MULTI-SERVICES STORAGE PLANT AT A DOMESTIC CUSTOMER'S PREMISES: EFFECT OF SIMULTANEOUS REQUESTS

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ABSTRACT

The progress in performance and cost of lithium-ion batteries, and the research and experiments about smart grids bring us to consider the introduction of low range storage devices (several kW; ½ hour to several hours) in the distribution grid. In particular, storage could be connected to the LV grid, in the premises of a client or close to him.

We studied two use cases of domestic storage, by electrochemical battery, which would contribute to two or three services, either regulated or deregulated. Both use cases could be profitable beyond 2020:

- *One around voltage smoothing, completed with reduction of outage duration and arbitrage on the energy market*
- *One around primary frequency regulation, with the same complementary services.*

The use case around primary frequency regulation seems to have a greater potential in storage installed capacity than the use case around voltage smoothing.

Nevertheless, the simple addition of the values of each service raises the problem that possibly, at the same time, two services or more will request to use the device. So we have to define a priority between the services and to calculate the loss of value for the services which have not priority.

More, in the use case around frequency regulation, we prefer withdrawing the service of arbitrage and keeping the outage duration service as only complementary service.

In both use cases, the loss of value appears to be quite limited. In particular, the outage duration service has naturally a simple way of coexistence with other services: it occurs only when the client equipped with storage undergoes a power cut.

More generally, it is consistent with the fact that both use cases have been researched and defined in order to minimize the risk and the effect of simultaneous requests of the storage device by several services.

INTRODUCTION

The progress in performance and cost of lithium-ion batteries, and the research and experiments about smart grids bring us to consider the introduction of low range storage devices (several kW; ½ hour to several hours) in the distribution grid. In particular, storage could be connected to the LV grid, in the premises of a client or close to him.

It is then necessary to define the technical functions that can be fulfilled by this domestic storage. Of course some functions are specific to its location. Each set of technical functions defines a use case. Afterwards we can examine the prospective profitability, in 2020-2025, of the use cases that we consider as interesting.

Finally, we will have to deal with the potential conflicts between the different services which will share one storage device.

TWO USE CASES OF DOMESTIC DISTRIBUTED STORAGE

We have examined distributed electrochemical storage applications, which are able to return a profit on the initial investment. We focused on lithium-ion technology. Then we studied combinations of services, which share one storage device, while remaining technically compatible.

We have looked into combinations of services, which allow to increase the value of a storage device, by avoiding combining incompatible services or services that would compete with each other too frequently for the use of the storage device.

We allow us to share the storage device between regulated and unregulated activities, and will consider the benefit for the whole electric system.

First combination: around voltage smoothing

The first combination of services shares a 6 kW / **31** kWh storage system between:

- Voltage smoothing, in order to prevent excessive voltages caused by PV generators on a low voltage grid
- A reduction in investment in distribution grid associated with outage duration targets

- Arbitrage on the energy market (service intended for the electricity producer).

The reinforcement that storage could avoid for a standard grid is converted into a fixed annual cost. Here is the breakdown of the annual values of these three services:

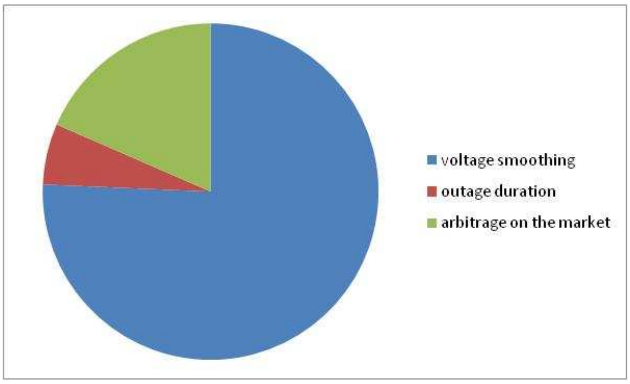

Figure 1: Use case around voltage smoothing: breakdown of the value of services per kWh of installed battery capacity in 2020

This combination of services is approaching profitability.

Achieving profitability is highly sensitive to various parameters, in particular for the main voltage smoothing service. Nevertheless, it is limited to low voltage feeders that are not evolving greatly, for which the problem of excessive voltage may be resolved in the long term.

