

Shippers and Network Capacity Booking in the Dutch Gas Market

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Abstract. *The main objectives of the Third Gas Directive (2009/73EC) approved by the European Union are: unbundling, creating an independent Transport Service Operator (TSO) and ensuring free access to the market. The separation of gas trading from transportation activities required new market rules and gas balancing. Thereby, the TSO's responsibilities are to maintain network pressures within acceptable bounds and to assure residual balancing whereas shippers must ensure adequate gas supplies.*

Each party involved in natural gas transport can contribute to maintaining the network in balance. If the pressure in the network grid fluctuates beyond certain bounds, each party is responsible for injecting/extracting gas into/out of the network to restore the pressure and keep the balance. The shippers' role is to balance the system if necessary and to ensure enough capacity booked for the natural gas transport. The booking capacity and the uncertainty in gas demand/supply due to alternative fuels, make it difficult for the shippers to deal with capacity booking management.

An agent-based model (ABM) is developed for understanding the mechanisms of booking the network such that the system is in balance yet capacity is available to ensure a safe and reliable operation of the grid. It simulates and different booking strategies of shippers. ABM create a flexible environment for experimentation by transposing actors (from the real life) into agents (in the model). They present a promising modelling approach for socio-technical systems to support decision makers.

The natural gas supply and demand is simulated; transactions between the parties are being done as well as the call of BPL, if needed. The simulations are used to investigate (new behavioral) strategies of the shippers regarding the network capacity booking. The paper presents the simulation results and reflects on the different strategies and their associated social costs.

Keywords. *Agent based models, simulation, gas market, balancing regime.*

1. Introduction into the Dutch gas market

The Dutch natural gas market is part of the European energy market. In the year 2000, the liberalization of the natural gas market has begun. The first steps in liberalizing the gas market were done by the European Union (EU) by proposing and adopting the three energy packages in 1996, 2003 and 2009. The third EU energy package – Third Gas Directive (Directive, 2009) was proposed in September 2007 and adopted by the European Parliament in September 2009. The goals of the third gas directive are: to

increase competition and efficiency, to ensure security of supply and to ensure the freedom of choice of consumers yet at a fair price.

In order to reach these goals the European Commission (EC) proposes a set of actions for the EU countries: to separate production and supply from transmission networks, to create an Independent Transport Service Operator (TSO) to ensure free access to the market to facilitate cross-border trade in energy, to have more effective national regulators, to promote cross-border collaboration and investment, to ensure greater market transparency on network operation and supply, to increase solidarity among the EU countries.

In 2005 Gasunie has split into N.V. Nederlandse Gasunie¹ – the *owner* of the national distribution grid, and Gas Transport Services (GTS)² – the *operator* of the grid. GTS which is also the Dutch Transport Service Operator (TSO) is a fully owned subsidiary of Gasunie. GasTerra³ is the company in the Netherlands with contractual rights on almost all assets. It is dominant on very short flexibility and has the rights on Groningen field – a very flexible supplier. It buys from small fields in order to stimulate production, buys from import and sells directly to industrial consumers but also on the TTF (Title Transfer Facility)⁴. Nevertheless, according to the Dutch Gas Act, GasTerra is obliged to offer at reasonable price flexibility to TSO and to resellers (Gas Act, 2004). Table 1 presents an overview of the Dutch natural gas market from upstream to downstream with market players involved and their scopes and activities.

Table 1. The Dutch Gas Market Overview

Value chain	MARKET PLAYERS					SCOPE AND ACTIVITY
Production/Imports	EBN - the Dutch state	StatoilHydro	ExxonMobil	Shell	Others	Gas production and import
Transport	Gasunie - grid owner/ GTS - grid operator					Gas transporting and storage. App 400 large consumers to GTS
Trading/ Wholesale	Sales to Dutch market		Export			Whole sale and export - dominated by GasTerra
	GasTerra	Others	GasTerra	Others		
Distribution	Liander	Enexis		Stedin	Others	Distribution to final users
Retail	Nuon	Essent		Eneco	Others	Retail to regional grid customers
	Residential and other (22%)	Gas to power (20-40%)		Industry & commercial (40-60%)		
Legend:						
Regulated	Deregulated					

