ENHANCING THE BUSINESS MODEL OF DISTRIBUTED STORAGE THROUGH OPTIMIZED MULTI-SERVICE OPERATION FOR TSO, DSO AND GENERATION OWNERS: THE VENTEEA REAL EXAMPLE.

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ABSTRACT

The French "VENTEEA" smart grid initiative is a 3.5-year field demonstration project that aims at enabling an easier integration of renewables in MV distribution networks. Among the various industrial pilots of new technologies and grid management systems that are tested within the project, this paper focuses on the 2 MW / 1.3 MWh lithium-ion battery commissioned in 2015. This paper describes the multi-service control approach that has been designed for this unit and provides some operational feedback from the first 8 months of operation.

INTRODUCTION

The VENTEEA project is a 3.5-year field demonstration program among the top initiatives of the French smartgrid R&D portfolio. Started in 2012, it is carried out by a team of 10 industrial and academic partners led by ERDF.

The goal of VENTEEA is to validate the key solutions that will ensure reliable/efficient operation of future MV distribution systems and allow integrating larger shares of renewables at the best possible cost. To this end, a distribution grid with high penetration of wind generation was selected to test industrial pilots of new technologies and control approaches including primary substation digital management package, real-time network state estimation, Volt VAR Control scheme and a Distributed Energy Storage System (DESS) on which this paper focuses. The selected network, remaining in commercial operation throughout the project, comprises a 20-MVA primary substation and six 20-kV feeders. It powers 3200 customers and hosts 2 wind farms rated at 6 and 12 MW.

The "Storage" work package of VENTEEA is carried out by Saft, Schneider Electric, EDF R&D, the L2EP, RTE and ERDF. Boralex, owner of the wind farms, helps to facilitate the experiment. Through the design, the construction and the operation of a 2 MW / 1.3 MWh battery system, the initial ambition of the project team was to get a better understanding of the potential of DESS to facilitate the integration of renewables and enhance the operation of power systems in the future. To this end, their objectives were notably 1/ to evaluate the ability of the tested DESS to provide a dozen of services as well as its operational performances under various conditions and 2/ to assess the practical feasibility of a multi-service/multi-stakeholder scheme to improve the business case of storage through the addition of several revenue streams. Some existing regulatory barriers in the French unbundled power system (*e.g.*, ownership) were intentionally relaxed within the framework of the project to help reaching this objective of the demonstration effort.

Following a brief technical description of the storage unit, this paper introduces how this "multi-service" approach has been put in place in practice and then focuses on some operational feedback from the first 8 months of operation.

DESCRIPTION OF THE STORAGE UNIT

The DESS tested within VENTEEA is shown in Figure 1 and its complete architecture is presented in Figure 2. As detailed in the previous CIRED paper [1], the plant consists in a 1.3-MWh lithium-ion battery connected to the MV grid through a 2.16-MVA Power Conversion System (PCS). The battery, manufactured by Saft, is made of 2 20-foot *Intensium Max IM+20M* containers (see a in Fig. 1), each of which comprising 12 strings of 28 Synerion® 24M modules. The PCS, manufactured by Schneider Electric, is made of 2 20-foot *ES Box RT 1080* containers (see b in Fig. 1), each of which comprising 2 540-kVA full 4-quadrant inverters and a 3-winding MV/LV transformer.

Figure 1: the DESS designed, built and operated within the framework of VENTEEA.

The storage unit is located in the immediate vicinity of the points of interconnection of the 2 wind farms involved in VENTEEA and operated by Boralex (see c in Fig. 1). To increase the demonstration potential in terms of multi-service operation, the DESS can be connected either to the MV feeder hosting the 12-MW plant or to the MV feeder hosting the 6-MW wind farm and customers. The required switchgears and the MV/LV transformer powering the auxiliaries of the storage unit are located in a dedicated MV substation (see d in Fig. 1). The storage unit was built in Q1 2015, entered in operation in Q2 2015 and has been in continuous service since then, *i.e.*, for more than 8 months at the time we write this paper (March 2016).

