THE CASE THE NATURAL GAS SUPPLY CHAIN: AID FOR EDUCATIONAL REFLECTION

Giuliano BASSO

Abstract

The established EU-wide regulatory regime, with the scope to intensify competition in all segments of the gas value chain and to ensure the Third Party Access to networks, is considered by gas network operators to constitute a challenge to ensure the usual quality and reliability of gas supply services. In the medium and long run this may hamper necessary investments into new gas infrastructures required for maintaining a satisfactory level of security of supply in the growing EU gas market and with increasing dependence on gas imports. Thus, a prudent regulatory regime faces both: market efficiency and Security Of Supply.

As contribution, the present paper will describe how the new rules of the European Energy market are changing the structure of decision-making, with particular reference to the management of plans to mitigate the consequences of major disruptions which could happen as consequences of coordinated malicious attacks to Energy Critical Infrastructures. The effective and efficient mitigation of major disruptions produces benefits reducing the risk of shortage of Energy in the Citizens and Economic systems but, doing this, reduces also the interest to perpetrate malicious attacks.

Specifically, the paper examines the consequence of the: 1) fragmentation of players ; 2) lack of accountability principally with regards to Security of Supply; 3) the plurality of operators along the gas logistic chain ; and 4) the need for enhancing 'consistent cooperation' between the concerned players.

The paper invites the community of stakeholders to identify structures, tools and actions necessary to prevent these risks. It draws attention to improving interoperability[1] between the players enabling 'consistent cooperation' based on: a) a clear accountability of each player; b) a more harmonized and timely updated information exchange; and c) decision making processes based on consistent sets [2] of models simulating the complex interactions along the gas supply chains[3].

Key words

Gas supply, gas network, disruptions, risks, fragmentation, security, gas market, interoperability.

The Trans-European Gas Network (TEN Gas)

The Trans-European Gas Network (TEN Gas) in its present state has evolved over the past four decades out of isolated sub-systems of natural gas supply existing in most of the EU25 Member States. Each sub-system was gradually built up at its own pace commensurate with the growing share of natural gas in the national primary energy mix. Each national sub-system represented a fully integrated gas value chain and had a remarkable degree of stability in terms of security of supply as it was controlled by one or few entities that were committed to strict public services obligations in their respective Member States. Those entities were solely responsible for decisions about gas supply contracts and investments in gas transportation and storage to ensure system capacity, reliability and adequacy of gas supplies.

In the absence of market competition gas prices were usually administered in response to the existing cost functions of suppliers. While serving a steadily growing and relatively price-inelastic gas demand, suppliers only had to observe the supply-side economics of their investments into gas infrastructures which they considered necessary for a reliable gas supply. Temporary losses due to over-capacities and redundancies in the provision of gas infrastructures or to operational inefficiencies in certain segments of the gas value chain could easily be recovered by extra profits in other segments by means of monopolistic price adjustments. This practice resulted in relatively high levels of national gas prices per unit of energy in almost all EU Member States as compared to alternative sources of energy (e.g. crude oil) or in comparison to other industrialized countries of the world with liberalized gas markets like the US. In the process of globalization of world commodity markets, persistently high gas prices began hampering the dynamics and international competitiveness of non-energy sectors in the EU. Gas to power plans lagged behind and private households remained reluctant to change to environmentally friendly gas consumption.

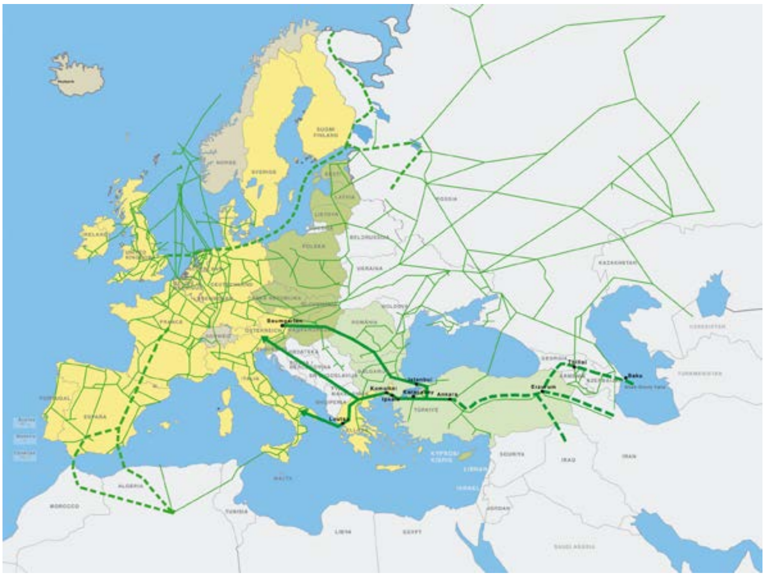

Fig. 1
Europe's natural gas pipeline network

The 1st EU Internal Gas Market (IGM) Directive 98/30/EC [3] and 55/2003 [2] opened up national gas markets to external competition. It enabled cross-border gas trade by stipulating non-discriminatory Third Party Access (TPA) to the grid at transparent tariffs where transparency means unbundling of the gas price into its commodity and service components.

