Considering linepack in multi-energy systems modelling

Linepack is the gas stored in pipelines, useful for flexibility purposes, and frequently overlooked in multi-energy models. A method for its implementation in Antares is presented.

Nikolaos POLITIDIS | **Tinhinane MEZAIR** | **Nicolas DERHY** | **Camille MASCLES**

1. Context

Linepack in brief : Linepack is defined as the total volume of gas stored in a pipeline at any given moment, which is partially used for flexibility purposes.

Importance : In France, linepack currently offers up to 200 GWh/day of flexibility to the methane network. It is expected to continue playing a role in future interconnected methane, hydrogen and electricity networks.

Current work :

- Modelling linepack as a short cycle storage in Antares (PyPSA-like software).
- Implementation of this approach in a regional case study.

Funding : This research was undertaken in the context of the PlaneTerr project, which aims to advance multi-energy planning and sector coupling in France. It was funded by the French Government as part of the France 2030 investment plan, operated by ADEME.

2. Introduction to linepack

The amount of linepack in a pipeline can be described by the following equation :

$$Linepack = f(P_{avg}, Z_m)$$

Where :
P_{avg} : The average pressure in the pipeline
Z_m : The average compressibility factor of the gas contained in the pipeline

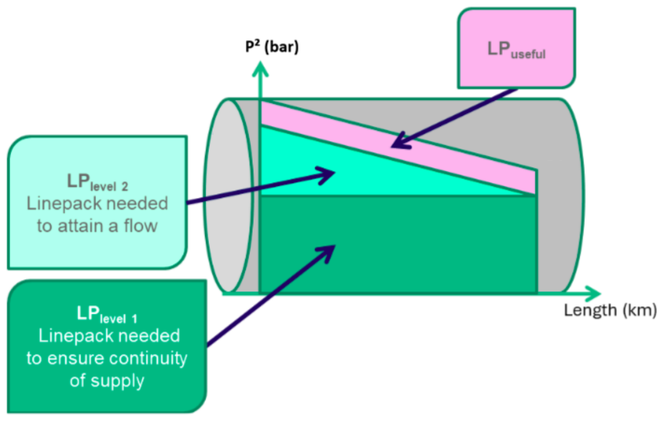


Figure 1 – Roles of linepack

Linepack fulfills multiple roles in a gas network. In the context of this work, we are concerned by its portion which can provide flexibility *(useful linepack)*.

Since, in French methane networks, linepack needs to be reset at the end of every gas day (at 6 AM), we consider it a form of intra-day flexibility. Linepack in hydrogen networks will not necessarily be regulated in the same way.

3. Historical methane data 2019-2024

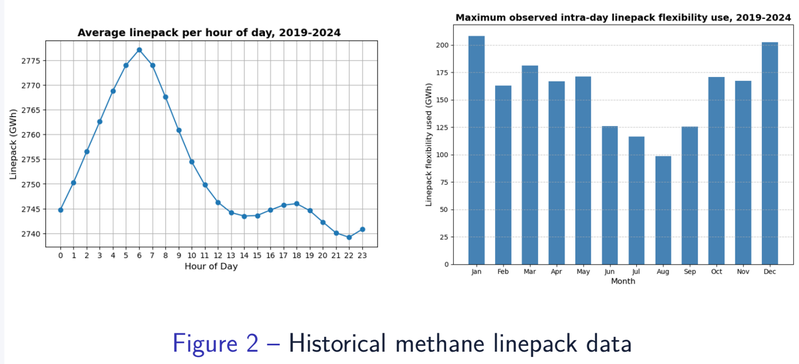


Figure 2 – Historical methane linepack data

Methane is stored at the start of the gas day in anticipation of the consumption to come.

Significant amounts of linepack flexibility are called upon throughout the year, with peaks of $100 - 200 GWh/day$ depending on the month.

The intra-day flexibility offered by linepack is bigger than that of the 5^{th} biggest gas storage in France.

