Flexible asset management for the transition to multigas networks

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Introduction

The future gas network will be different from the current operating network. The future gas network will deliver multiple services and the gas in the network will vary in composition, e.g. specific natural gas with hydrogen, and biogas will be transported. The current unidirectional, uni-gas network is undergoing a transition towards a network for sustainable energy sources. As a consequence, the future gas distribution and transport infrastructure will face the challenge of coping with the required increased flexibility of gas production and the increased variability of gas quality. The current infrastructure needs to be able to accommodate this variety of gas qualities and quantities without compromising the current reliability and safety.

Asset management

The imminent transition of the gas sector will not only influence the design of the infrastructures and its components, but also the operations and maintenance of the assets involved. "Asset management" comprises the design, planning, operation, maintenance and disposal of the physical assets in such a way that the asset base supports optimal performance of the organisation. Contemporary asset management for infrastructures has been standardized in e.g. the PAS-55 standard, involving technical as well as organisational issues. Most of the assets that will be used for the future systems are currently already in use (their replacement will take decades) so the transition to multigas systems will require an adaptation of the asset management practices for the current gas infrastructure and a reviewing of the existing asset management strategies. It will no longer be sufficient to maintain the current functionality of the infrastructure, but it will be necessary to actively integrate new demands with respect to flexibility and quality variability of the multi-gas options. New investments in innovative physical equipment and adaptations to existing equipment will be necessary that will allow for flexibility in the infrastructure's future, like for example smart meters, more advanced gas quality measurements, dynamic net control devices, local gas storage options or flexible biogas injection stations.

Risks and Real Options

Current asset management practice by many (Dutch) grid operators is rooted in a risk-based attitude on the existing mono-gas situation. Risks are generally seen as 'downside' risks, i.e. a risk event would negatively influence system performance, like system failures, leaking pipes, failing control mechanisms, but also non-technical risks such as regulatory risk, public image, etc. (Renn and Klinke, 2002). Risk management strategies and tools are often embedded in the asset management processes (Masera et al., 2006; Wijnia, 2005).

However, the future also poses opportunities ('upside risk") i.e. a risk event that could positively influence system performance, like improved tariff structures, increased gas consumption, better than expected technical life time of the assets, etc. Especially when considering future systemic changes to the infrastructure system, such as the mixing in of other gasses, decentralization, and dynamic net management, real options thinking is relevant. It may prevent lock-in into the current infrastructure system, by spotting opportunities and valuing those in a lifespan perspective. Preparing a system consciously for upside risks is known as Real Options Analysis. It has been shown (DeNeufville, 2003; Kulatilaka, 1993) that real option thinking increases the value of the system by making it more flexible and thus better prepared for an uncertain future.

As grid companies have to justify their current investments to the national regulator, their positions with regard to real options have to be understood by the regulator. Otherwise, extra investments that show no immediate or guaranteed pay-off (in terms of financial pay-off or keeping the system within legal constraints) would be considered wasteful by a regulator. The advantage of the real options approach is its transparency and financial underpinning of the required "extra" investment that will ultimately lead to overall lower societal cost, thereby safeguarding at least the public value of overall low cost service provision (affordability). This idea is not yet incorporated into the regulatory framework and it has been shown that some barriers still need to be overcome before a practical implementation of the Real Options Analysis (ROA) approach is achieved even within the sector (Herder et al, 2011; Lander and Pinches, 1998). Such barriers range from lack of (lifespan) data, lack of practical methods to execute the seemingly complex ROA calculations and to organisational and regulatory constraints, such as a strict division in many companies between the investment or project organisation and the operational divisions.

Another important issue that is still under-explored is how to monitor the status of the real options that have been embedded in a system (DeNeufville and Scholtes, 2011). Methods for monitoring a changing environment have been developed for policy making, but those notions have not found their way yet to the engineering community (Dewar et al., 1993; Dewar, 2002; Walker et al., 2001). The need for monitoring the status and value of the infrastructure will expectedly profit from developments regarding high tech gas network monitoring instruments, such as new sensors and inspection techniques. How to integrate the information obtained with these potential methods into the asset management process is, however, still an open issue.

