THE MARKETING AND CALCULATION OF GAS TRANSMISSION CAPACITY IN THE EU

J.P. PINON and C. CUIJPERS

CREG, Belgium
ABSTRACT

The unbundling of the formerly integrated activities of gas sales and transmission in Europe has created a distinct market for gas transmission capacity. In order to meet the capacity needs of all network users, non-discriminatory third party access arrangements to transmission capacity are being developed and implemented throughout Europe in accordance with the Second EU Gas Directive.

The paper discusses the marketing of transmission capacity and the calculation of the available capacity that transmission system operators (TSOs) are able to bring to the market. TSOs throughout Europe have a different approach to these issues as there is yet no industry-wide standard for the provision of transmission services and neither for calculating available transmission capacity. In this context, the Council of European Energy Regulators (CEER) agreed that transmission capacity providers need to provide better documentation and greater transparency for their capacity calculation processes. This paper contains a number of recommendations to achieve more consistency among capacity calculations.

The paper starts to set out capacity definitions and principles for a market-oriented provision of available capacities, so as to better meet the needs of network users and to enhance network efficiency. Because of the natural monopoly and other particular features of networks, specific procedures are needed to convert a given transmission capacity into marketable services. Network users, large and small, want assurance that easy entry on the network for any reasonable demand is guaranteed, whatever the chosen route, and that their contractual commitments will be respected. These market circumstances make a level playing field possible in which free choice and competition may lead to consumer benefits. These requirements are especially important during the market opening phase and their fulfilment may need some provisions in order to smooth out possible comparative disadvantages of newcomers. The requirements of efficient services and efficient operation of the network become even more stringent when networks are faced with situations of congestion. Network users need transparent and accurate information on the provision and the quality of these services.

Whereas the design of a package of transmission services is one first concern of the TSO, a second and likely more difficult issue is the calculation of the available amount of capacity. A framework will be set out in order to look at how capacity should be calculated. The aim is not to propose calculation methods that fit for all networks but rather to identify the central drivers which determine the amount of available capacity. The calculation of available capacity is generally based on computer simulations of the operation of the interconnected transmission network under a specific set of assumed operating conditions. The available capacity can vary considerably depending on the criteria used to calculate it. Obviously, the more interconnected and meshed network system, the more dynamic the network physics and consequently the more complex the calculation of available capacities. Among the different trade-off, the paper considers in particular the following: more firmness (reliability) means less available firm capacity. The market has to be adequately informed about the amount of available capacity that a network is able to provide and this implies that capacities are calculated consistently over time as well as across networks. However, the dynamic nature of networks makes it not possible to derive a fixed or constant amount of available capacity. Especially the way the network is being utilized (by the users) and operated (by the TSO) varies continuously over time. Hence the agreement on some calculation principles is expected by the market to inform the market correctly about the transmission services offered in one network and across European networks. The criteria used should be consistent with the TSO’s planning and operating criteria. The paper argues that capacity may be offered as firm as soon as the legal security of supply requirements are met. Network users must be informed about the events and their likelihood which caps reliability and this implies that **Force Majeure** events are defined beforehand.

This analysis, carried out from a regulatory point of view, contributes to specify criteria and accompanying incentives on how TSOs should ensure that capacity is offered to meet the needs of network users and that the right amount of capacity is made available.
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1. INTRODUCTION

The development of competition and the convergence to an internal European gas market require that capacities in gas transmission network are calculated and provided in a consistent manner both over time and across networks. The network users have to be adequately informed about the amount of capacity that a network is able to provide. The dynamic nature of networks as well as the natural monopoly situations, without industry-wide standards at the moment, gives a large flexibility to transmission system operators (TSOs) for calculating and providing capacity. These circumstances do not necessarily guarantee that networks are efficiently operated and that capacity is offered on a fair and non-discriminatory basis to all network users, large and small.