2. The new balancing regime and the shippers' capacity booking activity

2.1. Goals of the new balancing regime

In 2009 the collective grid operators sent a proposal to the Netherlands Competition Authority⁵ (NMa) which contains the changes codes of the market operation and the

¹ <http://www.gasunie.nl/en/gu/over-gasunie>

² <http://www.gastransportservices.nl/en/corporate/mission>

³ <http://www.gasterra.com/Pages/default.aspx>

⁴ <http://www.apxendex.com/index.php?id=202>

⁵ <http://www.nma.nl/en/default.aspx>

balancing proposal. The main goals of this new balancing regime are to increase the liquidity of the TTF, to ease the access to the Dutch gas market for new entrants, to integrate better the Dutch gas market into the Northwestern European one, and last but not least to ensure an affordable and reliable gas supply.

2.2. The new balancing regime and shippers' capacity booking activity

The new balancing regime of the natural gas market in the Netherlands has inured starting the 1st of April 2011. The main changes brought by this new regime are: introduction of a virtual transaction point (VPPV), program responsibility as separate service, System Balance Position (SBS), Individual Portfolio Imbalance (POS) and the Bid Price Ladder (BPL).

The design of this new regime relies on a market driven balancing mechanism. All the participants in balancing the gas system are called "program responsible parties" (PRP). Under the Dutch Gas Act, all parties that are connected to the gas transmission network have program responsibility. These PRP's are not individual consumers but utility companies.

Trading in the Dutch gas market is done on the TTF. This is a virtual trading point in the GTS system where volumes of natural gas can change ownership. It means that even though the gas physically exists in the network, it can change its ownership from one PRP to another, together with the consequences for the balancing the system. Besides TTF now exists the VPPV, which as described by the Dutch Gas Act, aims to facilitate the transfer of program responsibility. The VPPV represents a combination of the trades on the TTF plus the transfer of a PRP's own entry program to its own exit program. In other words, VPPV represents the network point for the submission of the entry/exit programs for the next day (Balancing procedure, 2011; Shippers, 2011).

PRP's are responsible for balancing any difference between their day-ahead program and the actual volume transferred on the intraday program. GTS now provides the shippers with two real time information signals: the SBS and POS. The latter represents the own imbalance of a shipper whereas the former represents the sum of all POS's. Using these two signals, each shipper can contribute to balancing the system.

Even when all shippers are in balance, the transmission system can experience a physical imbalance. TSO monitors the system constantly and establishes and publishes an interval (denoted as dark green zone) where the system is in balance. Only when the aggregate position of all shippers pushes the system outside the green zone, the system is out of balance. Thus, an imbalance in a particular shippers' portfolio does not necessarily trigger an imbalance in the whole system.

When the system goes outside the green zone, GTS calls the BPL mechanism to buy or sell gas. Gas that is bought or sold using this mechanism is allocated to the corresponding responsible parties in proportion to their individual imbalance. A

responsible party whose imbalance is the opposite of the total system imbalance is called *helper*, and consequently the imbalance in the same direction creates a *causer*.

Since shippers are responsible for maintaining the network in balance they have to make sure not only they have the commodity to be delivered but also enough capacity booked ex-ante. Each shipper signs with the TSO a contract for a certain amount of capacity that they will use further. However, different fluctuations of gas demand in the market make it difficult for the shippers to predict their capacity usage. It may be the case that not all booked capacity will be used at a certain point in time, or that more capacity is needed. This is extra capacity needed or not is called *flexibility*.

One may argue that why not all shippers book more capacity than they forecast and if not needed then not used. The opposite example would be to book less than forecasted, and if needed more just simply buy more capacity from TSO. In either way the liquid assets part plays an important role; high surcharges are required. Moreover, the entire network capacity is limited and thus it must be used wisely.

3. Modeling the shippers' behavior

3.1. Modeling approach

The new balancing regime has come with changes to the existing system. It is now based on penalties and incentives for the shippers and it stimulates shippers to participate in the market. Balancing the network becomes now a common task for the shippers. In the same time they now experiment (using the input in the model) with different over/under booking settings.

The emergent behavior of such a complex system is not obvious, and the properties are hard to deduce. The behavior of the whole system is different than the individual behavior of its components.

