AN ALTERNATIVE APPROACH TO ANALYZE COMPETITIVENESS BETWEEN STORAGE TECHNOLOGIES USING LCOS

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Overview

With the push for renewable and clean sources of energy for environmental concerns, grows the need for flexibility on the electric system to cope with increasing share of variable, non-dispatchable, and non-synchronous sources of electricity. Stationnary storage is among others (e.g. demand-side-management, EV, P2X, grid development, dispatchable generation…) a possible provider of flexibility [1].

Historically, Pumped Hydro Storage (PHS) has been the dominant large scale storage technology. However the recent significant cost decrease for li-ion batteries and the promising development of other technologies such as flow batteries or thermal storage, has risen the need to compare the economic performances of storage technologies. As storage could play different roles in the electric system (energy transfer with daily and seasonal storage, grid stability with ancillary services…), this comparison should be applicable to all possible services.

One of the indicators used to compare the economic performance of storage technologies is the Levelized Cost Of Storage (LCOS). It allows to go beyond the simple comparison of CAPEX and take into account other relevant parameters, such as the round trip efficiency. The LCOS is the price at which a given service must be remunerated for a storage technology to break even taking into account all costs associated with the provision of the service. There is no consensus in the literature in the level of details that must be provided in the cost breakdown description [2-4]. However there is surprisingly a wider consensus on the method to define the parameters used to describe the service performed, namely the number of cycles that a technology goes through and the cost of the recharging strategy typically given by a charging price. In this generic method these two parameters are defined for each service and assumed constant across all technologies.

This generic approach can effectively describe uses cases where the service to be provided is clearly defined in terms of behavior such as for exemple a volume-specific PPA, congestion management contract, black start… However it does not describe accurately the difference in performances for market exposed use-cases such as for instance wholesale arbitrage or merit order-activation based aFRR. For these use cases, the performance of the asset as well as the service provided itself will be highly affected by the technology and typically its round trip efficiency.

This study proposes an alternative approach, based on a realistic description of the participation of each technology to the service, in order to take into account their specificity. This approach can be used on all services but necessitates a specific design of simulation for each. To illustrate this approach, we apply it to the comparison of PHS, Li-ion batteries and a promising thermal storage technology called ETES (Electric Thermal Energy Storage – it combines a molten salt cycle and a steam turbine) providing arbitrage services fully exposed to wholesale prices.

Methods

The formula for the LCOS is the following :

$$LCOS = \frac{Capex + \sum_{t=1}^{H} \frac{\left(Opex_f^t + Opex_v^t + C_{recharge}^t + C_{other}^t\right)}{(1+i)^t}}{\sum_{t=1}^{H} \frac{E_d^t}{(1+i)^t}}$$

Where $C_{recharge}$ is the yearly cost of recharge (or discharge) to provide the service, C_{other} represents other costs that might be considered (taxes, residual value…) and E_d is typically the energy provided for the service. However as the LCOS is defined as the price at which the service should be remunerated to break even, E_d should be consistent with the unit of the service remuneration.

The breakdown of costs can be as detailed as wanted as to include for exemple ageing of a technology, self discharge, taxes… In the literature, an effort is made into detailing fixed and variable opex, as well as C_{other}^t. However, in the generic method, the energy discharged for the service is usually set up as a parameter assumed to be equal across all technologies while the cost of recharge is derived from this discharged energy (through the efficiency ρ) and the price of recharge λ^t which is also assumed to be identical across all the technologies:

$$C_{recharge} = \frac{E_d}{\rho}\lambda^t$$

These assumptions can lead to biaised results for some services. For instance, for wholesale arbitrage, the optimal dispatch on given price series, shows us as in Figure 1 that the cycling (and more generally the dispatch) of a technology, and also the charging price are highly dependent on the round trip efficiency of the technology.

In this study, the cycling and the cost of recharge for each technology, are thus calculated for arbitrage, based on a optimal storage dispatch found through linear programming. The critical input for the linear programming is then the wholesale price series

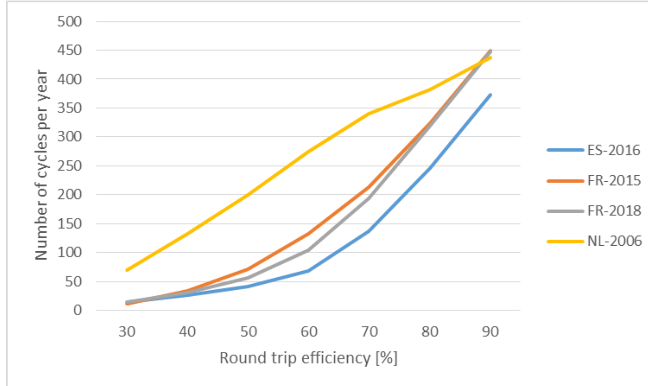

Figure 1 Number of cycles per year with the optimal dispatch on a daily approach, depending on the round trip efficiency

Results

To calculate the optimal storage dispatch, historical price series can be used but this method can also be used to determine the performance of the storage technologies with prospective energy mix, for instance with high share of renewables. In figure 2, historical price series of France, Spain and the Netherlands were used to analyse the impact of price on the optimal dispatch. For the generic method, the number of cycles is assumed to be equal to 1 per day while recharge price although assumed to be the same across all technology is varied, for the sensibility analysis, between 20€/MWh and 60€/MWh (the bar being the result for 40€/MWh .

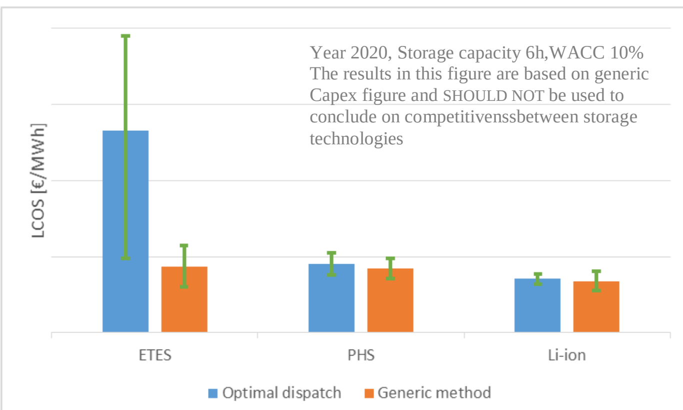

Figure 2 (LCOS of Li-ion/PHS/ETES depending on the price series with the optimal dispatch method compared to the generic method)

The use of different price series allows to capture the market dependency of each technology. In this regard, this method could be used to compute realistic distributions of the use case-dependant parameters for a Monte Carlo simulation.

As far as arbitrage is concerned, as round trip efficiency has an impact both on the cycling and the volume of charged energy (compared to the discharged energy), the impact of the price series on the LCOS is all the bigger when the optimal dispatch method is considered that the round trip efficiency is low, as it can be seen in figure 2 where ETES has a round trip efficiency around 40% while STEP are around 75% and Li-ion batteries around 85%.

Conclusions

In this study, we highlight the risks and limits of using a generic formula of LCOS to compare storage technologies across a variety of use-cases. Although the generic formula can provide meaningful insight when the storage technology is required to provide a precise and fixed service, it appears that when the service depends on market prices, each technology with their respective characteristics (round trip efficiency, dynamic constraints…) will behave differently and cannot be expected to provide the service in the same manner. A method based on a realistic modelisation of each technology's behaviour allows to provide this additional insight which can be useful to properly compare storage technologies. The methodology presented in this study can be extended to other use-cases but has to be adapted to the specificity and market design of each use-case.

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