VALUATION OF LARGE SCALE ENERGY STORAGE: OPTIMISATION VS SIMULATION METHODS

Antoine DEBILLE, Université de Nantes, LEMNA, France, +33 6 83 15 32 92, antoine.debille@segula.fr
Rodica LOISEL, Université de Nantes, LEMNA, rodica.loisel@univ-nantes.fr

Overview

This paper reviews the modelling techniques for energy storage system evaluation upon the communly used indicator levelised cost of energy (LCOE). The study case is the French storage plant Grand'Maison (1.8 GW), as power systems around the world will massively need bulk storage in the future to meet decarbonization targets with renewables [1]. The analysis is conducted over 6 years such as to understand the actual operation of the system, to establish modelling key parameters and to formulate essential hypothesis that build a realistic LCOE indicator for storage. Two different models are built to evaluate the economics of Grand'Maison, based on its operation over 8760 hours: one based on optimisation and one based on simulation. Our review of literature on LCOE techniques finds that most of studies compute the cost of storage based on the energy *discharged* only [2], ignoring thus charging flows and the storage duration; that cost of charging is often the *average* electricity price [3], [4], whereas the hourly price fluctuation heavily plays on the storage operation and profits; and that capacity factors are rated at their maximum, whereas in practice it oscilates around 25%. Our frame re-evaluates the method of cost calculation and integrates the economics into technological approaches by considering storage complexity in terms of instantaneous value instead of average costs, and ultimately suggests ways of understanding the storage as a system vector triggered by the other technology needs instead of analogy with pur power generators.

Methods

Two models are developed, one based on the actual operation of the Grand'Maison pumped hydro storage plant, and one based on the optimisation of its operation.

1) Actual observation. The first step is a volume approach, where the historical operation is considered over six consecutive years (2014-2019), at hourly time rate for each pumping and discharging mode. The outcome is the calculation of average operation over seasons like hour, week and month, such as to generate trends in terms of volumes and capacity factors, for future extrapolation. The second step consists in crossing volumes with spot power prices in order to check the correlation between pumping / discharging with off-peak / on-peak prices and hence determine the arbitrage profit per hour and per year, and ultimately the levelised cost of the Grand'Maison plant. To that, we build an open service calculator to compute the LCOE, implemented under Excel Visual Basic for Application, where we pre-define time-window profiles issued from the actual observations. The cost is simulated without any market price anticipation, based on the actual average hourly profile of Grand'Maison operation. The assumption is that storage is discharging or charging at specific hours, hence several time-windows are dedicated to pumping and discharging. Capacity factors are calculated for every hour within each time-window in order to reproduce a realistic operation, following hourly averages over the six years and alternatively, using maximum actual values per hour.

2) The second approach, based on optimisation, is used to compare trends with the actual results. An optimisation model is built to maximize the profit of the storage plant based on arbitrage strategy. The model is implemented in the Gams language using linear programming with the Cplex software. The model is dynamic over 8,760 time slices in order to mimic the behaviour of a storage plant over one year. To maximise profits, the pumped hydro storage operation is driven by perfect foresights of the hourly spot market prices of each selected year (2014-2019). The model describes partial equilibrium of the storage plant only, disconnected from the other power plants, thus there is no feedback from the power market, the system being constrained by the storage technology parameters only, such as the capacity of the reservoir, the stock level, the efficiency and nominal power.

Both modelling methods return hourly volumes of charging and discharging electricity, along with the stored level of energy; while every electricity volume generates a capacity factor. An average operation is then calculated for every hour as a means to draw a daily profile of operation. The economics of the plant is ultimately evaluated by calculating the profit made through arbitrage along with the levelised cost of energy value.

Results

Hourly results obtained with simulation and alternativey by means of optimisation show similar trends (Fig. 1). Profits are positive in both approaches, but obviously different, which differently affect the average costs (Fig. 2). Numerically, in the year 2015, profits are around 11 M€ in the Actual case and 20 M€ in Optimization, and the LCOE values are 350 €/MWh and 100 €/MWh respectively. The Actual case, capturing only 55% of the Optimal value, reveals that storage operation is mostly triggered by the French power system needs than by the spot price fluctuations, following less a price arbitrage strategy. Interestingly, when evaluations are based on the *average* prices instead of *hourly* values, profits are negative (see Simulated case at Fig. 2). We find that a lower LCOE in the Simulated case with MinMax values (250 €/MWh) exhibits negative profits (-21 M€), while a higher LCOE value in the Observed case (350 €/MWh), with positive profits (11 M€), clearly represents an interesting business case, beyond LCOE values.