Second combination: around frequency regulation

The second combination of services shares a 6 kW / **3** kWh storage system between:

- Distributed primary frequency regulation, as a replacement for conventional power plants (service intended for the electricity producer)
- A reduction in investment in the distribution grid associated with the average outage duration
- Arbitrage on the spot energy market.

The energy capacity of 3 kWh provides a guarantee of 30 minutes of frequency regulation reserve. Here is the breakdown of the values of these services:

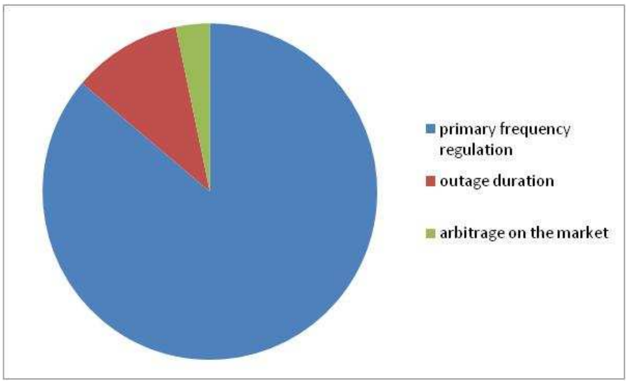

Figure 2: Use case around frequency regulation: breakdown of the values of services in € per kWh of installed battery capacity in 2020

Based on the chosen assumptions, this concept seems to be profitable beyond 2020, mainly thanks to the distributed primary frequency regulation service.

We used the current price of participation in the frequency regulation reserve, of € 16.96 per MW and per hour, published by the French TSO RTE; nevertheless, it is difficult to prejudge the long-term cost of establishing this reserve.

Compared to the first combination, the ratio between the annual value of services and the annual cost of storage is 50% better. This second use case seems to have a greater potential in storage installed capacity. In rural networks, the local percentage of equipped clients shall be limited to avoid creating high voltage constraints due to the injected power in case of low frequency.

EFFECT OF COMPETITIVE REQUESTS ON A STORAGE DEVICE

In the previous chapter, the natural temptation was to add up the three values of the different services. Nevertheless, as a single storage device can participate in several services, it is possible that at the same time two services or more are competing to use the device, beyond its sizing in storage capacity or in power.

To deal with this issue, for each combination, we shall first prioritize different services, by taking into account the technical needs of the distribution grids and the economic valuation of these services. Then we estimate the loss of value of the two services which have less priority.

Priority between services and loss of value in the first combination

Priority to voltage smoothing

Concerning the use case around voltage smoothing, the main service of solving the voltage constraint must be dealt with priority. Otherwise the grid constraint will not be completly solved, so we would loose the gain in avoided grid reinforcement.

Typical curve of stored energy and its effect on the "outage duration" service

We work out a typical yearly curve of the maximum energy which can be stored at dawn in our device, taking into account the need to store PV energy in the day. The maximum energy at dawn varies in function of the season: it is lowest in summer, when the need to store PV energy is maximum. We take into account as well a day ahead prevision of cloud cover and then of PV production.

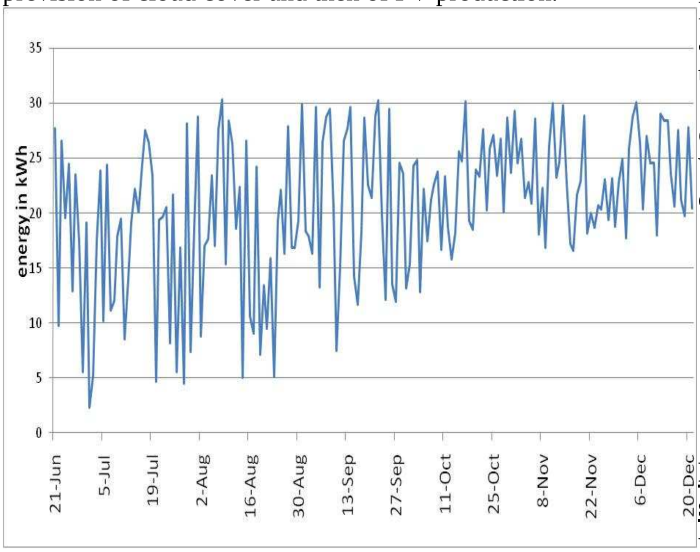

Figure 3 : typical curve of maximum energy stored at dawn

This curve has effects on the availability of storage for the other services. In summer, the energy remaining at dawn can be too low to feed the client equipped with storage in case of common grid interruptions.