4. Approach to linepack modelling

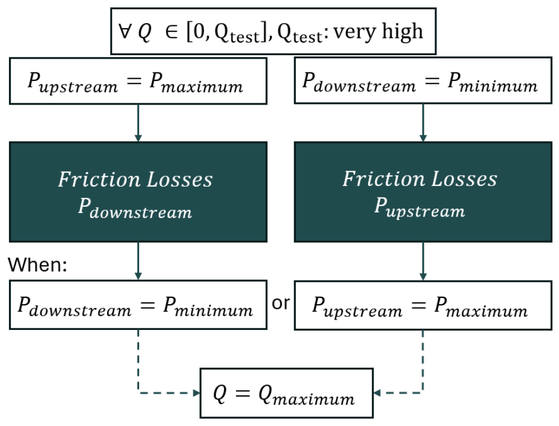


Figure 3 – Estimation of maximum gas flow for a given pair of max and min pressures via trial and error

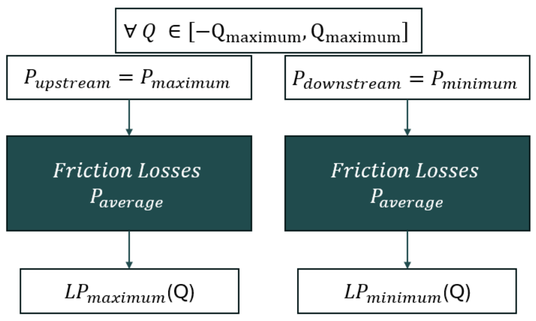


Figure 4 – Estimation of minimum and maximum linepack as a function of gas flow

First, we estimate the maximum gas flow in each pipeline based on its characteristics, as well as the minimum and maximum pressures which it can sustain.

We then describe the minimum and maximum linepack of each pipeline as a function of the gas flow [1]. We finally obtain :

$$LP_{useful}(Q) = LP_{maximum}(Q) - LP_{minimum}(Q)$$
$$\forall Q \in [-Q_{maximum},\ Q_{maximum}]$$

5. Integration in Antares

The useful linepack is represented in Antares using a Pumped Storage Plant (PSP) object [2], whose daily inflows equal its daily outflows.

The volume of the storage is tracked by a fictional "useful linepack" node, containing two thermal clusters and the "**Group 1**" of binding constraints.

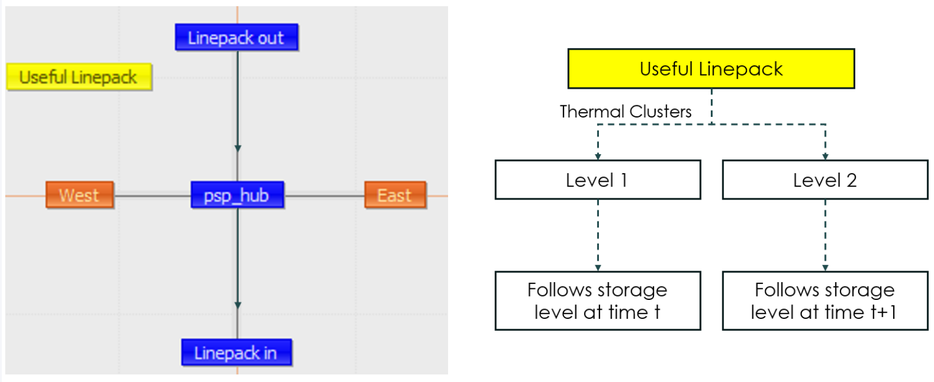


Figure 5 – Modelling of useful linepack in Antares through a (PSP) object

Binding constraints :
Group 1 : Tracking storage level via thermal clusters :

$$Level_2(t+1) - Level_1(t) = (Hub \rightarrow In) - (Out \rightarrow Hub)$$
$$Level_2(t) = Level_1(t)$$

Group 2 : Adding linearized forms of $LP_{maximum}(Q)$ and $LP_{minimum}(Q)$:

- $LP_{maximum}(Q)$:
$$Q \leq -a \times Level_1 + b \rightarrow Q + a \times Level_1 \leq b$$
- $LP_{minimum}(Q)$:
$$Q \geq c \times Level_1 + d \rightarrow Q - c \times Level_1 \geq d$$
- Where :
$$a, b, c, d \geq 0$$

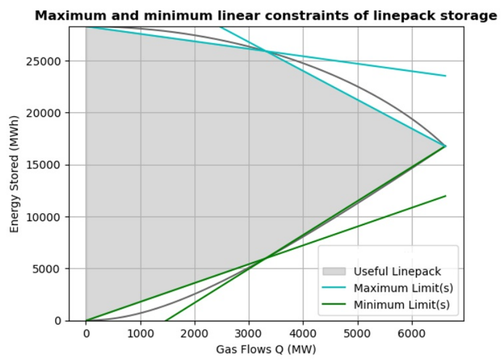


Figure 6 – Linearized maximum and minimum linepack constraints as a function of gas flow

6. Case study

This methodology was implemented in a case study of the Fos-sur-Mer French industrial hub.

