frequency containment reserves), aFRR as well as mFRR and RR (replacement reserves), which differ with regard to their technical as well as commercial characteristics [5]. The aFRR, mFRR and RR markets are implemented with the central settlement model. Since mFRR and RR are both manually activated and the processes are the same, further in this article we will refer to mFFR only.

2.1 ENTSO-E Network Codes and Guidelines

The ENTSO-E has implemented the Network Codes or Guidelines. These are European Union (EU) regulations containing legally binding rules. Europe’s cross border electricity markets are operated according to the rules in the network codes that govern the actions of the operators and determine how access is given to users. In the past, these grid operation and trading rules were drawn up nationally, or even sub-nationally. With increased interconnections between countries in the energy market, EU-wide rules have become increasingly necessary to effectively manage electricity flows. They govern all cross-border electricity market transactions and system operations alongside the EU regulation on conditions for accessing the network for cross-border electricity exchanges [4]. Although not part of EU, Switzerland plans to comply with the Network Codes in order to facilitate and simplify the cross-border energy trade and co-operation with other European transmission system operators. The System Operation Guideline [5] contains the rules for the load frequency control and reserve.

2.2 Definitions as per the System Operation Guideline

According to the System Operation Guidelines [5] a 'reserve providing unit' means a single or an aggregation of power generating units and/or demand units connected to a common connection point fulfilling the requirements to provide FCR, FRR or RR"; "'reserve providing group' means an aggregation of power generating units, demand units and/or reserve providing units connected to more than one connection point fulfilling the requirements to provide FCR, FRR or RR. Fig. 3 depicts the definition of reserve providing unit and reserve providing group. In this article the individual units are defined as technical units (TU). In Switzerland, it is possible to aggregate geographically distributed technical units in the grid levels 5 (36KV) and 7 (400V) in order to build a virtual power plant or a reserve providing group [6], [7]. This enables technical units like boilers, waste incineration plants or other industrial equipment to participate in the ancillary service markets. This in turn reduces the Swiss ancillary service markets' dependency on hydrological conditions, offers an additional business case for the operators of technical units and allows energy delivery companies to increase customer retention by offering an additional business opportunity to their customers.

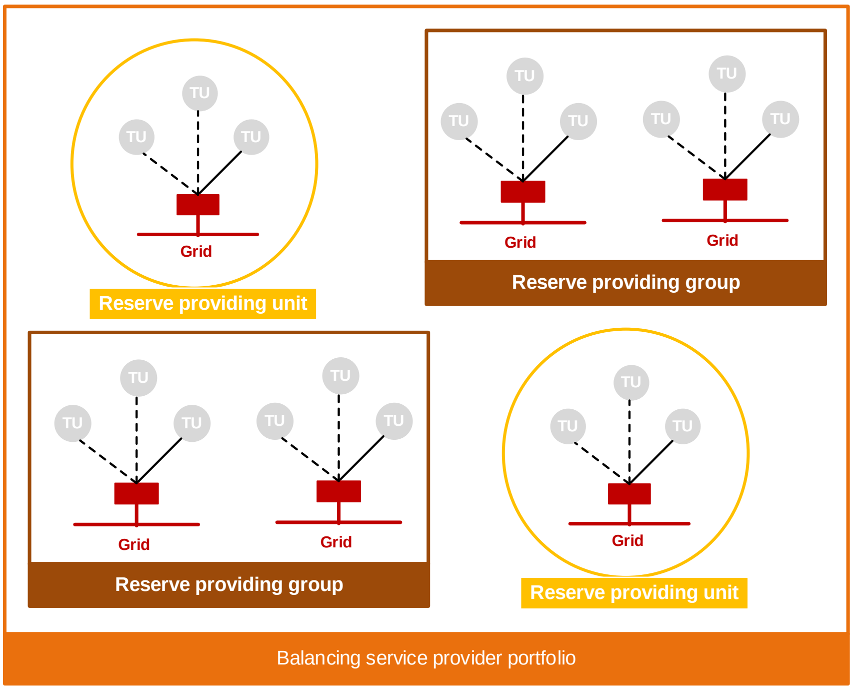

Fig. 3. Example of a BSP portfolio with two *reserve providing units* and two *reserve providing groups.* A *reserve providing group* can also include *reserve providing units.* A *technical unit* (TU) can either be a power generating module or a demand unit. The red box depicts a grid connection point.

In the following chapters the use cases for providing ancillary services to the Swiss TSO are described.