Complex Adaptive Systems (CAS) are systems evolving over time, composed by agents which react with each other according to what others agents do (Dooley, 1996). Agents are semi-autonomous entities that seek to maximize their objectives by evolving over time. Examples of such complex systems are economies, weather, traffic, social organizations, and most of the infrastructure systems that are composed of heterogeneous actors. One way to understand such complex systems is represented by the use of Agent Based Modeling (ABM).

In ABM, a complex system is decomposed into agents whose actions aim to simulate the behavior of the real life actors. The aggregate behavior as a result of interaction of the individual behaviors allows analyzing the system as a whole. (Nikolic, 2009) Creating an ABM of the old and new balancing regime aims to provide insight into the complexity and changes of this new system.

3.2. Goals of the model

The model aims to explore the different capacity booking scenarios that shippers can take. The model replicates the operation of the gas market in the new balancing regime; also the effects of the individual shippers' decisions on the operation of the system as a whole. Two sets of scenarios are chosen, one in which the imbalance in the system is constant and shippers' strategies are changed, and the second one in which the same strategies are applied but in a varying imbalance. Furthermore, the model will be extended and reused in future gas market related research.

3.3. Design of the model

The model simulates the operation of the gas market composed out of several types of agents: shippers, consumers, suppliers and TSO. The system is in balance as long as the aggregated system position is between the predefined and published bounds. Outside the bounds, whether long (pressure too high) or short (pressure too low) the system is out of balance. Only in case this happens, the TSO takes action. By taking action, TSO buys or sells gas according to the system's state.

The PRP's responsible with balancing are the shippers. They have to make sure their own portfolio and the total aggregate system position is in balance. It is considered that 100% is the reference point in capacity booking, and it means that the network is neither under nor over booked. Naturally 110% (or 1.1) means 10% over booking, 95% (or 0.95) signifies 5 percent under booking and so on. Shippers have a starting point in their booking strategy chosen by the user, as input (e.g. shipper "X" starts with a 10% extra capacity booked). Next, depending on their liquid assets and following mechanical rules, they adjust this variable with a certain percent. Several scenarios of this type are explored in order to understand the behavior of shippers in such a complex system. Depending on their portfolio size, there are three types of shippers in the model, small, medium and large. A small shipper has access to less suppliers, can sign a small amount of contracts, whereas a large shipper

In case the system goes out of balance the TSO calls the BPL. The bid ladder is constructed by using the volumes with their corresponding prices submitted by the PRP's, but not used in the spot market. At this stage only bids that can physically be delivered are accepted. To construct the BPL, the accepted bids are sorted based on the merit order, so that those with the lowest marginal costs are the first ones to be bought. The price of the last bid that satisfies the demand is the price used for the transactions on the BPL.

3.4. Agents

Agent Based Models methodology usually consists in decomposing the complex system into autonomous agents which interact with each other. The agents are represented using formalized concepts and definitions. This formalization is represented by the *ontology* of agents and technologies used. The use of ontologies

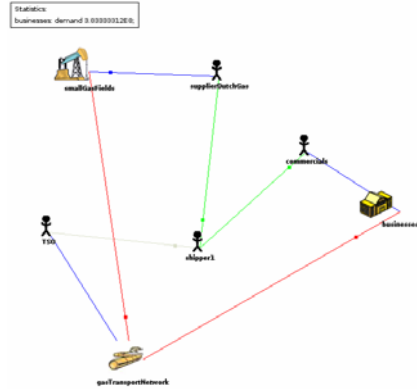


Fig. 1. Graphical Interpretation

The white background boxes in the above figure represent ontology *classes* that are *types of objects*. The grey background ones represent *objects* or *agents* of a certain type. Arrows in between them signify the relations in between them. In an ontology everything is a node. Every social node has a physical node attached; every agent has a technology attached. The social nodes are represented by the agents and consequently the physical nodes by technologies.

Agents in the model represent the decision makers in the real world: suppliers, consumers, shippers, TSO. Technologies in the ontology are used to describe the physical connections and reflect the physical constraints. Each agent owns, manage and operate a technology. For instance, the TSO (agent) has a technology assigned – the distribution grid which has certain physical characteristics that cannot be changed in any way. For convenience, agents that have similar behavior and/or roles are subtypes of an upper class agent.

