CALCULATING THE LEVELIZED COST OF ELECTRICITY STORAGE?

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Overview

The increasing share of variable renewable energy sources (vRES) in the electricity system leads to an increasing interest in different electricity storage options. Although useful and actively pursued, a generally accepted definition of a levelized cost of electricity storage, analog to the widespread used Levelized Cost of Electricity (LCOE) [1], does not yet exist. Such a measure could allow for simple verification of the economic viability of certain storage technologies in a given electricity market. Pawel [2] and Schoenung and Hassenzahl [3] proposed a measure using the same formulation as for the LCOE but employ storage technology characteristics instead of traditional electricity generator characteristics. This is a starting point to calculate the Levelized Cost of Storage, but the following points of attention must be well understood:

1. The absolute price at which electricity is discharged is of minor importance. Rather, the average price spread between charged and discharged electricity determines the revenue for the investor.
2. The calculated required price spread is not directly comparable to available price spreads in the electricity market as a limited energy storage capacity can prohibit the storage from charging and discharging on the most optimal moments.
3. The possible obtainable arbitrage revenue will be lower than the possible obtainable price spread due to the cost of efficiency losses.
4. The LCOS metric does not reflect possible revenues earned by the storage owner due to assistance for ancillary services

The aim of this work is to gain understanding in the first three points of attention listed above. Illustrative examples are presented and analyzed.

Methods

In first instance, the Levelized Cost of Storage (LCOS) is calculated as formulated in eq. (1), which is analog to the LCOE formulation in [1], but uses charging cost as fuel cost and takes the discharged electricity instead of generated electricity.

$$\mathrm{LCOS} = \frac{\sum (Capital_t + O\&M_t + Fuel_t) \cdot (1+r)^{-t}}{\sum MWh_t \cdot (1+r)^{-t}} \tag{1}$$

Where:

$Capital_t$	= Total capital expenditures in year t
$O\&M_t$	= Fixed operation and maintenance costs in year t
$Fuel_t$	= Charging cost in year t
MWh_t	= The amount of electricity discharged in MWh in year t, measure for the capacity factor
$(1+r)^{-t}$	= The discount factor for year t

Table 1: Technology characteristics for a NaS Battery

Characteristic		Battery
Round-trip efficiency	[%]	81
CAPEX	[€/kW]	300
Fixed OPEX	[%CAPEX/y]	1
Energy-to-power ratio	[kWh/kW]	7,2
Discount rate	[%]	5
Economic lifetime	[y]	12

Results

The arbitrage revenue required to break even the full cost for the investor depends on the characteristics of the storage technology, similar to the LCOE. However, it is important to notice that the LCOS, or thus the required arbitrage revenue, depends on the charging price and that an input zero charging price is not reflective of a real LCOS. Eq. (1) is used to calculate the LCOS for several values of capital cost, efficiency and charging cost, shown in Figure 1. NaS batteries are used in this example, the technology characteristics of which are listed in Table 1. The reference charging price in this example is chosen as 40 €/MWh. Three curves are shown, each for a different Number of Discharging Hours (NDH) at nominal power.

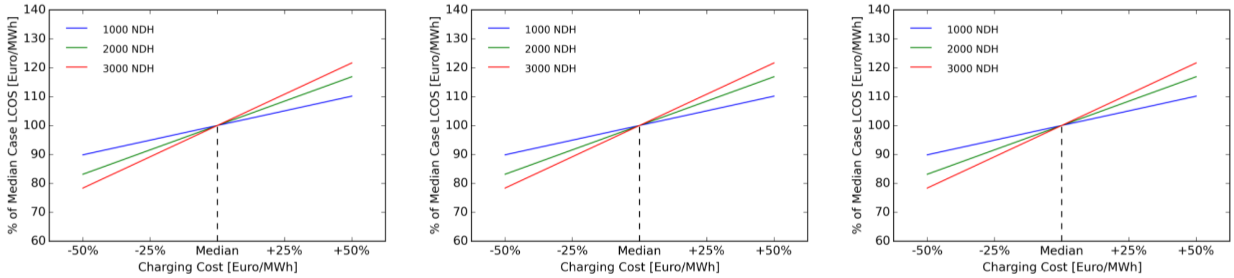

Figure 1: Variation of Capital cost, Efficiency and Charging Cost on the LCOS.

When going beyond a single measure to express the cost of storage, two curves can be calculated to assess the possible revenue from temporal price arbitrage with a certain storage technology, which are shown in Figure 2:

1. The Levelized Cost of Storage Capacity (LCOSC), which expresses the full capacity cost for the investor discounted over the number of discharging hours (NDH). This cost is equal to the LCOS formulated above, with a fuel cost taken as zero.
2. The Arbitrage Potential (AP) of a certain storage technology in a certain electricity market. This arbitrage potential differs from the price spread as it takes into account the extra charging cost due to efficiency losses and the possible non-optimal use of an available price spread due to limited energy storage capacity.

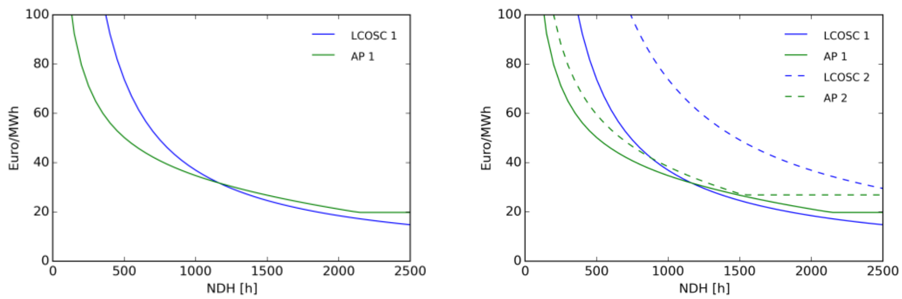

Figure 2: Levelized Cost of Storage Capacity (LCOSC) compared to the Arbitrage Potential (AP) in the Belgian 2015 Day Ahead Market. Storage technology parameters for technology 1 are as presented in Table 1 above. Technology 2 has the same fixed opex, economic lifetime and discount rate, but a capital cost of 600€/kW, a round-trip efficiency of 64% and an energy-to-power ratio of 10.000.

Conclusions

There are some challenges to express the levelized cost of stored electricity in a single measure. This is because the LCOS is dependent on economic storage characteristics and, unlike for the traditional LCOE, also depends on temporal characteristics of the electricity price profile.

An analysis of the entire electricity system will provide more information than a single levelized cost measure to compare different storage technologies in the electricity market.

References

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