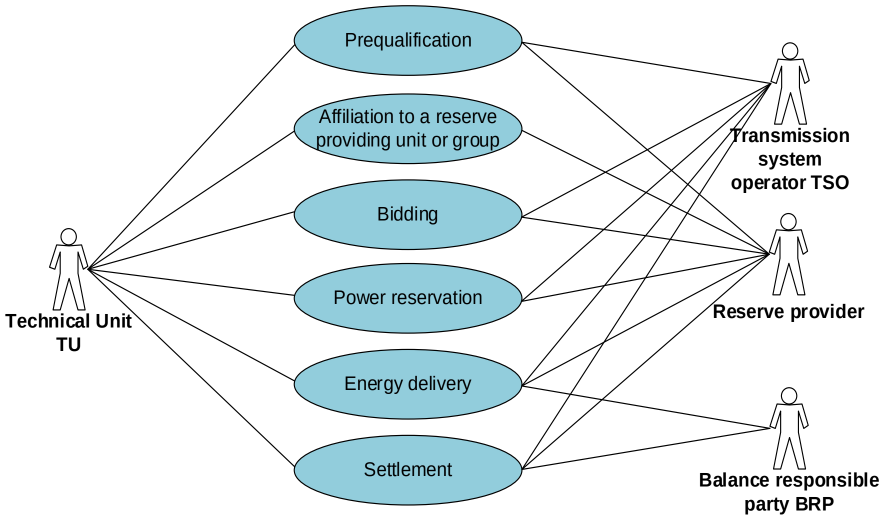

Fig. 4. Use cases for participation in the ancillary service markets in Switzerland [11].

2.3 Use case: Prequalification

Prequalification of *technical units* and affiliation to a *reserve providing unit* or *reserve providing group* [6]: the Swiss TSO pre-qualifies *technical units* to participate in the ancillary services as *reserve providing unit* or *group*. During the start of the prequalification, the BSP as operator of the portfolio decides together with the Swiss TSO if for the concerned technical unit a reserve providing unit or a reserve providing group should be defined. The reserve providing unit must fulfil the prequalification requirements on its own while the reserve providing group must fulfil the requirements as a group. The reserve provider and the owner of the technical unit are free to define their contract. As a matter of fact the market is such that often the owner of a technical unit selects from several competing offers from reserve providers within as well as outside its own balance group.

2.4 Use case: Bidding and power reservation

Bidding and power reservation process [8]: the Swiss TSO tenders different ancillary service products (one week product for FCR, six daily 4 hour blocks and one week product for mFRR, and one week product for aFRR). The reserve providers are requested to bid. A bid is characterized by a combination of quantity and price, where mutually exclusive bids are allowed. Typically the technical units are free to participate in a bid. If a bid has been accepted, the technical unit is obliged to keep the contracted power in reserve. In the case of a call the control energy called is remunerated separately for aFRR and mFRR. For aFRR the control energy price is bound to the SwissIX market price of electricity. For mFRR the reserve provider can put a separate control energy bid, where activation is as per the merit order list of all the energy bids. Thus the BSP can influence the frequency of activation by changing the energy price.

2.5 Use case: Energy delivery

In case of a request for aFRR or mFRR the Swiss TSO informs the reserve provider in real time, which in turn distributes the request amongst the aggregated technical units. For aFRR, the technical units are dispatched automatically [8]. If mFRR is required, the reserve provider is informed by e-mail and phone. The activation of the control reserve happens with a minimum lead time of 15 minutes [9].

The technical unit delivers monitoring data via the reserve provider, which aggregates and forwards it to the Swiss TSO (automatic, 10s values for mFRR and aFRR). On the next working day, the reserve provider must send schedules with the amount of energy actually activated to the Swiss TSO. These schedules have a resolution of 15 minutes and include the information about the balance group and supplier in which the control energy was activated. The Swiss TSO exchanges correction schedules with the reserve provider and the involved BRP, based on the information from the reserve provider. The measurement of the energy activated is explained in the following paragraph.

For technical units working according to a schedule, the delivered control energy is calculated as the deviation of the actual power value from the schedule as shown in Fig. 5 [10].