The research challenge

As the quality, and the future development and evolution of the physical infrastructure is to a large extent shaped by asset management, we hypothesize that it must be used to nudge the system towards achieving a sustainable, multigas infrastructure. Therefore, we have started research into how real option thinking can increase the future performance of the system, in terms of its flexibility and sustainability. This research will consist of a further extension of the ROA theory and its implementation with regard to the issues mentioned. It will be based on some real-life case studies undertaken in cooperation with several Dutch DSO's.

MonteCarlo model setup

A first result of the research is the development of a basic ROA-tool. The tool is an implementation of a Monte Carlo simulation which integrates a stochastic demand model with a gas grid design and dimensioning algorithm.

A gas distribution system in the simplest version of the model consists of:

- demands (positive demands of conventional customers and negative demands from biogas suppliers)
- pipeline routes (with or without the actual pipes)
- station locations (from which the distribution grid can be fed, with or without the actual installations)

The model captures the economic/technical issues of the gas distribution network and the business model of the network owner. The assets and demands are categorized into a limited number of definitions. There are separate definitions for the demands, the pipelines and the stations.

In addition to its definition each item has a few additional data:

- a name
- a location (demand and station)
- an optional, fixed commissioning date
- an optional, fixed decommissioning date
- a route (pipeline)
- a length (pipeline)
- an outlet pressure (station)

The estimation of the demand is the stochastic part of the model. Each potential customer (demand) is described by the following parameters:

- initial date (starting date for commissioning probability)

- stochastic time delay for commissioning, described by the rate function of the Weibull distribution: $p_c(t) = k_c/t_c\ (t/t_c)^{kc-1}$
  where:
  - p_c: time-dependent probability-density for delay to commissioning
  - t_c: characteristic time delay to commissioning
  - k_c: parameter , typically ≥ 1, shape factor

- stochastic time delay for decommissioning, described by the rate function of the Weibull distribution: $p_d(t) = k_d/t_d\ (t/t_d)^{kd-1}$
  where:
  - p_d: time-dependent probability-density for delay to decommissioning
  - t_d: characteristic time delay to decommissioning
  - k_d: parameter , typically ≥ 1, shape factor
- a set of zero or more other customers, each which can block the commissioning
- a set of zero or more other customers, all needed to be commissioned before commissioning
- a set of zero or more other customers, whose decommissioning triggers commissioning
- optional fixed commissioning date (when set overrules the stochastic model)
- optional fixed decommissioning date (when set overrules the stochastic model)

Each demand is associated with a demand definition, which prescribes the requested capacity (as function of temperature) and yearly revenue for the network owner. The revenue is income for the grid owner between years of commissioning and decommissioning of the demand, if it succeeds in connecting the customer with pipelines and stations with sufficient capacity.

Each station can be considered as an option to construct a station at a given location at a certain time and maintain it for a certain period, not exceeding its technical lifetime. A station is defined by a station definition, which consists of a capacity, lifetime and construction cost and yearly maintenance cost.
Each pipeline can be considered as an option to construct a pipeline in a given route (length) and maintain it for a certain period, not exceeding its technical lifetime. A pipeline is further defined by a pipeline definition, which consists of a diameter/material, lifetime, capacity and construction cost and yearly maintenance cost (per unit length).

Example
A minimum network consists of a single station, some pipes and some customers. See figure 1. Not visible in the figure are a modelled demand at the position of DistrictA and another district station at the positions of DS_Mainstreet. This additional demand is assumed to be commissioned when the original demand (DistrictA) is decommissioned. The additional station is commissioned when the life time of the original station is exceeded and there is still gas demand (either by DistrictA or by District_Mainstreet).