The twin directives DIRECTIVE 2004/67/EC [1] concerning measures to safeguard security of natural gas supply and the analogue addressing the electricity have the scope to ensure the security of Energy Supply in competitive market characterized by unbundling of services.

Clearly, the main goal of liberalisation policy is to bring down average gas prices by inducing higher cost efficiency in provision of natural gas and operation of gas infrastructures, but the concern of the Regulatory Bodies is also to keep the good records of Security of Supply historically achieved by the Operators.

The means of choice was to expose each segment of the gas value chain to international competition without prejudice to the Security of Supply. This is enacted by re-structuring of existing EU gas industries and also by allowing new players appearing on the EU gas market scene. As a preliminary result of liberalisation previously autonomous national networks are now interacting as interdependent sub-systems on an increasing scale in the single EU gas market. As TEN Gas is gaining its own momentum, it **will reshape all segments of the** gas value chain in each EU Member State by creating interdependencies and new options for gas supply and gas demand.

Market Conditions

Normally market integration and competition will enhance cost efficiency in every segment of a commodity's value chain. In the case of TEN Gas this will only be a benefit if the evolving single EU gas market is operating in a stable mode, i.e. if the price mechanism can perfectly balance supply and demand at each point and at each time without too much volatility. All energies bound to networks, like natural gas, represent a sort of natural monopoly of the entity controlling the network. This is the reason for third party access and for creating unbundled operators such SHIPPERS are.

Given the previous imperfect market conditions while sufficiently liquid gas spot markets have not yet evolved, in the transition period there exists a considerable risk of shortcomings in coordination between disaggregated gas market players in building up, operation and maintenance of adequately integrated gas infrastructures on a Trans-European scale. Temporary under-supply and price hikes might lead to crowding out and even important modification of gas demand which would affect afterwards the gas offer which in turn might have severe negative impacts on production and employment in non-energy sectors of the economy.

Social Benefit

It is the concern of the EU Commission that similar situations may occur in the liberalized EU gas market given the steady growth in EU gas consumption and increasing gas import.

From a welfare and economics point of view cost efficiency and grid stability can be contemplated as two public goods which should be allocated in such a manner that the resulting social benefit is maximized**. Basically this is an optimization task** of socio-economic planning. The matter has been investigated and the suggested solutions have been described in the parent paper: "EU Gas Market Liberalization and Security of Supply – an Antagonism?" by M. Klei [4].

The paper suggests that the cost of security of gas supply can be at least compensated by reductions in the service price for gas as a consequence of more cost efficiency in the provision and operation of gas infrastructures. Further the paper advocates an active Security of Gas Supply (SoGS) policy. While observing the principles of subsidiarity this SoGS policy should enable individual gas market actors, regulators in EU Member States and the EU Commission to control the trade-off between costs related to market efficiency and stability in a way that finally results in increasing net gains in social benefits for all EU gas consumers. **The paper finally recommends that a pro-active risk management system has to be adopted,** to be an effective instrument for smooth conversion of gains in cost efficiency as induced by competition into necessary investments for gas infrastructures in order **to safeguard a socio-economically acceptable level of security of gas supply** in the future.

This present paper progresses with the analysis of the impact of the ‘fragmentation’ of the industry in Europe on the Security of Supply and on the efficiency in exploiting the present gas infrastructures. This is because the increased number of players theoretically would affect the efficacy, efficiency and time of response of the decision making process which manages the European Gas supply chain.

Security of Supply

Security of Supply aims at maintaining and improving the current supply position of the final gas consumers while reducing the risks of gas price volatility in liberalized markets and increasing ‘dependability‘ of gas supply from far distant sources outside the EU. The degree of dependability is a consequence of the reliability of the gas infrastructures and of the availability of enough resource [redundancy] to face any possible unforeseen event that would jeopardize the supply to the final customer, such as a major disruption as a consequence of a malicious coordinated attach to Energy Critical Infrastructures.

The resources addressed are both the quantity of natural gas produced at the sources and the transport – distribution infrastructures [pipeline network, LNG] and, finally, the storage facilities to compensate for shortcomings of upstream gas.

