[*VALORIZATION OF THE FILTERING CAPACITY OF INTERMITTENT ENERGIES IN THE FUTURE DECARBONIZED MATRIX*]

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Overview

In view of The Paris Agreement to combat climate change, there is an increasing trend towards decarbonization worldwide, in order to accomplish the nationally determined contributions. This process is mainly based on the electrification of energy uses and on a change in the electric generation matrix, replacing conventional generation with renewable one. Its success is sometimes questioned because of the system capacity to absorb the additional intermittences associated with renewable energies. This is why, increasing system flexibility becomes crucial.

Recently, Uruguay has undergone a radical change in its electric generation matrix that places it as one of the leader countries in this issue [1]. When considered together, the wind and solar installed capacity exceed the demand in nearly 90% of the time. Nowadays, the intermittences introduced by the addition of renewable energy are compensated with the hydroelectric generation subsystem. Nevertheless, the hydroelectric resource is almost fully exploited with limited possibilities of increasing its capacity. Therefore, as long as new renewable generation is incorporated to the system, there will come a time when another source of flexibility is needed.

This work shows a method to calculate the value added to the system by the incorporation of agents capable of filtering the intermittences associated to renewable generation, as could be batteries, a pumped hydroelectric storage station or future responsive demands. The results presented in this work are for the particular case of batteries.

Methods

This work was done using the software SimSEE, a platform that simulates the optimal operation of electric systems [2]. Firstly the opportunity cost of storage systems was analysed by adding batteries to the long term expansion plan made by the Institute of Electrical Engineering of Uruguay for the period 2019-2046, with a weekly step. This was calculated as the difference between the earnings when selling energy at the marginal cost of the system (e.g. at peak times) and the cost of buying it at the marginal cost (e.g. at off-peak times). In the simulation a global efficiency of 0.81 was assumed for the storage system and three different capacities were examined: 80 MWh, 400 MWh and 800 MWh. For each of them the charge and discharge power rates were modified and its marginal value was computed for each of the cases. The computed marginal values of storage systems (i.e. opportunity costs of the storage systems) were then compared to their capital costs based on Lazard 3.0 [3], so as to determine when these systems become viable and which capacity is the most suitable to the system.

This first analysis deepened the understanding in the system sensitivity to capacity, charging and discharging power rates, and drop an estimation of when could this systems become viable. However, introducing a battery in an expansion plan that does not consider battery units to expand does not lead to the optimal operation neither of the battery nor of the system. This is why a new expansion plan for the period 2019-2046 was made using the software OddFace, a platform that simulates the optimal system expansion of electric systems. The expansion units considered in this plan were wind, solar, thermal units and batteries. Battery units had a roundtrip efficiency of 0.81, 80 MWh of capacity, the same charge and discharge power rate of 20 MW and a cost of 300 USD/kWh in 2018.

Taking the date and capacity that resulted from the expansion plan, a year simulation, with hourly step, was done in order to calculate the system cost to satisfy the demand and compare it with the base case without storage. The base case was the one obtained from another expansion plan that only allowed the system to expand with wind, solar and thermal units. The contribution of batteries in the system's reliability to meet the demand was also studied. Finally the economics of a project of this nature was analysed.

Results

Long-term evolution of opportunity costs

Fig. 1 shows the computed marginal value for 80 MWh of capacity and the seven cases for power rates while Fig. 2 shows the computed marginal value for 400 MWh and 800 MWh of capacity and the seven cases for power rates for each of them.

In Fig. 1 and Fig. 2: "CR" stands for charge rate, "DR" stands for discharge rate, "Min BAT cost" is the minimum capital cost for ion lithium batteries when used for peaker replacement in 2017, "Max BAT cost" is their maximum value and "2018 BAT cost" is the estimated value for 2018 [3]. An annual decline rate of 10% in the capital costs was assumed [3].