Consider that 0.5 kWh are necessary to feed the client during common interruptions. If the period from May 12th to August 30th were completely sunny, the state of charge of the device would be low at dawn to be able to absorb the energy for the voltage issue. This would reduce the outage duration avoided by the storage device by 8%.

But as we saw, the need to store PV energy can be reduced by the cloud cover; thus we estimate at about 4% the lost value on the « outage duration » service.

Priority between arbitrage and voltage duration

Now we fix the priority between the two complementary services: improvement of mean outage duration and arbitrage.

We find that it is more profitable to keep an energy reserve allowing to feed the client for one hour, by accepting to lower energy for arbitrage.

According to the typical curve of stored energy at dawn **Figure 3**, this energy is on average 65% of storage capacity ie 20 kWh. The stored energy shall keep a reserve energy of about 0.5 kWh (to feed the equipped client for one hour). Thus the value of the mean daily cycle in arbitrage is the difference between these two thresholds. We find that the resulting number of cycles is close to the theoretical maximum allowed for the expected value of the battery lifetime ie 10 years. Thus the loss of value in arbitrage is very limited.

Note that the activation of the services of voltage smoothing and outage duration lowering would be relatively rare; thus they have little effect on the number of cycles of storage.

Global effect of simultaneous requests of storage

We find that it does not modify significantly the breakdown of the values of services of **Figure 1**:

- The service of voltage smoothing is not affected as it has priority
- The value of outage duration is lowered by only 4%
- Arbitrage is limited by the number of cycles on the battery lifetime, rather than the coexistence with both other services.

Priority between services and loss of value in the second combination

Economic incompatibility between frequency regulation and arbitrage

We give priority to primary frequency regulation, which shows more profitability than both complementary services.

To minimize the energy capacity needed for a storage device which participates in the primary reserve, we count 6 kW (power of storage) for 30 minutes. In fact, the French TSO RTE requests 15 minutes of reserve duration, but we take a margin because the battery will not always be fully charged. The storage would provide only upward regulation, which is the most expensive to allocate.

When the frequency is above the set value of 50 Hz, the storage is no longer requested by the frequency regulation; but it must be charged to restore the primary reserve. It seems impossible to add a complementary curve for energy arbitrage which implies a regular and deep variation of the storage charge, while keeping the energy sizing.

Coexistence between frequency regulation and outage duration service: no loss of value

The outage duration service will intervene only in case of a power cut of the client. In this case, it does not affect the functioning of primary regulation beyond the loss of primary reserve due to the interruption. In principle, when the client is fed again by the main grid, the storage should be charged enough to continue its participation in regulation. Nevertheless, the value of this time of primary reserve restoration, assessed as unavailable for frequency regulation, is completely negligible.

Updated breakdown of values

We have actualized the breakdown of the values of services knowing that we abandon the service of arbitrage in this use case. Each sector shows the percentage of the remaining service compared to the total value of the initial **Figure 2**:

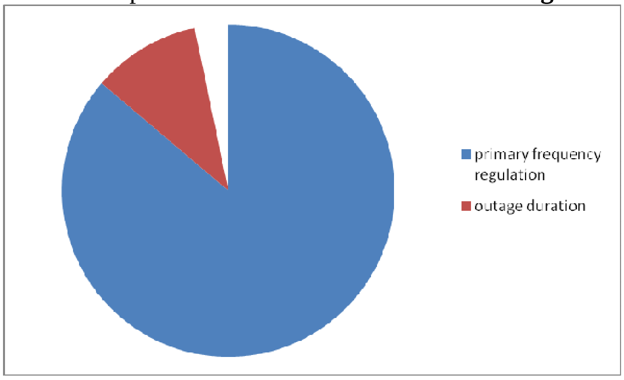

Figure 4 : breakdown of the values of services in € per kWh of installed battery after withdrawal of arbitrage

In the qualitative way, the effect is modest knowing that the withdrawn service was the least profitable.

CONCLUSION

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