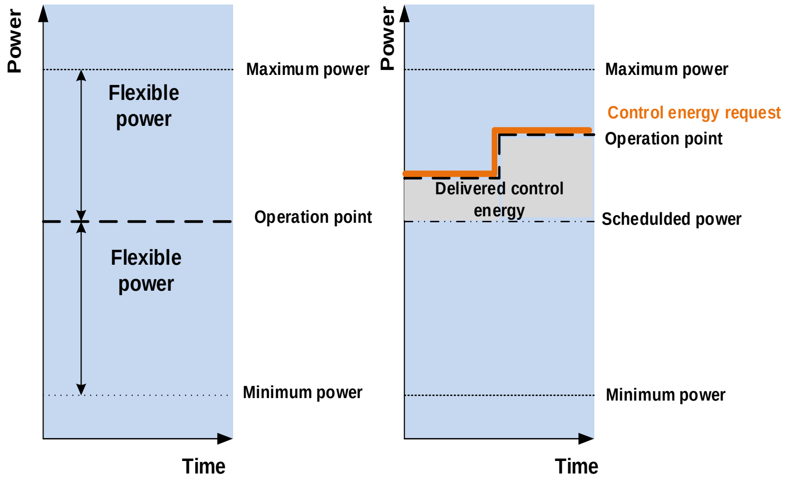

Fig. 5. Calculation of delivered control energy for technical units operated with schedules. The y-axis depicts the power of a technical unit. The operation point (consumed power for a load, delivered power for a generator.) is limited by the maximum and minimum power . The *technical unit* is operated according to a schedule ('scheduled power'). The control energy request causes the operation point to deviate from the scheduled power curve.

For smaller technical units which do not have a schedule a baseline method has been developed in the aggregator working group [3] which is illustrated in Fig. 6 in a simplified manner for the case of negative control reserve for loads and positive control reserve for generators. The effective delivered control power corresponds to the energy that was delivered in excess to or lesser than the power before the start of the control request [10].

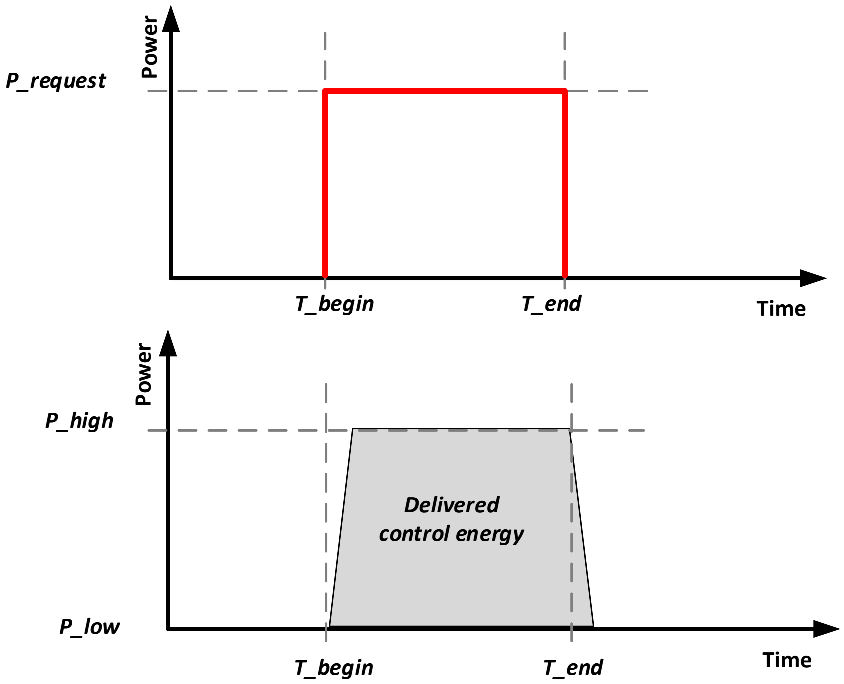

Fig. 6. Baseline method for calculating the delivered control energy. The y-axis depicts the consumed power for a load or delivered power for a generator. T_begin indicates the beginning of the control energy activation and T_end indicates the end of the control energy activation. P_request is the requested control power. P_low is the power of the technical unit before control energy activation and P_high is the power after the control energy activation.

Decisive is the last measured value of power P_low before the control energy activation at T_begin as well as the measured value of power P_high after T_begin (Fig. 6). The reserve provider must also consider the energy due to the ramps so that the BRP can be correctly balanced.

2.6 Use case: Settlement

The Swiss TSO remunerates control reserves (FCR, aFRR and mFRR) according to the bid price ('pay as bid'), where technical units are remunerated based on their contractual terms with the BSP [11].

For aFRR and mFRR positive control energy is remunerated as follows:

1. Between supplier and technical unit, excess production or reduced consumption is dealt with as defined by the energy delivery contract between the two parties.