This paper addresses from a regulatory point of view the issue of marketing and calculating available capacities in interconnected gas transmission networks. The aim is to develop a calculation framework that is helpful to look at incentives to ensure that the right amount of capacity is made available to market participants. This objective does not necessitate the design of calculation methods that would fit for each European transmission network and neither is there a need to question the performance of physical network models currently used by network operators. The focus is put on the network assumptions (scenario) necessary for simulating network performance and the matching between the scenario and the contractual commitments with network users regarding the reliability of transmission services. The distinction between the simulation method used by the network flow model and the selected scenario assumptions is important. The simulation method has to correspond to the physics and particularities of the network and is as such not optional. On the other hand, there is much more flexibility in the choice of the assumptions to design scenarios for simulating network performance.

The paper is structured as follows. Section 2 addresses capacity definitions and provision principles. The general scheme for calculating available capacity in gas transmission networks is discussed in section 3. Section 4 assesses the trade-off between reliability of service and the amount of available capacity. The importance of Force Majeure events for calculating available capacity is addressed in section 5. Section 6 is devoted to scenario building. Section 7 presents a general calculation procedure. Finally, conclusions are listed in section 8.

2. MARKETING OF GAS TRANSMISSION CAPACITY

Open access regimes to networks are successful in the creation of market liquidity only if the provision of transmission capacity is adequate. The marketing and calculation of available capacity involves a number of variables that require definition. Figure 1 shows capacity definitions which are used in this paper. Capacity is expressed in normal cubic meters per unit of time (m³(n)/h). The total useful capacity is equal to the total theoretical capacity (technical capacity) minus the capacity reserved by the TSO for system integrity and operational requirements.

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1 See Guidelines for Good Practice (GGP2) in the final conclusions of the 7th meeting of the European Gas Regulatory Forum, Madrid, 24-25 September 2003. Regarding the calculation of available capacity, reference is made to e.g. ETSO [1] for electricity transmission and NERC [2,3], RMPG [4] for natural gas transmission in the US.

2 Excellent work regarding gas flow modelling can be found in the deliverables of the EU "E-Gasgrid" project, see e.g. Basso et al. [5,6]. See also GIE’s position paper on available capacities [7].

3 See e.g. also the comments of CEER on GTE’s (Gas Transport Europe) report on calculation of available capacities [8].

4 This paper applies the definitions of the European Directive 2003/55/EC and the EU Regulation 1775/2005 on conditions for access to the gas transmission networks.
Figure 1. Capacity definitions for gas transmission.

Figure 1 illustrates the variation in time of the capacity (and load) of one particular entry point in an interconnected network and the capacity breakdown. The technical capacity and useful capacity vary in time because of network effects. The operational reserve is thought to be constant in this diagram and is booked by the TSO to guarantee system integrity. The booked capacity changes in steps because different shippers (network users) may book different schedules. Shippers should be able to match their transportation rights with the required capacity as well as duration of their delivery portfolio. Otherwise the shippers will bear inefficiency costs and there would be loss of market liquidity for capacity.

In order to activate the transportation right, shippers have to nominate booked capacity on a day-ahead basis. The nominated capacity changes very strongly according to predefined patterns (e.g. day versus night, weekend versus week days) as well as in a probabilistic way in function of their expected short-term off-takes which are influenced by e.g. weather forecasts or gas spot prices. The available firm capacity is the difference between the minimum technical capacity minus the operational reserve and the booked firm capacity according to the applied network flow scenario. This scenario differs from season to season in order to offer as much firm capacity as possible. The duration of the provided amount of firm capacity has to be adapted accordingly (see e.g. monthly firm capacity contracts). The operationally available capacity is greater than the available firm capacity and varies continuously. It changes due to the changing of technical capacity and nominated capacity way. The difference between the operationally available capacity and the available firm capacity must also be brought to the market but in principle on a short term and non-firm basis. Non-nominated but booked capacity has to be put on the day-ahead market by the TSO as non-firm capacity (the so-called “use it or lose it” principle. This is an important way of maximisation of available capacities.