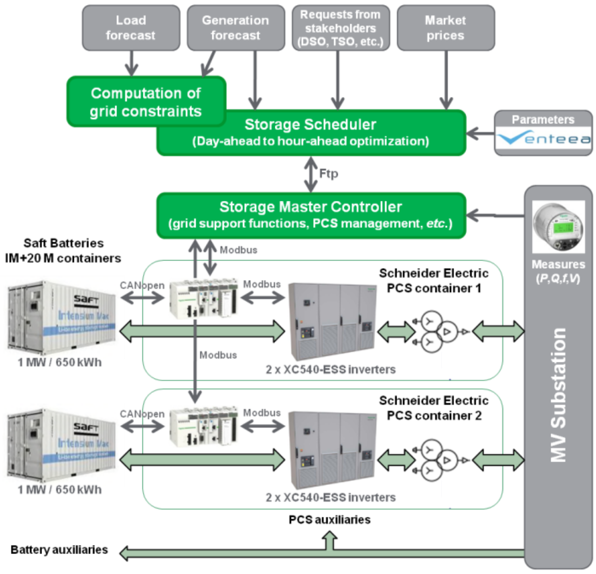

Figure 2: architecture of the DESS designed, built and operated within the framework of VENTEEA.

A CONTROL APPROACH ENGINEERED FOR MULTI-SERVICE OPERATION OF STORAGE

Energy storage assets can provide various services such as management of voltage/current constraints in distribution grids, participation in power system security and reliability, *etc*. However, if considered individually, most of these services 1/ do not continuously mobilize 100% of the power/energy capacities of a DESS (→ room for improved utilization) and 2/ do not generate enough revenue to reach profitability (→ economic need for improved utilization). That is why the combination of services, *i.e.* the use of storage units for multiple functions, is analyzed to 1/ operate them at their full potential and 2/ harvest more income from one or several stakeholder(s).

Taking this concept to the field is already within reach in the case of vertically integrated utilities but is more challenging in an unbundled power system, where its feasibility still needs to be proven. This is one of the key focuses of the VENTEEA "Storage" work package.

Table 1 gives an overview of the DESS services that have been selected to be tested within the framework of the project. To go as far as possible in the analysis of storage benefits and of their aggregation, these services concern 3 stakeholders: TSO, DSO and DG operator.

Stakeholder	Service
TSO	TSO1 – Participation in primary frequency control
DSO	DSO1 – Distribution peak shaving
	DSO2 – Local voltage control
	DSO3 – Contingency grid support
	DSO5 – Reactive power support
	DSO9 – TSO fees optimization
DG operator	DG1 – Support to the provision of ancillary services
	DG2 – Smoothing of short-term output fluctuations
	DG3 – Generation peak shaving
	DG4 – Energy time-shifting
	DG5 – Capacity firming
DESS operator	ARB – Time-of-use energy arbitrage

Table 1: overview of the storage services tested during the first 8 months of operation.

As shown in Figure 2, a dedicated control system made of two complementary levels has been developed make the storage unit capable of multi-service operation:

- The **Storage Scheduler** is a remote supervision layer that plans the DESS services ahead of real-time to maximize profitability while satisfying requests from the stakeholders and a set of constraints (power/energy capabilities of the plant, current/voltage limits of the network, *etc*.). The Storage Scheduler is run every 30 minutes; it 1/ estimates the headroom available in the grid to operate the DESS using load and generation forecasts and 2/ calculates an optimized planning for the next 36 hours. This functioning gives the level of visibility on the next day that is required to interact with the stakeholders/ markets and also allows making intraday adjustments if required to limit the impact of any deviation from the initial program (*e.g.*, see [2]). The program computed by the Storage Scheduler can be manually overridden if needed, which was largely used over the 1st semester of the experiment to send custom schedules to the battery system.
- The **Storage Master Controller** includes a local supervision of storage services that 1/ autonomously executes the optimized schedule received from the Storage Scheduler and 2/ takes appropriate actions if a contingency occurs. To this end, it features a library of control algorithms that has been developed within the framework of VENTEEA to manage the provision of each service in real-time based 1/ on setpoint(s) included in the optimized schedule (such as the primary reserve allocated to the DESS at a given time) and 2/ on local variables related to the grid (such as the measured frequency) or to the DESS itself (such as its State of Charge, *SoC*).

OPERATIONNAL FEEDBACK FROM THE

FIRST 8 MONTHS OF OPERATION

Overview of the experiment.

Over the 240 days of its first 8 months of operation from the beginning of July 2015, the storage unit tested within the framework of the VENTEEA project spent 222 days (92.5%) in perfect working order or with minor deficiencies having no impact on the operation. Most of the downtime occurred shortly after commissioning for various reasons including upgrades of some control routines and the replacement of small defective parts. The unit then reached a satisfactory level of availability for a field demonstration featuring new products –both Saft *IM+20M* and Schneider *ES Box RT 1080* containers were the first of their kind–: for instance, only 1 day of complete outage was recorded between the end of October 2015 and the beginning of March 2016.