The degree of redundancy of the resources is a result of an economic trade-off between the cost of resources set aside, and used only in exceptional situations, and the cost of the consequences of those exceptional situations that cannot be mitigated.

In this trade-off, managerial capability plays a substantial role in maximizing the optimal use of the available resource to mitigate the consequences of emergency situations.

The managerial tasks are based on planning and, afterwards, steering operations. Managing exceptional situations requires a specific capability to identify the best way to mitigate the consequences in the time span given [survival time] and to change the previously established plans until the abnormal situation is in place and produces its effects.

Decision making is the core of the management process. The degree of efficacy of the ‘decision making’ process depends – principally - on the accuracy of the data gathered and on the consistency of the model used to the reality of the business. The efficiency depends on the level of error induced during the decision making and by the time span spent to make the final decision. The more accurate and timely updated are the data and the less is the time necessary to make the final decision, the more the use of the managed resources tends to be efficient.

The above justifies the conclusion that the degree of efficiency decreases by the number of transactions between the players involved. Each transaction, in fact, generates a delay in time and an error. **When the decision making process is based on bilateral agreement and bilateral exchange of information, the number of transactions tends to be a ‘factorial’ function of the number of players**.

A way always used to reduce the delay and the error, is to simplify the decision making process. To simplify the decision making process each actor tends to: 1) reserve some ‘safety factors’; 2) define thresholds to guide the interoperability with the interrelated players and, finally, 3) to make stable the horizon securing ‘long term contracts’.

The method presently used, generates a simplified framework for the decision making, but, because it introduces the: 1) safety factors’; 2) the thresholds; and 3) the stability of contracts, they also introduce some degree of inefficiency compared with the maximum technical level.

The new rules of the internal market increased the number of players being part of the decision making chain. Doing so, they contributed to **enhancing the degree of risk** as a consequence of the **'domino effect'** between each player and the upstream and downstream interconnected players.

But at the same time those rules: a) enabled a better integration of the gas market; and b) increased the capabilities of the players to exchange flexibilities of the systems [gas line pack, stored quantities, interruptible capacities, etc].

If properly implemented, these new features facilitate the mitigation of abnormal situations, as are the major disruptions.

The 'unbundling' multiplied the number of players and redefined the role of the players in the market.

In the European gas chain more than 65% of the gas crosses more than one border. **The above implies a second factor of multiplication of players:** the number of infrastructure operators involved to transport gas from sources to the European consumers.

The freedom of the final customer to change the supplier and also switch type of energy [i.e.: oil, carbon, renewable, nuclear etc.], generates instability to the plans of the natural gas traders – shippers – system operators and authorities.

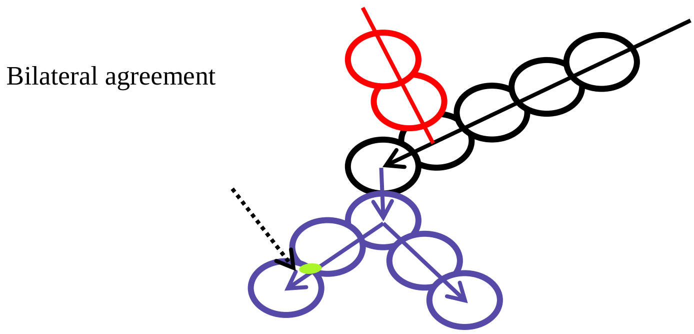

Fig. 2
Domino Effect

This instability reflects on the capability to: a) identify the necessary plans for additional investments; b) identify the level of necessary redundancy of the resources; and c) to make these plans as stable as the long term investments require.

In addition, the switching of customers from one trader to another or from one primary energy source to another, involves traders and shippers with different time horizons.

On the top of that, as a general rule, we should also **expect that the competition established between players tends to push the management towards the maximization of efficiency. A step of this process is the reduction of 'operational margins'.** It has to be said at this point that the commitment to increase efficiency has different motivation and weight depending on the actor considered. In fact the 'regulated' business – as the transport of gas is normally classified – is less sensitive to variation of volumes, where the traders and shippers are much more sensitive to the variations of volumes and prices.

Summing up, we can say that the global level of dependability of natural gas supply is an increasing function of the redundancy of resources and of the efficiency in using the overall resources. We can also say that efficiency is a decreasing function of the: number of players, number of safety factors', degree of each 'safety factor', and, finally, of the time necessary for each player to take their best decisions. The **above described causes**: a) the freedom of choice of the customer to choose the supplier and primary energy, and b) the aim at increasing efficiency, by reducing 'redundancy'[4], **induce as a consequence**: 1) a restriction of the horizon for reliable forecast of the traders – shippers; 2) asynchronous cycles of decision making to mitigate the consequences; and 3) a lack of clear signals for new investments necessary to cope with the evolution of demand and with the expected degree of Security of Supply.

