Title: A two-stage approach to represent the daily LNG carriers unloading in natural gas optimization models

Diana Navarrete-Cruz, Institute for Research in Technology (IIT), dmnavarrete@comillas.edu

Antonio Bello, Institute for Research in Technology (IIT), abello@comillas.edu

Pablo Rodilla, Institute for Research in Technology (IIT), prodilla@comillas.edu

Overview

Natural gas is expected to play a key role in the energy system of the next decade since it is one of the mainstays of global energy and can still replace more polluting fuels. At the same time, many countries' dependence on natural gas imports, which are subject to geopolitical conflicts, has increased significantly in recent years, making the natural gas supply vulnerable to disruptions and price fluctuations. The fact is that natural gas is becoming highly volatile, and its prices are often more volatile than those of other commodities. The conflict between Russia and Ukraine and the shocks to natural gas prices in Europe have been the most extreme proof of all this.

In this context, natural gas system optimization models are more fundamental than ever for both policymakers and companies. These models allow for impact assessment, diagnosis, and forecasting, and can be used as learning tools, providing a means for analyzing what-if scenarios.

Modeling natural gas systems is however challenging work because it entails representing specialized infrastructure, including pipeline networks, liquid natural gas (LNG) ports, and storage facilities, among others. This complexity is exacerbated when we attempt to comply with a daily granularity (relevant for operation) and a multi-year representation (needed for medium to long-term planning). In this situation, many trade-offs must be considered when modeling the natural gas system. We focus here on the specific problem of finding a trade-off representation for the LNG carrier unloading at LNG regasification facilities.

Methods

In this paper, we propose a new two-stage modeling approach to represent the daily LNG carrier unloading in gas systems optimization models. In particular, we apply the methodology to a model based on GASCOOP[1]. GASCOOP is an entry-exit gas optimization model that minimizes the total cost of the gas supply in a certain country (represented as a single node). As it is well known, market equilibrium can be found through cost minimization by assuming a perfectly competitive market. The model considers the national demand, LNG contracts, storage facilities, LNG regasification terminals, transportation by vessels, and international pipelines to find the market-clearing prices that balance supply (including storage) and demand in the hub (Figure 1), considering all involved sources of costs.

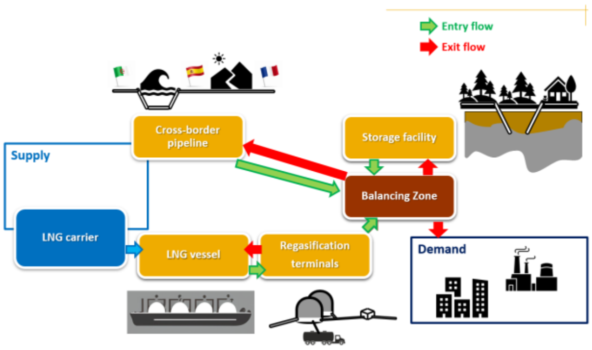

Figure 1. Schematics of the gas system optimization model.

The model features a daily granularity and a multi-year representation. While these characteristics allow for both optimizing short-term operation and mid-term decision-making, the model needs to be deterministic due to the large computational burden associated with such detail in full-scale gas systems.

Under deterministic optimization, perfect foresight leads agents to perfectly anticipate all future shocks, resulting in unrealistic decisions. This is particularly the case with the LNG carrier unloading schedules. Daily patterns tend to overschedule LNG carrier unloading during the first and last days of the month. This unusual behavior does not reflect the actual vessel arrival scheduling and also affects the resulting daily hub prices calculated by the model.

To avoid this problem without resorting to stochastic models, a new methodology is proposed. The approach consists of running the model in two steps. In the first one, we use a monthly granularity to optimize medium-term variables, including the monthly volumes of LNG needed (as well as others such as underground storage). In the second step, a daily execution is run in which a synthetic daily profile of LNG carriers unloading is exogenously computed and introduced into the model. This daily profile is determined based on historical data and is scaled to match the monthly volume computed in the first step.

Results

We have applied this fundamental model to a real-sized system focused on the Iberian gas system to illustrate how the approach significantly improves the model's results. Two case studies were analyzed in detail. In the first case study, the model is allowed to decide the optimal value of daily LNG carrier unloading under certain technical constraints. In the second case study, the two-step methodology is used. As previously mentioned, the first case study results show that the optimal unloading values are concentrated on the first or last days of the month. The second case study shows that the proposed model improves the daily unloading profile and obtains a more realistic and smoothed process behavior.

Conclusions

The proposed methodology has proven to be effective in representing LNG carriers in particular and all other fundamentals that are relevant to the decision-making process in the gas market. This two-stage methodology, which incorporates both fundamental and historical modeling, is sufficiently robust to adequately represent the dynamics of LNG carrier unloading in a manner that is realistic and consistent with a global market that is increasingly subject to structural changes.

References

[1] P. Dueñas Martínez, "Analysis of the operation and contract management in downstream natural gas markets," 2013, Accessed: Mar. 27, 2023. [Online]. Available: https://repositorio.comillas.edu/xmlui/handle/11531/50975