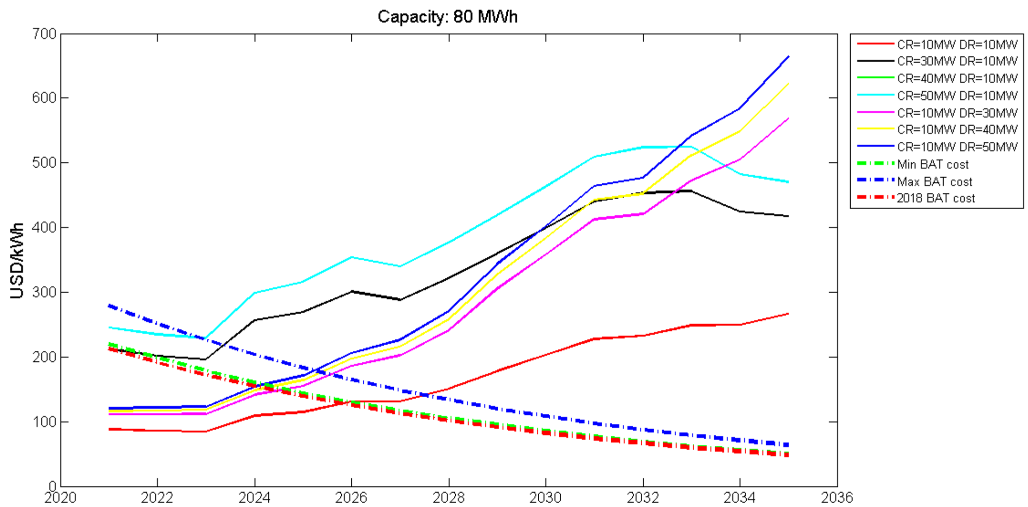

Figure 1: Marginal value for 80 MWh of capacity.

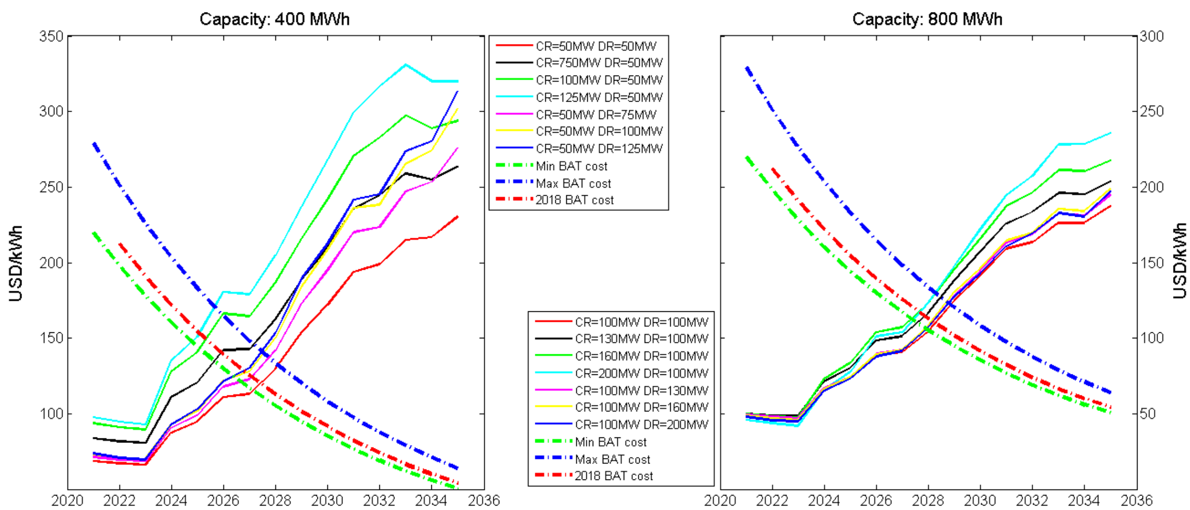

Figure 2: Marginal value for 400 MWh of capacity (Left) and for 800 MWh of capacity (Right).

From Figures 1 and 2 it can be concluded that smaller capacities see a greater benefit, becoming profitable sooner. Benefits grow in time, consistent with an increment in intermittent resources (solar and wind generation units) while hydroelectric units, which are the ones acting as filter nowadays, remain the same. It can also be noted that for 80 MWh of capacity systems with greater charging power rates see greater benefits at the beginning of the period. This situation is reverted at the end, becoming more valuable having greater discharging power rates.

On the other hand, the marginal value of the storage capacity was computed using the marginal cost of the system. In Uruguay, the spot price is calculated as the marginal cost with a cap of 250 USD/MWh. So the revenue of a storage system buying and selling in the spot market is lower than its marginal value. In order to recompose the optimal investment signal an additional payment for the services of the storage capacity should be considered.

Short-term analysis

The optimal expansion plan obtained for the period 2019-2049, with the inclusion of batteries as expansion units, install the first unit of this technology by 2030. Table 1 shows the expansion capacity installed by 2031, with and without battery expansion units.

Table 1: Expansion capacity by 2030 with and without batteries.

