TIME BASED APPROACH FOR LCOE AND NPV WITH APPLICATION TO GAS POWER AND HYDROGEN

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Overview

The low-carbon energy transition is creating new challenges for power systems with the global will for decarbonation and the need to develop more renewable energy systems (RES). Among the main issues, the intermittency of RES is raising new risks related to supply-demande imbalance and frequency stability for the electricity grid. In this context, hydrogen (H_2) appears as promising energy vector as it may enable both reducing carbon emissions and providing storage facilities and stability services for electricity. This statement also applies for conventional fossil power asset such as gas turbines (GT). In this case, carbon abattements can also be generated by co-firing natural gas (NG) with hydrogen.

However, despite the great promises of hydrogen for power, it first appears to be a nonecononomically competitive option in most practical cases given the current prices of hydrogen, natural gas and carbon. In particular, financial indicators such as LCOE and NPV are not competitive with the business-as-usual scenario. How then the introduction of the hydrogen constituent in a conventional gas-fired power plant can make economic sense? What leverages have to be implemented? And which elements should be considered to make this case more profitable?

This paper uses a business-oriented approach to analyse the value of hydrogen in gas power, and assess leverages and incentives that make such case profitable. The approach relies on LCOE and NPV calculations, which are usually considered by decision markers in the power industry. A time-based approach (TBA) that provides decomposition with sub-periods is considered and compared to the conventional one. Such approach enables to consider the full flexibility we can benefit from combining hydrogen production with a GT for different purposes (co-firing with natural gas, additional grid support, *etc.*).

First, conventional and time-based approaches are compared. Explanations about observed differences are then investigated and a discussion about the appropriateness of methodology when H_2 is involved is proposed. Besides, leverages and incentives to make such combination profitable are analysed on general and typical business cases. The time-based approach shows benefits for both GT plant (through grid services, co-firing H_2 with natural gas) and hydrogen value chain (through buffer storage for the grid, and the diversity of source and use that can be considered).

Methods

Two methodologies have been compared (see Table 1):

- A conventional approach with fixed yearly values for load factors (LF) and prices (NG, CO_2, electricity, *etc.*)
- A time-based approach with each year subdivised into sub periods with specific values for LF and prices.

<table>
<tr><th>Conventional approach</th><th>Time-based approach</th></tr>
<tr><td>Inputs (prices and load factor) are assumed to be constant over the year</td><td>Inputs (prices and load factors) are function of time, and depend on the considered sub-period k</td></tr>
<tr><td>$$LCOE = \frac{\sum_{i \in Year} \sum_{j \in Components} \frac{Cost_j(i)}{(1+r)^i}}{\sum_{i \in Year} \frac{OH(i) * LF_{GT}(i) * Power_{GT}}{(1+r)^i}}$$
$with$
$Cost_j(i)$: Costs related to component *j* during year *i*
$OH(i)$: amount of GT operating hours during year i
$LF_{GT}(i)$: GT yearly load factor during year *i*
$Power_{GT}$: Nominal GT power output in MW</td><td>$$LCOE = \frac{\sum_{i \in Year} \sum_{j \in Components} \frac{Cost_j(i)}{(1+r)^i}}{\sum_{i \in Year} \frac{\sum_{k \in Sub-Periods} OH(k,i) * LF_{GT}(k,i) * Power_{GT}}{(1+r)^i}}$$
$with$
$$Cost_j(i) = \sum_{k \in Sub-Periods} Cost_j(k,i)$$
$Cost_j(k,i)$: Costs related to component *j* during year *i* and sub-period *k*
$OH(k,i)$: GT operating hours during sub-period k during year *i*
$LF_{GT}(k,i)$:GT load factor during sub-period *k* of year *i*</td></tr>
<tr><td colspan="2">r: Discount rate
$i \in \{1, 2, \dots, Lifetime\}$: *i* considered year
$j \in \{GT, Electrolyser, Storage\}$: *j* considered component
k stands for sub-period (*e.g.* $k \in \{0, \dots 8760\}$ when considering 8760 hours a year)</td></tr>
</table>

Table 1 – Comparison on LCOE formulas for conventional and time-based approaches

Results

For the purpose of this abstract, we consider the following case study: GT is running at baseload (maximum capacity) by day (when electricity and NG price are high) while shut off by night (when prices are low). A constant volumetric H_2 proportion of 5% (by volume) is blended with natural gas.