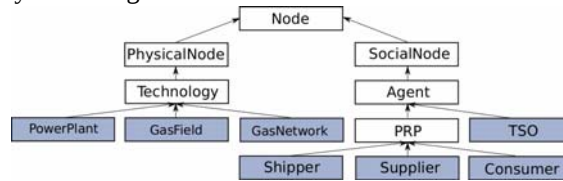


Fig. 2. Model Ontology

That is, a PRP, a consumer and a supplier are all a subclass of a GasAgent, but individually they have different roles. For explanatory purposes only, Figure 2 represents the simplified graphical interpretation of agents and their technologies assigned; the full one contains all the agents and technologies. It shows one type of each agent: one supplier, one consumer, one shipper and the TSO, and their technologies assigned. The red line represents the physical flow, the green one commodity contracts, blue line the ownership relation and finally, the gray one represents the transport contracts. Naturally in the model all agents are interacting, not just the ones showed in the above picture.

for conceptualizing domain knowledge has been a standard practice in information science (Fishwick, 2004).

In ABM, ontology provides a shared vocabulary that can be used to model a socio-technical system: the type of objects and concepts that exist, and their properties and relations (van Dam, 2009). As we built the model of the (new) balancing regime, we created the ontology used later on, as a simplified conceptualization of the real system (see Fig. 1).

3.5. Workflow of the model

The model is composed of the following agents: demand (commercial, electricity producers, export, households and industry), supply (Groningen field, small off-shore fields, import, LNG and storage), the TSO and the shippers. As mentioned above, each of these agents owns a technology.

First, the shippers book the capacity network utilization followed by the demand agents which send their request for natural gas to the shippers. Based on the quantities requested, the shippers purchase the amounts needed. The resulted gas quantity flows through the network from suppliers to consumers. Imbalance in the system is defined as the difference between the quantity of gas that leaves the network at exit points and the gas that enters the network at entry points.

Depending on the total system imbalance and whether the system is out of balance or not, the TSO calls the BPL accordingly. Shippers then send their bids with the balancing quantities and check the availability of the capacity. Helpers are rewarded whereas causers are penalized according to the BPL mechanism and the settlement price. In the last step the liquid assets of the agents is computed considering the penalties and rewards occurred. The agents sign two types of contracts: commodity and transport. Consumers and suppliers sign commodity contracts, whereas shippers sign commodity and transport contracts. It is worth mentioning that at this stage of the model the agents do not learn from their mistakes, they act mechanical.

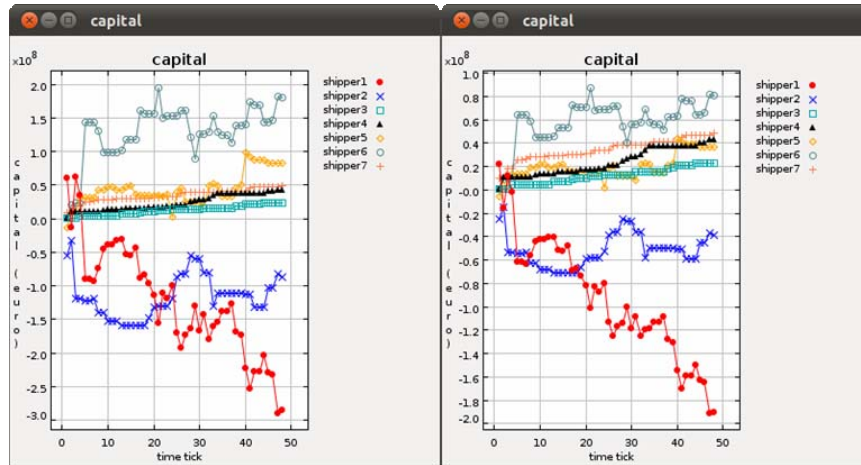


Fig. 3. Scenario 2 (left) and Scenario 5 (right)

4. Model results and insights

In this section we discuss the two types of scenarios that have been explored. As stated above, there are three types of shippers: large, medium and small. Shippers 1 and 2 have large portfolios, 3 and 4 are medium, 5, 6 and 7 are small size.