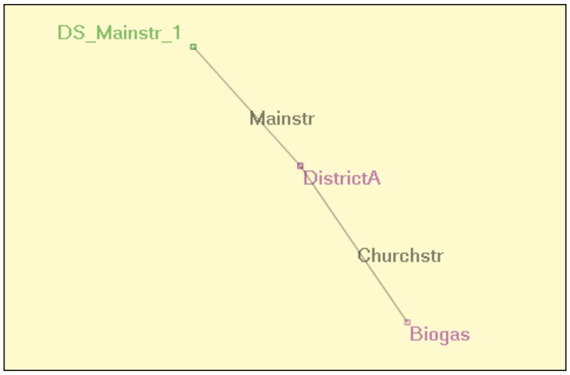


Figure 1 Layout of the minimum network.

As an example, two stochastic realisations (or instantiations) of DistrictA (with t_c=3 yr, k_c=1, t_d=40 yr, k_d=1) are shown in figure 2.

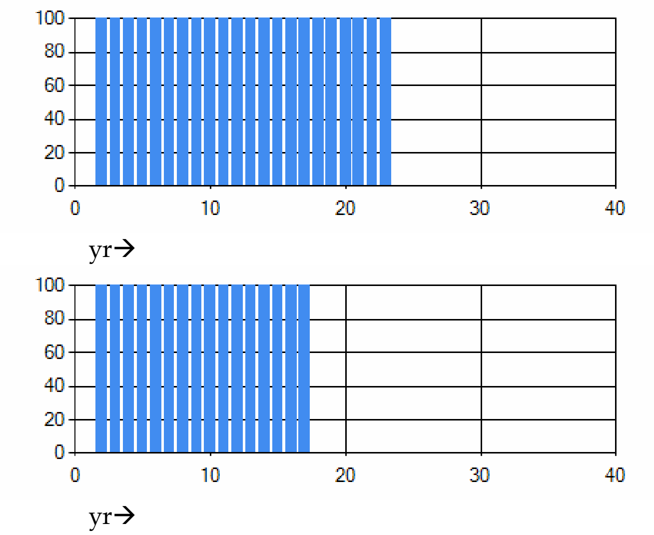


Figure 2 Typical realisations of the demand of DistrictA. Vertical axis: demand in m^3h.

The revenues are calculated as net present value, at the starting time of the simulation, at an interest rate of 5%. The yearly revenue for this type of demand is set at € 11,000 per 100 residential customers. This amounts to total revenue of € 143,181 and €118,195 in the examples.

The Monte Carlo simulation explores multiple realisations. The demand distribution of 10,000 of these realisations is shown in next figure (scaling by 1000).

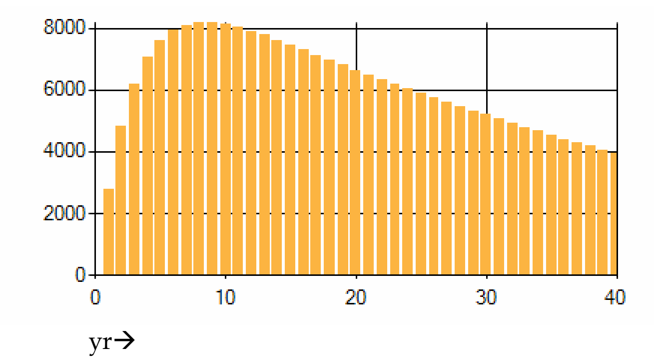


Figure 3 Average demand based on 10,000 realisations. Vertical axis: demand in m^3h, scaled by 100.

A histogram of the revenues, based on 10,000 realisations is shown in figure 4.