2. The Swiss TSO remunerates the BRP for the delivered control energy according to the SwissIX market price of electricity. The Swiss TSO corrects the operating schedule of the BRP to avoid balance energy being falsely allocated.

3. The Swiss TSO remunerates the reserve provider for the delivered control energy, subtracting the payment to the BRP.

4. The reserve provider remunerates the technical units according to their contract.

For aFRR and mFRR negative control energy is remuneration as follows:

1. Between supplier and technical unit, reduced generation or increased consumption is dealt with as defined by the energy delivery contract between the two parties.

2. The BRP remunerates the Swiss TSO for the delivered control energy according to the SwissIX market price of electricity. The Swiss TSO corrects the operating schedule of the BRP to avoid balance energy being falsely allocated.

3. The Swiss TSO pays the reserve provider the amount received from the BRP minus the control energy price.

4. The reserve provider remunerates the technical units according to their contract.

3 PARTICIPATION OF A WASTE INCINERATION PLANT IN THE ANCILLARY SERVICE MARKETS

In Switzerland there are 30 waste incineration plants with an installed electrical power of 423 MW. Most plants use extraction steam to supply district heating or industrial processes (combined heat and power) [12]. With some incineration plants the high pressure steam is additionally used to generate electricity. The generated electrical energy is used to meet the own energy demand of the plant and the rest is fed into the electrical grid. Until now 9 waste incineration plants are prequalified for ancillary services. With the example of Renergia Ltd, we show how the central settlement model is used to integrate industrial plants to participate in the ancillary services markets to provide aFRR and mFRR.

3.1 Organization

The municipal waste incineration plant Renergia Ltd is owned by eight waste disposal organizations from six cantons of central Switzerland and the paper production company Perlen Paper Ltd. It was commissioned in February23, 2015 [13]. The project was completed for an amount of 300.5 Million CHF. Renergia Ltd has 30 employees including management and administration staff [14].

3.2 Technical data and functioning of the plant

The waste incineration plant has the capacity to handle 200’000 t/a of waste, produce 150’000 MWh/a of electrical energy per year and 260’000 MWh/a of thermal energy per year [16]. As depicted in Fig. 7 there are two separate sections for burning the waste. Each of these sections can handle 12.5 t/h of waste. The heat is used to produce steam with a temperature of 420 Degree Celsius at a pressure of 41 bar. For the production of electricity a condensing steam turbine is used, which reduces the steam (115t/h) from 41 bar to 4 bar. After the high pressure stage the part of the steam is transported to the nearby Perlen paper factory for use in the paper production process. Another part of the steam is also used for the district heating of nearby villages. The remaining steam is used in the low pressure stage of the turbine. The exhaust steam from this stage is then condensed to water in air cooled heat exchangers. The condensed water is recirculated back into the boilers [15].

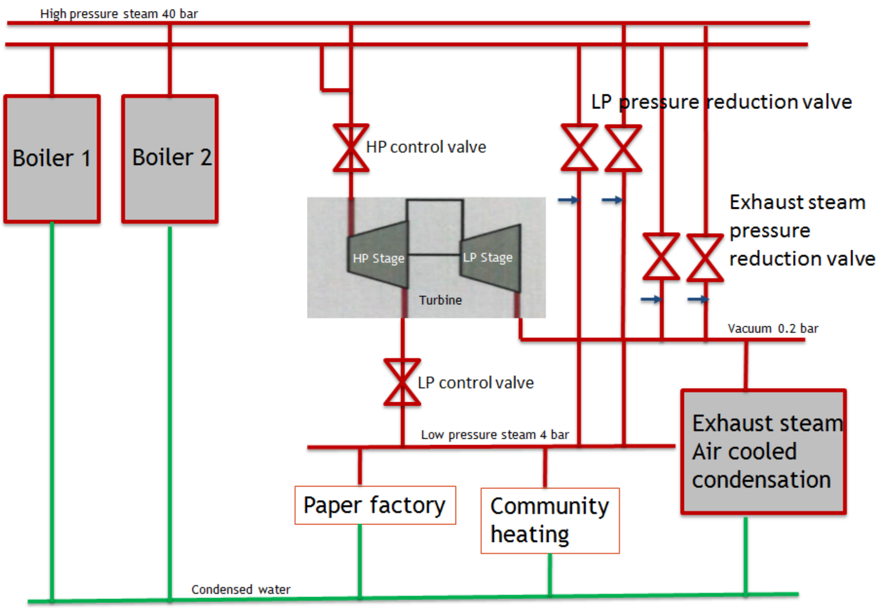

Fig. 7. Schema of the Renergia waste incineration plant [16]

The generators with a nominal power of 26 MW have an average feed-in of 19 MW. The own electrical consumption of the plant is around 2 MW [16].