Over its first 8 months of operation, the VENTEEA DESS has drawn/injected 310/226 MWh and 326/63 Mvarh from/to the grid; the battery has performed 170 equivalent full cycles. The Table 2 below presents some statistics regarding the modes of operation activated over the whole time period. As planned from the beginning of the experiment, the Storage Scheduler was active –to gain experience– but remained intentionally bypassed during the 1st semester of tests, the program of services being established manually ahead of real-time according to testing priorities of the project team. This first phase of the experiment mainly aimed at assessing the provision of all the considered services by the storage unit, either individually or combined. To this end, key performance indicators were defined and finely monitored to track both the behavior of the DESS (*e.g.*, efficiency) and the quality of the delivered service (*e.g.*, adequacy with the relevant grid code requirements). The second phase of the experiment started at the beginning of 2016 and consists in a progressive increase in the time spent by the DESS in full self-scheduling mode. A ramp-up trajectory has been defined in terms of the number of services handled by the Storage Scheduler and of complexity of the multi-service/multi-stakeholder scenarios under consideration.

Mode of operation	Cumulated activation time as on March 06 2016	
	Days with activation	Total activation time
TSO1	83 days	1384 hours
DSO2	111 days	1924 hours
DG1	55 days	944 hours
DG2	58 days	902 hours
DG3	19 days	108 hours
DG5	7 days	38 hours

Table 2: cumulated activation time of some of the services tested during the first 8 months of operation.

The following Figure 3 is a real example of daily planning of the VENTEEA DESS including several services combined both sequentially and simultaneously: participation in frequency control before 22:30 on Feb. 22 and after 06:00 on Feb. 23 (reserve at a fixed level –TSO1– or based on the output of the wind farm –DG1–), generation curtailment between 22:30 on Feb. 22 and after 06:00 on Feb. 23, continuous participation in local voltage control in parallel (DSO2).

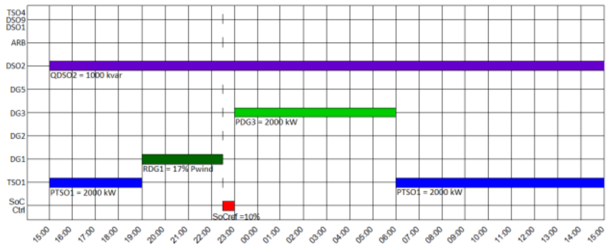

Figure 3: example of a daily planning of the VENTEEA storage unit (Feb. 22-23, 2016).

Some particular insights on the DESS operation.

Participation in primary frequency control.

The Figure 4 below illustrates the provision of primary frequency control by the DESS recorded from 14:00 to 19:00 on Feb. 23. In this mode of operation, the storage unit is controlled so as to respond proportionally to any frequency deviation from 50 Hz, without any intentional dead-band. On this sample, the Storage Master Controller is set so that the battery system delivers its full assigned reserve of 2 MW for a deviation of 200 mHz (+ 2 MW at 49.8 Hz and -2 MW at 50.2 Hz). In addition to the frequency response, an active *SoC* control is continuously carried out to ensure high availability of the service.

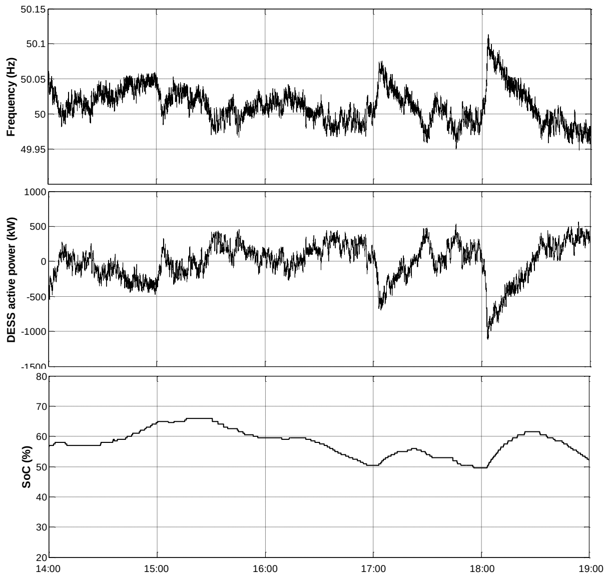

Figure 4: example of frequency control operation (grid frequency, DESS active power, DESS *SoC*).

The quality of the service supplied by the DESS is verified within VENTEEA by using the specifications defined in the French "*Règles services système"* (system services rules, see http://clients.rte-france.com/lang/fr/clients_producteurs/services_clients/services_systeme.jsp). So far, the ~1400 hours of operation already achieved has confirmed the ability of the battery unit to participate in primary frequency control.