The capacity of a transmission network depends on static and dynamic elements, as well as on operational constraints. The static elements are the technical characteristics of the network itself. These elements include the network architecture (positioning of the entry points, of the exit points and of the inner nodes; design of the arcs between the nodes; presence of other equipments which modify the properties of the flow) and the specific properties of the arcs and other equipments. In a gas transmission network, these properties include: (i) the diameter of the pipelines on each arc or portion of arc; (ii) the roughness of the pipeline material on each arc, which has an influence on the pressure
losses; (iii) for other equipments, such as valves or compression and heating facilities, the technical characteristics of these equipments. The dynamic elements refer to the way the network is being utilized (by the users) and operated (by the system operator). These elements vary continuously over time. For a gas transmission network, these variables include: (i) the properties of the gas injected/delivered at the entry/exit points (pressure, temperature, chemical composition); (ii) the distribution of the nominations between the various entry points of the network; (iii) the usage of the flexibility services offered by the system operator; (iv) the consumers’ gas demand at each exit point; (v) the operating mode of the ancillary equipments by the network operator.

The operational constraints are the boundaries set on each variable by the different parties. In particular: (i) the minimum/maximum pressure guaranteed at the interconnection points; (ii) the gas supply (at the entry points) and off-take (at the exit points) are required to be the same within certain margins; (iii) a minimum gas pressure is required at each exit point and this pressure threshold varies from consumer to consumer; (iv) the operating limits of the ancillary equipments have to be respected, typically on the volume flow and thermodynamic properties.

Because of the dynamic elements, the transmission capacity available in the network varies continuously. The dynamic elements are becoming more and more important because of the shift from a single-shipper environment to a multi-shipper. Furthermore, the uncertainty of dynamic factors increases drastically in a competitive market. Obviously, the more interconnected and meshed network, the more dynamic the network physics and consequently the more complex the calculation of available capacities. Making adequate assumptions about the variables is therefore necessary to estimate properly the capacity available in the network. System users have to be aware that available capacities vary as function of these determinants.

3. CAPACITY CALCULATION

The calculation of available capacities is generally based on computer simulations\(^5\). Network models depend on static and dynamic characteristics as well as on operational constraints. The static features depend on technical characteristics of the network itself (network architecture and physics). The dynamic elements refer to the way the network is being utilised by the users and operated by the TSO. These elements vary continuously over time. The operational constraints are the boundaries set on each variable by different parties (e.g. minimum pressures).

Making appropriate assumptions about the variables is necessary to robustly and accurately estimate the capacity available in the network, i.e. the scenario used will drive the output. This has to be done in a framework where capacity definitions are adequately specified. This calculation scheme is illustrated in figure 2.

\(^5\) An application to the Belgian gas transmission network can be found in CREG [9].
System operators have generally the best knowledge of the network physics and the network architecture. The physical modelling of the system is, however, not sufficient to calculate system performance. Before capacities can be calculated network models have to be fed with a large set of data together with initial and boundary conditions of the network. Many of these parameters are exogenous and they are subject to a varying degree of certainty:

- to calculate available capacity it is necessary to first estimate a network scenario and the first step in undertaking this is to identify the contractual commitments of the TSO (e.g. booked capacities and contractual pressure specifications);
- the dynamic assumptions refer e.g. to the way the network is operated by the TSO and to the behaviour of the net users. Model forecasts and statistical analysis of historical data provide valuable information to elaborate these assumptions;
- the necessary capacity for operational needs of a TSO has to be calculated according to the requirements for the efficient operation of the transportation facilities (safeguarding system integrity) including any operating margin necessary to ensure the security and reliability of the system, e.g. in case of sudden imbalance of a shipper or in case of a network breakdown.