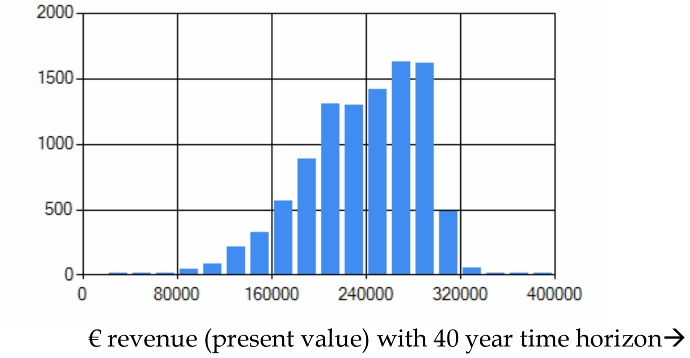
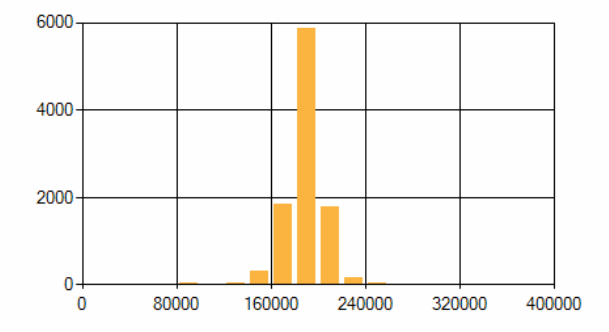


Figure 4 Histogram of revenues based on 10000 realisations.

Of course, the network owner has to invest, in order to provide capacity for the demand. A very inflexible strategy would be the investment in the construction of the station and the two pipelines at the starting date of the simulation. This would result in a fixed cost in the first year (or for some fixed interval if the costs would be financed over a certain period).

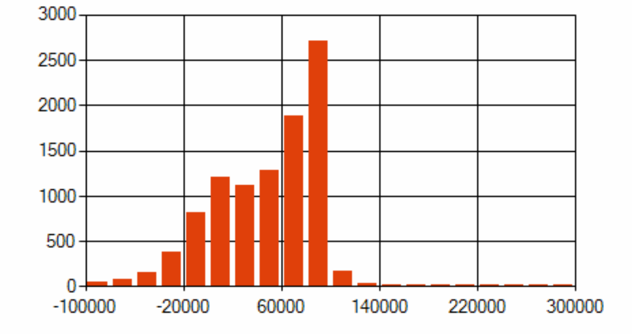
A more flexible strategy would be the construction of the station and the pipeline(s) just in time (as the demand arises). We assume that the capacity of the station and the pipelines are sufficient for both demands. A histogram of the costs of this strategy is shown in the next figure.



€ cost (present value) with 40 year time horizon →

Figure 5 Histogram of total costs in 40 yr, based on 10000 realisations, using a "just in time" strategy.

A histogram of the profits (some negative in this case) of this strategy is shown in the next figure.



€ profit (present value) with 40 year time horizon →

Figure 6 Histogram of total profits in 40 yr, based on 10000 realisations, using a "just in time" strategy.

The average revenue over the 10,000 simulations is € 237,933 and the average cost is € 189,299, which results in an average profit of € 48,634 over the 40 year simulation period as present value.
The losses occur mainly in those scenarios where the demand is relatively quickly decommissioned.

Future work

The work up to now has been of an exploratory character, demonstrating the feasibility of the implementation. Various refinements of the model will be added in the course of the investigation. For instance, the dimensions of the piping should not only be based on the demand as expected at minimum (winter) temperature, but also on the demand during summer time. This is especially relevant when a continuous supply of biogas is present. Also, the system must still be able to deliver the gas at sufficient pressure to the conventional customers in the absence of the biogas supply.

More types of assets and a more flexible use of the assets could be imagined and build into the simulation. Under circumstances, active control of the outlet pressure of the regulating stations could be an economical alternative for replacing or adding pipelines by pipelines with other diameters. Gas buffering in summer time could be an alternative for the shutdown of bio gas production.

Finally, more sophisticated strategies should be formulated and tested. The “just in time” strategy should be tested against conditional look ahead strategies. That is to say,. the dimensioning of the grid should not be based on the required capacity of the next year, but based on the expectations for the next decades, taken into account the realisation of the demands at a given point in time.

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