Considering profiles as per given on Figure 1, impacts from NG costs on LCOE, and from NG costs and electricity revenues on NPV are shown on Table 2 (*i.e.* for the sake of simplification, we neglected components costs such as CAPEX, O&M in this illustration and only consider NG, H_2 and CO_2 costs).

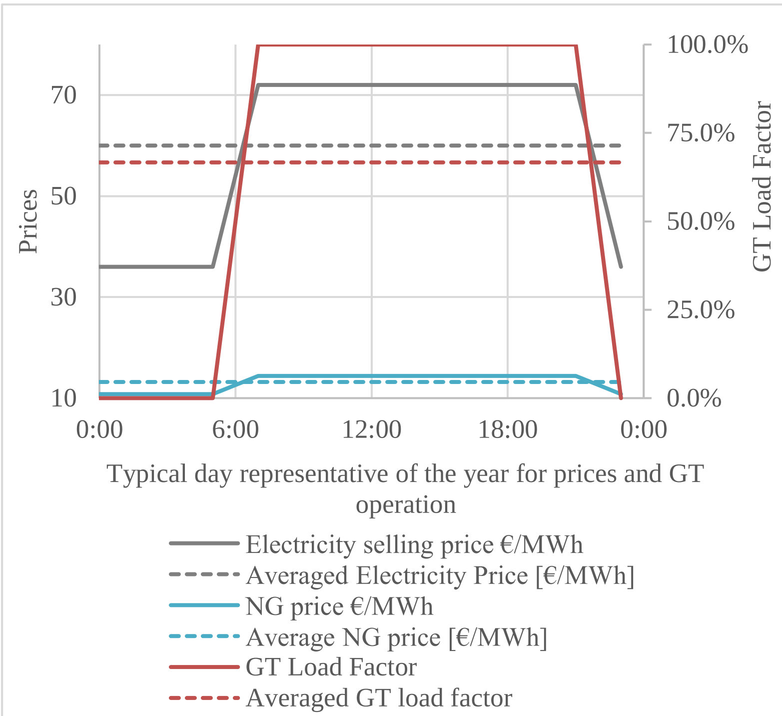

Figure 1 – Simplified example of electricity price and GT operating hours (OH) profiles that can be considered in LCOE and NPV calculations using the time-based approach (continuous line) vs the yearly values conventionally used (dashed lines)

	Conventional Approach	**Time-based Approach**
LCOE [€/MWh]		
NG	45.46	49.21
CO_2	12.25	
H_2	7.54	
Total	**65.25**	**69.00**
NPV [M€]		
NG	-258.96	-280.29
CO_2	-69.75	
H_2	-42.95	
Electricity	398.73	471.00
Total	**27.06**	**78.00**

Table 2 - Table showing impact of fuels (NG, H_2), CO_2 costs and electricity revenues on LCOE and NPV for the two approaches

Conclusions

Even though based on a simplified case study (with the simplified assumptions discussed earlier), this example illustrates that conventional and time-based approaches give very different results for both LCOE and NPV, while considering the same reference context. More realistic assumptions can then be considered. In particular, realistic profiles consisting either in several representative days (as done for this abstract, but with more details and contextual considerations regarding possible profiles) or more detailed values (say representing prices on second- or hourly- basis all year long) can be taken as inputs. Such investigations enable us to include more accurate grid-support service values in calculations.

Hence, in order to investigate such realistic case studies, similar calculations are run with time-based approach considering electrolyser and storage system for hydrogen. In these cases, several strategies of operation are assumed ("electrolyser system to extend grid-support from the GT", "green the GT by co-firing H_2 from renewables", *etc.*) in combination with different incentives and leverages for grid services and low carbon options. All these cases are studied and discussed in the paper.

Main reference

P. Graham., 2018. *Review of alternative methods for extending LCOE calculations to include balancing costs*. CSIRO, Australia.