Different flow patterns and configurations lead to strongly different capacity distributions in the network. The dynamic and probabilistic nature of system simulation outcomes regarding available capacity calculation necessitates transparent calculation procedures in order to inform the market correctly about the transmission services offered. It is crucial that the calculation principles are harmonised as far as possible and that any differences are understood and made clear to all parties.
4. TRADE-OFF BETWEEN RELIABILITY AND AMOUNT OF AVAILABLE CAPACITY

The following relationship is a key in the calculation of available capacity: the more (less) stringent the dynamic assumptions and operational constraints, the less (more) available capacity, the more (less) firmness of the available capacity. Firm capacity is defined as a service offered to customers under schedules or contracts that anticipate no interruptions, except for *Force Majeure*. It can be described as the guarantee that the nominations once accepted will effectively be carried out, except in emergencies including extreme operational circumstances. Based on simulations, the likelihood of such flow reductions can be assessed.

Figure 3 shows the trade-off between firmness and the amount of availability of capacity. A trade-off has to be promoted which meets market demand in a liberalized environment and guarantees that the maximum capacity is made available to the market according to the expected level of firmness. It is acknowledged that the market is inelastic concerning firmness and requires very high level of reliability of transmission. However, it is not sure that the network users would like to pay substantially more in order to reach a guarantee of one in one million years instead of one in twenty years for instance.

Figure 3. The trade-off between the firmness level and the amount of available capacity.

<table>
<thead>
<tr>
<th>firmness level</th>
<th>available capacity</th>
</tr>
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<tbody>
<tr>
<td>the most stringent assumptions, worst-case assumptions</td>
<td>more firmness, less capacity</td>
</tr>
<tr>
<td>less firmness, more capacity</td>
<td>the less stringent assumptions</td>
</tr>
</tbody>
</table>

The scenario characteristics determine the firmness and the associated amount of available capacity decline with the level of firmness. The question of firmness is therefore a prerequisite for calculating available capacities. Consequently, TSOs sell firm capacity according to a firmness level which has been beforehand defined, implicitly or explicitly. Up to now, firmness of firm capacity is taken as granted in the sense that only *Force Majeure* events cap firmness. Each TSO offers firm capacity according to a firmness level determined by his choice of network flow assumptions and simulation procedures. Hence, current practices lead to firmness levels of firm capacity which differ

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6 This relationship motivates e.g. that cost-reflective tariffs have to be proportional to the firmness level. The network efficiency is strongly determined by the reference reliability level for firm capacity.
strongly from TSO to TSO. Obviously, TSOs sell a double service: an amount of capacity and an associated quality label, namely the reliability (firmness) level. Transparency is needed in order to put a maximum of available capacity on the market and this under controlled firmness levels.

5. CONTRACTUAL FORCE MAJEURE EVENTS

The reliability guarantee of firm capacity is generally capped by contractual Force Majeure clauses. These clauses protect the TSO against unforeseeable events that are beyond the control of a prudent operator, and inform the network user of the degree of reliability. Hence, capacity may be offered as firm as soon as the delivery is guaranteed under all circumstances except in case of contractual Force Majeure events. Force Majeure is a common law concept and means superior or irresistible force that excuses a failure to perform. It is a cause that is beyond the control and without the fault of negligence of the party excused i.e. the TSO. Force Majeure events also must not be reasonably foreseeable. This is typically the case for emergencies due to unforeseeable technical failures like e.g. pipeline incidents and “acts of God” that justify a release of responsibility of the TSO.

Question is to which extent the performance of a network must be simulated according to theoretical worst case scenarios in order to guarantee the provision of capacity under any circumstance, even such market behaviours that are not realistic or completely illogical, e.g. that suddenly all consumers in one part of the country - or in a neighbouring network - would stop off-taking gas.