So, the **positive strategy is to maintain competition but at the same time it is to be proactive in mitigating** the impact of this competitive behaviour on the dependability of natural gas supply.

In order to balance the increasing risk resulting from the above described drawbacks, the players have the following main avenues:

- Counterbalancing the consequences of risk by increasing the 'operational margins'. This implies the adoption of higher degree of redundancy of resources but also increases the cost of gas delivered.
- Preventing and reducing the risk by managing business cycle more efficiently, including the transfer of the risk to financial – assurance institutions capable of covering their business against the fluctuations and abnormal events, when necessary.

In reality, it is likely that they will adopt a mix of them depending on the trade-off between the costs [5] and on the impact on the final price of the gas delivered. Out of the three, the **'prevention'** is expected to **be the far more important approach**. This is a consequence of: the characteristics of the business; the relevance of the gas market on the overall economy; and of the best practice.

From this point on, **the focus** of the present paper is **on actions envisaged as necessary to prevent the risk resulting from the impact of the fragmentation of players** on the decision making processes acting in the gas supply chain.

The general actions suggested are:

- clearly identify role relationships, including the accountabilities and authorities of each party in relation to meeting the required security standards for transportation systems and gas supply and with specific commitment to coordinate the necessary investments to ensure the proper level of redundancy,
- enable 'consistent cooperation' between the players,
- facilitate and make as efficient as possible the exchange of necessary, timely updated data and information between the players.

In the present situation, the transition from the previous configuration of the gas market to the new one has different degrees of implementation amongst the different regions of the European Market. In this scenario, if an attempt is made to specify roles on the basis of best practice, then the process could require several cycles before reaching a stable and exhaustive configuration.

The competitive approach, in fact, requires that each player is free to identify and choose the appropriate methods and tools to deliver the services for which he is accountable.

The above seems to explain the reluctance of the majority of the Operators presently operating in the European gas market to establish a coordination unit at Regional, or at European level for daily operations.

On the other hand, the currently established competition will boost efficiency in exploiting the presently available resources. The increase of efficiency will, likely, reduce redundancy of resources. As a consequence, if the behaviours of the different players are not guided and constrained, these behaviours will reduce the reliability of gas supply.

The reduction of redundancy, when happens, increases the frequency of 'abnormal conditions' and of the number of emergencies which requires coordinated actions between more than two operators. It is likely that this will increase more and more the need for coordination in operations between a larger numbers of players involved.

To facilitate and enable the transition from the present interoperability based on bilateral agreements to a more integrated behavior, it is suggested that the **interoperability** between the players **should be based on a 'consistent cooperative approach'.** In the opinion of the authors, **this mentioned vision appears to be in line** with the present needs of the players in **EU gas market**, the large majority of whom are not yet looking for an overall coordination**. This vision also accommodates the need for the players to continuously adapt their behaviour in order to maintain and exploit the market opportunities.**

Consistent cooperation

Consistent cooperation is the cooperation between the players to make the overall gas supply efficient and dependable. This cooperation is based on the consistent vision of the status and of the evolution of plans and operations.

The 'consistency' of the vision is an increasing function of the degree of: a) definition of the role of each player; b) their accountability against the common objectives of efficiently supplying natural gas; c) harmonisation of rules and procedures; and of d) trustable and as accurate as necessary representation of the real facts.

This 'consistent vision' is a consequence of the adoption of a set of **consistent** [6] **models** and of the related necessary data and information timely updated.

In order to enable this envisaged 'consistent cooperation', it is necessary to make available to the community of the players this consistent set of models and the related timely updated bases of data and information.

In view of the fragmentation of the players, their geographical location and the time constraints in decision making – both for operations and emergency response - the way the authors see the implementation of such enabling informatics infrastructures is not via a centralized structure coordinating the processes in detail, but via applications based on a **distributed architecture**.

The core of the architecture is based on: 1) 'harmonized' processes of collecting data; 2) agents capable of selecting the events and alerting the decision makers; and 3) on tools to evaluate the efficiency of the decisions made by each player.

The first step is to enable the decision making with a set of consistent models that could enable and facilitate the interoperability and could also **govern the 'domino effect'**. The focus of this first step is on modeling the physical behavior of the natural gas infrastructures[7] and their interdipendence, because those components of the gas system play the essential role in connecting sources with consumption and they are the arena where the competitors implement their decisions.