A model coupling electricity and hydrogen was created in Antares. The useful linepack of the hydrogen pipelines is considered a cheaper alternative to the underground storage.

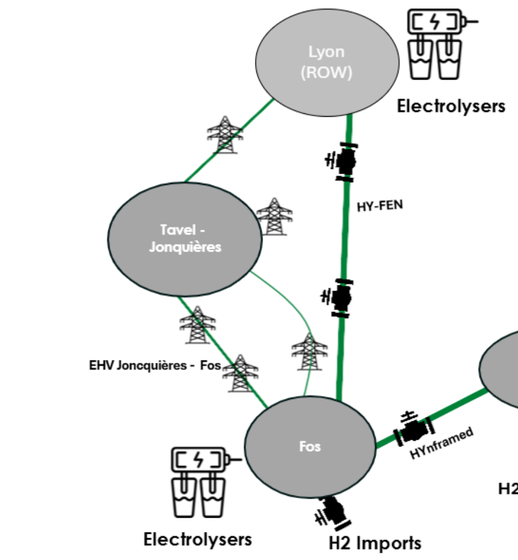


Figure 7 – Outline of the hydrogen and electricity model

Results indicate that linepack provides a substantial source of intra-day flexibility. In the studied configuration, the utilisation of underground hydrogen storage is reduced by approximately 24% when linepack is considered.

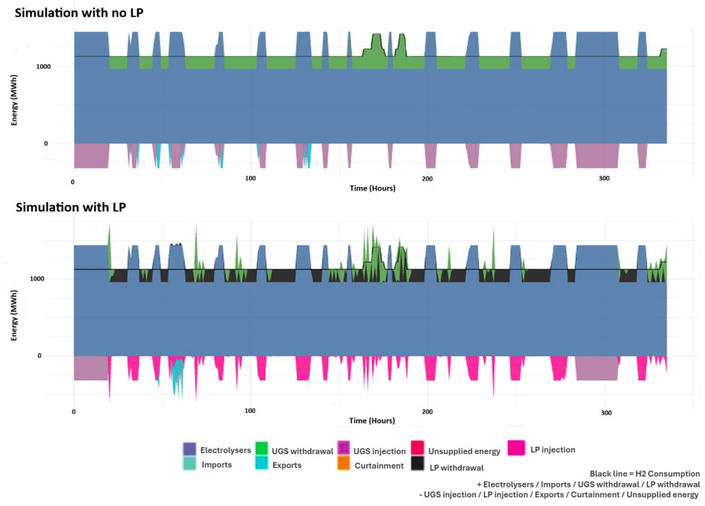


Figure 8 – Comparison of system operation with and without linepack flexibility

7. Conclusions

Key finding :

- Linepack reduces hydrogen underground storage use by 24% in our modelling.

Model limits :

- No explicit modelling of pressure
  - Linepack level is approximated at each time step
  - No interaction between adjacent pipelines
- Static modelling
  - No propagation of effects
  - Potential of unrealistic charging-discharging rates

References

[1] Rossi, B., Martin, F., de Carpentier, F., Optimizing linepack usage and intraday operations of a gas transmission network, a new approach on GRTgaz network, Proceedings of the International Gas Union Research Conference (IGRC). Pages 231-238, Copenhagen, Denmark, 17-19 September 2014.

[2] RTE, short cycle storage in Antares : Short term storage. https ://github.com/AntaresSimulatorTeam/Antares_Simulator/discussions/1133

A similar approach was elaborated by :
Philip Sargent, Michael Sargent, Linepack flexibility for hydrogen and natural gas pipes : A new flexibility metric for energy systems modelling, International Journal of Hydrogen Energy, Volume 132, 2025, Pages 139-142, ISSN 0360-3199, https ://doi.org/10.1016/j.ijhydene.2025.04.197.