Before the market opening, there was less uncertainty related to the shippers’ behaviour because the whole chain was under the control of the vertically integrated companies (single-shipper environment). Furthermore, entry points for gas delivery were known beforehand and valid for relatively long periods. In a liberalised environment the performance of networks depends more and more on the behaviour of different network users (multi-shipper environment) and this lies largely beyond the control of the TSO. This means that the performance of networks has to be calculated taking into account realistic worst-case scenarios caused by unusual behaviour of network users (third parties), even if such behaviour was never observed in the past.

The nature of Force Majeure is not changed but Force Majeure gets an enlarged scope in a multi-shipper environment. For instance, depending on the capacity allocation regime, the TSO can only guess the capacity needs of any incremental capacity use and may take the worst-case estimation with the consequence that available capacity will decline drastically (e.g. assuming the worst-case entry point and the worst-case exit point which has consequently the largest impact on system performance). Obviously, this choice of scenarios has a major impact on the amount of available capacity that can be brought to the market. It is inevitable, certainly for capacity allocation regimes which offer large freedom to the network users in their choice of route e.g. pure “entry-exit” regimes, that also extreme behavioural situations are included in the contractual Force Majeure events. This raises the question of which list of Force Majeure events is adequate in a multi-shipper gas market.

This paper proposes that capacity may be offered as firm as soon as the legal security of supply requirements are met. Capacity with a risk to be interrupted/reduced which is higher than this firmness standard, is considered as non-firm or interruptible capacity. This standard firm may differ from country to country according to the national security of supply standards. Furthermore there are countries with no specific regulation at the moment. Therefore, it may be appropriate to introduce “European firm” capacity which meets a common firmness level. The EU Directive 2004/67/EC concerning measures to safeguard security of natural gas supplies constitutes a basis for this procedure, in applying amongst other criteria, the coldest weather periods statistically occurring (EC

\[ ^7 \] Assumptions have to be made not only for already booked capacity but also on the more uncertain characteristics of incremental capacity use. For instance, the assumption whether all booked capacity will be nominated simultaneously and the assumption regarding the incremental off-take location are hypotheses with dominant consequences on the amount of available capacity offered to the market.

\[ ^8 \] Reference can be made to EC [10,11] for security of supply in the EU and e.g. CREG [9], Cuijpers [12] and Pinon & Cuijpers [13] for the Belgian situation.
2003). A key standard is e.g. the minimum “1 in 20” winters guarantee for households. Household supplies must be secured during daily peaks statistically occurring every 20 years. However, Member States are free to add minimum standards, including e.g. levels of security of supply for their national electricity system if it depends on gas supplies.

6. SCENARIO

Once standard firm is defined or alternatively once Force Majeure events are defined, the question of the corresponding network scenario for simulation raises. Generally, there exist various scenarios - depending on the specification of the underlying set of assumptions - which yield the same firmness level. The top-down approach where only the firmness level is specified, is not adequate and has to be combined with a bottom-up scenario construction assuring the specification of the different scenario assumptions. Assumptions are specified in order to be sure that the right amount of available firm capacity is calculated that meets the firmness standard. This corresponds to the maximisation of available firm capacity according to reasonable criteria for a predefined level of firmness, e.g. standard firm.

Network parameters for which no security standards are determined, are set at levels not according to theoretical worst cases but according to observed worst cases taking into account the adequate Force Majeure events\(^9\). This method is illustrated in table 1 and yields to a matching between the network scenario and both the legal security of supply requirements and Force Majeure definition.

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\(^9\) This means that if the use of ‘observed worst case’ is not appropriate for whatever reason, an adequate force majeure cap for that determinant has to be agreed and applied consistently.
Table 1. Network flow scenario building in order to derive firm capacity according to minimal security standards (1).