Together with the identification of this set of consistent model, the data bases of related data and information are designed to run the: forecast; what-if analysis; and finally to evaluate the efficiency of the decisions taken.

Because we said that there is a multiplicity of players, each player has his own level of 'decision making'. Each level of decision making has different targets in terms of accuracy and time horizon. For instance the decision making related to the weekly planning has a different need of accuracy compared with the real-time set point of the compressors to optimize the transport operations. This means that the accuracy of the topology of the infrastructures modelled, and of the data necessary to describe the boundary conditions, is different for the different models, depending on what set of decision making processes each of them is supporting.

The different degree of accuracy requires a different degree of simplification of the model, where by 'simplification' we address the index of the physical components and parameters considered in the model against the number of the component considered in the most accurate model. The 'residual complexity' is the result of the reduction of complexity, after the application of the 'simplification' process. The work carried out in the GAGSGRID has demonstrated that the relation between residual complexity[8] and degree accuracy[9] follows the 'Pareto' law [80% - 20%]. In fact it has been proven that in a specific analysed gas pipeline network an 'accepted error in pressure at the nodes of 5%' reduces the complexity of the model of 90% [only 10% of the component of the most accurate model are to be considered].

At the end, in order to boost efficiency and stability of the decision making processes, it must possible to build the class of models addressing the same set of infrastructures having a complexity depending on the accuracy required by each player or role, but each consistent with the others.

As one of the results of e_GASGRID, the research delivered a method and a set of tools [10] to generate in an 'objective[11] way' such a consistent set of models. The consistency of the models makes consistent the decision making processes at the different levels of the organisation and for the different levels of managerial responsibilities [physical operations, commercial, investment planning, and so on]. The consistency is essential to make all the components of the market and the teams of each player to work together to achieve the common goal in the most efficacious and efficient way.

The design of the set of consistent models gives, as by product, the design of the distributed data bases of data and information necessary to run consistently the different models used by the different players. Each model accesses to the allowed level of information through an agent which interfaces the model to the data base.

Conclusion

The ongoing increase of fragmentation of the players in the European gas market is perceived by operators to constitute a hazard to the usual quality and reliability of gas supply services.

The paper discussed the topic and demonstrated not only the opportunity but also the need to establish a 'consistent cooperation' between the players to maintain the high standards of Security of Supply and of dependability of gas supply to the final consumer, with particular regard to the mitigation of major Emergency Situations.

The paper recommends improving the 'consistent cooperation' between the 'contingency plans' that are the basis for the effective and efficient actions of Mitigations. The paper proposes also some technical tools that could effectively support such consistent cooperation.

The effective and efficient mitigation of major disruptions produces, in facts, benefits reducing the risk of shortage of Energy in the Citizens and Economic systems but, doing this, reduces also the interest to perpetrate malicious attacks.

NOTES:

[1] Interoperability is the ability of products, systems, or business processes to work together to accomplish a common task.
[2] In fact each player and also each different role requires a different model. Each model is differentiated by different: 1) degree of accuracy 2) time horizon, 3) region grouping supply and delivery points. If the models are not consistent, they induce an error in the decision making process which is an function increasing with the degree of inconsistency.
[3] Where more than 65% of the gas flow crosses more than one cross border and for this reason requires the interaction between more than two operators. All the rules and the data driving such interactions constitute the rules of 'interoperability'.
[4] Reduction to the minimum compared with the constrains due to the provisions of public service obligation and Security of Supply obligation when present.
[5] Most likely the 'efficiency' is the less expensive of the two because it optimizes the available resources rather then require additional investments or extra costs.
[6] 'consistent models' mean that the results of the simulations using the different models are the same within the error accepted.
[7] Transport infrastructures together with: LNG, Storages, firm and interruptible delivery per exit areas, supply capacities at the interconnection point with the production areas.
[8] Express as a fraction between the number of components considered compared with the total number of components of the systems when the maximum detail is considered.
[9] Accuracy is the precision expected of the resulting simulation compared with the values measured in a real situation having the same boundary conditions.
[10] The methodology is fully described in the deliverable of WP3 available in e_GASGRID site http://egasgrid.grenoble.eur.slb.com/egasgrid/img/public_doc.htm].
[11] Objective as 'non subjective'. This because to day the simplification of the models is made on the basis on the need and the experience of each operator. The 'objective' method suggested in e_GASGRID is based on mathematical method called 'symbolic simplification'. This mathematical method is applied to the set of equation describing the model at its maximum level of detail. The related technology has been developed by Fraunhofer-Institut für Techno- und Wirtschaftsmathematik.

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