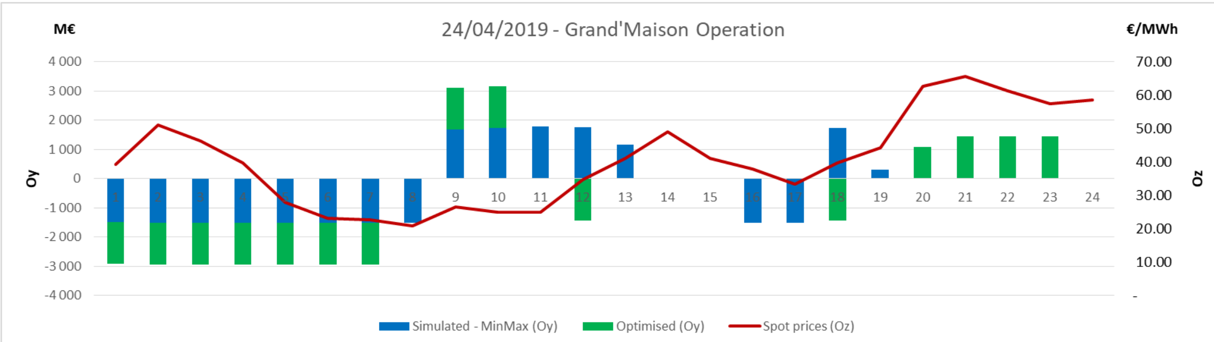

Fig 1. Grand'Maison optimised operation *versus* simulated operation (Min Max) over 24 hours

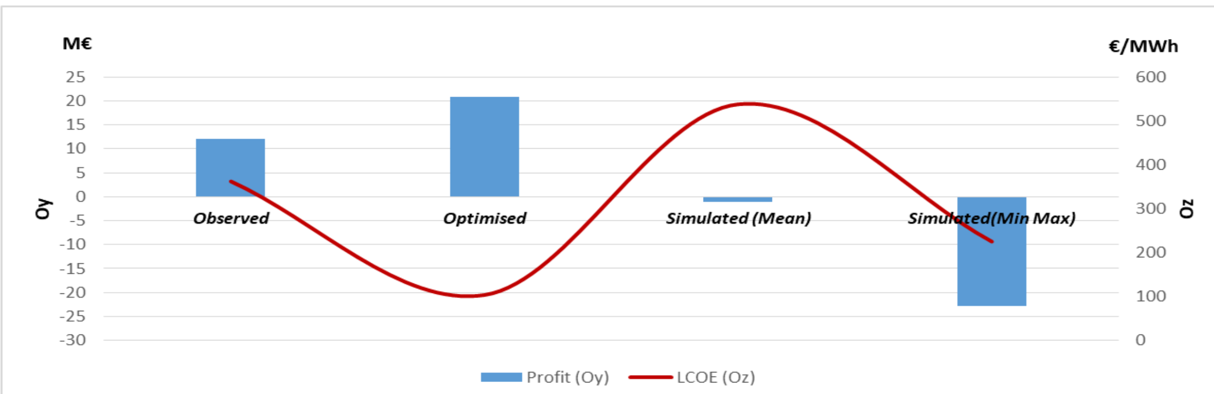

Fig 2. Comparison of profit and LCOE indicators amongst scenarios for the year 2015

Conclusions

In line with other studies, we conclude that storage evaluation is system-specific and depends on many exogenous criteria such as the weather, geography and politics; we complement the literature with a calculator that depicts hourly the operation of storage and conclude that the storage operation cannot be generalized based on average profiles only, even when the seasonality slice is the week period, as results still underestimate profits or overestimate costs. A high rate of operation might lower LCOE but negatively act on profits value. Ultimately, it is the hourly price profile which best evaluates the storage, as a proxy of the system behaviour and needs, since storage is primarily used in support to the power system, as complement more than substitute to power generators. Storage operation being the resultant of the power system, the LCOE computation should reflect the system behaviour as well, hence integrate at best price profile for each charging / discharging mode, and for each arbitrage and reserve provision service.

References

[1] RTE, 2021. Long-term forecast on Energy Scenarios in 2050. In French.

[2] IEA -NEA - OECD, 2020. Projected costs of generating electricity - 2020.

[3] A. Smallbone, V. Jülch, R. Wardle, A. P. Roskilly, 2017. Levelised Cost of Storage for Pumped Heat Energy Storage in comparison with other energy storage technologies. Energy Convers. Manag.152:221-228.

[4] V. Jülch, 2016. Comparison of electricity storage options using levelized cost of storage (LCOS) method. Appl. Energy 183:1594-1606.