<table>
<thead>
<tr>
<th>network flow assumptions</th>
<th>legal standard or observed worst case</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. operational margin</td>
<td>the amount needed to safeguard system integrity</td>
</tr>
<tr>
<td>2. disruption of national supply</td>
<td>national standard otherwise observed worst case</td>
</tr>
<tr>
<td>3. off-take by households</td>
<td>1 in 20 years peak day consumption</td>
</tr>
<tr>
<td>4. off-take by power plants</td>
<td>power generation at full capacity in those plants paying for firm capacity; utilisation rate during the day according to observed maximum (extrapolated)</td>
</tr>
<tr>
<td>5. off-take by other consumers</td>
<td>national standard otherwise observed highest consumption (extrapolated)</td>
</tr>
<tr>
<td>6. availability of storage</td>
<td>national standard otherwise observed worst case</td>
</tr>
<tr>
<td>7. synchronisation of capacity utilisation (nomination/reservation)</td>
<td>observed worst case <em>(and not necessarily the assumption that all categories of users nominate their full capacity at the same point in time)</em></td>
</tr>
<tr>
<td>8. geographical off-take patterns</td>
<td>for inland exits according to the above assumptions; for cross-border points, the booked capacity</td>
</tr>
<tr>
<td>9. pressure values</td>
<td>observed worst case <em>(and not necessarily the worst theoretical case; contractual lowest inlet and highest outlet pressure)</em></td>
</tr>
<tr>
<td>10. combination of entry flows</td>
<td>observed worst case</td>
</tr>
<tr>
<td>Etc.</td>
<td>etc.</td>
</tr>
</tbody>
</table>

\textit{sum of assumptions defines the network flow scenario for deriving the amount of standard firm capacity}  
\textit{product of standards gives the failure risk of standard firm capacity.}

(1) the list in the first column is based on the list presented in the EU Directive 2004/67/EC concerning measures to safeguard security of natural gas supplies

Figure 4 illustrates the result of simulating a network scenario that matches the legal security of supply obligations and the contractual \textit{Force Majeure} events.
The proposed standard calculation procedure is summarized in figure 5. The first step is to set an appropriate firmness level. Secondly, a scenario has to be composed that matches the firmness level. In addition, it is asked for openness on how available capacity is maximised. These two steps are the most difficult parts of the procedure. Once arrived at this stage, the scenario must be simulated, delivering the corresponding available amount of firm capacity as output.

Calculation procedure:

- **Step 1**: an agreement on the standard firmness level;
- **Step 2**: design of the scenario to guarantee that the appropriate amount of firm capacity is made available on the market;
- **Step 3**: scenario simulation with appropriate network model;
- **Step 4**: simulation outcome: amount of available firm capacity.
8. CONCLUSIONS

Transparency concerning the reliability of firm capacity in the single European gas market can only be achieved via a convergence of standards. This holds for both the marketing and calculation of available transmission capacity. The marketing and calculation framework of scenarios and procedures need to be harmonised - as much as possible - to ensure consistent information from European TSOs and that the right amounts of capacity are made available on the market.

It is shown that the intrinsic dynamic and probabilistic nature of network transmission performance explains the dependence on scenario assumptions for the calculation of available capacities. The trade-off between the amount of available capacity offered and the associated firmness has to be transparent, has to meet market demand in a liberalized environment. The network scenario determines the firmness and the associated amount of available capacity declines with the level of firmness. The question of firmness is therefore a prerequisite for calculating available capacities.

It is argued that the offer of firm capacity solely based on an accumulation of theoretical worst case network assumptions is not appropriate to meet the market expectations. Furthermore, the opportunity costs in terms of available capacities are considerable.

It is proposed that capacity may be offered as firm as soon as the legal security of supply requirements are met. Capacity with a risk to be interrupted higher than this firmness standard, is considered as non firm (or interruptible) capacity.
The presented calculation framework needs further investigation together with all the parties involved in the European gas market. Taking into account the complexity of network operations, the *Force Majeure* needs to be more precisely defined in a multi-shipper environment. Interruptions caused by exceptional flow patterns, due to unforeseeable market behaviour can be regarded as *Force Majeure*.

10. REFERENCES

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