In the first set of experiments – Scenarios 2 and 5 (see Figure 3) shippers have adopted the same strategy all over the simulation. The varying parameter in this case is the imbalance in the system, and in Scenario 2 the imbalance is higher than in Scenario 5. For the same type of strategy we notice that the revenue of the shippers in both cases is rather similar. Furthermore, regardless the size and direction (can be plus – which means system long, pressure too high, or short – too low) of the imbalance, not changing the strategy would trigger the same behavior. These simulations show that on the long run the imbalance in the system does not influence significantly the capital of shippers.

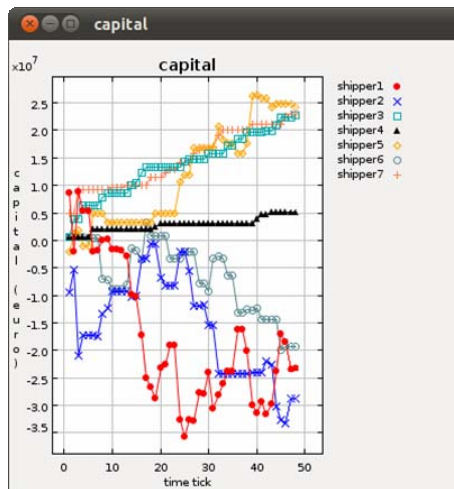


Fig. 4. Scenario 3

In the next set of experiments that we have performed we define two types of strategies that shippers can take. The rules in the first type such that if a shipper loses capital, then it will revert its capacity booking behaviour. This means that for example if its booking was 10% extra, it will diminish this extra booking with 5% and it will thus have only 5% extra capacity booked. If the shipper is neither losing nor winning, it will maintain its current booking capacity. Finally, if it wins, it will also maintain its booking capacity. This is the case in Scenario 3 (see figure 4). This kind of strategy is beneficial for the medium size shippers and in some cases for the small size.

The second type of strategy that we have defined has the following rules: if the shipper is losing capital, then it will lower the amount of booking capacity, similar as in the first type. Should it maintain its capital, which is neither lose nor win, then it will increase with the capacity booking with 5% in Scenario 1 and with 3% in Scenario 4 (see Figure 5). In case the shipper wins, it will again increase its capacity booking. By choosing this type of strategy the simulations show that shippers have a more dynamic behaviour on the market. Moreover, there is no shipper which majorizes over the others and also the behaviour of one influences the others. This second type of strategy will be further investigated with a varying imbalance in the system.

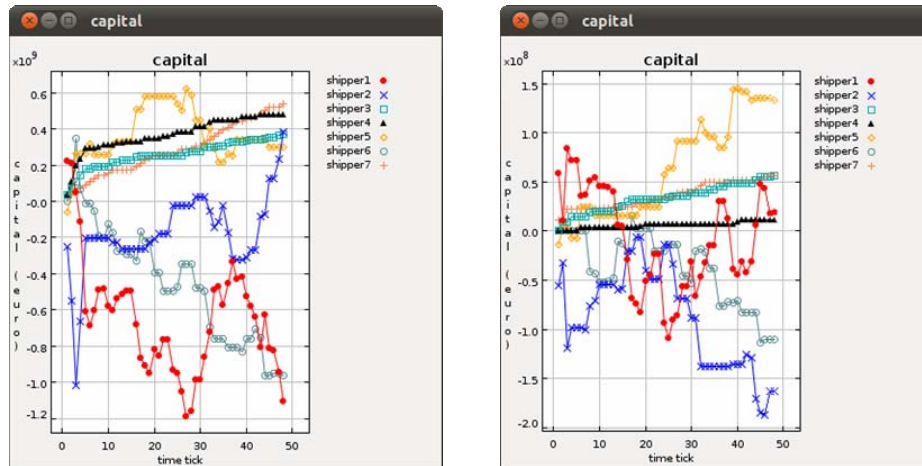


Fig. 5. Scenario 1 (left) and Scenario 4 (right)

5. Conclusions

As is the case with most agent-based models of complex systems, the process of building the model helps to conceptualize the system and to understand it. The aim of this paper is not to optimize any shippers' strategy but rather experiment with different ones and understand the functioning of the system.

The model has a set of assumptions and is not yet in the final state. In the future the model will be extended by adding storage facilities.

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This paper is a part of a broader research commitment having the goal to understand and simulate the interactions of the gas market with other markets, infrastructures and industries. In the future, the model presented in this paper will be combined with the existing electricity market models to explore the inter-market relationships and complexities.

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