Technology	Unit size	Price	Capacity without batteries	Capacity with batteries
Solar	50 MW	50 USD/MWh available	1000 MW	800 MW
Wind	50 MW	50 USD/MWh available	200 MW	350 MW
Thermal	60 MW	14 USD/MWh available	0 MW	0 MW
Battery	80 MWh	5.36USD/MWhh available	0 MWh	80 MWh

On the other hand, the first thermal unit is installed in 2033 when the system does not incorporate batteries, while it is postponed to 2048 when it does so.

The system operation in 2030 with the capacities showed in Table 1 was simulated with an hourly step in order to compare costs and reliability.

Figure 3 compares the system’s annual supply cost for 2030 with and without the inclusion of batteries. As can be seen, in average the cost is almost the same, slightly lower with batteries than without them. In the base case the supply cost is in average 794.50 MUSD while when installing batteries it lowers to 794.29 MUSD. Therefore, with the inclusion of batteries the system saves annually 210,000 USD in average.

When analysing the risk, Figure 3 shows that this is greater without batteries. In dry years, the difference in the system’s supply cost when having batteries and without them is of 58 MUSD approximately. In rainy years, however, having batteries is more expensive to the system. The difference in this case is smaller, approximately 12 MUSD.

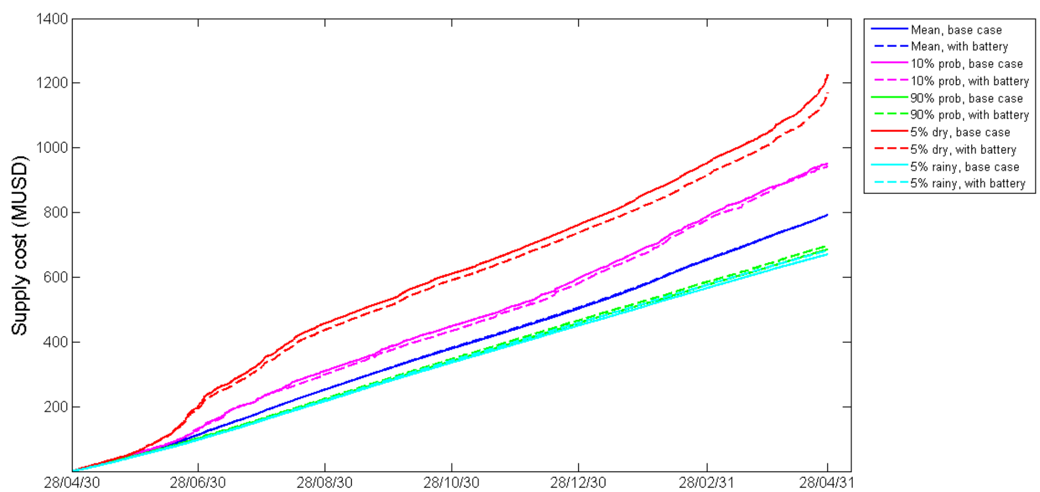

Figure 3: Supply cost.

Figure 4 compares the energy not delivered by the system with and without the inclusion of batteries. Without including them the system fails to deliver 1.73 GWh more in average compared to the case that installs batteries to the system. The situation is worse in dry years, raising this difference to 9.31 GWh. In rainy years, neither case fails to deliver energy.

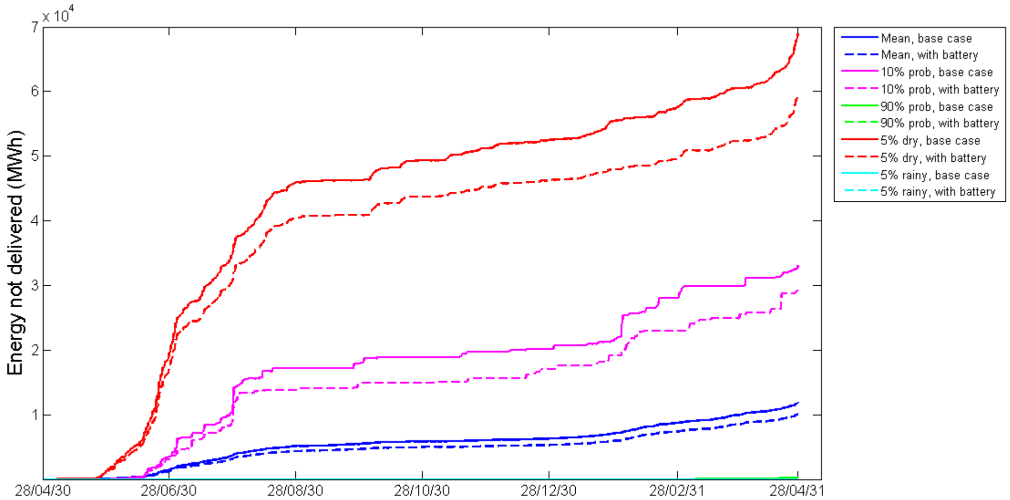

Figure 4: Energy not delivered.