4 DELIVERY OF ANCILLARY SERVICES

The ancillary service delivery includes a number of processes, steps and requirements like 24-hour availability. Renergia offers ancillary services through the reserve provider CKW Ltd. The reserve provider has a portfolio and has already established the processes with Swissgrid. Furthermore it ensures back up for the technical unit at Renergia within its portfolio.

According to the contractual terms with Renergia, CKW maintains an internal merit order list for the activation. Renergia Ltd has been prequalified for mFRR since May 2015 and for aFRR since May 2016.

4.1 Delivery of manual frequency restoration reserves

Renergia provides negative control reserve only i.e. it can offer to reduce generated power. During the activation of mFRR only a part of the steam is led to the high pressure stage of the steam turbine, thus reducing the amount of electricity produced. The waste incineration plant offers 10 MW to 14 MW of mFRR.

4.2 Delivery of automatic frequency replacement reserves

aFRR is activated in Switzerland according to a pro-rata process, which means that the Swiss aFRR demand is distributed to all reserve providers proportional to their successful bid amount. CKW as reserve provider creates an internal merit-order-list. Within that list technical units with lower opportunity costs will be activated first, which means call frequency for Renergia may differ from the Swiss TSO’s calls.

In order to prequalify for aFRR, a prequalification test has to be successfully completed [17]. A power gradient of 0.5% Pnominal/Sec is required. Fig. 8 depicts the successful aFRR prequalification test of the Renergia waste incineration plant.

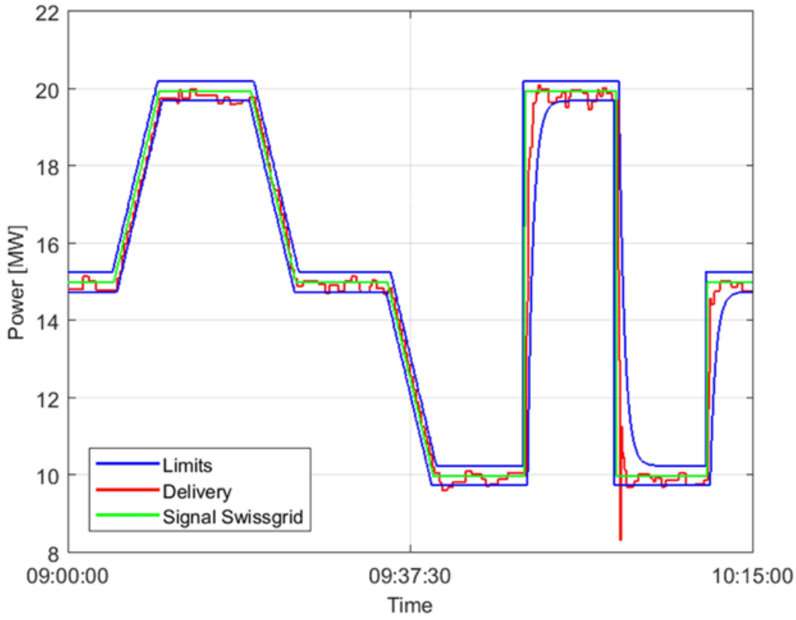

Fig. 8. aFRR test curve of the Renergia waste incineration plant

5 CHALLENGES

The presented model is successfully in place since November 2013, with clear advantages for the integration of DSR units in the ancillary service markets. Nonetheless, some improvement of process details is still possible. With 653 grid operators [18] and a correspondingly high number of suppliers, the amount of data which has to be handled by the Swiss TSO is high. Managing the data of technical units changing their suppliers and balance groups is not yet ideally resolved as there is no central data hub at present which could support automation of such activities. Another possible improvement to manage the high data volumes could be to make use of the metering systems to correct the activated energy of the balance groups instead of exchanging schedules.

6 FUTURE OUTLOOK

The Network Code on Demand Connection [21] will further encourage the use of demand-side response for grid stabilization. Furthermore with the standardization of the ancillary service products through the Network Codes and the cross border projects for the procurement of ancillary services, like FCR cooperation [19] and the TERRE project [20], flexibility providers in Switzerland will have access to larger volume markets. For the Swiss TSO such market changes help to reduce price volatility.

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