A question that remains open at this stage is the risk for power system security and reliability of using limited energy resources to provide frequency control services. Dedicated tests are carried out on the DESS under the supervision of RTE to feed this discussion.

Generation peak shaving.

The Figure 5 below illustrates the generation peak shaving performed by the DESS between 00:00 and 06:00 on Feb. 23. Based on the load and generation forecasts available on Feb. 22, a risk of constraint on the distribution grid had been anticipated for this time period. Therefore, the *SoC* of the DESS what brought to 10% on the evening of Feb. 22 and it was then dispatched to shave any peak above the calculated limit of 10 MW. The quality of the provision of this service is quantified based on the proportion of power peaks above the assigned limit that can effectively be shaved –100% in Figure 5–; it strongly depends on the accuracy of the generation forecasts.

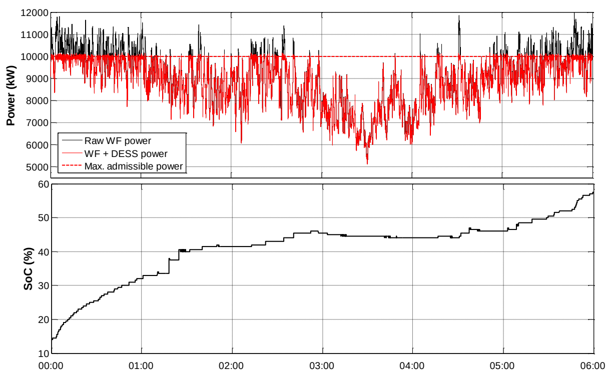

Figure 5: example of DG peak shaving operation (wind farm power w/ or w/o storage, DESS *SoC*).

Participation in local voltage control.

The local voltage control supplied on Feb. 23 in addition to the other services detailed above is illustrated in Figure 6. On this sample, the Storage Master Controller is set so that the reactive power of the storage unit responds to the voltage variations according to the $Q(U)$ characteristics presented hereafter. On Feb. 23, the $Q(U)$ control was utilized up to its allocated power of 1 Mvar during the high wind period at night and then remained activated, but not utilized in real-time, for the rest of the day. The performance of the DESS for this service is quantified computed as the proportion of time spent within the tolerance range illustrated in Figure 6 (usually > 95%).

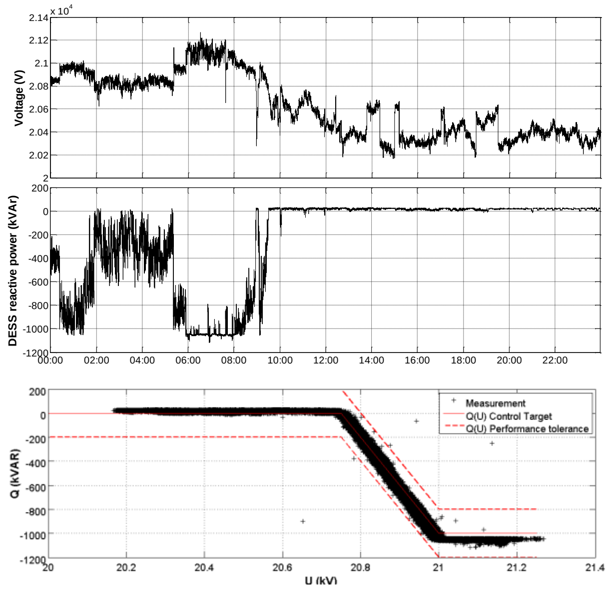

Figure 6: example of local voltage control operation (grid voltage, DESS reactive power, $Q(U)$ plot).

CONCLUSION

The 2-MW storage unit designed, built and commissioned within the framework of the VENTEEA project has been in operation for 8 months at the time we write these lines. So far, the 1st phase of the experiment has made it possible to demonstrate the ability of the DESS 1/ to provide all the targeted services, individually or combined, and 2/ to handle complex programs established ahead of real-time with up to 48 changes daily in the mix of activated modes of operation. The 2nd phase, started at the beginning of 2016, focuses on the assessment of the self-scheduling process included in the Storage Scheduler to ensure optimal multi-service/multi-stakeholder operation. In addition from all the lessons learned on technical matters, the project team expects to draw conclusions from the whole experiment on the regulatory evolutions that could allow taking the most of storage in unbundled contexts.

ACKNOWLEDGMENTS

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