The marginal value of the installed battery is graphed in Figure 5. The mayor benefits for the battery are obtained when there is lower hydroelectric energy available, i.e. in dry years. The marginal value drops significantly in rainy ones. The difference between them is near 6 MUSD. In average, the annual profit of the system is approximately of 1.78 MUSD. However, as was mentioned in the Section *"Long-term evolution of opportunity cost"*, the marginal cost in Uruguay has a cap. Therefore, the revenue of the storage system would actually be lower than its marginal value. Today the cap is of 250 USD/MWh. However, by 2030 this cap should be increased, as it will be lower than the most expensive thermal unit (which variable cost will be of 271 USD/MWh as oil price rises). In Figure 5 the benefit considering a cap of 400 USD/MWh is also graphed. The marginal value in this case is of 0.53 MUSD, almost the same as in rainy cases.

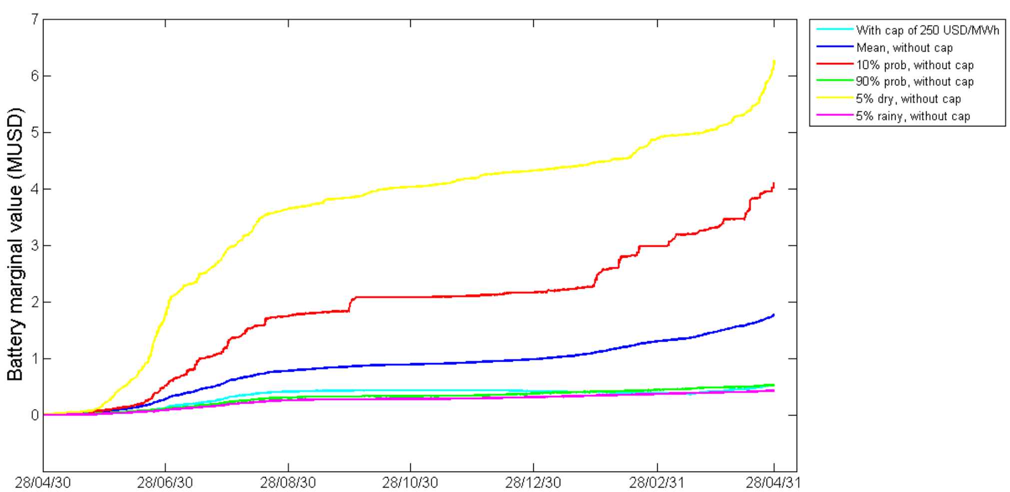

Figure 5: Battery marginal value.

Expressing the average marginal value in USD/kWh of stored energy, the benefit of the system would be of 222.5 USD/kWh without cap and of 66 USD/kWh with it. Considering that the annual decay rate in capital cost of the technology is of 10%, by 2030 the cost would be of 85 USD/kWh. Therefore the battery would be profitable as long as the marginal cost of the system is not limited. The minimum annual decay rate in capital cost that makes the system viable is of 3%.

With a capital cost of 85 USD/kWh in 2030, the investment would be of 6.8 MUSD. If the system earns 1.78 MUSD annually, the PAYBACK would be of 3.8 years. However, with a cap of 400 USD/MWh in the system marginal cost, the investment would not be profitable as the PAYBACK would be of 13 years, bigger than the system life span of 10 years approximately. So, in order to recompose the optimal investment signal an additional payment for the services of the storage capacity should be considered.

On the other hand, this study only takes into account the revenue from energy arbitrage. But energy storage is capable of delivering more services, such as firm capacity to renewable generation, peak shaving, capacity reserves, and deferral in the expansion of transmission and distribution infrastructure, among others. If this other benefits were valued, storage could become viable even sooner.

Conclusions

Due to the renewable installed capacity and the limitations to expand the hydroelectric subsystem, the Uruguayan power system shows the need to redefine some market rules, as in particular the concept of firm capacity and perhaps the definition of storage capacity as a new market product, providing an adequate pricing scheme to achieve system efficiency, which reflects real costs and benefits of the new resources.

A deeper analysis is needed in order to determine the complete value storage systems bring to the electric system. In particular, batteries' lifespan and cycling must be included.

References

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[3] Lazard Levelized Cost of Storage Analysis – version 3.0. Nov. 2017.